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Crop Updates 2009 - Cereals

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Building soil carbon for productivity and implications for carbon accounting

Jeff Baldock, CSIRO Land and Water, Adelaide, SA

KEY MESSAGES

Composition of soil organic carbon

- Soil organic carbon is composed of a wide range of different materials with different chemical and physical properties and different extents of decomposition.

Functions of organic carbon/organic matter in soil

- Soil organic matter contributes to a variety of biological, chemical and physical properties of soils.
- Chemical—cation exchange, pH buffering, reduces effects of sodicity.
- Physical—water retention, soil structural stability, soil wettability, soil temperature.
- Biological—energy for microbes, provision of nutrients and resiliency.
- Increasing soil organic carbon content can result in an increase in the ability of a soil to hold water and thereby lead to enhanced productivity.

Calculating changes in soil organic carbon content

- Soil carbon content represents the balance between inputs and outputs.
- Values are required for the depth, bulk density and carbon content of the soil layer you are interested in to determine how much carbon is present.
- Changes in soil carbon content are slow and typically require at least 5 years to be detectable.
- Simulation models can be used to predict the likely outcomes of management practices on soil carbon content.

$$ from sequestration—fact or fiction?

- Maximising crop productivity will maximise carbon inputs and soil organic carbon content.
- At current prices, it is hard to justify modifying management practices for the sole purpose of selling carbon credits.

SOIL ORGANIC CARBON: WHAT IS IT?

Soil organic carbon is a complex and heterogeneous mixture of materials. These materials vary in their physical size, chemical composition, degree of interaction with soil minerals and extent of decomposition. Although determining the impact of management practices on soil organic carbon contents is important, it does not tell us anything about the type of organic carbon present. For example, is the organic carbon dominated by pieces of plant residue or more recalcitrant charcoal? It is therefore important to determine the composition of soil organic carbon to gain an appreciation for the implications of management practices and changes in organic carbon content on soil productivity. We now recognise four different types of soil organic carbon:

- Crop residues—shoot and root residues > 2 mm residing on and in soil.
- Particulate organic carbon—individual pieces of plant debris that are smaller than 2 mm but larger than 0.053 mm.

- Humus—decomposed materials less than 0.053 mm that are dominated by molecules stuck to soil minerals.
- Recalcitrant organic carbon—dominated by pieces of charcoal.

FUNCTIONS OF ORGANIC CARBON/ORGANIC MATTER IN SOIL

Organic carbon/organic matter contributes to a variety of functions in soils. These functions can be broadly classified into three types: biological, chemical and physical (Figure 1). Strong interactions (represented by the grey arrows) often exist between these different functions. For example, the

biological function of providing energy that drives microbial activity also results in improved structural stability and creates organic materials that can contribute to cation exchange and pH buffering.

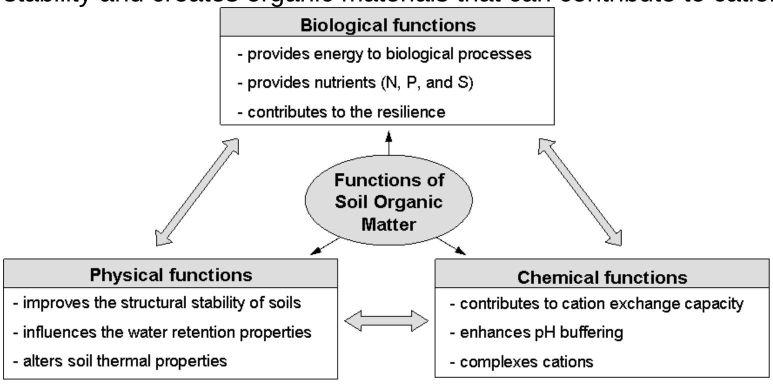


Figure 1 Functions performed by organic matter present in soils.

Future predictions of climate change suggest that most regions of Australia will be become warmer and drier based on increases in the concentrations of greenhouse gases (carbon dioxide, methane and nitrous oxide) in the atmosphere. Under such conditions it will become even more important than it currently is to be able to maximise the storage of plant available water in soils. The amount of plant available water a soil can hold is determined by two parameters:

1. the lower limit—the amount of water in the soil that plants cannot extract; and
2. the upper drained limit—the amount of water that can be held against drainage.

The difference between the upper and lower limit defines the potential available water holding capacity (PAWC) of a soil. If this value can be increased even marginally it will help to maintain or enhance potential productivity by allowing the soil to retain more water each time it rains.

In the absence of subsoil constraints such as salinity, the lower limit is defined by soil clay content and increases with increasing clay content (Figure 2). Evidence from WA sands suggests that increases in organic carbon content can also increase the amount of water present at the lower limit. The upper limit is also affected by the content of clay and organic carbon clay (Figure 2). For any given clay content, as organic carbon increases the upper limit, and therefore WHC, of the soil increases. An analysis of the influence of increasing soil organic carbon content by 1% of total soil mass (e.g. from 0.7% to 1.7%) on the soil PAWC was completed using data collected from red brown earths of the mid-north region of SA. This analysis indicated that such an increase in carbon content in the surface 0–10 cm soil layer would increase PAWC from its original value by 2 to 4 mm with the effect diminishing as soil clay content increased (Figure 3). Although the change in WHC for sandy-low clay content soils is predicted to be larger than for clay soils, it would be much more difficult to increase soil carbon content on sands relative to clays.

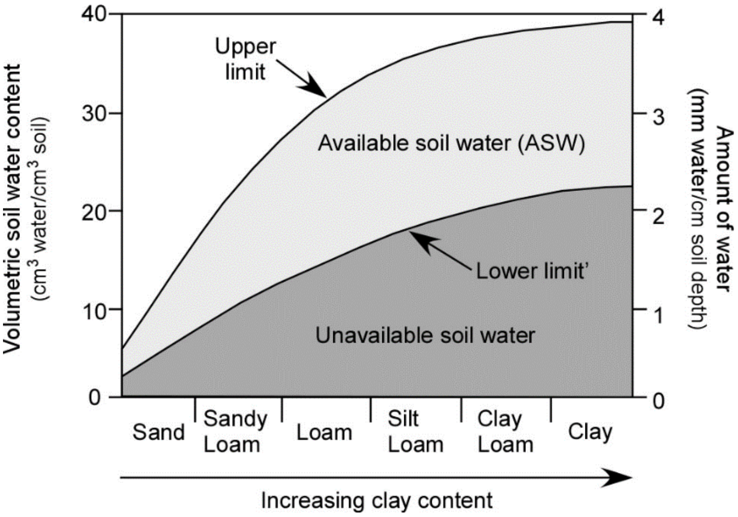


Figure 2 Changes in upper and lower limits of soil water content with changes in clay content. The light grey area defines the plant available water holding capacity of the soil.

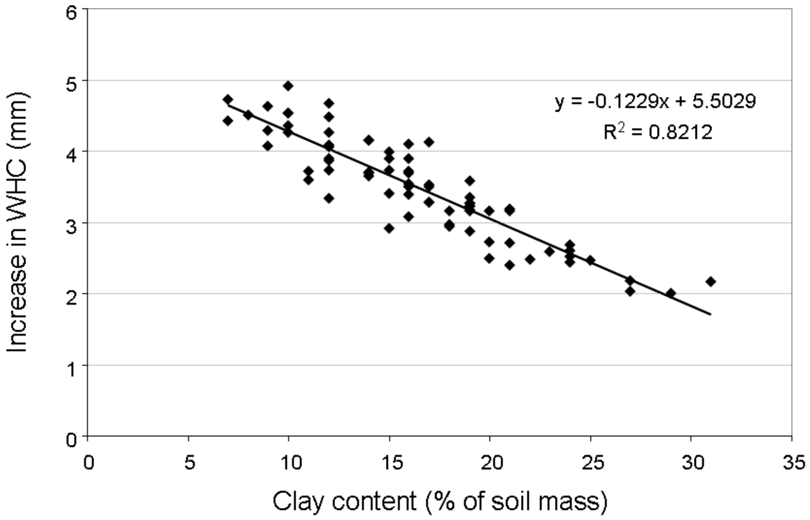


Figure 3 Change in soil water holding capacity (WHC) induced by increasing soil organic carbon content by 1% of total soil mass for red-brown earths of the mid-north of SA.

WHAT DETERMINES SOIL ORGANIC CARBON CONTENT?

The amount of carbon in a soil results from the balance between inputs (plant residues) and losses (microbial decomposition and associated mineralisation). Figure 4 the bucket represents the amount of carbon a soil could potentially hold. This amount will vary with factors such as soil clay content, soil depth, and bulk density and is not influenced by management. The bucket will be smaller for a sand than a clay soil.

Figure 4 Inputs and losses define soil organic carbon content.

To increase the content of organic carbon in soil, the input of residues must be increased and/or the rates of loss of carbon must be decreased.

Inputs are controlled by the type and amount of plant residue added to the soil. Any practice that enhances productivity and the return of plant residues (shoots and roots) to the soil opens the input tap and will result in an increase in soil carbon. For example, appropriate use of fertilisers to maximise productivity also maximise returns of organic residues to the soil. However, an upper limit to the input of residues exists in Australian dryland agriculture because of the limitation that the availability of water places on potential plant productivity. Maximum soil carbon contents will be obtained for any management system if productivity and capture of carbon are maximised by attaining 100% water use and nutrient use efficiencies.

Losses of carbon from soil result from decomposition and conversion of carbon in plant residues and soil organic materials into carbon dioxide. Processes that accelerate decomposition open the losses tap further; while those that slow down the rate of decomposition will close the losses tap and help to maintain or increase soil carbon. Reducing the extent of cultivation has been suggested to result in enhanced soil carbon levels. Results from Australian studies suggest that while this may be true for some soils, for other soils such an effect has not been observed (Figure 5). It should also be noted

that even shifting to a zero tillage system is unlikely to result in soil carbon values equivalent to those that would be obtained under a pasture system.

CALCULATING CHANGES IN SOIL ORGANIC CARBON CONTENT

The amount of organic carbon found in a soil can be calculated using values for the depth (cm) of the soil layer of interest, the soil bulk density (g/cm^3) and the soil carbon content (%) (Equation [1]). Using Equation [1], indicates that a 30 cm layer of soil having a bulk density of 1.2 g/cm^3 and a carbon content of 1.2% contains approximately 43 Tonnes of C/ha.

$$\text{Organic C (T C/ha)} = \text{Depth (cm)} \times \text{Bulk density (g/cm}^3) \times \text{Carbon content (\%)} \quad [1]$$

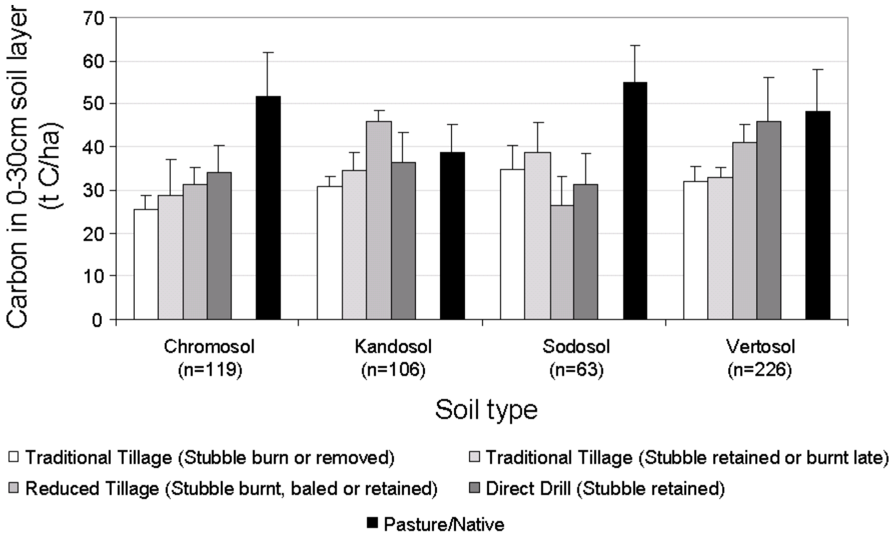


Figure 5 Change in soil carbon induced by different levels of tillage for several different Australian soil types. The number of samples of each type of soil are given by n.

Suggestions have been put forward that altering management practices can increase soil organic carbon content from 2% to 4% in 5 years. Is this really possible?

If we use the same bulk density as above (1.2 g/cm^3) and restrict our calculations to the top 10 cm of soil where organic carbon is most easily increased, at 2% carbon the soil would contain 24 tonnes C/ha. At 4% carbon the same soil layer would contain 48 tonnes C/ha. This indicates that 24 tonnes of C/ha would have to be added to the soil. Since plant residues contain approximately 45%C this would equate roughly to 50 tonnes/ha of dry matter (DM). If this increase was to occur over 5 years, then an additional 10 tonnes DM/ha/year **above that currently being added** would be required if no decomposition occurs. If half of the residues added were in the form of roots below ground, then we would have to add an additional 5 tonnes shoot DM/ha/year. Since we know that at least 50% of the added plant residues will decompose, annual additions of approximately 10 tonnes shoot DM/ha/year **above that currently being added** would be required to achieve an increase in soil organic carbon content from 2% to 4% in five years.

Under dryland conditions typical of the Australian cereal belt, increases in returns of shoot dry matter of this magnitude are unlikely and thus it is hard to substantiate such changes in C content. However, in specific locations where rainfall may not be used efficiently to produce agricultural crops/pastures (particularly regions with significant amounts of summer rainfall and where annual crops are being produced) significant increases in crop production and residue returns are possible by modifying existing management practices. Conversion of annual to perennial pastures and altering grazing practices from set stocking to rotational grazing will enhance plant dry matter production and increase soil carbon content.

PREDICTING THE INFLUENCE OF MANAGEMENT ON SOIL CARBON CONTENT

Soil organic carbon content changes very slowly. When this fact is considered along with the annual variability in rainfall normally experienced at any given location, measurements of soil organic carbon over several decades may be required to accurately define the effects of particular management treatments on soil organic carbon contents. We have used a soil carbon model (RothC) to predict the likely soil organic carbon content that would be obtained under wheat production using average

climatic conditions and retaining all crop stubble. At Roseworthy the water limited grain yield was calculated using the French-Schultz approach (slope = 20 kg grain/mm water and slope = 110 mm water). To define the potential long term soil carbon content (equilibrium soil carbon content), wheat production was set to 75% of the water limited potential was used along with a harvest index of 0.37 and a root:shoot ratio of 0.43 to calculate the crop residue addition rate including roots. The equilibrium soil C content predicted for the 0-30 cm layer was 86 tonnes C/ha. It should be noted that in these modelling analyses a clay content of 15% was used.

In Figure 6 the estimated changes in the amount of soil organic carbon content stored in the 0–30 cm soil layer is presented for different levels of wheat production defined in terms of water use efficiency (WUE). The predicted wheat grain yields (for Roseworthy) are given in parentheses after each WUE value in the legend. The changes in soil carbon associated with a 25 year time frame are given in Table 1. The model predictions suggest that if we were to move wheat yields to an average of 4.5 t grain/ha (100% WUE), soil carbon would increase by about 11 tonnes C/ha over the 25 year period, and by about 32 tonnes C/ha if we could obtain wheat yields equivalent to 150% of current water use efficiencies. These data show that carbon changes will be slow but enhancing productivity, if it can be maintained, will result in increased soil carbon levels. Other management scenarios (e.g. conversion to pasture production) may provide larger increases; however, if such management changes are made, attempting to claim carbon credits in a carbon trading scheme will limit future options for land use because the new levels of carbon attained would have to be maintained.

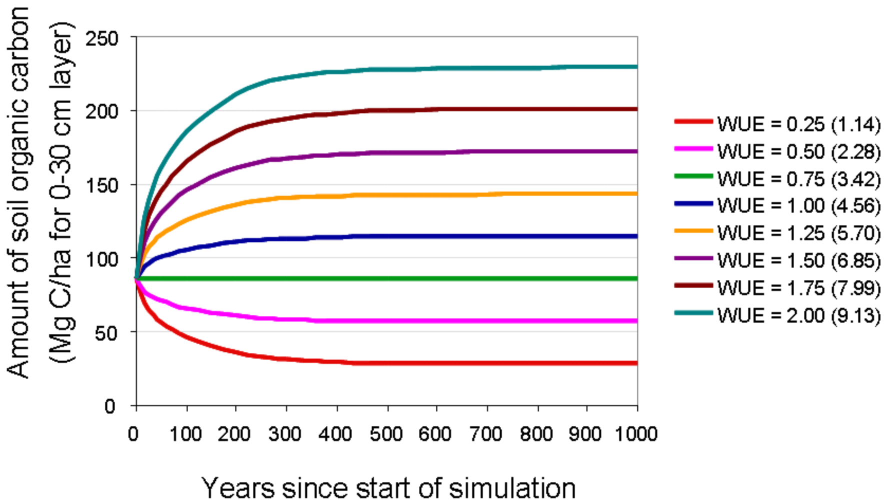


Figure 6 Changes in the amount of carbon stored in the 0–30 cm soil layer at Roseworthy, SA predicted using the RothC soil carbon cycling model for different water use efficiencies (WUE).

Table 1 **Change in soil carbon after 25 years for different levels of wheat productivity**

Wheat grain yield (t/ha)	Water use efficiency (% water limited potential)	Total amount of carbon stored in the 0–30 soil layer (t C/ha)		
		0 years	25 years	Change
1.1	0.25	86	65	-21
2.3	0.50	86	75	-11
3.4	0.75	86	86	0
4.6	1.00	86	97	11
5.7	1.25	86	107	21
6.8	1.50	86	118	32

$$ FROM SEQUESTRATION—FACT OR FICTION?

There is no doubt that soils could potentially hold more carbon. The challenge is to be able to do this while still maintaining an economically viable farm enterprise. Some potential options include:

- enhancing the proportion of perennial vegetation in pastures or conversion of portions of cropped paddocks that continually give negative returns to perennial vegetation;

- increased retention of crop residues, reduced stocking rates and increased use of green manure crops to return more plant material to the soil;
- optimise farm management inputs to maximise water use efficiency and thus maximise the return of crop residues to soil but be careful not to generate other greenhouse gases in the process which may offset any benefits.

At a price of < $20 per tonne of sequestered carbon and the slow potential rates of soil carbon change, it will be hard to economically justify modifying management practices for the purpose of selling carbon credits alone. Under such pricing, carbon credits should be considered as a secondary benefit that may be realised whilst attempting to enhance soil productivity by building soil carbon content.

Reviewed by: Bill Bowden

Fact or Fiction: Who is telling the truth and how to tell the difference?

DC Edmeades, agKnowledge Ltd, PO Box 9147, Hamilton

AIMS

In most farm budgets fertiliser is normally the largest item of discretionary expenditure. How a farmer spends the fertiliser dollar can and does have a major impact on the financial bottom line. The fertiliser industry is also large in terms of total revenues and profits and hence there is strong motivation to 'get a piece of the action'. There are now many players in the fertiliser market.

We also live at a time when the dominant political philosophy is 'laize faire'. People in western democracies want their governments at arms length and preferably not interfering with their desire to make a buck. Thus, were possible government rules and regulations are abandoned in favour of 'caveate emptor'—let the buyer beware! There are no rules to control the behaviour of the various players.

Making matters worse, at least for the farmer, science itself is under threat. There was a time when science was the authority and that authority was based on evidence. Truth was defined by the balance of the evidence. This has been eroded by post-modern philosophy: now the truth is defined by opinion- what you feel is your truth. And, importantly Political Correctness demands that all opinions must be given equal weight, irrespective of the balance of the evidence. It is this environment which nurtures and encourages belief in things like organic farming and homeopathy which are not evidence based but belief based. They both depend on dogma.

The consequence of all these modern forces is that farmers today are inundated with information, much of it unsolicited, contradictory and of dubious quality. Not surprising farmers are very confused. Who do they believe and who can they turn to?

In this talk I want to give you some tools that I hope will enable you to tell fact from fiction, and to lessen the risks of legal action by those who may feel threatened by what I have to say I make my motivation clear.

"Those who are fortunate enough to have chosen science as a career have an obligation to inform the public about voodoo science." Robert Park

"The special responsibility of scientists is to inform the world of its choices." Robert Park

WHAT IS SCIENCE?

There are two common questions I get from the public about science and they indicate to me that we (i.e. scientists) must do more to enhance science literacy in society.

1) Scientists are always arguing—who am I to believe? This is normal, healthy and essential for science to progress. Science is about testing ideas against the evidence and scientist must debate and argue and test again. As more and more evidence come to light we can have more and more confidence that we a getting nearer the truth. This is best seen in hindsight. For example we all now agree that the sun is the centre of the solar system, that the earth is not flat and that atoms are not solid. But these were matters of public debate in their time resolved only by getting enough evidence. A problem for the public arises when new areas of science emerge and the subsequent scientific arguments spill into the public arena (e.g. climate change, stem cell research).

2) "If science is so good how come scientists do not know everything?" Science will never know everything for the simple reason that everything question has not been asked and every conceivable experiment has not been done. Science evolves raising new questions and new

techniques develop so that new types of measurements can be made the important point is that the more mature the science the more confident we can be.

3) “You have not tested product ‘A’ so how can you say it does not work?” As science develops theories are formulated and then tested and if they stand the test of time (i.e. more and more evidence) we say we have a law. Some common ‘laws’ which are useful in the science of fertilisers are: a) Liebigs Law of the minimum; b) the principle of cause and effect; and c) there are 16 nutrients required for plant growth. By applying such laws to a given product we can deduce whether a product will be effective of otherwise.

By making use of our knowledge of science—what it is, how it should be conducted and what scientific laws to apply—we can construct a list of tests that can be applied to information about fertiliser products to help us decide what weight to place on the available evidence.

TESTS FOR SCIENCE?

Test 1 (Plausibility Test)

In this test we apply the Principle of Cause and Effect. Things do not happen by chance. If there is an effect there must be a cause. This universal principle applies also to nature and hence to soils and plants. Related to this we must ask the question: what is the mechanism by which this product works, or is claimed to work, and is it plausible? Be very cautious if the mechanism claimed for the product defies a well established principle of science.

Test 2 (Credibility Test)

Examine the advertising and promotional information you are given about a product or service. If you detect one or a combination of the following, the product or service is not likely to be credible.

a) Is the product/service promoted on the basis of a doomsday message? “We are ruining our soils, polluting our water, poisoning our stock, endangering human health.”

b) Does the company literature suggest a conspiracy? “You cannot trust the Universities or the Department of Agriculture—they are in the pocket of the big fertiliser companies.”

c) Is the product/service promoted solely on testimonials?

d) Is the product/service promoted because it is natural or a very old practice only recently rediscovered?

e) Is the product/service so new and exciting that it is ahead of science or beyond science or requires a new paradigm of understanding?

f) Is the product/service developed by a lone genius, overlooked by science?

Test 3 (Evidence test)

This test is in essence the ‘acid test’—where is the evidence?

a) What are the specific claims made for the product/service?

b) Beware of products/services for which very general non-specific claims are made.

c) Beware of products/service which make multiple claims.

d) Where is the evidence for the claim(s)? Is it published in a reputable peer reviewed science publication?

e) If it is not published in the scientific literature ask who conducted the research. Is there a conflict of interest? Were the trials properly designed and conducted? Get it checked by an independent scientist.

f) Is there supporting evidence for the product/service such as other trials by other independent agencies in other countries?

g) Ignore anecdotal evidence (testimonials).

h) Soils vary—a product may work in some situations and not in others!

“The only antidote to pseudo science is science itself.” Carl Sagan

Test 4 (Common Sense test)

Use you common sense when the salesman calls. Ask the obvious question: If what you are told is true and it is indeed a good product/service and the claimed benefits are true then every farmer would be using the product and service? Apply Test 2 as you listen to the answer.

“If it sounds too good to be true it probably is.” Dr J Roche

Test 5 (Reality Test)

Many products and services are sold on basis that we are destroying our planet, our soils and our health. Many today believe that science is the cause of these dilemmas. So let us remind ourselves how successful science and its close cousin technology have been. We live longer now than at any time in our history, we grow more food than at any time on our history and our food is abundant and healthy. This is clear evidence not of destruction but of science and its success.

Paper reviewed by: Bill Bowden

Four decades of crop sequents trials in Western Australia

Mark Seymour, Department of Agriculture and Food, Western Australia

KEY MESSAGES

A database that collates crop sequence trial data from over 160 trials is now available.
On average, wheat after lupin out yielded wheat after wheat by 0.5 t/ha. Greater increases in wheat yields following lupin occurred after the availability and widespread use of good, selective herbicides coinciding with the uptake of no-till seeding in the 1990s.

AIMS

Collate all of the available trial results from crop sequence experiments conducted in WA and use the database to quantify the rotational benefits of break crops. In addition determine the need for crop sequence research in the future.

METHOD

Over 150 crop sequence experiments have been conducted throughout WA since the 1960s to determine the rotation effects of leguminous or oilseed crops in cereal based rotations. The vast majority of these experiments have been conducted by the DAFWA. The results of these experiments and the limited number conducted by other organisations are available in various formats, but have never been collated in the one place in a uniform way. This paper briefly describes the production of a Microsoft Access database that collates the available information and provides a summary of break crop effects in WA.
The database currently holds 10 191 records consisting of trial x year x this year's crop x previous crop(s) x nitrogen combinations. The results of 167 trials appear in the database, around 165 are DAFWA experiments, one trial had CSIRO as the lead agency with DAFWA input and the remaining experiment is the rotation trial run by the Facey Group at Wickepin.

The database is available for DAFWA staff at \\Agessrdc01\users\Seymour\Break crop rotation database. People outside of DAFWA should contact the Mark Seymour (mseymour@agric.wa.gov.au) for copies.

Notation for crop sequences and rotations used in this paper and on occasions in the database are as follows:

- Abbreviations for major crops are – wheat (W), barley (B), canola (N), lupin (L), field pea (Fp), linseed (Li), oats (O), fallow (Fa), vetch (V), chickpea (K), faba bean (H), and mustard (Mu).
- Crop sequences are listed in order, e.g. LWW refers to lupin followed by wheat followed by wheat.
- Reference to the particular part or year of the crop sequence uses the notation/n. For example, for a LWW sequence LWW/1 refers to the first crop, lupin. LWW/2 refers to the first wheat after lupin and LWW/3 refers to the third crop, which in this case is the second wheat after lupin.

The base data

Fields that appear in the main database include trial information such as trial number, major personnel involved, site (farmer's name), location (nearest town), agzone, soil type, year(s) of experiment, the current year's crop and sometimes which variety was used, nitrogen application rate (kg N/ha), details of the previous 6 crops if available, some coding for rotation types and phase (incomplete), general comments, and some brief information on other treatment applied such as: ripping, fertiliser, time of sowing.

Crop traits in the database include grain yield, grain yield of previous crop if available, dry matter—usually peak or harvest biomass (noted if otherwise) and grain protein. Plants include: barley, canola, cereal rye, chickpea, faba bean, fallow, field pea, lentil, lathyrus, linseed, narrow-leafed lupin, albus lupin, yellow lupin, oats, serradella, sub. clover, medic, volunteer pasture, summer crops, triticale, vetch and wheat. Distinctions are made between harvest, green or brown manured, ploughed in, not harvested or stubble removed treatments, mixes of species and other variations.

Additional information linked to the database include rainfall records for the nearest meteorological station to the experiment from which annual rainfall, growing season rainfall (May to October) and stored water have been calculated. Stored water is estimated by using the formula: 10% of the previous November and December rainfall plus 20% of January and February rainfall, plus 55% of March rainfall plus 75% of April rainfall. Total water available to the plant (mm) was then estimated as rain falling during the growing season plus stored water.

RESULTS

As part of the GRDC project "Increasing the Profitability of Cropping Systems in Western Australia using Lupins, Oats, Oilseeds and Pulses" a detailed report is being prepared which summarises some of the database results. An extract of the section of this report that deals with narrow-leafed lupin is given below.

Wheat after narrow-leafed lupin

Narrow-leafed lupin has been the most widely examined break crop species with over 150 trials x year combinations available in the database. If we look at the raw data from all of the trials (Figure 1) we can see the range of yields obtained in the trials. The majority of wheat on wheat (WW/2) yields are less than 2.5 t/ha indicating that in the trials conducted to date it has been difficult to achieve yields higher than 2.5 t/ha with wheat sown after wheat.

In general it is also noticeable that the majority of wheat after lupin responses above the 1:2 ratio line occur when wheat on wheat yields are below 1.5 t/ha, indicating an agronomic issue with wheat-wheat which the inclusion of lupin helps to remediate. Invariably these issues have been identified in individual trials to be the presence of Take-all or high levels of annual ryegrass or brome grass. The outlier on the y-axis of yields of lupin-wheat at or above 4 t/ha when wheat-wheat yields less than 1.0 t/ha are from the trial 91KA111 at West Katanning in which Take-all was a factor that severely limited the yield of wheat on wheat and a wide range of break crops such as lupin, field pea and canola provided a good break from the disease. Similarly the outlier where WW/2 yields close to zero and LW/2 yields 2.5 t/ha is from a trial at South Carrabin in 1995 where brome grass became very difficult to control in the wheat on wheat plots.

Similarly there are occasions where the lupin sequence fails. For example, the outlier on the x-axis where WW/2 yields 1.8 t/ha and LW/2 yields close to zero are from a trial in 1983 at Nabawa (78C1) where wild radish was not able to be controlled in the lupin phase and the weeds swamped the following cereal crop. In later years the availability of diflufenican solved this issue, although in recent times wild radish has again become harder to control in the lupin year with selective herbicides.

Overall though wheat sown after lupin out yields wheat sown after wheat. A linear relationship can be fitted to the response of wheat after lupin compared to wheat after wheat over a wide range of wheat on wheat yields. If the outliers discussed earlier are removed this relationship is: GY of LW/2 = 0.9 (GY of WW/2) + 0.6, $r^2 = 0.58$, $P < 0.001$, GY = grain yield. If we were to constrain the regression through the origin the regression would become: GY of LW/2 = 1.34(GY of WW/2), $r^2 = 0.45$, $P < 0.001$.

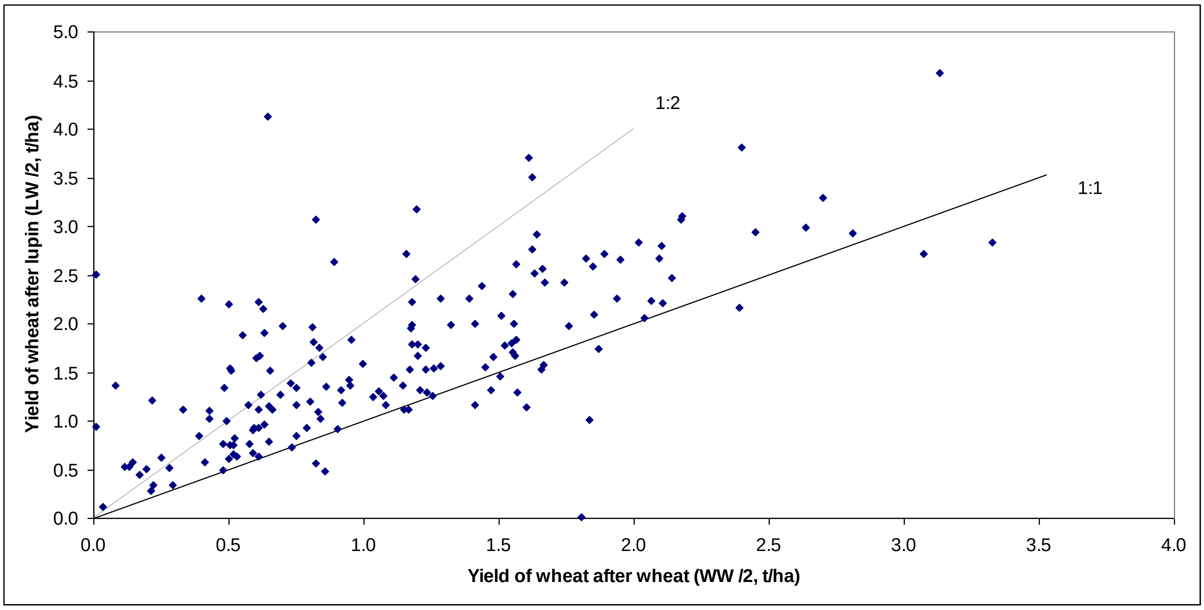


Figure 7 Relationship between the yield of wheat sown after wheat (WW/2) and the yield of wheat sown after lupin (LW/2) in 88 trials (167 trial x year combinations) in experiments conducted throughout WA since 1974. Linear curves indicate 1:1 and 1:2 ratios.

Another way to look at the data set is to consider the magnitude of the difference in yield (Ydiff) between WW/2 and LW/2 and the frequency in which various levels of Ydiff occur. In the first instance we will look at Ydiff averaged across all rates of nitrogen applied to the second year of wheat. Figure 8 shows that whilst there are relatively few instances where Ydiff is more than 1.5 t/ha, in 10% of instances Ydiff is less than or equal to 0 t/ha, and the distribution is centred around 0-500 kg/ha range with the mean increase in yield being 540 kg/ha.

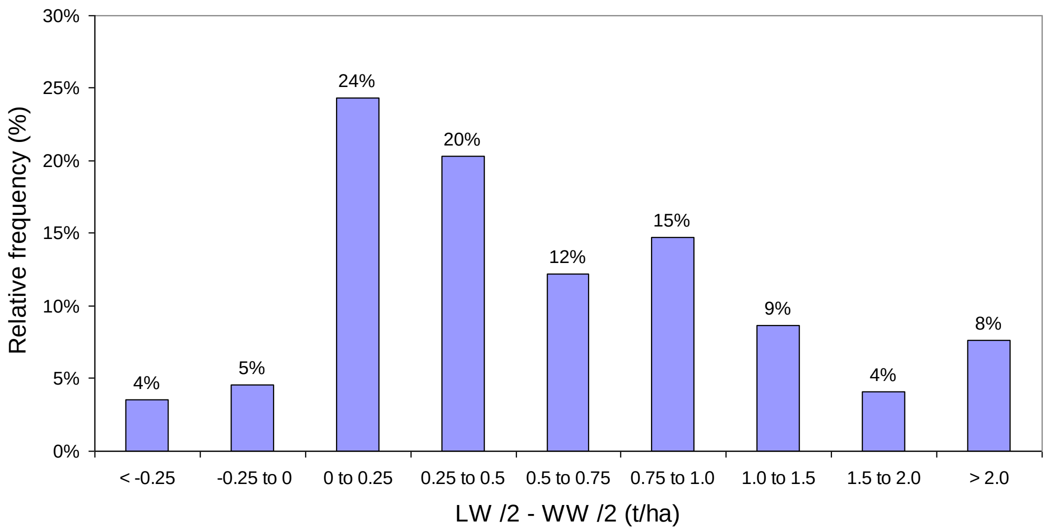


Figure 8 Relative frequency (%) in which the difference in yield (Y diff, t/ha) between wheat following lupin (LW/2) and wheat following wheat (WW/2) falls into 9 yield categories. Data are from 167 trials x year combinations in 86 trials conducted in WA since 1974.

As seasons influence the magnitude of any break effect it can be useful to compare the upper limit of the water use efficiency of the different rotations. To do this we calculated modified French and Shultz figures for the two rotations. We then fitted by eye a boundary line encompassing most of the data points (data not shown). Using this method the potential water use efficiency for wheat after lupin was 19 kg/ha/mm and was 15 kg/ha/mm for wheat after wheat.

Response to nitrogen

It is widely known that one of the major effects of lupin will be the residual nitrogen they supply to the following crop. Results discussed so far have been averaged across all the nitrogen fertiliser rates applied to the following wheat crop. In order to evaluate the effect of residual nitrogen on Ydiff we first grouped rates of applied nitrogen fertiliser into five groups labelled 0N, 25N, 50N, 100N, 150N, where 0N = all treatments where no nitrogen fertiliser was applied, 25N = where up to 25 kg N/ha was applied, 50N = 25 to 50 kg N/ha, 100N = 50 to 100 kg N/ha, and 150N = more than 100 kg N/ha. We then restricted the dataset to the 31 trials that included at least four of these five groups so that n = 67 for all N groups except 150N which had 44 observations. Residual maximum likelihood (REML) models were then fitted using Genstat 10 with N group as the fixed effect and Trial.Year as the random effect.

Overall nitrogen applied as fertiliser had a significant ($P < 0.001$) but small effect on Ydiff (data not shown). The largest Ydiff was 556 kg/ha and occurred when no nitrogen fertiliser was applied. Ydiff decreased as the rate of nitrogen fertiliser increased so, the highest nitrogen fertiliser group (150N) produced a Ydiff of 396 kg/ha.

Do changes over time affect the response to nitrogen?

The difference in yield between wheat after wheat and wheat after lupin appears to change over time with a gradual rising trend from 1974 up to 1990 when the difference in yield between LW/2 and WW/2 increases dramatically and then drops off again after 1993 (Figure 9).

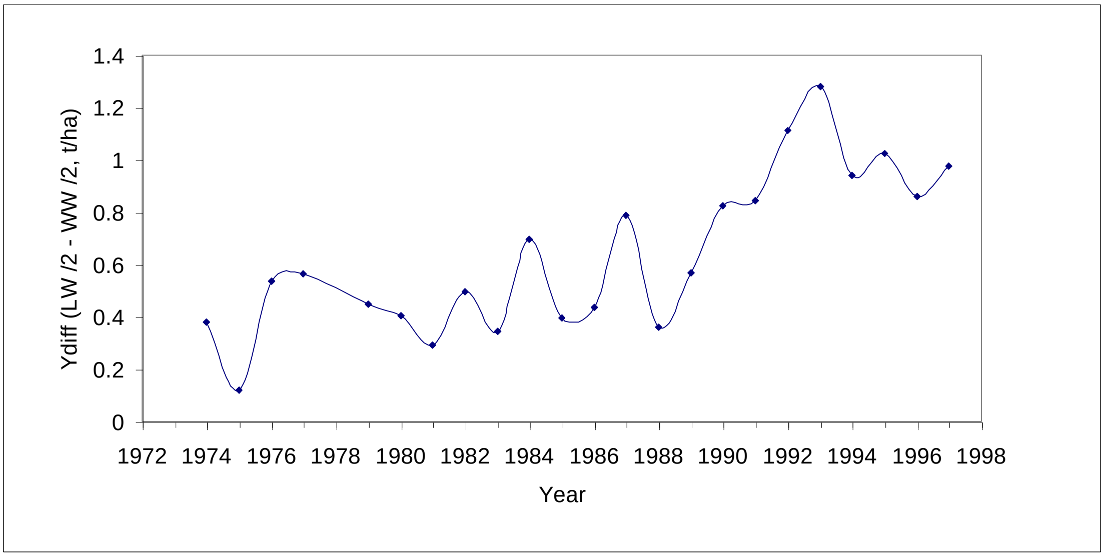


Figure 9 The difference in yield between wheat after wheat (WW/2) and wheat after lupin (LW/2) over time.

To investigate this observation further we restricted the data set to the years when the most number of lupin Agzones had trials, which was the period 1983 to 1995. This showed a relatively flat period from 1983 to 1991 and then an increase in the period following. We then considered the changes in the 1990s that led to this unprecedented increase in the difference in yield between LW/2 and WW/2. Was it environmental, such that we had a run of years that suited wheat after lupin more so than wheat after wheat? Or were there changes in agronomic practices that were of benefit to wheat after lupin or made lupin a better break crop?

To separate the effect of rainfall from management we compared the water use efficiency of the two sequences (data not shown). This showed that the difference between the WUE of LW/2 and WW/2 was, for the first time, consistently above 3 kg/ha/mm from 1990. Around that period of time there was a shift to no-till machinery both on farms and for experimental purposes. There was also a wider use of more effective herbicides for in-crop control of grass and broadleaf weeds in lupin crops, and rotations shifted to more continuous cropping as sheep numbers declined throughout WA. In

general, comments from trials in the period 1990-95 indicated that the lupin plots were generally free from weeds and there were few reports of poor lupin growth in the trials. Thus these changes seemed to be of benefit both for the lupin crop and the following cereal.

This is further demonstrated if we group the data into two periods: '1983-89' and '1990-95'. The Ydiff was 0.4 t/ha in the 1983-89 period and 0.9 t/ha 1990-95 period ($P < 0.001$) and this difference remained even when the peak year of 1993 was removed from the analysis. Of interest then was to see if the agronomic changes also changed the response to fertiliser nitrogen. To do this we had to further reduce the dataset because there were few trials that included rates of fertiliser nitrogen above 100 kg/ha (n = 6).

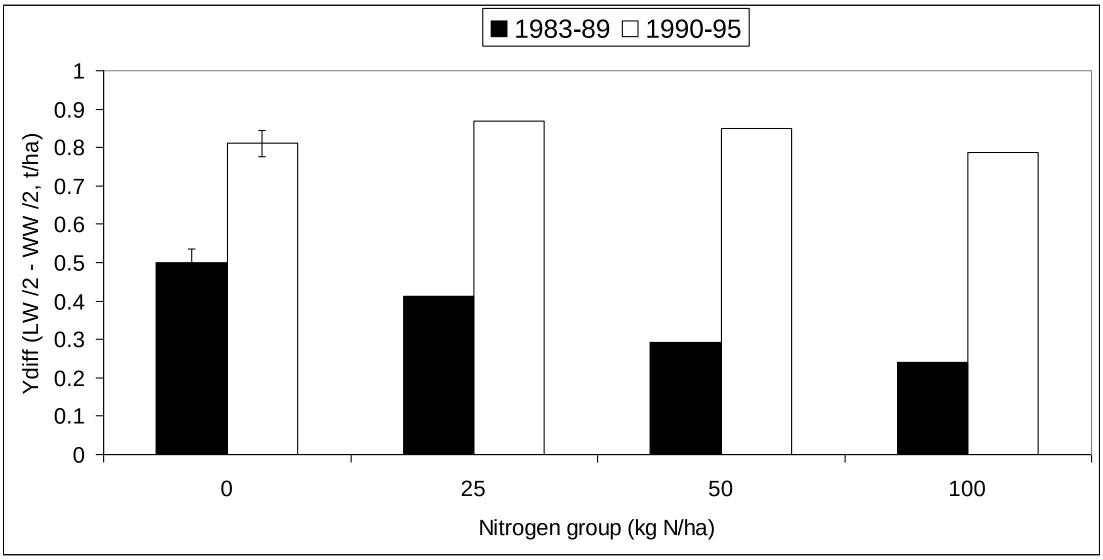


Figure 10 Response of Ydiff (LW/2-WW/2 in t/ha) to nitrogen fertiliser application in the wheat year for the periods prior to and after 1990.

Prior to 1990, as the rate of nitrogen increased the difference in yield between LW/2 and WW/2 decreased (Figure 10). However, since 1990 nitrogen has no effect ($P > 0.05$) on the difference in yield. It appears that since 1990 wheat after lupin continues to respond to increasing rates of nitrogen whereas in the previous period wheat after lupin did not respond to increasing rates of nitrogen whilst wheat on wheat did.

CONCLUSION

A database has been collated from all of the available crop sequence experiments conducted in WA. Over 10 000 records representing the results of over 160 experiments conducted since 1966 appear in the database, allowing for rigorous interrogation of rotation effects over a long period of time. In the experiments conducted to date continuous wheat was rarely as productive or economically viable as rotations that included either a pasture or break crop, regardless of amount of nitrogen fertiliser applied.

In general terms, since 1990, both the yield of wheat on wheat and the likelihood of a response to lupin in the following year have increased at all levels of applied nitrogen. This corresponds to a period where more effective herbicides were used, rotations shifted to more continuous cropping and trials were more likely to be sown with no-till machinery

If changes to crop management in the past have influenced the size of the break crop effect then we need to consider the implications of even more recent changes to crop management. In particular the benefits of break crops are likely to be influenced by the modern use of more effective fungicides, inter-row seeding to avoid last years crowns and roots, metering out of nutrition throughout the growing season, and the reduced effectiveness of weed control.

KEY WORDS

crop sequence, break crop, lupin

ACKNOWLEDGMENTS

Thanks to: Pam Burgess for helping to collate the data, Andrew Van Burgel for statistical advice, and all the previous researchers who provided the data. Funds for the work are provided by DAFWA and GRDC.

Project No.: DAW161

Paper reviewed by: Peter White

2008 Break Crops Survey Report

Paul Carmody, Development Officer, Department of Agriculture and Food, Western Australia, South Perth

KEY MESSAGES

- The majority of growers believe that break crops play, and will continue to play, an important role—this is true across all farming types but particularly wheat/lupin farmers.
- The primary reasons why growers chose break crops were their break crop effect, disease control in cereals and supply of nitrogen they can provide.
- Growers would like more information on choice of the most suitable break crops for their own situation.

AIMS

The aim of the 2008 Break Crops Survey was to capture the current attitudes of farmers towards the four primary break crops grown in Western Australia; canola, field peas lupins and oats. This survey forms part of a review by the Break Crop Project which is funded by GRDC in partnership with DAFWA, CSIRO and UWA. The results of this survey present an up to date assessment of how farmers regard break crops in their farming system. What influences their preferences, how important are break crops and what do they believe the future of break crops to be? It was the first time such an extensive survey has been conducted in WA embracing the break crops collectively and focuses their role in today's farming systems.

METHOD

A quantitative survey of 225 grain growers was conducted during October–November by DAFWA using farmers randomly selected from the CRIS database. Farmers were evenly distributed across the northern, central and southern wheatbelt. Twenty five farmers (property size > 800 ha) from each of the high, medium and low rainfall areas within each region were interviewed. The response rate to the phone survey was very positive with less than 15% refusal by participants (Synovate 2008). This reinforced the general belief in the future importance of break crops in their farming systems.

Table 1 **The classification of farmers was made according to the area of crop and pasture. The number within each category is listed**

Classification definition for purpose of this survey	*Farmer type*	No.
Pasture area of 20 to 60% of the total farm area. Wheat and barley are dominant crops.	*Mixed farmer*	81
More than 60% of farm is devoted to pasture for sheep. Less than 40% of farm is in crop in any one year. Wheat and barley dominate the cropping operations.	*Livestock dominant farmer*	50
Pasture occupies less than 20% of the farm area. Cereals dominate the system. More than 80% of farm is in crop and **less than** 10% is lupins in any one year.	*Intensive Cropper*	55
Pasture occupies less than 20% of the farm area. More than 80% farm is in crop and **more than** 10% is lupins in any one year.	*Wheat-Lupin Farmer*	39

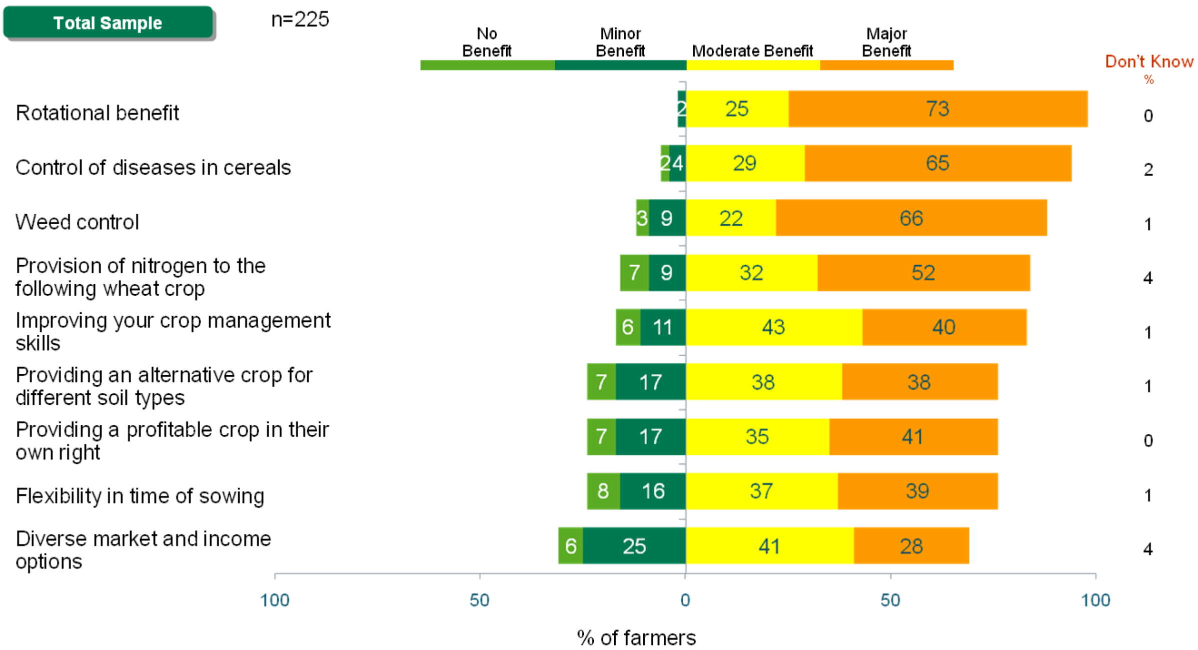
Farmers were classified into 4 groups as per table 1, with mixed farmers making up 36% and intensive croppers representing 26% of those surveyed. The definitions of grower types were established by the project team with reference to Lawes findings (2008).

RESULTS

The vast majority of participants believe break crops are of major importance in the future of their farming systems. The high rainfall areas were stronger in this belief (100%) compared to the low rainfall areas (93%). Yield variability was rated as the biggest problem associated with break crops.

Establishment of break crops in drier seasons and the overall costs of growing break crops were also found to be major barriers. Lapsed farmers (n = 24) cited “not enough quality land to grow them” or “we’ve been in drought for 2–3 years”, whereas those who have never grown break crops (n = 13) suggested “it just goes back to pasture, there is no reason to do it” or “there was no return on them”. Farmers interestingly tolerated the poorer returns from break crops to realise either the rotational benefit, disease control or weed control for their cereals. Almost half the participants said they would prefer to grow only wheat or barley exclusively if is was sustainable. Whether these growers did not have appropriate information or a break crop that suited there situation, or their attitude towards break crops prevents them from growing them, is still unknown. This is an example of a limitation of this survey.

Fig 1. Rotational benefits, disease control and weed control are considered the key benefits offered by break crops

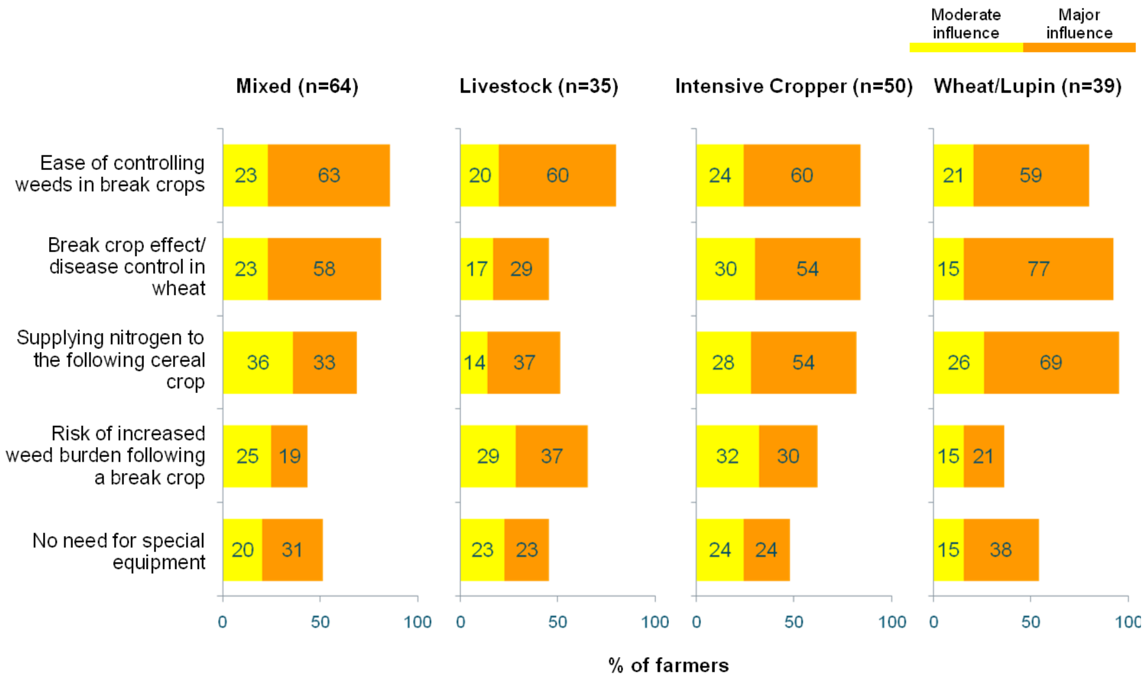


Q Based on your experience and knowledge, to what extent do break crops provide the following benefits to farmers?

The large majority of farmers are growing break crops for the rotational benefit, disease control in cereals and weed control. Interestingly, income diversity is a lot less important as a benefit of break crops. Figure 1 shows that the majority of farmers using break crops (97%) recognise the control of diseases in cereals as a benefit compared to those not currently using break crops (81%).

Supply of nitrogen to the following crop was a factor that influenced more wheat/lupin growers choice of break crop (95%) than phase croppers (51%). Similarly, the disease break factor influenced more wheat/lupin growers than phase croppers. All growers had a similar view on ease of weed control in break crops. Wheat/lupin growers were strongly influenced by the lack of requirement for specialised equipment in their break crop decisions.

Fig 2. Influences on break crop choice by farming type



Survey question: To what extent do each of the following factors influence your choice of break crop?

While most farmers say they understand which break crops are more suitable for them, they are interested in information which helps them make better decisions and manage the risk associated with different break crops. The key information needs identified were:

- information which helps them choose the most suitable break crops for their situation;
- tactical and strategic advice on break crop management;
- research outcomes of key projects.

The research needs identified by participants were:

- technology that makes break crop establishment easier and more reliable;
- better qualification of the break crop effect;
- opportunities to add value, particular amongst the wheat-lupin farmers.

Mixed farmers (47%) and the phase croppers (48%) rated pastures as more important than break crops, compared to intensive croppers who rated pasture as similar to break crops in terms of importance. Over 70% of participants felt pastures were of equal, or more importance, than break crops in their rotation.

Participants were also asked about climate change impacts on their crop choice in the future. Two thirds felt it would have at least a modest impact. There was a distinct difference between the three regions with 75% growers in the north and 71% in the central regions saying climate change will have a moderate to major impact compared to only 49% from the south.

Participants showed a strong preference for being kept informed by Farmnotes, electronic newsletter or brochure. This is contrary to previous client surveys regarding information delivery which indicated AgMemos and press releases as a preference. This feedback was consistent across the different farm types.

CONCLUSION

The survey successfully captured current attitudes towards lupin, canola, field peas and oats. Most growers recognise the importance of break crops but still have difficulty attributing an economic value on their benefit in the system. Some still need clearer information on when and where to use break crops in their system.

This survey reiterated variability in yields, costs and establishment of break crops as the main concerns amongst growers. The survey reinforces our ideas about the needs for research into understanding the break crop effect and the establishment of break crops in drier, more variable seasons. Improving the profitability of break crops would be best achieved through improving yield and not necessarily reducing the cost to grow them.

When asked about future research requirements most growers (179) did not offer anything other than issues listed in the survey questions. Additional issues suggested by a few growers included variety specific agronomy, more versatile crops, basic applied agronomy and further research into GM crops.

The survey highlighted that future research should be focused on where break crops best fit within the farming system to maximise profitability and sustainability.

See also '*A decade of attitude toward break crops*' in these proceedings.

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KEY WORDS

break crops, rotations, grower attitudes, survey

ACKNOWLEDGMENTS

Dr Peter White and Mr Ian Pritchard who assisted in the development of the questions for the survey. Mr David Robinson (CRIS) for generating the random list of landholder names across the wheat belt. Julieanne Harmer and Linda Tagni from Synovate who conducted the phone survey.

Project No.: DAW 00161

Paper reviewed by: Dr Peter White

Attitudes of Western Australian wheatbelt growers to 'Break Crops'

Paul Carmody and **Ian Pritchard**, Development Officers, Department of Agriculture and Food, Western Australia

KEY MESSAGES

Growers need information on how to choose the most suitable break crops for their cropping situation. Clearer definition of the systems benefits of break crops would enable them to make better informed crop choices.

The benefits growers are looking for in break crops vary depending on the status of the paddock they were intending to sow the break crop in.

Most growers believe they know what they need to know about the management of growing break crops.

Growers choose break crop based on their agronomic benefits and not the relative profitability of the crop itself.

Yield variability is the major limiting factor to a break crop's profitability.

BACKGROUND

The area sown to break crops in Western Australia (canola, lupins, field pea and oats for hay and grain) grew from 640 000 tonnes in 1987 to a peak of 2 800 000 tonnes in 1999 before falling back to 773 000 in 2007.

What has been the cause of this roller coaster ride for break crops?

The lupin, pulse and canola industries and to a lesser extent the oat industry have emerged from the industry specific development programs of the nineties with mixed success. A review of where these programs need to head has been called for by GRDC in partnership with DAFWA and growers groups. Applied agronomy projects at the time developed robust management packages for these crops with singular visions of driving each forward without really considering how they fit within WA farming systems.

In a joint initiative by GRDC and DAFWA, a break crops project was established in 2008. One of the aims of the break crop project is to establish what growers' attitudes are towards break crops and the information and research needed to progress break crops in WA.

AIM

To determine grower attitudes toward break crops in Western Australia and the information and research needs to progress break crops in WA.

METHODS

Commodity based research and industry surveys were reviewed to determine the issues and drivers surrounding the adoption of break crops. The review ran parallel to a series of industry workshops, case studies, interviews and an extensive industry survey (see other paper in this booklet). The complex nature of how growers choose break crops and attitudes towards them meant qualitative and quantitative data was needed to provide a balanced view.

An industry workshop was held in Perth during April 2008 with a cross section of agribusiness, researchers and agronomists to discuss the issues regarding break crops. This was followed by four regional workshops (Buntine, Cunderdin, Katanning and Yearling) with growers and agribusiness to discuss their crop choices and future farming systems. Interviews and surveys with advisers were also done to determine the factors that influence their advice to clients regarding break crops. The

reviews, interviews, workshops and past surveys have been collated to establish a consensus on attitudes towards break crops in Western Australia.

RESULTS AND DISCUSSION

An industry workshop in April 2008 with advisers and researchers provided an up-to-date review of the current issues with each break crop. The issues were categorised into seven main areas: weeds, diseases, yield, harvest, soils, price and others. The frequency with which participants raised an issue was 'mapped' and this provided a pattern of issues for each of the break crops.

Similar patterns of concerns emerged for lupin, oats and canola (price, disease, weeds) but field peas stood out as having a different set of issues namely yield (low yields or variable), harvest difficulties and frost (others). The main concerns of oat hay were leaf disease and annual ryegrass toxicity (ARGT). Interviews with advisers during the year confirmed these concerns. Researchers tended to focus on disease issues while advisers were more concerned about weeds.

Table 1 **The primary issues raised for each of the break crops identified during the April 2008 industry workshop**

Canola	Blackleg disease impact on yield and the constraint it puts on being able to rotate canola flexibly around the farm.
Field Pea	Better varieties for low rainfall areas and frost management dominated the concerns for field peas.
Lupin	The lack of a cost effective and efficient weed control and the poor competitiveness of the crop against weeds management of it in the rotation.
Oats Grain	Limited export markets, poor market information and price volatility is considered a serious impediment to growers considering entering the industry.
Oats Hay	The risk of ARGT contamination, chemical residues and the impact of foliar disease all point to a major issue for the management of the quality of hay.

Pulses

In 2003 a stratified survey of growers found that risk of wind erosion, susceptibility to frost, harvest difficulties and susceptibility to disease (blackspot) along with the misunderstanding that field peas are only suitable for heavy soils were the main perceived physical barriers to their adoption (Market Equity 2003). Growers valued field pea over the other break crops for their; flexibility in time of planting, the effect on soil nutrition (Nitrogen), disease break and wide soil type suitability.

While growers appreciated the value they could get from sowing field peas, the key barriers to doing so were related to the perceived risks of crop failure (frost), harvesting difficulty and wind erosion. Growers also indicated a preference for alternative break crops with which they have more knowledge, experience and confidence.

Growers tended to evaluate return on investment from a particular crop in a very ad hoc fashion. For example, for break crops they focussed on the outright costs and returns of growing a particular break crop in a given year, which resulted in field peas being seen to provide a lower return on investment.

Interestingly, the field pea survey also revealed that lupins and canola had several advantages in common; easier to harvest, better weed control options, able to grow on lighter soils and able to be sown earlier than field peas.

A 2006 chickpea survey revealed the main issues with this crop were (in descending order of importance): management of ascochyta blight (disease), low and variable yield, difficulty in controlling weeds within the crop and harvesting.

Lupins

The growth in lupin production mirrored that of canola during the late nineties but has not recovered from its downward trend since. Lupin production recently has been highly variable—due to poor seasons and inadequate farm gate cash return. Growers recognise the indirect rotational benefits of

lupins but many simply cannot make satisfactory cash income from them (Fellows 2006). Statewide average yields are around 1.1 t/ha versus a financial break-even level of about 1.5 t/ha. Apart from disappointing yields in recent years one the biggest agronomic issues for the crop has been weed

control (White 2007). Without pushing the wheat/lupin rotation out another year with canola or barley, herbicide resistant weeds become a major challenge for the crop and can reduce the benefit it has (Michael 2008).

Fellows (2006) also found that poor yield in sub-optimal or marginal conditions is also a barrier to the lupin industry. Growers who put lupins in less than favourable conditions and fail are reluctant to try them again. Even with the release of new varieties like Jenabilup, which is more suitable for the southern high rainfall districts, there is resistance to try them again. During the regional workshops in 2008 growers where calling for better adapted varieties for their district.

The key constraint to lupin production is that lupin production has relied almost exclusively on selective herbicides and moisture activated, soil borne, pre-emergent herbicides for almost 30 years. The subsequent development and management of herbicide resistant weeds throughout the lupin production area remains one of the single biggest challenges for the crop.

Disease has also impacted on lupins with anthracnose (north) and CMV (south) being the main concerns of growers however they pale into insignificance compared to their greatest concern—weed management. Changes to farming practices and good quality extension material like the brochures on Managing Weeds in Lupins can only partially address the problem. Hence, for this reason, growers are showing increasing support for the development of GM herbicide tolerant lupins.

The Lupin Taskforce (DAFWA 2007) identified key areas for action to curb the downward trend in production; lupin breeding was to focus on GM herbicide tolerant varieties and the development of varieties that have appropriate level of disease resistance for a given region. From an agronomy view point alternative weed control, better weed management information and clearer definition of the rotational benefits of lupins were called for.

Canola

The most successful of all four break crops in WA since 1999 has been canola. In 2008 over one million tonnes was produced. A national survey conducted by Insightrix Research (2006) found that the major triggers that growers use to decide whether to grow canola were: timing of the break of the season (53%), price (40%) and the presence of soil moisture. The most important factors influencing their decision to grow, or advise others to grow, canola were: weed control (81%) cereal root disease (80%), herbicide rotation (74%), profitability of following crop (69%) and diversification of farming system (56%).

The factors growers felt limited canola production were: variability in rainfall (63%), soil issues (25%), climate (24%), commodity prices (23%), cost of production (21%) and susceptibility to disease (20%).

Crop canola is grown across a wide range of agro-climatic zones in Western Australia and growers have a complex mix of attitudes towards it—ranging from “would prefer not to grow it if I could get away with lupins more often” to “its no longer a break crop but our main crop”. Generally growers in the north consider canola riskier than lupins while the reverse is true of growers in the southern wheatbelt. Part of this difference is associated with the difficulty of establishing canola in the drier parts of the northern wheatbelt and also some memory of the major diamondback moth infestations in the north during the 2001 and 2002 seasons.

Oats

Past surveys of the oat industry are very limited with little data to explain changes in attitudes to oats and their role as a break crop in Western Australian farming systems. There are few serious agronomic constraints to oat production in WA. Nitrogen management and leaf diseases are cited (Winfield 2007) as major issues that need to be addressed. Nitrogen management itself is well known but how exactly N impacts on the quality of oat is less clear. Over the past decade, oats have emerged from an era where growers would “scratch them in for some feed” to a serious crop in their own right. Some growers in the Great Southern now use oats as the main source of income choosing to rotate them with canola or barley (Knell 2008). Growers in some districts will sow oats upon oats, knowing there is little risk of serious root disease.

During the 2008 regional workshops many participants did not consider oats a true break crop. Katanning growers stated there were benefits in growing oats as a type of break crop in that the soil appeared to be more friable following an oat crop.

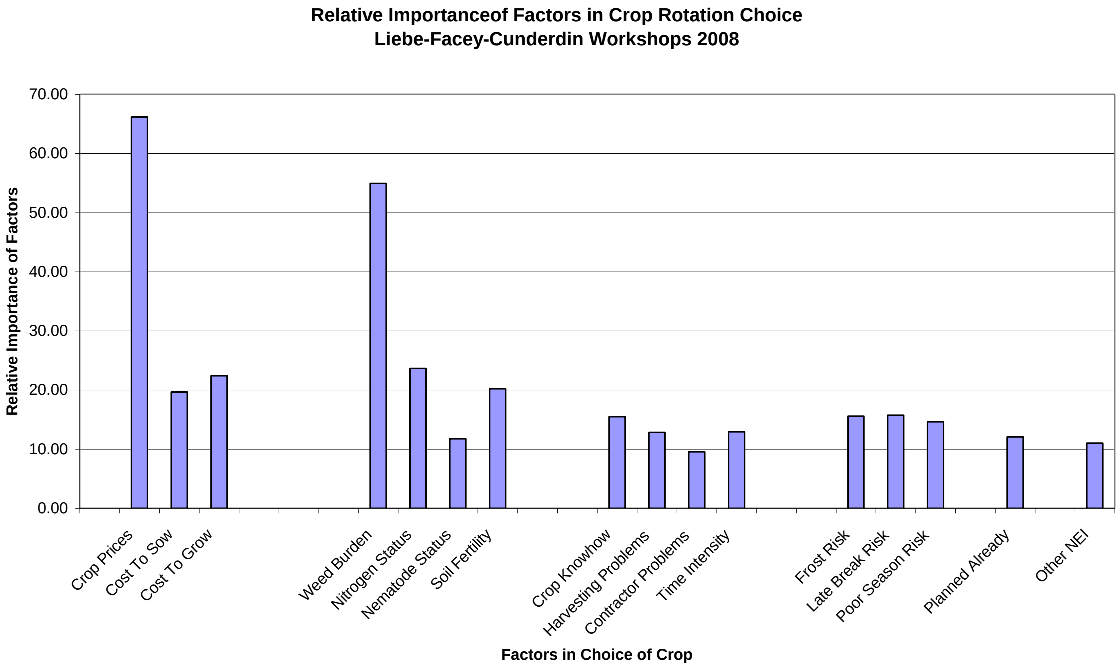

Figure 1 A ranking of factors that influence growers choice of crops for a paddock next year. A composite of the results from Buntine, Cunderdin and Yearling grower workshops 2008 (23 growers).

Regional workshops

At the regional workshops, growers were asked to rank factors influencing their crop choice for their paddocks the following year. A list of 16 factors was presented to growers who then ranked them in order of importance. The crop price (see Figure 1) was ranked highest in terms of influencing crop choice followed closely by weed burden. Cost of growing the crop ranked third with nitrogen status, cost to sow and general soil fertility. The key finding from the three grower workshops was the importance growers place on weed burden relative to economic factors in their crop choice.

Other important outcomes of the workshops were a comprehensive list of the issues for break crops and the belief that break crops had an important role to play in future farming systems. Table 2 captures a summary of these outcomes along with views expressed in past surveys or studies.

Table 2 **A summary of grower perceptions of 'Break crops' on the main issues of concern**

Issue	Field Peas	Lupin	Canola	Oats/Grain	Oats/Hay
Best soil types	Prefers heavier soils	Good Sandplain	Wide range of soils types	Wide range soils, tolerates water logging	As for grain oats
Profitability	Profitable but risk of crop failure a concern (frost risk)	Declining profitability, lower prices	Highly profitable but risky	Low production risk, but high market risk	Highly profitable but substantial production and market risk
Yields	Ave > 1.2 t/ha Stable	Ave > 1.5 t\ha Highly variable	Ave > 1.5 t/ha (national) Highly variable	Av yield >? Variable Nitrogen management	> 5 ? tonne/ha Variable

Issue	Field Peas	Lupin	Canola	Oats/Grain	Oats/Hay
Establishment	Generally easy	Easy but difficult in dry starts	Difficult to obtain even establishment	Easy	Easy
Disease break	Effective	Effective	Very effective	Good to not sure	No sure
Weed control effectiveness	Limited ability	Limited effective options	Good weed control possible	Reasonably competitive but limited options	Very effective
Planting flexibility	Late sowing good flexibility	Limited to early sowing	Limited to early sowing	Reasonable flexible	Reasonable flexible
Harvest	Difficult	Easy	Reasonable easy	Easy	Logistically difficult
Quality	Not an issue	Some issues, need for human food quality	Low oils in dry finishes	No real concerns with domestic market	Serious concern regarding ARGT and leaf diseases
How hard/easy is it to grow?	Reasonably easy	Easy but for weed management	Reasonable compared to cereals	Easy to grow	Easy to grow difficult to get quality right

CONCLUSION

A study of grower attitudes towards lupin, canola, field peas and oats indicates that most growers recognise the importance of break crops but still have trouble putting a real dollar value on the benefits the crops provide to the cropping system. It was clear from the interviews, case studies and regional workshops that majority of growers and advisers were comfortable with the information they could access on how to manage the different break crops. However, they were not able to identify the benefits different break crops had in their particular situation or in which part of their system break crops would bring the best returns.

The most revealing aspect of the review, including the results of the 2008 Break Crop Survey (see other paper in this booklet) was that growers' choice of break crops was often based on agronomic factors and not on the profitability of the break crop itself. Yes, growers would like break crops to be more profitable but they were still motivated primarily by the agronomic and rotational benefit they offered. Often the trigger to choose a break crop was driven by the paddock situation such as weed burden and type, disease/pest pressure, soil type/fertility.

The study confirmed that growers' main concerns regarding break crops are: variability in yields, costs and establishment. The survey reinforced the need for research into understanding the break crop effect and the establishment of break crops in drier, more variable seasons. Improving the profitability and therefore the adoption of break crops would be best achieved through improving yield potential and yield variation. The cost of producing break crops is a universal barrier to their adoption and there is little that can be done to address this.

The review provided the project with a clear research direction into break crops and highlighted that it is not the break crop itself that is important but where it best fits within the farming system to maximise profitability and sustainability.

ACKNOWLEDGEMENTS

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Project No.: DAW 00161

Paper reviewed by: Dr Peter White

The value of organic nitrogen from lupins

Alan Meldrum, Pulse Australia

KEY MESSAGES

- Modern lupin cultivars contribute a rotational benefit to wheat production.
- Wheat following lupin yielded 13% more than wheat following wheat.
- Residual N from lupins delivered a consistent 1% gain in wheat protein across all N rates.

BACKGROUND

Lupin production has declined in WA in recent years because of low commodity prices and drought. Growers' attention has also been focussed on annual cash returns from grain crops. The rapid rise in the price of nitrogenous fertiliser in 2008 renewed interest in lupin production, and the rotational benefits to the following cereal crop.

Previous research has established a good rule of thumb for residual N from lupins. However, modern varieties may provide less residual N than older varieties if they produce higher yields.

A trial to determine the value of residual N from a modern lupin cultivar was attempted at four sites in 2007. Trials at Mingenew with MIG collaboration, and Marchagee with Liebe Group collaboration, failed in 2007 due to drought. The site at south Yealering, in collaboration with the Facey Group, produced a large variation in wheat yield across the site in 2008 with no significant result. This was possibly due to the very dry August and September. The trial conducted at Wongan Hills is reported here.

AIMS

To determine if Mandelup lupin, a high yielding modern variety, provides similar rotational benefits as found by previous research with older varieties.

METHOD

In 2007 four treatments were applied to lupins (cv Mandelup) to deliver varying amounts of residual nitrogen. One wheat variety was sown for the wheat on wheat comparison (cv Carnamah).

In 2006 the paddock was cropped to wheat. For the three years prior, 2005, 2004 and 2003, the paddock had a grassy volunteer pasture with low legume content.

Table 1 **Treatment table for lupins sown in 2007**

Treatment	Anticipated N residue	Sowing date
Lupins sown early and harvested	Normal expected level of residual N	28 May 2007
Lupins sown late and harvested	Less than normal level of expected residual N	15 June 2007
Lupins brown manured at first pod development	Higher than expected residual N	28 May 2007
Lupins brown manured and slashed to enhance N mineralisation	Much higher than expected residual N	28 May 2007
Wheat	No residual N	31 May 2007

In 2008, 3 rates of nitrogen were applied across the 2007 plots to wheat (cv Carnamah). The nitrogen rates were 0, 25 and 50 units of N delivered as Flexi-N immediately prior to sowing.

The biomass and grain yields were measured in 2007, while wheat yields and grain quality were measured in 2008.

RESULTS

2007

Lupins (cv Mandelup) were established at two dates: 28 May and 15 June. Wheat (cv Carnamah) was established 31 May. The trial site was weed free for the entire season.

The later lupin sowing performed better due to low moisture during establishment for the early sowing. Despite this, plant numbers were similar for both. A favourable spring enabled the later sown lupins to yield better.

Brown manuring was conducted on 19 September using 2 L/ha of glyphosate.

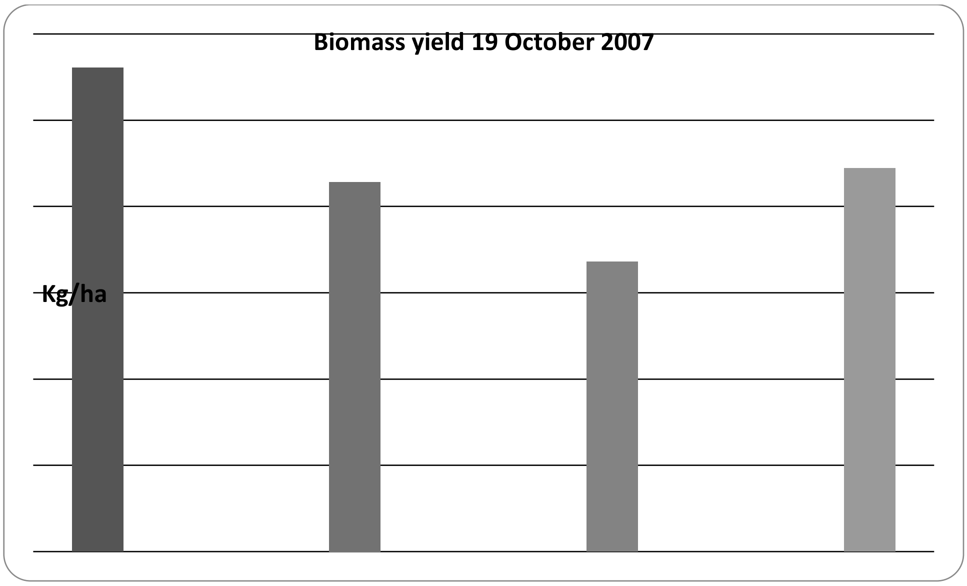

Figure 1 2007 biomass yields.

The 2007 yields were acceptable in a difficult season. No measurements were taken of residual soil moisture from the brown manuring treatments.

Table 2 **Biomass and grain yield results from 2007**

	Treatments	Biomass	Yield
Lupin	early sown + harvest	4285	1.58
Lupin	late sown + harvest	4442	1.70
Lupin	early sown + Brown manure	3360	0.00
Lupin	early sown + BM + Slash	-	0.00
Wheat	district practice	5600	2.73

Soil test data showed an increase in Nitrate nitrogen from the brown manure treatments but no increase from the harvest treatments over the level in wheat stubble.

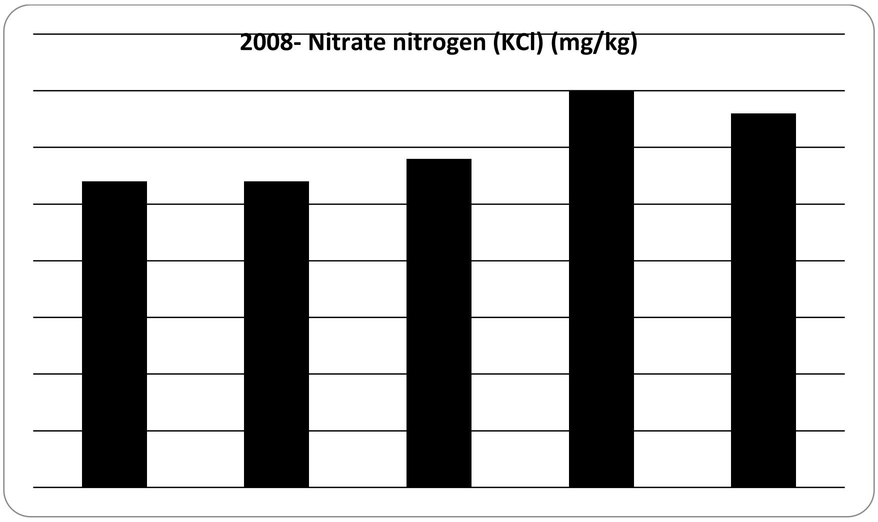

Figure 2 Soil Nitrate levels, April 2008.

2008 Wheat yield

Carnamah was planted on 12 June 2008. The nitrogen rates were applied as Flex-N IBS at right angles over the 2007 treatments with two replications within each replication from 2007.

Table 3 **Yield results from 2008**

		2008 N rates		
	2007 treatments	**nil N**	**25 units N**	**50 units N**
Lupin	early sown + harvest	3.01	3.16	3.18
Lupin	late sown + harvest	3.22	3.27	3.24
Lupin	early sown + Brown manure	3.14	3.34	3.34
Lupin	early sown + BM + Slash	3.01	3.42	3.25
Wheat	district practice	2.63	2.84	2.77
Response to applied N in 2008 – l.s.d. 5%			0.08	
Response by wheat to 2007 treatments – l.s.d. 5%			0.25	
Response to applied N and 2007 trmts – l.s.d. 5%			0.34	

The response of wheat to applied N in 2008 was highly significant across most treatments. The response of wheat following lupins was highly significant irrespective of lupin treatment.

There were few significant interactions between residual N levels and applied N. There is a trend of decreased wheat yield in treatments with high levels of residual N.

2008 Grain protein—analysis by Australian Grain Centre

Table 4 **Wheat protein analysis from 2008**

		2008 treatments		
	2007 treatments	**0 units N**	**25 units N**	**50 units N**
Lupin	early sown + harvest	10.8	11.4	12.2
Lupin	late sown + harvest	11.1	11.3	12.4
Lupin	early sown + Brown manure	11.9	12.5	13.4
Lupin	early sown + BM + Slash	12.0	12.4	13.3

Wheat	district practice	9.8	10.2	11.2
	l.s.d. @ 5%		0.5	

Wheat protein was higher in all treatments following lupins than following wheat.

Twenty-five units of N on wheat following wheat produced less protein than 0 N after lupins. Protein increased for all treatments where yield declined, showing that yield potential for this situation was attained. Applied N was able to lift wheat protein after wheat to above the 10% requirement for the APW grade.

CONCLUSION

The response to applied N by wheat was similar regardless of the previous crop or treatments, indicating that lupins at this site have delivered a yield increase which may be due to factors other than the residual N. This is possibly due to root disease suppression by the 2007 lupins. The very dry August and September would have suppressed any significant leaf disease incidence. The paddock history indicates a potential for cereal root disease which would have been adequately reduced by the lupins in 2007.
The background Nitrate status of the paddock may have suppressed the potential response to applied N. Significantly, lupins raised wheat protein in the following crop by 1%, as shown in Table 4.

It is also possible that wheat in 2008 could have responded to residual soil moisture from the brown manuring treatments. A trend to increased yield is apparent at 25 units of N, with increased protein at 50 units of N.

Early maturing varieties of lupins can attain acceptable yields from later sowings given favourable spring conditions, as shown in Table 2.

Continued yield benefit is expected from the lupin residual N as this continues to mineralise over the next two seasons.

KEY WORDS

lupins, nitrogen, wheat, yield, protein

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The area of break crops on farm: What farmers are doing compared to estimates based on maximising profit

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KEY MESSAGES

- Break crops increase farm profit, although in some cases the optimal area for break crops on the farm is small. There is an upper limit to break crop area beyond which whole-farm profit drops—i.e. more is not necessarily better.
- The response of whole farm profit to per cent of the farm allocated to break crops is relatively flat. This result highlights, at least in economic terms, why adoption of break crops is highly variable within one rainfall zone.
- The modelled area of break crops at maximum profit is higher than that found in farm surveys and can be explained in part by lower break crop yields being realised by farmers but also raises questions about farmer motivations for adoption of break crops.
- The scope for increased area of broadleaf break crops beyond 35 to 40% of the farm is limited, even if the yield boost they provide to cereals increases. There are risks to break crops dropping out of the system if yield boosts to cereals and yields of the break crops themselves are less than assumed in current whole-farm economic models.

AIMS

Break crops (pulses, lupins, canola, oats) have long been a fundamental component of cropping sequences in Western Australia. Profitable use of break crops has depended on biophysical, economic and social factors. Here we attempt, by modelling, to isolate the effects of agro-climatic region (i.e. soil types and rainfall), commodity prices and the interactions between break crop production and other enterprises run on a farm (e.g. sheep production). These estimates are compared to farm survey data collected by FARMANCO in the low and medium rainfall zones that show what area farmers are actually growing. We also sought to determine the relative importance in variation in the yield of break crops, their price, and the boost to the yield of following cereals in determining their area on farms?

METHOD

This paper used MIDAS bio-economic modelling to explore the biophysical and economic drivers likely to influence the area of break crops grown on mixed farms in the WA agricultural region. A consistent modelling approach was used in four agro-climatic regions with representative farms: Central wheatbelt (Cunderdin), Eastern wheatbelt (Merredin), Great Southern (Kojonup) and South Coast (Jerramungup). At the time of this analysis a fully-functioning version of MIDAS for the northern wheatbelt was not available. Regions vary in term of farm size, crop and pasture production, stocking rates, soil types and crop-pasture rotations (Table 1, Robertson et al. 2008). We tested variation in break crop area on farm in response to factors affecting break crop productivity, profitability and competitiveness with competing enterprises (e.g. sheep production) under a variety of scenarios.

Table 1 **Characteristics of modelled representative farms used for break crop area modelling**

	Central Wheatbelt	*Great Southern*	*South Coast*	*Eastern wheatbelt*
Farm Area (ha)	2 000	1 000	2 500	3 800
Annual rainfall (mm)	350–400	500–600	400–500	300–350
Representative crop yields (t/ha)	Wheat: 0.9–2.4 Canola: 0.8–1.1 Lupins: 0.5–1.5	Wheat: 1.2–2.2 Canola: 1.4–1.6 Lupins: 0.3–1.5	Wheat: 0.6–2.8 Canola: 1.2–1.8 Lupins: 0.7–1.1	Wheat: 0.9–1.8 Canola: 0.7–1.1 Lupins: 0.5–1.3

The modelling analyses are compared with and informed by statistics on area and yields of crops from farms from the low rainfall (250 to 350 mm MAR) and medium rainfall (350 to 450 mm MAR) regions obtained from the database of the farm management consultancy company, FARMANCO, for the seasons 2004, 2005 and 2006.

RESULTS AND DISCUSSION

Farm survey of break crop area and yield

In both low and medium rainfall zones, lupins are the most popular break crop (50–66% of growers) (Table 2). In the medium rainfall zone, canola was next most popular at 35–45% of growers, but in the low rainfall zone canola and field pea had similar popularity at 15–26% of growers. Faba beans were moderately popular in the medium rainfall zone (8–21%), but they along with chickpea was of minor interest in the low rainfall zone (< 4%). Oats for grain were grown by 30–40% of growers in both zones and oaten hay was moderately popular in both zones (18–34%). The popularity of fieldpeas, faba beans and canola fluctuated more than most of the other crops from season to season.

In the both rainfall zones between 2004 and 2006 the area attributed to wheat, barley, lupins and canola cropping enterprises was relatively stable (Table 3). In the medium rainfall zone, lupin crops and canola crops occupied 8–12% and 8–9% of farm area and other break crops occupied 4–10% of farms that grew them. In the low rainfall zone, lupin crops and canola crops occupied 6–8% and 7–10% of farm area and other break crops occupied 0–10% of farms that grew them. In both zones, farm-to-farm variation in lupin and canola area percentages formed an exponential distribution implying that a large number of farms grew very few or no break crops.

Table 2. Percentage of farmers in the low and medium rainfall zones that grew each crop

	2004	2005	2006	2004	2005	2006
	Low rainfall			Medium rainfall		
Number of growers	**80**	**82**	**83**	**150**	**158**	**165**
Wheat	100%	100%	99%	97%	97%	97%
Barley	75%	71%	63%	86%	82%	81%
Lupins	50%	55%	53%	64%	66%	64%
Canola	15%	13%	19%	35%	45%	42%
Field peas	16%	26%	17%	19%	25%	15%
Faba beans	1%	2%	2%	8%	21%	16%
Chickpeas	3%	4%	1%	2%	3%	2%
Oats	29%	30%	36%	41%	38%	42%
Oaten hay	18%	18%	19%	28%	27%	34%

In the medium rainfall zone, lupin yields varied markedly from season to season (Table 3). Average yields across the farms were: 1.19 t/ha (2004), 1.61 t/ha (2005) and 0.86 t/ha (2006). These yields varied markedly between growers. The top 25% produced more than 1.47 t/ha in 2004, 1.9 t/ha in

2005 and 1.12 t/ha in 2006. Canola yields also varied from season to season averaging 0.96 t/ha (2004), 1.26 t/ha (2005) and 0.73 t/ha (2006). The top 25% of growers produced at least 1.12 t/ha in 2004, 1.49 t/ha in 2005 and 0.95 t/ha in 2006. Canola and lupin yields were approximately 50% of the

corresponding yield of cereals, although there was considerable season-to-season variation in the lupin to cereal yield ratio for farms that grew wheat and lupins. In 2004 and 2006, lupin yields, on average, achieved 57% and 56% of cereal yield respectively. In 2005, when growing season rainfall was higher, lupin yields achieved 71% of cereal yield. In 2004 and 2006, canola achieved 46% and 44% of wheat yield, but in the better 2005 season, this ratio increased to 58%.

Lupin yields also varied with season in the low rainfall zone: 0.75 t/ha (2004), 1.15 t/ha (2005) and 0.53 t/ha (2006) (Table 3). The top 25% of lupin growers produced more than 0.98 t/ha in 2004, 1.43 t/ha in 2005 and 0.80 t/ha in 2006. Canola yields also varied with season and averaged 0.71 t/ha (2004), 1.04 t/ha (2005) and 0.54 t/ha (2006). The top 25% of growers produced at least 1.04 t/ha in 2004, 1.21 t/ha in 2005 and 0.69 t/ha in 2006. In the poorer seasons of 2004 and 2006, lupin yields achieved just 42% of cereal yield. This increased to 63% of cereal yield in 2005. In 2004 and 2006, canola achieved 45% and 42% of wheat yield, but in the better 2005 season, this ratio also increased to 50%.

Table 3 **Characteristics of farms in the survey of break crop area and yields, for the low and medium rainfall regions over three seasons. Statistics are only for those farms that grew that crop**

	2004	2005	2006	2004	2005	2006
	Low rainfall			Medium rainfall		
Farm size (ha)	**3318**	**3365**	**3457**	**2924**	**3056**	**3136**
Growing season rainfall (mm)	172	226	138	250	317	179
Average farm yield (t/ha)						
Wheat	1.47	1.77	0.99	2.05	2.27	1.51
Barley	1.58	1.89	1.33	2.12	2.33	1.67
Lupins	0.75	1.15	0.53	1.19	1.61	0.86
Canola	0.71	1.04	0.54	0.96	1.26	0.73
Field peas	0.51	1.07	0.56	0.70	1.13	0.66
Faba beans	0.58	1.27	0.91	1.02	2.35	1.60
Chickpeas	0.42	0.49	0.60	0.26	0.28	0.21
Oats	1.31	1.92	0.89	1.87	2.37	1.36
Percentage of farm under crops						
Wheat	63%	65%	51%	41%	40%	35%
Barley	11%	12%	12%	13%	12%	12%
Lupins	7%	8%	6%	12%	11%	8%
Canola	10%	10%	7%	8%	9%	8%
Field peas	4%	2%	0%	4%	4%	6%
Faba beans	2%	5%	7%	8%	8%	10%
Chickpeas	0%	6%	7%	7%	5%	9%
Oats	3%	3%	4%	3%	4%	4%
Oaten hay	6%	8%	9%	3%	4%	4%
Pasture	34%	34%	46%	37%	36%	42%

Relationship between break crop area and farm profit

Modelled optimal area of break crops for three farming systems, Central Wheatbelt, South Coast and Eastern Wheatbelt is around a quarter to a third of farm area and around 40 to 50 per cent of total crop area. For most of the models the curve of profit against area of break crops is flat around the optimum point, meaning the area of break crops can be increased or decreased by 5–10 percentage points with no impact on profit. The exception to this is the Great Southern, where an area of break

crops of more than 8% results in a sharp decline in profit. The optimal area of break crops in the Great Southern farming system is only 5%, out of a total crop area of only 13%, due to the superiority of pastures on 50% of the soils in the model.

Sensitivity of break crop area to variation in key factors

At high break crop prices relative to cereals (see Table 4 for prices used), break crops as a percentage of total crop area goes up from 23 to 36% in the Eastern wheatbelt, 38 to 46% in the Central wheatbelt, 27 to 36% in the South Coast and 5% to 9% in the Great Southern. This suggests that improvements in break crops prices can be a driver for greater adoption. With such changes there were interesting shifts in the composition of break crops. In the Eastern wheatbelt, canola area dropped at the expense of legumes, while in the Central wheatbelt more canola was selected.

In contrast to grain prices, changes in sheep prices (Table 4) have only a small impact on break crop area. In the Eastern Wheatbelt break crop area varied 18 to 23% depending on sheep prices, 30–40% in the Central wheatbelt, 27 to 32% in the South Coast and 6 to 8% in the Great Southern. This is because the impact of changing sheep prices is to shift total crop area, with the per cent of break crops within that total crop area remaining similar.

Table 4 **Commodity prices used in sensitivity analysis**

	Standard	*Low grain*	*High grain*	*High break grains*	*Low sheep*	*High sheep*
APW ($/t)	300	200	400	300	300	300
Barley	300	200	400	300	300	300
Feed barley	250	150	340	250	250	250
Lupin	250	150	330	330	250	250
Canola	550	250	850	850	550	550
Field peas	250	200	380	380	250	250
Faba beans	250	200	450	450	250	250
Chick peas	300	200	500	500	300	300
Lamb ($/kg)	3	3	3	3	2.25	3.75
Ewes ($/hd)	40	40	40	40	30	50
Wethers ($/hd)	50	50	50	50	37.5	62.5
Wool (¢/kg, WMI)	900	900	900	900	750	1050

An increase of 50% to the break crop boost (see Table 5 for model assumptions) to following cereal yield will increase break crop area because rotations based on break crops become more profitable than others due to greater profitability of the cereal phase. Changes in break crop area were 23 to 27% in the Eastern wheatbelt due to more lupins being selected and 38 to 39% in the Central wheatbelt due to more canola being selected. Similar small shifts were seen in the South Coast and Great Southern situations. Increasing the boost by a further 50% does not result in much extra area, for similar reasons that increasing break crop area beyond a certain point will not increase whole-farm profit any further. Interestingly, break crop area is more sensitive to a halving of the boost to cereal crops For example, in the Eastern wheatbelt model, break crop area dropped from 23 to 15% with a halving of the boost, and from 38 to 23% in the Central wheatbelt. This suggests that maintaining yield boosts to cereals following break crops will be critical to retaining break crops in farming systems, although it also suggests that any improvements in the boost beyond what is assumed in Table 4 may not deliver greater break crop area.

Table 5 **Per cent increase in wheat (W) after various break crops used in four MIDAS models**

Crop sequence	*Central Wheatbelt*	*Eastern Wheatbelt*	*South Coast*	*Great Southern*
W after 3 yr pasture	25	20	20	9
W after 2 yr pasture	18	16	25	6
W after 1 yr pasture	15	8	25	6
2nd W after pasture	12	8	20	6
W after legume	20	20	25	27
2nd W after legume	12	12	0	9
W after legume and canola	25	24	25	27
2nd W after legume and canola	15	12	0	9
W after canola	20	4	5	27

Modelled area of break crops versus farm survey

The area of break crops at maximum profit is higher than that found in surveys of farm data. For example, at standard assumptions 23% of the Eastern wheatbelt, 38% of the Central wheatbelt, 27% of the South Coast and 5% of the Great Southern farms were occupied by break crops. The results of the farm survey (Table 2) showed in the medium rainfall region most farmers had between 8 and 12% area under lupin and between 8 and 9% area under canola. The sum of the areas at the upper end of this range is somewhat lower than the economically-optimal values generated by MIDAS for the Central wheatbelt region (closest to the medium rainfall zone). In the low rainfall zone, adoption of lupin (6–8%) and canola (7–10%) was below optimal values generated by MIDAS for the Eastern Wheatbelt region, although the sum of the upper range for both species (18%) is similar to the 21% from MIDAS. The possible reasons for such discrepancies are worth considering and may shed some light on motivations for farmer adoption of break crops. One possible explanation is that as profit vs. break crop area is quite flat around the optimum, farmers are choosing to operate at the lower end of that comparatively flat region (and maybe even slightly below that) because they perceive break crops to be more risky, more demanding in terms of management, or more difficult to market, so that they are willing to trade-off whole-farm profit.

Another possible explanation is that the yields being assumed in MIDAS are higher than what most farmers are achieving in commercial reality. For the medium rainfall region, this does not seem to be the case. The 2004–2006 average canola and lupin yields were 0.95 and 1.2 t/ha, which fall in the middle of the range of yields assumed in the Central wheatbelt MIDAS model (closest in farming systems and yield levels to the medium rainfall region) at 0.8–1.1 t/ha for canola and 0.5–1.5 t/ha for lupins. In contrast, in the low rainfall region, on-farm yields do seem to be lower than those assumed in the Eastern wheatbelt MIDAS. The 2004–2006 average canola and lupin yields were 0.71 and 0.74 t/ha compared to model assumptions of at 0.7–1.1 t/ha for canola and 0.5–1.3 t/ha for lupins. Model sensitivity analysis suggested than improving break crop yield in its own right may improve the profitability of rotations including those species and this result in those rotations being selected more frequently in optimal farm plans. When MIDAS runs were conducted with reduced canola and legume yields, these crops reduced in area (and even to zero area) in the optimal farm plans, particularly so for canola. Certainly when both break crop yields and the boost to cereals from break crops was reduced, break crop area reduces greatly. This reduction is mitigated somewhat when high grain prices (such as seen in 2008) are assumed with areas dropping back to around 30–50% of that found under standard settings.

CONCLUSIONS

Overall, the results show that break crops are an important component of the farming system, even where the optimal area is small. It is clearly costly to exclude break crops from farm plans. However,

the fact that farmers are growing much smaller areas of break crops than would appear economically optimal suggests that a greater understanding is needed of what break crop yields and the boost to following cereals are being achieved on farms, as well as farmer perceptions of the role and performance of break crops in their farming system.

KEY WORDS

economics, MIDAS, canola, lupins, prices, costs, cereal

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Identification of WALAB2014 as a potential albus lupin variety for northern agricultural region of Western Australia

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KEY MESSAGES

1. WALAB2014 flowers and matures earlier and is more resistant to anthracnose than Andromeda.
2. It yielded as much as Kiev Mutant in northern agricultural region.
3. New lines with earlier phenology and higher level of resistance than Andromeda continue to emerge in the breeding program.

BACKGROUND

Andromeda is currently the only variety with substantially improved resistance to anthracnose over Kiev Mutant. Although it is recommended in low to medium rainfall areas, where the risk of anthracnose is moderate to low, it has not been popular because of its late maturity. There is a need to develop varieties substantially better than Andromeda in disease resistance and yield potential. Kiev Mutant is an early flowering and high yielding variety well suited to WA conditions, if it had resistance to anthracnose. Varieties such as Kiev Mutant with anthracnose resistance will be required for successful crop production in WA. A strong association between anthracnose resistance and lateness has slowed the process of developing early and disease resistant varieties in albus lupins.

AIMS

To develop new albus lupin cultivars with early maturity and high levels of anthracnose resistance so that reliable production can recommence in WA.

METHOD

Twenty-five to thirty crosses are made every year to combine early flowering, disease resistance and high yielding traits in albus lupins. Early generations are advanced using a single pod descent method and single plants are selected at F4/F5 generations. Their seed is multiplied and genetically stable lines are evaluated at multiple sites for yield and seed quality, and disease resistance at Medina. About 150 lines in 2007 and 200 lines in 2008 in Stage 2–1 and 2–2 trials were evaluated for yield and agronomic characters at Woorree and Avondale. Due to shortage of seed, not all lines were tested at all sites. Seven lines were tested in CVT at Mingenew. Observations were taken on phenological parameters and their grain yield was harvested. Quality tests, such as grain size and alkaloid contents were measured in harvested grain samples. All these lines were also tested for anthracnose reaction under irrigated conditions at Medina disease nursery.

RESULTS

In 2007 WALAB2013 and WALAB2017 in Stage 2–2 trial yielded as much as Kiev Mutant at Woorree (Table 1). Although their yield was higher than Andromeda, the level of resistance and earliness was similar. At Avondale, these lines did not perform as well as they did at Woorree. There were two lines in Stage 2–1 trial (WALAB2014 and WALAB2015) that yielded more than Kiev Mutant, were earlier flowering and had higher level of resistance to anthracnose than Andromeda. Another line WALAB2016 was identified as a high yielding line from a small plot trial and no comparative data are presented in the table. Among them WALAB2014 was highest yielder and had bigger seed, similar to that of Kiev Mutant. The above five lines were advanced to CVT program in 2008.

Table 1 **Grain yield, seed quality, phenology and anthracnose reaction of selected albus lupin lines in 2007. Anthracnose rating is in 1–5 scale where, 1 is immune and 5 is extremely susceptible. Flowering and maturity are in 1–5 scale, where 1 is very late and 5 is early, similar to Kiev Mutant**

Name	Woorree		Avondale		Seed weight	Alkaloid % *	Flower-ing	Maturity	Anthra-cnose
	kg/ha	%Kiev Mutant	kg/ha	%Kiev Mutant					
WALAB2014	1126	114	1257	106	31.8	0.024	3.5	4.0	3.2
WALAB2015	1033	105	1170	99	27.2	0.015	3.5	3.5	3.2
WALAB2013	981	100	929	78	30.6	0.026	3.8	3.5	3.5
WALAB2017	967	98	1114	94	28.9	0.030	4.0	4.0	3.3
02B011–6	932	95	1006	85	28.0	0.017	3.0	4.0	3.5
02B009–9	885	90	1010	85	28.0	0.019	3.8	3.5	3.0
02B015–14	874	89	989	83	30.5	0.013	3.0	2.5	2.8
01B003–5	833	85	1113	94	21.3	0.018	2.5	2.5	3.0
97B072–5	810	82	1489	126	28.3	0.033	4.0	3.0	3.4
01B002–4	800	81	849	72	24.2	0.026	4.0	5.0	3.5
97B072–11	794	81	971	82	26.9	0.031	3.0	2.0	3.3
02B011–1	787	80	1138	96	26.1	0.017	4.0	3.0	3.1
WALAB2008	623	63	906	76	24.9	0.019	3.6	3.0	3.0
Andromeda	776	79	1266	107	29.9	0.028	2.5	3.5	3.5
Kiev Mutant	984	100	1186	100	32.9	0.016	4.8	4.9	4.6

* Alkaloid results are from a screenhouse grown grain samples and they are generally higher than they would be if the plants were grown in an open field.

In 2008 yields at Woorree were about average, but they were poor at Avondale (Table 2). Avondale suffered waterlogging at the start of the season and was droughted later. 03B021–10 was the highest yielder at Woorree and yielded more than Kiev Mutant at both locations. It was early flowering, but its anthracnose resistance was poor. WALAB2014 yielded as much as Kiev Mutant at Woorree and 23% more at Avondale. It was earlier in flowering and maturity and had better resistance to anthracnose than Andromeda, consistent with the last year's results. Its white and bold seeds were as big as that of Kiev Mutant. The CVT trial at Mingenew showed that WALAB2014 yielded 100% of Kiev Mutant and it was one of the highest yielders. WALAB2016 yielded slightly higher and had similar level of anthracnose resistance to WALAB2014, but it was a late maturing line. Although we have limited data of only two years for WALAB2014, the results are consistent and the yields are equivalent to or higher than Kiev Mutant in all locations. Considering its potential, WALAB2014 is being fast tracked and currently its pedigree seed is being multiplied at Manjimup over summer. This line will be evaluated further in 2009 and if the results are satisfactory, it will be released in 2010. Andromeda was released primarily because of its resistance to anthracnose, but WALAB2014 is higher yielding and has better resistance to anthracnose than Andromeda.

Another line 97B072–5 was the highest yielder at Avondale producing more than 25% of Kiev Mutant in both 2007 and 2008. Its yield, however, was less than that of Kiev Mutant at Woorree in both years indicating a regional adaptation and it might be a good variety for Avondale region. Its anthracnose resistance is similar to that of Andromeda. Avondale is cooler and has longer growing season than that of northern sites.

Besides these lines, there are many other lines in the breeding program that are earlier and have better anthracnose resistance than Andromeda. Recently, three molecular markers for anthracnose

resistance in albus lupin have been developed and validated. Such markers were used for the first time in WA albus breeding program this season in segregating populations. The use of marker assisted selection has helped to identify early and resistant lines earlier in the breeding cycle which will enable to evaluate only promising lines in yield trials. It seems that combination of early flowering and anthracnose resistance is possible with a different source of early flowering line, such as P28283, but very difficult with Kiev Mutant.

Table 2 **Grain yield, seed quality, phenology and anthracnose reaction of selected albus lupin lines in 2008. Anthracnose rating is in 1–5 scale where, 1 is immune and 5 is extremely susceptible. Flowering and maturity are in 1–5 scale, where 1 is very late and 5 is early, similar to Kiev Mutant**

Names	Woorree		Avondale		Mingenew #		Flower-ing	Maturity	Anthra-cnose
	kg/ha	%Kiev Mutant	kg/ha	%Kiev Mutant	kg/ha	%Kiev Mutant			
03B021—10	1833	107	794	106			4.0	4.0	3.8
WALAB2014	1722	100	922	123	1625	100	4.5	4.5	3.0
Kiev Mutant	1719	100	751	100	1622	100	5.0	5.0	5.0
02B011—1	1716	100	656	87			4.0	4.0	3.3
02B011—6	1702	99	857	114			3.5	4.0	3.4
03B013—14	1687	98	898	120			3.5	4.5	3.1
03B019—9	1672	97	522	70			3.0	4.0	2.8
03B004—3	1594	93	631	84			4.0	4.0	2.9
WALAB2013	1590	92	384	51	1254	77	3.0	4.0	3.8
97B072—5	1527	89	1028	137			3.5	4.0	3.3
03B003—1	1513	88	638	85			4.0	4.0	2.9
01B002—4	1437	84	587	78			4.0	3.5	3.3
WALAB2016	1428	83	635	85	1656	102	2.0	3.1	3.3
03B021—11	1387	81	601	80			4.5	3.5	3.0
WALAB2015	1379	80	769	102	1352	83	3.5	3.0	3.2
Andromeda	1300	76	498	66	1403	86	3.0	3.0	3.3
WALAB2017	1285	75	764	102	1527	94	4.0	4.0	3.5
03B004—10	1244	72	841	112			5.0	4.0	3.3

It was a CVT site, only limited lines were tested and plots were bigger than the breeders' plots at Woorree and Avondale.

CONCLUSION

WALAB2014 is high yielding, early maturing and has improved level of resistance to anthracnose over Andromeda. Its yield and grain quality are similar to Kiev Mutant and will be suitable for growing in the northern agricultural region where anthracnose risk is moderate to low.

KEY WORDS

L. albus, early flowering, anthracnose resistance, grain yield

ACKNOWLEDGMENTS

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Enhancement of black spot resistance in field pea

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KEY MESSAGES

1. Progress has been made in enhancing black spot resistance in agronomically desirable lines in field pea.
2. More adapted resistant lines identified will be incorporated in crosses by the Australian Field Pea Improvement Program (AFPIP) and selected lines will go in nation wide yield trials.

BACKGROUND

Black spot (Ascochyta blight), caused by *Mycosphaerella pinodes,* is the most important disease of field pea across southern Australia. Development of resistant germplasm will be slow because of the low level of resistance found in the available germplasm collections and polygenic inheritance of the resistance. However, considerable progress has been made in the last few years towards this goal in Western Australia and many breeding lines with a moderate level of resistance have been developed. Consequently, WA has been identified as a primary breeding site for black spot resistance by the National Pea Breeding Program.

AIMS

1. To screen germplasm developed by the National Field Pea Breeding Program against black spot.
2. To identify new sources of resistance and develop germplasm combining desirable agronomic characteristics with black spot resistance.
3. To contribute enhanced germplasm to the national program for crossing, further evaluation and selection.

METHODS

More than 350 breeding lines from the National Field Pea Breeding Program were screened at Medina where infection with black spot naturally occurs every year. This site has been identified as a 'hot spot' for black spot screening in Australia. To identify new sources of germplasm with resistance to black spot nearly 300 lines were obtained from the Australian Temperate Field Crops Collection at Horsham and were screened at Medina.

About 40 crosses are made every year in WA between agronomically suitable lines and the best black spot resistance lines. The early generations are advanced using the single seed descent (SSD) method in glasshouses and single plants are selected at F4–F5 stage under black spot epidemic in the field at Medina. Genetically stable lines are screened for resistance and for agronomic desirability over two years before being advanced to yield trials. We report here results from the advanced yield trials conducted at Bolgart, Dalwallinu, Pingrup and Merredin and the black spot resistance evaluated at Medina in 2008. Each yield trial had three replications and plot size was 1.2 x 10 m. The black spot evaluation nursery at Medina had 3 m row plots and was replicated 2–3 times depending upon the trial. It was sown in the third week of May 2008 and subjected to natural infection by the black spot fungus endemic in the area.

RESULTS

The disease developed very early at Medina and was adequate throughout the season. All the susceptible lines, such as Dundale and Helena were heavily infected where almost the whole plant was covered with black spots. However, due to poor growth in some parts of the trial disease severity was high and as a result some potentially resistant lines showed greater than expected level of infection.

Fifteen lines obtained from the Australian Temperate Field Crops Collection at Horsham showed some resistance. Accession ATC 6296 from Moldova was early flowering and all others were landraces collected mainly from Henan Province in China with some wild characteristics and very late phenology. Further collection from Henan Province may provide a better source of resistance to black spot. In the present collection, however, their level of resistance was not higher than the WA bred line WAPEA2211. WAPE2211 is the first germplasm developed in an agronomically suitable background with a moderate level of resistance and this level of resistance has been used as a benchmark in the program. More than 50 lines in F6 showed some resistance and among them a dozen lines had resistance higher than WAPEA2211. All the latter lines had good agronomic features and yielded greater than Kaspa in a small plot trial.

Two sister lines, 04P674-06BS-2 and 04P674-06BS-4 from Stage 21 and three lines in Stage 22 showed higher level of resistance than WAPEA2211. Besides these lines, there were many other lines in Stage 2 showing similar level of resistance to WAPEA2211. Some of these lines were, however, agronomically poor and they will be utilised only in a crossing program. It appears that late flowering lines have better resistance than the early flowering lines. Among the breeding lines obtained from the national pea breeding program, about two dozen lines in Stage 2 and about a dozen lines in Stage 3 had similar level of resistance to WAPEA2211. However, two lines in Stage 2, 04H037P-05HO2001 and 04H005P-05HO2004, were slightly better than WAPEA2211.

In advanced yield trials, 00P040-5-WA1 was the highest yielder in all locations with nearly 30% more grain yield than Kaspa followed by WAPEA2211 (Table 1). The former is slightly inferior to the latter for black spot resistance, but both are superior to Kaspa. There were half dozen lines which yielded higher than Kaspa at all locations. 00P097–006 and 98P795–4 had better resistance than WAPEA2211 and yielded 5% and 3% more than Kaspa, respectively. Some of these lines will be promoted to the National Testing Program. Although 99P961-2 had the highest level of resistance, it was a very poor yielder. This will be a very good source of resistance in the crossing program. WAPEA2211 was the second highest yielder also in Stage 21 trials out-yielding Kaspa by 33%. This line has maintained a moderate level of resistance in the last three years of disease nursery evaluation and has performed equally well at all locations. Although WAPEA2211 does not tolerate to downy mildew well, it should be considered for release in WA because downy mildew has never occurred in epidemic proportion even on susceptible varieties, such as Parafield. Currently, there is nothing amongst advanced lines that is as good as WAPEA2211 for yield and black spot resistance.

CONCLUSIONS

New lines with moderate resistance to black spot in an agronomically suitable background continue to emerge in the breeding program. There are a few lines that have higher levels of resistance than that of WAPEA2211. More promising resistance has been seen at earlier stages of the breeding cycle showing a good promise for the breeding strategies applied.

KEY WORDS

field pea, black spot, resistance, yield

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Table 1 **Flower colour (Fc, w white, p purple, pk pink), leaf type (Lt, S semi-leafless, C conventional), development score (Ds, 0–9, 0 no flowering, 3 flowering, 4 pod initiation, 9 fully developed seed), maturity score (Ms, 1–9, 1 earliest maturing), agronomic desirability (Sn, 0–3, 3 most desirable), standing ability (St, 1–9, 1 totally lodged and 9 all plants upright), overall mean yield in kg per ha from four locations, black spot reaction (Bs, 1–9, 1 immune and 9 extremely susceptible) at Medina and seed type at Bolgart in WA bred advanced lines**

Name	Fc	Lt	Ds	St	Ms	Sn	Yield	%Kaspa	Bs	Seed type
00P040—5—WA1	PK	S	2	6	4	2.5	2469	129	5.7	White
WAPEA2211	PK	S	2	7	5	3	2254	118	5.0	Dun
Yarrum	P	S	3	5	6	2	2108	110	6.0	White
Bundi	W	S	5	6	4	2	2104	110	6.2	Blue
00P097—004	W	S	3	7	5.5	3	2085	109	5.5	White
01P231—002	W	C	5	3	4	2	2055	108	5.3	White
00P097—006	W	S	2	7	5	3.5	2001	105	4.8	White
00P040—9	W	S	3	7	6	3	1993	104	5.7	White
98P795—4	P	S	3	6	5	2.5	1974	103	4.8	Blue
Helena	P	C	5	2	6	2	1957	103	7.3	Spec/dun
00P040—27	P	S	2	6	5	3	1926	101	5.0	Dun
Kaspa	PK	S	3	4	6	1	1909	100	6.0	Dun
00P097—005	W	S	5	6	5	3	1898	99	5.2	White
225—5	P	C	4	2	7	2	1894	99	7.5	Dun
00P992—01	P	S	2	6	6	2	1863	98	6.0	Dun
00P983—016	W	S	3	5	6	2.5	1808	95	5.2	White
00P119—006	P	C	3	2	6	2	1753	92	5.0	Dun
Dunwa	P	C	5	2	7	2	1739	91	7.5	Blue
00P119—002	W	S	3	4	5	2.5	1739	91	5.0	Blue/White
00P116—1	W	S	3	5.5	5	2.5	1715	90	5.2	Blue
00P097—04Y—9	W	S	3	6	6	3.5	1676	88	5.2	Spec/dun
00P040—15	W	S	1	6	7	2	1642	86	5.3	Dun
Dundale	P	C	5	2	2	0	1567	82	7.5	Dun
00P983—020	P	S	4	4	4	1	1542	81	6.0	Dun
00P983—011	P	S	4	5	6	2	1530	80	5.5	White
00P983—014	P	S	5	5	5	1	1498	79	5.8	Blue
00P040—5	PK	S	2	6	5.5	3	1463	77	5.7	Blue/White
00P097—002	W	S	3	4	6	2	1339	70	5.2	Spec
26SL	W	S	4	6	6	2	1301	68	5.0	Blue/White
00P106—002	W	S	5	6	5	2	1296	68	5.8	Blue/White
99P916—1	W	S	3	4	7	1	1242	65	5.2	Dun
00P050—005	W	S	3	5	6	0	1175	62	5.3	Dun
99P851—9	P	S	4	3	3	0	1127	59	5.3	Dun
99P961—2	W	C	3	3	7	0	999	52	3.8	Dun

3─1	W	S	4	4	6	2	989	52	5.0	Dun
330─1	W	S	5	4	6	2	755	40	5.0	White

Desi chickpea breeding: Evaluation of advanced lines

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KEY MESSAGE

Thirty lines with good ascochyta blight resistance and high yield will be promoted to the stage 3 of the Crop Variety Testing in 2009.
Many advanced lines have higher levels of ascochyta blight resistance than Genesis 836.

BACKGROUND

The desi chickpea (*Cicer arientinum* L.) is well adapted to a range of fine textured soils of Western Australia and was readily adopted when introduced in the mid 1990s. The area rose quickly to 80 000 ha in 1999 but with the outbreak of ascochyta blight it declined sharply and very little chickpea is now grown in the state. With the availability of more resistant varieties there are prospects of renewed interest in the crop, but the new resistant varieties are poorly adapted to Western Australia and their seed quality does not match the earlier releases (Sona and Heera) that are unfortunately very susceptible to ascochyta blight.
In 2005, a new breeding project based on an international partnership between DAFWA, CLIMA, ICRISAT (India) and the Council of Grain Growers Organisations (COGGO) was started with the aim of accelerating the development of ascochyta resistant, high quality varieties that are adapted to Western Australia. This paper reports the results from the 2008/2009 season of the advanced breeding lines developed in this program.

AIMS

- To evaluate advanced breeding lines for yield, seed quality, ascochyta resistance and related agronomic characteristics.
- To select lines for inclusion in the stage 3 CVT trials in 2008.

METHODS

Limited availability of seed for some entries required the testing to be split into two advanced variety trials. The larger trial (C22DE) contained 120 entries located at Bolgart, Dalwallinu, Northam and Konnongorring. The smaller trial (C22CR) contained 48 entries and was located at Bolgart, Dalwallinu and Northam. Both trials had two replications at each site. Trials were evaluated for yield, height, seed quality and other agronomic traits in the absence of ascochyta blight using a spatially balanced row-column design. Plot size was 1.20 m x 8 m. Trials were sown on 28 May for Bolgart, 29 May at Konnongorring, 2 June at Dalwallinu, and 17 June for Northam. Ascochyta blight was controlled through an initial fungicide spray (Dithane Rainshield at 2 kg/ha) 4 weeks after seeding and then as required dependent on observed disease infection. The yield data were analysed using the statistical package ASREML.
Additionally all lines were screened in an ascochyta blight disease nursery at Medina, where three replications were sown on 14 May. Plots under overhead irrigation were inoculated with diseased stubble and no fungicide treatments were applied in order to evaluate resistance.

RESULTS

Rainfall for the 2008 season was variable across all sites when viewed on a monthly basis, while total annual rainfall would indicate a normal year. Above average rainfall occurred in April, July and September, while it was below average in May, June and August. A dry May resulted in trials at

Dalwallinu being sown later than usual and Merredin site was relocated to a more reliable location at Northam. As a result, the Northam trials were sown late and average site yield across both advanced trials was only 800–900 kg/ha.

When averaged across all sites 31 lines, combined from both advanced breeding trials, produced yields greater than or equivalent to Genesis 836, a partially ascochyta resistant desi variety currently recommended for growing in WA (Table 1 and Table 2). Only six lines yielded greater than Genesis 836 at Bolgart, however, there were 45 lines at Dalwallinu, 64 lines at Konnongorring and 47 lines at Northam, yielding greater than Genesis 836

Top yielding lines 9702–1147–WAD3, 97020–1314–WA3–WAD8, 97020–1147–WAD13, 99-485CD-WAD9-WAD10, 02C488–WAD1 and 97020–1314–WA3–WAD9 performed well at all sites and had greater resistance to ascochyta blight than Genesis 836. All six lines are tall plant types with heights ranging from 48 cm to 53 cm and seed size and quality better than any of the currently recommended varieties.

Two lines have a level of resistance to ascochyta far superior to any commercially available variety; ICCX–40121–WA–F3–P1 is a crossbred developed by ICRISAT with excellent seed size and quality, while 02C488–WAD14 is a locally bred line that yielded well at Dalwallinu and Konnongorring.

Table 1 **Grain yield of selected lines from chick pea advanced breeding trial (C22CR) at Bolgart (Bolg), Dalwallinu (Dalw) and Northam (Nor) along with plant height (1–9, 9 very tall), seed coat colour (1–9, 1 most desirable), 100–seed weight and ascochyta blight score (0–9, 9 most susceptible). These lines have potential to be selected for promotion to stage 3 CVT of 2009**

Variety	Plant height rating	Grain yield % Genesis836				Seed colour rating	100 seed weight (g)	Asco. score at Medina
		Bolg	Dalw	Nor	Across site mean			
02C497—WAD1	6	89	66	102	84	5	16	4
02C500—WAD2	5.5	93	75	101	89	5	16.5	3
02C500—WAD7	7	96	75	112	96	5	17.6	4
02C860—WAD2	6	94	78	102	89	5	16.4	4
02C860—WAD4	7	95	97	98	93	5	24.2	4
97020—1314—WA3—WAD9	7	101	96	115	106	4	19.3	4
97—139B*30—99V4001—WAD6	5.5	95	71	101	89	5	15	3
97—139B*30—99V4001—WAD7	5	91	92	100	93	6	14.9	4
98047—1—7—WAD14	6.5	98	89	72	81	4	23.7	4
98244—WA8—WAD2	6.5	95	95	94	90	3	15.2	5
99057—WA9—WAD7	5.5	93	84	94	89	5	18.1	5
99262—WA7—WAD4	7	94	89	103	95	3	18	5
99262—WAD14—WAD2	6.5	97	84	103	95	5	15.7	4
99—448B—WAD4—WAD2	6.5	98	68	87	83	5	19.8	3
99—485CD—WAD4—WAD1	7	92	69	100	87	4	18.7	5
ICCX—40121—WA—F3—P1	7.5	92	74	91	83	4	21.4	2
Genesis510	5.5	96	94	93	96	5	16.5	4
Genesis836	7.5	100	100	100	100	4	18.1	5

Sonali	5	94	91	89	88	6	16.8	5
Genesis836 yield (kg/ha)		**1278**	**632**	**1139**	**1079.4**			
CV%		**11.2**	**15.8**	**13.7**				

Table 2 **Grain yield of selected lines from chick pea advanced breeding trial (C22DE) at Bolgart (Bolg), Dalwallinu (Dalw), Konnongorring (Konno) and Northam (Nor) along with plant height (cm), seed coat colour (1–9, 1 most desirable), 100–seed weight and ascochyta blight score (0–9, 9 most susceptible). These lines have potential to be selected for promotion to stage 3 CVT of 2009**

Variety	Plant height (cm)	Grain yield % Genesis 836					Seed colour rating	100 seed weight (g)	Asco. score at Medina
		Bolg	Dalw	Konno	Nor	Across site mean			
02C488—WAD1	49	96	102	110	114	107	4	21.1	3
02C488—WAD14	41	92	100	106	95	98	4	14.5	2
02C488—WAD2	44	101	99	103	95	100	4	17.6	4
02C488—WAD9	48	92	98	112	97	100	4	16	4
02C491—WAD3	41	96	102	108	94	100	4	20.2	4
02C491—WAD6	48.5	93	103	109	88	98	3	22.3	3
02C500—WAD10	45	96	94	100	108	100	4	16.4	4
02C500—WAD11	43	93	97	103	107	100	4	17.2	4
02C500—WAD12	43	91	98	101	114	101	4	17	4
02C500—WAD15	45.5	94	98	108	104	102	4	15.8	4
02C500—WAD16	45.5	90	97	106	105	100	4	17	4
02C500—WAD5	42.5	95	99	108	104	102	5	17.5	4
02C500—WAD8	46	81	100	108	111	99	5	15.1	3
02C500—WAD9	43	96	100	110	109	105	5	16.7	3
02C611—WAD1	44.5	86	99	111	98	98	5	16.2	4
02C829—WAD2	44.5	88	98	104	101	97	5	18.1	4
02C860—WAD13	40	95	104	107	78	94	4	22	4
02C860—WAD8	41.5	96	102	111	109	105	5	18.8	3
02C860—WAD9	42.5	92	94	103	102	98	5	17.1	4
02C862—WAD1	42	97	102	104	98	101	5	17.9	4
02C884—WAD4	49.5	97	101	107	109	105	5	19.4	4
97020—1147—WAD13	48.5	100	106	111	111	110	4	21.8	5
97020—1147—WAD3	48	101	104	113	123	113	4	22.6	4
97020—1314—WA3—WAD1	45	98	102	99	108	103	5	18.5	4
97020—1314—WA3—WAD8	49.5	102	102	108	117	110	4	20.4	4
97020—1772—WAD7	46	101	99	99	105	103	3	18.3	3
98235—1—1—WAD4	45	89	99	108	97	97	4	22.2	4
98321—WA2—WAD3	41.5	90	98	113	113	105	5	19.1	5
99139—WAD2—WAD2	46.5	99	101	99	101	100	2	16.1	4
99262—WA7—WAD10	47.5	97	99	108	89	98	4	17.1	4
99262—WA7—WAD23	51.5	97	98	105	119	107	5	16.3	4
99262—WAD14—WAD12	60	97	101	97	108	101	4	18.2	4
99262—WAD14—WAD5	53	91	101	102	111	100	5	16.3	3
99262—WAD14—WAD7	50.5	91	99	101	115	101	5	16.4	5
99262—WAD22—WAD5	44	95	100	104	96	98	3	15.9	4
99—448B—WAD4—WAD7	46	97	98	115	94	102	5	17.2	4
99—485CD—WAD9—WAD10	52.5	102	96	109	112	108	3	17.4	4
99—485CD—WAD9—WAD6	49	90	101	112	113	106	5	19.8	5

Genesis510	46	94	100	113	98	102	5	17	5
Genesis836	57	100	100	100	100	100	4	19	5
ICCV 04531	42.5	91	99	104	89	94	5	25.7	4
ICCV 04534	47	95	100	105	91	97	5	16.2	5
ICCX-40027-WA-F3-P10	41.5	79	97	103	77	84	4	24.7	5
ICCX-40095-WA-F3-P2	51	95	103	101	104	101	5	17.6	5
Sonali	40	90	101	91	97	92	6	16.3	5
Genesis836 yield (kg/ha)		**1167.6**	**512.7**	**939.3**	**862.5**	**875.6**			
CV%		**12.70%**	**20.10%**	**8.60%**	**13.40%**				

KEY WORDS

chickpea, desi, breeding, ascochyta blight, resistance

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Paper reviewed by: Kedar Adhikari

Pulse Breeding Australia—Australian Field Pea Improvement Program (AFPIP)

Ian Pritchard[1], Chris Veitch[1], Stuart Morgan[1], Alan Harris[1] and **Tony Leonforte [2]**
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BACKGROUND

Field pea breeding in Australia is undertaken by Pulse Breeding Australia (PBA). The program is nationally focused and involves collaboration between VicDPI, NSWDPI, SARDI, DAWA and the University of Sydney. The main objective of this program is to expand the field pea industry in Australia through the development of new varieties with broad adaptation across Australia and also with suitable adaptation for specific production regions of Australia. Western Australia is responsible for evaluating new breeding lines being developed by the program, and undertaking a breeding and screening component for improving black spot resistance. This paper describes planned and potential field pea lines to be released in the next two to three years and yield data for planned releases and commercial varieties from experiments undertaken in WA in 2008. Stage 3 is the final trial of the National Program and top lines selected from here enter the National Variety Testing scheme.

AIMS

- To identify breeding lines with improved and stable yield, appropriate phenology, lodging and pod shatter resistance at harvest and improved disease resistance in WA.

METHOD

Each trial had three replications with plot size 1.25 x 8 m using spatially balanced row-column design. Treatments included a set of control varieties. The yield data were analysed using the statistical package ASREML.
In 2008 trials were planned for sowing at Dalwallinu, Merredin, Pingrup and Wittenoom Hills. Due to seasonal conditions however the Merredin trials were transferred to Northam.

RESULTS

All sites in 2008 experienced good growing conditions for all (Dalwallinu) or part of the growing season. Wittenoom Hills, Northam and Pingrup had good rainfall interspersed by long dry spells. The Northam site was affected by a number of spring frosts and, due to high experimental error, the results are not presented. Despite this the Northam experiment provided an excellent screen for salinity tolerance and virus resistance. Good yields were obtained at Dalwallinu, Pingrup and Wittenoom Hills. Table 1 shows the results of these trials along with those of NVT trials that had acceptable levels of experimental error.

DISCUSSION

Planned Variety Releases

OZP0601: An early flowering Kaspa type variety. Broadly adapted and higher yield potential in short growing seasons and low rainfall environments. It has a similar disease profile to Kaspa, but is less susceptible to late season powdery mildew. OZP0601 continues to perform well relative to Kaspa. Release is planned for 2011.
OZP0602: An early to mid flowering Kaspa type variety. Broadly adapted and higher yield potential in short growing seasons and low rainfall environments. It has a similar disease profile to Kaspa but is less susceptible to late season powdery mildew. It has a longer flowering window than 601. OZP0602 continues to perform well relative to Kaspa, Release is planned for 2011.

OZP0703: A new early to mid flowering semi-dwarf dun type variety. Broadly adapted and higher yield potential in short growing seasons and low rainfall environments. It has good resistance to bacterial blight and the new strain of downy mildew in SA. It is not shatter resistant and may lodge. Release is planned for 2011–12.

Potential Variety Releases

OZP0804: A high yielding Kaspa type line. OZP0804 has high tolerance to boron and is resistant to powdery mildew. OZP0804 is mid to late flowering, appears to be broadly adapted, and also appears to have much higher resistance to the new strain of downy mildew in SA. It is one of the best performing OZP lines in Stage 3 and NVT trials in 2008. Potential release > 2012.

OZP0805: A high yielding Kaspa type line. It is resistant to powdery mildew, PSbMV, and BLRV. It is early to mid flowering and appears to be broadly adapted. One of the best performing OZP lines in Stage 3 and NVT trials in 2008. Potential release > 2012.

KEY WORDS

field pea, Pulse Breeding Australia (PBA), black spot

ACKNOWLEDGMENTS

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Table 1 **2008 WA combined S3/NVT yield data (%Kaspa) for planned variety releases from PBA and commercial varieties. Best performing lines at each site are highlighted**

Region	Agzone2	Agzone2	Agzone2	Agzone3	Agzone5	Agzone5
Nearest town	Bolgart	Dalwallinu	Katanning	Pingrup	Scaddan	Wittenoom Hills
Variety name	%Kaspa	%Kaspa	%Kaspa	%Kaspa	%Kaspa	%Kaspa
Kaspa t/ha	1.33	2.05	2.46	2.11	2.14	2.80
Bundi	NT	134[a]	97[b]	97[a]	80[a]	92[a]
Kaspa	100[b]	100[b]	100[b]	100[a]	100[a]	100[a]
Parafield	117[b]	79[b]	107[a]	66[c]	62[b]	81[b]
Sturt	143[a]	107[b]	109[a]	71[c]	66[b]	65[b]
Yarrum	89[c]	127[a]	93[b]	76[b]	80[a]	80[b]
OZP0601	89[c]	116[a]	114[a]	91[a]	81[a]	105[a]
OZP0602	NT	124[a]	105[a]	93[a]	104[a]	103[a]
OZP0703	147[a]	108[b]	121[a]	87[b]	74[b]	96[a]
Site Mean (t/ha)	1.46	2.21	2.55	1.63	1.59	2.67
CV (%)	12.3	10.6	12.0	12.4	14.8	7.1
l.s.d. (t/ha)	22	23	20	12	22	11

[a] Significantly higher yielding than [b].

[b] Significantly higher yielding than [c].

NT: Not tested.

Table 2 **Features of potential releases relative to commercial lines**

Name	Grain type	Plant height	Leaf type	Flowering time	Pod shatter resistant	Early vigour	Lodging at harvest	Boron	Salinity	Blackspot	Downy mildew PF[A]	Downy mildew KP[B]	Powdery mildew	Bacterial blight	Virus BLRV	Virus PSbMV
BUNDI	W	SD	SL	EARLY	R	GOOD	FAIR	S	S	MS – 6.8	R	MS	S	S	S	S
KASPA	D	SD	SL	LATE	R	GOOD	FAIR	S	S	MS – 6.6	R	S	S	S	S	S
YARRUM	D	SD	SL	MID	S	FAIR-POOR	FAIR	S	MT	S – 7.1666	S	S	R	MS	MR-MS	R
STURT	W	Tall	C	EARLY	S	GOOD	POOR	MT	MT	MS – 7	MS	MS	S	S	S	S
PARAFIELD	D	Tall	C	MID-EARLY	S	GOOD	POOR	S	MT	S – 7	S	S	S	MS	S	S
OZP0601	D	SD	SL	EARLY	R	GOOD	FAIR	S	MT	MS – 7	R	S	S	S	S	S
OZP0602	D	SD	SL	EARLY	R	GOOD	GOOD	S	S	S – 7.25	R	S	S	S	S	S
OZP0703	D	SD	SL	EARLY	S	FAIR-GOOD	FAIR	MS	MT	MS – 6.75	MS	R	S	R	S	S
OZP0804	D	SD	SL	MID-LATE	R	FAIR-GOOD	FAIR-GOOD	HT	MT-HT	S – 7.5	MS	R	R	S	S	S
OZP0805	D	SD	SL	EARLY-MID	R	GOOD	FAIR-GOOD	MT	MT-HT	MS – 7	MS	S	R	S	R	R

[A] Parafield strain of downy mildew. This strain is virulent on Parafield, Kaspa has good resistance. Widespread in field pea cropping regions.

[B] Kaspa strain of downy mildew. This is a new strain of downy mildew virulent on both Parafield and Kaspa. Has only been identified in SA at this stage.

Interaction between wheat varieties and fungicides to control stripe rust for grain yield and quality

Kith Jayasena, Geoff Thomas, Rob Loughman, Kazue Tanaka and **Bill MacLeod**, Department of Agriculture and Food, Western Australia

KEY MESSAGES

- Extreme yield loss (87–94%) occurred in a susceptible variety under very high stripe rust disease pressure in a long season environment in 2007 and 2008.
- Yield losses of 27–54% were observed in varieties with partial resistance to stripe rust under high disease pressure.
- Strategic fungicide application provided significant yield benefit in all except the resistant variety, the degree of benefit was greatest in susceptible varieties.
- A fully resistant variety expressed zero yield loss, however major gene resistance has not proved to be durable for stripe rust.
- Partial stripe rust resistance combined with strategic fungicide application can be used to minimise yield losses and restrict epidemic development.

INTRODUCTION

Puccinia striiformis f.sp. *tritici*, the causal fungus of stripe rust in wheat was first detected in Western Australia in the Lake Grace Shire in 2002. Significant yield losses have been observed in susceptible wheat varieties. The use of partially resistant varieties combined with fungicide control remains a poorly understood aspect of disease management.

AIMS

To determine how varieties with different levels of stripe rust resistance respond to fungicide for the control of stripe rust.

METHOD

The interactions between varietal resistance and fungicide application on stripe rust development and crop yield were assessed in experiments in 2008 and 2009 at Manjimup Horticultural Research Station. Varieties with a range of stripe rust resistance, EGA Bonnie Rock (S-VS), Carnamah (MS-S), Wyalkatchem (MS), Janz (MR-MS) and GBA Ruby (R) were tested in combination with 3 fungicide treatments being either nil, partial or full fungicide control. Full control consisted of *Tebuconazole* (Folicur 430SC) @ 290 mL/ha applied at early stem elongation (Z31), flag leaf emergence (Z39/40), ear emergence (Z55) and late flowering (Z68) to provide maximum disease protection to maximise yield. Partial fungicide control consisted of a single application at ear emergence (Z55) in 2007 or two applications commencing with the first sign of the stripe rust (Z32) and again at ear emergence (Z55) in 2008. In 2007, the trial was sown on 5 July, adjacent to susceptible wheat (cv Harrismith) that was inoculated twice on 30 July and 23 August. In 2008 the trial was sown 20 June adjacent to susceptible wheat (cv Westonia) that was inoculated with stripe rust on 24 July 2008.

RESULTS

In both years, the stripe rust pressure was high. In 2007, the stripe rust severity ranged from 4 to 96% in untreated control plots whereas in 2008 the disease severity varied from 6 to 93 per cent among the five wheat varieties tested (Table 1). GBA Ruby (resistant) had no response to fungicide for stripe rust control. Application of fungicides either as single, double or multiple sprays reduced the stripe rust levels in all other wheat varieties, in both years. Under these experimental circumstances, where the varieties were subject to continuous disease pressure from nearby infected wheat, partial fungicide control was less effective than full protection with multiple fungicide sprays in Carnamah, EGA Bonnie Rock, Janz, and Wyalkatchem.

Over two years, extreme yield losses (87–94%) were observed in EGA Bonnie Rock under very high stripe rust disease pressure in a long season environment. In Janz and Wyalkatchem, partial resistance reduced the impact of stripe rust however yield losses of 27–54% were still observed.

Partial fungicide protection combined with partial resistance reduced yield losses to 17–30%, depending on variety. Application of fungicides significantly increased the yield compared to untreated control in all the varieties tested except for GBA Ruby (Table 1).

In 2007, screenings varied from 3.3 to 18.4 per cent among the untreated varieties whereas in 2008, it varied from 0.8 to 7.9 per cent (Table 1). EGA Bonnie Rock had higher screenings in both years. An application of fungicides increased the hectolitre weight in all varieties tested except GBA Ruby.

CONCLUSIONS

Varieties with partial to full resistance significantly out performed susceptible varieties when stripe rust was not controlled or only partially controlled in conditions that were ideal for disease development. Additional disease control and yield benefits were achieved through strategic fungicide application to all varieties except the resistant variety GBA Ruby. Yield response to fungicide intervention was dependant on variety resistance, with the response being greatest on varieties with stripe rust rating of 'VS' to 'MS' compared to 'MR' to 'R'. Among the varieties tested, Carnamah and EGA Bonnie Rock had high stripe rust levels compared to Janz and Wyalkatchem, which in turn were higher than GBA Ruby in both years. There was no fungicide response in control of stripe rust and yield increase on the resistant variety GBA Ruby. The observed increase in yield was also associated with some reduction in screenings (mainly in EGA Bonnie Rock) and an increase hectolitre weight.

Australian and international experience shows that that single major gene resistance to stripe rust, though fully effective, is not durable in the long term. GBA Ruby carries Yr27, which is currently fully effective in WA even under high disease pressure. Recent reports indicate development of Yr27 virulence in the stripe rust population in eastern Australia.

Some varieties such as Yitpi and Wyalkatchem carry partial stripe rust resistance. Partial resistance can be derived from several genes and generally has proved to be more durable than single major gene resistance against stripe rust.

Partial resistance genes usually express after flag leaf emergence to head emergence stages and are commonly known as adult plant resistance (APR). APR is sensitive to high disease pressure and environmental conditions which favour stripe rust, such as the conditions experienced in these experiments. The first visible stripe rust symptoms were observed at early stem elongation in 2008 and early booting in 2007. The early occurrence of rust and favourable long season environment placed maximum pressure on the varieties with partial resistance in these experiments.

The varieties with partial resistance genes showed high levels of infection, however yield from these varieties was significantly higher than in susceptible types. In general, partial stripe rust resistance combined with strategic fungicide application can minimise yield losses and restrict epidemic development, particularly in conditions that favour prolonged disease development.

KEY WORDS

wheat, stripe rust, foliar fungicide spray

ACKNOWLEDGMENTS

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Project No.: DAW00159 Managing disease constraints in Western Region Farming Systems

Paper reviewed by: Jeremy Lemon

Table 1. Stripe rust severity, yield and some grain quality parameters in results of interaction between wheat vari
from 2007 to 2008.

Year	Variety	% disease severity at Z75/Z77* (avF nec to avF-1 nec)			Yield (t/ha)			Screening (%)	
		Fungicide			Fungicide			Fungicide	
		Nil	Partial control †	Full control #	Nil	Partial control	Full control	Nil	Partial control
2007	Bonnie Rock	100a**	66b	19c	0.5a	2.1b	3.9c	18.4a	8.8b
	Carnamah	90a	81a	41b	1.6a	2.6b	4.2c	8.4a	6.3ab
	Wyalkatchem	53a	48a	26b	2.0a	3.1b	4.1c	3.3a	2.1a
	Janz	50a	42a	14b	2.5a	3.1b	4.1c	8.1a	5.4ab
	Ruby	4a	3a	2a	3.8a	4.1a	3.9a	3.9a	3.8a
2008	Bonnie Rock	93a	53b	14c	0.2a	1.1b	3.4c	7.9a	5.5b
	Carnamah	58a	41b	16c	1.8a	2.8b	4.0c	1.8a	1.7a
	Wyalkatchem	35a	31ab	21b	2.1a	3.2b	4.6c	1.0a	0.9a
	Janz	26a	18a	7b	2.9a	3.3a	4.0b	2.1a	1.6a
	Ruby	6a	5a	4a	4.6a	4.6a	4.6a	0.8a	1.0a

† Partial fungicide control consisted of a single application (Folicur @ 290 mL/ha) at ear emergence (Z55) in 2007 or two applica
stripe rust (Z32) and again at ear emergence (Z55) in 2008.

Full fungicide control consisted of Folicur 430SC @ 290 mL/ha applied at early stem elongation (Z31), flag leaf emergence (Z
flowering (Z68)

* per cent leaf area under necrosis due to stripe rust infection at approximately milk development stage (Z75/77) on the top two
to Flag-1.

** Means followed by the same letter in the same row for each parameter are not significantly different at the *p* = 0.05 level.

Findings of canola disease survey 2008 and its implications for better disease management in 2009

Ravjit Khangura, WJ MacLeod, P White, P Carmody and **M Amjad**, Department of Agriculture and Food, Western Australia

KEY MESSAGES

- The survey results indicated that levels of Sclerotinia stem rot were substantially high in the northern agricultural region and some crops were also badly affected in the southern areas.
- Levels of blackleg were low in northern areas, moderate in central and high in southern areas.
- Incidence of club root was generally low in all areas except for a few crops in the northern region that had high incidence of mild forms of club root.
- Powdery mildew levels were high in the northern region, low in the southern region and no powdery mildew was observed in the central region.
- Survey results highlight that Sclerotinia and blackleg were the two predominant diseases affecting canola yields in 2008. Growers need to carefully manage both these diseases in order to minimise losses.

AIMS

To monitor root and stem diseases in canola crops to provide timely feedback to the industry about the fungal diseases which need to be considered in establishing and managing canola crops.

METHOD

Samples were collected from canola crops across the Western Australian grainbelt. About 100 stems were collected for each sample along a 200 m transect. Stems were washed and rated for severity of internal infection of blackleg on a 0–4 scale (0 = no disease, 4 = more than 75% stem cross section showing internal necrosis). Disease incidence (% plants with crown cankers) and disease severity expressed as percent disease index (PDI) for each sample were calculated. Plants were also assessed for the incidence of Sclerotinia stem rot (SSR) caused by *Sclerotinia sclerotiorum*, club root caused by *Plasmodiophora brassicae* and powdery mildew caused by *Erysiphe cruciferarum*.

RESULTS

A total of 74 samples were collected from canola crops. About 16% samples were cultivar (cv) Beacon, 15% cv Thunder, 14% cv Cobbler and 12% each cv Bravo and cv Tornado. A majority of the crops were sown in paddocks where there had been at least a three year break since the previous canola crop. Prevalence of disease (percentage crops affected) was highest (100%) for blackleg followed by that of Sclerotinia stem rot, club root and powdery mildew respectively (Figure 1). When averaged across all samples, the incidence of blackleg was highest compared with that of other diseases (Figure 2). Average severity of internal infection of blackleg was 23%. The range of incidence within a sample, across all samples, was 6–95% for blackleg, 0–65% for Sclerotinia stem rot, 0–44% for club root and 0–98% for powdery mildew. Average incidence of various canola diseases in different agricultural regions is presented in Figure 3.

Implications of findings of 2008 canola disease survey

Although blackleg levels were lower particularly in the northern agricultural region than reported from previous surveys (conducted during 2001–2004). Low levels of blackleg in the northern region were expected due to continuous dry conditions during the past few years and very little canola being grown in the region. As a result the 2008 canola crop was subjected to low blackleg inoculum levels. This year, canola growers in all areas need to carefully manage blackleg in their canola crops given there is sufficient blackleg inoculum around. The wetter than normal conditions over summer may cause the early spore production from the 2008 stubble therefore, posing the risk of major spore showers coinciding with the susceptible seedling stage of the crop.

Sclerotinia stem rot incidence appears to have risen in the past few years. High levels of SSR in some crops indicate growers need to manage the risk of Sclerotinia in their current season's crops. They should avoid sowing close to paddocks that had high incidence of Sclerotinia in 2008. In high risk situations, growers should use fungicides recommended for the control of Sclerotinia in canola.

Although club root didn't emerge as a serious problem, its widespread incidence means that growers are required to maintain good hygiene practices and be extra cautious in order to prevent the spread of this pathogen with machinery to club root free paddocks. Other options to prevent the spread of club root are the control of Brassica weeds, long rotations and sow club root free seed. This disease is recognised as a key disease in Alberta, Canada as it has spread rapidly and caused significant losses of yield in canola crops.

High levels of powdery mildew were also found in some crops, however, the impact of powdery mildew on canola yields is not known. Further work is required to determine the effect of powdery mildew on canola production.

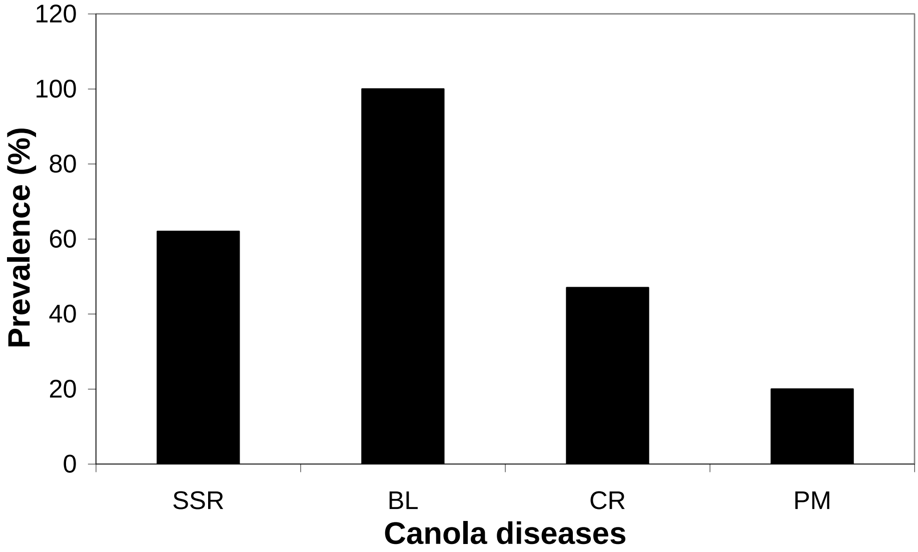

Figure 1 Prevalence (percentage crops affected) of various canola diseases in Western Australia during 2008. (SSR = Sclerotinia stem rot, BL = Blackleg, CR = club root, PM = powdery mildew.)

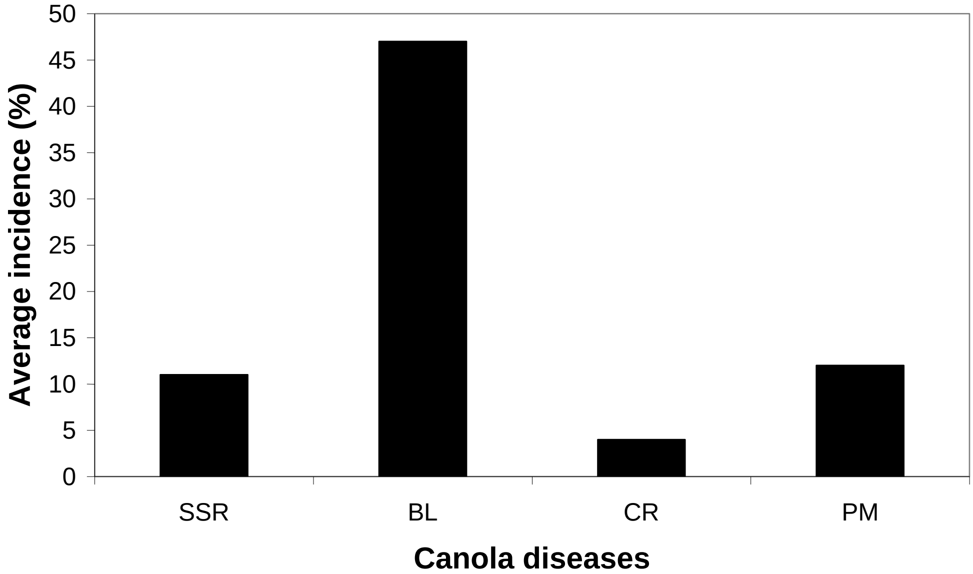

Figure 2 Average state-wide incidence of various canola diseases in Western Australia during 2008. (SSR = Sclerotinia stem rot, BL = Blackleg, CR = club root, PM = powdery mildew.)

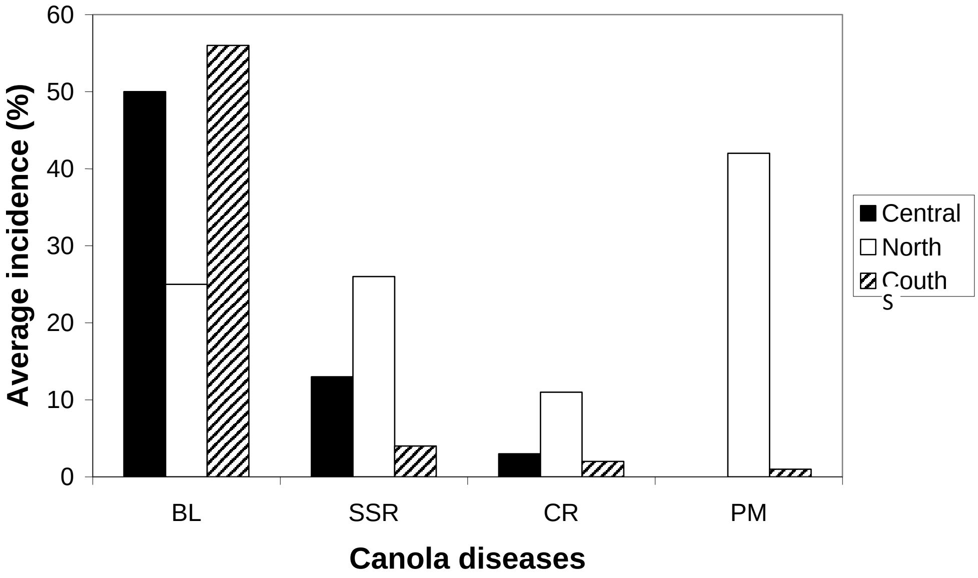

Figure 3 Average incidence of various canola diseases in different regions of Western Australia during 2008. (SSR = Sclerotinia stem rot, BL = Blackleg, CR = club root, PM = powdery mildew.)

CONCLUSION

Growers need to minimise the risk of infection by blackleg and SSR, in particular, avoid sowing their 2009 crop close to paddocks badly affected with Sclerotinia in 2008. Club root levels were low in most crops but this disease was widely distributed across canola growing regions of WA. Powdery mildew was also detected for the first time particularly in the northern agricultural region, however, its impact on canola yields is not known.

In 2009, seasonal conditions appear to be conducive for blackleg, growers need to reassess their risk from blackleg, especially if growing moderately resistant varieties, in order to minimise yield penalties. Growers are also encouraged to use fungicides to protect crops in which the susceptible seedling stage will coincide with the peak of spore showers. The risk from spore showers in different regions will be updated regularly and available through the Department of Agriculture's website (www.agric.wa.gov.au/cropdiseases) or Pestfax.

KEY WORDS

canola, blackleg, Sclerotinia stem rot, club root, canola powdery mildew, disease survey

ACKNOWLEDGMENTS

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Paper reviewed by: Bill MacLeod

Combating wheat leaf diseases using genome sequencing and functional genomics

Richard Oliver, Australian Centre for Necrotrophic Fungal Pathogens, Murdoch University

KEY MESSAGE

Detailed studies of fungal pathogen genes based on the genome sequences of *Stagonospora nodorum* (cause of stagonospora/septoria nodorum/glume botch) and *Pyrenophora tritici-repentis* (cause of yellow spot) suggest that wheat cultivars can be differentiated on the basis of their genetic predisposition to sensitivity to an important fungal toxin and this information will assist growers in selecting lower risk varieties and assist breeders in selecting improved resistance in breeding. These developments should contribute significantly to integrated disease management to reduce losses to these diseases.

BACKGROUND

Two of the major diseases of wheat are Stagonospora (Septoria) nodorum blotch (SNB) resulting in leaf and glume blotch (caused by *Stagonospora nodorum)* and yellow spot (YS) (caused by *Pyrenophora tritici-repentis).* Both can cause losses of up to 20–40% in affected crops. SNB is mainly a problem in WA whilst YS is common in most wheat growing areas in Australia. Many diseases caused by similar fungi in related genera have stubble survival stages and have been exacerbated by the adoption of reduced tillage. These include the wheat diseases SNB and YS, the barley net-blotch diseases, canola black-leg and the legume black spot and ascochyta blights.

No wheat cultivars are completely resistant to either SNB or YS and many currently grown and newly released cultivars are classified as moderately susceptible or susceptible. As resistance is incomplete and genetically complex, the development of molecular tools that assist breeding for resistance (marker-assisted selection) has been very challenging and few have been adopted by the breeders.

RESULTS

The Australian Centre for Necrotrophic Fungal Pathogens (ACNFP) has undertaken a study of *Stagonospora nodorum* based on the analysis of the entire fungal genome sequence of a Western Australian isolate. The 38 million base pair sequence is the largest genomics project undertaken and analysed by any group in the Southern hemisphere. The identification of the genes encoded by this pathogen has revolutionised our understanding of the interaction with wheat. In collaboration with groups in North Dakota and Zurich, we have shown that *Stagonospora nodorum* produces a series of toxins that interact with specific wheat receptors. One of these toxins is also produced by *Pyrenophora tritici-repentis*, the YS pathogen. The fungal isolate produces a toxin and if the wheat cultivar possesses the relevant receptor gene, the interaction produces a leaf spot that enables disease to flourish. Without the relevant receptor gene the disease is slowed, but not eliminated. This revelation has opened up an improved pathway for the control of these diseases.

We have so far obtained detailed evidence for the expression of three toxins by Australian isolates of SNB. The toxin we know most about is called ToxA. Both SNB and YS produce this toxin and the wheat receptor gene has been identified and designated *Tsn1*. Cultivars that lack this receptor gene are easily identified using either molecular markers or the reaction to the ToxA protein and are more resistant to SNB and YS. We therefore suggest that growers avoid using cultivars that contain the receptor gene and are therefore more susceptible to SNB/YS. There appears to be no deleterious effect if the receptor gene is absent. We are also working with the breeders so that they can remove the gene from breeding lines being used to create the next generation of varieties.

Varieties without the toxin receptor gene *Tsn1* have a lower than average risk of severe YS and SNB diseases. These include Blade, Brookton, Calingiri, Carnamah, Cascades, Cunderdin, EGA blanco, EGA bonnie rock, EGA eagle rock, GBA ruby, H45, Machete, Nyabing, Perenjori, Westonia, and Wyalkatchem.

Varieties with the toxin receptor gene *Tsn1* have a higher than average risk of severe YS and SNB diseases. These include Amery, Arrino, Binnu, Bullaring, Cadoux, Camm, Carinya, Catalina, Chara, Clearfield JNZ, Clearfield STL, Corrigin, Datatine, Drysdale, EGA2248, EGA Gregory, EGA Jitarning, Eradu, Frame, GBA Sapphire, Gladius, Halberd, Harrismith, Janz, Kalannie, Kennedy, Kukri, Kulin, Mira, Mitre, Schomburgk, Sentinel, Silverstar, Spear, Stiletto, Sunco, Tammarin Rock, Tincurrin and Yitpi.

CONCLUSION

The identification of toxins in the SNB/YS system has identified a step-by-step breeding strategy to reduce the incidence of these diseases. We expect that implementation of this and related knowledge of major toxin genes in breeders' selections will lead to a reduction in the impact of this disease progressively over successive breeding cycles. We emphasise that these pathogens produce a number of toxins and so Tsn1 will be responsible for only part of the resistance response. The next research question is whether other similar pathogens—the barley net-blotch diseases, canola black-leg and the legume black spot and ascochyta blights—can be attacked in the same manner.

KEY WORDS

Stagonospora, Septoria nodorum blotch, glume blotch, yellow spot or tan spot, barley net-blotch diseases, canola black-leg, pea black spot, ascochyta blights

Project No.: GRDC UMU00022

Paper reviewed by: Geoff Thomas, Rob Loughman

Distribution and survival of wheat curl mite (*Aceria tosichella*), vector of *Wheat Streak Mosaic Virus*, in the WA grainbelt during 2008

Dusty Severtson, Peter Mangano, John Botha and **Brenda Coutts**, Department of Agriculture and Food, Western Australia

KEY MESSAGES

Volunteer wheat collected during April to July, which was at the heading growth stage, were 100% infested with wheat curl mite (*Aceria tosichella*; WCM). Samples collected from sown wheat from seedling to flowering growth stage had no detected infestation, however, sown wheat in the grain fill growth stage (October-November) were 67% infested.
Field trials conducted near Merredin and Wongan Hills indicated that the presence of an infested slowly dying host in the immediate vicinity of a wheat crop, could contribute considerably to the eventual populations of WCM present on the wheat crop.

These investigations confirm the wide distribution of the mite over the WA grain belt and confirm the value of practising some form of control of mite numbers in high *Wheat Streak Mosaic Virus* (WSMV) risk areas. For such situations we propose the control of volunteer wheat and other grass hosts by ensuring this material is dead or removed by grazing by at least two weeks prior to germination of the sown wheat crop.

INTRODUCTION

WCM may have been in WA for a long time. However, the first documented record of its presence dates from a survey conducted in 1993. WCM breed rapidly in warm weather, with the optimum temperature range for reproduction between 24–27 ºC. The mite is well adapted for aerial dispersal, and relies on this method for its survival, requiring the continuous presence of a living, green host. WCM is the only known vector for WSMV and direct damage by feeding results in minor and mostly undetectable yield loss in WA field conditions.
In autumn 2006, WSMV was detected for the first time in WA. Surveys for the virus in spring 2006 found it to be widespread throughout the WA grainbelt with incidences in crops ranging from < 1–100%. The potential impact of WSMV infection on yields was unknown under WA conditions as hot, dry summers and cool winters were unlikely to favour WCM populations and virus spread. However, in 2006 a commercial crop of wheat growing near Merredin was found to be heavily infected (incidence >95%) with WSMV. The crop was infected at the early seedling growth stage by mites transferring the virus from advanced self sown, herbicide treated wheat plants within the paddock. The WSMV infection resulted in an estimated 80% yield reduction compared to nearby healthy crops. Furthermore, WSMV has been shown to be seed borne in wheat at low levels (< 1%).

As there are no in-season control options for WCM or WSMV, control of volunteer wheat prior to germination of sown wheat crops is considered the most effective strategy. Previous cases of high WCM and WSMV infection resulting in yield loss have occurred in situations where wheat crops were germinating in the presence of a large source of infected wheat volunteers or other grasses that followed summer and autumn rains. Where these host plants are sprayed with herbicides such as glyphosate, their gradual death encourages the movement of viruliferous mites onto the young wheat crop.

AIMS

- To investigate the presence and distribution of WCM throughout the WA grainbelt at various times of the year, and various growth stages of wheat and other grasses.

- To determine the risk of WSMV infection to wheat crops where the virus may be present from viruliferous mites or seed-borne sources.
- To investigate the ability of WCM to build up and disperse onto healthy plants in field conditions within the central wheatbelt of WA.

METHOD

WCM surveys

Volunteer wheat was sampled opportunistically during April-July and multiple samples were taken from the 14 locations found with volunteers. Approx. 50 locations were sampled throughout the wheatbelt during May-September which ranged from seedling to flowering growth stages. Sampling was limited at these growth stages given the high time and labour inputs of whole-plant inspections under stereo microscopy. Each site consisted of randomly sampling 20 whole seedlings or 30 tillers depending on available growth stages. Wheat leaves were pinned on foam boards and inspected for mites under stereo microscopes.
During October-November, samples were taken along crop edges (within a 50 m length) at 92 locations situated throughout the WA grainbelt at grain fill growth stage. For samples at the ear emergence growth stage or later, 20 ears were trimmed of awns, placed on strips of black sticky contact and allowed 7–9 days to dry. Mites crawled out of the ear as it commenced to dry and were trapped on the uniform black contact film, allowing subsequent counting of the light coloured mites under a stereo microscope. The black sticky contact method provided a simple and reliable means of assessing mite numbers in wheat ears, especially where numbers were too low to detect consistently directly on the intact head.

Subsamples of mites found were confirmed as the wheat curl mite species (*Aceria tosichella*) using morphological characteristics. As mites could not be removed intact from the sticky contact surface, 30 ears were sampled at sites and 10 of them left in reserve under refrigeration. These reserved heads where used to extract mites from locations where the mites were in high numbers (i.e. 10 or more per ear). Ears were dissected under stereo microscope and mites slide mounted for identification under 1000x oil immersion and phase contrast compound microscopy.

Leaf samples from the 64 locations sampled during April-September were tested for WSMV by ELISA using WSMV-specific antibodies. Samples during October-November could not be tested due to lack of green leaf material.

Field trials (Wongan Hills and Merredin)

Identical field trials were done at Merredin and Wongan Hills research stations. WSMV infected/WCM infested wheat plants were transplanted into plots of healthy wheat cv Calingiri at crop emergence so as to simulate 0%, 0.2%, 0.5% and 1% seed infection (0, 4, 18 and 36 'infector' plants per plot). The trials were a randomised complete block design with 6 replicates; plots were 5.4 x 10 m with 20 m buffer between plots. The 'infector' plants were infected with WSMV by sap inoculation and then manually infested with WCM from a reared colony in glasshouse prior to being transplanted into plots. Samples of wheat leaves, whole plants or heads were taken throughout the season to determine the level of WCM abundance and spread. Random leaf samples were taken from each plot every four weeks to determine WSMV incidence. The leaves were tested by ELISA using WSMV-specific antibodies.

RESULTS

Autumn survey (April-July))

WCM were found in relatively high numbers in wheat at all 14 sites sampled throughout the WA grainbelt from April to July where wheat was in head (Figure 1). The volunteer plants were surviving in pockets (often less than 10 plants) of heading volunteer wheat and grasses in roadside ditches and paddock edges where they had not been controlled by herbicide or grazing. WSMV was confirmed to be present with WCM near Doodlakine, Munglinup and Mount Madden in wheat volunteers, at the heading growth stage, originating from spilled grain in roadside ditches. Opportunistic sampling of wheat volunteers prior to ear emergence growth stage revealed no presence of WCM (40 locations). WCM were also found on feathery windmill grass (*Chloris virgata*) and paspalum (*Paspalum* sp.) bordering infected wheat in ear at two sites.

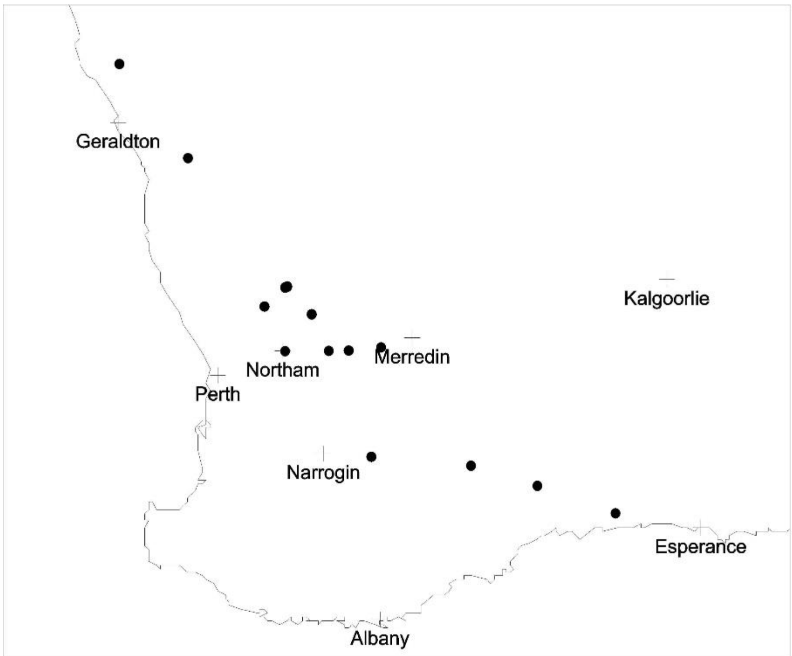

Figure 1 Locations of volunteer autumn wheat in ear found between April and July 2008. WCM present at all locations.

Seedling to flowering (May-September)

WCM were not detected on any of the 50 samples collected from the edges of sown wheat paddocks throughout the grainbelt prior to early grain fill growth stage. WSMV was also not detected.

Grain fill growth stage (October-November)

A survey of wheat ears at the soft dough growth stage during October-November revealed varying levels of WCM at 62 of 92 sites sampled (67%) (Figure 2).

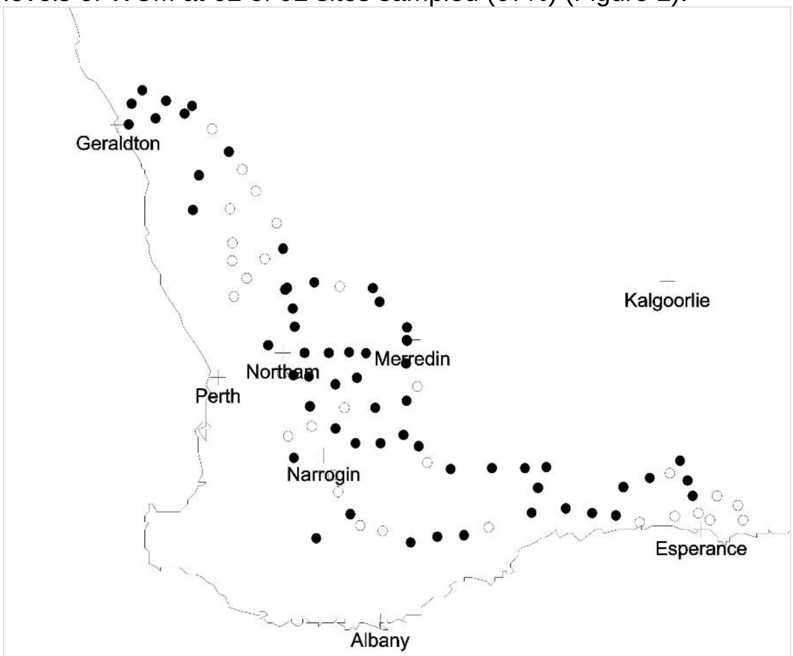

Figure 2 Sampling locations indicating presence (filled circle) and absence (open circle) of WCM within 20 randomly sampled wheat heads at soft dough growth stage (October-November).

Field trials (Wongan Hills and Merredin)

Very low numbers of WCM were found at Wongan Hills and Merredin when sampling seedlings, tillers and flowering heads, even in the plots with high numbers of 'infector' plants introduced (36 infector plants/plot to simulate 1% WSMV-infected seed).

At Wongan Hills, the treatments 0, 4, 18 and 36 infector plants introduced into plots resulted in the means of 52.5, 68.3, 65.0 and 71.7% of sown wheat plants infected with WCM, respectively, when sampled at the soft dough growth stage.

At Merredin, the treatments 0, 4, 18 and 36 infector plants resulted in the means of 9.2, 11.7, 21.7 and 63.3% of sown wheat plants infected with WCM, respectively, when sampled at the soft dough growth stage.

WSMV was detected in plots at Merredin on the final sampling date (14 October) only. The virus was detected in plots with 4, 18 and 36 'infector' plants at incidences of 1–2%. At Wongan Hills, WSMV was not detected on any sampling date in any plot.

DISCUSSION

Field survey

Although no outbreaks of WSMV were reported in 2008, the field surveys have shown that large populations of WCM are present during April-July. Therefore the risk of WSMV epidemics exists in all regions of the WA wheatbelt, particularly at locations with a history of WSMV. The presence of WSMV and spread by WCM will be more significant where summer/autumn rainfall allows for a build-up of WSMV-infected host plants and subsequent infection of wheat crops during early plant growth.

The abundance of WCM and WSMV in the WA grainbelt is considered to depend on pre-season rainfall encouraging a germination of self sown wheat and other grasses that act as hosts to the virus and mite that coincides with autumn temperatures above 24 ºC.

The summer/early autumn of 2007/08 was dry and few samples were available during the autumn sampling from April-July 2008. It was therefore surprising to find high numbers of WCM on the few heading wheat volunteers at this time. Some pockets of WCM-infested wheat were even found isolated from other host plants by distances greater than 500 m (e.g. next to bush reserves). These finds demonstrate the mite's strong survival ability and dispersal over widespread areas. WCM populations are anticipated to be in much higher numbers in seasons where a wetter summer/autumn and widespread wheat volunteers are present.

The extremely low populations of WCM found during the May-September survey period on young wheat crops appears to be related to a number of possible causes including:

- low initial population sources;
- late dispersal of mites from green autumn host plants; and
- cool winter temperatures not conducive to mite build-up.

However, in spite of the low winter population, build-up and dispersal during early spring is evident from the heading samples taken during October-November.

Field trials (infector plants)

The Merredin and Wongan Hills field trials have shown that WCM can eventually infest a high proportion of wheat plants in a paddock from an initial low number of infested plants. The levels of infestation will generally increase relative to abundance of nearby infested host plants, with levels having reached 63.3% at Merredin and 71.7% infestation at Wongan Hills from 36 infector plants scattered amongst 54 m^2 plots of wheat (1% initial infection).

Despite the high level of WCM found during late spring, no WSMV was detected in collected leaf samples from Wongan Hills and very low levels (1–2%) were detected at Merredin. The absence of mites in samples taken at the seedling stages suggests that there was very little mite movement from

the transplanted infector plants until late in the season. It appears that the mites were content to stay on the infector plants until the plants commenced to die naturally, which eventually encouraged the mites to migrate off to the nearby crop plants. At this stage the sown plants were advanced and commencing to form ears.

CONCLUSION

The survey and field trial results have confirmed certain aspects of WCM dispersal behaviour. Since the presence of WCM is essential in the transmission and widespread infection of WSMV, known hot spots of mites should be targeted for timely control. High populations of viruliferous mites need to be dispersing and landing on new seedlings within the seedling growth stages for WSMV to have a significant impact on crop yield. This information should be taken into account in the development of a management strategy. Later infection periods are likely to be of little consequence on yield. Yield loss has generally been minimal or not detected where wheat crops are infected post-tillering. The mass dispersal of WCM from host plants will be delayed until conditions on the host are unfavourable for the mites. This could be the premature death of wheat host plants by herbicides used for weed control or the natural aging and eventual death of plants. The abundance of nearby WCM source plants during dispersal will generally determine the mite and disease transmission level. Prevailing winds accompanying the mite dispersal phase will also influence population spread and direction.
Higher risk WCM/WSMV situations occur in seasons with high summer/autumn rainfall promoting host plants, and warmer autumn temperatures favouring WCM reproduction and dispersal. As there are no in-season control options for WCM or WSMV, control of volunteer wheat and grasses prior to crop germination remains essential for an effective management strategy.

Based on the current observations as well as literature on the population dynamics of WCM, it follows that WCM could survive for some time after the death of the host. Thus, after herbicide spray, a break of at least two weeks between complete death of host plants and crop germination is important to ensure the death of WCM present in the paddock.

KEY WORDS

Wheat Curl Mite, WCM, Aceria tosichella, Wheat Streak Mosaic Virus, WSMV

ACKNOWLEDGMENTS

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Paper reviewed by: Bill MacLeod

Partial resistance to Stagonospora (Septoria) Partial resistance to Stagonospora (Septoria) nodorum blotch and response to fungicide in a severe epidemic scenario

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[2]Australian Centre for Necrotrophic Fungal Pathogens, Murdoch University, Western Australia

KEY MESSAGES

1. Use of varietal resistance to Stagonospora nodorum blotch (SNB) reduces the requirement for fungicide in control of this disease.
2. In severe epidemics fungicide can reduce the impact of SNB on both susceptible and partially resistant varieties.
3. The highest level of disease control on the upper two leaves (using a single fungicide application) is achieved when fungicide is applied at early booting.
4. Timing of fungicide application may be less critical for partially resistant varieties, enabling the optimisation of fungicide use for this disease together with other diseases, such as stripe rust.

INTRODUCTION

Stagonospora nodorum is a major fungal pathogen of wheat and other cereals in many parts of the world. It induces stagonospora nodorum blotch (SNB) of leaves and glumes and is one of the most severe fungal diseases affecting wheat production in Western Australia. A 30–50% reduction in grain yield has been reported with an estimated loss to grain growers in excess of $58 million annually in wheat growing regions with high disease pressure. These studies were conducted as part of a broader study on disease assessment with SNB to distinguish varietal and fungicide effects at various stages of plant growth.

AIMS

To determine the optimum timing of fungicide application for the control of SNB in wheat varieties varying in resistance.

METHOD

Cultivars Millewa (susceptible) and EGA Blanco (moderately resistant) were used in this study. The experiment was sown in 2007 at South Perth in an irrigated field nursery in a split-plot design with three replications. An artificial epidemic of SNB was created by spreading infected straw around the plots and by infecting a pre-grown buffer of the susceptible variety Tincurrin planted around the plots. Treatments consisted of Folicur (Tebuconazole) application @ 125 g/ha after disease measurement on the second highest leaf showing infection at various stages of plant growth {6 weeks after sowing (WAS) (tillering), 8 WAS (stem extension), 10 WAS (early booting), 12 WAS (heading), 14 WAS (anthesis) and 16 WAS (soft dough)} as infection moved up the canopy. Treatments with no Folicur application and total protection (Folicur application at fortnightly intervals) were also included. A final assessment of disease on the flag leaf (F) and the leaf below (F-1) was made at the 16 WAS on all treatments.

RESULTS

High levels of disease were observed on plots exposed to infection and not protected with fungicide (Figure 1). Leaf disease severity of Millewa was significantly higher than EGA Blanco throughout the experiment indicating the effectiveness of partial resistance in EGA Blanco in reducing leaf disease development.

When fungicide application timing was compared as final leaf disease severity at 16WAS variety Millewa was more sensitive to variation in fungicide timing than EGA Blanco (Figure 2). The highest level of disease control on the upper two leaves (using a single fungicide application) was achieved when fungicide was applied at early booting (10WAS). Inferior disease control was observed in Millewa with 2–4 weeks earlier or later application of fungicide. Disease control on EGA Blanco was less sensitive to fungicide timing and application of fungicide over a 4 week period (8, 10 or 12 weeks) resulted in similar levels of disease control.

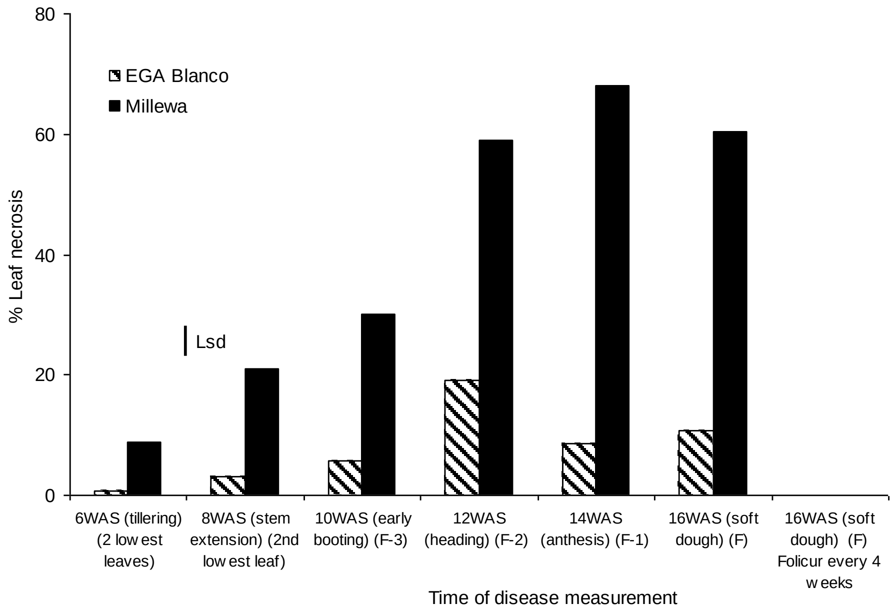

Figure 1 Disease progress of Stagonospora nodorum blotch up the plant canopy at various stages of plant growth in wheat varieties Milewa and EGA Blanco. WAS = Weeks after sowing; F = Flag leaf; F–1 = Leaf below the flag leaf; F–2 = Second leaf below the flag leaf; F–3 = Third leaf below the flag leaf.

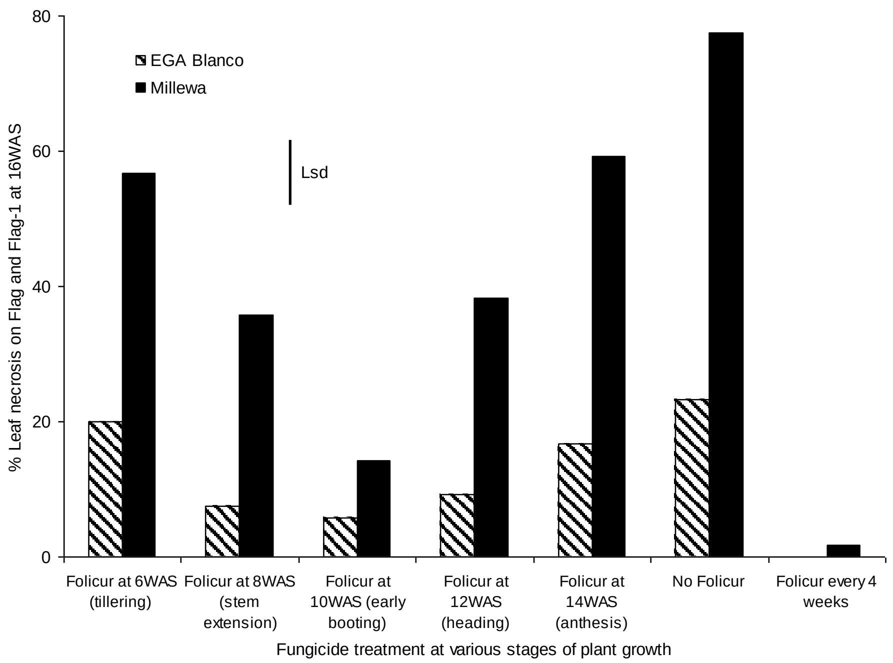

Figure 2 Final assessment of Stagonospora nodorum blotch on the flag leaf and the leaf below (Flag–1) at 16 WAS (weeks after sowing) after a single application of fungicide at various stages of plant growth in wheat varieties Milewa and EGA Blanco.

CONCLUSION

The response of EGA Blanco compared to Millewa indicates that the development and use of variety resistance to SNB will reduce the requirement for fungicide in control of this disease. In severe epidemics fungicide can also reduce the impact of SNB on a variety that is partially resistant to this disease, with the added benefit that timing of fungicide application may be less critical than for more susceptible variety, thus enabling the optimisation of fungicide use for this disease together with other diseases, such as stripe rust.

KEY WORDS

partial resistance, Tebuconazole, timing of fungicide application

ACKNOWLEDGMENTS

Support of Cereal Pathology staff at DAFWA is gratefully acknowledged.

Project No.: DAW120

Paper reviewed by: Geoff Thomas

Black pod syndrome in lupins can be reduced by regular insecticide sprays

Peter White and **Michael Baker**, Department of Agriculture and Food, Western Australia.

KEY MESSAGES

Competition for assimilates between pods on the main stem and lateral branches does not seem to be the cause of black pod syndrome.
Some evidence indicates that Bean Yellow Mosaic Virus (BYMV) may be one cause of black pod syndrome in lupins, but this still needs to be confirmed.

BACKGROUND

Lupins grown in mild high rainfall environments, particularly in the southern wheatbelt, sometimes produce yields considerably below their potential. Many pods on these plants appear black and contain seeds that are flat and underdeveloped. We have termed this disease black pod syndrome; its cause is unknown.
Jenabillup was released in 2007 because it showed some resistance to black pod syndrome. In trials where black pod syndrome was severe, Jenabillup produced 30% more yield than Mandelup (White et al. 2007). Despite its improved resistance, however, the yield of Jenabillup was still reduced by black pod syndrome in these trials. A better understanding of the causes of black pod syndrome will enhance yields further by improving crop management and breeding for resistance.

Observations by farmers and results from trials indicate that BYMV may have some role in causing black pod syndrome, but evidence is scant and there may be other causes.

AIMS

Identify further avenues of research into the causes of black pod syndrome in lupins by determining if the severity of symptoms of black pod syndrome can be increased or decreased by either: regular applications of insecticide, supplying a full complement of nutrients to plants, or removing some pods from plants.

METHOD

A field trial was conducted at the Esperance Downs Research Station. It was sown on 17 May and located on a paddock that had grown wheat the year before. Four genotypes (Quilinock, Jenabillup, Mandelup, Tallerack) received three types of treatment (regular insecticide sprays, full nutrient application, control (untreated)) replicated four times. A split-plot design was used with the treatment as the main plot and genotype as the sub plot. Treatments were designed to cause differences in the severity of black pod syndrome and were not designed to investigate possible management options for black pod syndrome.
The regular insecticide treatment contained a mixture of Confidor (200 mL/ha) (plus a pulse penetrant) and Fastac (500 mL/ha) and was sprayed onto plants every two weeks starting from the emergence of the lupin seedlings. Buffers were placed in the trial to separate the sprayed from the unsprayed treatments. The full nutrient treatment contained a commercial granulated micronutrient fertiliser plus urea. Urea was applied at 180 kg/ha, split into three equal doses (60 kg/ha each) broadcast at sowing, flowering and podding. The commercial fertiliser was drilled with the seed at sowing. Plots received the following rates (kg/ha): 6, Cu_2SO_4; 4, $ZnSO_4$; 17, $MnSO_4$; 0.2, $CoSO_4$; 25, $MgSO_4$; 120, K_2SO_4; 0.25, Na_2MoO_4. Nutrients applied in this treatment were in addition to the basal fertiliser rates applied to all treatments across the trial. Basal fertiliser was applied as a sulphur coated superphosphate with additional $MnSO_4$. Rates of nutrients applied were (kg/ha): 14, P; 12, S; 10, Ca; 8 Mn.

About 13 weeks after sowing plants were at the open flower point on the main stem and some had reached the budding point on the primary lateral branches. At this stage five plants were selected at random from plots of Mandeup and Jenabillup and the top three primary lateral branches were

removed from the plant. Similarly five more plants were selected from the same plots and all branches and leaves were removed below the top three primary lateral branches. All of these plants were tagged and harvested separately at maturity.

RESULTS

Symptoms of black pod syndrome

Some plants in all treatments showed symptoms of black pod syndrome. When plants were untreated about 20 plants/m^2 of Mandelup and Tallerack had black pod syndrome (Figure 1). This equated to about 60% of the plants in the plots. Only about 10 plants/m^2 of Jenabillup and Quilinock had black pod syndrome when plants were untreated. This equated to about 25% of the plants in the plot. Applying insecticide reduced the number of plants with black pod syndrome for all genotypes. Applying fertiliser increased the number of plants of Mandelup and Tallerack with black pod syndrome but did not affect Jenabillup or Quilinock.

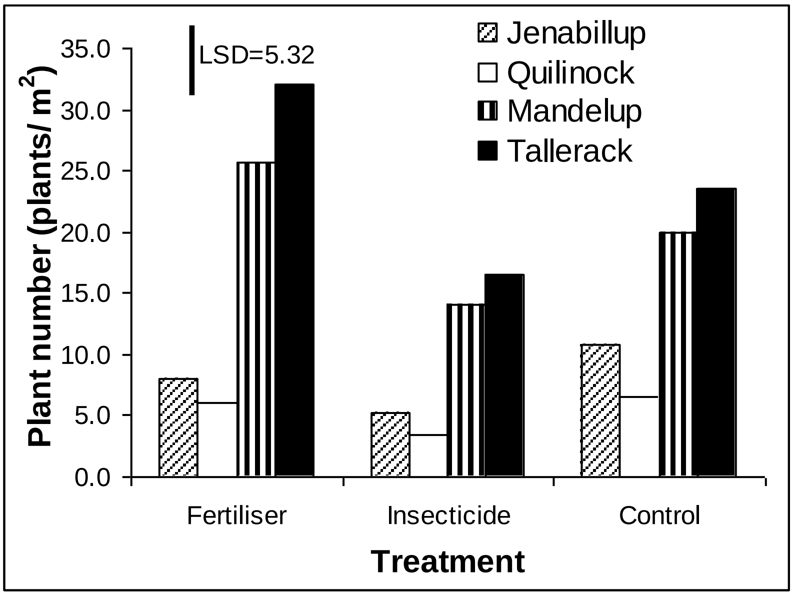

Figure 1 Number of plants showing symptoms of black pod syndrome when Jenabillup, Quilinock, Mandelup or Tallerack, were left untreated (control), received regular applications of insecticide or received a full complement of nutrients as fertiliser.

Removing the top three primary lateral branches from plants or removing all branches and leaves below the top three primary lateral branches did not affect the proportion of plants that showed black pod syndrome (data not presented). Mandelup still showed a greater number of plants with black pod syndrome than Jenabillup and the number of plants were either decreased or increased by application of insecticide or fertiliser in the same proportion as plants that had not had branches removed.

Grain yield

Grain yields were closely related to the number of plants showing black pod syndrome. Jenabillup and Quilinock produced higher grain yields than Mandelup or Tallerack (Figure 2). Similarly, applying insecticide increased grain yields while applying extra fertiliser decreased grain yields. These responses mirrored the effect treatments had on the number of plants with black pod syndrome. Yields were about 3 t/ha when less than five plants per m^2 had black pod syndrome, and only 1.5 t/ha when about 20 plants per m^2 had black pod syndrome (Figure 3). Total shoot biomass showed similar responses as grain yields (data not shown).

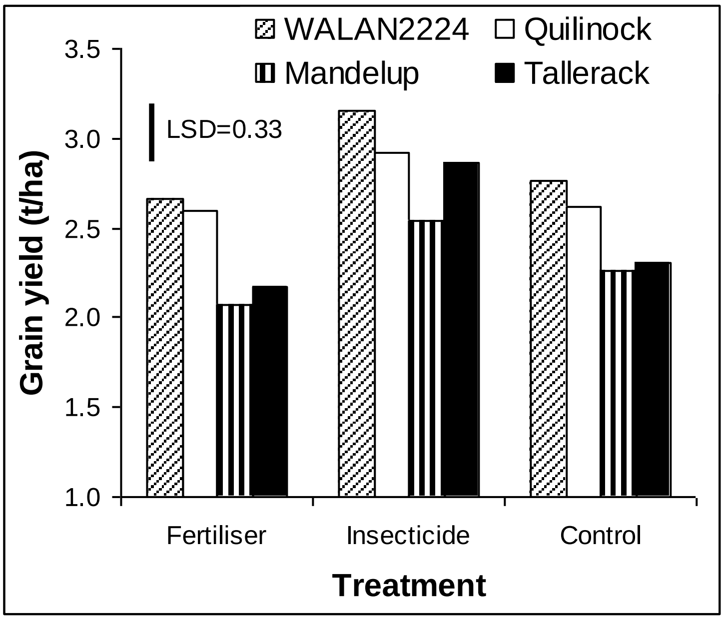

Figure 2 Grain yield of plants showing symptoms of black pod syndrome when Jenabillup, Quilinock, Mandelup or Tallerack, were left untreated, received regular applications of insecticide or received a full complement of nutrients as fertiliser.

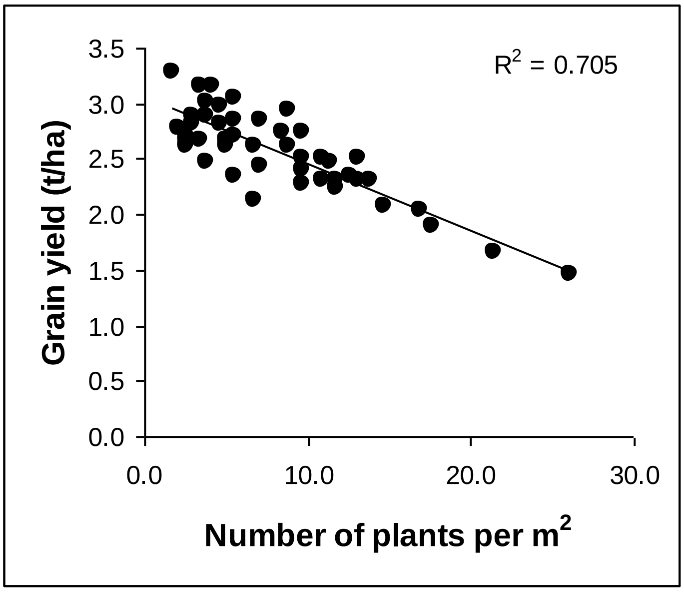

Figure 3 Correlation between the number of plants with black pod syndrome and grain yield. Each point represents an individual genotype x amendment x replicate combination.

DISCUSSION

Regular application of insecticide was aimed at reducing the transmission of BYMV by reducing the number of aphids entering the plots to feed on plants. However it was recognised that insecticide application would have also had a wide range of additional effects unrelated to transmission of BYMV. Results from this trial, nevertheless are consistent with the theory that a link between BYMV and black pod syndrome exists and more detailed research into this possible link is required. Other possible causes of black pod syndrome in lupins cannot be ruled out, however, the results from this trial are not consistent with the hypothesis black pod syndrome is cause by a nutrient deficiency or through competition between pods for limited assimilates.

The increased incidence of black pod syndrome when extra fertiliser was applied was unexpected. If black pod syndrome was related to a nutrient deficiency then its severity would be expected to be decreased by fertiliser application rather than increased. Total biomass production was not increased by fertiliser application so it is unlikely that the high rates of some nutrients may have induced, through a dilution effect, a deficiency of other nutrients that were in marginal supply (particularly boron which was not applied). Possibly the very high levels of nitrogen applied to plants made them more attractive to aphids causing a higher incidence of BYMV related black pod syndrome.

Removing branches from plants was aimed at altering the competition between pods forming on the main stem and lateral branches for assimilates. Removing lateral branches may be expected to reduce competition for assimilates, while removing leaves and basal branches from the main stem may be expected to reduce assimilate supply to pods on the main stem. It is unlikely that black pod syndrome is related to assimilate supply because removing branches or leaves had no affect on the number of plants showing black pod syndrome. This, in fact, is not surprising given that lateral branches of lupins become autonomous in their carbon supply early on in their development (Palta et al. 2007).

KEY WORDS

narrow-leafed lupin, black pod syndrome, BYMV

ACKNOWLEDGMENTS

Mr Colin Boyd and Mr Colin Norwood sowed, managed and harvested the trials. Their help in this research is gratefully acknowledged.

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Paper reviewed by: Kedar Adhikari and Bob French

Incorporating new herbicide tolerant juncea canola into low rainfall cropping systems in Western Australia

Mohammad Amjad, Department of Agriculture and Food, Western Australia

KEY MESSAGES

- New varieties of herbicide-tolerant juncea canola (Oasis CL and Sahara CL) have performed well in agronomic testing in Western Australia in terms of grain yield for a range of seed rates, nitrogen rates and row spacings.

AIMS

To investigate the agronomic performance of new herbicide tolerant juncea canola cultivars at different seed rates, nitrogen rates and row spacings.

BACKGROUND

Juncea canola (also called canola quality juncea) is a new oilseed crop with similar quality characteristics to normal canola (edible oil with a low level of erucic acid and the meal is an animal feed with low glucosinolates) but is reported to be more suited to dryland environments. Some of the beneficial traits of new juncea canola varieties include pod shatter resistance, unique blackleg resistance, yellow seed colour and improved heat and drought tolerances relative to normal canola. The Victorian DPI and Viterra (Canada) are currently breeding herbicide tolerant juncea canola *(Brassica Juncea)* varieties. Two juncea canola IT tolerant varieties 'Oasis CL' (Coded JO5Z-08920) and Sahara CL (Jo5Z-08960) were commercially released in 2008 in the eastern states.

The Department of Agriculture and Food, Western Australia (DAFWA) is conducting juncea agronomy trials in WA as a part of the National Brassica Juncea Agronomy project funded by GRDC and coordinated by John Sykes, DPI NSW.

METHOD

The trial design was a completely randomised block design with three replicates in three banks. Two IT herbicide tolerant cultivars Oasis CL and Sahara CL were tested at five seed rates (1, 2, 4, 6, 8 kg/ha) and at three row spacings (22, 44, 66 cm). IT open-pollinated canola 44C79 and Oasis CL were tested at four nitrogen rates (5, 30, 60, 90 kg/ha). Trials were sown on 21 May following cereal crops in 2007 at Wongan Hills. There were three separate blocks exploring interaction between: cultivars x seed rate; cultivars x row spacing; and cultivars x nitrogen rate.
Basal treatments for the trial were; 22 cm row spacing, 4 kg/ha juncea canola seed rate and fertiliser 50 kg/ha MAP (or equivalent) was drilled below the seed at seeding in all three blocks. Talstar/endosulphan (bare earth) was applied immediately after seeding for pest control. In the nitrogen rate block, all five nitrogen rates were topdressed before seeding. Ammonium Sulphate (140 kg/ha) was topdressed on both the seed rate and row spacing blocks six weeks after sowing.

Trials were closely monitored and controlled for weeds, insects and diseases throughout the growing season. The in-crop On-duty/Intervix herbicide was applied at the four leaf stage to control broad leaf weeds.

RESULTS

The 2008 season at Wongan Hills started with a late seasonal break in May followed by a dry June and then wet July. The site received 245 mm growing season rainfall (May to October) with a total of 374 mm for the year. Mild temperatures and the good finish to the season improved the juncea canola production. Oil quality data are currently being processed and are not yet available.

Cultivars x Seed rate

The main effects of cultivars and seed rate on plant establishment (plant population) were significant. The mean plant population was higher for Sahara CL (106 plants/m^2) than Oasis CL (64 plants/m^2). Plant establishment increased from 28 to 153 plants/m^2 as seeding rate increased from 1.0 to 8 kg/ha (Table 1). Both cultivars produced similar yields (1.85 t/ha). Grain yield increased with seeding rate (Table 1). Figure 1 illustrates the response of juncea canola grain yield to plant population at Wongan Hills. Juncea canola attained the maximum yield of 2.14 t/ha at a seed rate of 6 kg/ha (with plant population of 122 plants/m^2), suggesting that it may have higher yield potential in medium to high rainfall areas.

Table 1 **Effect of seeding rate on plant establishment (plant population) and grain yield of new herbicide-tolerant juncea canola**

Seed rate, kg/ha	Plants/m^2			Yield, t/ha		
	Sahara CL	Oasis CL	*Average*	Sahara CL	Oasis CL	*Average*
1.0	37	18	*28*	1.60	1.49	*1.55*
2.0	62	33.7	*48*	1.88	1.72	*1.80*
4.0	97	56	*77*	1.80	1.89	*1.85*
6.0	145	99	*122*	1.94	2.09	*2.01*
8.0	191	115	*153*	1.88	2.14	*2.01*
Average	*107*	*64*	*85*	*1.82*	*1.87*	*1.84*
l.s.d. (0.05)						
Cultivars		*14*			*0.17*	
Seed rate		*22*			*0.26*	
*Cultivars*seed rate*		*32*			*0.37*	
CV		*21.5%*			*11.8%*	

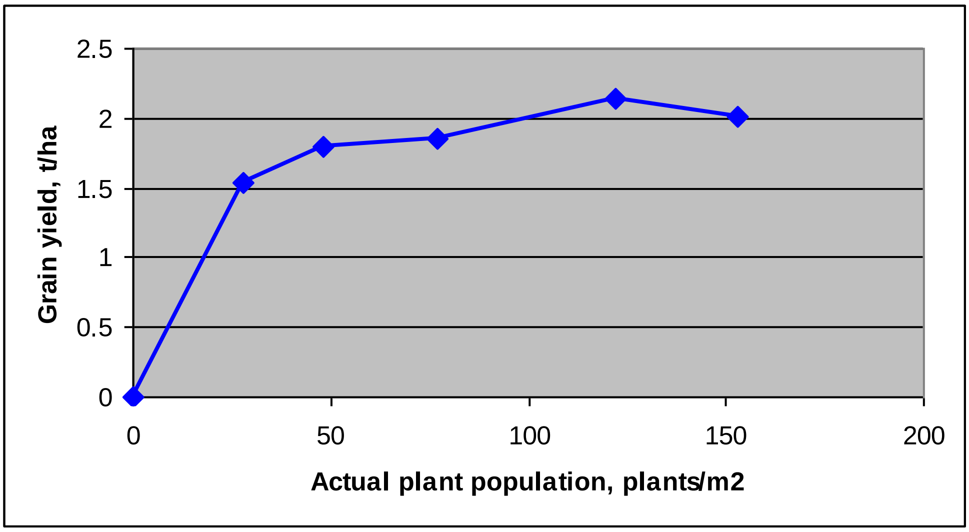

Figure 1 The relationship between juncea canola seeding rate (actual plant population) and grain yield.

Cultivars x row spacing

The main effects of cultivar and row spacing on plant establishment (plant population) were significant but had no effect on grain yield (Table 2). The mean plant population was higher for Sahara CL (48 plants/m^2) compared to Oasis CL (33 plants/m^2). Juncea canola yielded 1.63 t/ha, which was similar for all three row spacings and indicates that juncea canola might not experience a yield penalty if sown in wide rows.

Table 2 **Effect of row spacing on plant establishment (plant population) and grain yield of new herbicide-tolerant juncea canola**

Row spacing, cm	Plants/m²			Yield, t/ha		
	Sahara CL	Oasis CL	*Average*	Sahara CL	Oasis CL	*Average*
22.0	32	25	*28*	1.72	1.67	*1.70*
44.0	51	33	*42*	1.77	1.56	*1.67*
66.0	61	40	*51*	1.59	1.47	*1.53*
Average	*48*	*33*	*40*	*1.69*	*1.57*	*1.63*
l.s.d. (0.05)						
Cultivars		*11*			*0.23*	
Row spacing		*14*			*0.33*	
*Cultivars*row spacing*		*20*			*0.46*	
CV		*27.0%*			*17.10%*	

Cultivars x nitrogen rates

Nitrogen rates had no effect on crop establishment or grain yield (Table 3). The mean plant population for 44C79 CL canola was more than twice (73 plants/m^2) that of juncea canola Oasis CL (27 plants/m^2). Similarly 44C79 CL canola yielded better 1.84 t/ha than juncea canola 1.25 t/ha.

Table 3 Nitrogen rate effects on plant establishment (plant population) and grain yield of new herbicide-tolerant oilseeds, juncea canola (Oasis CL) and canola (44C79 CL)

Nitrogen rate, kg N/ha	Plants/m²			Yield, t/ha		
	44C79 CL	Oasis CL	*Average*	44C79 CL	Oasis CL	*Average*
5.0	79	26	*52*	1.66	1.12	*1.39*
30.0	72	26	*49*	1.86	1.20	*1.53*
60.0	80	28	*54*	2.04	1.30	*1.67*
90.0	62	30	*46*	1.80	1.36	*1.58*
Average	*73*	*27*	*50*	*1.84*	*1.24*	*1.54*
l.s.d. (0.05)						
Cultivars		*10*			*14*	
Nitrogen rate		*14*			*22*	
*Cultivars*nitrogen rate*		*19*			*32*	
CV		*22.0%*			*21.50%*	

CONCLUSION

Based on limited testing in the WA environment, the new herbicide-tolerant juncea canola shows promise from a grain yield perspective and may provide an alternative oilseed species. Further field evaluation of new herbicide-tolerant juncea canola is needed across a range of environments and seasons in Western Australia to determine if it can become a profitable break crop in cereal rotations.

KEY WORDS

canola (*Brassica napus*), varieties, cultivars, canola quality juncea or juncea canola (*Brassica juncea*) agronomy, grain yield, oil

ACKNOWLEDGMENTS

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Varietal differences in germ end staining of barley

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KEY MESSAGES

- The varieties Gairdner, Hamelin, Baudin and breeding line WABAR2315 suffered less germ end staining than other malt varieties.
- Hindmarsh, Commander and Stirling were the varieties worst affected.

AIMS

To assess the current range of malt barley varieties for germ end staining of grain.

INTRODUCTION

The precise cause of germ end staining or black point, in barley, is still unknown. While fungal growths of *Alternaria* species were initially believed to be responsible and do cause other forms of grain discolouration, fungi do not cause germ end staining in barley. Current theory is that oxidised phenol activity during grain ripening may be responsible although how this relationship affects the level of germ end staining in barley is unknown (Sulman et al. 2001a). What is known however is that humid environmental conditions during ripening result in the development of germ end staining and that varieties exhibit different levels of resistance (Sulman et al. 2001b). In the current WA barley variety guidelines, No ratings have previously been published for susceptibility to germ end staining, however impact on grain quality can affect the grade that grain is accepted into and hence payment received by growers.

METHOD

Two types of trials in the medium and high rainfall zones; barley variety x time of sowing (TOS) and malt variety x nitrogen, were opportunistically assessed for germ end staining by a CBH trained technician according to the definition provided by CBH Ltd (November 2008). Trial designs were randomised blocks with three replicates per treatment.
One hundred grains per plot were subsampled and results multiplied by four to compare results directly with CBH limits. Test comparisons between counts of 100 and 400 grains showed that using 100 grains provides a reliable estimate. Counts of 100 grains were therefore used for the sake sample through put.

For the 2008/09 harvest, grain accepted into the CBH Malt 1 segregation must have no more than 45 grains out of 400 affected by germ end staining and no more than 60 affected per 400 for Malt 2. Only the results for malt varieties or potential malt varieties are presented here as there is no germ staining limit for feed grades.

Lines assessed were Stirling, Baudin, Buloke, Flagship, Gairdner, Hamelin, Vlamingh, Hannan, Hindmarsh, WABAR2315 and Commander (formerly known as WI3416-1572).

Table 1 **Details of trials assessed for germ staining (location, date of sowing and date of harvest)**

Location	Trial type	Date(s) of sowing	Date of harvest
Gibson	Variety x TOS	27 May 2008 19 June 2008 15 July 2008	8 December 2008
Gibson	Malt variety x N (0, 20 60 kg N/ha @ tillering)	26 May 2008	7 December 2008
Wittenoom Hills	Variety x TOS	21 May 2008 11 June 2008 1 July 2008	22 December 2008

Newdegate	Variety x TOS	19 May 2008 10 June 2008 3 July 2008	23 December 2008
Jacup	Malt variety x N (0, 20 60 kg N/ha @ tillering)	26 May 2008	8 January 2009

RESULTS

Environmental conditions in 2008

The 2008 season offered ideal conditions for the development of germ end staining during grain ripening in November in the lower wheatbelt and south coast. The contrast between rainfall in November 2008 and November 2007, where no germ end staining was observed is shown in Figure 1 below. At each site the minimum and maximum relative humidity for November were also higher in 2008 than in 2007 or for the long term average (data not shown).

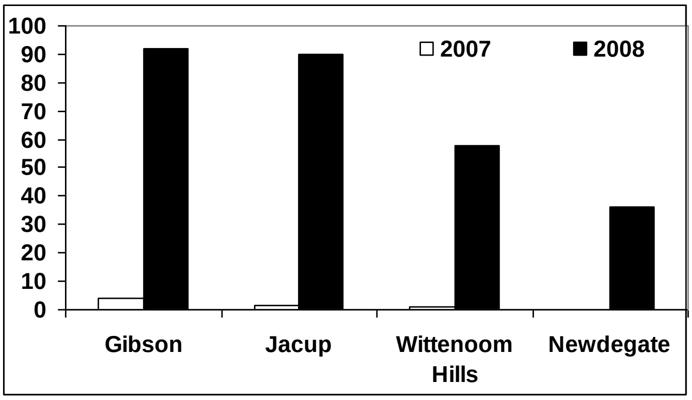

Figure 1 November rainfall (mm) for trial sites in 2007 and 2008.

Varietal differences

Each site showed different levels of staining although they were not directly related to the amount of rainfall received in November. The order of staining severity was Gibson > Wittenoom Hills > Jacup >> Newdegate. Results here will focus on Gibson and Wittenoom Hills.

At Gibson Hindmarsh, Stirling and Flagship were the worst affected on average while Gairdner, Hamelin and Baudin were least affected (Table 2).

At Wittenoom Hills Hindmarsh, Buloke, and Stirling were the worst affected on average while Gairdner, Hamelin, WABAR2315 and Baudin were the least affected (Table 3).

Overall, the most consistently susceptible variety appears to be Hindmarsh, followed by Commander and Stirling. Gairdner, Hamelin and WABAR2315 are more resistant to germ end staining.

Table 2 **Number of grains affected by germ end staining per 400 grains at Gibson in 2008 for three times of sowing (TOS). Figures in bold indicate greater than 45 grains/400 affected**

	Time of sowing		
Variety	**27 May**	**19 June**	**15 July**
Stirling	**229**	**48**	**56**
Baudin	**52**	10	40
Buloke	**74**	**98**	8
Flagship	**261**	38	16
Gairdner	36	4	6
Hamelin	**61**	0	2
Vlamingh	**101**	0	8
Hannan	**117**	44	20
Hindmarsh	**362**	22	**46**
WABAR2315	**80**	24	18
Commander	**122**	24	40
Average	136	28	24

ANOVA	Significance	l.s.d. (0.05)
tos	p = 0.012	37
variety	p = < 0.001	42
tos.variety	p = < 0.001	73

Table 3 **Number of grains affected by germ end staining per 400 grains at Wittenoom Hills in 2008 for three times of sowing (TOS). Figures in bold indicate greater than 45 grains/400 affected**

	Time of sowing		
Variety	**21 May**	**11 June**	**1 July**
Stirling	**72**	45	31
Baudin	29	37	23
Buloke	**88**	27	40
Flagship	44	9	44
Gairdner	**47**	20	21
Hamelin	36	31	20
Vlamingh	44	44	16
Hannan	24	**88**	27
Hindmarsh	**57**	**71**	35
WABAR2315	44	25	20
Commander	32	**53**	39
Average	47	41	29
ANOVA	**Significance**	**l.s.d. (0.05)**	
tos	ns		
variety	p = 0.029	30	
tos.variety	ns		

Effect of nitrogen

The rate of nitrogen applied did not affect the development of germ end staining in the varieties tested.

Effect of time of sowing

Time of sowing significantly affected germ end staining at Gibson (Table 2), but not at Wittenoom Hills (Table 3). At Gibson, the first time of sowing was severely affected and many varieties exceeded accepted limits, relegating them to feed grade. Second and third times of sowing generally had lower levels of staining. There was also a highly significant interaction between time of sowing and variety ($p < 0.001$) at Gibson and including average maturity time as a covariate did not alter this interaction. There was no statistical significance between germ staining levels within varieties at different times of sowing at Wittenoom Hills, however there was a slight trend towards less germ staining with later sowing.

CONCLUSION

The WA malting varieties Gairdner, Baudin and Hamelin all appear to have good levels of resistance to germ end staining, along with the potential new malt line WABAR2315. The high yielding variety Hindmarsh appeared to be the most susceptible variety tested.

While early sowing in the time of sowing trial resulted in higher levels of germ end staining there was no affect of nitrogen rate on germ end staining in an accompanying nitrogen rate trial in Gibson.

KEY WORDS

barley, germ end staining

ACKNOWLEDGMENTS

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Paper reviewed by: Mark Seymour and Ben Curtis

Wheat variety performance in the Central Agricultural Region in 2008

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KEY MESSAGES

- The yields and gross returns of several newer APW varieties, including the more recently released varieties Mace and Magenta, was comparable, if not better than Wyalkatchem at some times of sowing across three sites at Corrigin, Merredin and Wongan Hills. Likewise the performance of the three new noodle wheats, Binnu, Fortune and Yandanooka was comparative to that of Calingiri.
- The average yield with late May sowing at Wongan Hills was 37% higher than the average yield with 3 July sowing. Average yield with mid May sowing at Corrigin was 41% higher than with late June sowing. Average grain yields at Merredin did not differ significantly between sowing times.
- The screenings levels of Binnu did not differ distinctly from those of the other noodle varieties, even with the later sowing times.
- High screenings and low hectolitre weight were not an issue at any of three trial locations in 2008.

AIMS

To investigate the performance of new wheat varieties at different sowing times in the central agricultural region in 2008.

METHOD

Three field trials were conducted at Corrigin, Merredin and Wongan Hills in 2008. Twenty–four wheat breeding lines from various Australian breeding companies were sown at three times of sowing in a randomised block design with three replications. The first time of sowing (TOS), at Merredin (Agzone 4), was sown on 29 April after a good rain to generate information on early sowing. A light irrigation was applied in May to save the crop due to a very dry spell. Germination in TOS1 at Merredin was patchy compared to TOS 2 and TOS 3. Grain yield was limited by frost damage in all time of sowings at Merredin. At Wongan Hills (Agzone 2) TOS 1 was in late May but the second and third time of sowing was delayed until 15 June and 3 July respectively, when rainfall allowed. At Corrigin (Agzone 2) TOS 1 was 12 May. Subsequent sowings were at 20 and 25 days after, when rainfall permitted. Soil type and crop rotation for the three sites were as follows: Wongan Hills a sandy loam following pasture, Corrigin following canola and at Merredin a clay loam following pasture.
Data on grain yield, grain protein, hectolitre weight and screenings were recorded and analysed using Genstat.

Note: Screenings include whole and cracked grain. Gross income was calculated on the average yield and quality for each treatment using cash price. Base scale: APW $292.5. Grade spreads: H2 +$12, AUH2 -$5, ASW1 -$25, ASFT +$25, ANW1 -$25, ANW2 -$35, AGP1 -$30.

RESULTS

April-October rainfall was 277.8 mm at Corrigin, 282.6 mm at Merredin and 301.2 mm at, Wongan Hills. Minimum rainfall was recorded in the month of August at all trial sites. However, significant rainfall was received in September/October at all locations.
Yield and grain quality results are presented in Table 1 for Corrigin, Table 2 for Merredin and Table 3 for Wongan Hills. Sowing times had a significant effect on grain yield and protein at both Corrigin and Wongan Hills but not at Merredin.

The soft wheat EGA 2248 was the highest yielding variety at Corrigin, followed by Magenta and Carnamah. EGA 2248 only met protein standards for soft wheat when sown in late May. The newly released variety Mace, Fang and Fortune were among the top performers at this site. Mace offers excellent resistance to stem, stripe and leaf rust. Most of the noodle varieties achieved the delivery standard of 9.5–11.5% protein at all time of sowings (Table 1). None of the eligible varieties met the minimum delivery standards for AH or APW with late May sowing. The gross returns of Carnamah, Magenta, Mace, Yitpi and EGA2248 were higher than that of Correll, Fang, Gladius, Espada and Fortune.

There was no significant difference between yields of the top yielding varieties Espada, Gladius, EGA Wentworth, Bumper, Derrimut and RAC1423 with late April sowing at Merredin (Table 2). While the grain yields of the newly released variety Bumper were comparable those of the top yielding varieties at this site the gross returns were below the higher gross returns recorded. The gross returns of the durum wheat variety Jandaroi were amongst the highest with 18 June and 18 July sowing. Most of the AH varieties achieved protein levels in excess of 13% in TOS 2 and TOS 3. All noodle wheat varieties recorded protein levels above 11.5% at all times of sowing. All varieties had consistently low screenings (< 5%) and high hectolitre weight (> 74 kg/kL).

The newly released varieties Mace and Fortune were among the top yielders, including Magenta, Yandanooka, Binnu, Yitpi, Young and Wyalkatchem at Wongan Hills (Table 3). The yield of Fortune was comparable to Arrino, Binnu, Calingiri and Yandanooka. Grain protein levels for all noodle varieties grown at Wongan Hills were within the delivery standards at all times of sowings except for Binnu and Fortune in TOS1. The gross income of Magenta, Yitpi and Mace was higher than for Tammarin Rock, Carnamah, EGA Bonnie Rock and Wyalkatchem. All of the varieties had low screenings and hectolitre weight exceeding the 74 kg/hl minimum standard.

CONCLUSION

The results presented in this paper justify consideration of some of the new wheat varieties as replacements for commercial favourites in the central agricultural region. Mace and Magenta were notably amongst the most consistent varieties in terms of gross returns across times of sowing at Corrigin and Wongan Hills. On the whole the three new noodle varieties Binnu, Fortune and Yandanooka performed comparatively with Calingiri across times of sowing and sites.

KEY WORDS

wheat varieties, wheat agronomy, time of sowing, grain yield, protein, screenings, hectolitre weight

ACKNOWLEDGMENTS

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Paper reviewed by: Tom Sweeny

Table 1 **Effect of sowing time on yield, quality and economic returns of wheat varieties at Corrigin in 2008**

Grade	Variety	Grain yield (t/ha)			Mean	Protein (%)			Mean
		12 May	4 June	24 June	(t/ha)	12 May	4 June	24 June	(%)
	Carnamah	2.61	1.40	1.44	1.82	8.9	11.8	11.1	10.6
AH	EGABonnieRock	2.39	1.23	1.11	1.58	9.7	13.0	12.7	11.8
	Yitpi	2.41	1.50	1.34	1.75	9.6	12.8	11.5	11.3
	Axe	1.55	1.12	1.05	1.24	10.6	12.8	12.8	12.1
	Carinya	2.04	1.31	1.36	1.57	9.1	12.2	11.0	10.8
	Catalina	1.44	1.30	1.35	1.36	9.4	11.8	10.8	10.7
	Correll	2.23	1.36	1.53	1.71	9.4	12.2	11.0	10.9
	DerrimutWt	2.22	1.35	1.39	1.65	9.0	11.5	10.1	10.2
	Espada	2.20	1.37	1.44	1.67	9.9	12.3	11.3	11.2
	Fang	2.22	1.39	1.48	1.70	9.0	11.7	10.3	10.3
APW	Gladius	2.35	1.33	1.37	1.68	9.8	12.3	12.0	11.4
	Magenta	2.27	1.57	1.70	1.85	9.6	12.2	10.5	10.8
	Mace	2.65	1.39	1.43	1.82	8.6	12.1	10.7	10.5
	Young	2.29	1.43	0.79	1.50	9.9	12.1	11.7	11.2
	LR Lincoln	1.43	1.20	1.36	1.33	9.7	12.9	11.1	11.2
	Wyalkatchem	2.48	0.95	1.26	1.56	8.9	13.2	11.3	11.1
	Zippy	2.13	1.14	0.91	1.39	10.3	12.4	13.1	11.9
ASFT	EGA2248	2.9	1.4	1.35	1.88	9.0	12.3	11.5	10.9
	Arrino	2.47	1.38	1.30	1.72	9.7	12.1	11.5	11.1
	Binnu	2.48	1.32	1.30	1.70	9.2	11.4	10.5	10.4
ASWN	Calingiri	2.29	1.52	1.46	1.76	9.6	11.6	10.5	10.6
	Yandanooka	2.13	1.29	1.36	1.59	9.5	12.5	11.1	11.0
	Fortune	2.39	1.54	1.46	1.80	9.1	11.5	11.1	10.6
Unclassified	RAC 1423	2.07	1.33	1.23	1.54	10.1	12.8	11.5	11.5
	Average within each TOS	2.24	1.34	1.32	1.63	9.48	12.2	11.3	11.0
	TOS (l.s.d.)	0.24				0.2			
	Var (l.s.d.)	0.32				0.3			
	Var (l.s.d.) between TOS	0.54				0.6			
	Var (l.s.d.) within TOS	0.52				0.6			
	%CV	19.9				3.3			

Table 2 **Effect of sowing time on yield, quality and economic returns of wheat varieties at Merredin in 2008**

Grade	Variety	Grain yield (t/ha)			Mean (t/ha)	Protein (%)			Mean (%)
		29 April	18 June	18 July		29 Apr	18 June	18 July	
APDR	Jandaroi	1.01	1.19	1.09	1.10	14.7	15.5	14.9	15.0
	Carnamah	1.22	1.26	1.45	1.31	13.1	14.6	12.3	13.3
AH	EGABonnieRock	1.49	1.16	1.37	1.34	12.8	13.8	13.3	13.3
	TammarinRock	1,53	1.21	1.20	1.21	12.0	13.7	13.2	13.0
	Yitpi	1.54	1.19	1.22	1.32	11.5	15.3	14.3	13.7
	Axe	1.51	1.31	1.15	1.32	12.4	12.9	13.7	13.0
	EGA Bounty	1.20	1.22	1.21	1.21	12.6	13.7	13.5	13.3
	Catalina	1.32	1.28	1.30	1.30	12.5	13.4	13.1	13.0
	Correll	1.14	1.23	1.24	1.20	12.9	14.1	13.5	13.5
	DerrimutWt	1.68	1.42	1.19	1.43	12.0	13.9	13.3	13.1
	Endure	1.15	1.51	1.15	1.27	13.3	13.4	14.6	13.8
	Espada	1.60	1.52	1.40	1.51	12.4	13.6	13.8	13.3
APW	Gladius	1.51	1.53	1.45	1.50	12.8	13.5	14.5	13.6
	Magenta	1.59	1.24	1.22	1.35	12.5	14.2	14.5	13.7
	Mace	1.62	1.29	1.21	1.37	12.5	14.2	13.2	13.3
	EGAWentworth	1.57	1.37	1.52	1.49	11.8	13.2	13.2	12.7
	Young	1.44	1.37	1.30	1.37	12.5	13.5	13.5	13.2
	LR Lincoln	1.45	1.27	1.26	1.33	12.2	13.8	13.5	13.2
	Wyalkatchem	1.39	1.12	1.34	1.28	13.0	14.4	13.5	13.6
	Zippy	1.51	1.20	1.05	1.25	12.9	14.5	14.2	13.9
	Binnu	1.48	1.25	1.43	1.39	12.6	13.4	12.3	12.8
ASWN	Calingiri	1.41	1.38	1.24	1.34	12.2	13.1	13.8	13.0
ASW	Bumper	1.49	1.46	1.36	1.44	12.1	13.5	13.1	12.9
Unclassified	RAC 1423	1.48	1.40	1.43	1.44	12.8	14.0	12.8	13.2
	Average within each TOS	1.43	1.31	1.28	1.34	12.6	13.9	13.6	13.3
	TOS (l.s.d.)	0.53				2.1			
	Var (l.s.d.)	0.18				0.9			
	Var (l.s.d.) between TOS	0.54				2.3			
	Var (l.s.d.) within TOS	0.31				1.5			
	%CV	14				7.4			

Table 3 **Effect of sowing time on yield, quality and economic returns of wheat varieties at Wongan Hills in 2008**

Grade	Variety	Grain yield (t/ha)			Mean	Protein (%)			Mean	
		23 May	15 June	3 July	(t/ha)	23 May	15 June	3 July	(%)	23
	Carnamah	3.13	1.86	1.82	2.27	9.4	11.0	10.5	10.3	
AH	EGABonnieRock	3.30	1.79	1.67	2.25	9.9	11.7	11.3	11.0	
	TammarinRock	3.29	1.78	1.81	2.29	9.6	10.8	10.6	10.3	
	Yitpi	3.22	1.75	2.18	2.38	10.0	11.1	10.5	10.5	
	Axe	2.81	1.90	2.09	2.27	9.8	10.9	10.8	10.5	
	Carinya	3.03	1.97	1.86	2.29	9.7	11.1	10.3	10.4	
	Catalina	3.07	1.82	2.10	2.33	9.5	11.0	10.3	10.3	
	Correll	2.75	1.80	2.35	2.30	10.2	10.6	10.2	10.3	
	DerrimutWt	3.35	1.62	1.85	2.27	8.6	10.4	10.0	9.7	
	Espada	3.07	1.63	1.81	2.17	9.5	10.9	10.7	10.4	
APW	Gladius	3.13	1.70	2.14	2.32	8.9	11.6	10.8	10.4	
	Magenta	3.37	2.07	2.39	2.61	9.3	11.5	10.0	10.3	
	Mace	3.35	1.74	2.18	2.42	8.5	11.2	10.1	9.9	
	EGAWentworth	3.13	1.89	1.74	2.25	9.5	11.0	10.3	10.3	
	Young	3.16	2.06	1.80	2.34	9.1	10.5	10.8	10.1	
	LR Lincoln	3.21	1.66	1.96	2.28	9.5	11.1	10.6	10.4	
	Wyalkatchem	3.39	1.74	1.88	2.34	9.1	11.4	10.7	10.4	
	Zippy	2.99	1.77	1.55	2.10	9.6	11.0	11.9	10.8	
	Arrino	3.00	1.73	1.92	2.22	10.3	11.2	10.2	10.6	
	Binnu	3.36	1.68	2.14	2.39	8.9	10.5	9.7	9.7	
ASWN	Calingiri	3.11	1.69	1.99	2.26	9.8	10.7	10.2	10.2	
	Yandanooka	3.16	2.15	2.16	2.49	9.8	11.9	10.1	10.6	
	Fortune	3.19	1.68	2.15	2.34	9.0	10.9	10.4	10.1	
Unclassified	RAC 1423	3.22	1.56	2.15	2.31	10.0	11.2	10.1	10.4	
	Average within each TOS	3.16	1.79	1.99	2.31	9.5	11.1	10.5	10.3	
	TOS (l.s.d.)	0.43				0.9				
	Var (l.s.d.)	0.22				0.4				
	Var (l.s.d.) between TOS	0.51				1.1				
	Var (l.s.d.) within TOS	0.39				0.7				
	%CV	10.5				4.5				2

Barley variety identification using DNA fingerprinting

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KEY MESSAGES

Single Nucleotide Polymorphisms can be used to successfully identify barley varieties and the technology will be applicable to other crops.

AIMS

Varietal purity is an important commercial driver in the trade of malting barley. Receival standards for malting barley across Australia specify a minimum of 95% varietal purity. Current variety identification methods within the grain trade rely on differentiation by protein molecular weights, but increasingly the industry is confronted with different varieties demonstrating identical protein patterns and inhibiting conclusive varietal identity of a parcel of grain.

DNA based technology, and particularly single nucleotide polymorphisms (SNPs), are potentially a useful commercial tool for conducting variety identification and this project was established to test the feasibility of developing a cost effective commercial test for varietal identity and varietal purity in barley, using SNPs.

BACKGROUND

DNA code is made up of combinations of four nucleotides: Adenine (A), Cytosine (C), Thymine (T) and Guanine (G). Recent research shows that differences in the position of just a single nucleotide can be used as genetic markers or as unique differentiators between different varieties. This difference in the individual nucleotides between two DNA fragments is known as a Single Nucleotide Polymorphism
The use of DNA based fingerprinting for identification is largely based on techniques which make use of anonymous differences in large regions of the DNA sequence. Various types of markers (RAPDs, AFLPs, microsatellites and SNPs) are often useful for distinguishing individuals. They are not necessarily linked to any particular trait and all have advantages and disadvantages for the species over which they are deployed. For a marker to be useful in a commercial test it must be reproducible, cost competitive and suited to high-throughput analysis. It should also preferably have technological longevity. The high frequency of SNPs across a DNA sequence makes them a preferred marker for varietal identification. They are suited to automation through high-throughput analytical platforms and they provide technological longevity, due to the fact that they directly relate to individual DNA bases.

METHOD

SNPs are increasingly being routinely used within genetic studies and breeding programs for quantifying genetic variability and as genetic markers for selection purposes. As such, the technology can be readily applied to individual seeds or plants to type those seeds and plants to a particular variety. However, the cost of testing sufficient individual seeds or plants to be able to confirm the varietal identity of a crop or parcel of grain with an acceptable level of statistical confidence would be commercially prohibitive at current technology costs. Applying this technology to a composite sample of grain or plant material that was sufficiently large enough to provide reasonable representation is more cost effective. For the purposes of developing and testing such an approach, a sample of approx. 1000 seeds has been used.
Using single individual seeds or plants, each SNP loci will call a single base (A, C, T or G) if the individual is homozygous at that locus and will call two bases if it is heterozygous at the locus. For crop varieties that have been released with a high level of homozygosity (e.g. barley), it can be expected that most SNP loci will call a single base. However, when working with the population that makes up a variety, the frequency of loci that call more than one base will increase, reflecting the heterogeneity of the population that makes up the variety.

The cost effective use of this technology relies on identifying loci that are homogeneous within each of two varieties being compared and therefore only call one base, but call a different base for the two varieties. SNP loci which are homogeneous within a variety are defined as informative SNPs for that variety. For a sample to be assessed as a particular variety there should not be any mismatches at any of the informative SNP loci. SNP loci that are informative for two varieties, but call different bases for each variety are defined as discriminating SNPs as they can be use to differentiate between the two varieties.

To date, 45 barley SNPs have been evaluated and 33 of those have been determined to provide reliable data that can be used and the results for those 33 SNPs is reported.

SNP No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
BAUDIN	T	C	T	A	G	T	C	C	A	C	T	A	A	C	A	G	T	C	C	G	C	G	T	A	G	T	A	C	T	A	C	C	A
	A											G			G															C			
GAIRDNER	A	C	T	C	G	T	C	C	A	T	C	A	G	A	A	G	T	C	C	G	T	G	T	A	G	T	A	C	T	C	T	T	G
	T			A						C									T				C							A	C	C	

Figure 1.

The SNP profiles for two barley varieties, Baudin and Gairdner, are shown in Figure 1. For each variety there are SNPs that call only one base (e.g. 2, 3, 4, 5 for Baudin and 2, 3, 5 for Gairdner) and SNPs that call two bases (e.g. 1, 12, 15 for Baudin and 1, 4, 10 for Gairdner). The ones that call only one base are informative SNPs, and represent areas of homogeneity (uniformity) within the variety. These informative SNPs can be used to type a variety.

When comparing Baudin with Gairdner, it can be seen that SNPs 11, 13, 14, 21 and 33 are not only informative for each variety, but different between the varieties. These are discriminating SNPs for these two varieties and can be used to distinguish between them. If the informative SNP profile for a sample matches that of a reference variety and sufficient SNPs are used to ensure the presence of discriminating SNPs between any two varieties within the suite of varieties of interest, it is possible to determine the varietal identity of the sample.

In the case of a mixture of two or more varieties, the varieties present should be able to be identified because they will demonstrate a match for the informative SNPs for each variety but, at those loci that discriminate between the varieties present, both matching bases will be called. In such cases, the technology being used provides the opportunity for estimating the relative frequency of occurrence of each base and if those estimates are accurate, they should provide a pathway for estimating the level of contamination.

To date, this project has evaluated 34 current commercial Australian barley varieties. Initial characterisation of varieties against the 33 SNPs was conducted on reference samples of varieties held by the Australian Winter Cereals Collection in Tamworth NSW. Subsequent testing of that characterisation data is currently being evaluated in a proving trial using variety samples provide by the barley breeding programs and major barley marketing and grain storage companies.

Given that for 34 varieties, there are 1122 possible pair-wise comparisons, software has been written to summarise and interpret the data. With this software it is possible to quickly compare the results for a blind sample against all reference varieties to determine the variety identity of a sample and to detect mixtures of varieties.

RESULTS

Table 1 summarises the number of informative SNPs for each of the 34 varieties, within the set of 33 reported SNPs and, for each variety, the number of the other varieties against which discriminating SNPs exist.

All varieties have informative SNP loci amongst the set of 33 SNPs, but some varieties (e.g. Barque, Cowabbie, Fitzroy, Grout and Lockyer) are more limited.

Eighteen of the varieties have at least one discriminating SNP against all other 33 varieties. Only two varieties have three or more discriminating SNPs against all other varieties.

Table 1 **Number of informative SNPs for each of 34 barley varieties within the set of 33 reported SNPs and the number of the other varieties against which discriminating SNPs exist**

Variety	Informative SNPs	No of other varieties for which discriminating SNPs (DSNP) exist			
		> 0 DSNP	> 1 DSNP	> 2 DSNP	> 3 DSNP
Barque	10	23	13	6	1
Baudin	29	32	31	31	25
Buloke	26	31	30	28	25
Capstan	26	32	30	27	23
Cowabbie	14	30	21	13	6
Dhow	31	32	32	30	30
Doolup	33	33	32	31	31
Fitzgerald	23	33	33	31	29
Fitzroy	17	33	29	26	17
Flagship	29	33	32	32	30
Fleet	30	32	31	29	27
Franklin	32	33	33	32	31
Gairdner	25	33	32	27	25
Galleon	30	32	31	30	26
Grimmett	22	33	32	30	26
Grout	17	31	25	21	15
Hamelin	29	32	31	28	26
Hannan	32	33	33	32	29
Keel	32	32	31	28	26
Lockyer	17	33	31	27	22
Lofty Nijo	26	33	32	28	27
Mackay	30	32	32	30	29
Maritime	30	33	31	31	30
Molloy	31	33	33	33	31
Mundah	28	33	32	31	29
Roe	17	28	24	15	6
Schooner	25	31	29	23	18
Sloop	32	33	31	28	26
Sloop SA	27	32	30	25	23
Sloop VIC	27	33	32	31	27
Stirling	33	33	30	27	24
Tantangara	25	32	29	29	28
Urambie	31	33	33	33	33
Vlamingh	16	33	29	21	13

CONCLUSION

The results demonstrate that it should be possible to develop a cost effective method, by applying SNP based technology to composite samples, to determine the varietal identity of barley varieties. Further work is required to evaluate more SNPs and identify a suite that will provide better discrimination amongst barley varieties. Further work is also required to develop profiles for varieties of interest, not included in the set reported here. To achieve reliable discrimination between varieties, it is considered that at least three discriminating SNPs for any variety pair would be desirable.

Preliminary evaluation of the proving trial would indicate that the methodology is effective in identifying varieties provided by the collaborators. However, as was anticipated, there have been some relatively minor issues associated with discrepancies between different sources of the same varieties. If such a

system is adopted by the industry, these issues will not be on-going as they are a function of retrospectively fitting a highly discriminating technology to an older less discriminating system. Also as expected, differentiation has been limited in some cases by the present lack of discriminating SNPs.

Reliable identification of contaminants is not possible at present. Data from the proving trial indicates that this will require more optimisation if a meaningful assessment of varietal purity around the commercial 95% level is to be achieved.

The results to date indicate that, with the implementation of a more extensive suite of SNPs, it will be possible to implement a reliable qualitative test that will indicate the identity of the major variety present in a sample. Such a test would be expected to also be able to identify major contaminants at levels greater than 10%. While this will not be the test ultimately desired by the industry, it would address the likely major sources of contamination of grain deliveries and assist the barley industry in meeting its contract trade obligations and could be considered as an interim measure, while further optimisation of the technology is undertaken to provide reliable estimates of contamination at critical trade levels. Such a test is likely to be able to be offered at a cost of approximately $60–70 (excl. GST).

SNPs occur in all species and there is no reason why the technology, once established in barley could not be readily transferable to other crop species, provided suitable SNPs have been identified and are available.

KEY WORDS

variety Identification, single nucleotide polymorphism, DNA fingerprinting

Paper reviewed by: Dr Chengdao Li

Forecast disease resistance profile for the Western Australian barley crop over the next three years

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KEY MESSAGES

There is likely to be a shift in the disease resistance profile of the Western Australian barley crop with the adoption of newer high yielding malt and feed barley varieties in the next three years. This paper outlines what the disease profile of the state's barley crop may look like up to the release of new malting barley varieties in three years time.

AIMS

To stimulate discussion on what could be the immediate short term disease scenarios in the Western Australian barley industry due to the adoption of new barley varieties now on offer.

BACKGROUND

Last year an edition of 'Landmark' the Journal of the NIAB Association of the UK highlighted the situation faced by Scottish wheat growers in 2007 with a brown rust epidemic (Bayles 2008). Normally brown rust is a rarity in the northern areas of the UK. Seasonal circumstances in 2007 unfortunately favoured its development. The article inferred that breeding for disease resistance can be ineffective where seasonal circumstances favour a disease of low priority that becomes a major cause of crop loss as a result. In the UK example the focus had been on breeding resistance for yellow rust at the expense of developing useful brown rust resistance.

This NIAB article prompted an examination of the current disease resistance profile of the barley crop in Western Australia. The examination included predictions of the disease resistance profile in three years time. These predictions assumed a certain level of adoption of the new varieties now available either accredited for malting or released as feed. Among these varieties there is enhanced disease resistance to one or a number of the common diseases that pose a risk to the WA barley crop.

METHOD

The area planted to the current barley varieties grown in Western Australia was obtained from industry estimates gathered in 2007 and 2008 (Table 1). These areas were then converted into a percentage of the total area devoted to barley in that season. While most of the newly released varieties do not feature significantly in this data yet, Vlamingh has seen a dramatic adoption of planting in 2008 to account for 10% of the barley area.

Based on the most recent data available from DAFWA's Pathology Group (Russell et al. 2008), disease scores for the 6 most prominent leaf diseases and CCN were attributed to each variety (Table 2). For older varieties reference was made to the Crop Variety Sowing Guides (CVSG) of 2005 (Garlinge 2005) and 1989 (Brown 1999) to complete missing data. These are designated with lower case letters in Table 2. Disease scores were rated on an 'alpha' scale of 6 degrees of severity of VS (very susceptible), S (susceptible), MS (moderately susceptible), I (intermediate), MR (moderately resistant) and R (resistant). Any ES (extremely susceptible) ratings were grouped with the VS rating. Varieties were rated as either S or R to CCN. CCN resistance ratings have not been assessed for a number of new varieties (Table 2).

The total area of all the varieties with the same disease rating for each of six diseases was then calculated. A profile was determined for each disease using these values as a percentage of total barley area, based on the 2007 and 2008 figures (Figures 1 to 6).

Table 1 **Percentage area of barley varieties in Western Australia in 2007 and 2008, including estimates for the 2011 season**

Barley segregation	Variety	2007 Area planted %	2008 Area planted %	2011 % (Forecast)
Malt	BAUDIN	24.35	22.01	18
	BULOKE	0.29	2.44	30
	FLAGSHIP	0.00	0.04	0.5
	GAIRDNER	21.42	18.70	10
	HAMELIN	11.53	10.13	9
	SCHOONER	0.53	0.17	0
	STIRLING	16.65	10.28	5
	VLAMINGH	0.30	10.44	13
Feed	BARQUE	0.56	1.25	1
	BEECHER	0.08	0.08	
	CAPSTAN	0.14	0.18	
	CHEBEC	0.01		
	DASH	0.96	1.68	1.5
	DOOLUP	0.15	0.11	
	FITZGERALD	0.79	0.51	
	FLEET		0.11	1
	HANNAN		0.00	1
	HARRINGTON	0.10		
	HINDMARSH		0.02	4
	KEEL	0.36	0.18	
	KETCH	0.01		
	LOCKYER		0.02	1
	MARITIME		0.02	
	MOLLOY	0.81	0.72	
	MOONDYNE	0.00	0.01	
	MORRELL	0.00		
	MUNDAH	15.43	15.35	2
	OCONNOR	0.38	0.21	
	ONSLOW	0.15	0.16	
	ROE		0.02	1
	SKIFF	0.29	0.21	
	SLOOP	0.05	0.04	
	UNICORN	0.07	0.07	
	URAMBIE		0.00	
	YAGAN	4.54	4.63	2
	YARRA	0.06	0.19	
Total malt		**75.08**	**74.21**	**85.5**

Total feed	**24.92**	**25.79**	**14.5**
TOTAL	**100**	**100**	**100**

The percentage area of barley varieties in Western Australia in three years time (2011) was estimated. This estimate is subjective and open to further debate. The proportion of malt varieties is expected to increase in the future due to the high yielding accredited malt variety Buloke exhibiting yields that are competitive with feed varieties. Disease profiles were calculated using the 2011 estimates Figures 1 to 6 depict the difference in disease profile between recent seasons and 2011, based on the estimates of variety plantings for 2011.

Table 2 **Disease rating of barley varieties from DAFWA plant pathology group (upper case) and older ratings from 1989 and 2005 Crop Variety Sowing Guides (lower case)**

Barley segregation	Variety	Scald	Net type—net blotch	Spot type—net blotch	Mildew	BYDV	Barley leaf rust	CCN
Malt	BAUDIN	I	S	S	S	MR	S	S
	BULOKE	MS	MS	MS	MR	MS*p*	S	S
	FLAGSHIP	MS/I	I	I	MS	I*p*	S	R
	GAIRDNER	I	I	S	MS	R	S	S
	HAMELIN	S	S	S	S	VS	S	S
	SCHOONER	MS	I	I	S	MS*p*	MS*p*	S
	STIRLING	S	S	S/MS	S	I	S	S
	VLAMINGH	MR	I	S	S	MS	MS	S
Feed	BARQUE	MR	S	I	R	I	S	R
	BEECHER	s	s	s	s	es	sp	
	CAPSTAN	I	MS	I	I	S	MS	R
	CHEBEC	*	*	*	*	*	*	*
	DASH	R	I	S	R	S	R	R
	DOOLUP	VS	S	S	S	I	S	R
	FITZGERALD	mr	I	MS	I	MR	S*p*	
	FLEET	MS	S	S	I	Ip	R	R
	HANNAN	MR	S	S	MS	S*p*	S	
	HARRINGTON	s	MS	I	I	I*p*	S*p*	
	HINDMARSH	MR	MS	S	MR	MS*p*	S	R
	KEEL	mr	r	mr	s/mr		vs	
	KETCH	*	*	*	*	*	*	*
	LOCKYER	I	I	S	MS	S*p*	S	
	MARITIME	I*p*	MS*p*	S*p*	S	S	-	R
	MOLLOY	S	S	MS	MS	I*p*	S	S
	MOONDYNE	ms	MR	I	I*p*	MR	R*p*	
	MORRELL	mr	mr	ms	r	i		
	MUNDAH	S	MS	MS	S	MS*p*	S	S
	OCONNOR	ms	I	MS	S	VS	S*p*	
	ONSLOW	s	MR	I	S	I	MS*p*	
	ROE	S/MS	MS	I	I	S*p*	S	
	SKIFF	s	R	S	I	I	S*p*	
	SLOOP	s*p*			i*p*		vs*p*	
	UNICORN	vs*p*	i*p*	ms	mr*p*	mr	s*p*	
	URAMBIE	r	r	vs	ms		s	
	YAGAN	ES	I	S	MS	S	S	
	YARRA	S	MS	S	S	S	S*p*	R

Capital letters = ratings from DAFWA Plant Pathology Project 2007. *p* = provisional.

Lower case = ratings from other sources, i.e. CVSG 2005, eastern states variety guides. * = No information available.

The varieties Hannan and Hindmarsh are listed as feed for the purpose of this exercise. These varieties may become accredited malt varieties in future. Any changes will be announced by the commencement of the 2010 season for Hannan and 2011 for Hindmarsh. Any changes shouldn't influence the area of each of these varieties. Hannan would be suitable for a small domestic market that is likely to be managed by planting contracts. If Hindmarsh became accredited for malting any effect on area of this variety wouldn't be expected until after 2011. The same applies for any new elite malting lines currently being tested for malt accreditation (i.e. WABAR 2315).

RESULTS

With the exception of BYDV (Figure 1) and to a lesser degree, Net type-net blotch (Figure 2), the disease resistance profile of the barley crop in Western Australia appear to strengthen slightly based on estimates of variety composition in 2011.

Barley Yellow Dwarf Virus (BYDV)

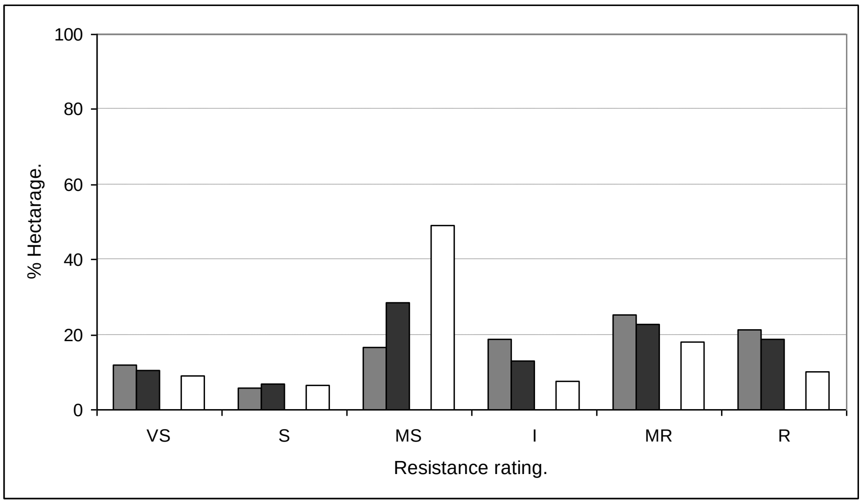

Figure 1 Disease profile for barley in Western Australia for barley yellow dwarf virus (BYDV) as of 2007 ( ), 2008 ( ) and projected for 2011 (□).

Net type—net blotch

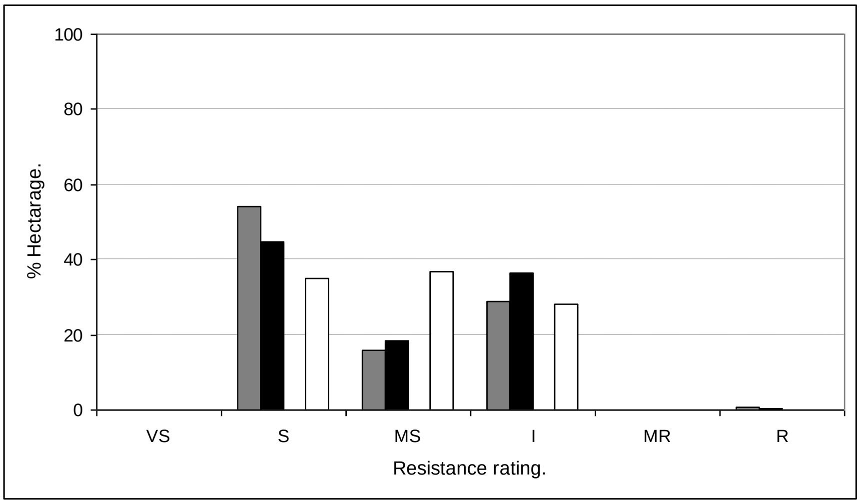

Figure 2. Disease profile for barley in Western Australia for Net type—net blotch as of 2007 ( ), 2008 ( ) and projected for 2011 (□).

Figures 1 and 2 indicate a decrease in the area planted to I and/or MR and R rated varieties for BYDV and Net type-net blotch. The levels of resistance to Spot type-net blotch (Figure 3) and Barley leaf rust (Figure 4) may not change appreciably in the next six seasons. In contrast there is a clear increase in the proportion of the crop rated moderately resistant to powdery mildew (Figure 5) and to a lesser degree scald (Figure 6).

Spot type—net blotch

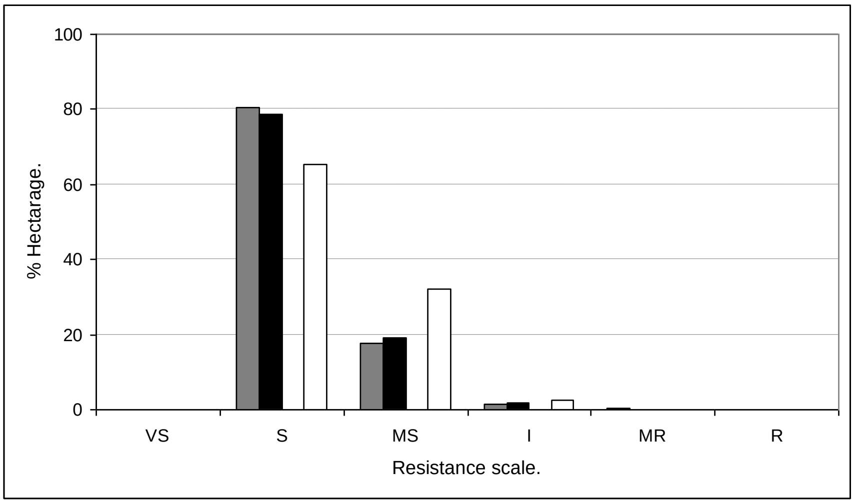

Figure 3 Disease profile for barley in Western Australia for Spot type—net blotch as of 2007 (▒), 2008 (█) and projected for 2011 (□).

Barley leaf rust

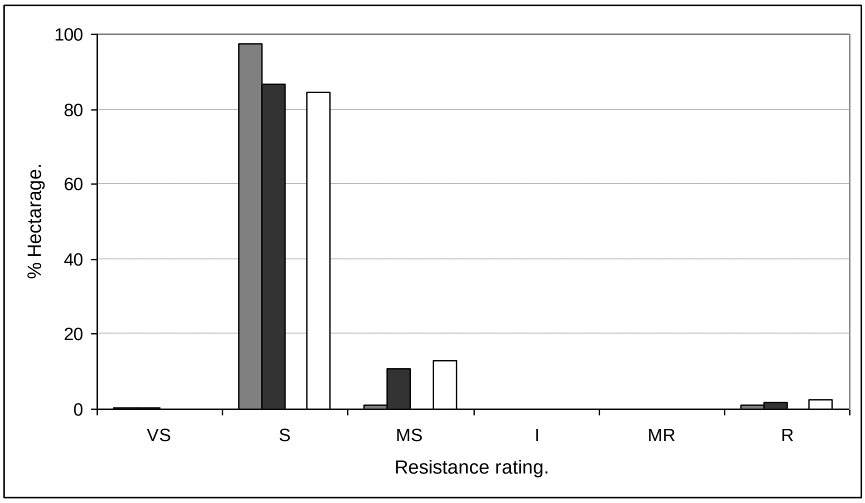

Figure 4 Disease profile for barley in Western Australia for barley leaf rust as of 2007 (▒), 2008 (█) and projected for 2011 (□).

Powdery mildew

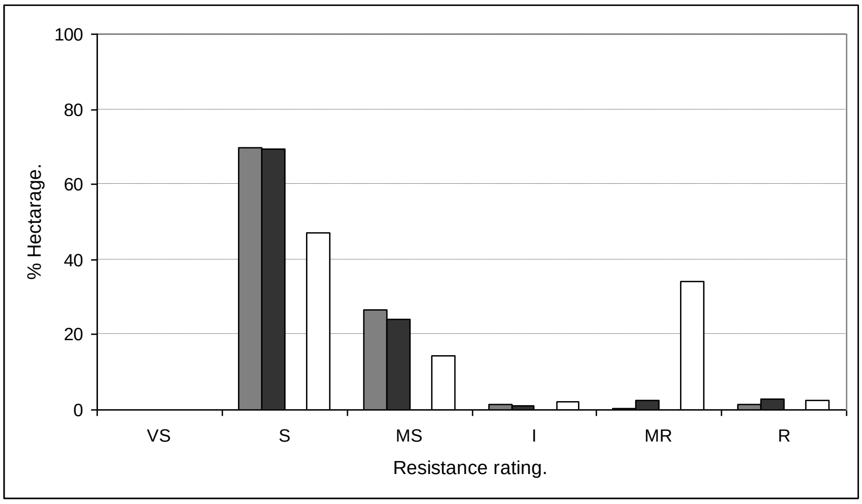

Figure 5 Disease profile for barley in Western Australia for powdery mildew as of 2007 (▒), 2008 (█) and projected for 2011 (□).

Scald

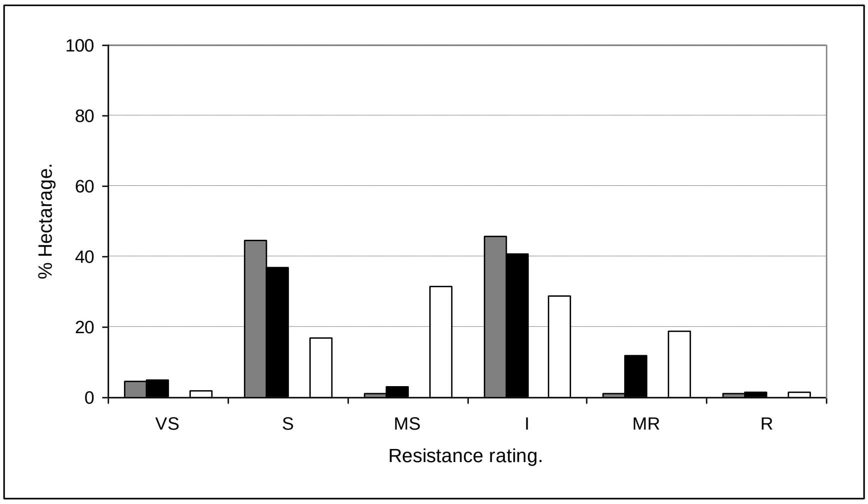

Figure 6 Disease profile for barley in Western Australia for scald as of 2007 (▒), 2008 (█) and projected for 2011 (□).

A resistance level of intermediate or better can be considered as the minimum level to be useful for impacting on the requirement for disease management intervention (i.e. reducing the requirement for fungicide applications). Table 3 shows the projected change in this group of resistance levels, highlighting the expected improvement in the levels of powdery mildew resistance. While there is a projected improvement in resistance to Spot type-net blotch and BLR, the overall proportion of varieties with poor levels of resistance is expected to be high. A clear reduction in overall resistance to BYDV and Net type-net blotch is also projected, while overall resistance to scald may decrease slightly.

Table 3 **Proportion (%) of the Western Australian barley crop with a resistance rating of 'I' or better in 2007, 2008 and estimated for 2011**

Disease	2007	2008	2011
Barley leaf rust	1.0	1.8	2.5
BYDV	65.3	54.2	35.5
Net type-net blotch	29.8	37.0	28.0
Powdery Mildew	3.3	6.7	38.5
Scald	48.1	54.4	49.5
Spot type-net blotch	1.8	2.0	2.5

DISCUSSION

Based on the results it could be suggested that a general improvement, though slight, in the overall disease resistance profile of the barley crop in Western Australia can be expected in the next three seasons.

A notable improvement can be seen in the projected disease profile for powdery mildew which is a significant problem in the high–medium rainfall areas. This improvement can be attributed to the projected adoption of Buloke, which has superior powdery mildew resistance amongst the other malting varieties. It is expected that Buloke will replace the feed variety Mundah to some extent which will contribute to this improvement. This will come at the cost of resistance levels to other diseases. Buloke is likely to displace Gairdner and Baudin which both have superior resistance to scald, and BYDV and Gairdner also has superior net type-net blotch resistance.

Table 3 indicates a very subtle, if any, improvement in overall resistance to barley leaf rust and Spot type-net blotch in 2011. The increased susceptibility of the crop to BYDV is also highlighted. This is mainly brought about by the anticipated decline in the area of Baudin and Gairdner. Another consideration is the areas where susceptible varieties are likely to be more prominent. For example Vlamingh has had an influence on the projected decrease in resistance to BYDV in this exercise. Vlamingh and Buloke are more likely to be grown in the western medium to high rainfall environments which are more suited to BYDV development. This could lead to an increased requirement to mitigate the risk from this disease in these areas.

Despite a slight improvement in projected levels of resistance to barley leaf rust well over 80% of the area still likely to be sown to susceptible varieties in three years time (Figure 4 and Table 3). This disease may be the greatest threat to the state's barley crop, especially on the south coast and adjoining districts.

The profile for scald shows a more even spread of the disease resistance within the crop by 2011 (Figure 7). While there is no net increase in varieties rated intermediate or better the proportion of the crop moderately susceptible or better is projected to improve. Buloke and Flagship are likely to exacerbate this disease threat in medium rainfall environments because of their susceptibility.

There is a suggestion that the increased area sown to Buloke may contribute to decreased powdery mildew disease pressure in susceptible crops such as Baudin. These sort of influences are not well understood.

While this exercise indicates lower vulnerability to some barley diseases in coming seasons growers will still be required to maintain a vigilant approach to disease management. The results suggest that more emphasis on barley leaf rust, BYDV and scald may be required in coming seasons.

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KEY WORDS

barley, malt, feed, disease, resistance, pathology

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Malting barley varieties differ in their flowering date and their response to changes in sowing date

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KEY MESSAGES

- The correct choice of sowing date for different barley varieties is the key to maximising yield potential.
- Understanding a barley variety's flowering date assists in the development of agronomic and risk management packages for advisors and growers.

AIMS

With so many new malting varieties available for sowing, there is some confusion as to what varieties are actually early flowering like Stirling and what varieties are actually later flowering than Stirling. This paper aims to provide the latest guides for agronomists and consultants to advise their clients on variety choice.

BACKGROUND

Development or time to flower in barley is controlled by temperature and daylength. Barley is known as a 'long day' plant, as its development is often inhibited under shorter days (daylength less than 16 h). Varieties grown in Western Australia differ in their response to sowing date because of differences in the duration of their basic vegetative phase (BVP) and their daylength length sensitivity (DLS).

Basic vegetative period (BVP)—Is the minimum number of leaves formed on the mainstem when a plant has had its vernalisation response satisfied and is grown in a daylength above 16 h. BVP modifies the plant's response to temperature and daylength. As our daylength never exceeds 16 h in Western Australia, we measure the BVP of barley varieties by growing them with supplementary lighting.

Daylength sensitivity (DLS)—DLS is a measure of the sensitivity of a variety to daylength and reflects the responsiveness of a variety to a change in sowing date. DLS is the difference in duration to awn emergence between plants grown with and without supplementary lighting. DLS insensitive varieties will form the same number of leaves on the mainstem, regardless of sowing date. The final leaf number on DLS sensitive varieties, however, will differ due to sowing date.

Vernalisation response (VRN)—VRN is a measure of the responsiveness of a variety to a certain number of 'cold' hours needed to initiates it development. All barley varieties currently grown in Western Australia are spring types and as such have little or no vernalisation requirement, although varieties such as Ulandra from New South Wales have a mild vernalisation requirement.

DISCUSSION

Stirling has been the dominant barley in Western Australia for nearly 25 years. One of the reasons for this varieties adaptation to most locations and sowing dates is because it has short BVP and a high DLS (Table 1). Varieties with medium BVP and moderate DLS (i.e. Buloke, Flagship and Gairdner) or with long BVP and mild DLS (i.e. Franklin) are better suited to earlier sowing opportunities than Stirling. However. they are often less suited to later sowing opportunities as there is a risk of flowering too late. Varieties with short BVP and very high DLS (i.e. Baudin and Skiff) are adapted to both early and late sowing dates. Therefore in order to understand how a variety may respond to changes in sowing date or when it may flower at a given sowing date relative to another variety, it is important to

know the BVP and DLS of the varieties concerned. The BVP and DLS ratings of current malting varieties and the feed variety Mundah are listed in Table 1.

Table 1 **BVP and DLS responses of current malting barley varieties and the feed variety Mundah and their relative maturity ratings (from Farmnote 312)**

Variety	Basic vegetative phase (BVP) rating	Daylength sensitivity (DLS) rating	Maturity rating
Baudin	Short	Very high	Medium
Buloke	Medium	Medium	Medium
Flagship	Medium	Medium	Medium
Gairdner	Medium–Long	Medium	Medium
Hamelin	Short	High	Early
Schooner	Short–Medium	Medium	Medium
Stirling	Short	High	Early
Vlamingh	Short–Medium	High	Medium
Mundah	Short–Medium	Low	Very early

The duration to awn emergence is a reliable way of representing differences between varieties in flowering date. Baudin, Buloke, Flagship, Gairdner and Vlamingh are classed as medium spring maturity varieties based on their duration to awn emergence from a late May to early June sowing.

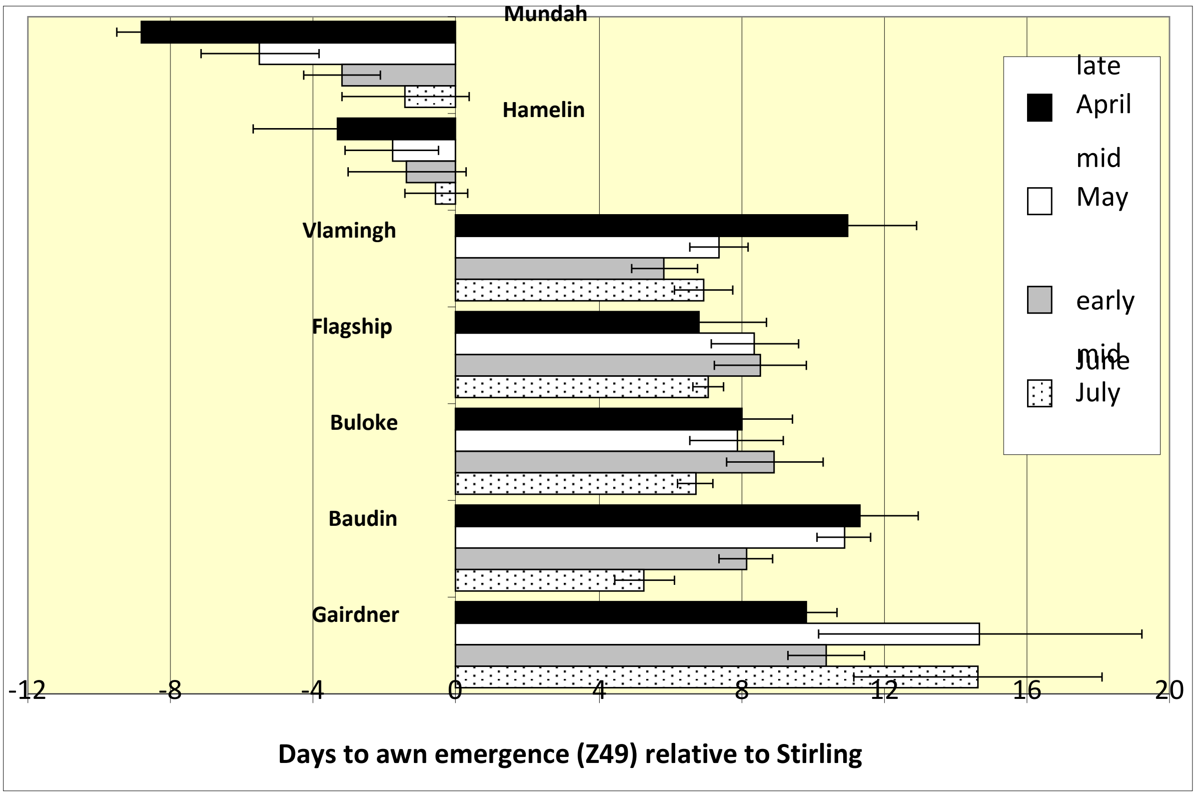

Figure 1 Average difference (± se) in duration to awn emergence (days) between Stirling and Mundah, Hamelin, Flagship, Buloke, Baudin and Gairdner when sown in either late April, mid May, early June and mid July. [Note: This is a composite analysis of flowering date data from three locations—Northam, Katanning and Esperance—and different seasons.]

The factors that control the flowering date response of Baudin, Buloke, Flagship, Gairdner and Vlamingh differ (Table 1) and this influences how they respond to changes in sowing date (Figures 1 and 2). Figure 1 shows the difference in their duration to awn emergence between all the varieties depicted in Table 1 relative to Stirling, excluding Schooner. Figure 2 shows how the time to awn emergence from sowing decreases with delays in sowing date.

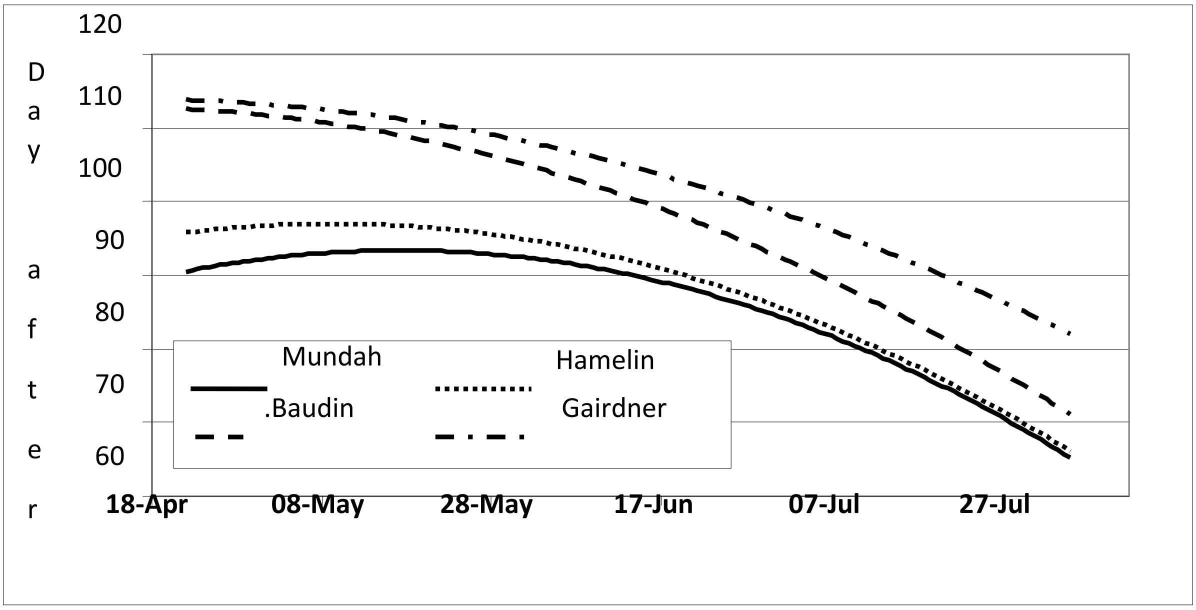

Figure 2 Days after sowing to reach awn emergence for four varieties differing in BVP and DLS (Mundah, Hamelin, Baudin and Gairdner) for sowing from late April to late July. [Note: This is a composite analysis of flowering date data from three locations—Northam, Katanning and Esperance—and different seasons.]

VARIETY NOTES

Buloke: Buloke is a medium spring variety.

Buloke reaches awn emergence earlier than Gairdner at all sowing dates and is up to three days earlier to awn emergence than Baudin with early May, late May and early June sowing. Buloke may be slightly later flowering than Baudin with July sowing as Baudin's development pattern is highly sensitive to daylength. If Buloke and Baudin were sown in summer, Baudin would flower earlier than Buloke, as Buloke has a longer BVP.

Buloke is always later flowering than Hamelin, Mundah and Stirling. Buloke reaches awn emergence some 8–10 days later than Hamelin and 6–8 days later than Stirling, depending on sowing date.

Baudin: Baudin is a medium spring variety.

Baudin's development pattern is based on a short BVP and a very high DLS. Baudin is generally a couple of days earlier to awn emergence than Gairdner at all sowing dates during winter, but the differences between Baudin and Gairdner increase as seeding is delayed.

Baudin may reach awn emergence at the same time as Stirling or later depending on when it is sown. When sown in summer Baudin flowers at a similar time to Stirling. When sown in winter the development pattern of Baudin is delayed because of sensitivity to daylength. As seeding is delayed, awn emergence differences between Stirling and Baudin decrease from 10–12 days in April to 4–6 days in July.

Flagship: Flagship is a medium spring variety.

The developmental pattern of Flagship is similar to that of Buloke and both will reach awn emergence within a couple of days of each other at all sowing dates.

Flagship is always later flowering than Hamelin, Mundah and Stirling. Flagship reaches awn emergence some 8–10 days later than Hamelin and 6–8 days later than Stirling, depending on sowing date.

Gairdner: Gairdner is a medium spring variety.

Gairdner has the longest period between sowing and awn emergence of all current malting varieties and will form at 10–13 leaves on the mainstem before it will flower. With May sowing Gairdner may be up to 6 days later than Buloke, Baudin, Flagship and Vlamingh.

Gairdner is always later to awn emergence than Hamelin, Mundah and Stirling, regardless of sowing date. Gairdner reaches awn emergence some 10–14 days later than Hamelin and 8–12 days later than Stirling, depending on sowing date.

Hamelin: Hamelin is an early spring variety.

Hamelin has a development pattern which is similar to that of Stirling. That is, short BVP and high DLS. Hamelin reaches awn emergence up to four days earlier than Stirling depending on sowing date, with differences between the varieties decreasing as seeding is delayed from April to July.

Stirling: Stirling is an early spring variety

Stirling has a development pattern which is well suited to the Western Australian environment. It has a short BVP and a high DLS. Stirling will flower with as few as 6 leaves on the mainstem when grown over summer, but may have up to 12 leaves when it flowers with winter sowing.

Vlamingh: Vlamingh is a medium spring variety.

The development pattern of Vlamingh is slightly different to that of Buloke and Flagship, having a short to medium BVP and a high DLS compared to the medium BVP and DLS of Buloke and Flagship. It reaches awn emergence later than Buloke and Flagship with April sowing but within a couple of days of Buloke with mid May to July sowing. Vlamingh reaches awn emergence at a similar time to Baudin with April sowing, but is slightly earlier with May and June sowing.

Vlamingh is later to awn emergence than Hamelin, Mundah and Stirling. Vlamingh reaches awn emergence some 8–12 days later than Hamelin and 6–10 days later than Stirling depending on sowing date.

KEY WORDS

barley, malt, feed, varieties, maturity, flowering date, Western Australia

ACKNOWLEDGMENTS

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Market development for new barley varieties

Linda Price, Barley Australia

The decision for a maltster or brewer to take on a new ingredient (i.e. raw malting barley or processed malt different to what they have been regularly purchasing) in their manufacturing business is an extremely serious decision.

From a brewer or a maltster's perspective, terms like consistency, reliability, performance, known characteristics, predictability, and varietal understanding are key to their requirements from malting barley or processed malt.

Malting barley, to a maltster, is at the very core of their business—the confidence and understanding they have of the malting barley variety is one of their main business ingredients. Although the malting process is a scientific one, familiarity with the variety to the maltster is key to getting the most out of the variety in terms of performance.

Maltsters (like growers) are chasing yield—they want to purchase 1000 t of barley and sell as close to 1000 tonnes of malt as possible. A maltster's ability to 'read' the variety to make it perform to its optimum is a lot due to the maltster's familiarity with the variety and all its nuances.

Maltsters need significant reasons to change varieties of malting barley as change represents risk—risk that can be beneficial to their business as well. Malting, like farming, is a business with large overheads and small margins and every post must be a winner in a successful malting company.

The quality of the malt produced must be appealing to the customer, the brewer. Consistency of quality is integral to the appeal. The malt must meet the brewer's set of specifications in terms of its quality performance in the brewhouse; as with the maltster, the brewer is chasing yield and when the brewer buys 100 tonnes of malt he wants to make as many hectolitres of beer as possible. The term for quantifying this is extract. Extract is a key parameter that Australia's barley breeders are continually seeking to improve.

[NB: 1 tonne of malting barley yields around 70 hectolitres of beer, depending on recipe, etc. a hectolitre is equal to 100 litres.]

Australian maltsters all service two distinct markets—the local brewing market (predominantly sugar adjunct or pure malt brewing) and the international brewing market (predominantly a starch adjunct market). There are a few exceptions to this rule of thumb in market needs.

The international brewing market is either one or two degrees away from the Australian barley farmer. Farmers either sell raw malting barley via grain marketers to overseas maltsters (who make the malt and then sell this malt to local brewers); or the farmers sell (either direct or via grain marketers) to Australian maltsters and the Australian malting companies sell processed malt (almost 800 000 tonnes/year) to overseas brewers.

Many brewers operate in highly sophisticated, computerised production factories and require malt of consistent supply, reliable performance and quality, and malt that the brewer is comfortable using.

Many breweries make beer in batch sizes of hundreds of hectolitres using significant amounts of raw ingredient, and it is vital to the business (as in any business) that the product is made successfully.

Depending on the brew being made, the brewer will issue a list of specifications to the maltster detailing quality parameter requirements like fermentability, total nitrogen (aka protein in barley), diastatic power, Kolbach, wort viscosity, wort colour, etc.

The quality parameters of the malt (derived from the inherent quality characteristics in the specific variety of malting barley) are vital to the brewer from a production and profitability perspective. The brewer over time has no doubt become used to certain malt blends made from specific varieties and will seek to use them again as they deliver the result required.

It is therefore unlikely a brewer would ever request a new and unknown variety because of risk—financial and production risk in dealing with an unknown barley variety. The impetus for varietal change would either come from the maltster or the grain marketer.

Many breweries around the world have their own brewery-specific list of varieties they accept and it can take up to a year for brewers to be satisfied with their own evaluation of the performance of the new malt.

When a new malting barley variety is released to Australian barley farmers there is a vital balancing act to be managed to step production with market demand for the new variety.

On release of a new variety, it will have been through many years (8+) of micro and commercial scale trials in Australia to determine its suitability as a malting and brewing variety. The commercial scale trials are conducted through the industry-endorsed Varietal Accreditation process driven by Barley Australia, the Malting and Brewing Industry Barley Technical Committee (MBIBTC) and the GRDC/industry-sponsored Pilot Brewing Australia. From this data, all maltsters and brewers in Australia are able to see the barley perform in commercial and micro-scale tests.

Simultaneously, grain marketers and maltsters are beginning to discuss the new lines with their customers overseas. When accreditation in Australia is achieved, and supply is increasing (as bulk-up and adoption commences by the farmers) small parcels of the variety are sent to the potential purchasers for the purchaser's own trials in their factories.

In initial stages this could be as little as 1 kg, as brewers and maltsters look to make purchasing decisions. Slowly, evaluation for individual companies takes place and for brewers this can take up to six months for a full evaluation of one batch as shelf life of the beer (termed 'stability') is a key parameter.

Often the trial batches are done in conjunction with the malting or marketing company sending a technical representative to help the customer through the malting or brewing process and explain the benefits of the new variety.

For the Australian barley industry players, considerable time and effort is expended by individual companies in order to launch the new varieties in to the marketplace overseas.

It is for this reason that the importance of Barley Australia, MBIBTC and Pilot Brewing Australia is increasing. As we move into the deregulated environment industry-good bodies take on an increasingly important role in the market development for new varieties. It is important for all the industry that there are congruent messages regarding each variety and also that there is some generic promotion of the new variety to the international marketplace.

The de-regulated marketplace for barley does raise the level of difficulty in getting new varieties to the market. There is requirement for increased levels of coordination and communication between growers and marketers, maltsters and brewers.

The stepping of growers' barley production with market demand is critical to not only price structure but price sustainability in the longer term. It is important to remember that the world international malting barley trade is only around 4 million tonnes and when one considers Australia's market share (between 40 and 65%) and the number of varieties on offer from all over the world there is not a lot of margin for error.

A coordinated approach is the way forward for successfully growing new varieties in to the market—this involves grower engagement with their marketers and maltsters, involvement in the regional barley councils and an increased awareness requirement for what the market requires in malting barley varieties.

A new malting barley variety, no matter how agronomically spectacular, needs to be carefully placed into farm rotations with a mind that market share of any variety takes time to grow.

Price relativity will always reflect the demand for a variety but it is important to remember that a variety emerging on to the market may be priced lower than existing varieties while the market establishes where it sits in relation to other varieties for quality demand and value.

Understanding the nature of the international malting and brewing market helps to explain the need for moderate introduction and adoption of new varieties for malting barley, and careful industry stewardship from the relevant industry groups help to manage this function.

Response of wheat varieties to sowing time at Mt Barker, Katanning and Newdegate in 2008

Brenda Shackley and **Vicki Scanlan**, Department of Agriculture and Food, Western Australia, Katanning

KEY MESSAGES

- In general frost and late rains in 2008 favoured the yields of the longer maturing varieties, particularly at the Katanning site.
- Magenta dominated the yield results across the three regions while Wyalkatchem's performance was extremely variable and well below the performance of many other varieties.
- Preliminary falling number results indicate large differences between varieties at Mt Barker, ranging from extremely poor sprouting tolerance to moderately poor sprouting tolerance.
- Grain quality results were not available at time of printing.

AIMS

To investigate the performance of new wheat varieties at different times of sowing. To identify any specific risks associated with new varieties in the southern agricultural region of WA.

METHOD

Field based trials were located on duplex soils at the Mt Barker Research Station, the Great Southern Agriculture Research Institute in Katanning and the Newdegate Research Station in 2008. The trials included 24 wheat varieties from various Australian breeding programs, at three sowing times. There was a huge range in sowing times reflecting the different seasons experienced at Mt Barker, Katanning and Newdegate. The sowing dates were 16 May, 30 May and 13 June at Mt Barker; 6 May, 23 May and 16 June at Katanning and 16 May, 4 June and 26 June at Newdegate.

RESULTS AND CONCLUSION

Season

The 2008 season was extremely variable with good to patchy starts around the regions, a wet July then a dry August, frost, and then good end of season rainfall which then continued into harvest leading to sprouted grain in some areas.

The growing season rainfall was 382 mm at Mt Barker, 306 mm at Katanning and 349 mm at the Newdegate. Rainfall at the end of October was 71 mm at Mt Barker, 45 mm at Katanning and 90 mm at Newdegate. Mt Barker then received 166 mm in November and 26 mm in December, while Katanning had 26 mm and 20 mm respectively. Newdegate had 36 mm in November and 63 mm in December.

Grain yield

Time of sowing did not result in significant differences in overall grain yields at any of the sites, which is attributable to the wet finish to the season. The average grain yields across times of sowing ranged from just over 4 t/ha at Mt Barker to 2.6 t/ha at Katanning and 2.5 t/ha at Newdegate. In comparison there was a significant interaction between time of sowing and variety, with frost and late rains playing a major role in how the varieties responded when sown at a particular date.

The performance of Wyalkatchem in 2008 was extremely variable—frost damage being the main cause at Katanning and to a lesser extent at Newdegate. In turn, Magenta (released in 2007) was either the highest yielding variety or not statistically distinct from the highest yielding variety. The exception was at the first sowing time at Katanning, which suffered severely from head frost damage (Table 1). Magenta is not recommended in Agzone 6 due to low sprouting tolerance, similar to

Wyalkatchem. The full data set of falling numbers was not available at the time of printing but will be reported in future.

The long season soft wheat EGA Jitarning also performed well in 2008—receiving less frost damage and able to utilise the late rains in 2008. The newly released APW Endure (IGW2784), which is the longest maturing Intergrain variety, was also able to 'escape' major frost damage at the Katanning site along with Calingiri (Table 1).

Seven new wheat varieties Espada (APW), Mace (APW), Fang (APW), Endure (APW), Fortune (ASWN), Zippy (APW) and Bumper (ASW) were released in 2008 targeting Western Australian growers. The early maturing variety Zippy was the lowest yielding at Katanning and Newdegate, even at the later sowing dates. The early maturity of this variety was unlikely to be an advantage with the wet finish experienced in the 2008 season. Time will tell if this variety has an advantage over others with later sowing and a drier finish. Fortune yields were similar to Calingiri and superior to the shorter season noodle varieties Binnu and Yandanooka (and Arrino at Newdegate). Mace exhibited superior yields compared to Wyalkatchem at the early times of sowing at all sites. Espada and Fang also exhibited impressive yields at various times of sowing across the sites. Bumper was not included at any of the three sites.

Long term yield data from National Variety Testing (NVT) for the period 2000 to 2007 indicate that while Wyalkatchem is one of the highest yielding varieties the recently released varieties Espada and Magenta have comparable long term yields (please refer to the Wheat Variety Guide 2009 Western Australia). Other varieties such as Fang and Young are competitive with Wyalkatchem in various Agzones. Overall the soft wheat Bullaring is the highest yielding named variety tested in the NVT system.

Preliminary sprouting results

Low falling number or poor sprouting tolerance was one of the major issues in 2008. Preliminary data also indicates some issues with staining for some of the varieties. Due to the late harvest the grain quality results are not available at this stage. Please refer to the regional updates papers and the Wheat variety guide 2009 Western Australia for the grain quality results.

Preliminary results show that the largest range of falling numbers occurred at the Mt Barker with the May sowing times. The values ranged from below 80 seconds for Carnamah to above 350 seconds for EGA Eagle Rock. EGA Eagle Rock was also competitive with the highest yielding varieties at the mid May sowing at Mt Barker but had the lowest yields at the later sowings. Falling numbers at the later sowing date only ranged from 250 seconds for Carnamah to above 400 for EGA Eagle Rock. A similar range is associated with the early May sowing at Katanning where less late rain occurred. Although Newdegate received more late rain than Katanning, the later dates of sowing resulted in higher falling numbers generally.

KEY WORDS

wheat varieties, wheat agronomy, time of sowing, grain yields

ACKNOWLEDGMENTS

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Paper reviewed by: Steve Penny

Table 1 **Grain yield (t/ha) response of wheat varieties to sowing time at the Mt Barker, Katanning and Newdegate Research Stations in 2008**

Grade	Variety	Mt Barker			Average	Katanning*				Newdegate			Average
		14 May	30 May	13 June		6 May	23 May	16 June	Average	16 May	4 June	26 June	
AH	Braewood	4.4	4.5	4.1	4.3								
	Carnamah	4.4	4.2	4.8	4.4	1.3	2.8	2.6	2.2	2.0	2.2	2.5	2.2
	EGA Bonnie Rock									2.7	2.2	2.4	2.4
	EGA Eagle Rock	4.5	3.5	2.9	3.6								
	EGA Gregory	3.7	3.8	3.3	3.6								
	Yitpi	4.1	4.0	3.8	4.0	2.8	3.3	2.9	3.0	2.8	2.5	2.6	2.6
APW	Annuello	3.9	4.1	3.6	3.9								
	Axe									2.5	2.4	2.2	2.3
	Carinya	3.8	4.1	4.0	4.0	2.4	3.2	2.9	2.8	2.4	2.2	2.6	2.4
	Catalina	4.1	3.8	3.6	3.8	1.8	3.0	2.5	2.4	2.5	2.6	2.6	2.6
	Correll	4.1	3.9	3.9	4.0	2.6	3.3	3.0	3.0		2.7	2.5	2.6
	Derrimut Wt	4.1	3.7	3.4	3.7					2.5	2.7	2.5	2.6
	EGA Bounty	4.3	4.6	4.3	4.4								
	EGA Wentworth	4.1	3.8	4.2	4.0								
	Endure (IGW2784)	4.0	4.1	4.3	4.1	3.2	3.0	2.6	2.9				
	Espada	3.9	3.8	3.7	3.8	2.0	3.0	2.8	2.6	2.8	2.6	2.4	2.6
	Fang (RAC1400)	4.2	4.0	4.0	4.0	3.0	3.2	3.1	3.1	2.7	2.6	2.5	2.6
	Gladius	3.8	3.7	3.9	3.8	1.8	2.8	2.7	2.5	2.7	2.8	2.6	2.7
	LRP Lincoln	4.3	4.0	3.7	4.0	1.7	3.2	3.0	2.6	2.5	2.5	2.5	2.5
	Mace (RAC1372)	4.5	3.7	4.0	4.1	1.9	2.9	2.7	2.5	**3.0**	2.5	2.4	2.6

	Magenta	**4.8**	**4.8**	4.4	**4.6**	2.6	3.1	2.9	2.9	2.9	**3.1**	2.7	**2.9**
	Wyalkatchem	4.2	3.9	4.3	4.2	1.2	3.2	2.5	2.3	2.4	2.4	2.1	2.3
	Young	3.9	4.0	4.4	4.1	1.2	2.4	2.6	2.1	2.7	2.9	**2.8**	2.8
	Zippy (IGW2838)					0.3	1.3	2.0	1.2	1.8	1.8	2.0	1.9
ASWN	Arrino									2.0	2.2	2.4	2.2
	Binnu					1.7	2.7	2.3	2.2	2.3	2.3	2.5	2.4
	Calingiri	4.3	4.4	4.3	4.3	3.4	3.0	2.7	3.0	2.5	2.7	2.5	2.6
	Fortune (IGW2856)					3.1	3.0	**3.1**	3.1	2.7	2.5	2.7	2.6
	Yandanooka					1.5	2.3	3.0	2.3	2.3	2.5	2.2	2.3
ASFT	Bullaring					3.1	**3.5**	2.6	3.1				
	Datatine					2.8	3.0	2.5	2.8				
	EGA 2248					2.2	2.6	2.7	2.5				
	EGA Jitarning	4.2	4.3	**4.7**	4.4	**3.5**	3.5	2.8	**3.2**	2.9	2.6	2.6	2.7
	Average	*4.1*	*4.0*	*4.0*	*4.1*	*2.2*	*2.9*	*2.7*	*2.6*	*2.5*	*2.5*	*2.5*	*2.5*
		Fpr	l.s.d.			Fpr	l.s.d.			Fpr	l.s.d.		
	TOS	0.798	0.7			0.149	0.8			0.899	0.4		
	Variety	< .001	0.4			< .001	0.3			< .001	0.2		
	TOS*Variety	0.050	0.8 (0.6)			< .001	0.8 (0.6)			< .001	0.5 (0.3)		
	CV (%)	9.5				13.6				7.7			

* Katanning was severely affected by frost.

Flowering dates of wheat varieties in 2008 at three locations in Western Australia

Darshan Sharma, Brenda Shackley and **Christine Zaicou-Kunesch**, Department of Agriculture and Food, Northam, Katanning and Geraldton, Western Australia

KEY MESSAGES

The phenology experiments examined a range of maturities available in Western Australia, including the extremely late EGA Wedgetail and the early Zippy.
Some cultivars behave differently if sown too late or too early and this effect is also location specific.

Cultivars tended to flower later in 2008 compared to 2007.

AIMS

The aim of this article is to provide growers with a decision support information that could be used to manage frost and screenings risks to wheat crops in Western Australia.

METHOD

About 50 wheat lines were grown at four different sowing dates at three locations selected on the basis of day length and minimum and maximum temperatures over three years. The locations were: Geraldton, Northam and Katanning. Sowing was undertaken in unreplicated, one metre long rows with three repeated checks.
Observations on the number of heads showing anthesis were recorded at 2–3 days intervals and date of 50% anthesis was calculated. Anthesis or flowering date is the date when 50% of the heads are showing yellow anthers. Heading was also recorded by a similar method but not presented.
Parameters for Flowering Calculator V0.91 were also calculated on the basis of pooled data from 2006, 2007 and 2008 but predictions are not presented here. Instead, in line with 2006 and 2007, the actual flowering dates of varieties tested in 2008 are shown in Table **2**.

RESULTS

Mid-anthesis dates of 30 wheat cultivars are given in Table 1. The colour coded maturity groups in this table are relative to other varieties when sown at the same time. The extremely late and early maturity 'checks' were cultivars EGA Wedgetail and Zippy, respectively.
Compared to Wyalkatchem, the new release Mace flowered a few days later at Geraldton and Northam (unless sown mid-June) but was slightly quicker at Katanning. In the south, Magenta, Fang and Yitpi appear to have similar flowering times, all being slightly later than Wyalkatchem. The new noodle release Fortune took slightly longer time to flower than Calingiri when sown early, but the trend at later sowing in Katanning was the opposite. Endure is an option for early break, as it was consistently a cultivar of long duration across all sites.

A frost event at the Katanning site on 22 September caused a large amount of head damage and did led to difficulties in recording the anthesis times. Some varieties appearing to 'flower' later although this was also confounded with the overall lower temperature in 2008 (see below).

Effect of season

Compared to 2007 (refer to Agribusiness Crop Updates Cereals book 2007), most cultivars flowered later in 2008 and the difference was greatest at the late-April, mid-May and early-June sowing dates at Katanning, Northam and Geraldton, respectively. These differences most probably reflect the influence of temperature profiles at these locations over two seasons but a clear attribution is difficult without proper analysis. Nonetheless, a simple conclusion could be drawn that a difference in 1–2 degrees in winter temperature (June-July) could correspond to a flowering date difference of about up to two weeks.

Please note the extra maturity class of 'very long duration' include in Table 1 compared to the 2007 table. Comparisons of the areas shaded between the two years will not be relevant due to the different spread of the maturity classes. The data is now more in line with the maturity classifications used elsewhere.

Sown too early

When sown too early (24 April), cultivars Carinya, Correll and Gladius, which otherwise belonged to medium maturity groups, tended to flower early like short season cultivars.

Sown too late

When sown too late (20 June) at Geraldton, Magenta tended to behave more like a long duration rather than a medium-long season cultivar. In contrast, cultivars Binnu, EGA Jitarning and perhaps Gladius and Fang when sown late at Katanning, tended to flower relatively sooner or quicker.

CONCLUSION

Flowering date depends upon sowing date, location, season and varietal response. Some cultivars when sown too early will tend to flower earlier. When sown late, most of the cultivars will tend to flower relatively earlier or quicker.

KEY WORDS

flowering date, anthesis, heading date, wheat, agronomy, new varieties, phenology

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Table 2 **Flowering date* for 30 wheat varieties at different sowing dates at three locations in Western Australia in 2008**

Grade	Variety	Geraldton				Northam				Katanning			
		24 Apr	16 May	3 Jun	20 Jun		16 May	3 Jun	20 Jun	24 Apr	16 May	3 Jun	20 Jun
AH	Carnamah						15 Sep	26 Sep	2 Oct	12 Sep	28 Sep	3 Oct	17 Oct
	Yitpi						19 Sep	30 Sep	6 Oct	24 Sep	30 Sep	11 Oct	20 Oct
APW	Axe	27 Jun	22 Jul	19 Aug	2 Sep		10 Sep	22 Sep	28 Sep	5 Sep	21 Sep	2 Oct	9 Oct
	Bolac	12 Jul	15 Aug	4 Sep	17 Sep		26 Sep	4 Oct	13 Oct	24 Sep	8 Oct	17 Oct	23 Oct
	Carinya	3 Jul	8 Aug	2 Sep	14 Sep		17 Sep	29 Sep	4 Oct	14 Sep	3 Oct	12 Oct	21 Oct
	Catalina	1 Jul	27 Jul	23 Aug	6 Sep		16 Sep	24 Sep	1 Oct	9 Sep	29 Sep	9 Oct	19 Oct
	Correll	7 Jul	6 Aug	1 Sep	14 Sep		17 Sep	24 Sep	3 Oct	14 Sep	29 Sep	11 Oct	18 Oct
	Derrimut	3 Jul	1 Aug	28 Aug	10 Sep		18 Sep	26 Sep	3 Oct	10 Sep	30 Sep	9 Oct	17 Oct
	EGA Bounty	13 Jul	9 Aug	30 Aug	14 Sep		21 Sep	25 Sep	3 Oct	19 Sep	5 Oct	15 Oct	22 Oct
	EGA Wedgetail		***23 Sep***	***30 Sep***	***15 Oct***		***7 Oct***	***11 Oct***	***16 Oct***	***9 Oct***	***13 Oct***	***19 Oct***	***26 Oct***
	Endure (IGW2784)	17 Aug	2 Sep	12 Sep	25 Sep		29 Sep	3 Oct	8 Oct	8 Oct	12 Oct		29 Oct
	Espada	12 Jul	7 Aug	30 Aug	11 Sep		17 Sep	24 Sep	28 Sep	17 Sep	3 Oct	10 Oct	19 Oct
	Fang (RAC1400)	3 Aug	21 Aug	6 Sep	16 Sep		23 Sep	30 Sep	1 Oct		2 Oct	12 Oct	15 Oct
	Gladius	13 Jul	6 Aug	29 Aug	11 Sep		13 Sep	24 Sep	30 Sep	13 Sep	30 Sep	7 Oct	12 Oct
	Lincoln	8 Jul	28 Jul	26 Aug	9 Sep		12 Sep	24 Sep	27 Sep	6 Sep	27 Sep	6 Oct	20 Oct
	Mace (RAC1372)	9 Jul	8 Aug	29 Aug	11 Sep		16 Sep	23 Sep	30 Sep	8 Sep	25 Sep	2 Oct	12 Oct
	Magenta	15 Jul	11 Aug	4 Sep	18 Sep		23 Sep	30 Sep	6 Oct	17 Sep	2 Oct	9 Oct	18 Oct
	Spear									24 Sep	1 Oct	10 Oct	23 Oct
	Westonia	2 Jul	22 Jul	21 Aug	8 Sep		11 Sep	21 Sep	28 Sep	3 Sep	24 Sep	3 Oct	
	Wyalkatchem	4 Jul	30 Jul	25 Aug	12 Sep		14 Sep	21 Sep	2 Oct	13 Sep	30 Sep	9 Oct	17 Oct
	Zippy (IGW2838)	26 Jun	18 Jul	16 Aug	2 Sep		5 Sep	15 Sep	26 Sep	9 Sep	21 Sep	2 Oct	9 Oct
ASWN	Arrino	1 Jul	29 Jul	30 Aug	12 Sep		16 Sep	23 Sep	8 Oct	8 Sep	29 Sep	2 Oct	12 Oct
	Binnu	18 Jul	30 Jul	26 Aug	8 Sep		17 Sep	5 Oct	5 Oct	17 Sep	1 Oct	9 Oct	15 Oct
	Calingiri	18 Jul	14 Aug	4 Sep	16 Sep		19 Sep	27 Sep	3 Oct	21 Sep	10 Oct	16 Oct	20 Oct
	Fortune (IGW2856)	24 Jul	17 Aug	3 Sep	16 Sep		26 Sep	29 Sep	5 Oct	23 Sep	3 Oct	12 Oct	15 Oct
	Yandanooka	16 Jul	7 Aug	1 Sep	15 Sep		16 Sep	22 Sep	7 Oct	16 Sep	26 Sep	10 Oct	19 Oct
ASFT	Bullaring						25 Sep	29 Sep	10 Oct	24 Sep	10 Oct		
	EGA2248						14 Sep	24 Sep	27 Sep	15 Sep	25 Sep	6 Oct	12 Oct
	EGA Jitarning						24 Sep	28 Sep	9 Oct	26 Sep	5 Oct	12 Oct	19 Oct

ASW	Bumper (IGW2836)	18 Jul	12 Aug	1 Sep	13 Sep		14 Sep	29 Sep	1 Oct	10 Sep	26 Sep	5 Oct	12 Oct

Very Long duration	Long duration	Medium duration	Short duration

Empty cells = Data was not available this year.

Maturity classes in this table could be different from previous years because this year the data has been classified into four instead of three categories in order to make it more user-friendly.

Agronomic responses of new wheat varieties in the northern agricultural region in 2008

Christine Zaicou-Kunesch, Department of Agriculture and Food, Western Australia

KEY MESSAGES

In a season with good summer rain and finishing rains in September the delay in seeding had a greater effect on yield decline on the sandplain at Mingenew than the loamier soils at Marchagee and Mullewa.

Axe and Zippy (early maturing) did not yield significantly better than most other varieties sown in June but tended to have better screenings levels.

The season favoured the performance of longer maturing varieties. Magenta was a high performing variety in the majority of trials in the northern agricultural region however this variety is very susceptible/susceptible to blackpoint.

AIMS

To assess the performance of recently released varieties, particularly Axe, Bumper, Espada, Fortune, Gladius, Mace, Magenta and Zippy, in the northern agricultural region (NAR).

METHOD

Field based agronomy trials were conducted in 2008 on yellow sandplain at Mingenew (Agzone 1), loamy sand at Marchagee (Agzone 2) and sandy loam at Mullewa (Agzone 4). Twenty four varieties from various wheat breeding organisations were sown at three sowing times in a randomised split block design.

Sowing times were 2 May, 10 June and 24 June at Mullewa, 1 May, 16 May and 12 June at Marchagee and 1 May, 20 May and 18 June at Mingenew. April to October rainfall was 223.8 mm at Mullewa (95 mm was recorded for January to March), 324 mm at Marchagee and 278 mm at Mingenew.

Information available through the National variety testing program (NVT) and phenology trials conducted in 2008 has also been utilised for discussion in this paper.

Note: Full grain quality data not available at time of printing.

RESULTS

Time of sowing response—across all varieties

There was a decline in yield of 20 kg/ha/day at Mingenew (average across all varieties) when seeding was delayed from early May to mid May compared to an increase in yield by 30 kg/ha/day (average across all varieties) at Marchagee during the same period (Figure 1). The second sowing opportunity was six weeks after the first at Mullewa. The decline in yield during this period was 15 kg/ha/day (2 May–10 June). Growing season rainfall was greater at Marchagee than Mingenew. September and October rain was 73 mm at Marchagee and 44 mm at Mingenew.

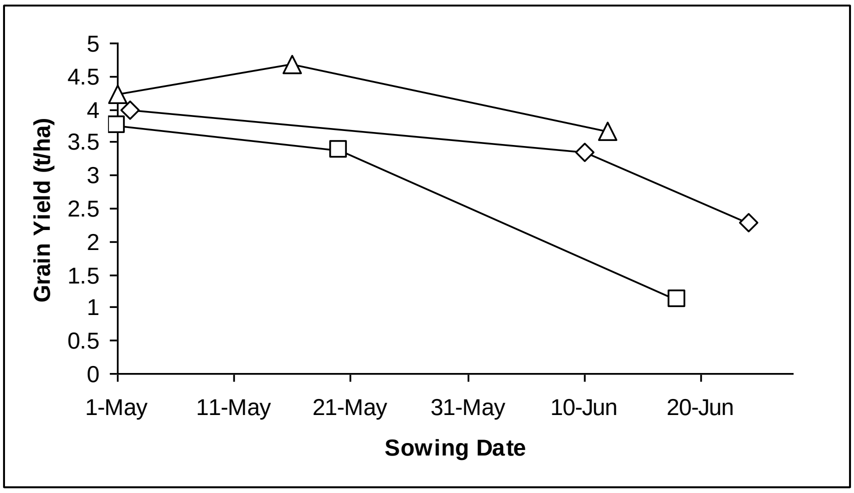

Figure 1 Average grain yields at Mullewa (◇), Mingenew (□) and Marchagee (△) when sown at various times between early May and late June in 2008.

Sowing wheat options—APW

The recently released variety Mace (AGT1372) flowered on average 3 days later than Wyalkatchem (average over 4 sowing times) in the northern districts. It has a preliminary classification of APW (final classification in April 2009). Mace has a good resistance to stem (mod resistant provisional), stripe (resistant/moderately resistant) and leaf rust (resistant provisional). It has a provisional black point resistance rating of moderately resistant which was confirmed by the lower incidence of blackpoint in Mace compared to other varieties at the Mingenew site.
Mace performed similarly to Wyalkatchem in the 2008 NVT trial program at all locations in the NAR except Marchagee. However, in time of sowing trials at Marchagee and Mingenew, Mace was one of the highest yielding varieties. In contrast Mace was lower yielding than Wyalkatchem when sown on 2 May on the sandy loam at Mullewa, but yielded similarly at the other sowing times.

Magenta sown in the first week of May was the top yielding APW variety at each of the time of sowing trials in 2008 and yielded significantly better than Wyalkatchem. Magenta performed similarly to Wyalkatchem and was amongst the highest yielding varieties in the 2008 NAR NVT trials sown in the second week of May at Carnamah on loamy clay, Pithara on sandy loam and Marchagee on loam. Magenta outyielded Wyalkatchem in the NVT trial at Maya. The NVT long term yield (2000–07) of Magenta is similar to Wyalkatchem.

Magenta has a long coleoptile and good leaf disease profile however it is very susceptible/susceptible to pre harvest sprouting. In 2008 at Geraldton, Magenta flowered about ten days later than Wyalkatchem and is considered mid-long maturity. Screenings may be an issue if Magenta is sown in late May or June.

Espada and Gladius recorded yields below the highest yielding varieties in both the NAR NVT and time of sowing trials in 2008. However, long term NVT yields (2000–07) indicate that Gladius yields are only slightly lower than Wyalkatchem (97%) and Espada yields are similarly to Wyalkatchem. Espada is moderately susceptible/susceptible to blackpoint and Gladius is moderately resistant.

Early maturing varieties Axe and Zippy sown in June 2008 yielded similarly or lower than other varieties, however they had slightly better screening levels (data not published). In 2007 the rainfall recorded was much lower than 2008, however around 20–25 mm of rain fell in September. Axe performed similarly to the majority of other APW wheat varieties sown in June or July in this year. The performance of these varieties in a dry finish is yet to be determined. Axe flowered 8 days earlier

and than Wyalkatchem and Zippy flowered 10 days earlier than Wyalkatchem in 2008 at Geraldton (average across 4 sowing times).

The ASW variety Bumper yielded similarly or lower than Wyalkatchem in all NAR NVT trials in 2008. The NVT long term yields (2000–07) of Bumper are similar to Wyalkatchem. Bumper was only included in the TOS trial at Mullewa and its performance was similar to Wyalkatchem at each seeding time between early May and late May. Bumper is unlikely to attract better returns than leading APW varieties based on yield results (assuming APW offers a premium over ASW).

Sowing wheat options—ASWN

Binnu, Yandanooka and Fortune all performed similarly and their respective yields were not significantly different to those of Calingiri at most sowing times across all sites. The yields of Calingiri were significantly higher than Binnu with 2 May sowing at Mullewa and Marchagee, where Calingiri also out yielded Yandanooka. Yandanooka is taller than the other varieties and stubble management in higher yielding crops may be a consideration where subsequent cropping is planned for the paddock. Binnu had higher screenings than the other noodle varieties at Mingenew, however levels did not exceed 5% (data not published). Binnu, Fortune and Yandanooka all have better noodle quality than Calingiri and provide some improvements in disease resistance (refer to Wheat variety guide 2009 Western Australia). Fortune flowered 6 and 3 days later than Calingiri in the 2008 phenology trials when sown in early April and mid May.

Sowing wheat options—AH

Carnamah yielded well across all sowing times on the sandy loam at Mullewa in 2008 but on the sandplain soils at Mingenew the relative performance of this variety declined considerably with delayed seeding. In general, across all three time of sowing trials, Carnamah outperformed EGA Bonnie Rock in 2008 however screenings were similar and within industry standards (data not published). The NVT long term yields (2000–07) of Carnamah and EGA Bonnie Rock are similar. EGA Bonnie Rock is very susceptible to stripe rust. Carnamah is very susceptible to sprouting. Tammarin Rock out performed EGA Bonnie Rock, however its resistance to black point is poor compared to EGA Bonnie Rock.

CONCLUSION

Good summer rain and finishing rains in September and October favoured the relative performance of the longer maturing varieties.

Early May seeding resulted in significantly higher yields than later sowing, however the delay in seeding had a greater effect on yield decline at Marchagee and Mingenew than at Mullewa.

The performance of many of the new wheat varieties was comparable, or better in some situations, than that of commercial favourites. The results for Mace, Magenta and the three new noodle varieties Binnu, Fortune and Yandanooka in particular justify their consideration as replacements for older varieties.

KEY WORDS

wheat varieties, agronomy, crop management, time of sowing

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Table 1 **Effect of sowing time on yield (t/ha) of wheat varieties at Mingenew, Mullewa and Marchagee in 2008**

		Mingenew			Ave	Mullewa			Ave	Marchagee			Ave
		1 May	20 May	18 June		2 May	10 June	24 June		1 May	16 May	12 June	
AH	Carnamah A	4.19	3.42	1.03	2.88	4.81	3.47	2.46	3.58	4.94	5.15	3.92	4.67
	EGABonnieRock A	3.56	3.76	1.15	2.82	3.36	3.09	2.37	2.94	4.36	4.50	3.87	4.24
	TammarinRock A	3.75	4.27	1.30	3.11	3.60	3.60	2.61	3.27	3.85	4.70	3.65	4.07
	Yitpi A	4.07	3.19	1.37	2.88					4.61	4.46	3.78	4.28
APW	Axe A	2.54	2.48	1.03	2.02	2.98	3.03	2.01	2.67	2.27	3.64	3.35	3.08
	Carinya A	3.52	2.28	0.78	2.19	4.00	3.01	1.95	2.99	4.12	4.34	3.17	3.88
	Catalina A	2.98	3.41	1.03	2.48	3.65	3.25	2.15	3.02	3.40	4.30	3.91	3.87
	Correll A	4.24	3.35	1.24	2.94	3.99	3.37	2.29	3.22	4.22	4.86	3.46	4.18
	Derrimut Wt A	2.48	2.65	0.73	1.95	3.59	3.28	2.21	3.03	2.93	4.14	3.51	3.53
	EGAWentworth A	3.04	2.73	0.74	2.17	3.48	2.89	1.86	2.74	3.99	4.11	3.39	3.83
	Espada A	3.87	3.68	1.17	2.91	3.77	3.23	2.30	3.10	4.11	4.59	3.64	4.11
	Gladius A	3.75	3.46	1.36	2.85	4.22	3.18	2.16	3.19	4.11	4.63	3.71	4.15
	LRPLincoln A	4.60	2.65	1.04	2.76	3.93	3.37	2.25	3.18	4.05	4.62	3.36	4.01
	Mace A	4.12	3.79	1.44	3.12	3.66	3.55	2.67	3.29	5.08	5.40	3.66	4.71
	Magenta A	4.71	4.17	1.16	3.35	5.07	3.76	2.30	3.71	5.72	5.36	3.98	5.02
	Wyalkatchem A	4.54	3.85	1.38	3.26	4.45	3.62	2.37	3.48	4.76	5.27	3.65	4.56
	Young A	3.05	3.46	1.12	2.54	3.12	3.34	2.17	2.88	3.63	4.68	3.73	4.02
	Zippy A	2.62	2.82	1.14	2.19	2.30	3.17	2.12	2.53	2.84	4.40	3.55	3.60
ASW	Bumper A					4.71	3.51	2.31	3.51				
ASWN	Arrino A	3.74	3.35	1.23	2.77	4.27	3.57	2.16	3.33	4.22	4.83	3.61	4.22
	Binnu A	4.24	3.88	1.00	3.04	4.46	3.30	2.21	3.32	4.70	4.94	3.61	4.42
	Calingiri A	4.46	3.87	1.22	3.18	5.34	3.58	2.51	3.81	5.41	4.89	3.73	4.68
	Fortune A	4.12	3.54	0.98	2.88	4.88	3.58	2.38	3.61	5.06	5.13	3.69	4.63
	Yandanooka A	4.20	3.66	1.03	2.96	4.31	3.55	2.52	3.46	4.99	4.97	4.31	4.76
	Average within eachTOS	3.75	3.38	1.12	2.75	3.98	3.36	2.28	1.20	4.24	4.69	3.66	4.20
	TOS (l.s.d.)	0.32		Var (l.s.d.)	0.25	0.73		Var (l.s.d.)	0.25	0.15		Var (l.s.d.)	0.24
	Var (l.s.d.) between TOS	0.44		%CV	10	0.75		%CV	8.3	0.42		%CV	6
	Var (l.s.d.) within TOS	0.49				0.42				0.42			