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Crop Updates 2003 - Cereals

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Recognising and responding to new market opportunities in the grains industry

Graham Crosbie, Manager, Grain Products Research, Crop Breeding, Plant Industries, Department of Agriculture

INTRODUCTION

I appreciate the opportunity to highlight some of the exciting initiatives that are underway at the Department of Agriculture in the area of grain quality research.

The Department has a key role in the following:

- Market research to identify end-use trends and market quality requirements.
- Identifying new market opportunities.
- Basic studies to clarify the importance of specific quality traits for significant products.
- The development of improved screening tests for application in plant breeding.

WHEAT

Noodle wheat

The development of wheat for Japanese udon, that was initiated in Western Australia in 1989/90, provides an excellent example of the many facets of grain quality research and of the potential benefits that can be achieved.

The research, which was led by Graham Crosbie, included:

- Market visits to learn about trends in noodle manufacture and market requirements.
- Formation of technical links with Japanese flour mills and noodle manufacturers.
- Recognition of the importance of specific quality traits.
- Segregation of varieties with desired qualities (1989/90 season).
- Separate pooling to reward growers with the full market return (1992/93 season).
- Visits by Japanese noodle experts to provide training in noodle assessment (1990 to 1997).
- Development of the Flour Swelling Volume test (with Bill Lambe) to select for starch quality in wheat breeding (1989 to 1993).
- Collaboration with wheat breeders Mr Robin Wilson and Dr Ian Barclay in the development of new noodle wheat varieties.
- Continued research towards further quality improvement (e.g. improved colour stability).

This work has resulted in:

- The recognition of Western Australia as a world leader in the development of wheat for Japanese udon.
- Clearly defined quality objectives for udon noodles. This has in turn improved the ability of our breeding program to select new wheat varieties that meet the quality requirements for this very discerning market.
- Substantial premiums for Western Australian growers (about $30/t above ASW in the last couple of years).

Soft wheat

The existing Australian Soft (AS) grade was established 25 years ago, based on the variety Tincurrin. Production rose to 300,000-400,000 tonnes during the 1980s and 1990s but in recent years has fallen to below 100,000 tonnes, due to more profitable alternatives and problems with the small grain character of club-head varieties. Although Japan was an initial target, the main soft wheat markets are South Korea, Malaysia and S. China, where it is used mainly for biscuits, cakes and steamed buns.

A new GRDC-funded project ("Market requirements for soft wheat", DAW700) is currently underway, aimed at rejuvenating this grade. The researchers are G. Crosbie, R. McLean and N. Sy.

Aims of the project are to:

- Review key products manufactured from soft wheat.

- Establish quality requirements of these products.
- Develop improved quality testing methods.
- Develop improved quality objectives for breeding and grain receival.
- A renewed focus on the requirements of Japan,

A recent visit to Japan established that they have a requirement for 1 million tonnes of soft wheat that is largely being met by Western White. Western White is the quality benchmark for soft wheat in this market and Japan is not actively seeking to find an alternative for this wheat. On the positive side, an agreement has been met for a DAWA food technologist to be trained in the Japanese sponge-cake method. We also plan to define the quality characteristics required for sweet biscuits, steamed buns and tempura flour. Once these are defined, we will have a much better understanding of the quality attributes that are required by the Japanese market. This will allow us to modify the selection pressure in our soft wheat breeding program to identify new varieties that have the quality characteristics that are suitable for this market. We need to at least match and ideally improve on the quality of Western White.

Noodle and dumpling wheat for Taiwan

A recent visit to Taiwan established that there is a large opportunity to export Australian wheat into this market. Taiwan currently imports approximately 900,000 tonnes of wheat from the US each year. This market is heavily focused on US wheat and US specifications, however it does provide a “window into China”. Milling industries in Taiwan are highly competitive and are looking for opportunities that Australian wheat may be able to deliver. There is also a small, but growing interest in Japanese-style udon noodles.

GRDC has recently funded a joint project between BRI Australia Ltd (K. Quail and S. Huang), Department of Agriculture (G. Crosbie and N. Sy), and Curtin University (V. Solah and A. Limley) (BRI0005). The aim of this project is to identify superior wheats that are well suited for noodles and dumplings. This study will include the effects new processing technology has on the quality of the end product . The findings of this work will be applicable to other Asian countries, including mainland China.

Hard wheat

Quality improvement in hard wheat, specifically for the Australian Premium White (APW), APWT and Australian Hard (AH) wheat grades, will result from the following research activities:

- The "Noodle and dumpling wheat for Taiwan" project.
- A study completed in 1999 into the starch quality requirement of alkaline noodles.
- The development of new rapid quality screening tests for application on early generation breeding lines (see *Supporting Technologies*).
- The development of a computer program by chemist Bill Lambe that brings together yield and quality in the form of a $ per hectare value, allowing superior lines to be readily identified.

Wheat Quality Objectives Group (DAW607)

The Wheat Quality Objectives Group (WQOG) was formed in 1993 because there was a need for better quality objectives in breeding. The group decided early that the starting point in defining objectives should be the product, not the grade. The motto of the group is "If we can set better objectives than our competitors and achieve these objectives, then we will have a valuable marketing advantage"

Members of the Group's Steering Committee include the main contributors to Australian research into the quality requirements of wheat-based foods: A. Blakeney, R. Cracknell (Chairman), G. Crosbie (Convenor), D. Miskelly, L. O'Brien, K. Quail, T. Westcott, R. Williams

The process used by the group:

- Identify significant products and processes.
- Describe the products and processes.
- Identify quality requirements as specified by the market.

- Incorporate requirements as indicated from the results of quality research.
- Recommend quality objectives for Australian wheat breeding programs.
- Identify gaps in our understanding of quality requirements.
- Recommend to GRDC priorities for wheat quality research.
- Produce a comprehensive report.

Significant outcomes from the work of the group are:

- Improved market-focused objectives in wheat breeding.
- The Group's study provided the technical basis for the AWB's introduction of the APW grade.
- The GRDC quality research program became product-focused in the mid-1990s.
- Acceptance by GRDC of many WQOG recommendations for quality research.

BARLEY

Allen Tarr and Stefan Harasymow are the main researchers here.

Research directions

- Main focus on malting quality for premium markets.
- Commercial malting trials on promising new varieties Baudin and Hamelin.
- Development of screening tests for malting quality.
- New interest in Shochu, a fermented and distilled product.
- Shochu research
- Funding needed.
- Allen Tarr is working with Peter Portmann of CBH Ltd and Japanese manufacturers.
- Pearling characteristics - importance of grain shape, hardness, pearling yield.
- Starch quality.

Main outcome:

Maximising the potential of barley to achieve premium grades for malting and Shochu.

LUPINS

Role in aquaculture

Research Officer Sofie Sipsas, with technical officers Wayne Hawkins and Ross Maas, collaborates with Dr Brett Glencross, Department of Fisheries, in research into the potential use of lupins in aquaculture as a replacement for fish meal.

Key findings from this work are:

- Feeds incorporating lupins have been satisfactorily prepared using an experimental extruder.
- Higher protein content associated with higher protein and energy digestibility.
- A potential role for lupin protein concentrates.
- Yellow lupins (*L. luteus*) with higher protein content, compare favourably with soybean meal as a replacement for fishmeal. Access to higher yielding, more robust *L. Luteus* varieties are needed to increase production of this species and capitalise on this quality advantage.

Potential food products

There is growing interest in in the potential role of lupins in the manufacture of food ingredients, such as fibre and protein isolates. Sofie Sipsas and Dr John Snowden are working on a new GRDC-funded project- "New lupin products".

Project aims:

- Identify varieties with superior processing characteristics for the manufacture of protein isolates.
- Study effects of processing conditions on yield and functional properties of protein isolates.

Potential outcomes:

- Commercial manufacture and export of lupin-based fish feeds.
- The development of lupin-based food ingredients.

SUPPORTING TECHNOLOGIES

Near- infrared reflectance (NIR) analysis

Research at the Department has resulted in the development of new NIR calibrations that allow for the prediction of a number of quality traits simultaneously on whole grain samples. This means that we can screen early generation wheat breeding lines much faster, at lower cost, and at an earlier stage than before. The elimination of poor quality material at an earlier stage will result in improved efficiency in both field and laboratory components of breeding and hasten the development of new varieties. Much of this work was carried out with funding from GRDC and involved collaboration with Drs B. Osborne and I. Wesley from BRI Australia Ltd.

Calibrations that have been developed and now being applied are:

- Wheat: Grain protein, grain hardness, flour yield, flour yellowness, flour water absorption (G. Crosbie and Y. Wang).
- Barley: Grain protein, grain colour, malt extract (A. Tarr and S. Harasymow)
- Oats: Grain protein, oil, grain colour, groat % (M. Hall).

Single kernel characterisation system (SKCS)

The single kernel characterisation system allows for the rapid measurement of the frequency distribution of single grains for hardness, weight and width. Non-uniformity in the distribution may indicate that a breeding line is mixed for this character and needs re-selecting.

The SKCS unit has been calibrated for the following tests:

- Wheat - average grain hardness, screenings, moisture content (W. Lambe, W. Morris).
- Barley - hardness, plumpness (Shochu studies, A. Tarr).

Work is currently underway by Allen Tarr on a test for the measurement of malt hardness and friability.

Image analysis

Image analysis involves photographing a grain sample and analysing the digital image. This offers the potential for rapid measurement of grain colour and grain shape. In relation to shape, the instrument may be programmed to predict screenings level, and to distinguish between broken and whole grains.

Tests currently being applied are:

- Oat milling yield (the percentage of whole groats recovered after dehulling of oats) (M. Hall).
- Broken grain in pearled barley (Shochu studies, A. Tarr).

Current research is focusing on:

- Barley grain shape and its effect on yield and shape of pearled grain (Shochu studies, A. Tarr).
- Colour and shape in lupins and field peas (S. Sipsas/P. Burridge).

Biotechnology

A key area of biotechnology research is the development of new analytical techniques for application in selecting for quality improvement in early generation plant breeding material. An advantage in the development of molecular markers is that this offers the potential to predict grain quality traits from the analysis of leaf material. Key researchers in this area include Drs R. Appels, M. Francki and C. Li.

Tests currently being applied:

- A suite of approximately 15 molecular markers are being applied in the wheat and barley breeding programs and several of these are involved in quality improvement. The markers include genes directly involved in quality traits (e.g. markers for starch and noodle quality in wheat and thermo-stable beta-amylase in malting barley) as well as markers closely linked to other quality traits (e.g. markers for flour colour and grain hardness).

Current research includes:

- Participation in the Australian Winter Cereals Molecular Marker Program to identify molecular markers for quality traits and other characteristics such as disease resistance.
- Utilisation of a new analytical technique to rapidly identify seed storage protein types that are pivotal in determining quality attributes of flour samples.

CONCLUSIONS

- The continued investigation of the quality requirements of key markets and products is vital in ensuring that quality objectives in crop breeding remain market-focused.
- The availability of new technologies will lead to the development of a range of new quality screening tests for application in crop breeding. This will necessitate the regular review of quality testing strategies to ensure that the most efficient tests are fully utilised.

KEY WORDS

Quality, wheat, barley, oats, lupins, market research, quality objectives, quality tests, biscuits, cakes, tempura flour, noodles, dumplings, steamed buns, malt, malting quality, shochu, protein isolates, near-infrared reflectance analysis, single kernel characterisation system, image analysis, biotechnology, molecular markers.

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Stripe rust - where to now for the WA wheat industry?

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KEY MESSAGES

- Stripe rust is capable of causing substantial losses in all wheat growing areas of WA. Yield losses over 50 per cent were measured in 2002 in regions where drought did not constrain the disease.
- To minimise damage to the WA industry, avoid very susceptible varieties that will promote regional outbreaks with heavy losses. Among varieties on hand for 2002, preferably sow those that are moderately susceptible or intermediate in resistance or better.
- Breeding lines resistant to WA stripe rust are present in the Crop Variety Testing program and provide good prospects for future resistant varieties. New breeding strategies and field selection for resistance in disease nurseries will greatly improve the prospects for durable stripe rust resistant varieties in the medium term.
- In the short term, fungicides used at seeding (seed dressings or applied in-furrow with fertilizer) and foliar fungicide sprays will mitigate risk and minimise losses. Fungicides will be least effective with high disease pressures in very susceptible varieties.
- A community awareness program for green bridge management will target on-farm surveillance on St Patrick's Day, Monday 17 March, to gauge regional rust risk in the lead up to seeding.

BACKGROUND

Wheat stripe rust (*Puccinia striiformis* f.sp *tritici*) was first recognised as distinct from leaf and stem rust in the 1800's but is likely to have affected wheat since pre-Biblical periods. In Australia there have been three introductions of stripe rust. In 1979 a European strain occurred in Victoria and subsequently spread throughout eastern Australia and New Zealand but failed to spread to Western Australia. A second introduction, which is adapted to barley grass and certain barleys, was detected in eastern Australia in 1998. The third introduction discovered in August 2002 ended 23 years of WA isolation from the effects experienced with this disease elsewhere in Australia. All introductions are believed to have involved accidental human movement of rust spores.

Following the simultaneous reporting of the disease in the Lake Grace and Gnowangerup shires, an incident response was established under the *GrainGuard Biosecuirity Plan* and a Department of Agriculture survey confirmed that the initial outbreak was confined to these two general areas. The Australian Cereal Rust Control Program, Cobbitty, tested and designated the pathotype in Western Australia as 134 E16 A+ which does not occur in eastern Australia. The origin of this strain remains unclear but candidate regions of origin include America, the Middle East or possibly eastern Africa. Fungicide control was required in many parts of the Great Southern and South Coast regions. By the end of the season the disease had spread to all regions of the wheatbelt. In mid December it was detected on wheat regrowth in the Borden area and in mid January it was detected on volunteer wheat near Lake Grace and north of Esperance near Grasspatch.

2002 EXPERIENCE

Yield and quality losses

Measured yield losses ranged from zero in two droughted experiments (Lake Grace area), 30 per cent (1 t/ha) in a 3.3t/ha crop (cv. Calingiri, S. Stirlings) and up to 50 per cent in cv. Brookton in variety trials at N. Gnowangerup. The yield effects under extreme disease pressure were estimated to be approximately 65 per cent for very susceptible varieties. Very poor grain development was observed in these cases. Grains were highly shrivelled and stripe rust infection inside the glume resulted in dark spots on the grain where black rust spores of *P. striiformis* (teliospores) developed. Note, however, that stripe rust is not seed borne.

Variety performance

Among the 11 varieties comprising 90 per cent of the wheat area in WA, only Camm has effective major gene resistance (Table 1). Major resistance genes for stripe rust deployed in WA, including Yr6 (Stiletto), Yr7 (H45, Westonia, Wilgoyne) and unknown major resistance genes (Calingiri), are ineffective with 134 E16 A+.

Table 1. Response to stripe rust of 11 wheats that comprised 90 per cent of wheat area in WA in 2002.

	2002 area (%)	Stripe rust: Provisional CVT rating (0-9)	R genes*
Carnamah	25	4	-
Westonia	19	2	Yr7*
Calingiri	18	4	Unknown major gene(s)*
Arrino	8	3	-
Camm	4	7	Yr17
Stiletto	3	4	Yr6*
Cascades	2	3	-
Machete	2	4-5	-
Brookton	2	2	-
Halberd	2	4	-
Spear	2	4	-
Eradu	2	4	-
H45	2	2-3	Yr7*

* ineffective against 134 E16 A+

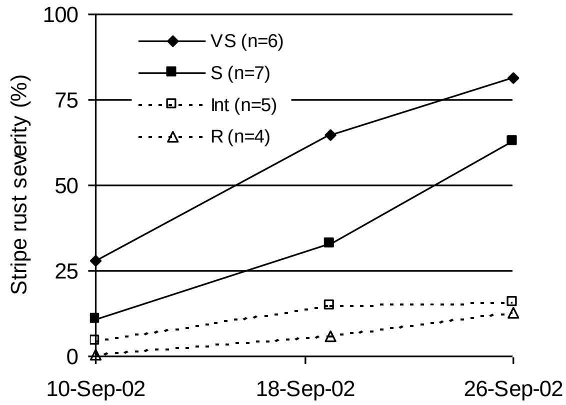
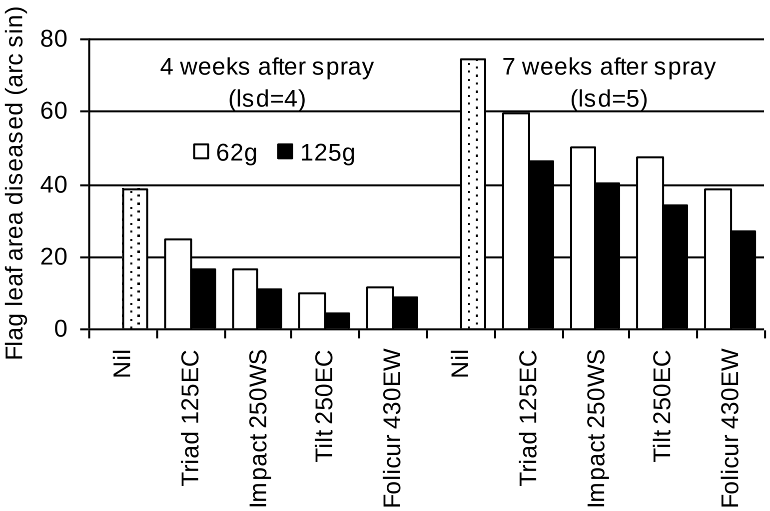


Fig 1. The effect of resistance on stripe rust development. Responses are the mean of 6 very susceptible (VS), 7 susceptible (S), 5 intermediate (Int) and 4 resistant (R) varieties grown at N. Gnowangerup in 2002.

The current reliance on susceptible and very susceptible varieties will result in high disease pressures being experienced in many areas. Very susceptible varieties develop the disease extremely rapidly (Fig 1) and produce vast quantities of spores. This promotes and sustains epidemic development and provides greater opportunities for the pathogen to evolve new pathotypes. Epidemic progress is much slower in varieties possessing partial resistance. Varieties that are moderately susceptible to intermediate lost 10-20 per cent yield compared to 30-40 per cent losses for susceptible to very susceptible varieties in trials at N. Gnowangerup (Table 2). Partial resistances of varieties such as Wyalkatchem should be better expressed at the paddock scale since small experimental plots are affected by spore load from susceptible neighbours.

Stripe rust on partially resistant varieties will be more readily controlled, requiring less frequent treatment. This will be most evident where disease onset is later in the season, as partial resistance normally starts to express from around head emergence. An examination of regional variety performance and estimated stripe rust risk using the *e-VarietyGuide to stripe rust* (see Crop Updates paper by M. Salam *et al.*) predicts significant benefits from changing planting intentions away from VS varieties towards MS, Intermediate or R varieties.

Fig 2. The effect of fungicides, applied once at 62 or 125 gai/ha, on flag leaf area affected by stripe rust, S. Stirlings, 2002 (data courtesy of Dr K. Jayasena, DAWA).



Fungicide performance

Stripe rust was detected in a crop of cv. Calingiri at the early booting stage (Z43) and 8 fungicide treatments were applied two days later. Fungicides reduced the leaf area affected by stripe rust to different extents when assessed 4 and 7 weeks after treatment (Fig 2). Untreated plots yielded 2.4t/ha. All fungicide treatments increased yield significantly (2.8-3.1t/ha).

Only Folicur430EW at 125gai/ha (3.3t/ha) outyielded some other fungicide treatments. Maximum profits were observed from full rates.

Table 2. Yield of wheat varieties under moderately severe stripe rust infection in two experiments at N. Gnowangerup in 2002 (Data courtesty of Crop Variety Testing, DAWA).

	Provisional CVT resistance rating	02GS62 Yield (t/ha)		Rel. yield	02GS59 Yield (t/ha)		Rel. yield
	(0-9) WA stripe rust	Nil	Fung[1]	(%)	Nil	Fung	(%)
Amery	3	1.21	2.01	60	-	-	-
Brookton A	2	1.06	1.99	53	1.31	2.42	54
Cadoux	3?	-	-	-	1.81	1.91	95
Camm A /Yr17line[2]	7	2.27	2.33	97	2.45	2.54	97
Carnamah A	4	1.88	2.12	89	1.85	2.28	81
Cascades A	3	1.30	2.25	58	1.39	1.93	72
ClearfieldSTL A	4	1.92	2.23	86	-	-	-
EGA Bonnie Rock A	3	1.78	2.50	71	-	-	-
H45 A	2-3	1.20	1.53[3]	78[3]	-	-	-
Lang A	5?	-	-	-	2.16	2.22	97
Machete	4?	1.57	2.05	76	1.96	2.66	74
Mira A	7	2.27	2.35	97			
Spear	4?	2.03	2.32	87	2.34	2.52	93
Sunco	7	1.41	1.55	91	-	-	-
WAWHT2454	6	2.19	2.23	98	-	-	-
WAWHT2525A	6	2.06	2.29	90	2.10	2.35	90
Westonia A	2	1.75	2.48	71	1.94	2.81	69
Wyalkatchem A	5	2.23	2.40	93	2.08	2.63	79
LSD5%		0.25			0.52		

[1] Fungicide treated plots received three applications of 500mL/ha Impact 250SC*

[2] A related line possessing Yr17 is depicted in the absence of Camm in 02GS59

[3] Effects under estimated due to inadequate disease control.

A common theme of grower experience with fungicide in 2002 was the advantage when controlling infection at initial stages. Attempts to control established disease in very susceptible varieties resulted in reduced duration of control. This experience may encourage some growers to use prophylactic fungicide applications. However a campaign of regular crop monitoring, initially targetting very susceptible or early sown paddocks, will both reduce unnecessary chemical use and ensure that disease is detected as early as possible for optimal control.

Fungicide treatments used at seeding (seed dressings and in-furrow fertiliser applications) are valuable for managing stripe rust risk and can provide median periods of suppression between 6(±2) and 12(±4) weeks. Their use is highly advised in situations where 1) early infection is likely (green bridge and neighbouring risk areas); 2) rapid disease development is likely (VS varieties) or 3) in situations where early fungicide spraying is not feasible. Partially resistant varieties can also benefit from these treatments if infection commences before late stem elongation when adult plant resistance starts to manifest.

CONCLUSION

Future impact

Severe drought in 2002 in most areas limited the impact of stripe rust by containing the epidemic to the Great Southern region. Here the extensive and often repeated use of fungicide was required to control the disease, providing some insight into the capacity of stripe rust to develop and spread. Very susceptible (VS) varieties will continue to promote regional outbreaks with potential for heavy losses and their removal from all areas of the wheatbelt is recommended as soon as possible.

While the industry adjusts to the presence of stripe rust over the next 5 years, potential for high levels of disease will put available resistance genes under pressure. Large rust populations that develop in epidemics increase the likelihood of rust mutation for increased virulence. Stripe rust resistance present in Camm has been overcome in this way in eastern Australia and its likely duration in WA is not possible to predict. Varieties with partial resistance such as Wyalkatchem will perform better in the absence of heavy disease loads contributed from VS varieties.

Regional adaptation, migration and the green bridge

Dennis (1987a,b) described climatic factors influencing infection and spore survival of *P. striiformis*. A comparison of weather data for southern (Scaddan), central (Merredin) and northern (Mingenew) locations indicates that conditions favouring either infection or spore survival outside the growing season are less frequent for northern areas than for southern areas (M. Salam, pers. comm). It is possible that under conditions that are marginal for the survival of the pathogen (e.g. absence of an extensive green bridge) stripe rust in southern areas may be expected to result from local survival where as regional spore migration could be more important in northern wheatbelt areas. While this may give some indication of probabilities, Park (1990) found that summer conditions in the north eastern Australia were suitable for infection by stripe rust on several occasions through the summer intercrop period. The most important factor in the occurrence of stripe rust in the growing season is the proximity to oversummering hosts, the "green bridge". A community awareness program for green bridge management will target on-farm surveillance on St Patrick's day, Monday 17 March, to gauge regional rust risk in the lead up to seeding. Volunteer wheat present in autumn represents the greatest risk.

Biosecurity and implications for eastern Australia

The progressive extension of the geographic range of *P. striiformis* over the past 25 years has witnessed the arrival of the pathogen in eastern Australia (1979), New Zealand (1981) South Africa (1996) and now WA. The WA pathotype combines virulence for Yr6, Yr7, Yr8, Yr9, YrA and possibly Yr10. Most of these virulences have been recorded in eastern Australia, though not in this combination. The occurrence of partial as well as major resistances in eastern state's varieties reduces the threat that the WA pathotype poses in eastern Australia. However it is highly desirable to contain this pathotye in WA so that the combination of virulences will not be spread to eastern Australia. Similarly, pathotypes in eastern Australia and elsewhere in the world continue to pose a threat to the future security of the WA industry and further risks of introduction must be minimised. **Because of the occurrence of different strains of leaf, stem and stripe rusts, care must be taken when travelling interstate or receiving interstate or overseas visitors, since spores carried on clothing could be responsible for introducing new strains of rusts. Thoroughly wash potentially contaminated clothes, shoes etc before visiting crops after travelling interstate or overseas. A high degree of vigilance is still required.**

Breeding multigenic resistance

Advanced breeding lines with stripe rust resistance provide good prospects for the future. New breeding strategies and field selection for resistance through exposure to the disease will greatly improve the prospects for new stripe rust resistant varieties in the medium term.

It will be important to use the WA stripe rust in local breeding plots in order to select resistances that are effective. In addition, plant breeders will be aiming to select for resistance that remains effective throughout the commercial life of the variety if regularly exposed to the disease. Experience elsewhere shows that major gene resistances to stripe rust are not durable, especially if deployed alone. Combinations of several minor genes, which generally operate in the adult plant stages of growth, have proved more reliable. With the advent of stripe rust in WA, breeding methods employed elsewhere in Australia to maximise the accumulation of these genes are now possible in WA by field screening in early generations.

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Paper reviewed by: R. McLean and G.Thomas

Benefits of a Grains Biosecurity Plan

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WHO IS PLANT HEALTH AUSTRALIA?

Plant Health Australia (PHA) is a public company, with 26 members including the Commonwealth government, all state and territory governments, and a range of plant industry organisations.

The company was formed to address high priority plant health issues, and to work with all its members to develop an internationally outstanding plant health management system that enhances Australia's plant health status and the sustainability and profitability of plant industries.

National Biosecurity Planning is one of many projects presently being undertaken by PHA to address high priority plant health issues.

WHAT IS INDUSTRY BIOSECURITY PLANNING?

Industry Biosecurity is the protection from risks posed by organisms to each plant industry through actions such as exclusion, eradication, and control. Industry biosecurity is a shared responsibility involving governments, industry, and the general community.

GrainGuard is a WA based biosecurity plan that involved both the WA government and industry. The Grains Biosecurity Plan being undertaken by PHA is to build on the work of GrainGuard by taking it to the national level and completing more detailed assessment and planning by involving all stakeholders across the country.

Industry Biosecurity Planning involves identifying and documenting industry threats; undertaking and documenting appropriate pest risk assessments; developing an agreed emergency plant pest priority list; developing an Industry Risk Mitigation Plan; developing an Incursion Contingency Plan; developing Pest Specific Contingency Plans (if considered appropriate); agreeing on, and documenting the roles and responsibilities of stakeholder groups; developing appropriate communication and consultation strategies; and planning and undertaking regular Industry Biosecurity Plan reviews.

BENEFITS OF BIOSECURITY PLANNING

- a more rigorous basis for strategic planning due to a structured consideration of key risks;
- decreased costs, as unacceptable risks are identified early and managed;
- more effective and efficient biosecurity programs;
- greater openness and transparency in decision-making and ongoing management processes;
- decreased loss/incident damage; and
- ownership of decisions, and a commitment to delivering real outcomes.

ROLE OF AGRIBUSINESS

Agribusiness will play an important role in Industry Biosecurity as they will be a critical component of several risk mitigation methods. Private sector consultants are now undertaking a lot more one to one contact with growers than the government sector and perform the role of front-line passive surveillance. Agribusiness can further assist with active surveillance for specific exotic threats. There will also be a role in communicating and training industry on a number of risk mitigation activities.

In the event of an exotic pest incursion, agribusiness will need to be involved in the initial reporting of suspect symptoms on plant crops and any preliminary de-limiting surveys undertaken to scope the extent of an incursion.

PROCESSES IN DEVELOPING AN INDUSTRY BIOSECURITY PLAN

Industry Biosecurity Planning Groups (IBPG) have been convened based on the regional split used by GRDC. The IBPG coordinate the development of the plan using relevant resources. All stakeholders are part of the process and regular communication and consultation will be sought. PHA will negotiate, ratify and register the plans and the cost sharing agreements which are a critical part of the process. Once the plan is implemented it will clearly define roles and responsibilities of those involved. A regular review process with be put in place.

All stakeholders are encouraged to become involved in the biosecurity process. To review Threat Summary Tables (TST's) and other planning documents visit the PHA website www.phau.com.au/Grains . Password for accessing the TST's is **grains**.

BIOSECURITY PLANNING SUCCESSES

The most recent success of biosecurity planning was the stripe rust incursion management undertaken in WA last year. Through GrainGuard detailed assessment was made of the risk posed by this disease. The assessment concluded that due to the biology of the organism eradication was unlikely to be feasible and that risk mitigation measures should be reviewed to ensure that the risk of entry was minimised. When the incursion occurred in 2002, the decision not to eradciate was already made and there was no unnecessary crop destruction or quarantining of properties. The emergency response was able to concentrate on communicating to industry control and management activities and to assess the extent of the outbreak.

Another success from GrainGuard was the review of quarantine regulations regarding lentil imports. Through the threat identifcation process lentil anthracnose was identified as a high risk potential threat to the industry yet no restrictions on lentil imports were in place. A similar review completed by DPI (Victoria) had also identified this pathogen as a serious threat. GrainGuard in conjunction with DPI (VIC) worked with the lentil industry to provide the necessary data to allow Biosecurity Australia (Commonwealth government) to put in place quarantine regulations. Lentils must now be imported under these regulations (risk mitigation measure) which will limit the potential for this exotic pest to enter Australia.

A recent detection of a suspect *Trogoderma* species (initially thought to possibly be Khapra beetle) highlights the importance of maintaining active surveillance and encouraging industry to be aware of these potential threats and to be undertaking their own passive surveillance.

At present PHA through the Grains Industry Biosecurity Planning process are working with the Grains Council of Australia to have Biosecurity Australia review the present regulations on import of wheat, barley and oats from New Zealand. The present regulations pose a serious threat for introduction of exotic pests into Australia and the review should identify the need to tighten the present regulations to ensure Australia's small grain industries are adequately protected.

BIOSECURITY PLANNING SCENARIO

In developing the Grains Industry Biosecurity Plan many exotic threats will be identified and there will be a need for considerable consultation before recommendations on risk mitigation measures are made. In completing the canola plan as part of GrainGuard an exotic pathogen was identified as a potentially serious threat. The pest is *Verticillium dahliae* var. *longisporum* which causes the disease Verticillium wilt. This is a serious pathogen in countries where it is presently established but there is some disagreement on its potential impact in Australia.

At present canola has no quarantine restrictions for pathogens into Australia. From a risk assessment point of view the assessment made suggests that some quarantine restrictions should be imposed on the import.

This, however, has implications for industry development as breeders would have decreased access to new germplasm. As well as this it is highly likely that government stakeholders would consider the removal of this pest from the cost sharing agreement in which case industry would have to bear the full cost of any incursion as no risk mitigation has been undertaken.

It is because of issues such as this scenario that all members of an industry are encouraged to participate in the process.

ACKNOWLEDGMENTS

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MORE INFORMATION

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Can we improve the drought tolerance of our crops?

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KEY MESSAGES

While growers have adopted management practices to gain improved yields under water-limited environments, breeders can assist in providing more drought-tolerant cultivars. Traditional breeding has seen a steady increase in yields of dryland crops, but examples are given in which targeted breeding for drought-prone environments has yielded significant increases in yield in wheat and maize for marginal environments. Examples are also given where WA breeding programs have provided new germplasm of lupin and chickpea for extreme terminal drought. These suggest that targeted breeding programs can help to provide cultivars with significantly improved drought tolerance.

INTRODUCTION

The halving of grain production and the reduction in the growth of Australia's Gross Domestic Product in 2002 is clear testimony to the impact that drought has on agriculture and the national economy. While severe drought that prevents the harvesting of any crop is a relatively rare event, in seven out of the last 80 years potential wheat yields at Wongan Hills, WA were predicted to be less than 0.3 t/ha. On the other hand, the constraints to production from drought, particularly terminal drought, are commonplace and dryland cropping in Australia has been adapted to maximise production from seasonal rainfall and its expected distribution. In recent years growers have adapted practices such as reduced tillage to minimise soil evaporation, early planting to take advantage of more of the growing-season rainfall, increased rates of fertilization to boost early crop growth and adoption of cultivars better suited to the average length of the growing season. All these have resulted in a lessening of the impact of severe drought in recent years.

Nevertheless, as 2002 testifies, drought still has a major influence on grower income and the question arises in such seasons as to whether there are any possibilities for improving the drought tolerance of our crops. While the increase in early planting on minimal rainfall has increased the risk of drought affecting seedling growth and possible crop failure, the much more common scenario in Western Australia is a reduction in winter rainfall and failure of spring rains leading to terminal drought. This has been the focus of my research and will be the major focus of this paper.

AIM

The aim of this paper is to review the methods employed by breeders and physiologists to improve crop yields in water-limited environments and to report on several successful cases where drought tolerance has been improved to the benefit of growers.

DROUGHT

Any program of breeding for drought tolerance needs to identify the type and timing of drought that the crop is likely to encounter. Using cluster analysis Dr Graeme Wright of Kingaroy Queensland identified five types of drought encountered in that environment, namely, early drought, mid-season drought, late drought with relief near harvest, progressive moderate drought and progressive severe drought. In mediterranean-climates such as Western and South Australia, the most common type of water shortage is terminal drought. Studies at Merredin have shown that in both an average and drier-than-average season, the depletion of soil water through decreasing rainfall and lower relative humidities in spring led to the seed filling phase in chickpea occurring when leaf photosynthesis was very low, leading to reduced yields and smaller grain size compared to chickpeas given supplemental irrigation. However, early planting can lead to drought occurring in the seedling and early vegetative phase. Studies by Drs D. Arbrecht and R.J. French with wheat, lupin and faba bean have shown that drought at this stage rarely kills the plants, but can halt development until the rain commences again.

METHODS FOR BREEDING FOR DROUGHT TOLERANCE

The principal way that breeders, from Farrer onwards, have adapted crops to Australian dryland farming systems has been to match phenological development to the average rainfall distribution. This has involved developing varieties that flower early to escape terminal drought by reaching maturity before the drought becomes severe (Table 1). However, this is akin to walking a tightrope because early flowering increases the risk of frost damage and in better-than-average seasons determinate crops such as wheat and barley have little potential to take advantage of late rains. This has led to the search for cultivars that can tolerate the drought and still produce an economic yield.

Breeders have adopted three methods to identify and breed drought tolerant cultivars:

1. Selection for yield in drought-prone environments.

Plant breeders traditionally evaluate their advanced lines for yield in a range of environments. For over 30 years CIMMYT, the international centre for wheat and maize improvement in Mexico, has had an active breeding program for improved yields of wheat under irrigated conditions. This led to significantly increased yields under irrigation, resulting in the so-called Green Revolution, but it also led to cultivars with increased yields under rainfed conditions where rainfall or soil storage was sufficient to give yields above 2 t/ha.

For areas where the average yield is less than 2.0 to 2.5 t/ha, selecting genotypes for high yields in these target environments is preferred. The major problem is that seasons vary and many site-by-season yield trials need to be conducted to identify those cultivars that yield well in these water-limited environments. Nevertheless, this form of selection has led to a steady increase of 6 kg/ha/year in wheat over the past century in Western Australia. Likewise, studies with lupin at Merredin have shown that the recently-released cultivars Belara and Quinilock, which were selected for yields in a range of environments in WA, not only yielded 30 to 40% higher than Merrit in a average seasons, but 80% higher than Merrit in the extremely dry season of 2000 (Palta, Turner, French and Buirchell, 2003). Improved management practices have given an approximate additional 7 kg/ha/year over the same period. Also, selection in extreme marginal environments may throw up genotypes with an ability to yield under extreme conditions. In 2002 Dr Tanveer Khan, pulse breeder at the WA Department of Agriculture, identified two lines of chickpea that produced several pods per plant at Merredin when the remainder of the breeding population failed to produce a single pod. These lines, which had a common parent, will be used as parents in the chickpea breeding programs in the future.

2. Use of drought-tolerant germplasm in breeding programs.

While the example from chickpea may be considered a serendipitous find based on good observation, since 1997 CIMMYT has embarked on a directed program to improve the yield of wheat for rainfed marginal environments. This has involved the incorporation of genes from goat grass (*Aegilops squarrosa*), a drought-resistant wild relative of current wheats, into bread wheat. This was achieved by crossing the goat grass with durum wheat to produce a synthetic hexaploid wheat. While this was agronomically poor, it was crossed with high yielding, disease resistant and agronomically-adapted bread wheats to give drought resistant and disease resistant high yielding lines. Studies in several environments over 2 years have shown that these lines are 30% higher yielding than the high-yielding parent in water-limited environments (CIMMYT, 2001). In one case where the lines were given 120 mm of pre-sowing irrigation on top of 30mm of residual moisture in the profile in an environment with no growing-season rainfall, the drought-resistant line gave 3 t/ha, whereas the high-yielding line bred under irrigated conditions only yielded 0.5 t/ha. This highlights the rapid progress that can be made with a directed program for improved drought tolerance. These lines are now being used in the Australian wheat breeding programs. However, the quality of the genotypes still needs to be evaluated and progress to incorporate drought tolerance into high-quality bread wheats may be slower.

The CIMMYT maize drought-tolereance breeding program has achieved similar results of 25 to 30% yield increases over the best local cultivars in dryland maize in Africa, but this has taken more than 25 years to achieve (Bänziger, Mugo and Edmeades, 2002). Thus, breeding for drought-tolerance, even directed breeding for drought tolerance, can be very slow.

Table 1. Drought tolerance traits and their usefulness and ease of screening in breeding programs (modified from Turner 2001).

Trait	Usefulness	Ease of Screening
Drought escape		
Phenological development	Very High	Easy
Drought tolerance		
Early Vigour	High	Easy
Transpiration efficiency	High	Easy, but costly
Stomatal control	High	Difficult
Osmotic adjustment	High	Difficult
Deeper and denser roots	High	Very difficult
Membrane stability	Low	Easy

3. Breeding for specific drought-tolerance traits.

Physiologists working with breeders have suggested a number of putative drought-tolerance traits (Table 1) and several breeding programs have selected for one or more of these traits in a directed breeding program.

Early in the drought-tolerance breeding program for maize at CIMMYT, a short anthesis-to-silking interval was observed to be important in increasing the fertility and yields of maize in drought-prone environments. This became the focus of the breeding program in Mexico and led to the development of the drought-tolerant lines now used extensively in Africa.

Osmotic adjustment, the accumulation of solutes in the leaves to maintain turgor and growth, was shown by Dr Jim Morgan of NSW Agriculture in the 1970s and 1980s to confer high yield characteristics in wheat for drought-prone environments. In 2001 a bread wheat incorporating the gene for osmotic adjustment was released in Austarlia for commercial production in drought-prone environments. Its yield in drought-prone environments of Western Australia still awaits evaluation.

High transpiration efficiency, i.e., high rates of photosynthesis per unit of water transpired, has been shown to be an important trait for wheat grown primarily on stored soil moisture in southern Queensland and northern New South Wales. Breeding for genotypes incorporating this trait has resulted in yield increases of about 10% over traditional varieties in low rainfall environments of the region (Rebetzke, Condon, Richards and Farquhar, 2002).

Early vigour has been shown to be important for wheat for sandy soils and the mediterranean-type climate of Western Australia (Turner and Nicolas, 1998). While cultivars differing in early vigour have still to be fully evaluated, simulation analysis suggests that yield increases of 15% can be expected on average from early vigour alone (Asseng, Turner, Botwright and Condon, 2003) and even higher increases in yield can be expected when early vigour is associated with deeper rooting.

CONCLUSIONS

Crops cannot be grown without rain or the presence of soil moisture in the profile, thus complete "drought-proofing" of crops is not possible. While crop yields in marginal rainfed environments have increased steadily through traditional breeding methods, directed breeding for specific traits or the incorporation of genes from drought-resistant landraces or progenitors provides a way for significant advances in yield for drought-prone dryland environments. While selection for some of these traits may be difficult in traditional breeding programs, the development of rapid selection methods and molecular markers should enable rapid progress in the future.

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KEY WORDS

Drought escape, drought tolerance, breeding methods, terminal drought

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Paper reviewed by: Michael Poole and Jairo Palta

The Silence of the Lambing

Ross Kingwell, DAWA & University of WA

KEY MESSAGES

(i) The silence of the lambing that characterised wheatbelt farming in the 1990s is under challenge.

(ii) The next few seasons are a potential bonanza for most farmers.

(iii) The longer term is less rosy. Among the challenges to broadacre farming are maintenance of grain transport infrastructure, addressing social and management issues and responding to climate change.

AIMS

To outline the emerging situation for grain and sheep farmers and highlight a few issues affecting the future viability of farm businesses.

THE STORY

Following the collapse of the Reserve Price Scheme in the early 1990s, depressed wool prices reduced profits from sheep and encouraged many farmers to shift further into cropping. However, in recent seasons the relative profitability of some crops has been challenged by drought, herbicide resistance, higher input prices and disease threats, although their adverse impacts have been softened by very high grain prices. Sheep and wool prices also have climbed to historical highs with percentage increases in prices outstripping those of grains. New phase pastures suited to particular soils and system niches have become available to further bolster the relative profitability of sheep enterprises.

So in this current decade will the silence of the lambing remain a feature of farming or will a re-building of investment in sheep continue?

Wool: the Current Situation

The industry currently is characterised by low stocks, a low production base nationally and internationally, strong product demand, an improved quality of national product and a limited ability to rapidly escalate production. In December 2002 the Australian Wool Forecasting Committee forecast that wool production in 2002/3 would be around 495 million greasy kilograms which is about 240,000 bales less than in 2001/2. This represents the lowest wool production level since 1950/1. What makes this supply reduction of even greater importance is the absence of a wool stockpile, including low stocks of wool held by growers and a run-down in processor stocks. China, Australia's main wool customer, has announced it will increase its wool import quota in 2003 by 4.5% to a record 352,000 tonnes clean.

Australian producers have altered the micron composition of their wool production toward more highly priced finer wools. In calendar year 2002 the prices of all micron grades in the 21 to 25 micron range increased by over 50 per cent and 19 micron wool increased by 21 per cent. These high prices for wool are forecast to continue in the medium term (2 to 3 years).

Sheep for Meat: the Current Situation

In December 2002 the executive director of the Sheepmeat Council of Australia commented that Australia already faced a contract shortage of four million prime lambs for overseas markets. Widespread severe drought in the Eastern States will lessen competing supplies of sheep meat and wool in 2003. It will take a few seasons for Eastern States' farms to recover their sheep and wool production. Lamb production within the US is forecast to be lower in 2003, increasing the opportunity for additional Australian lamb exports to this key market. Lamb and shipper prices are forecast to remain high, softening as Australian and overseas supplies increase. Certainly in the next few years maintained high prices for lambs will ensure that there is no silence of the lambing.

Grains: the Current Situation

Grain prices also have been at historically high levels and these prices also are forecast to continue into season 2003, followed by a subsequent highly probable softening sometime in 2004. Drought conditions in Australia and north America have reduced their production causing carryover stocks of grain in major exporting countries to be at their lowest since the mid-1990s (see Figure 1).

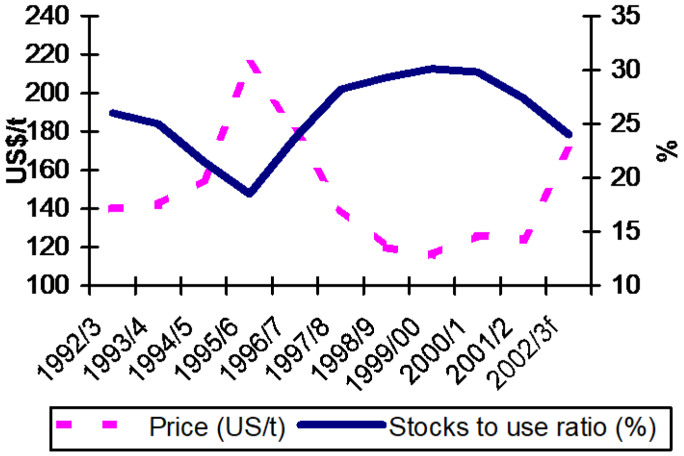


Figure 1. World prices and Stocks-to-use ratio of wheat: 1992/3 to 2002/3

With a decent season in 2003 many farmers, at least in prospect, are likely to generate substantial profits almost irrespective of their enterprise mix. So in the short term irrespective of whether the silence of the lambing continues or reverses, and depending on weather, pests and diseases, most farmers will make a lot of money in seasons 2003 and 2004.

Season 2003 and probably season 2004 are potentially bonanza years. But beyond these potential bonanzas what are the challenges for broadacre farming?

A Few of the Coming Challenges

Grain Transport Infrastructure: Roads & Rail

The length of highways and main roads currently affected by salinity is estimated to be about 250 km and the length of affected local and unclassified roads is around 3850 km. The annual cost of repairs and maintenance due to salinity is assessed to be almost $20,000 per kilometre for highways and main roads and around $6600 per kilometre for local and unclassified roads. The total combined current annual cost of salinity-related road repair is $20.9M. However, as salinity spreads, the length of highways and main roads at risk of being salt-affected over the next few decades will be around 1,190 km and the length of affected local and unclassified roads will be almost 23,000 km. Assuming no change in the cost per kilometre repaired, and assuming all roads in need of repair are fixed then the annual cost of repairs and maintenance due to salinity will increase to $23.7M for highways and main roads and $151.9M for local and unclassified roads. The combined annual cost will be $175.5M. To put that annual cost in perspective; to generate the annual equivalent revenue would require an annual grain levy of around $17 per tonne.

If only highways and main roads and local roads are repaired (i.e. unclassified roads are not repaired) then the annual cost falls to around $65 million with around 80 per cent of this cost attributed to local roads rather than highways and main roads. Hence, an issue for many shires and governments will be whether or not it is financially defensible to maintain the current rural network of local and/or unclassified roads.

Grain growers greatly depend on roads for delivery of inputs and transport of grain so the escalation of road repair and maintenance costs in coming decades has important ramifications for the ease and profitability of grain production. There are also important spatial differences in road costs. The northern wheatbelt will experience little change in these costs whereas the eastern wheatbelt and parts of the central wheatbelt face large increases

A similar story, but far less expensive, applies to railways. The length of railways classified as currently threatened by salinity is estimated to be 214 km, while the length forecast to be affected by salinity in coming decades is just over 1040 km. The likely range of current repairs and maintenance costs due to salinity are between $0.5M to $1.5M per annum with these costs rising to become the equivalent, in today's dollar terms, of annual costs of up to $7M or less than a dollar per tonne of grain. As with

roads, there are spatial differences in these costs, with the eastern and central wheatbelt being worse affected.

Social and Management Issues

One of the largest challenges to broadacre farming will come from the farm family and their changed social and economic expectations. A twin challenge for many farmers will be how to consistently generate farm profits while also making the social and personal life on the farm attractive and appealing, particularly to wives and the next generation. Historically, most farm families were willing to sacrifice income, standard of living and personal enjoyment for the good of the business. In the future, this may be less common.

The combination of high equity of many farm businesses, smaller family size, family break-up pressures and more investment choices outside the business, mean a fine balance will have to be maintained regarding the financial and social viability of the farm business. If the farm business does not provide a standard of living within desired family obligations and aspirations then the long-term legacy of the family business may be in doubt.

The quest for additional profit will see many farmers operating increasingly larger and complex businesses. These larger, more complex and fewer businesses will require more sophisticated management. Farmers' need for specialist advice as well as integration advice will increase although aggregate demand for these services may diminish due to a decline in the broadacre farming population.

Farm management will involve new emphases such as biotechnology, information and electronic technology, business analysis, group labour and process management, accreditation and contractual services. However, farm management will also involve more of the same such as decisions on the farm's enterprise mix, machinery replacement, land leasing or purchase, labour hiring and off-farm investments.

Family needs, education expenses and the reduced social and employment diversity in inland rural regions may lead some farm families to reside off their farms, at least for some years during their period of ownership and management of the farm business. The profit benefits of economies of size are forecast to continue, and together with declining family size, will further fuel rural de-population. The vibrancy of some rural communities will be further challenged, and isolation and loneliness will remain important issues affecting farm businesses.

Climate Change

The southwest of WA often supplies around half of Australia's wheat production, 40 % of Australia's wool production and 70% of Australia's grain legume production. Almost all wheat and wool is exported. Hence, the production ramifications of climate change in southwest Australia have implications for the State and national economy.

The various climate prediction models largely agree that there will be a significant decline in winter and spring rainfall in grain growing regions of WA. The implications for WA cropping of the climate forecasts are:

(i) a probable later start to growing seasons,

(ii) warmer, shorter growing seasons on average,

(iii) higher CO_2 concentrations that may increase crop yield, even under declining rainfall. However, grain protein may decrease.

(iv) rising temperatures that reduce the risk of frost yet more hot days during grain filling could reduce yields.

(v) less waterlogging yet less heavy winter rains that may disadvantage crops grown on clay and duplex soils in low rainfall regions.

(vi) more frequent extreme weather events (eg consecutive days of extreme heat) that could adversely affect crops.

(vii) altered risks of damage from pests and diseases. Higher temperatures are favourable to many insects, though the activity of some species will depend on any changes to summer rainfall. Warmer conditions in winter and spring favours many plant diseases.

The impact of climate change on crop sowing is illustrated for the eastern wheatbelt using farmers' current sowing rules. The average start of sowing will, over the next 20 years, become on average around 5 days later towards late May. Opportunities to sow early in April or May will lessen and sowing opportunities in June will increase (see Figure 2). The interval between sowing opportunities within a growing season will also lengthen so timeliness of sowing will become even more important.

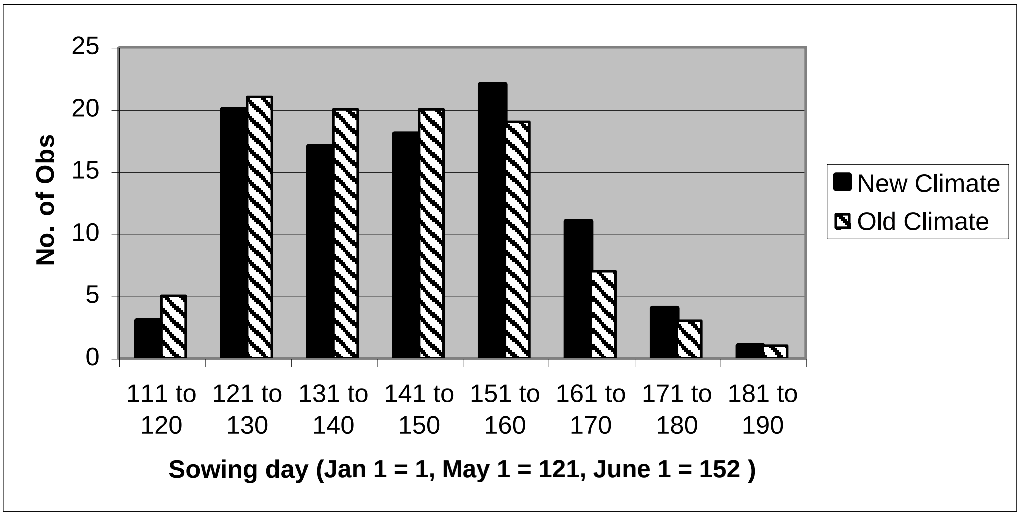


Figure 2. The start of crop sowing with and without climate change in the eastern wheatbelt

The low rainfall parts of the WA wheatbelt are major sources of grain production. However, the impact of climate change is to reduce the frequency of years that have very high crop yields due to either bountiful summer rain or an early start to crop sowing followed by favourable growing conditions. By contrast weather-years with a later start to crop sowing with less bountiful winter and spring rain will become more frequent. It's the former types of weather-years that are major sources of profit, especially for crop dominant farms.

So the practical implication of the unfolding change in distribution of types of weather-years is that many farm businesses may experience fewer very high profit years. These are the years often crucial for debt repayment and capital purchases. In the future, farms may experience longer periods of low or moderate incomes and this could increase financial pressures on those farm businesses.

CONCLUSION

Because grain and sheep farming is about to enter a period of buoyant commodity prices, generating a profit may not be a problem in the short run, assuming reasonable seasons and no pest or disease catastrophes. However, generating profits in the long run is more problematic. There are challenges ahead such as maintaining grain transport infrastructure, accommodating family and business aspirations and anticipating impacts of climate change.

KEY WORDS

farm profits, infrastructure, farm management, climate change

Maximising performance of wheat varieties

Brenda Shackley, Wal Anderson, Darshan Sharma, Mohammad Amjad, Steve Penny Jr, Melanie Kupsch, Anne Smith, Veronika Reck, Pam Burgess, Glenda Smith and Elizabeth Tierney, Department of Agriculture.

KEY MESSAGES

- 2002 was a year to forget in many areas but most varieties did have similar responses to sowing time, N and plant population to other years.
- Of the local varieties with some degree of rust resistance Wyalkatchem (sowing mid May onwards), Carnamah (mid to late May) and Calingiri (May) are the highest performers.
- Carnamah was less yield responsive to applied N in 2002, similar to Wyalkatchem and Mitre. Wyalkatchem and Carnamah have an average response to plant population. On limited data Bonnie Rock required higher rates of N and more plants/m^2 than other varieties.

AIMS

It is well recognized by grain growers in the state that there are appropriate management conditions required for any wheat variety to obtain optimal performance. The questions that growers must answer include optimum sowing times, optimum nitrogen rates and plant densities to meet both yield and quality targets.

With agronomy projects based in the North, Central, Great Southern and South Coast our aim is to characterise WA wheat varieties for their yield and quality responses to agronomic practices. The information presented in this paper has been derived since 1999 and concentrates on the three WA varieties with the best available resistance to Stripe rust. In addition there are limited data for the new limited release Bonnie Rock and some interstate lines.

METHOD

Trials were located from Geraldton to Esperance, covering a range of soil types and rotations.

Response to sowing time was based on experiments usually with three sowing times (the first close to the break and thereafter at 15 to 21 day intervals). Sowing time response is based on the spread and the frequency of dates at which the variety achieved its maximum yield.

Nitrogen (N) response as used here is the change in yield between nil and the first N rate used (usually 20 to 50 kg/ha of N) in responsive situations. Data from experiments where there was no significant yield response to N were not used for assessment of N response.

Response to seed rate was assessed as the estimated optimum plant population, from experiments containing target populations 50 to 300 plants/m^2. Average seed size, and estimated field establishment should be used in calculating seed rates. Optimum plant population is estimated as the point on the yield repsonse curve where yield increases 2.5 kg/ha for each additional 1 plant/m^2. It is the minimum population (or seed rate) required under good conditions in a weed-free environment.

RESULTS

Time of sowing

In 2002 the maximum yield of Carnamah, Calingiri, Wyalkatchem, Westonia and Bonnie Rock were achieved in the later half of May, the first opportunity to sow many of the trials. The results were similar to those reported at the Updates in 2002 for trials in 1999 to 2001. Calingiri is the only variety that appears to have a restricted range of sowing times (mid-May). Carnamah has an optimum sowing time of mid-May onwards, while Wyalkatchem has a wider optimum of mid-late May, and Westonia and Arrino late May. There are limited data for Bonnie Rock but it would appear to be similar to Carnamah. Mitre, Yitpi, Mira and others were included in two trials at Esperance in 2002 but with limited data and extreme ranges the optimal sowing time was not defined.

Nitrogen efficiency

The efficiency of nitrogen use in 2002 was lower overall than in other years (Table 1). The ranking of the varieties over the years is similar with the exception of Carnamah in 2002. In other years Carnamah was one of the most yield efficient users of N but in 2002 it was similar to Wyalkatchem, one of our least yield responsive varieties to applied N. Data from 2002 suggests that Bonnie Rock is as responsive or more than Carnamah.

Table 2: Agronomic efficiency of nitrogen use (kg of grain/kg of N applied) of wheat varieties in 2002, 1999-2001 and All years

Variety	2002 Average	Average 1999-2001	All years
Carnamah	4	13	11.5
Wyalkatchem	4	8	6
Calingiri		10 (2)	
Westonia	4.5 (1)	11	10
Bonnie Rock	7		
Mitre	4.5 (1)		
H45	8.5 (1)		

(1): Only one trial

Plant population

Carnamah's optimum plant population of 100 plants/m^2 was similar to the 2001 findings. Based on the 2.5:1 ratio (see method) Wyalkatchem's optimum plant population is also between 100-120 plants/m^2. (Actually higher in 2002 due presumably to seasonal conditions). Bonnie Rock achieved an optimum population between 135 and 145 plants/m^2, suggesting it is similar to Calingiri in it's requirement of a high plant population to achieve maximum yield. Data from one trial sown late June at Mt Ridley (Esperance) found both Mitre and H45 to have an optimum plant population of 60-65 plants/m^2 ie a very flat yield response.

CONCLUSION

Wyalkatchem, Carnamah and Calingiri have the best available rust resistance of the WA wheat varieties and were some of the highest performers in the agronomy trials throughout the state. ***Wyalkatchem*** is adapted to sowing from mid May onwards, reaching its top yields at slightly later sowings than Carnamah. This variety is shown to be more protein responsive than yield responsive to applied nitrogen. It responds to average plant populations (100-120 plants/m^2 or 55 kg/ha seed rate) but under the conditions last year it required a plant population above 200 plants/m^2 to achieve the highest yield. Even with mid-season maturity, ***Carnamah*** is one of the most adaptable wheat varieties to sowings from mid May. This variety has shown to be one of the most yield responsive to applied N, although the poorer performance in 2002 suggests this response may be season-dependent. Carnamah has an average response to plant population, requiring 100 plants/m^2 (about 50kg/ha of seed). ***Calingiri*** is adapted to mid-may sowing, requires a plant population of over 135 plants/m^2 (>60 kg/ha of seed), and is probably more yield than protein responsive to added N. ***Bonnie Rock***, which has a limited release to Agzone 1 and 4, appears to also be adapted from mid May sowings onwards. Limited data from 2002 also suggests that it has a high yield response to N and also plant population of 135-145 plants/m^2. Not a variety for low input situations. ***Mitre*** when sown late June in Esperance in 2002, was neither yield responsive to applied N or plant population. More data are required.

KEY WORDS

Wheat, varieties, agronomy, time of sowing, nitrogen, seed rate, yield.

ACKNOWLEDGMENTS

Thanks to GRDC for some of the funding, the managers and staff of the Crop Variety Testing team and the Research Support Units.

Project No.: DAW 12

Paper reviewed by: **Wal Anderson**

Wheat Variety Performance in Wet & Dry

Peter Burgess

KEY MESSAGES

In recent years a number of new wheat varieties from a range of private and public institutions have been introduced into the farming system. New varieties are being released to growers at an increasing rate due to commercial pressures from breeding programs and from grower demand as a result of poor performance of existing varieties.

AIM

Through small plot research, evaluate new and soon to be released wheat varieties from a range of public and private breeding institutions to determine suitability for a range of West Australian soil types and environmental conditions.

METHOD

Agritech Crop Research conducts wheat variety evaluation trials as part of the GRDC funded projects AGT19 and AGT17 in the central west, central and southeast wheatbelt. These trials are located across a diverse range of locations (West Bolgart, South Dowerin, Maya, Buntine, Doodlakine, Meckering, Corrigin and Holt Rock). WA and interstate varieties are evaluated across a range of soil types and environmental conditions in small plot replicated trials. The results are analysed according to yield and quality parameters and ranked on gross earnings per hectare.

RESULTS: THE TOP 15 PERFORMING VARIETIES 1999-2002

1999 Bolgart (wet season)			1999 Kellerberrin (wet season)			1999 Koorda (wet season)		
Variety	**Yield t/ha**	**Income $/ha**	**Variety**	**Yield t/ha**	**Income $/ha**	**Variety**	**Yield t/ha**	**Income $/ha**
Datatine	4.792	$824.61	Cunderdin	3.297	$547.57	Camm	4.928	$867.72
Brookton	4.919	$807.11	Brookton	3.333	$528.55	**RAC 868**	4.938	$867.01
RAC 873	4.329	$799.05	**Krichauff**	3.215	$513.05	Westonia	4.897	$850.02
Camm	4.306	$786.19	**RAC 868**	3.174	$509.68	**RAC 873**	4.835	$844.09
Cadoux	4.051	$782.17	**RAC 873**	3.061	$494.60	Calingiri	4.434	$836.16
Carnamah	4.363	$774.78	Westonia	3.025	$488.78	**Yitpi**	4.774	$835.83
Cunderdin	4.606	$769.57	Perenjori	2.909	$487.49	Cadoux	4.336	$828.52
Calingiri	3.924	$755.68	Nyabing	3.030	$485.04	**Krichauff**	4.959	$816.15
Westonia	4.456	$737.82	Calingiri	2.973	$481.86	Brookton	4.846	$797.55
Nyabing	4.155	$725.38	Cadoux	2.963	$480.24	Nyabing	4.516	$797.44
H45	4.039	$701.09	**H45**	2.994	$476.29	Tamaroi	3.673	$797.33
Rac 868	3.947	$687.09	Camm	2.999	$475.58	WAWHT 2151	4.702	$785.61
Perenjori	3.588	$676.63	**Yitpi**	2.824	$467.60	Cunderdin	4.655	$766.12
Yitpi	3.472	$654.75	WAWHT 2151	2.922	$464.83	Carnamah	4.640	$759.01
Krichauff	3.623	$612.58	Datatine	2.670	$462.12	**H45**	4.542	$758.88
LSD (P=0.05)	*697kg/ha*		*LSD (P=0.05)*	*297kg/ha*		*LSD (P=0.05)*	*358kg/ha*	

2000 High Rainfall (Bolgart)			2000 Medium Rainfall (Sth Dowerin)			2000 Low Rainfall (Buntine)		
Variety	**Yield t/ha**	**Income $/ha**	**Variety**	**Yield t/ha**	**Income $/ha**	**Variety**	**Yield t/ha**	**Income $/ha**
RAC892	4.280	$ 765.00	Westonia	1.991	$ 378.00	Calingiri	4.527	$ 955.00
Frame	3.961	$ 700.00	Arrino	1.842	$ 344.00	**RAC868**	3.987	$ 711.00
Brookton	3.961	$ 686.00	Carnamah	1.646	$ 343.00	**RAC873**	3.976	$ 707.00
Carnamah	3.951	$ 679.00	WAWHT2137	1.770	$ 343.00	**Kukri**	3.740	$ 680.00
Camm	3.940	$ 676.00	**RAC873**	1.775	$ 341.00	Camm	3.817	$ 676.00
Perenjori	3.652	$ 669.00	**Kennedy**	1.651	$ 323.00	**Frame**	3.940	$ 668.00
Chara	4.002	$ 660.00	Camm	1.667	$ 322.00	**Yitpi**	4.079	$ 662.00
Calingiri	3.909	$ 652.00	Amery	1.646	$ 320.00	Westonia	3.868	$ 646.00
Nyabing	3.642	$ 627.00	**RAC868**	1.636	$ 319.00	Cadoux	3.843	$ 645.00
H45	3.426	$ 618.00	**Yitpi**	1.559	$ 309.00	Cunderdin	3.858	$ 625.00
Cadoux	3.724	$ 606.00	Calingiri	1.620	$ 301.00	**Halberd**	3.807	$ 585.00
Cunderdin	3.642	$ 599.00	Brookton	1.502	$ 297.00	Arrino	3.452	$ 574.00
RAC873	4.002	$ 572.00	**Stiletto**	1.471	$ 289.00	Brookton	3.776	$ 541.00
RAC868	3.899	$ 561.00	WAWHT2046	1.487	$ 284.00	Carnamah	3.138	$ 519.00
Yitpi	4.023	$ 559.00	**Mulgara**	1.445	$ 282.00	Kalannie	3.092	$ 498.00
LSD (P=0.05)	*323kg/ha*		*LSD (P=0.05)*	*248kg/ha*		*LSD (P=0.05)*	*412kg/ha*	

2001 High Rainfall (Bolgart)			2001 Medium Rainfall (Cunderdin)			2001 Low Rainfall (Kellerberrin)		
Variety	**Yield t/ha**	**Income $/ha**	**Variety**	**Yield t/ha**	**Income $/ha**	**Variety**	**Yield t/ha**	**Income $/ha**
Calingiri	4.563	$1,210	Calingiri	3.097	$790	Karlgarin	3.014	$719
Lang	4.053	$1,081	Wyalkatchem	3.338	$778	**Yitpi**	2.922	$714
Chara	4.342	$1,046	Arrino	3.133	$771	Calingiri	3.004	$696
Stiletto	4.300	$1,040	Cunderdin	3.071	$750	**Giles**	2.906	$695
Babbler	4.285	$1,036	Karlgarin	3.050	$735	Wyalkatchem	2.840	$694
Karlgarin	4.311	$1,031	WAWHT2281	3.030	$724	**Lang**	2.840	$691
WI99069	4.234	$1,027	Brookton	3.045	$717	Cunderdin	2.798	$686
Yitpi	4.198	$1,001	**Stiletto**	2.886	$715	**Mitre**	2.814	$680
Brookton	4.192	$975	**Yitpi**	2.973	$708	**Babbler**	2.762	$666
Carnamah	3.843	$958	**Giles**	2.912	$706	Nyabing	**2.726**	$666
Stylet	4.218	$956	Westonia	2.958	$704	Carnamah	2.685	$665
Camm	4.053	$953	**Baxter**	2.809	$700	Brookton	2.881	$665
H45	3.889	$952	**Chara**	2.942	$700	**Stylet**	2.726	$656
Petrie	4.084	$947	Nyabing	2.942	$698	Arrino	2.829	$654
Kukri	4.110	$936	**Babbler**	2.963	$693	**Baxter**	2.690	$648
LSD (P=0.05)	*394kg/ha*		*LSD (P=0.05)*	*315kg/ha*		*LSD (P=0.05)*	*265kg/ha*	

2002 High Rainfall (Bolgart)			2002 Medium Rainfall (Cunderdin)		
Variety	**Yield t/ha**	**Income $/ha**	**Variety**	**Yield t/ha**	**Income $/ha**
Wyalkatchem	3.267	$912.93	Wyalkatchem	2.009	$585.52
Yitpi	3.598	$907.82	WAWHT2193	2.015	$563.09
Calingiri	3.175	$896.96	**Stylet**	1.829	$533.06
Yitpi	3.360	$896.68	Westonia	1.841	$520.91
Stylet	3.360	$894.94	WAWHT2530	1.796	$509.97
RAC 964	3.333	$894.03	Arrino	1.779	$506.93
RAC 891	3.373	$888.48	WAWHT2549	1.768	$503.79
RAC 951	3.399	$880.40	Carnamah	1.706	$497.21
GBAI 099	3.161	$876.98	**GBAI 099**	1.734	$494.97
GBAI 099	2.989	$857.45	**WI99069**	1.667	$490.85
Camm	3.201	$831.08	Camm	1.588	$485.85
RAC 964	3.042	$817.90	**Yitpi**	1.672	$484.80
RAC 891	2.937	$807.29	WAWHT2281	1.712	$482.70
Lang	2.950	$806.34	**H45**	1.745	$481.53
WAWHT2193	2.937	$795.23	**RAC 891**	1.650	$480.89
LSD (P=0.05)	*310kg/ha*		*LSD (P=0.05)*	*210kg/ha*	

CONCLUSION

In recent times we have been able to evaluate a wider range of Eastern State bred varieties due to greater access to the material. We have compared their performance to WA bred material. Trial results show many of the improved varieties are performing better than the older varieties they are designed to replace, indicating there is genetic improvement in the new material. This will ultimately benefit growers. At the high rainfall sites, disease resistance is often a major factor influencing variety performance, where as in the medium and low rainfall sites it is more often variety adaptation to seasonal conditions (quicker finish) and soil type. Interstate-bred varieties make up around 50% of the top 15 performing varieties in the last two years. With continuing widespread evaluation of local and interstate material we will be able to provide an ongoing and up to date database on variety performance to growers and professionals in agriculture.

KEY WORDS

Variety, Environnment, Soil, Performance, Wheat.

ACKNOWLEDGMENTS

All growers who have provided land for the trials. GRDC for funding the research projects.

Project No.: AGT19, AGT 17

Paper reviewed by: Ashley Bacon

e-VarietyGuide for stripe rust – an updated version (1.02 – 2003)

Moin Salam, Megan Collins, Art Diggle and Robert Loughman
Department of Agriculture, Western Australia.

KEY MESSAGES

An early version (1.01 – 2002) of the e-VarietyGuide for stripe rust, released in October 2002, was well received by the Agribusiness community of Western Australia. Many recipients suggested that the effect of seeding treatment should be incorporated into the estimator to make it more useful. Accordingly, a revision has been made in this version (1.02 – 2003). The current version also includes revised stripe rust ratings for some of the wheat varieties based on 2002 experimental results.

AIMS

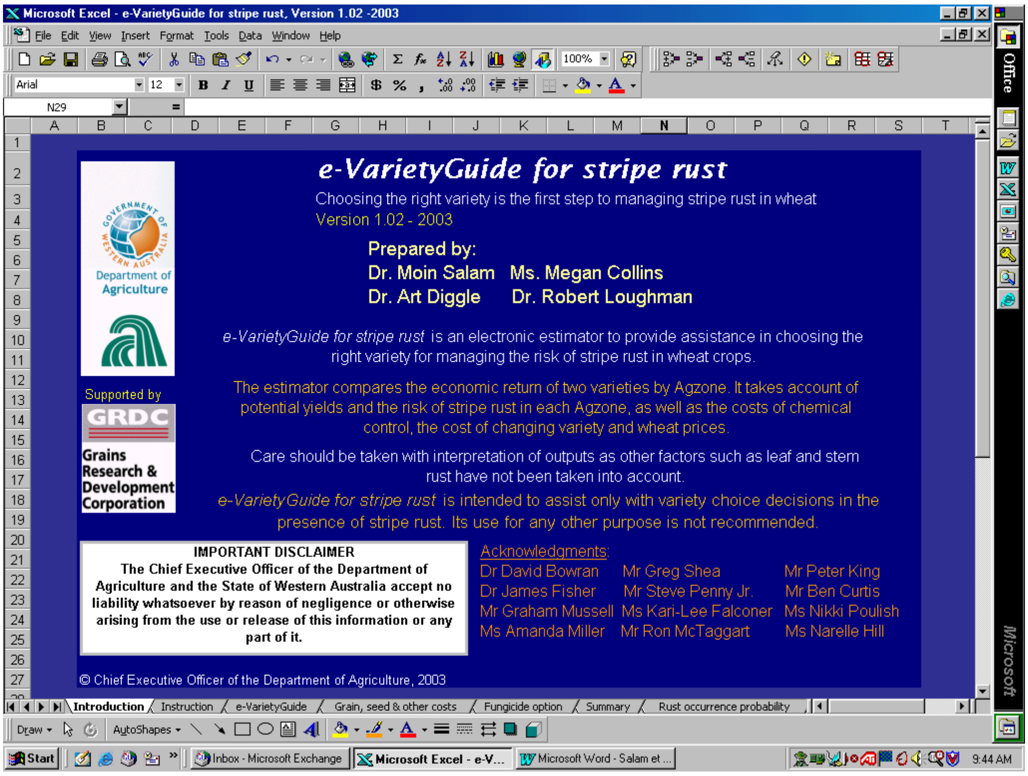
- To provide assistance in choosing the right variety for managing stripe rust in wheat.
- To compare economic returns of two wheat varieties by Agzone by taking account potential yields and risk of stripe rust as well as costs of chemical control, cost of changing variety and wheat prices.

THE ESTIMATOR

The e-VarietyGuide for stripe rust is intended to assist with variety choice decisions in the presence of stripe rust in wheat. The estimator considers the following:

- The performance of the varieties according to Agzone, as per data from Crop Variety Sowing Guide 2002.
- The estimated level of stripe rust resistance in the varieties.
- The risk of stripe rust in each Agzone, expressed as the probability of stripe rust first occurring at the beginning of July, August or September, or not at all.
- Seeding treatment (seed dressing or applied in-furrow with fertilizer) reduces the probability that stripe rust will occur in all times (July, August or September). The amount of reduction depends on the effectiveness of the product to be used.
- The number of foliar applications of fungicides required to manage stripe rust in varieties of different susceptibility according to when they become infected.
- The cost and estimated benefits of spraying and/or seeding treatments.

The estimator is a simple, easy-to-understand Microsoft Excel-based programme. It consists of 11 worksheets: Introduction – an overview of the estimator highlighting its aims, objectives, and limitations; Instruction – provides instructions on the use of the estimator; e-VarietyGuide - main input and output section; Grain, seed & other costs – allows specification of grain price according to grade, seeding rate, seed price, cost of changing variety and other input costs; Fungicide options – allows fungicide and application cost or cost and effectiveness of the seeding treatment to be specified, and provides information on products available for seeding treatment; Summary – provides details of the output; Rust occurrence probability – allows the probability of stripe rust occurrence in July, August or September, or not at all to be set according to Agzone; also shows the effects on net return of any changes in these figures; Variety information - lists wheat varieties and their relative yield potentials in each Agzone together with their stripe rust, leaf rust and stem rust resistant ratings; Assumptions, A - shows the underlying assumptions of yield loss due to stripe rust at different resistance ratings, and yield loss recovery of the varieties for different numbers of sprays applied; Assumptions, B - shows stripe rust occurrence probability in each Agzone, and spray requirement for stripe rust control in relation to the resistance rating of a variety and the time arrival of stripe rust; and Assumptions, C - shows how seeding treatment changes the probability of time of occurrence/not occurrence of stripe rust in relation to the effectiveness of the product to be used.



Advisers, consultants, agronomists and development officers are the intended users of this estimator. Care should be taken with interpretation of results as the estimator has several limitations including those mentioned below.

SOME LIMITATIONS OF THE ESTIMATOR

- Other rust diseases (such as leaf and stem rust) do not have a bearing on the yield loss or yield recovery estimates. This means that the outputs only apply for stripe rust. For example, Camm wheat is susceptible to leaf rust and stem rust but the estimator considers only the need to spray and/or apply seeding treatment for control of stripe rust to which Camm is resistant.
- The estimator does not consider the effect of varying of sowing time on stripe rust infection.
- Some varieties do not have yield potential estimates for some regions (eg, soft wheat) and consequently not all comparisons will be possible.

AVAILABILITY

The CD of the e-VarietyGuide for stripe rust, Version 1.02 – 2003 is available in the Agribusiness Crop Updates 2003 and Regional Crop Updates 2003, or in the DAWA-Centre for Cropping Systems, Northam (telephone (08) 9690 2000); fax (08) 9622 1902; email: northam@agric.wa.gov.au).

KEY WORDS

Electronic variety guide, stripe rust, wheat.

ACKNOWLEDGMENTS

The Grains Research and Development Corporation (GRDC) provide funds for this research. The GID and CVT of DAWA sponsor for production of CDs.

Project No.: DAW 00018

Paper reviewed by: Dr. Robert Loughman and Dr. Art Diggle

Baudin and Hamelin – new generation of malting barley developed in Western Australia

Blakely Paynter, Roslyn Jettner and Kevin Young, Department of Agriculture

KEY MESSAGES

Hamelin and Baudin offer significant malting quality improvements over Stirling and Gairdner. Improved malting quality is a key trait to maintaining our competitiveness in international markets like China, Korea and South America.

Hamelin is seen as a replacement for Stirling with wide regional adaptation, slightly improved grain yield and improved grain colour. Screening levels in Hamelin are likely to be slightly higher than Stirling. It has similar disease susceptibility as Stirling. A potential risk of pre-harvest sprouting (similar susceptibility as Harrington) makes it less suitable for production in southern high rainfall areas.

Baudin may be grown as an alternative to Gairdner. It has wider regional adaptation than Gairdner particularly in the medium rainfall areas, due to a plumper grain shape and more adaptable phenological pattern. Baudin may also be an option for early May sowing in low rainfall areas where Gairdner has been tried. Baudin is susceptible to most diseases except scald. The grain yield of Baudin is comparable to the best feed barley varieties and Gairdner barley.

RELEASE OF HAMELIN AND BAUDIN

Western Australia exports over 80% of the barley produced, with grain meeting export malting specifications being exported to countries such as China and Korea. China is our most important market with an annual (but growing) requirement for 3 Mt of malting barley. Australia typically supplies 45% of China's needs followed by the EU (20%) and Canada (15%). Domestic barley grown in north east China makes up the remainder of the barley needed.

The current specification for malt being demanded by the Chinese brewing market is for a lowly modified malt with high malt extract, high free amino nitrogen and low wort boil colour. This malt is added to the mash with between 25% to 40% rice adjunct to produce a pale yellow style of beer. Whilst the blending of Australian, Canadian and European malt is common to achieve that specification, the major issues facing Chinese maltsters using Australian barley varieties are:

- Slow rates of modification of some varieties (eg Stirling),
- Low diastatic power (eg Schooner),
- Low free amino nitrogen levels when gibberellic acid is not used (eg Gairdner),
- High turbidity of the mash (eg Stirling), and
- Poor wort boil colour (eg Arapiles).

Different environmental conditions during the malting process (cooler temperatures experienced in northern China during steeping slow down modification) and the pale yellow style of beer produced impact on how well new Australian varieties are accepted in the Chinese malting and brewing market. As we have known for some time Stirling is not well accepted by many maltsters, particularly those in northern China with poorer process control during malting.

Two new barley varieties – Hamelin (tested as WABAR2104) and Baudin (tested as WABAR2080) were released as provisional malting by the Western Malting Barley Council in conjunction with the Department of Agriculture in November 2002. These varieties are being evaluated for their suitability to overseas markets including China. Micro-malt results indicate that both varieties show improvements in malt extract, diastatic power and free amino nitrogen relative to both Stirling and Gairdner. These micro-malt results also suggest faster rates of modification are characteristics of the new varieties. Improved modification rate should better suit them to the Chinese market than Stirling.

It is anticipated that the Grain Pool will pack containers of Hamelin and Baudin grain to send overseas at the end of the 2003/04 harvest to obtain feedback from our international buyers of malting barley. Feedback from these customers combined with commercial malting and brewing trials in Australia will determine whether or not Hamelin and Baudin are upgraded to a general malting classification from their current provisional malting status.

HAMELIN MANAGEMENT

Hamelin is a cross between Stirling and Harrington and is an early spring maturity barley. It flowers near the same date as Stirling and has the same phenological development pattern as Stirling (high level of daylength sensitivity). Hamelin has a similar plant appearance to Stirling with similar height straw that may be less prone to lodging with slightly less head loss.

Hamelin has a similar response to agronomic practices as for Stirling and should be managed in a similar manner to achieve maximum grain yield and quality. Target a sowing date of late May and sow following a non-legume crop. Hamelin is adapted to a wide range of soil types, although like Stirling it is not suited to soils that are high in levels of boron or aluminium. Sowing on highly fertile soils following a long history of legumes or heavy soils in low rainfall areas may increase the level of grain protein above that suitable for the malting industry.

Hamelin is susceptible to powdery mildew, barley leaf rust, net-type net blotch and scald and moderately susceptible to spot-type net blotch. To maximise production from this variety, farmers will need to protect their crops from foliar diseases by developing an integrated management strategy that includes crop rotation, stubble management and seed or foliar fungicides.

BAUDIN MANAGEMENT

Baudin is a cross between Stirling and Franklin and is a medium maturity spring barley. Its development pattern is based on a high level of daylength sensitivity and therefore has a wider regional and sowing date adaptation than Gairdner. Baudin shows more potential for sowing in Agzones 1, 2 and 5 than currently exists with Gairdner.

Baudin is a semi-dwarf barley with a plant habit that is similar to Fitzgerald and Skiff. It has strong straw, good head retention and excellent standing ability. Screenings of Baudin are less sensitive to management than Gairdner due to its plumper-shaped grain, however crop management targeted at minimising screenings is critical. Selecting a soil type with good moisture holding capacity and sowing in May increases the opportunity for Baudin to meet malting specifications.

Baudin is a high yielding barley that tends to produce grain with a low protein. Calculate the nitrogen required to grow Baudin at 10 per cent protein, using a similar fertiliser regime as for a high yielding crop of Gairdner. Baudin should be grown following canola or wheat in low take-all disease situations. It may be suitable for sowing after a legume crop however adjustments need to be made to the rate of nitrogen fertiliser applied to manage grain protein and screenings.

Baudin is susceptible to spot-type net blotch, barley leaf rust, powdery mildew and net-type net blotch and has intermediate resistance to scald. Powdery mildew and scald can be managed by applying a registered fungicide to the seed or fertiliser. Foliar fungicide may be required during stem elongation.

OBTAINING SEED AT 2003/04 HARVEST

Hamelin and Baudin attract a CIR (end point royalty) of $3/t delivered. No seed royalty is payable on any seed purchased. Seed of both Hamelin and Baudin will be available at the 2003/04 harvest from registered seed licensees. Farmers who have bought and grow either Hamelin or Baudin during the 2003 season can apply for a seed selling licence to become a registered seed licensee. Growers will need to have their seed meet certified or registered seed standards to be suitable for an on-selling licence. Further information about how to obtain a seed selling licence will advertised around August.

KEY WORDS

Barley, malt, Hamelin, Baudin

ACKNOWLEDGMENTS

The development of Hamelin and Baudin was undertaken by staff within the Department of Agriculture and the University of Western Australia and supported by GRDC and the Western Malting Barley Council.

Project No.: DAW00045, DAW00051, DAW00059

Paper reviewed by: Roslyn Jettner

Oaten Hay Production

Jocelyn Ball, Natasha Littlewood and Lucy Anderton, Department of Agriculture

KEY MESSAGES

- Although a high-risk crop, oaten hay has the potential to outperform all other cereals with respect to gross margins.
- Phosphorous (P) significantly increases both hay and grain yield.
- Increased seeding rate can reduce weed biomass.
- Wandering and Vasse have performed well in hay trials.

INTRODUCTION

Although the market is thriving, producing oaten hay is still a "risky" business. The high input costs and the volatile market associated with oaten hay enhance the risk. Farmers need to consider this carefully before embarking on hay production programs. Nutritional requirements for oats, selection of a suitable variety and weed management options, are all factors to consider when growing oats for oaten hay. By looking at these issues thoroughly, returns from oaten hay can be very favourable as suggested in Table 1.

Oat agronomy trials in 2002 included studies on nutrition (phosphorous (P), potassium (K) and nitrogen (N)), oaten hay varieties and weed management. These trial results will assist in general recommendations for oaten hay production with an aim to reduce some of the production risk associated with growing oaten hay.

Table 1: Gross margin returns ($/ha) from various cereal crops in the Great Southern.

Gross income($/ha)		**WHEAT 385.00** (2.2 t @ $175)	**BARLEY 330.00** (2.2 t @ $150)	**CANOLA 402.00** (1.2 t @ $335)	**OATEN HAY 900.00** (7.5 t @ $120)
Input costs ($/ha)					
Seed	Seed	14.00	12.00	16.00	16.80
	Seed treatment	6.24	6.40	-	10.92
Fertiliser	NPS Compound	37.20	37.20	56.50	36.00
	Urea	25.20	18.00	36.00	36.00
	Potash	-	-	-	71.40
	Cartage	3.42	3.06	3.60	6.57
Chemicals	1st knockdown	4.45	4.45	6.40	7.84
	2nd knockdown	25.10	25.10	-	10.00
	Post emergent	11.10	11.10	43.00	24.64
Machinery	Fuel & oil	22.00	22.00	24.00	18.00
	Repairs etc.	23.00	23.00	25.00	18.00
Contractors		-	-	22.00	330.00
Labour		11.25	11.25	11.25	-
Insurance		2.98	2.55	2.68	-
Interest		8.37	7.92	11.54	26.38
Total variable costs ($/ha)		**194.30**	**184.03**	**267.97**	**612.55**
Gross margin ($/ha)		**190.70**	**145.97**	**134.03**	**287.45**

OPTIONS FOR IMPROVING OATEN HAY RETURNS

Variety

What is the best oaten hay variety to grow? Two of the most widely grown varieties for oaten hay are Carrolup (18% of area sown to oats) and Vasse (2% of area sown to oats). This is due to their thin stem and colour, but do they have a high hay yield? A hay trial conducted at Avondale Research Station in 2002 demonstrated that Vasse was a higher yielding hay variety compared to Carrolup, Esk, Massif, Vasse, Winjardie and Wandering (Figure 1). Vasse also has the advantage of being resistant to leaf rust and septoria. This is important, as septoria has caused a significant amount of

downgrading in the past. Vasse however, is a late maturing variety that is not suitable for the low rainfall areas. Carrolup had the lowest hay yield.

Hay yields from the feed oat Wandering were comparable to Winjardie, but it may encounter resistance with the export hay market due to its thicker stem diameter. Sowing at higher seed rates can reduce stem thickness. Growers should check exporters' specific requirements if they are interested in growing hay for the export market.

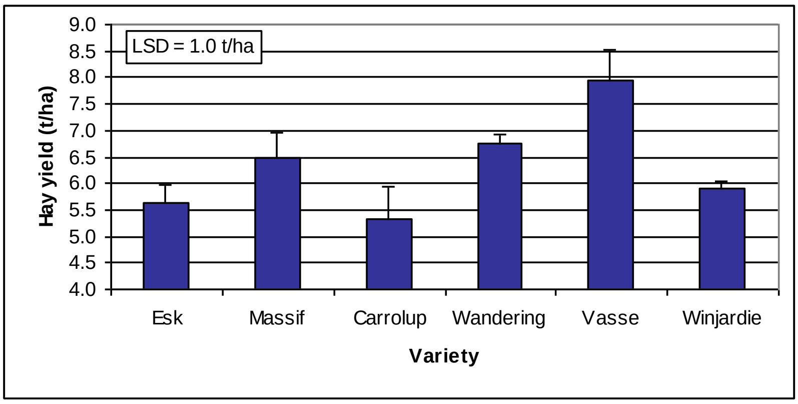


Figure 1. Comparison between the hay yield (t/ha) of different oat varieties when grown at Avondale Research Station in 2002.

Nutrition

Nutrition is important for oaten hay production. Soil testing both before and after production is essential, as both nutrient removal and nutrient requirements are big issues (and are often confused). Both are critical in terms of future production and current returns.

Phosphorus (P) is an important nutrient for hay production. A P rate trial west of Katanning (background P = 21 ppm 0-10cm), showed hay yield improvements of nearly 40% when P was applied. Hay yields of Carrolup increased from 6.3 t/ha with no P applied to over 10 t/ha when more than 30 kg P/ha was applied. Differences in the P requirements of different varieties were also found. Traditional milling lines (Carrolup and Hotham) had a higher requirement for P than the non-milling lines (Dalyup and Wandering) (Figure 2). This trial also indicated that the requirements to maximise hay yield and grain yield were similar, suggesting that current soil test recommendations for grain production will maximise hay yield. Further research will be conducted in 2003 to confirm these observations.

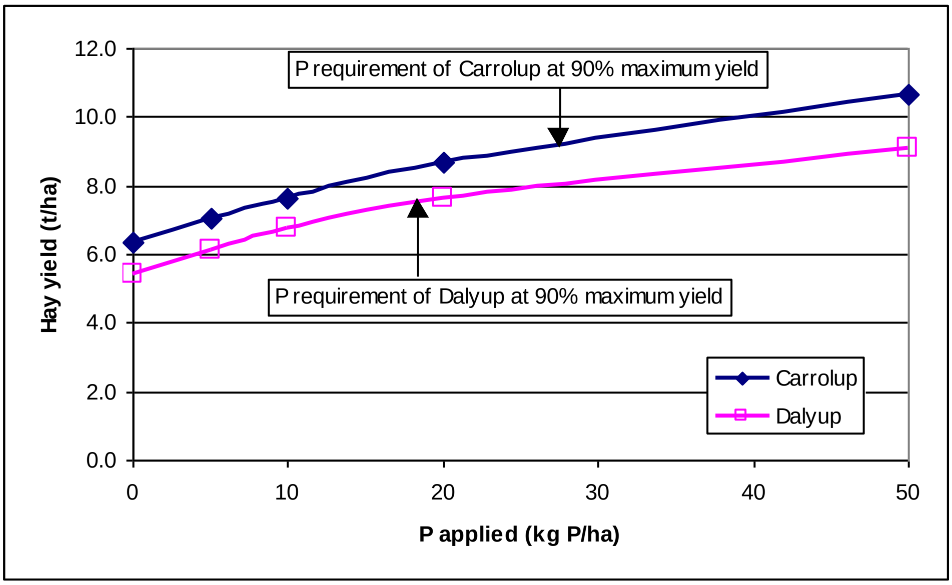


Figure 2. Relationship between phosphorus application (kg P/ha) and between the hay yield (t/ha) of two oat varieties when grown at West Katanning in 2002. Carrolup required 28 kg P/ha to reach 90% maximum yield whilst Dalyup only required 19 kg P/ha.

It is important to budget for potassium (K) in the years following oaten hay production, as K has been proven to affect the amount of screenings produced in wheat the following year. Research conducted by Glen McDonald has shown that K is required to maximise hay yields particularly when P is applied. Potassium may also increase the digestible energy of the hay.

Weed Control

Weed competition not only reduces hay yield, its presence in the bale can cause downgrading or rejection for export hay production. Two factors that have the biggest impact on weed competition are the seeding rate of the oats and the use of appropriate herbicides. A trial at Katanning Research Station in 2002 found a significant reduction in weed contamination when the number of oat plants sown was increased from 240 to 400 plants/m^2. Herbicide applied in the same trial also showed reductions in weed biomass (Figure 3), without affecting hay yield. This reduction in weed biomass may be the difference between the acceptance, rejection or downgrading of your hay (export hay has a weed contamination limit of 5%).

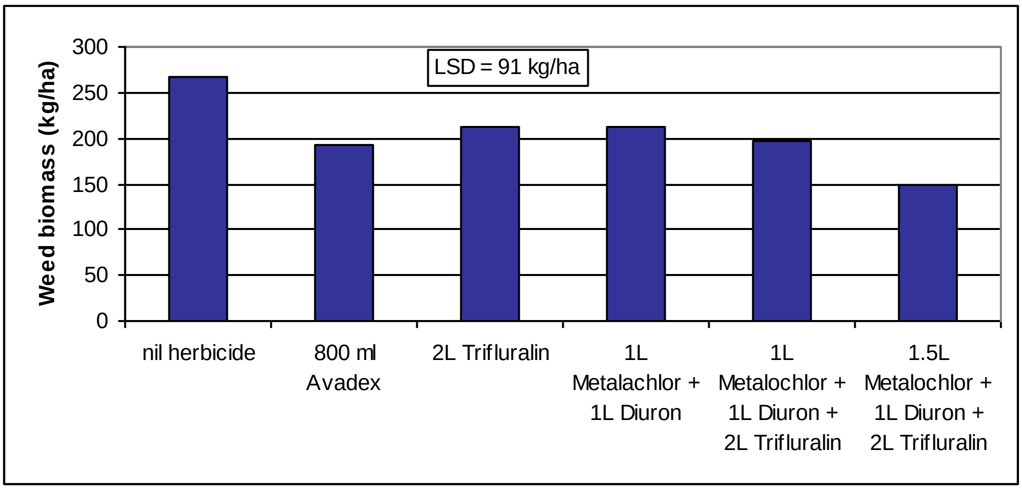


Figure 3. Impact of different herbicide combinations on weed biomass (kg/ha). Note: some of these herbicide treatments are off label and are used only for scientific purposes.

CONCLUSION

- Oaten hay yield can be improved by sowing an appropriate variety, applying enough fertiliser to meet current growth and that removed when cutting hay and minimising weed growth.
- Phosphorous (P) has a big impact on oat production. Additions of P can significantly increase both hay and grain yields, with the requirements for hay and grain similar. Oat varieties may differ in their P requirements. Although nitrogen (N) and potassium (K) are important to hay, their influence may not be significant without adequate P application.
- Controlling weeds in oaten hay production is vital. Increasing seeding rates and applications of recommended herbicides can reduce weed biomass considerably and reduce the risk of rejection.
- Wandering and Vasse are two hay varieties that have performed well in the medium to high rainfall areas between Katanning to Northam. Although Carrolup had a lower hay yield in a trial at Avondale it is still well regarded as a dual-purpose oat, that is suitable for both hay and grain production.
- By considering these findings, oaten hay has the potential to outperform all other cereals with the respect to gross margins.

KEY WORDS

Oaten hay, economics, nutrition, weed control, variety

Project No.: DAW 705

Paper reviewed by: Alex Douglas and Blakely Paynter

Improvement of waterlogging tolerance in wheat and barley

Irene Waters and Tim Setter, Department of Agriculture Western Australia

KEY MESSAGES

A recent review by Setter and Waters (Plant and Soil) has highlighted different types of waterlogging and the effects on crop production. Large spatial and temporal variation in waterlogging, highlight the need to characterise the environment to allow mechanistic approaches to germplasm improvement for target environments. Genetic diversity in waterlogging tolerance exists in wheat and barley and different mechanisms of tolerance are important depending on the stage of development when waterlogging occurs.

AIMS

Details of the timing, duration and intensity of waterlogging in soils are important for extrapolation of results between regions, to enhance germplasm exchange relevant to specific environments, to set guidelines for controlled experiments in the glasshouse and laboratory for accurate phenotyping and to give clues about possible adaptive traits for waterlogging tolerance. Our research has focussed on developing screening methods for use in germplasm improvement for waterlogging tolerance at the germination and seedling stages where the greatest effects on crop production are seen in Western Australia.

METHOD

The work has been carried out in laboratory, glasshouse, controlled field plots and naturally waterlogged field sites in Western Australia with either Western Australian, national or international germplasm that has various tolerance to waterlogging.

RESULTS

Waterlogged environment

Waterlogging throughout the year and at different soil depth can be integrated by the Sum of Excess Water that occurs each day in the primary root zone of the top 30cm soil layer (SEW_{30}). SEW_{30} maps were constructed to characterise the extent and duration of waterlogging over a season and show good correlation between waterlogging occurrences and reductions in yield.

Plant growth

The timing, duration and intensity of the waterlogging events greatly influences waterlogging tolerance with germination and seedling stages being most affected.

Germination stage

Laboratory experiments show mean seed survival of varieties, waterlogged in soil for 4 days, was 68 and 41% for Australian wheat and barley respectively. There was a significantly greater mean germination of International wheats, which were specifically selected for waterlogging tolerance (84%; Table 1). Survival of seeds of Cadoux, after 8 days in waterlogged soil, was less than 10%.

Vegetative plant stage

Varieties grown in glasshouse pot trials showed diversity based on shoot growth both during 28 days continuous waterlogging and 21 days after removal of waterlogging. The most tolerant varieties (Ducula-4 and Chara) had nearly twice the shoot growth during the waterlogging relative to the intolerant variety Cascades. However, these tolerant varieties did not all have high shoot growth after removal of waterlogging (Chara; Table 1).

Whole plant growth

The most tolerant varieties at the early stages of development did not always have the greatest yields when grown in the field, exposed to intermittent waterlogging equivalent to 6 days waterlogging to the soil surface. The grain yields are the result of the waterlogging event and all the other stresses that the plants are exposed to during the growing season.

Table 1. Genetic diversity for waterlogging tolerance at the seed and vegetative stages in temperate cereals based on A) seed survival, B) shoot dry matter increase and C) grain yield as % of non waterlogged plants (±sem).

	%Seed Survival	**Shoot Growth (%)**		**Grain Yield (%)**
WA Wheat		**During WL**	**After WL**	**[WL Yield, t/ha]**
Cadoux	91 (2)			18 [0.5]
Cunderdin	88 (15)			37 [1.2]
Brookton	84 (5)	44	35	29 [1.0]
Cascades	80 (19)	36	15	23 [0.7]
Spear	78 (3)	47	25	33 [1.0]
Westonia	57 (5)	44	41	
Champtal	47 (3)			81 [1.3]
Camm	32 (5)	48	8	
WA Barley				
Skiff	72 (12)			35 [1.3]
Fitzgerald	47 (8)			47 [1.8]
Onslow	45 (3)			30 [1.0]
Franklin	42 (6)			16 [0.6]
Molloy	33 (8)			44 [1.8]
Harrington	31 (13)			29 [0.8]
National/International wheat				
Ducula –4	68 (2)	60	45	81
Chara	94 (6)	60	7	153
Doubled Haploids				
96W639-D-1-17		36	26	79
96W639-D-6-5		49	44	12
96W639-D-6-32		60	27	96

CONCLUSIONS

There is genetic diversity for waterlogging tolerance and when combined with molecular markers development of rapid screening protocols for germplasm improvement in early generations for breeding programs would be possible. This work is continuing in Western Australia and is being extended with collaborative projects in India (ACIAR) and China.

KEY WORDS

Wheat, barley, waterlogging

ACKNOWLEDGMENTS

These results have been accumulated with the assistance of Pam Burgess, Mark Seymour, Glenn McDonald, Ray Tugwell, and Ben Biddulph

Project No.: DAW 342, UWA 340, DAW 292 and CS1/1996/025

Paper reviewed by: Dr Tim Setter

Broadscale variety comparisons featuring new wheat varieties.

Jeff Russell, Department of Agriculture, Centre for Cropping Systems, Northam.

KEY MESSAGE

The evaluation of crop varieties is often done in small scale intensive research plots. This is beneficial for screening a large number of varieties in a controlled environment thereby limiting site variability. However, such sites are costly to establish and manage, resulting in there being only a limited number of sites due to the financial resources available to conduct this important research.

Growers can carry out low cost farm scale research to complement the intensive research. Such research can provide additional information of a practical nature and display the performance of the treatments in an environment closer resembling the variability found in the paddock. The principles outlined in the "***Test As You Grow***" kit and the service provided through the kit can help growers to conduct sound farm-scale research on their own properties.

AIM

To evaluate new varieties at a broadscale level and compare results with small plot tests.

METHOD

The new APW wheat variety EGA Bonnie Rock (WAWHT2281) was released in August 2002. EGA Bonnie Rock has been set as a replacement variety for Carnamah in the north - eastern wheatbelt. Previous comparisons have been made between the two varieties in small plot Crop Variety Test (CVT) sites prior to release. In 2002, large scale sites were established to complement variety comparisons conducted by Agritech. Sites with the Liebe Group (Wubin) and the Holt Rock spray groups (King Rocks) were severely affected by drought to rule out drawing conclusions on performance. However, two sites with the Kunjin TOPCROP group (Kunjin and Bulyee) have provided useful information on variety performance. At these sites, two Arrino replacement lines (WHWHT 2550 and 2551) were also included.

Table 1. Site details of the two large scale and one small plot variety comparisons conducted at Corrigin.

Sites	**Bulyee**	**Kunjin**	**Kunjin**
Plot size and replication	150 m x 11 m, harvested width 10.9 m. 2 replicates of each variety with Westonia used as a control every third plot (nearest neighbour).	150 m x 12 m, harvested width 9.3 m. 2 replicates of each variety with Westonia used as a control every third plot (nearest neighbour).	Small plot 20 m length, harvested width of about 2 m. 3 replicates of each variety with Carnamah used as a standard.
Soil type	Variable: Loamy sand through to loam	Sandy loam grading to loamy sand	Gravel sandy loam.
Sowing date	8^{th} June 2002	24^{th} June 2002	14 May 2002
Seeding rate	60 kg/ha	50 kg/ha	75 kg/ha
Fertiliser	Cropstar 70 kg/ha Urea 60 kg/ha topdressed.	Agstar 80 kg/ha	Unknown, usually Agras with urea topdressed.
Paddock History	1 Pasture / 1 wheat rotation.	2 Pasture / wheat rotation	Canola / wheat

RESULTS

Table 2. Yield and quality characteristics of the wheat varieties compared.

Variety	Plants (/ sqm)	Yield (kg/ha)	% Yield of Westonia	Protein (%)	Screen (%)	Hectolitre Weight (kg/hL)	Stain-ing (%)	Grade	Income ($/ha)
Broad scale sites				**Bulyee**					
Westonia	105	1069	100	13.8	4.3	394		AH	326
WAWHT 2550	116	888	83	14.8	2.6	401		ASW	294
Arrino	112	1033	97	14.6	2.0	400		ASW	250
LSD (5%)	13	208		0.8	2.0	4.5			
				Kunjin					
Westonia	81	900	100	13.9	1.7	400	0.5	PW	270
EGA Bonnie Rock	76	685	76	15.0	1.4	399		AS	195
WAWHT 2551	73	860	96	14.6	0.5	392		AS	248
LSD (5%)	15	257		1.4	0.4	6.8			
Intensive site				**Kunjin**					
Carnamah	N/A	659	80	15.6	0.0	400		AH	229
EGA Bonnie Rock	N/A	708	86	15.0	0.0	396		AH	213
Westonia	N/A	828	100	17.0	0.0	391		Feed	169
Arrino	N/A	686	83	16.7	0.0	394		Feed	140
LSD (5%)		180							

AWB base rates used for income, AH $285, APW $271, ASW $261, Feed $235 (7/01/02).

CONCLUSION

The acceptance of these results needs to be taken with caution. The late break / dry season that occurred is not typical of most. Growing season rainfall was down by 30 – 40%. A later time of sowing of the Agritech site was abandoned due to the seasonal conditions.

It would be very useful to compare the results found here with those gained from the respective Departmental CVT sites that were located in the same agrozone before making decisions on variety performance. Full results of all the varieties tested by Agritech can be found in the extended version of this paper on the CD.

KEY WORDS

On-farm research, broadscale testing

ACKNOWLEDGMENTS

Thanks goes to Wes Baker, Richard Guiness , Ross Fitzsimmons and Rolf Meeking who gave of their time to conduct these on - farm variety comparisons in a very trying season.

Project No.: GRDC DAW599

Paper reviewed by: John Blake

Barley Improvement in the Western Region - the integration of biotechnologies

Reg Lance, Chengdao Li and Sue Broughton, Department of Agriculture Western Australia

KEY MESSAGES

The barley improvement program will develop barley varieties with increased yield, improved agronomic performance, disease and stress tolerance; and with malting quality that is desired by the market. The combined integration and employment of the key biotechnologies of marker assisted selection (MAS), doubled haploids (DHs) together with the breeding technologies of single seed descent (SSD) and male sterile facilitated recurrent selection (MSFRS) will be the major means by which improvements will be achieved.

AIMS

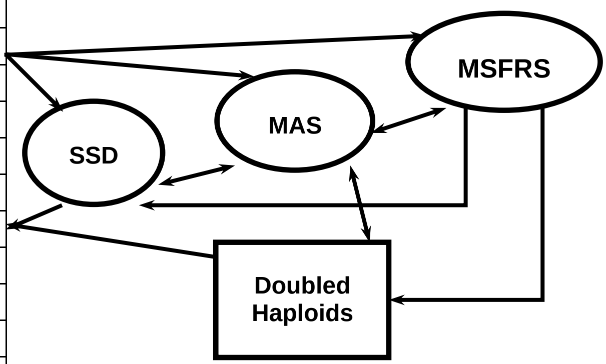
The integration of the biotechnologies will : a) increase the rate of genetic gain, b) improve the selection efficiencies within the breeding program, c) reduce the cycle time (the time taken between making a cross and using the selected progeny in a second round of crossing) and finally d) reduce the time taken to release new varieties.

METHODS

Breeding Methodology and integration of biotechnologies :

Figure : Barley Breeding Method (Based on F2 Progeny) and the integration of biotechnologies

Year	Stage	Generation	Traits Screened
0	G/H	P1 x P2	
0 S	G/H	F1	
1	Spaced plants	F2	A
2	S1, (1-0)	F2/3	A Y Q(D)
3	Stage 1-1	F2/4	A Y Q D
4	Stage 1-2	F2/5	A Y D
5	S2, (2-0)	F5/6	A Q
6	Stage 2-1	F5/7	A Y Q
7	Stage 2-2	F5/8	A Y Q D
8	Stage 3-1	F5/9	A Y Q D
9	Stage 4-1	F5/10	A Y Q D
10	Stage 4-2	F5/11	A Y Q D
11	Release	F5/12	



A = Agronomic, Y = Yield, Q = Quality, D = Disease

Doubled haploids and single seed descent reduce the time taken to release a variety by 2 to 3 years. Marker assisted selection, both pre- and post DH production, single seed descent or through the conventional program enhances the "genetic value" of populations through the selection for desirable traits. Male sterile recurrent selection increases the rate of genetic gain through reducing the cycle time to 2 - 3 years and through appropriate selection strategies.

Marker assisted selection (MAS) :

The molecular genetic marker program includes three components: gene discovery, validation of molecular markers and marker assisted selection (MAS). The WA barley improvement program has been part of the GRDC's National Barley Molecular Marker Program and is part of the Australian Winter Cereal Molecular Marker Program. The Department of Agriculture is also a core member of the

CRC - Molecular Plant Breeding. Through these programs molecular markers have been or are in the process of being discovered and validated for key traits of economic importance.

Doubled Haploids

Doubled Haploid (DH) lines represent over 25% of the overall breeding program and 45% of the stage 2 component. The proportion of DH lines will increase in the future. Since 1993, over 25,000 DH lines have been produced in WA. Large numbers of DH lines tested in the field and derived from the F1 of single crosses have limited genetic value. Pre-screening of segregating donor plant populations by MAS significantly increases the chances of recovery of desired barleys saving field testing resources.

RESULTS

Marker Assisted Selection :

Genetic markers for traits of economic importance currently available to the WA barley improvement program include : a) pre-harvest sprouting tolerance, b) kernel discolouration resistance, c) net type net blotch resistance d) powdery mildew resistance (*mlo, Mla*), e) thermostable beta-amylase (*Bamy1*), f) basic vegetative period (*bvp*) and photoperiod response (*ppd*) and g) acid/aluminium tolerance. Marker validations currently undertaken include ; spot-type net blotch, leaf rust, and loose smut resistance genes and the boron toxicity tolerance genes. So far, over 10,000 lines have been screened using molecular markers.

Accelerated introgression of target genes (alleles) utilising MAS :

The acid soil tolerance of a newly introduced barley lines showed 20 to 50% yield advantage over Stirling on acid soils in WA in spite of late maturity. The gene controlling acid soil/aluminium tolerance has been mapped to chromosome 4H and microsatellite markers are available to select this gene employing MAS. Acid soil tolerant versions of Baudin and Hamelin are being developed using MAS. Four backcrosses will be completed in 2003 and lines acid soil tolerance will be field tested in 2004.

The transfer of a thermostable beta-amylase gene into Gairdner has been achieved using similar methods. Over 400 Gairdner derived lines with the thermostable beta-amylase gene will be field tested in 2003. Preliminary results have shown the improvement of diastatic power.

Improving Genetic Value of DHs Through MAS :

The donor plants have been screened by molecular markers for BYDV, NNB, PM, *bvp* and malting quality. The DH lines with powdery mildew resistance will be in the stage 2 trial next year.

CONCLUSION

Barley improvement in the future looks particle bright. The integration of the biotechnologies ; marker assisted selection (MAS), doubled haploids (DHs) together with the breeding technologies of single seed descent (SSD) and male sterile facilitated recurrent selection (MSFRS) are having a and will continue to have significant impacts. They will enhance the rate of genetic gain, improve breeding selection efficiencies, reduce cycle time and reduce the time taken to release new varieties.

KEY WORDS

Barley, biotechnology, marker assisted selection, doubled haploids

ACKNOWLEDGMENTS

Grains Research and Development Corporation, Western Malting Barley Council

Project No.: DAW00045, DAW00053

Paper reviewed by: Dr Hossein Khabaz-Saberi

The Western Australian State Agricultural Biotechnology Centre – what we are and what we do

Michael Jones, WA State Agricultural Biotechnology Centre, Murdoch University, Perth, WA 6150.

KEY MESSAGES

The WA State Agricultural Biotechnology Centre (SABC) is a collaborative research centre that was established to provide WA institutions with state-of the-art equipment and facilities for research in plant, animal, and microbial biotechnology. The SABC has expanded rapidly over the past 10 years, and now has a critical mass of expertise and world class facilities for R&D in agricultural biotechnology. The SABC operates in a cost-effective manner as a 'Research Hotel" to provide the widest possible access of its facilities and infrastructure to academic, government and commercial researchers, who carry out leading research in specific areas and also make significant contributions as research providers to underpin plant breeding and animal health in the State.

AIMS

The aim of this presentation is to provide an overview of the activities of the SABC – what it has to offer, how it operates and outline some research undertaken in the SABC.

ORGANISATION

The SABC is a university Centre based on the main Murdoch University campus. The SABC was set up as a multi-user centre between the following partners:

- Murdoch University
- University of Western Australia
- The Department of Agriculture of Western Australia
- Curtin University of Technology

The SABC has a Management Committee with an independent Chair, Mr Hendy Cowan, and senior representatives from the Centre partners. The core staff consist of the Director (Prof Michael Jones), Deputy Director (Prof Graham Wilcox), Laboratory R&D Manager (Dr David Berryman), Office Manager (Ms Andrea Tongue), Technical Officer (Ms Frances Brigg) and Lotteries Microarray Officer (Ms Grace Chan).

Approach

The Centre focuses on molecular activities that involve or promote primary production of commercial livestock, crop plants or microbes, or their subsequent processing for added value. The unique aspect of the SABC is that it combines plant, animal and microbial research in one cost effective high technology centre. It is also unique in the way that it provides open access and research expertise and combines government, commercial and university research focuses. The multi-user research centre concept is underpinned by the core staff, and the Centre provides flexibility, critical mass and a firm commitment to applied science.

RESEARCH GROUPS AT THE SABC

In 2002 a total of 200 researchers used the SABC facilities: including 16 research groups, the DAWA Biotechnology Laboratory and four commercial companies, 105 were based there full time, with 95 external researchers using the facilities. These include: the Plant Biotechnology Research Groups (plant viruses, nematodes, molecular markers and mapping) The DAWA Biotechnology Lab (markers and mapping), the Centre for High Throughput Agricultural Genetic Analysis (CHAGA), the Western Node of CRC for Molecular Plant Breeding/Value Added Wheat CRC, the Australian Centre for Necrotrophic Fungal Pathogens (ACNFP), Animal Biotechnology groups in Molecular Parasitology, Animal Virology and Bacteriology, Rumen Biotechnology, Perth Zoo and commercial companies Grain Biotech Australia, Saturn Biotech, Protemics International and ID+PLUS.

CORE FACILITIES

The facilities at the SABC include:

- PC2 containment glasshouses/growth chambers (for GM work)
- Extensive PC2 containment laboratory area
- Full facilities for cell biological, tissue culture and molecular research
- Culture rooms
- Confocal scanning laser microscope
- Micromanipulators
- Real time fluorescence PCR
- DNA sequencers
- Robotic workstations
- Genomics facilities: microarrayer and microarray reader
- Full proteomics facilities from 2D gel separation to MALDI-TOF mass spectrometer
- Single nucleotide polymorphism discovery and analysis (Transgenomics Denaturing HPLC, Pyrosequencer)
- Lab for radioactive tracer work
- Bioinformatics support through the Centre for Bioinformatics and Biological Computing (CBBC)

SOME EXAMPLES OF RESEARCH CONTRIBUTIONS

Researchers in the SABC are at the forefront of a number of research areas, including development of high throughput, low cost, molecular diagnostic tests for plant and animal diseases, for marker-assisted selection for crop variety improvement and for livestock improvement, and in understanding basic processes in plant and animal diseases. There is a close association with staff in the DAWA Crop Improvement Centre to help focus on solving real life problems, and with staff in animal health at DAWA. In other areas, rumen bacteria have been engineered to detoxify toxic compounds in native plants for ruminant livestock protection, and to increase digestibility, and there is development of new vaccines for livestock and companion animals.

Biotechnology implies commercial applications, and the SABC supports companies spun off from local research, providing a supportive environment when cash flow tends to be more limiting, and a resource for contract research for established companies.

CONCLUSION

The WA State Agricultural Biotechnology Centre (SABC) is the major resource for agricultural biotechnology in Western Australia. The SABC fulfills three roles in WA – first, defined research groups carry out high quality R&D in more traditional research programs, second, it acts as a “Research Hotel” to provide wide access to researchers in WA from a range of organisations that would otherwise not be able to afford the platform technologies, and third, it acts as a bioincubator for new companies in Ag Biotech. The success of the SABC concept has been recognized by the State Government as a “Centre of Excellence in Industry-Focussed R&D”, and the SABC approach is being used a s a model for other research centres in the State.

KEY WORDS

Biotechnology, molecular biology, gene discovery, gene mapping, wheat, barley, lupins, chickpea, vegetables, production animals, virology, fungi, nematodes, bacteria, parasitology, genomics, proteomics, bioinformatics

ACKNOWLEDGMENTS

We thank the following for financial support for SABC facilities and R&D: Murdoch University, Curtin University, DAWA, UWA, ECU, GRDC, ARC NH&MRC, PRDC, RIRDC, Horticulture Australia, Australian Research Council, Glaxo-Smith Kline, Saturn Biotech, WA State Government.

Reviewed by Prof Keith Gregg

Protein and DNA methods for variety identification.

Dr Grace Zawko, Saturn Biotech Limited

KEY MESSAGES

Although there has been a sustained increase in productivity of crops using classical approaches to breeding and selection, this approach is being superseded by selection procedures based on knowledge, genetics and the molecular bases of desired traits. New value-enhanced varieties are now being generated that provide farmers with a chance to capture additional price premium from the commodity marketplace by providing specialised products that increase value to end-users.

Because of the increased emphasis on quality and tailoring products for specific markets, in a competitive market there is a need for product traceability and quality assurance systems, variety identity preservation, seed purity and segregation of grains, and enhanced quality and breeding traits.

Over the last decade techniques have been developed to analyse proteins and DNA in great detail. The result of the explosion in applications and number of molecular selection/diagnostic tests is a need to provide high throughput, low cost testing services, by applying automation in handling and processing samples, coupled with the latest techniques of molecular genetic analysis.

The need for rapid approaches to variety identification of grains relate to the trend to developing niche market to gain higher price for grains, the advent of end point royalties and need for quality control. With the advent of new technology, stricter quality control and international competition, the need for efficient testing has become much more important. Exporters, importers and consumers globally are demanding higher quality products, including specific varieties of grain for specific purposes.

Two types of tests can be used for variety ID. These are tests based on the patterns of storage proteins present in cereal grains, and tests based on fingerprints of the DNA of seeds. Extraction of storage proteins from grains has been used for many years, and involves separation of the proteins by gel electrophoresis. This process is slow, and the resolution is now inadequate to resolve closely related varieties. One factor for protein based ID is that only a small subset of proteins is analysed, and the proteins present can be influenced by the conditions under which the plants are grown. The new technology which utilisers MALDI-TOF (Matrix Assisted Laser Desorption Ionisation – Time Of Flight) mass spectrometry has enabled a new approach to protein based ID, in that with a rapid protein extraction system and procedures, a protein profile can be generated in a short time, which provides accurate measure of the size (molecular weight) of the separated proteins, and is amenable to automation.

DNA fingerprinting is a more rigorous approach to variety ID, because the DNA in all cells of a plant is constant. The fingerprint is not affected by how the plants are grown. The DNA technology however, is more expensive than protein based variety identification, as it is more laborious to generate a DNA fingerprint involving DNA extraction, amplification and labelling, separation of fragments on a DNA sequencer, and data analysis.

DNA microsatellite techniques have been utilised. Microsatellites are regions of DNA which have repeated sequences of 1-5 bases. The number of repeat units varies among different individuals, and the pattern of repeats at different sites is thus unique to an individual or a variety. They are ideal for genetic markers due to their abundance and diversity.

AIMS

- to develop the methods required for routine testing for variety ID for wheat at the protein and DNA levels
- to utilise rapid methods for unambiguous variety segregation for quality and purity assessments

METHOD

1. Development of a database of authenticated samples of wheat varieties

Following consultations with CBH and DAWA a number of selected wheat and barley varieties were obtained from them, and from other sources. The varieties were discriminated using MALDI-TOF ms and DNA microsatellites

Schematic diagram of the process of MALDI-TOF

Grinding (250 seeds)

↓

Extraction of proteins (70% EtOH)

↓

Addition of protein extract to a specific matrix (Sinopinic acid)

↓

Plating samples on the MALDI-TOF plate

↓

Generation of protein profiles (MALDI-TOF)

↙ ↓

Interpretation utilising Data Explorer™

Conversion of MALDI-TOF profiles to text files

↓

Interrogation of Artificial Neural Networks, Results of interrogation (ie. Variety ID) returned

Schematic diagram of the process of DNA microsatellites

Grist

↓

DNA extraction

↓

Primer (microsatellite) selection

↓

Polymerase Chain Reaction (PCR)

↓

Gel Electrophoresis (377 ABI PRISM Sequencer)

↓

Data analysis (GeneScan™)

Thirty replicates for MALDI-TOF and three replicates for DNA microsatellites of each of the authenticated samples were tested for detailed discrimination between the varieties.

Statistical cluster analyses (UPGMA) were performed to ascertain the relatedness of the selected varieties.

2. Discrimination of wheat varieties for commercial testing

The analyses involved two stages of discrimination between crop varieties. The first stage involved diagnosing different varieties using protein profiling by mass spectrometry (MALDI-TOF). The second stage involved confirmation or further discrimination of the varieties using DNA fingerprinting

The samples (approximately 500g of grain) were mixed thoroughly and two sub-samples, ‘A’ and ‘B’, of 250 grains each were selected.

Sub-sample ‘A’ was tested initially. The results were matched with the protein profile and DNA fingerprint of the authenticated variety. Ambiguous results were verified by testing sub-sample ‘B’.

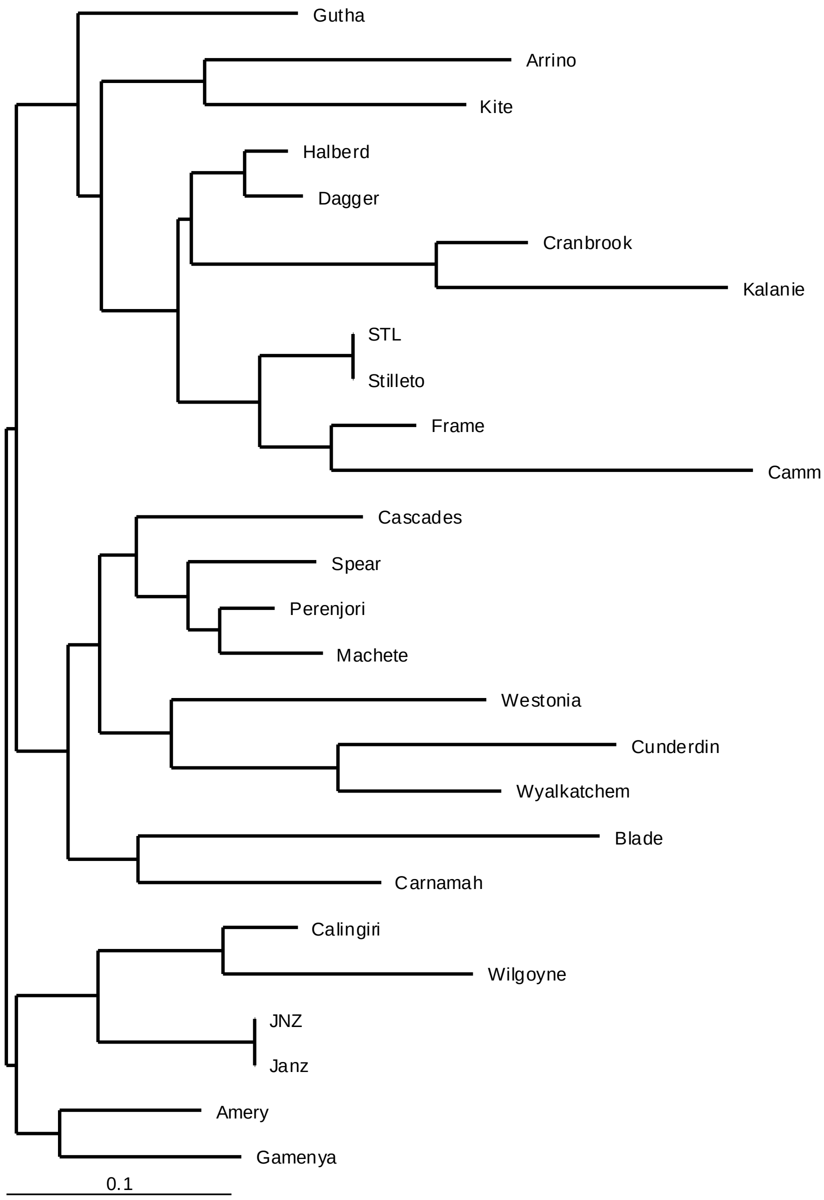
RESULTS

1. Development of a database of authenticated samples of wheat varieties

Visual interpretation

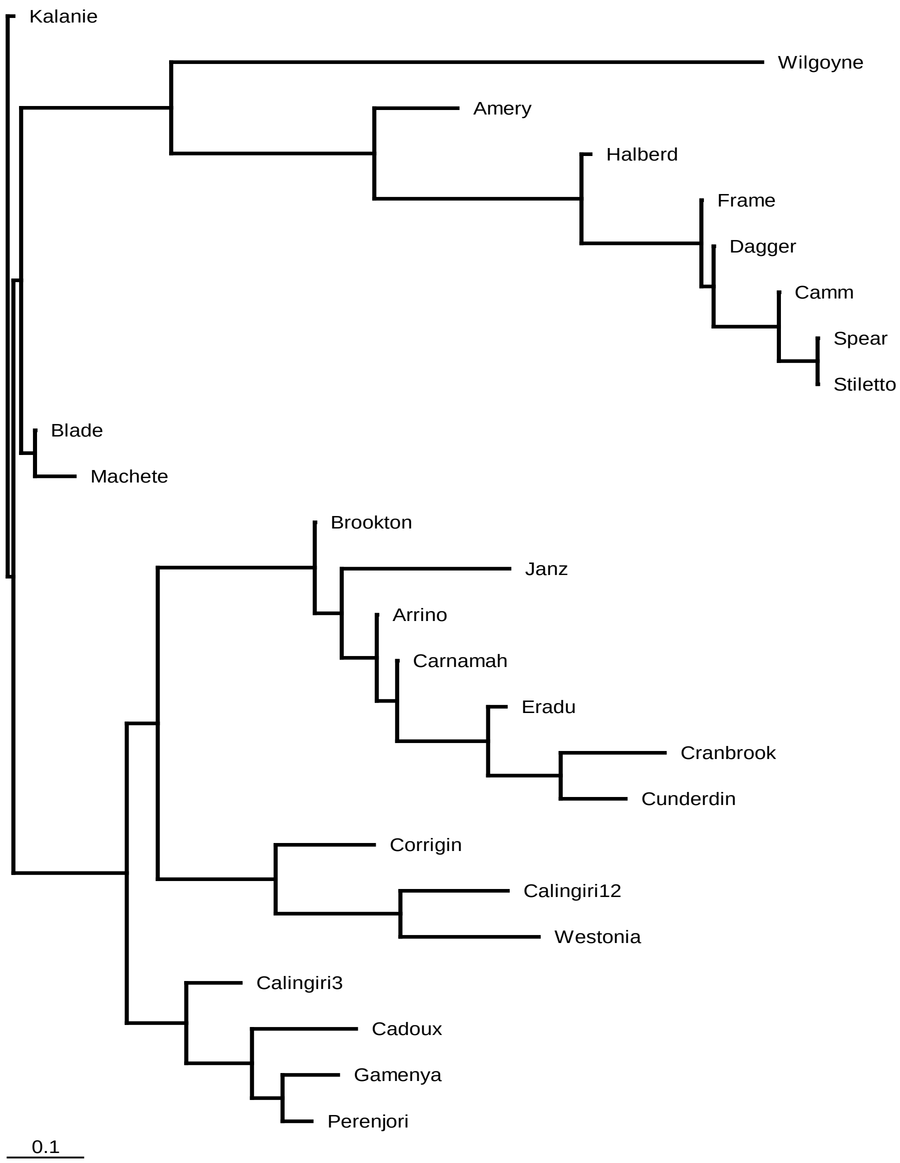
Out of 26 wheat varieties tested, 24 varieties were differentiated with MALDI-TOF (Figure1).

Figure 1. Cluster analysis depicting MALDI-TOF differentiation of most commonly sown wheat varieties.



Out of 25 wheat varieties tested, 24 varieties were differentiated with DNA microsatellites (Figure2.)

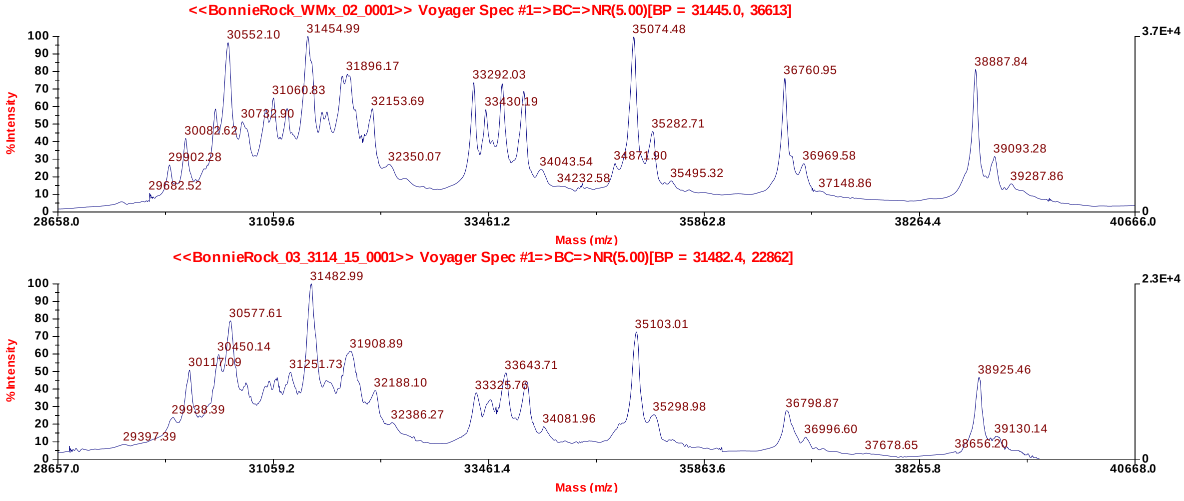
Figure 2. Cluster analysis depicting MALDI-TOF differentiation of most commonly sown wheat varieties.



2. Discrimination of wheat varieties for commercial testing

Because the differences between most cultivar are obvious, the protein profiles of test samples were directly compared with protein profiles of the authenticated samples (Figure 3).

Figure 3. Matching of protein profiles of test and authenticated samples



CONCLUSION

The identification of wheat varieties by protein profiling and DNA microsatellites has been undertaken successfully. Subject to the fact that released varieties are not themselves 100% genetically uniform, the results can be used for routine variety ID.

MALDI-TOF protein profiling is certainly more rapid and specific than the current protein-based variety ID methods, less costly, can be automated, and provides an IT database. In addition, it facilitates auditing and should stand scrutiny in a court of law when backed up with DNA microsatellite fingerprinting. Microsatellite fingerprinting is more time consuming, but also a more accurate approach to identify varieties.

KEY WORDS

Protein profiling, DNA fingerprinting, MALDI-TOF, microsatellites.

ACKNOWLEDGMENTS

We thank the following for support: SABC, Bioinformatics at Murdoch University, DAWA, CBH and CHAGA

Paper reviewed by:

Prof Keith Gregg

The Centre for High-throughput Agricultural Genetic Analysis (CHAGA)

Keith Gregg, CHAGA, Murdoch University, Perth, WA 6150.

KEY MESSAGES

CHAGA was created to help bring the benefits of high-throughput genetic analysis to agriculture in Western Australia, but it is intended that benefits will ultimately be extended to the whole of Australia. Established for less than one year, we are already delivering improved methods to our joint partners for application in WA agriculture.

AIMS

To introduce participants in Western Australia's crop industries to the new Centre and its planned developments in high-throughput genetic analysis to assist in breeding, selecting, and monitoring of crops in the State.

BENEFITS OF GENETIC ANALYSIS

The need for genetic analysis can be seen in almost every aspect of plant, crop, and animal production. As examples:

- the accurate selection of breeding stocks for the development of improved crop plants is crucial in developing varieties suited to particular locations, soil-types, climate, etc.
- Screening to ensure the health of seed stocks can avert large losses to diseases that are identifiable prior to planting, increasing the certainty of economic viability.
- The correct identification of e.g. grain varieties is central to keeping specific varieties pure and therefore in marketing them for specific purposes.
- Quality control of produce, from field to supermarket is increasingly important in obtaining the optimum value for the producer.

Industry's changing priorities for genetic testing will require flexibility in the delivery of analytical services and constant development and improvement of analytical methods. For example, because of the current climate in public opinion, there is commercial value in being able to demonstrate that produce contains no genetically modified materials. In time, as public attitudes to GM foods evolve, this is likely to give way to a need for assurance that a particular shipment of produce is from a specific genetically modified source, to ensure that important properties are present.

Genetic analysis is already an advanced science with a large number of 'markers' already available to identify desirable or undesirable genetic features. In medicine such tests are now commonplace and are helping to predict and avoid serious health problems. However, the major difference between clinically applicable genetic analysis and analysis for agricultural purposes is that high price does not prohibit the use of tests relating to human health. It is economically difficult for a plant breeder or produce handler to pay current prices for analysis of hundreds of seedlings or grain samples. Therefore, the widespread use of genetic analysis in agriculture is limited by economic factors. To overcome this problem, a great deal of work remains to be done on sample collection, processing, and analysis technologies.

KEY REQUIREMENTS FOR GENETIC ANALYSIS IN AGRICULTURE

For genetic analysis to be used routinely in agriculture, the cost of each analysis must be affordable. Even within a single industry, costs that may be acceptable for performing a small number of tests on bulk loads of grain may be unmanageably expensive for testing a large number of seedling plants during an extensive backcrossing project. With the likelihood of shrinking profit margins and the increasing importance of rising production scales, genetic analysis has to be highly cost-effective to gain widespread use in agriculture. Internationally, technology is moving in this direction. If Australia is to remain competitive on a global scale, the availability and affordability of genetic analysis must be improved.

AUTOMATION AND COST REDUCTION

The most immediate way to reduce analysis costs is to reduce human input, by using machines to perform the repetitive steps in sample processing and analysis. Therefore, the use of robotic workstations is a first requirement of cost reduction. There has been widespread adaptation of laboratory tests, which were developed in single reaction tubes, to be performed in multi-well plates equivalent to many reaction tubes, with fluid handling systems that deliver reagents to multiple wells at a single operation. Scaling up from single tubes to 96-well plates occurred some years ago, and now the 96-well plate is gradually giving way to plates of 384 wells, or even 1536 wells. This reduces the cost by allowing more reactions per plate, but also reduces the volume of reaction mixtures since each well in the more complex plates holds a smaller fluid volume. This permits cost saving through the reduced consumption of expensive biochemical materials.

CHAGA'S ROLE

The role of CHAGA is to develop systems that will allow increased adoption of these powerful technologies, through simplification of methods, automation of as many steps as possible, and perhaps through integration of test systems so that a single machine can perform analysis of several different kinds concurrently, to allow economy of scale to be achieved without the need for very large demands on a single type of analysis. Analysis of results, when they are produced in very large numbers, must also be handled by automated systems that do not require a large input of operator time. The field of 'bioinformatics'… the handling of large amounts of biological information by computers… is a vital component of the high-throughput system. A considerable amount of development is occurring in this field, which will continue to produce more efficient ways to handle data and use it to best effect.

RESULTS

The major remaining bottle-neck in genetic analysis is the process of sample collection and processing, to produce extracts suitable for automated analysis. We have developed simple, low cost methods for processing of animal samples, for analysis by a variety of methods. For plant tissues, which can contain many different substances that interfere with analysis, development of ways to overcome these problems is a current priority within CHAGA. Even more basically, the very process of collecting material for analysis (e.g. leaf material for crop breeders) is being streamlined as part of this first-priority project. The first research outputs from CHAGA, which provide reduced-cost methods for grain variety identification, are now being released to partner organisations for implementation and commercialisation.

CONCLUSION

With input from the agricultural industries to define their needs and to provide test samples for development of methodologies, CHAGA is dedicated to delivering high-throughput methods and technologies that will accelerate the creation of improved plant varieties and increase efficiencies in crop production and handling.

KEY WORDS

High-throughput, genetic analysis, plant breeding, quality control, variety identification, genetic selection, crops, sample collection, sample processing, data handling, genetic databases.

ACKNOWLEDGMENTS

CHAGA is a WA State Government funded Centre of Excellence, established as a joint venture with financial input from Murdoch University, Curtin University of Technology, Department of Agriculture WA, and Saturn Biotech.

Paper reviewed by: Prof. Mike Jones

Potassium - topdressed, drilled or banded?

Stephen Loss, Patrick Gethin, Ryan Guthrie, Daniel Bell
Wesfarmers CSBP

KEY MESSAGE

Do not drill 20 kg K/ha or more with the seed as this can result in reduced cereal establishment and yields depending upon soil type and season. Banding K 4-5 cm away from the seed (as K-Till or MoP) is safe under most conditions and can improve early K uptake and growth above MoP topdressed. However, these benefits may only occur in dry seasons when the topsoil remains dry for extended periods and on soils with moderate cation exchange capacities where K movement into the rooting zone may be restricted. Topdressing MoP is recommended for ameliorating K deficient soils when applications of K above 15-20 kg/ha are required, but placing a small amount of K near the seed (drilled or banded) may also be advantageous if the soil is acutely deficient.

BACKGROUND AND AIM

Muriate of Potash (MoP; KCl) has a high “salt index” and large applications near the seed can reduce crop establishment. Hence, MoP tends to be topdressed before or soon after sowing, especially where large doses are required to ameliorate K deficient soils. It is assumed that topdressed MoP is rapidly washed into the topsoil with autumn rains where it is immediately available for plant uptake. However, this may not occur in all situations. While MoP is the most common K fertiliser, there are starter fertilisers containing nitrogen (N), phosphorus (P), sulphur (S) and potassium (K) that can be drilled with or banded near the seed to supply maintenance or starter amounts of K. A series of cereal field trials was conducted to compare the effectiveness of topdressed, drilled and banded K in WA.

METHODS

Nine experiments were conducted from 2000-2002 with wheat and barley (Table 1). The trials included a nil K treatment, 2-4 rates of MoP topdressed immediately before seeding, and 1-2 rates of K-Till (a fully compounded starter fertiliser - 6.1% N, 12.0% P, 17.0% K, 3.2%S) up to 40 kg K/ha drilled with the seed or banded 4-5 cm below. Trials included a range of other treatments depending upon the location – five trials included MoP drilled with the seed and banded below. Other nutrients were supplied in adequate amounts via starter (NPS) fertilisers banded below the seed, and Urea or Flexi-N (urea ammonium nitrate) topdressed before seeding and 6-8 weeks later. The trials included 3 replicates and were a randomised block design. Plots were 2.1 m (9 rows) x 20 or 40 m long, and were sown with Conserva Pak or Primary Sales Superseeder points on 22.5 cm row spacings.

Table 1: Summary of experimental site and 0-10cm soil characteristics.

Site	Year	Soil type	K mg/kg	OC %	Reactive Fe mg/kg	pH 1:5 $CaCl_2$	Sowing time
Yuna	2000	Brown grey loamy sand	22	0.60	357	4.9	01-Jun
Pingrup	2000	Lt brown sandy loam	51	0.70	175	4.4	08-Jun
Dandaragan	2000	Brown sandy loam	47	0.74	340	4.5	27-Jun
Gibson	2001	Brown grey loamy sand	55	1.23	311	4.7	29-May
Mullewa	2002	Brown sandy loam	32	0.48	330	4.7	22-May
Beacon	2002	Brown clay	38	0.79	576	4.9	12-Jun
Piawanning[A]	2002	Grey brown loam	36	1.50	651	4.9	14-May
Piawanning[B]	2002	Grey sandy loam	41	1.75	360	5.5	14-Jun
Narrogin	2002	Grey brown sandy loam	23	1.43	633	4.7	14-Jun

RESULTS AND DISCUSSION

Dry conditions in all three years resulted in late sowing times, limited crop growth and moderate yields at most sites. Apart from Beacon in 2002 which yielded <300 kg/ha, Piawanning[A] in 2002 which was frosted and Pingrup in 2000, most sites produced significant yield responses to MoP topdressed.

Apart from at Pingrup in 2000, all 5 trials where MoP was drilled with the seed resulted in a reduction in plant density at rates of 40 kg K/ha or more. At 3 sites (Yuna 2000, Gibson 2001, Piawanning[A] 2002) densities were also reduced with MoP drilled at 20 kg K/ha. At Gibson 2001 and Mullewa 2002, K-Till appeared more toxic than MoP when drilled at 20 kg K/ha (Fig. 1). This may relate to the higher salt effect with KTill and the proliferation of roots around the K-Till granules in response to its NPS content, thereby enhancing the toxicty. In the MoP drilled treatments, the NPS starter fertiliser was banded away from the MoP and seed. In other trials plant density was not reduced when K-Till was banded at 20 kg K/ha or more. MoP banded also had no effect on plant densities in all 3 trials including these treatments.

At several sites where K-Till was banded, or where plant density was not reduced by K-Till drilled, applications of K-Till up to 20 kg K/ha and with extra MoP topdressed at higher rates resulted in significantly greater early plant growth (Fig. 2) and K uptake (Fig. 3) than MoP topdressed. This did not always translate into greater yields at the end of the season, however, this was expected given the dry seasonal conditions at most sites. While K drilled provided the best K uptake on a per plant basis, the reduced plant density in this treatment often resulted in poor growth per unit area. MoP todpressed appeared the least efficient method of supplying K to plants early in the year of application, especially under the dry conditions in 2002. The low availability of MoP topdressed could be partly attributed to light rainfall during winter which was unable to wash sufficient K into the rooting zone and the fact that the top soil was dry for most of the season making the fertiliser K unavailable at most sites. In addition, WA soils running into K deficiency are no longer limited to the deep sands. Soil K reserves are starting to become depleted to deficient levels on some loams and clays with moderate cation exchange capacities where K from topdressed MoP may not readily move into the rooting zone.

One site where K-Till banded was clearly superior to MoP topdressed was at Narrogin which was sown to barley in 2002. This site was chronically K deficient (Table 1) and the K-Till banded treatment (one rate only) was visually superior to MoP topdressed (both at 24 kg K/ha) throughout the season. Despite the dry spring conditions, the K-Till banded treatment produced 16% more grain yield than MoP todpressed at 24 kg K/ha, a yield equivalent to MoP topdressed at 48 kg K/ha (Fig. 3).

KEYWORDS Fertiliser, Potash, plant nutrition, cereals

Fig. 1: Plant establishment at Gibson 2001

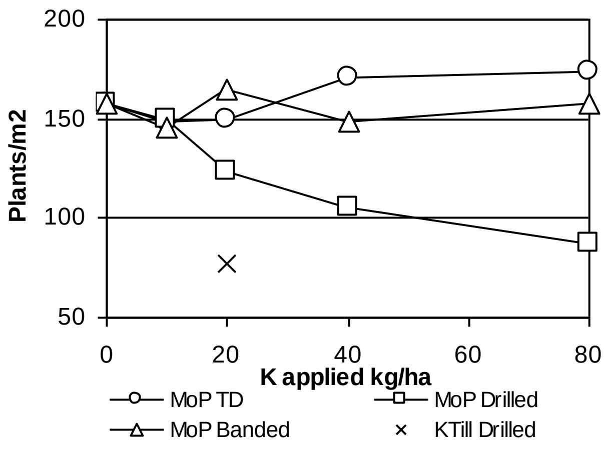


Fig. 2: Plant weights at PiawanningA 2002

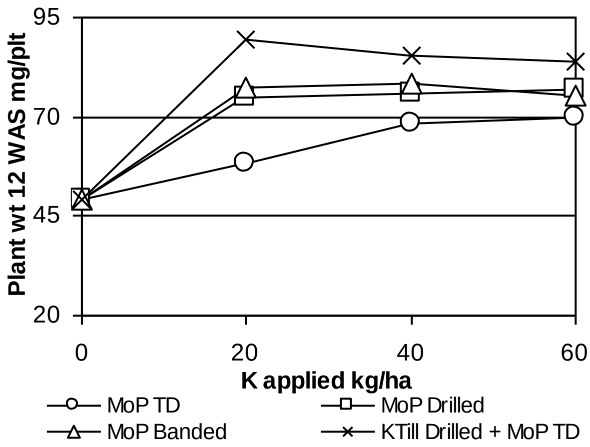


Fig. 3: K uptake at Beacon 2003

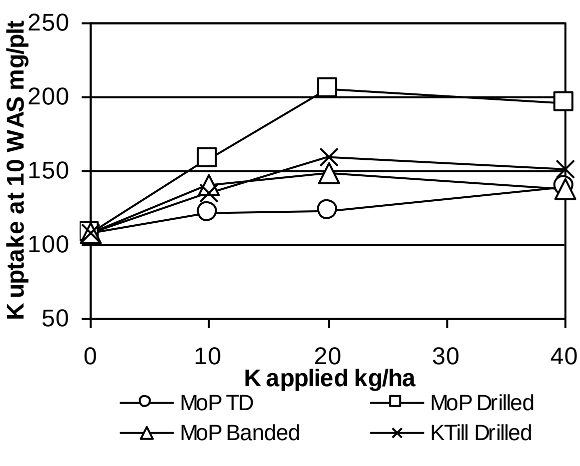
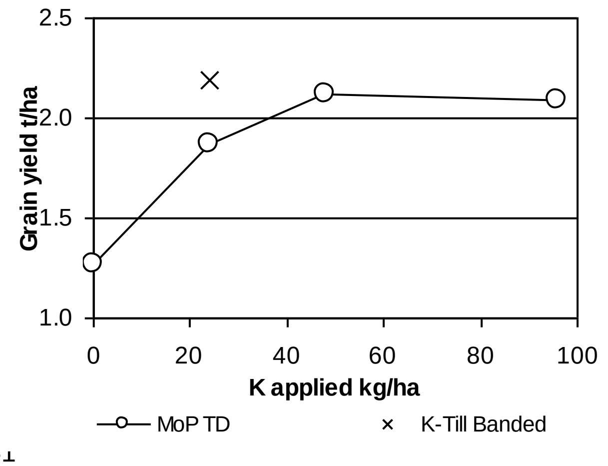


Fig. 4: Grain yield at Narrogin 2002



Liquid phophorus fertilisers in WA

Stephen Loss, Frank Ripper, Ryan Guthrie, Daniel Bell and Patrick Gethin,
Wesfarmers CSBP

KEY MESSAGE

The results from ten useful phosphorus (P) responsive trials conducted over 3 years produced inconsistent evidence that liquid P and solid fertilisers differ in their ability to supply P to cereals in WA. Given these inconsistent agronomic results to date and the price premium of liquids compared with solid P fertilisers, agronomists should be cautious about encouraging growers to adopt liquid P fertilisers until further work is completed.

BACKGROUND AND AIM

Research on the Eyre Peninsula SA showed liquid forms of P produced significant improvements in wheat P uptake, plant growth and grain yield on highly P fixing, alkaline, calcareous soils, especially in dry seasons. Results from trials conducted in WA in 2000 and 2001 found liquid P sources produced 5-10% more yield than solid fertilisers at 3 out of 7 sites (summarised at the 2002 Crop Updates). Another 6 similar trials were sown in 2002, 3 of which produced additional useful results.

METHODS

Useful field experiments were conducted at Northampton, Gnowangerup and Frankland in 2002. Other similar trials sown at Kununoppin, Lake Grace and Salmon Gums were severely affected by drought. The trials compared 4 rates of solid mono-ammonium phosphate (MAP) with liquid ammonium polyphosphate applied at two rates and a nil P treatment. Urea was topdressed immediately before seeding to provide basal N and Muriate of Potash was also topdressed at Gnowangerup and Frankland. Liquid treatments were diluted with water and applied at 126 to 219 L/ha depending upon the site. The trials included 3 replicates and were a randomised block design. Plots were 2.1 m (9 rows) x 20 m long and were sown with Conserva Pak or Primary Sales Superseeder points on 22.5 cm row spacings. Solid and liquid products were banded about 4 cm below the seed. Carnamah wheat was sown at all 3 sites.

Table 1. List of trial site characteristics.

Site	Year	Soil type	P	OC	Reactive Fe	pH	Sowing
Northampton	2002	Brown grey loamy sand	13	0.78	257	5.0	21-May
Gnowangerup	2002	Light grey loamy sand	20	1.18	154	4.4	18-Jun
Frankland	2002	Brown gravelly loamy sand	32	3.76	414	5.0	28-May

RESULTS AND DISCUSSION

Northampton

Plant P levels at 6 weeks after sowing showed a good response to P application and a significant trend of higher P content in the solid fertiliser than the liquid fertiliser treatments (data not presented, $P<0.05$). Grain yields at the end of the season responded to the application of P, increasing from 2.9 t/ha in the nil to about 3.4 t/ha, and the liquid treatments produced about 200 kg/ha less grain than solid treatments, even when applied at 20 kg P/ha (Fig. 1, $P<0.05$).

Gnowangerup

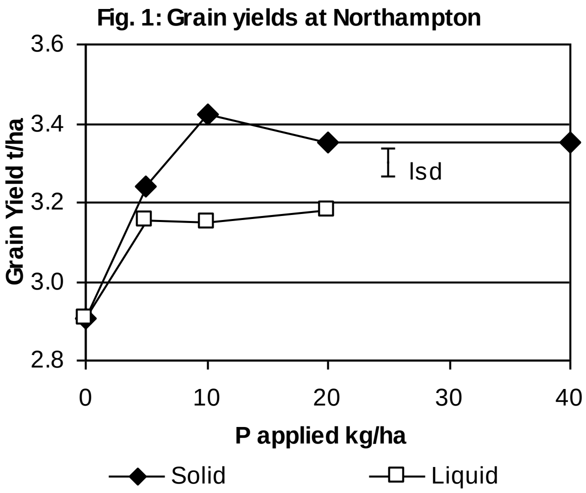
The soil at this site was low P fixing. Although wheat growth and yields were limited by low rainfall there was a consistent trend of solid P being superior to liquid in terms of early plant growth and P uptake measured at 8 weeks after sowing (data not presented, $P<0.05$). Grain yield responses to P application were small, increasing from 1.3 t/ha at nil P to 1.6 t/ha at 15 kg P/ha (Fig. 2, $P<0.05$). Nonetheless, yields were significantly greater with the solid P than liquid source ($P<0.05$).

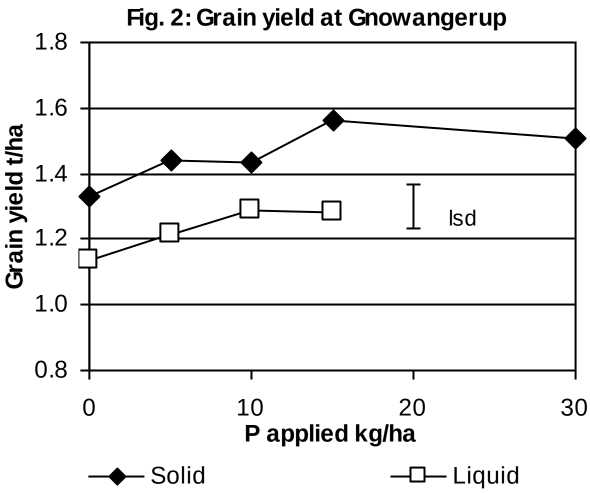
Frankland

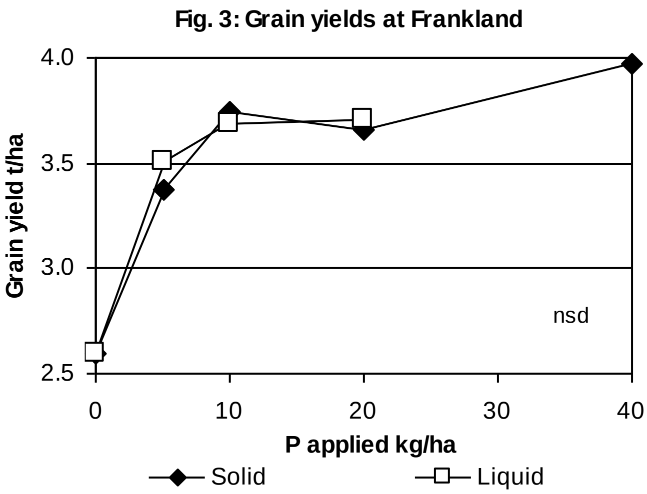
This site was a typical acid, highly P fixing “Forest Gravel Soil”, and it was clearly evident from early in the season it was highly P responsive. Plant sampling 6 weeks after sowing showed a trend of better growth and P uptake in the liquid P than the solid P treatments, however, the differences were not statistically significant (P>0.1). Yields increased significantly from 2.6 t/ha at nil P to 4.0 t/ha at 40 kg P/ha (Fig. 3; P<0.05). Liquid and solid forms of P were equally effective at supplying P for wheat growth and yield.

Unlike evidence collected in SA, the results from these 3 trials in 2002 together with the previous 7 trials conducted in 2000 and 2001 show inconsistent benefits of liquid P sources over solid fertilisers in WA. Despite a wide variation in soil characteristics such as soil pH, texture or Reactive Iron content at the trial sites, these did not give any clues as to situations where liquid or solid P might be advantageous. Further research is required to draw firm conclusions. Flexi-N is proving popular despite a price premium over Urea because of its logistical and other non-agronomic advantages. Given liquid P fertilisers are likely to be at least twice as expensive as solids, they would need to offer large non-agronomic benefits to be economically viable, if their agronomic effectiveness is similar to solids.

KEYWORDS plant nutrition, wheat, fluid







Wheat Nutrition in the High Rainfall Cropping Zone

Narelle Hill[1] and Laurence Carslake[2], [1]Department of Agriculture, [2]Wesfarmers Landmark.

KEY MESSAGE

Significant grain yield responses were obtained with P+N nutrition at two sites. Further yield increases were obtained with the addition of trace elements, with potential yields reached at one site. Fertiliser rates used by the farmers did not increase grain yields above the unfertilised controls. Although responses to N are often found in the high rainfall zone, large responses to P are not. Substantial increases in net returns were found from using higher P and N rates than are commonly used by farmers. Further research needs to address the availability and crop responses to P in subsequent years. After two years of experiments we suggest that the key to achieving potential yields in the high rainfall cropping zone is to keep a balance of nutrition by using a combination of soil and plant analyses.

AIMS & BACKGROUND

It has been recognised that the majority of crop yields in the high rainfall zone of southern Western Australia are below their potential. The potential yield calculated by French and Schultz (1984) in the high rainfall areas (approximately 400-700 mm average annual rainfall) is in the range of 6-10t/ha for cereals and 3-6 t/ha for canola. Shire yields in the high rainfall zone for 2001 averaged 2.4 t/ha for cereals and 1.4 t/ha for canola.

The aim of this project is to explore the factors limiting crop yields. Our small plot trials in 2001 using no-tillage, deep-banded sowing methods and optimum management produced cereal yields in excess of 6.6 t/ha. The most significant increases in crop yield were due to the addition of high amounts of nutrients [nitrogen (N), phosphorus (P), potassium (K), and trace elements (TE)], particularly N. Farm-scale research trials commenced in 2002 to investigate the effects of high amounts of nutrients on canola, wheat and barley in rotations. The outcome of these trials is to develop the optimum nutrition management package to maximise crop yields, quality and economic return in the high rainfall area. This paper concentrates on the effects of nutrition on wheat yield following canola in 2001.

METHOD

Farm scale wheat nutrition trials were sown at Rylington Park, Boyup Brook (GSR (Apr-Oct) = 504 mm) and Gorden River Estate, Cranbrook (GSR (Apr-Oct) = 340 mm), following a canola crop in 2001. The soil tests in the top 0-10 cm and 10-20cm are shown in Table 2.

Carnamah wheat was sown at Boyup Brook (BB) on 21st May 2002 and Calingiri wheat sown at Cranbrook (CK) on 10th June 2002 at 80 kg/ha with farmer seeding implements using knifepoints with 18cm spacings. Nutrients were deep banded at the rates in Table 1, with extra nitrogen and trace elements applied at 6 weeks and extra nitrogen at 10 weeks post sowing. Plants were analysed for nutrient levels prior to both applications. The sites had a basal of gypsum (120 kg/ha, 18%S) to ensure sulphur would not limit yield. Insects, disease and weeds were controlled before and throughout the growing season to ensure only water and nutrients could limit crop yield and quality.

Table 1. Nutrition treatments, nutrients and rates (kg/ha) and nutrient cost/ha ($) (relative to Control) for wheat nutrition trials at Boyup Brook (BB) and Cranbrook (CK), 2002.

No	Treatments	Nutrients and rates (kg//ha)	Nutrient cost/ha ($)
1	Control	21.6S, 27Ca (basal gypsum)	0
2	Phosphorus (P)	49.2P, 22.6S, 42Ca	97
3	P + Nitrogen (N)	147.2N, 49.2P, 22.6S, 42Ca	211
4	P + N + Potassium (K)	147.2N, 49.2P, 49.5K, 22.6S, 42Ca	246
5	P + N + K + Trace Elements (TE)	147.2N, 49.2P, 49.5K, 22.6S, 42Ca, 1.5Cu, 1Zn, 4Mn, 0.7Mo	412
	Farmer practice	BB – 74N, 14P, 30K CK – 58.9N, 17.7P, 35K	BB - $105 CK - $121

Table 2. Pre sowing soil test results for 0-10cm and 10-20cm at wheat nutrition sites.

Site	Depth	Soil type	pH	OC	N	P	K	S	Ca	Mg	Na	Al	PRI
	Cm		$CaCl_2$	%	Ppm				CM/kg				
BB	0-10	Dark loam	5.0	5.1	40	43	188	8.6	6.2	1.0	0.2	0.4	270
	10-20		5.1	2.2	15	24	130	7	*	*	*	*	
CK	0-10	Loamy sand	4.3	2.0	6	57	29	11.2	1.8	0.4	0.2	0.5	
	10-20		4.6	0.5	1	18	24	4.3	*	*	*	*	

RESULTS

Plant numbers

Plant numbers for both sites showed no difference between nutrition treatments. There was an average of 170 wheat plants/m^2 at Boyup Brook and 257 wheat plants/m^2 at Cranbrook. Presswheels were used at Cranbrook, different soil types, and sowing time could have caused the big difference in plant numbers.

Plant analysis

At Boyup Brook for the first time of sampling (6 weeks post sowing - 2/7/02), P and K for the control and farmer practice treatments were low in the plant, and copper (Cu) was low on all except the P+N+K+TE treatment. At Cranbrook, manganese (Mn) was high for all treatments and Cu low on the control. The second plant sampling and four weeks after the foliar application of N and TE (10 weeks post sowing) showed that P and Cu were low and Mn high in the plant for all treatments at both sites, although Cu was adequate on the P+N+K+TE at Cranbrook. In addition, calcium (Ca) and K were low on the P+N treatment at Boyup Brook (Data available from authors).

Grain yield, quality & Harvest Index

There was a marginal increase in grain yield at both sites with the addition of P. The major response was due to N, which further increased yield in the presence of P at both sites. There was no significant yield increase due to K, but the addition of trace elements also increased yield at both sites. The farmers fertiliser strategies did not increase grain yield over the unfertilised control at either site (Table 3).

Table 3. Effects of nutrition on heads/m^2, Harvest index (%), grain yield, quality components and net return ($/ha) at Boyup Brook (BB) and Cranbrook (CK) wheat trial sites.

Treatment	Heads/m^2		HI (%)		Grain yield (t/ha)		Screenings (%)		Grain protein (%)		Net return ($/ha)	
Site	BB	CK	BB	CK	BB	CK	BB	CK	BB	CK	BB	CK
Control	295	330	38	38	3.5	2.9	2	2	11	10	870	718
Phosphorus (P)	332	398	39	34	4.0	3.3	1	2	10	9	910	728
P + Nitrogen (N)	441	513	34	33	4.8	4.1	2	5	11	12	999	817
P + N + Potassium (K)	397	523	38	31	4.9	4.2	2	5	11	12	979	809
P + N + K + Traces (TE)	457	620	38	33	5.2	4.5	1	5	11	12	900	706
Farmer practice	320	373	31	30	3.5	3.3	2	2	11	10	770	704
Lsd *($p<0.05$)*	120.6	114.2	6.9	2.4	0.44	0.44	ns	1.5	1.0	0.7		
Lsd *($p<0.1$)*			5.3	1.8	0.34	0.33						

The extra N increased protein (%) and screenings (%) at Cranbrook, but not at Boyup Brook (Table 3).

The increase in grain yield for the extra nutrition treatments was a result of increased head number/m^2 at both sites (Table 3). The harvest index (HI%) was significantly lower for the farmer practice at both sites than all other nutrition treatments, except for P+N at Boyup Brook and P+N+K at Cranbrook, possibly indicating a nutritional imbalance. However, the soil fertility and rainfall at Boyup Brook could possibly have supported greater plant and tiller numbers than were achieved.

Actual vs potential yields and economics

Growing season rainfall (April – October) was 504mm and 340mm for Boyup Brook and Cranbrook respectively, equating to potential yields at the two sites of 7.9 t/ha and 4.6 t/ha. The highest yield reached at Boyup Brook was 5.3 t/ha and at Cranbrook, 4.5 t/ha. This calculation indicates that even though the Boyup Brook site yielded most it was still well below the rainfall-limited potential yield. At this site, losses of water may also be greater than the figure of 110mm used by French and Schultz, as significant rainfall events occurred in June and July, potentially also causing loss of applied N through leaching. N is important for increased tillering, and at harvest, significant tiller mortality (> 50%) had occurred, reducing yield potential at the site. In contrast, at Cranbrook, tiller mortality ranged between 10% and 30%, and potential yields were achieved.

Table 3 shows the net returns ($/ha) for the two sites. At Boyup Brook, paying the extra $106 for P + N gives an extra $229 net return over the farmer and an extra $129 net return over the control. Similarly at Cranbrook, paying an extra $90 for P + N gives an extra $113 return over the farmer and an extra $99 return over the control. The results suggest that it does not pay to add K + TE. However, grain yields were increased by the TE treatment and the rates for the purpose of the experiment were excessive and possibly only required every 10 years. This must be taken into account when determining the economic returns.

CONCLUSION

The most significant increase in grain yield at both sites was from the application of P + N, although a marginal response to P was observed. Further marginal yield increases were recorded by the addition of K + TE at both sites. Although pre-sowing soil P was adequate at both sites, the early plant analyses showed that P in the plant and dry matter was low, thus the response to the added P treatment in grain yield. Although responses to N are often found in the high rainfall zone, responses to P are not and the marginal response to P could be explained through the high PRI at Boyup Brook, thus making P temporarily unavailable. At Cranbrook, the pH was extremely low possibly making P form insoluble compounds with Fe, Mn and Al, reducing its availability. Root pruning of the wheat plants through herbicides, removal of Vesicular Arbuscular Mycorrhiza and Aluminium toxicity are other possible explanations. The availability of P in successive years and the interaction of N and P in this environment require further work.

Although grain quality was slightly reduced with the addition of nutrients, this did not affect marketability. The net returns from the P + N treatment at both sites easily justified the practice in 2002. Potential yields were reached at Cranbrook, despite apparent acidity, low soil K test and low plant P, but it is possible that relatively low ear numbers at the Boyup Brook site could have limited yield. This may have been achieved through a higher plant population and/or higher fertiliser rates and or better planting technique.

KEY WORDS

Nutrition, nitrogen, phosphorus, grain yields, wheat, quality.

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Management options for root lesion nematode in West Australian cropping systems

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KEY MESSAGES

- Use of **resistant** or **moderately resistant** hosts in rotational sequences is the most effective option for management of *Pratylenchus* (root lesion nematode).
- **Susceptible** crops should be avoided where high nematode numbers have been detected.
- Varieties resistant to one nematode species may be susceptible to another, so rotations will vary.
- Growers need to know not only the nematode levels, but also identity of the species present.

BACKGROUND

- Yield limiting densities of root lesion nematode occur in at least 40% of WA cropping paddocks.
- Losses of at least 5% (and more often 10–15%) are common for wheat (Table 1) and barley, representing an annual production penalty of $20–$60/ha over 2.5 million hectares.
- WA is unique in that 7 species of *Pratylenchus* have been found associated with crop damage.
- Poor (i.e. moderately resistant) or non-host (i.e. resistant) crops can be used in rotations to reduce nematode levels in the soil. Good hosts (i.e. susceptible) will increase nematode levels.

Table 1. Nematode density and yield of wheat with and without nematicide (Temik 150G).

Site	Variety	*P. neglectus*/g root (10 weeks)		Grain Yield (t/ha)		Yield Gain (%)
		Nil Nematicide	Plus Nematicide	Nil Nematicide	Plus Nematicide	
Dumbleyung	Brookton	144,000	13,000*	2.07	2.21*	6.7
Tammin	Brookton	5,600	2,700*	1.23	1.43**	16.3
Doodlakine	Machete	325,000	6,000***	2.48	2.63**	6.0
Neridup	Machete	8,200	600***	2.31	2.39*	3.5
North Howick	Machete	82	3*	2.98	3.14*	5.4

Difference between nil and plus nematicide treatments significant at * P<0.05, ** P<0.01, ***P<0.001

CURRENT RECOMMENDATIONS

- Above ground symptoms are indistinct. Paddock diagnosis is difficult and often misleading.
- Avoid susceptible crops if nematode numbers are high (e.g. most wheat varieties and chickpea).
- Resistant crops (e.g. pea, faba bean) will prevent build-up of nematodes (Table 2).
- Some wheat has moderate resistance to *P. neglectus* (e.g. Cascades, Perenjori, Wyalkatchem).
- Highly susceptible wheat varieties should be avoided in areas where *P. neglectus* levels are high (e.g. Westonia, Eradu, Ajana, Carnamah, Cunderdin, Karlgarin, Camm, Brookton).

Table 2. *P. neglectus* levels following different crops at Doodlakine, 1999.

Crop (1999)	*P. neglectus*/g soil at sowing (2000)
Fiord Faba Bean	0.45 a
Dundale Field Pea	0.43 a
Karoo Canola	0.85 ab
Merrit Lupin	1.45 bc
Stirling Barley	1.71 c
Dunkeld Canola	1.83 c
Heera Chickpea	1.91 cd
Dalyup Oat	3.08 de
Nyabing Wheat	3.29 ef
Machete Wheat	4.77 f
SED	*0.19*
LSD	*0.37*
CV%	*26.20*

ISSUES AND CHALLENGES

Nematode species diversity

Seven *Pratylenchus* species have been found associated with crop damage in WA: *P. neglectus*, *P. thornei*, *P. teres*, *P. zeae*, *P. brachyurus*, *P. penetrans* and *P. scribneri*. As in Eastern Australia, *P. neglectus* and *P. thornei* are the most common. All have wide host ranges, which will differ between species. This presents a challenge to development of rotations to manage each nematode. Identification of species microscopically can be difficult, particularly when mixed populations occur. DNA based diagnostic methods are not yet in place for species other than *P. neglectus* and *P. thornei*.

Relevance of data from Eastern Australia

Much data is available from Eastern Australia for management of *P. neglectus* and *P. thornei*. However, it would be unwise to rely solely on this information until we can determine if WA nematodes perform in the same way.

Risk categories, yield loss and tolerance limits

Nematode levels can be measured. However, what do these numbers mean in terms of potential crop loss, and how does this change with seasonal and regional conditions? Risk categories are likely to be quite different to those determined elsewhere in Australia. Rainfall, soil type, pH, cropping practices, crop varieties, presence of other pests or diseases will influence tolerance limits.

Radopholus nativus *(burrowing nematode)*

Until detected in WA in 1998, *R. nativus* had not been recognised as an economic pest. High densities caused damage to wheat at Wyalkatchem, and this nematode has since been identified over a wide area of WA. Lupin seems to contribute to build-up of this nematode. The potential economic threat to wheat-lupin rotations requires investigation, as does the susceptibility of other crop hosts.

SOLUTIONS

Resistance/susceptibility of field crops

CVT and wheat breeding trials will be assessed in 2003. Nematode identities and densities will be characterised, and multiplication rates determined as an indicator of host resistance/susceptibility.

Ability of crop varieties to host Pratylenchus *species and* Radopholus nativus

The range of nematode species (7 *Pratylenchus* plus *R. nativus*) will be multiplied in the laboratory, and plants inoculated with a known number of a single species. Crop varieties and advanced lines will be tested against each nematode. Tests will include comparison between SA and WA isolates.

Diagnostics and identification of Pratylenchus *species*

Collaborators in Adelaide and Canberra are helping us to more accurately identify *Pratylenchus* species through traditional morphological taxonomy and development of DNA based methods.

Tolerance limits

Data comparing nematode numbers and crop yields will be required over many seasons/sites.

PROPOSED OUTCOMES

- Characterise a wide range of crop varieties for resistance/susceptibility.
- Information on hosting abilities for the range of WA *Pratylenchus* to identify key limiting species.
- Reduced nematode impact through grower awareness of options to manage these pests.

KEY WORDS

nematode, management, rotation, resistance

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Aeration can profit your grain enterprise

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SIMPLE PROCESS - BIG BENEFITS

Ambient aeration is a simple process of blowing unheated (natural) air through a bulk of grain. Principally aeration is used to cool grain and preserve its quality. Air passing through the grain equalises the temperature and moisture throughout the stack over time. The moisture content in the air surrounding the grains gradually achieves a balance or equilibrium with the moisture in the grain. It will remain at that equilibrium until new air is introduced into the spaces between the grains and depending on whether the air is wetter or drier the grain will either give up moisture or gain it. Airflows are measured in litres / second / tonne (l/s/t) and the more frequently the air between the grain changes, the quicker the target temperature is reached.

During the aeration process some moisture may be removed and it is this process that can lower the temperature of the grain, similar to a water bag - evaporative cooling. To dry the grain quickly you need a very high flow of air (10 - 30 l/s/t) depending on the initial moisture content. For each 50 tonnes of grain you have to remove 500 litres of water (1/2 tonne) for a 1% drop in moisture content. This would need something like 30 l/s/t for eight hours or longer with an ingoing relative humidity of about 25%. If you are attempting to dry in a standard 50 tonne silo the air also has to carry this water through at least 5 metres of grain. If the fans have to be turned off because the relative humidity is too high, the moisture laden drying front becomes stalled, putting the grain in that area at risk of moulding. Most aeration equipment being fitted in WA is low flow (2 - 3 l/s/t) for cooling or maintenance of the grain only.

NEED MORE HARVEST POWER?

If you think you need a bigger faster harvester to get the grain off quicker you may consider using your existing machine and harvesting before the grain is completely dry on the stalk. Studies by CSIRO show that the optimum harvest time for grain is 16% moisture content.

Grain left standing in the field post maturity, loses yield and quality over time. Almost every year there is some loss of malting quality barley or premium seed due to late rains. Earlier harvesting, reduces field losses and the risk of damage from rain. Over moisture grain is loaded into an aerated silo or field bin for cooling, to protect it from moulding. It can then be dried in a warmed air drier or blended with over dry grain harvested later in the season. An alternative process is to manage the stack by loading over dry grain on top of over moist grain. The later loaded grain will pick up the moisture from the air that has just passed through the lower (moister) grain, increasing the delivery weight.

LONG TERM STORAGE

Cool grain can be stored long term. To hold the grain in a safe condition fans are operated as needed. Low temperatures and regular air movement reduce insect activity dramatically. Higher moisture content grain can be stored - up to 14% at 20ºC or below. This is particularly useful for lot feeders or piggeries that have a high throughput of grain with limited opportunities for fumigation. However aeration alone will not guarantee that no insects are present. If you have to deliver into a nil tolerance market you will have to fumigate to be sure there are no insects in the grain. You can achieve this either by having the aerated silo sealed or by using the hospital silo technique. Only the grain you plan to deliver is fumigated in a smaller sealed silo.

Fumigation is not a quick process and you must always allow at least 10 - 14 days for the gas to kill all stages of the insects and allow for ventilation and withholding periods. If the silo is aerated, the ventilation period can be reduced to 24 hours.

COOL STORAGE IS VITAL TO RETAIN SEED QUALITY.

There is good evidence from CSIRO that the best quality seed placed into storage and kept cool will retain its viability and vigour much longer than seed that was left standing too long and has sustained some damage to the seed coat. Any weather damage while standing in the paddock from moisture or heat reduces the germinability. High storage temperatures are commonly achieved when harvesting later in the season and because grain is a good insulator the core of the grain bulk retains a lot of that heat for most of the storage period

Storing any grain that is less than 100% germinable leads to a faster reduction in the germinability and vigour of the seed in store. Laboratory tests by CSIRO show high quality grain that is 99.99% viable, when stored at 11% moisture and 35ºC, falls to 98.6% viability after 4 1/2 months in store. Lower quality seed of 99.5% viability drops to 85.5% in the same length of time. Under normal farm storage conditions this effect will be masked because when outloading there is mixing of all grains and so a severe loss of viability in some of the seeds from the hotter parts of the silo may not be noticed. Other environmental factors combine and the resultant germination loss may be put down to some other factor.

VALUE PROTECTION

Early harvesting protects the value of Shochu or malt barley, avoiding mould staining and sprouting. Placed under aeration, the colour and germinability is preserved. Harvesting early removes the grain before heat becomes a problem but it is more likely to be high in moisture. An aerated silo removes the problem and cools the grain to a safe temperature. When storing premium seed long term aim for a grain temperature of 20ºC at 12.5%. For moisture contents of 14 - 16% the temperature should be reduced to 15ºC.

A controller is the key to maintaining low temperatures and removes the guesswork from the operation. It can also be set up to select dry air so that there will be some moisture removal during the storage period making the grain safer. An aeration kit bolted onto an elevated silo for around $650 is excellent insurance.

CONCLUSION

The success of the aeration is heavily dependent on the temperature and moisture of the incoming grain as well as the ambient RH and temperature of the available air. What happens one year may not be repeated the following year or even month. Despite it’s simplicity, aeration needs a high degree of understanding and monitoring. An automatic controller takes much of the guesswork out of the process.

Aeration is valuable harvest management tool. It can be used every year to preserve grain quality and broaden your harvest window. When the harvesting conditions are difficult it will prove of immense value to be able to continue harvesting before rain downgrades the grain.

The viability of quality seed will be preserved by keeping it cool during the storage period.

Aeration has the potential to deliver a greater profit improvement to your grain enterprise than the latest, fastest harvester and at a fraction of the price.

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