Enhancing Supplies of High Quality Barley to Meet Pork Industry Demands in Queensland and Northern New South Wales

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Report prepared for the Co-operative Research Centre for an Internationally Competitive Pork Industry

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Executive Summary

This project was funded because more reliable and consistent protein and energy supplies can reduce pork production costs. An improvement in the quantity and quality of barley available to the Pork Industry could help stabilise costs. New feed barley varieties, utilization of recommended production practices, and efficient feed quality determinations for barley are the first steps in this process.

This project was designed to study management practices for production barley and to expand the variety development goals of the Barley Breeding Australia – North Region (BBA-North) barley breeding program located at the Hermitage Research Station, Warwick to include feed quality for pigs. Regional variety drill strip trials (up to 12 sites) and agronomic studies were conducted, grain samples from production experiments and BBA-North breeding trials were assess for pig feed quality, and selected crosses were fast tracked to rapidly produce pure lines for evaluation. Bulk grain samples of elite varieties were provided for pig feeding trials. Rapid assessment of feed value of barley samples from breeding and agronomic trials were conducted using near infra-red spectrometry (NIR) and appropriated calibrations.

Key findings of the project were:

1) Using ABS data, the regional production of barley and location and size of pig production throughout the northern region was analysed in order to select sites for establishment of replicated barley drill strip trials which would be relevant to the preferred grain sourcing area for the pork industry.
2) Good agronomic production practices were shown to produce more grain and improve the feeding value of barley. Maintenance of plump grain under heat/drought stress is a varietal trait.
3) The barley variety Shepherd was commercialised in 2008 and seed was available to growers in 2009. Recommended production practices for Shepherd were distributed.
4) Utilisation of NIR screening of grain samples and calculated estimates of feed quality will make breeding barley varieties with good feed quality more feasible.
5) Breeding lines with consistently higher digestible energy (DE) levels and lower husk content were identified. One of them, ND19119-5 introduced from the USA, was recommended for release.
6) Breeding material was identified that could rapidly improve the drought/heat tolerance of barley grown in the Northern region was identified.
7) Two populations of doubled-haploid barley lines were developed for future studies of pig feed quality attributes, foliar disease resistance, and agronomic traits.

Potential users of information and research results on barley are:

1) Pig feeders – the feeding value of barley was found to be variable across varieties and production areas. These differences could be rapidly estimated using NIR technology.
2) Barley growers – new varieties grown using recommended agronomic practices can increase returns.
3) Pork industry – improved barley varieties and production practices can contribute to the economic health of all sectors.
4) The value these findings to the Australian Pig Industry depends on their uptake by components of the industry.

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1. Introduction

Background and rationale for conducting the research

Grain is fed to animals for the high energy content of its starch. Barley (*Hordeum vulgare*) is an important source of feed for the pork industry, but the quantity and quality of barley available for pigs (*Sus scrofa domesticus*) in the GRDC Northern region are variable. Significant improvements in barley production systems and barley varieties can be made, but those improvements should address also the needs of the pork industry.

Background: Pork production involves two biological systems, animal and plant, which interact with both the environment and each other. To develop efficient pork production systems, both components need to be optimised. Numerous studies and sustained breeding efforts have focused on improvement of animal breeds and their ability to utilise feed stocks efficiently. Feed quality parameters, the cost of ingredients, animal genetics and specific animal growth stages are used to develop least-cost feed formulations. Yet, variations in grain quality based on its origin and variety are often given minimal consideration in livestock production systems. In barley, faecal digestible energy (DE) levels for pigs vary by much as 15% over varieties and sources (Fairbairn et al. 1999). Significant differences exist among barley varieties for feed quality parameters (reviewed by Newman and McGuire, 1985) and considerably more variation has been reported in world collections of barley (Bowman et al. 2001). More effective and efficient systems for measurement of barley quality would make utilisation of this variability in feeding systems and barley improvement more feasible.

Rapid estimates of barley quality: Determination of genetic and physical variability in barley for feeding pigs has been limited by the lack of reliable, fast, and low-cost estimates of the energy content and nutritive value. Fairbairn et al. (1999) demonstrated that the physical and chemical compositional parameters as determined by standardized methods can be used to estimate digestible energy (DE) values of barley samples for pigs. Near-infrared (NIR) reflectance spectroscopy was developed in the 1970’s for rapid assessment of malt quality parameters such as protein and moisture contents (Burger and LaBerge 1985). Newman and Newman (1992) and Fox et al. (2003) reviewed the quality attributes of barley and their biochemical expressions. Using non-destructive near-infrared transmission spectroscopy, current NIR calibrations can predict malt and feed quality parameters (Helm et al. 2008). Satisfactory estimates of other quality attributes can be made with either NIR reflectance or transmission spectroscopy (Kays et al. 2005). The NIR calibrations developed through the Premium Grains for Livestock Program (PGLP) for Australia grown feed grains (Flinn 2003) provide the technology needed to study the effects of crop management on grain quality and to develop varieties with better feed quality. Lu et al. (2000) has already demonstrated that NIR measurements could be an effective tool in breeding for malt quality of barley.

Variety evaluation and breeding: This project evaluated the quantity and quality of feed barley varieties currently available to the Pork Industry in Queensland and northern New South Wales. Agronomic practices that can optimise barley production in the region were examined. Breeding procedures were initiated to rapidly improve feed quality of barley for pigs. To do this, the project dovetailed with research being carried out by the Barley Breeding Australia – Northern Region (BBA-North) barley breeding program. The aim is to deliver to the pork industry improved varieties and recommended on-farm management practises for them.

2. Methodology

Agronomic studies: This project used two strategies to deliver the proposed outcomes. Firstly, trial management was used in conjunction with an investigation of on-farm agronomic practices to develop best practice protocols. These recommendations were designed to produce high yields of barley grain with optimum feed quality for pigs. The first stages of this work included interactive consultation with grain growers and pig producers to identify the key grain and quality needs for the Northern industry. Consultation with the Grain Search project participants was used to refine the consultation and extension methodologies. Data obtained from this activity were fed back into the breeding program and made available to the Pork CRC, key industry groups and stakeholders.

Part 2 of the agronomy aspect of the project involved multiplication of selected breeding lines for intensive on-farm testing to develop optimum agronomic management practises that target grain production for the pig industry. The larger experiments were conducted in close collaboration with CHM and their agronomists. The aim of these trials was to identify varieties and management practices that could benefit the pork industry by improving barley supply and lowering grain production costs. Replicated drill strips (2 replications at each site) containing 10 to 12 entries were planted at up to 11 Northern region sites in 2007 through 2009. Sites were chosen to distribute them over the Northern region based on pig and barley production (see Appendix 1). Agronomic production practices used were based production recommendations for barley in the region. Yield data were collected from each site and quality samples were submitted for NIR analyses of feed quality. The replicated agronomy strip trials were grown and harvested in 2007 from nine sites: Duaringa (Central Queensland), Orion (Central Queensland), Felton, Dulacca, Macalister, Bithramere, Grafton, North Star (Tulloona), and Weemalah. The replicated agronomy strip trials were conducted and harvested in 2008 from eight sites: Orion (Central Queensland), Burnett (near Kingaroy), Dulacca, St George, Lundavra, Pittsworth, Weemalah, and Tulloona (west of North Star).

Agronomic studies conducted under the GRDC Agronomy Project for the northern region examining the time of planting, seeding rates and depth of planting were also conducted in 2007 through 2009 at a few locations using approximately 20 varieties. Yield data and quality samples were collected from these trials. In an addition, trials and seed increases were grown to produce sufficient grain supplies of new barley lines to conduct extensive wet chemistry and live feeding trials in collaboration with the Pork CRC Subprogram 1B projects.

Guidelines for on-farm management practises and supply chain arrangements were published for new barley varieties as they were commercialised. Besides and outline of variety attributes, these guidelines included information management on planting times, soil type, nutrition requirements, and pest and disease risks. Promotion of the packages and management techniques was conducted to ensure maximum uptake of new varieties and management practises.

Quality assessment: Near infrared (NIR) spectroscopy is a rapid, non-destructive and inexpensive tool that was used to screen grain samples for feed and malt quality of breeding lines and varieties in the BBA-North barley breeding program. Drill strip trials, agronomy experiments, and barley breeding yield trials grown in the northern region were evaluated using NIR. The yield trials were grown at up to 18 locations in the Northern region using partially replicated designs. Most yield trials were grown in farmers' fields and used recommended production practices. After harvest of individual plots from field trials, grain samples were cleaned and weighed and yields were determined using appropriate statistical analyses. Grain samples (500 or 1000 grams from each plot) were used to determine physical and chemical properties of the grain. Sub-samples were scanned though a Foss NIRSystems 6500 and the readings were used to estimate chemical properties of grain quality. Faecal and ileal digestible energy values were estimated using calibration equations develop by the Premium Grains for Livestock Program (Finn, 2003). Many other grain quality parameters were determined using these and other equations (Table 1).

Table 1. List of grain quality parameters measured on grain samples of barley in 2007 to 2009 using traditional and near infra-red (NIR) transmission spectroscopy methods.

Agronomic quality parameters

Yield was measured and calculated to t/ha.

Physical grain quality tests

- Grain size
    - screenings (SCR) % of grain <2.2mm
    - retention (RET) % of grain >2.5 mm
    - plump grain (PG) % of grain >2.8mm
- Hectolitre weight (HLW), weight per volume kg/hl

NIR predictions

- Traditional predictions
    - L colour
    - Protein % as is
    - Moisture %
    - Starch % as is
    - HWE Hot Water Extract – % wort able to be extracted from malted barley
    - PSI hardness
    - ADF fibre %
    - Husk %
- PGLP equations
    - Pig faecal digestible energy
    - Pig ileal digestible energy
    - Ileal to faecal DE ratio
    - Pig faecal DE intake index
    - Total starch % of dry matter
    - ß-glucans % of dry matter
    - Xylose % of dry matter
    - Insoluble arabinoxylans % of dry matter
    - Total soluble non-soluble polysaccharides % of dry matter
    - Acid detergent fibre % of dry matter
    - Englyst neutral detergent fibre % of dry matter
    - Crude fibre % of dry matter
    - Specific weight kg/hl
    - Hydration capacity

Calculations

Energy/ha – combines the DE (faecal or ileal) with the yield to give a value of MJ/ha. Parameters that were looked at to describe pig feed quality were faecal and ileal DE, grain size and starch.

The NIR based estimates of grain quality parameters and selected physical traits such as percentages of plump kernels and test weights were used to evaluate grain samples from agronomic and drill strip trials. The main quality traits used in selecting lines for pigs were high digestible energy (DE) and low fibre/husk values. The physical traits plus estimates of grain protein and extract values were used to identify lines potentially having good malt quality. Breeding lines with improved quality traits were chosen for advancement to the next cycle of field evaluations and the best ones were used as parents for new crosses. Wet chemistry and feeding trial studies were coordinated through another project in the Pork CRC Subprogram 1B.

Barley breeding: The second strategy improving the quality of barley involved using fast-track breeding, high throughput pathology and rapid feed quality assessments to deliver varieties with high yield, disease resistance and improved feed quality. Much of this work was conducted as part of the BBA-North project. Inputs from the BBA-North involved a multidisciplinary scientific approach including barley breeding, plant pathology, cereal chemistry, molecular biology, agronomic practices, and industry development. This Pork CRC project dovetailed with activities of the BBA-North program, through 1) the application of pork specific selection tools (NIR quality assessment) to identify breeding lines with high feeding value for pigs, 2) fast tracking specific breeding populations targeting pig feed quality attributes, and 3) identifying and increasing selected lines to provide grain samples for more detailed chemical and feeding trial assessments.

Replicated yield trials were conducted by BBA-North at up to 18 sites for Stage 3 trials, 9 sites for Stage 2, 2 sites for Stage 1 trials from 2007 through 2009 in Queensland and northern New South Wales (approximately 9,000 plots per year). Data were collected on maturity, plant height, lodging, straw breakage, and grain yield per plot. Entries in yield trials were screened for reactions to seven foliar diseases: leaf rust (*Puccinia hordei*), spot form of net blotch (*Pyrenophora teres* f. *teres*), net form of net blotch (*Pyrenophora teres* f. *maculata*), powdery mildew (*Blumeria graminis*), scald (*Rhynchosporium secalis*), spot blotch (*Bipolaris sorokiniana*), and stem rust (*Puccinia graminis*). Seedling tests were conducted in glasshouse facilities for the first four diseases and adult plant tests were conducted in specific disease screening nurseries for all diseases. Grain samples were collected from the yield trials and analysed for feed and malt quality parameters. Primary traits targeted in these evaluations included high yield, high pig DE, low fibre/husk, improved disease resistance, and better adaptation to northern environments.

Initial tests indicated that introductions from the North Dakota two-rowed barley breeding program and introductions from other parts of Australia have many desirable quality and disease reaction attributes. Crosses were made in 2007 between the North Dakota (ND) introductions and Australian varieties to transfer these attributes to high yielding material adapted to the Northern region. The traits of particular interest are large plump kernels; heat tolerance or 'stay green'; reduced lodging; and resistance to spot blotch and stem rust. The first large group of lines selected from these crosses were entered in 2009 yield trials.

Speed breeding efforts: Three approaches to rapid generation of breeding lines were tested: 1) single-seed-descent using off-season nurseries, 2) production of doubled-haploids via anther culture, and 3) utilization of F2 derived lines in yield trials. Generation of doubled-haploid (DH) populations was supported using funding from the Pork CRC because this seemed the most effective use of this resource.

New crosses were made among selected lines and varieties to increase desirable attributes including feed quality. To rapidly develop new lines for testing, three crosses were chosen to produce DH lines. Using this procedure, pure lines can be available for initial phase of testing in one year. Plantlets were produced from hybrid plants via anther culture by Sue Broughton, Cereal Doubled Haploid Program, Department of Agriculture and Food, South Perth, WA. The plantlets were transferred at the Hermitage Research Station in small containers; individual plantlets were transferred to pots and eventually transplanted in a field protected by bird netting. Seed was harvest from the diploid plants to produce genetically homozygous lines. These lines were evaluated for reaction to spot form of net and seed supplies were increased during 2009 for yield trials in 2010.

3. Outcomes

Summary

- Good agronomic production practices were shown to produce more grain and improve the feeding value of the grain produced. Maintenance of plump grain under heat/drought stress is a varietal trait that can be manipulated by planting date, soil moisture and seeding rate.
- Variety characteristics were found to play an important role in grower uptake of new barley varieties in the Northern region e.g. Grout.
- Shepherd barley was commercialised in 2008 and seed was available to growers in 2009. Recommended production practices for Shepherd were developed and distributed.
- NIR screening can estimate the feed quality for pigs of barley grain samples rapidly and can be used as a tool in breeding for feed quality.
- Breeding lines with consistently higher digestible energy (DE) levels and lower husk content were identified. One of them, ND19119-5 introduced from the USA, was recommended for release.
- Two populations of doubled-haploid barley lines were developed and recommended for future genetic studies of pig feed quality parameters, foliar disease resistance and agronomic traits.
- The utilisation of introductions from North Dakota in the BBA-North breeding program will facilitate rapid improvements in agronomic traits, yield, foliar disease resistance and grain quality of barley varieties recommended for the northern region.

Research results and discussion

1. **Production practices and demonstration drill strips**

The concept of using agronomic practices to improve crop production involves two components: 1) optimisation of recommended production practices and 2) identification of traits that make new varieties popular. The first relies on identifying better production practice and distribution of this information to producers while the second is based on the suitability of a variety to production practices currently used by growers.

Drill strips: The entries selected for the drill strip trials were partially based on the utilisation of barley varieties in the northern region (Table 2). New varieties were added to the list as data accumulated on their adaptation to the northern region. Sites for the drill strips were selected based on pig numbers in various production areas and the amount of barley produced in the parts of the northern region (Appendix 1). Twelve trial sites for drill strips were initially identified.

The replicated drill strip trials grown in 2007 experienced relatively dry conditions at planting and throughout the season. Thus, a few sites were not planted and harvested and yields at many sites were relatively low. Over trials, the highest yielding varieties were Commander and Shepherd (Table 3). The lowest yielding entry was the variety Gairdner, which is widely grown as for malting barley in the region. Bithramere near Tamworth and

Grafton were the sites with more rainfall and the highest yields. Data on estimates of feed quality parameters were collected, but are not presented here.

Table 2. Estimates of the market share in percentage of barley varieties grown in 2007 in the Northern region, May 2008.

Northern New South Wales		
Variety	**Market share %**	**Comments**
Gairdner	28	Malting driving this
Fitzroy	15	Eastern areas
Grout	28	Could be larger if a western plant
Mackay	5	East and west
Binalong	3	East only dropping quickly
Grimmett	8	Western areas
Skiff	7	East and west
Other	6	Includes Capstan, Cowabbie, Kaputar, Schooner (Gilgandra, Dubbo)
	100	
Queensland		
Variety	**Market Share - %**	**Comments**
Grout	40	Right across strength in CQ & West and short fallow
Mackay	10	CQ & West - some central downs
Gairdner	7	Mainly along border around Goondi - could be a bit more on downs this year if growers are chasing malt and don't like Fitzroy.
Fitzroy	8	SE downs and border/irrigation
Grimmett	5	West and along border
Kaputar	5	All over
Tallon	10	Central downs Dalby
Binalong	8	Central downs Dalby
Other	7	Skiff, Corvette,
	100	

Table 3. Yield data from barley varieties grown in replicated drill strips grown in the Northern region in 2007.

	Test sites in 2007 for replicated drill strips									
Variety	**Duaringa**	**Orion**	**Felton**	**Macalister**	**Dulacca**	**Bithramere**	**Grafton**	**Tulloona**	**Weemalah**	**Average**
	Grain yield in MT/ha									
Commander	2.66	2.28	2.23	2.90	3.13	5.22	4.51	3.36	3.63	3.32
Shepherd	3.10	2.63	1.51	2.58	3.10	5.15	4.83	3.08	3.20	3.24
Grout	2.70	2.38	2.05	2.46	2.96	5.11	4.05	3.10	3.11	3.10
NRB01145	3.25	2.64	1.70	2.10	2.87	4.81	4.33	2.88	3.03	3.07
Skiff	2.81	2.47	1.39	2.46	2.70	4.53	4.47	3.09	3.36	3.03
Fleet	2.33	2.24	1.49	2.17	3.30	4.76	3.90	3.34	3.49	3.00
Fitzroy	2.92	2.38	1.35	2.06	2.41	4.74	5.06	2.82	2.93	2.96
Mackay	2.00	2.25	1.18	1.95	2.71	5.03	5.15	2.77	2.85	2.88
Gairdner	2.42	1.70	1.15	2.17	2.45	4.15	4.15	2.73	2.84	2.64
Average	2.69	2.33	1.56	2.32	2.85	4.63	4.49	3.02	3.16	

The weather conditions during the 2008 winter season were more favourable for barley production in the northern region. Data were collected on yield from all trials and grain quality estimates were made. Hindmarsh, Commander and Grout were the highest yielding entries over locations (Table 4). However in individual trials, rankings of highest yielding varieties responded differently to site specific environments. For example, ND19119-5 had high yields at Pittsworth and at St. George.

Table 4. Yield data for barley varieties grown in replicated drill strips grown in the Northern region in 2008.

	Test sites in 2008 for replicated drill strips								
Variety	**Burnett**	**Dulacca**	**Lundavra**	**Tulloona**	**Orion**	**Pittsworth**	**St George**	**Weemalah**	**Average**
	Grain yield in MT/ha								
Hindmarsh	2.24	2.08	5.54	3.40	4.83	2.75	4.64	3.53	3.62
Commander	2.41	1.55	3.90	3.59	4.66	3.14	4.17	4.60	3.50
Grout	2.80	1.51	5.47	3.14	4.50	2.59	4.19	3.63	3.48
Shepherd	2.54	1.71	3.49	3.05	4.68	3.25	3.90	3.76	3.30
Fitzroy	2.16	1.93	4.84	2.24	4.34	3.29	4.10	3.07	3.26
ND19119-5	2.00	1.64	2.92	3.02	3.84	3.31	4.53	3.38	3.08
Skiff	2.32	1.69	4.60	2.49	4.18	2.75	3.67	2.85	3.07
Fleet	2.08	2.05	2.44	3.59	4.39	2.69	2.95	3.17	2.92
Gairdner	1.77	1.37	3.83	2.37	3.88	2.56	3.29	2.96	2.75
Average	2.36	1.77	4.43	2.99	4.45	2.98	3.87	3.43	

The quality of the grain harvest from the strips showed considerable variation over sites and barley varieties. Grain retention values are often used in marketing feed barley and therefore varietal differences plump grain percentages affect the market price of barley. In general, recently released varieties had higher retention values than older varieties such as Gairdner and Skiff (Table 5). ND19119-5 had much higher plump grain values than other varieties tested. At several trials, ND19119-5 was the only variety that produced samples that could be classified as Feed #1 based on grain retention over a 2.5 mm slotted screen.

Table 5. Grain retention percentages for barley varieties grown in replicated drill strips grown in the Northern region in 2008.

	Test sites in 2008 for replicated drill strips								
Variety	**Burnett**	**Dulacca**	**Lundavra**	**Tulloona**	**Orion**	**Pittsworth**	**St George**	**Weemalah**	**Average**
	% Grain retention on a 2.5 mm slotted screen								
Hindmarsh	64.1	77.7	36.3	46.2	89.6	7.5	26.8	53.9	50.1
Commander	37.1	35.4	58.9	56.9	91.8	36.9	33.7	48.8	49.9
Grout	52.8	65.1	64.6	34.7	90.0	8.7	27.5	66.5	51.2
Shepherd	56.6	40.7	56.0	42.9	93.5	53.5	40.7	55.8	55.0
Fitzroy	34.3	37.7	33.7	19.1	93.3	28.1	11.0	20.1	34.7
ND19119-5	91.8	88.8	93.3	88.2	98.6	89.4	91.0	94.3	91.9
Skiff	15.1	37.8	18.4	9.7	91.3	5.2	3.2	11.5	24.0
Fleet	64.0	75.0	74.6	71.5	96.4	30.9	45.9	71.7	66.2
Gairdner	27.7	9.9	19.7	29.1	85.4	11.7	8.8	31.8	28.0
Average	47.5	50.4	51.6	39.1	92.7	27.5	29.3	48.8	

Test weights in kilograms per hectolitre were variable over varieties except at the Orion site where all varieties had plump kernels (Table 6). The varieties Fitzroy and Fleet had the lowest estimates for kg/hl while ND19119-5 and Hindmarsh had the highest values.

Table 6. Test weight values for barley varieties grown in replicated drill strips grown in the Northern region in 2008.

	Test sites in 2008 for replicated drill strips								
Variety	**Burnett**	**Dulacca**	**Lundavra**	**Tulloona**	**Orion**	**Pittsworth**	**St George**	**Weemalah**	**Average**
	Test weight (kg/hl)								
Hindmarsh	65.7	69.3	72.5	66.7	67.0	65.8	67.8	66.8	67.7
Commander	61.4	65.6	68.5	65.7	65.9	65.5	63.9	62.0	64.8
Grout	64.0	66.7	70.4	65.5	66.9	63.4	64.9	66.2	66.0
Shepherd	63.6	66.4	69.4	66.0	66.9	68.5	65.7	65.7	66.5
Fitzroy	57.5	64.1	64.8	60.2	65.0	63.8	56.2	56.9	61.0
ND19119-5	64.6	70.1	71.4	68.5	66.9	68.7	68.4	67.9	68.3
Skiff	62.1	67.3	68.4	62.8	66.9	65.0	61.3	62.2	64.5
Fleet	57.1	65.2	67.8	63.3	64.4	61.4	60.0	60.2	62.6
Gairdner	64.0	64.4	68.8	68.4	66.5	65.4	67.3	66.4	66.4
Average	61.8	66.2	68.7	64.5	66.2	65.0	63.1	63.3	

The yield data collected from the barley drill strip trial suggest that predicting which variety is best for a given paddock and planting time is nearly impossible. However, the data also show tends such as Hindmarsh yielding well at many locations. Other factors besides location should be considered in selecting barley varieties. Some of these include disease reactions, lodging potential, post-ripe straw breakage, and seed costs.

Comparisons for chemical components of grain quality were made. However, only data on pig faecal digestible energy (DE) and percent husk are presented because these traits are most likely to affect feeding values of various barley seed lots. The correlations among quality traits are often high. Hindmarsh, Skiff and ND19119-5 had the highest DE values over locations (Table 7). The trial at Dulacca, which had the lowest average yield, produced grain with the highest DE values. Comparing of grain samples from combinations of locations and varieties, the difference in DE values between the highest and lowest was nearly 9%.

The percent husk values were also variable, but did not closely parallel values for DE. ND19119-5 had the lowest values for percent hull followed by Hindmarsh (Table 8). Fleet, Commander, and Shepherd had the highest average values. Across location and variety combinations, the percent husk values varied by nearly 40%. Base on these data, both environmental and varietal factors influence the feeding value of barley grain. These differences are difficult to predict using traditional measures of grain quality: grain plumpness and hectolitre weight. Utilization of varietal differences for these attributes appears the most effective means of making short-term gains in quality of barley for pigs. However, varietal differences in yield potential could be an economic offset to the advantages in grain quality.

Table 7. NIR estimates of pig faecal energy values for samples of barley grown in replicated drill strips grown in the Northern region in 2008.

	Test sites in 2008 for replicated drill strips								
Variety	**Burnett**	**Dulacca**	**Lundavra**	**Tulloona**	**Orion**	**Pittsworth**	**St George**	**Weemalah**	**Average**
	Pig faecal digestible energy (MJ/kg)								
Hindmarsh	12.8	13.3	13.1	12.9	12.8	13.0	12.9	12.9	12.9
Commander	12.6	13.0	12.8	12.8	12.7	12.8	12.6	12.6	12.7
Grout	12.5	12.9	12.6	12.6	12.6	12.7	12.5	12.4	12.6
Shepherd	12.4	12.9	12.6	12.6	12.5	12.8	12.4	12.4	12.6
Fitzroy	12.4	12.9	12.9	12.7	12.7	12.9	12.6	12.6	12.7
ND19119-5	12.8	13.3	13.2	13.0	12.8	12.8	12.9	12.9	13.0
Skiff	12.7	13.2	12.9	12.9	12.7	13.0	12.7	12.7	12.9
Fleet	12.2	12.7	12.5	12.4	12.3	12.3	12.2	12.4	12.4
Gairdner	12.4	12.8	12.7	12.9	12.8	12.7	12.6	12.7	12.7
Average	12.5	13.0	12.8	12.7	12.6	12.8	12.6	12.6	

Table 8. NIR estimates of hull percentages (% husk) for samples of barley grown in replicated drill strips grown in the Northern region in 2008.

	Test sites in 2008 for replicated drill strips								
Variety	**Burnett**	**Dulacca**	**Lundavra**	**Tulloona**	**Orion**	**Pittsworth**	**St George**	**Weemalah**	**Average**
	% Husk on the grain								
Hindmarsh	13.3	10.4	10.6	12.2	12.7	12.5	11.7	11.5	11.9
Commander	13.7	12.6	12.3	13.4	13.4	13.3	12.6	12.6	13.2
Grout	14.0	11.1	11.4	12.9	14.1	12.9	13.0	12.4	12.7
Shepherd	14.0	13.2	12.0	13.4	14.1	13.7	12.2	12.5	13.2
Fitzroy	14.2	12.5	11.7	12.9	14.0	13.7	13.0	12.2	13.0
ND19119-5	12.3	10.6	10.0	11.1	12.5	11.4	10.7	10.6	11.2
Skiff	14.0	12.5	11.7	12.9	13.6	12.5	13.2	11.8	12.8
Fleet	13.7	11.7	12.9	13.6	14.1	14.0	13.3	13.1	13.3
Gairdner	14.3	12.8	11.9	12.7	13.5	13.5	12.2	12.2	12.9
Average	13.8	12.0	11.7	12,8	13.6	13.3	12.6	12.2	

Variety selection by growers: The acceptance and utilisation of new varieties by barley growers is difficult to predict because each growers needs to evaluate varieties in his paddocks and under his management practices. The variety Grout was released in 2005 and gained considerable popularity in the northern region (Table 2) even though it is not accredited for malting and brewing. Grout production has expanded into wetter production areas of the northern region for which it was not recommended. In retrospect, evaluation of the data accumulated on the performance of Grout provides some information on its rapid acceptance.

Although the yield differences were not large, the data from the drill strip trials indicate that Grout had the highest average yield among varieties available to barley growers in 2007 and 2008 (Table 3 and 4). Estimates of plumpness based on retention percentages also suggested that Grout has an advantage (Table 5). However, no advantage in test weight values was observed (Table 6). The most important feature of Grout appeared to be early maturity, which was found across planting dates (Figure 1). Rapid plant maturation means that Grout may escape the effects of dry, hot weather, which often occurs late in the growing season. When frequent rain events occur late in the spring in the Northern region, early maturing varieties have a distinct advantage at harvest time.

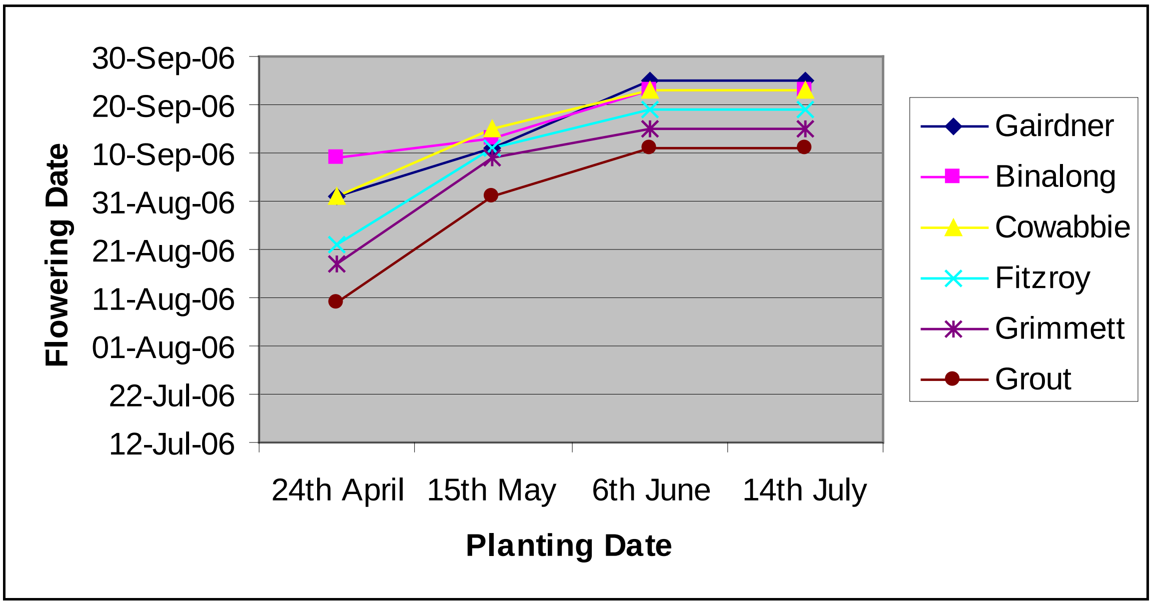

Figure 1. Heading dates of barley varieties from the data collected from a phenology trial at Moree in 2006.

Agronomic trials: The agronomy trials were supported in the Northern region by a GRDC Agronomy Project. They provide additional information about management practices and varietal responses. The agronomy trials examined several aspects of barley production including time of planting, depth of sowing, seeding rate, nitrogen fertilisation, grazing, and fodder production. Field trials were conducted mainly near Tamworth and Warwick. Detailed results are not presented here, but some observations relevant to barley production are included below.

Earlier planting dates generally produced higher yields when the crop was not damaged by frost. Grain from earlier planting dates generally had higher retention values, lower protein and better grain quality profiles. Grazing caused a higher yield reduction in plots planted at later dates and grazing of early planted trials tended to reduce grain protein. Higher nitrogen application rates increased yield and grain protein. Early nitrogen application appeared more effective than split applications. Depths of seeding to 15 cm had little effect on grain yields, except for the varieties such as Hindmarsh where deep sowing reduced emergence and stands. Seeding rates that produced 1 to 1.5 million plants per hectare seemed to optimise yields.

A few differential variety responses to the treatments were observed. Late planting of ND19119-5 at Warwick increased its yield relative to other varieties. Low grain plumpness scores and low test weight values were found frequently when drought affected trials. Final production levels and grain quality were influenced by varietal specific responses to various production practices and environment.

Table 8. Summary of feed quality estimates for barley varieties and experimental lines grown in Stage 3 yield trials in the GRDC Northern region from 2006 through 2008, data from 40 trials.

Genotype	Retention %>2.5 mm	Test weight kg/hl	Protein %	Digestible energy MJ/kg	Total energy MJ/ha
Buloke	71.1	66.3	12.5	12.74	44634
Commander	87.3	66.5	12.1	12.65	48653
Fitzroy	68.0	64.3	12.2	12.65	45895
Gairdner	66.2	67.1	13.5	12.61	39508
Grout	82.2	66.8	11.9	12.51	48845
Hindmarsh	80.1	67.9	12.9	12.79	51332
Mackay	68.5	67.5	12.3	12.67	44898
Shepherd	84.4	68.0	12.6	12.56	46472
ND19119-5	95.6	68.9	13.1	12.96	40058
ND23164	94.1	66.1	12.5	12.72	33108
NRB04182	74.8	67.5	11.9	12.57	46548
NRB05387	77.8	67.6	12.3	12.67	46934
NRB05395	74.7	67.9	12.0	12.73	44699
NRB05433	75.7	67.5	12.2	12.59	47350
NRB05549	81.1	67.7	12.2	12.59	45448
NRB06052	70.9	66.9	12.1	12.70	48874
NRB06053	71.9	68.0	12.7	12.70	49063
NRB06059	72.6	68.7	12.6	12.66	46884
NRB06071	68.7	67.5	12.5	12.67	42404
NRB06301	78.9	68.9	12.8	12.73	43862
NRB07046	89.8	68.4	12.9	12.61	44005
NRB07069	91.0	67.5	12.1	12.64	47512
NRB07078	70.2	65.9	12.0	12.57	45296
NRB07082	83.1	65.7	12.4	12.64	44981
NRB07127	88.0	67.6	11.7	12.58	48757
VB0611	78.6	64.4	12.1	12.57	52531
WABAR2312	84.5	68.4	13.1	12.67	44730
WABAR2315	84.9	66.8	13.3	12.68	45337
WABAR2450	73.9	66.4	12.5	12.60	47964
WABAR2452	84.3	66.3	12.8	12.65	43950
WI4262	79.8	65.3	12.9	12.99	44243

2. NIR quality evaluations

Quality testing of breeding material: Experimental lines and varieties in BBA-North yield trials were screened for feed and malt quality parameters using NIR. The summarised results are based on variable numbers of entries in advanced yield trials over three years using yield and quality data collected from 40 trials (Table 8).

A few entries such as ND19119-5 and WI4262 were found to have higher faecal DE (MJ/kg) values than most entries. ND19119-5 also had high values for grain retention and test weight, but high values for these traits did not appear to be associated with higher faecal DE levels. Values for energy production per hectare (MJ/ha) were estimated for the entries. Grain yield was found to be by far the most important trait influencing energy production per unit area. Some entries such as VB0611 had very good yields, but relatively low test weight values. Entries with low test weight values did not necessary have low DE values.

To understand the potential impact of DE value variability on barley breeding, the quality data were used to estimate heritability for barley grown in the northern region. Faecal and ileal DE values had heritability estimates across the sites of 0.65 to 0.90 for faecal DE and 0.79 to 0.89 for ileal DE (Hocroft et al. 2009). The heritability statistic provides an estimate of the total variance caused by genetic factors. The heritability estimates at most sites were greater than 0.80 indicating that transfer of these traits to improved breeding material is possible. Differences among environments contributed a small portion of the variance. The heritability of yield varied across the 17 sites with scores for yield ranging from 0.47 - 0.85. Again this suggested that yield improvements over variable environments are possible.

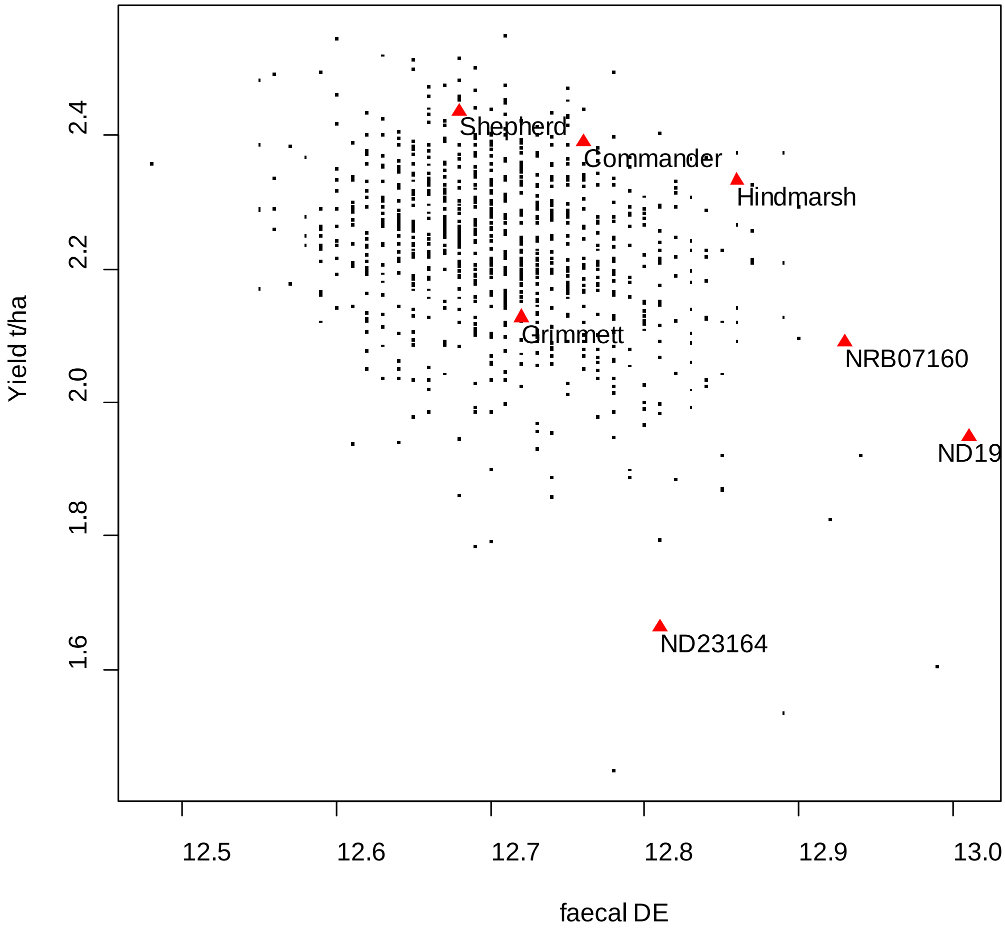

Figure 2. Scatter plot of BLUPs for yield vs. faecal digestible energy (DE) for barley lines in BBA-North trials from 2006 to 2008 (Hocroft et al. 2009).

Since the combinations of yield and DE values can have different influences the variety that grain growers and pig feeders prefer, the summarised data from yield trials is present in a scatter diagram (Figure 2). Recently released varieties had better average yields, but they showed variability in DE levels. Lines with high DE values were relatively rare and low yielding, but a possible exception is Hindmarsh.

The high heritability estimates for yield and DE suggested that both traits can be improved in barley varieties developed for the northern region. Since there seems little relationship between these traits (Figure 2), active selection for both will be required to breed varieties desirable for both of them. In fact, data from a preliminary yield trial grown in

2008 (not shown) suggest that a few entries have high values for both traits. This means that there may be considerable opportunity to develop high energy barley varieties for pigs.

3. Shepherd barley commercialised

The breeding line NRB03470 was recommended for commercialisation in 2008 based on high yield, good grain quality and improved resistance to foliar pathogens of barley. The name Shepherd was selected for the line to honour the contributions of Barry Kenneth Shepherd to the game of cricket and to the Western Australian Cricket Association. Shepherd seed was increased by AWB Seeds during 2008 season and was made available to growers in 2009. Sales were about 150 MT, enough to plant 6,000 to 7,000 hectares. Growers in many parts of the northern region evaluated Shepherd in their paddocks during 2009. Some excellent reports on grower satisfaction were received.

The data on the performance of Shepherd in comparison to other barley varieties in the Northern region is summarised in the attached management package (Appendix 4). The data collected for this report is from on trials conducted by BBA-North and supported by GRDC. The accumulated information was later used to develop an AWB Seeds fact sheet for Shepherd.

4. Barley breeding evaluations

Establishment of breeding goals: The barley breeding effort for the Northern region funded in part by Grains Research and Development Corporation (GRDC). The primary objective is development of high-yielding barley varieties adapted to the northern region with good malt and/or feed quality. Although barley improvement has been an ongoing project since the late 1960's, the recent introduction of new germplasm has encouraged a re-evaluation of breeding opportunities.

Tests on an introduction from the North Dakota two-rowed barley program indicated significant differences in seed size, a measurement of and tolerance to heat stress, occurred among entries in yield trials (Figure 3). Even if a portion of the seed size advantage of ND19119-5, a sister line of the US variety Rawson (Franckowiak et al., 2007), was recovered during the breeding process, new varieties would have a distinct advantage over current varieties. ND19119-5 was also found to be resistant to spot blotch and stem rust, which are likely to be important diseases if barley production is expanded into coastal areas of the Northern region and Northern Queensland. The higher DE values of ND19119-5 (Table 8) were an unexpected bonus. This implies that the feed quality of barley grown in the Northern region can be improved. However, the lower energy yield per unit area of ND19119 (Figure 2) of ND19119-5 will restrict where if can be recommended for production in Australia.

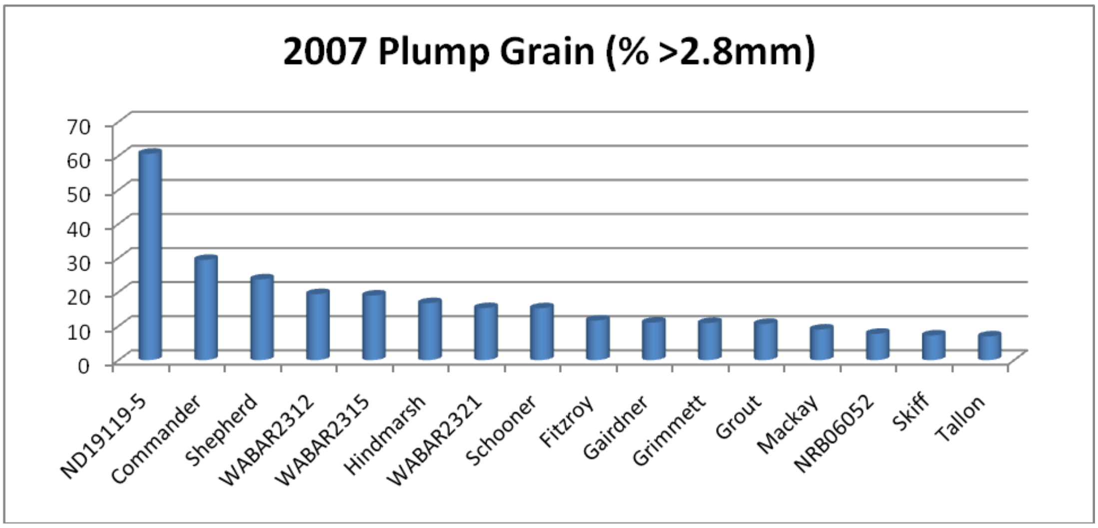

Figure 3. Percentages of plump kernels comparisons for ND19119-5 and selected barley varieties grown in the GRDC Northern Region, averages from 14 trials grown in 2007.

Evaluation of breeding lines: Since 2006, breeding lines and varieties were tested in the Northern region for agronomic traits, disease reactions and grain quality. The advanced experimental lines [NRB06053 (Mackay/Baronesse), NRB06059 (Mackay*2/WI3214) and NRB07127 (Fitzroy/Amulet)] with the highest values for DE per hectare were no better than best check varieties (Commander, Grout and Hindmarsh) included in advanced yield trials (Table 8). These breeding lines were selected primarily based on yield, malt quality attributes, and disease reactions (Table 9). Release of these lines is not being considered because they do not offer a distinct advantage over current varieties.

A summary of disease reactions observed in screening nurseries indicates that most varieties are susceptible to one or more of the foliar diseases that occur sporadically in the northern region. The foliar disease reactions of best experimental lines such NRB05433 (WABAR2045/2*Mackay) and NRB07127 showed that improvements in disease resistance were being made. These lines were also among the better ones for kernel retention and yield. However as anticipated, they did not show improvements in DE levels and other feed quality traits. These traits were not used as selection criteria during the development of these lines. This illustrates the point that an active selection program for specific traits is needed to improve them.

Release of ND19119-5: To take advantage of the improved seed size of ND19119-5, its stability in seed size in stressed environments, and its higher DE values in the northern region, ND19119-5 was recommended for commercialisation in June 2009. The attributes of ND19119-5 were outlined (Appendix 2). Although it yields less in many ‘good’ environments and is susceptible to powdery mildew and a new pathotype of leaf rust are of concern, the advantages offered in drought and heat stressed environments could benefit a large number of barley growers. Also, its resistance to spot blotch could be valuable in coastal areas of the northern region. Barley Breeding Australia approved proceeding with commercialisation, but a release plan has not been finalised.

Table 9. Foliar disease reactions for barley varieties and experimental lines tested using inoculated seedling and field nurseries in 2008.

Variety or line	Leaf rust	Net form net blotch	Spot form net blotch	Powdery mildew	Scald	Stem rust
Binalong	VS*	VS	MS	VR	S	VS
Buloke	VS	R	S	VR	MS	VS
Commander	VS	MS/S	S	MR-MS	S	VS
Fitzroy	R	R	S	VS	MS	MS
Flagship	S	MR	MR	MR-MS	MS	VS
Fleet	MS	R	MR	MR	MR	VS
Gairdner	S	R	VS	VS	S	VS
Grimmett	S	VS	S	VS	S	S
Grout	VS	R/S	MS	VR	VS	S
Hannan	VS	R/S	MS	VS	MR	VS
Hindmarsh	MS	R/S	VS	MR	MR	S
Kaputar	VS	R	S	VR	S	S
Mackay	MR-MS	MS	S	MR	MS	S
Roe	VS	R	MS	S	S	VS
Schooner	S	R	MS	S	MR	VS
Shepherd	MR	MR/S	S	VR	VS	VS
Skiff	S	MR/S	S	VS	MS	VS
Tallon	S	MS	VS	VR	MS	VS
Vlamingh	VS	R	MS	VS	MR	R
I97-600R-1	R	R	MS	VS	VS	R
ND19119-5	R	MR	MS	VS	MS	R
ND23164	VS	VR	S	VS	MS	R
NRB04182	MR	MR/S	S	VR	S	VS
NRB05387	MS	MS	S	MR-MS	S	S
NRB05395	MR	MR-MS	S	MR-MS	S	VS
NRB05433	MR	R/S	MS	MR	MS	S
NRB05549	VS	MR/S	S	VR	VS	VS
NRB06052	R	MR	VS	VR/S	S	S
NRB06053	MR	MS	S	MR	S	VS
NRB06059	R	MS/VS	R	MR	MS	VS
NRB06071	R	VS	S	R	S	VS
NRB06301	VR	MR/S	S	MR-MS	MS	VS
NRB07046	VR	MR	S	VS	S	VS
NRB07069	MR	R/S	MS	VS	S	VS
NRB07078	MS	MR	MR	VS	MR	VS
NRB07082	R	MR	MS	VS	MR	S
NRB07127	R	MR/S	MS	VR/MS	S	VS
VB0611	R	MR	MS	S	MS	VS
WABAR2312	MR	MS	MS	VS	MR	VS
WABAR2315	R	MS	MR-MS	VS	MR	VS
WABAR2450	VS	R	VS	VR	MS	S
WABAR2452	VS	MR	S	VR	VS	MS
WI4262	VS	MS/VS	MR	VS	R	VS

* R - MR = Very little to no disease found. No management decisions on disease control required. MR – MS = Moderate levels of disease observed. Monitor crops for disease development before management decisions are made. S-VS = High levels of disease observed. Management decisions will be required to reduce yield losses. MR/S – MS/VS = Variable response due to race changes in the pathogen.

5. Utilisation of introduced germplasm

Evaluation of introductions: Incorporation of the North Dakota (ND) two-rowed barley germplasm into the BBA-North barley breeding program involves a large number of traits and is a relatively high risk undertaking. These traits such as maturity and plant height are controlled by diverse genetic systems. Since barley varieties are inbred lines, the diverse genetic components need to be sorted so they function as an efficient unit. To utilise the advantages of seed size and heat tolerance of ND lines, the problem of relatively low yield needs to be resolved. The recovery of high-yielding breeding lines from crosses must be rapid and at a high frequency in order to select varieties with adequate disease resistance and grain quality attributes. Several crosses were made in 2006 to the available ND lines, F1 plants were grown during the summer season using glasshouse facilities, F2 progenies were grown in space planted nurseries in 2007. Individual plants were selected and harvested from the 2007 nurseries. After visual screening for seed quality traits, they were grown in 2008 preliminary yield trials. Introductions from Canada, China and the ICARDA barley breeding program in Mexico were also included in this crossing and selection approach. Additional breeding lines introduced from Canada, ICARDA and North Dakota during 2007 were included in the 2008 preliminary yield trials.

Initial breeding results: Results from screening of entries in the 2008 preliminary yield trials indicated that about 3% of the entries are resistant to four foliar diseases: leaf rust, powdery mildew, and net and spot forms of net blotch. Half of these lines were selected from crosses among northern region varieties and lines. Several were from the ICARDA program or from crosses to them and only a few involved crosses to ND lines. Of the 3% of the lines with the highest yields, over half were from crosses among material bred for the northern region. One third of the high yielding lines were from crosses between ND and northern region lines. Among the 3% with best grain quality, based on test weight, percent retention and DE values, 3/4 were introductions from North Dakota. The rest were from one cross: ND21089-1 x NRB04382 (Scarlett/Wpg 8412-9-2), but none ranked high for both disease resistance and yield. These results were from the first test of material involving ND lines as parents and demonstrate that ND lines can be valuable in improving barley for the Northern region.

Initial results from 2009 preliminary yield trials indicate that frequency of high yield lines with multiple resistances to foliar diseases is much higher than in 2008. However, the largest improvements were in grain size, test weights, and hot water extract values (an initial measure of DE). A number of lines harvested from the Breeza irrigation site also had low protein content values. A few lines had adequate combinations desirable traits so that they can be considered as new varieties. Realisation of the contributions of the ND will require a few more years of breeding.

6. Fast-track breeding

Evaluation of speed breeding techniques: Three approaches to rapid generation of breeding lines were tested: 1) single-seed-descent using off-season nurseries, 2) production of doubled-haploids via anther culture, and 3) utilization of F2 derived lines in yield trials. The development of three doubled haploid populations was supported by the Pork CRC because this approach appeared most effective speed breeding procedure.

Single seed descent populations: Initial contracts on utilization of single seed decent procedures for generation were initiated before the Pork CRC agreement was signed. The progenies received were skewed based on morphological markers and were from crosses that did not produce high yielding lines. Thus, four new populations were started using BBA-North resources and facilities at the Leslie Research Centre. The crosses are C06.046 (ND19119-5/NRB01140), C06.048 (ND19119-5/Fleet), C07.063 (NRB06059/ND21089-2) and C07.162 (ND19119-5/NRB06059). For each generation starting with the F2, seedlings were planted in individual cones and grown in growth chambers fitted with metal halide and/or high pressure sodium lights and temporarily supplemented with incandescent lights (Blumstein et al., 2009). The incandescent lights were run 24 hours per day and removed after 4 weeks. This protocol ensures saturation of radiance from the desirable far-red (700-750 nm) wavelengths and enhances reproductive development. These lighting procedures synchronized heading of the plants so that extremely early or late lines were not lost. Three generations were grown per year, but generation of recombinant inbred lines (RIL) was not completed by the end of this project because the growth chambers malfunctioned during one cycle of generation advance.

Doubled-haploid populations: The doubled haploid plantlets were received in plastic containers growing agar in May 2008. They were transplanted to potting media and later to the field in a birdcage. Transplanting was completed during July 2008 and seed was harvested from individual plant in December. Lines in three doubled haploid populations were tested by the BBA-North program for seedling reactions to spot form of net blotch. Individual DH lines that are highly resistant to spot form net of net blotch were found in all three crosses [C07-095 (SMO1645/ND23117-2), C07-273 (ND24260-1/Flagship), and C07-276 (ND24388/NRB06059)]. Seeds of the DH lines from two crosses (C07-273 and C07-276) were planted in partially replicated plots in June 2009. These plots were primary for seed increase, but initial agronomic evaluations were also conducted. After the elimination of tetraploid lines, there are 343 lines in the C07-273 progeny and 421 in the C07-276 progeny. Generation of molecular marker maps using the DH lines in these progenies is under way using other sources of funding. Since the feed quality profiles of ND24260-1 and ND24388 were good in an 2008 trial, several DH lines with resistance to spot form of net blotch and large, plump kernels were included in 2009 preliminary yield trials. Preliminary results from the 2009 trials indicate that a few of these lines have multiple resistances to foliar diseases and high yield potential. Preliminary grain quality test results for some lines are good, but not outstanding. DH lines ready for advanced yield trials were generated in a little over two years from the F1 seeds that were harvested in November 2007.

Testing of early generation selections: The introduction of ND lines from North Dakota created an opportunity to breed much improved barley varieties for the northern region. However, the timeframe in which positive results must be achieved is short. Current funding for the BBA-North breeding program extends until June 2011. Speed breeding procedures can not accommodate the number of crosses or the volume of material required to demonstrate positive results from this undertaking. Even utilization of off-season nurseries does not provide adequate development time. Thus, early generation selections from individual F2 and F3 plants are being evaluated in preliminary yield trials, disease screening nurseries, and NIR screens for grain quality.

Results from the 2008 preliminary yield trials and evaluations (reported above) suggest that rapid generation advance and early generation evaluation could be an effective means of developing quickly improved feed barley varieties. Many of the desirable traits have high heritability estimates and this should be reflected in the best lines identified in preliminary yields. Initial results from the 2009 preliminary trials, which contain many more lines selected from crosses to ND lines, indicate that about 10% of the new lines have yields equal to or better than the best check varieties. A few have excellent lodging resistance. About 20% of the entries were resistant to 3 or 4 diseases. Thus much improved barley varieties for the northern region can be developed rapidly.

4. Application of Research

Application of the research findings in the commercial world

1. Application of recommended production practices by individual barley growers could improve the probability of higher yields and better quality grain.
2. The NIR technology and the calibrations for estimation of feed quality for pigs were used in this study to determine the quality of barley grain samples. There exists a possibility this approach can be applied by pork producers to estimate feed values.
3. Shepherd, an advanced breeding line, was released in 2008 for commercial production in the northern region based on higher yields, better disease resistance, good physical characteristics of the seed, and greater performance stability.
4. The introduction from North Dakota, ND19119-5, was tested and recommended for commercialisation based on its large kernel size, higher DE content and the ability to produce good yields in marginal environments.
5. Improved barley varieties that can make barley production more profitable are being developed. The improved varieties will help keep barley as an important crop in the northern region in the face of both climate change and pathogen evolution.

Opportunities uncovered by the research

1. Replicated barley drill strips grown in farmers' paddock through out the northern region have provided information on production of barley varieties and estimates of the risks associated with each variety. Data from the limited number of yield trials grown during variety development are not adequate to sample the range of northern region environments, which are highly variable from year to year and location to location. Therefore, the drill strips can provide another source of information available to barley growers.
2. Barley varieties bred specifically for pork producers will be very challenging because marketplace incentives are needed to make barley production economically viable for growers. Many quality attributes of good feed barleys such as high starch content are similar to those requested by maltsters and brewers. Since increased production of barley is a common interest of both industries (Appendix 4), new barley varieties for the northern region may need to serve both purposes to be attractive to barley growers.
3. The ability to obtain estimates of feed quality attributes using a non-destructive procedure (NIR reflectance and appropriate calibrations) reduces the cost of data collection. This makes a concentrated effort on breeding for those attributes feasible.
4. The incorporation of introductions from North Dakota into the BBA-North barley improvement program has created an opportunity to rapidly improve barley varieties for the northern region. Key attributes included: a) improved grain size and feed quality for pigs, b) better tolerance to heat and drought stress, c) improved yield stability in less productive environments, d) multiple resistances to at least five foliar diseases, and e) improved tolerance to lodging.
5. Two doubled haploid populations were generated in part to facilitate future studies on the inheritance of feed quality parameters and to identify molecular markers for the controlling elements. This resource will facilitate development of barley varieties better matched to needs for pork producers.

Commercialization/Adoption Strategies

Barley production in the northern region lacks the volume and reliability needed to entice more pork producers to regularly use barley in rations for pigs. Improved varieties and specific management recommendations have been and will be developed to address the issue of price dockage based on receival standards. Barley varieties having better feed quality are possible, but price incentives are needed to ensure that grain growers produce high quality barley for the pork industry.

- **Potential benefits to cost of production:** More barley production near pork producers' operations can be encouraged by using improved varieties and better production practices. Reducing the frequencies of crop failure in local areas would benefit both grain growers and pork producers by cutting transportation costs.
- **Ease of adoption by producers:** Utilizable energy measured as DE in part determines the profitability of pork production. The utilisation of barley varieties with high DE values offers the possibility of lower costs. However, growers may pay higher seed costs and better management practices may needed.
- **Impact of the research:** This project has provided additional information about barley production practices and the potential for barley varieties. Two improved varieties were recommended for commercialisation. Estimations of feed quality using NIR will make improving the feed quality of barley a realistic goal.

5. Conclusion

This project has contributed positive elements to the future sustainable development and profitability of the pork production industry in Queensland and northern New South Wales by addressing the current issues regarding feed grain supplies. A step toward achieving the barley production goal was made by providing barley growers and pork producers access to new varieties and production practice recommendations.

Original project deliverables:

- The Northern Barley Improvement Program has a long history of delivering varieties that meet market requirements. It is anticipated that this will continue with the delivery of new varieties and information packages that meet the needs of grain growers and pig producers. Through this project, BBA-North aims to deliver three new barley varieties targeting the needs of the pork industry with a seven to nine year time frame. The varieties will have been selected for high yield, agronomic adaptation, disease resistance and quality profiles that are specifically suited to pig nutrition.

- The Agronomy aspect of the project will initially deliver factual data on the feed grains needs and opportunities for the Queensland and northern New South Wales pig industry. This data will be used by the project team, the Pork CRC and DPI&F to develop strategic direction in their activities.

- The Agronomy aspect of the project will subsequently deliver best practise management strategies to maximise feed barley production and quality for the grain production catchment areas for the Northern pork industry. These strategies will be communicated to grain growers through this project, private consultants, pork industry partners and the Northern region Barley Industry Development Officer.

Project deliverables compared to achievements:

- The BBA-North barley breeding program has identified and made available for commercialization one variety, ND19119-5, with improved DE values. A second variety, Shepherd, with higher yield potential and better disease resistance, but with no feed quality improvements, was commercialized in 2008. Germplasm was identified that forecasts the possibility of improvements in feed quality for pigs. The first variety bred using this resource might be available in 2011. Delivery of the additional new varieties for use by pork industry will meet the 2013 to 2015 time frame of the original deliverables.
- Estimates of pig numbers and barley production in various parts of the northern region was completed (see Appendix 1). Survey information was discussed with the project team and used as a basis for selection location where barley drill strip trials were planted in 2007. Subsequent planting were based on co-operator interests, project resources, and local environmental conditions at planting.
- Best practise management strategies were summarised in the information provided on Shepherd barley. Additional reports have covered the attributes and production risks associated with barley varieties recommended for the northern region. A report on management strategies for ND19119-5 is being prepared.

6. Limitations/Risks

To the application of the research findings: New varieties and recommended production practices have risks associated with their utilization because they are based on a limited number of trials over a relatively short period of time. From this sample of environments, predictions can be made, but they are still predictions. The uptake of new varieties and management practices has costs associated with it as growers move from what they know into the unknown. Similarly, feeding new barley varieties to pigs is not risk free. Yet, as demonstrated by the rapid increase in Grout production in the Northern region, some new varieties are much more acceptable to growers and producers than others.

Original analysis of project risks:

This project has a low-medium risk level. Most of the technologies are proven and the BBA-North germplasm base and methods are well established. Main risk areas are associated with the potential for climatic interference in the planned field program and successful transfer of the outputs to the grains and pork industries. In answer to these issues, breeding programs are structured to take climatic variation into account, and collaboration with the Northern BIDO and CHM agronomists should ensure industry uptake of project outputs.

Current analysis of future risks:

The production of feed grains in the northern region is highly variable over seasons and locations due to variable climatic conditions. Changing climatic conditions, e.g. global warming, has already altered the barley breeding targets by making early maturity, tolerance to heat and drought stress and yield stability much more important. Varieties with higher yield potentials are desirable if they do not impose unacceptable levels of risk when seasons are less than optimal. To address the inadequate barley production in the area and climate change, we choose to modify the genetic base from which new varieties will be developed. Introduction of barley germplasm from North Dakota into the breeding program has the potential to expand barley production in the northern region, but also it puts at risk continuation of the gradual improvements realised with varieties such as Grout.

The rapid non-destructive analyses of feed quality that are possible with NIR and current calibrations will make breeding for feed quality in barley feasible. The high heritability of the traits measured suggests that rapid progress toward higher feed quality is an achievable goal. However, the current calibrations are based on studies in which the genetic potential of barley was not considered. Using those calibrations in barley breeding programs could lead us in wrong directions if fine tuning of the calibrations is not undertaken.

The research on crop management practices and barley improvement can lead to increased production of barley in the Northern region. The development of products from applied research on barley will be gradual; however financial support is required to assure the continued flow of improved varieties and production recommendations for them. Yet, the current prospects for continued support for this research are tenuous.

Barley varieties with higher DE values may improve gain rates, but are these changes adequate to provide higher profits?

7. Recommendations

Barley production in the northern region has gradually declined over the past twenty years. Climate change (drier and warmer) and more aggressive barley pathogens have played a large role in the gradual loss of barley as an important feed grain in the northern region. Since barley breeding programs have not adjusted their breeding objectives rapidly, current varieties do not adequately compensate for these environmental changes. Improved production practices have helped mitigated the changes in climate, but they have not succeeded in changing the observed trends in barley production.

As a result of the outcomes in this study the following recommendations have been made:

- Continued research on production practices and testing of new varieties over the diverse environments of the northern region will finetune management recommendations for each variety. Continued support of this research by the Pork CRC and GRDC is recommended.
- Non-destructive analyses of barley quality using NIR has shown marked feed quality differences among varieties and grain samples of a given variety across paddocks. Further research on the accuracy of feed quality calibrations, which translate wave length intensities into quality parameters, is needed for direct and indirect use by pork producers.
- NIR estimations of the feed quality parameters for barley varieties and breeding lines have demonstrated significant and highly heritable differences among them. These measurements can be used to breed varieties with improved quality. Continued screening of breeding materials for feed quality is recommended.
- Adequate research was conducted to determine that barley varieties with much better feed quality and tolerance to heat and drought stress can be developed for the northern region. The long-term support necessary to accomplish this object is unlikely to continue based on indications from GRDC and the Queensland Government. Since supplementary support from the Pork CRC is unlikely to modify

the situation, discontinuation of Pork CRC support for barley improvement in the northern region is recommended.

- Barley varieties developed in other regions of Australia will likely contribute little to improving the adaptation of barley to the northern region. Thus, the decline in barley production in the northern region will probably continue because other crops will be more attractive to farmers.
- Genetic tools for rapid improvement of feed quality can be identified using existing genetic resources, but they are dependent on having an effective barley breeding program to use them. Thus, further studies on feed quality for pigs in barley mapping population may have limited value.
- The domestic malting and brewing industry would prefer to source malting quality barley from within the northern region. Thus, they may partially support continuation of barley breeding in the northern region.

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Appendix 1: Agronomic Research Plan for the Pork CRC Project

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Progress to date- 2007

Within the northern grain producing region twelve (12) distinct areas have been identified which have different industry or production perspectives, and form a basis for twelve variety strip trials to be planted in 2007 (Table 1, Figure 1). The information from growing these trials is to form a base line for measurement of adaptation of both new varieties and promising cultivars to commercial grain growing environments which produce grain for use by pork producers.

Detail of the regions is attached. Boundaries of the regions reflect pork producing areas such as the Burnett and Darling Downs.

Table 1. The distribution of pigs by statistic divisions in 2005.

Statistical division	No. of pigs
Darling Downs	355,726
Wide Bay-Burnett	159,418
Northern	65,982
Central West	53,324
Fitzroy	27,590
South West	23,926
Moreton	14,937
Mackay	14,924
Brisbane	5,941
Far North	3,683

Australian Bureau of Statistics

2005 Agricultural Commodity Survey

Statistical Division by Commodity

Service providers for planting and maintaining the trials have been organised in Qld and NSW, and sites chosen across the region. Two of the strip trials are to be located on properties owned by pork producers within the CHM alliance (Cameron Hall McLean), which is part of the project. These trial sites are at Lundavra, north of Goondiwindi (Cameron), and Pittsworth, on the Central Downs (McLean). Previous crop history is to be recorded in detail, and soil types at each strip trial site. Stored soil moisture at planting is to be measured at Lundavra and Pittsworth, the CHM sites, in order to quantify the contribution to yield on very different soil types. Lundavra is a grey brigalow-belah vertisol while Pittsworth is upland basalt derived soil.

These trials were designed in consultation with MCA agricultural consultants happened at Goondiwindi in November 2006. More discussion took place at the Pork CRC meeting at Hastings Point in February. MCA are agronomic consultants for Cameron Pastoral Company.

These meetings ensure the strip trial design and entries reflect current commercial practice for both grain and pork producers in the northern region.

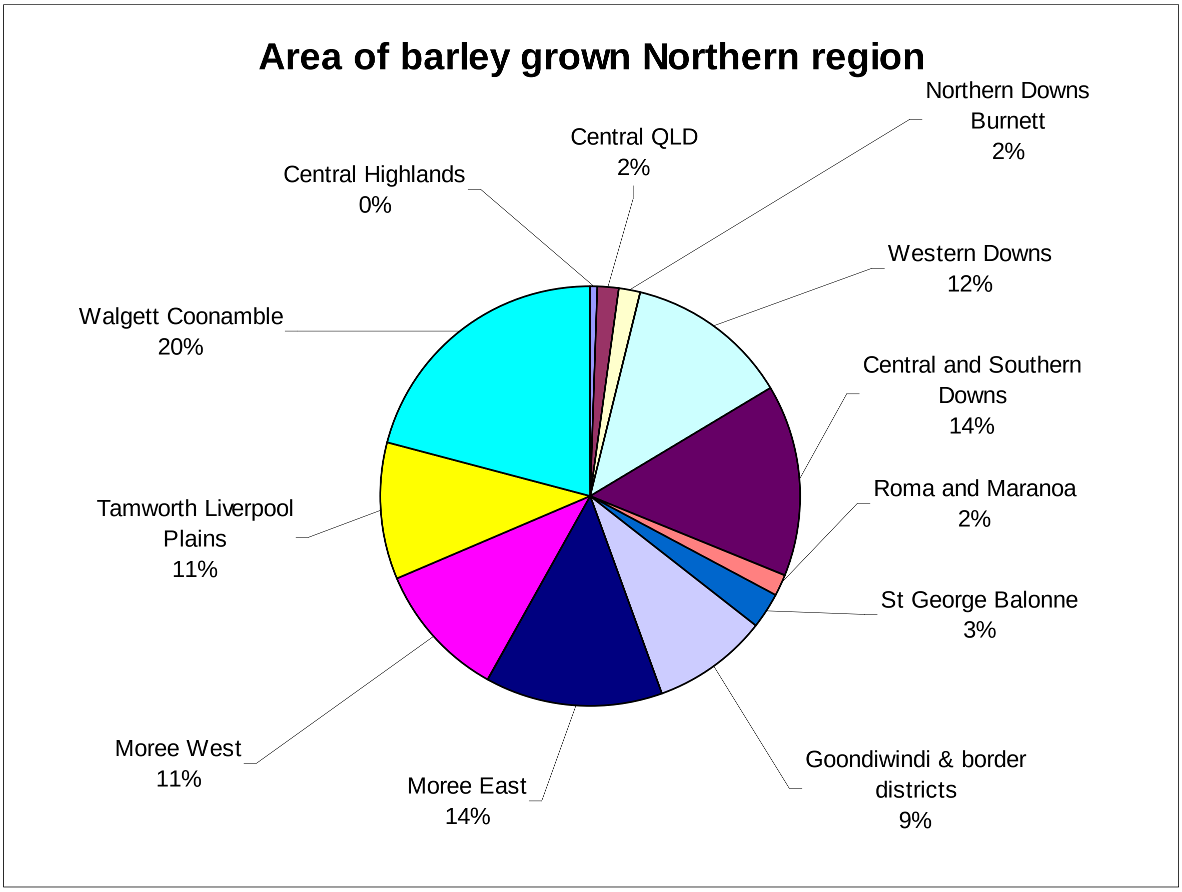

Figure 1. Barley production area in various parts of the Northern region in 2005.

These trials were designed in consultation with MCA agricultural consultants happened at Goondiwindi in November 2006. More discussion took place at the Pork CRC meeting at Hastings Point in February. MCA are agronomic consultants for Cameron Pastoral Company. These meetings ensure the strip trial design and entries reflect current commercial practice for both grain and pork producers in the northern region.

The strip trials have nine entries and are replicated twice, to ensure statistical validity of the results. They have plot dimensions of 50 metres x 2 metres. This allows for genuine paddock conditions when comparing varieties, whilst adhering to research protocols. Planting equipment has commercial tynes, row spacing and press wheels. Standard plot harvesters are to be used for measurement of plot yield. Selection of the nine entries in the series of trials is designed to produce information for grower utilisation of current and potential popular varieties. Entries have varieties popular in commercial production in the region, as well as promising introductions and breeding lines.

In order to quantify the components driving barley grain yield in a commercial situation, each trial plot is to be measured for harvest index and grain yield. Fungicide treatments will be applied if spot form of net blotch is present in any of the trials across the region. This allows opportunity for work on commercial spray timing relative to crop growth stages, and estimate the associated efficacy and efficiency. The environments are to be characterised for rainfall and temperature where possible, and some estimate of frost damage in the trials measured if this occurs. Planting dates for the trials at each site will be chosen with an awareness of frost risk, but they will allow early planting to obtain information for commercial decisions by barley growers.

Table 2. Variety drill strip trials planned for 2007.

Region	Contact	Machinery	Co-operator
1 Central Highlands	Richard Routley	Emerald	
2 CQ Theodore	Peter Keys	Biloela	
3 Kingaroy	Scott Campbell	KRS	
4 Central and Southern Downs	Brian McLean	HRS	
5. Western Downs	Ross Von Pein	LRC	
6. Roma and Maranoa	Ann Maree Bach	LRC	Gibson
7. St George	Janelle Reichstein	LRC	
8. Goondiwindi/Border	Lundavra	LRC	Cameron
9. West Moree	NSW DPI	NSW Ag	
10. East Moree	NSW DPI	NSW Ag	
11. Liverpool Plains	NSW DPI	Tamworth	
12. Central West NSW	NSW DPI	NSW Ag	

As grain quality is so important in the region, NIRS analysis for grain protein and pig digestible energy will be a component of the trial work. Analyses for kernel plumpness will be carried out to determine the variety interactions with locations, nutrition level and season on grain size. This work will be very important in determining the need for barley varieties which tolerate heat stress in the Northern region.

One of the main commercial problems the trials hope to solve is the need to produce barley varieties which respond with higher grain yields when higher nitrogen levels are applied. Current varieties increase grain protein rather than yield, which is not important to grain producers or end users. Introductions have been identified which increase barley grain yield while maintaining a lower grain protein than current varieties.

2008- 2009 It is planned to use the same varieties in 2008 for validation of 2007 results, and then assess the trial entries to see if they reflect current commercial practices. Contacts will be maintained with commercial agronomists to ensure the direction of the research is relevant to the grain and pork industries. Because the trials are being conducted with a limited budget the number of areas within the Northern region in which strip trials are grown may be reduced following 2007.

Appendix 2: Performance Summary for ND19119-5

Complied by Jerome Franckowiak, DEEDI

Grain yield comparisons: Yield data were collected from 31 replicated trials grown over two years in the Northern region. ND19119-5 averaged 20% lower than the yields of the best variety Grout, but its average yield was similar to that of Gairdner (Table 1). When the yield data are compared for individual trials, the yields of ND19119-5 were variable, but not always low (Table 2). The drill strip trials (two replications) grown in the northern region during 2008 showed lower average yields for ND19119-5 (Table 3).

Table 1. Yield and agronomic comparisons for ND19119-5 and selected barley varieties based on yield trials grown in the northern region during 2007 and 2008.

Genotype	Yield 2007	Yield 2008	Average yield	Heading date	Plant height	Straw breakage
	t/ha	t/ha	t/ha	Days 31/8	cm	1 to 5
Trials	17	14	31	3	5	3
ND19119-5	2.28	3.17	2.73	24	100.8	3.0
Grout	2.79	4.09	3.44	26	75.2	3.0
Gairdner	2.16	3.20	2.68	34	78.4	2.0
Commander	2.72	4.01	3.37	28	72.8	3.8
Shepherd	2.73	3.91	3.32	26	78.2	1.8
Fleet		3.81		28	79.2	4.0
Hindmarsh	2.63	3.96	3.30	26	64.8	3.0

Table 2. Yield comparisons from individual trials for ND19119-5 and selected barley varieties based on yield trials grown in the northern region from 2007 to 2008.

Genotype	2007 Breeza	2007 Jondaryan	2007 Moree	2007 Tara	2008 Bithramere	2008 Moree	2008 Springton	Average yield
	t/ha							
Trials	1	1	1	1	1	1	1	31
ND19119-5	4.53	1.56	1.11	2.48	3.31	2.12	3.75	2.73
Grout	3.47	3.34	1.42	2.96	3.50	3.33	4.42	3.44
Gairdner	4.41	2.54	0.55	1.66	2.94	2.33	3.70	2.68
Commande	4.14	3.00	1.23	3.06	3.50	3.32	4.36	3.37

r								
Shepherd	4.11	3.43	1.06	3.02	3.07	3.38	4.27	3.32
Hindmarsh	3.63	3.00	1.42	2.19	3.88	3.28	4.27	3.30

Table 3. Yield comparisons for ND19119-5 and selected barley varieties from drill strip trials grown in the northern region during 2008.

Variety	Northern region location							
	Burnett	Lundavra	North Star	Orion	Pittsworth	St George	Weemelah	Average
					t/ha			
Commander	2.5	3.5	3.2	4.8	2.3	4.2	4.3	3.5
Fitzroy	2.2	4.5	2.3	4.7	3.7	4.0	2.9	3.5
Fleet	2.3	2.6	3.3	4.7	3.3	3.3	3.4	3.3
Gairdner	1.8	3.5	2.3	4.1	3.3	3.1	3.0	3.0
Grout	2.8	4.8	3.2	4.7	3.0	4.2	3.9	3.8
Hindmarsh	2.4	5.5	3.3	5.0	2.8	4.8	3.4	3.8
ND19119-5	2.0	3.0	3.0	4.0	2.6	4.5	3.5	3.2
Shepherd	2.5	3.3	2.9	4.8	2.6	4.1	3.7	3.4
Skiff	2.3	4.3	2.3	4.3	2.5	3.9	2.7	3.2
LSD 0.5	0.3	0.9	0.4	0.3	0.4	0.7	0.6	

Table 4. Yield comparisons for ND19119-5 and selected barley varieties based on 2008 NVT trials grown in Queensland, yields as percent of trial mean.

Region	SWQ	SWQ	CQ	CQ	
Nearest Town	Goondiwindi	Chinchilla	Springsure	Moura	Average
Variety Name	%	%	%	%	%
Binalong	100	102	105	94	100.3
Capstan	99	98	101	99	99.3
Commander	121	115	102	117	113.8
Dash	91	104	96	93	96.0
Fitzroy	101	104	105	101	102.8
Flagship	121	105	97	97	105.0
Fleet	121	83	99	95	99.5
Gairdner	90	86	97	90	90.8
Grimmett	91	103	100	73	91.8
Grout	92	104	97	112	101.3
Hannan	108	93	100	99	100.0
Hindmarsh	94	112	109	122	109.3
Kaputar	93	102	100	95	97.5
Mackay	89	107	110	100	101.5
ND19119-5	78	88	79	103	87.0
Shepherd	110	107	117	90	106.0
Roe	93	96	102	120	102.8
Skiff	114	90	104	114	105.5
Tallon	90	98	97	84	92.3

Vlamingh	103	105	94	108	102.5
Site Mean (t/ha)	3.19	4.33	4.11	2.06	3.4
CV (%)	9.31	5.54	4.68	10.5	
LSD (t/ha)	0.49	0.39	0.31	0.35	

The yield comparisons for ND19119-5 from NVT trials were based only on trials grown in 2008. Data from trials grown in eastern Australia indicate that ND19119-5 is generally lower in yield than most other entries except when the trial means were low (Tables 4 to 7).

Table 5. Yield comparisons for ND19119-5 and selected barley varieties based on 2008 NVT trials grown in northern New South Wales, yields as percent of trial mean.

Region Nearest Town	N/W Coonamble	N/W Gilgandra	N/W Tulloona	N/W Walget t	N/E Tamworth	N/E Yallaroi	 Averag e
Variety Name	**%**	**%**	**%**	**%**	**%**	**%**	**%**
Binalong	92	103	90	113	107	95	100
Buloke	105	100	100	89	97	99	98
Capstan	90	100	102	107	108	102	102
Commander	109	111	101	102	106	110	107
Cowabbie	101	104	97	105	103	99	102
Fitzroy	96	99	95	108	93	104	99
Flagship	109	102	109	98	100	96	102
Fleet	102	99	111	105	99	126	107
Gairdner	94	103	88	105	84	99	96
Grimmett	96	96	101	93	92	90	95
Grout	102	97	88	103	120	118	105
Hannan	109	107	106	96	88	106	102
Hindmarsh	107	100	121	102	115	97	107
Lockyer	104	106	112	99	107	99	105
Mackay	104	104	103	112	105	103	105
ND19119-5	94	96	63	83	86	97	87
Roe	102	94	104	95	121	115	105
Schooner	101	100	106	88	90	105	98
Shepherd	108	102	94	102	97	108	102
Tantangara	91	99	107	105	100	90	99
Urambie	-	-	-	-	110	82	96
Vlamingh	94	101	104	109	101	100	102
Yarra	-	-	-	-	91	113	102
Site Mean (t/ha)	3.79	4.2	3.74	5.37	5.49	2.87	4
CV (%)	4.12	3.87	11.8	2.88	4.24	7.71	
LSD (t/ha)	0.25	0.27	0.72	0.25	0.41	0.38	
LSD (%)	7	7	19	5	7	13	

Table 6. Yield comparisons for ND19119-5 and selected barley varieties based on 2008 NVT trials grown in southern New South Wales, yields as percent of trial mean.

Region Nearest Town Crop Type Trial ID	N/W Goonumbla	S/E Quandialla	S/E Wagga	S/W Lockhart	S/W Condobolin	S/W Mayrung	S/W Merriwagga	N/E Wongarbon		
Variety Name	%	%	%	%	%	%	%	%	**Average % TM**	**No of Trials**
Hindmarsh	86	110	126	132	116	92	220	91	121.6	8
Fitzroy	110	111	113	-	-	96	156	102	114.7	6
Hannan	96	98	113	104	123	100	136	91	107.6	8
Lockyer	106	108	104	99	109	110	109	110	106.9	8
Buloke	102	99	105	102	108	99	121	96	104.0	8
Roe	99	98	114	117	105	106	107	86	104.0	8
Keel	-	104	89	112	114	94	125	89	103.9	7
Grout	96	91	100	97	103	100	139	99	103.1	8
Fleet	117	107	104	108	107	103	69	105	102.5	8
Yarra	-	100	89	94	97	106	123	102	101.6	7
Flagship	103	99	119	95	91	110	94	99	101.3	8
Commander	107	104	125	109	109	110	28	108	100.0	8
ND19119-5	73	76	110	92	106	53	208	79	99.6	8
Shepherd	109	104	83	111	100	104	76	110	99.6	8
Gairdner	99	96	113	83	93	97	101	98	97.5	8
Schooner	97	85	108	89	111	96	101	88	96.9	8
Vlamingh	103	104	104	95	89	105	70	103	96.6	8
Cowabbie	99	96	99	93	98	110	70	103	96.0	8
Baudin	-	97	102	89	103	95	84	-	95.0	6
Tantangara	94	100	103	86	100	106	53	99	92.6	8
Fairview	-	104	102	82	76	108	81	-	92.2	6
Site Mean (t/ha)	5.45	5.8	1.58	2.22	1.5	5.07	0.48	5.69		
CV (%)	4.72	3.37	23.01	6.92	6.79	7.39	24.46	2.34		

LSD (t/ha)	0.42	0.33	0.6	0.27	0.18	0.64	0.2	0.22		

Table 7. Yield comparisons for ND19119-5 and selected barley varieties from 2008 NVT trials grown in Victoria, yields as percent of trial mean.

Region	**North Central**	**North Central**	**Mallee**	**Mallee**	**Mallee**	**Mallee**	**Mallee**	**Wimmera**	**Wimmera**	**Mallee**	
Nearest Town	**Colbinabbin**	**Balliang**	**Birchip**	**Hopetoun**	**Murrayville**	**Pira**	**Woomelang**	**Kaniva**	**Minyip**	**Walpeup**	
Variety Name	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**Ave TM**
Keel	108	90	123	126	196	152	151	123	161	180	141.0
Hindmarsh	117	155	121	128	165	160	131	119	145	157	139.8
Roe	99	-	125	103	151	133	137	110	127	150	126.1
ND19119-5	-	92	112	94	170	147	108	108	126	173	125.6
Fleet	135	122	93	110	125	113	116	118	150	123	120.5
Grout	-	105	102	104	130	110	130	116	109	150	117.3
Maritime	-	-	114	104	120	121	118	113	96	117	112.9
Lockyer	97	107	-	-	-	-	-	110	127	-	110.3
Sloop SA	-	-	100	107	114	105	126	100	127	98	109.6
Buloke	87	141	112	115	102	110	86	110	109	115	108.7
Hannan	117	89	94	93	120	106	114	117	126	91	106.7
Fitzroy	96	108	-	-	-	-	-	114	104	-	105.5
Yarra	96	-	104	97	88	97	85	108	111	132	102.0
Flagship	69	110	93	95	108	103	106	108	118	98	100.8
Schooner	79	68	88	97	111	113	110	101	134	100	100.1
Commander	127	82	99	111	49	90	84	121	87	48	89.8
Shepherd	-	145	98	101	52	63	76	94	62	78	85.4
Mackay	-	88	78	80	41	59	51	133	82	29	71.2
Site Mean (t/ha)	**2.61**	**0.44**	**1.4**	**3.37**	**1.06**	**1.29**	**1.69**	**2.13**	**1.67**	**0.58**	**1.624**
CV (%)	10.97	31.84	8.44	7.58	15.02	11.73	13.11	4.75	7.54	18.1	
LSD (t/ha)	0.48	0.23	0.2	0.42	0.27	0.25	0.36	0.17	0.22	0.19	

Agronomic comparisons: Heading dates for ND19119-5 were generally one to two days before Grout and Kaputar (Table 1), but maturity often was 7 to 10 days later than Grout. Seedlings have an erect growth habit and relatively wide leaves. Plants are very tall, about 25 cm taller than Grout (Table 1), but lodging scores were often lower than those of other tall varieties. ND19119-5 was fairly tolerance to post-ripe straw breakage and head loss. We have observed a problem with the of kernel loss (detachment) after maturity, especially when harvest was delayed by storms for several weeks. The loose hull adherence of ND19119-5 will caused some seed quality issues if the headers are not properly set. However, there is no evidence that loss of seed viability was associated with skinned grain.

Disease reaction comparisons: ND19119-5 has a surprisingly good level of resistance to foliar diseases that can cause losses in the Northern region (Table 8). The two foliar diseases for which ND19119-5 does not have a high level of resistance are powdery mildew and spot form of net blotch. ND19119-5 has adult plant resistance to powdery mildew, but it is not known how effective this type of resistance is. It shows some resistance as seedlings to spot form of net blotch and moderately susceptible to susceptible as adult plants. Resistance to spot blotch is of particular importance because it opens up opportunities for barley production in the subtropical parts of the Northern region. This resistance also increases the probably of harvesting grain from late sown crops through out the region. ND19119-5 is resistant to stem rust, which minimizes another potential risk factor.

Table 8. Disease reaction comparisons for ND19119-5 and selected barley varieties.*

Genotype	Powdery mildew	Leaf rust	Net net blotch	Spot net blotch	Leaf scald	Spot blotch	Ste m rust	Covere d smut
ND19119-5	S/MR†	R	MR	MS	MR	MR	R	R
Grout	R	S	MR	MS	VS	MS-S	S	S
Gairdner	S	S	MR	VS	S	S	S	S
Commande r	MR-MS	S	MR-MS	MS	MR	S	S	MR
Shepherd	R	S/MR	MR-MS	S-VS	S	S	S	R
Fleet	MR	MS	R	MR	R	S	S	R
Hindmarsh	MR	S/MR	MR-MS	VS	VR	S	S	MS
Roe	S	S	R	MS	MR	S	S	R

* Disease assessments were supplied by Greg Platz and Damian Herde (DEEDI) based on data collected from seedling and adult plant evaluations conducted in 2007 and 2008. † S/MR indicates adult plant resistance and seedling susceptibility.

Grain plumpness and size comparisons: ND19119-5 was introduced in part because of its large kernel size. It was preferentially used as a parent in the North Dakota State University breeding program because it has slightly larger kernels than its sister line Rawson. Unlike many other large seeded introductions, ND19119-5 increases kernel width, but not length. The kernel size and weight comparison for Rawson indicate that it produces larger and plumper grain than other North American barley varieties (Table 9). The large grain size of ND191119-5 is associated with high values for percentages of grain retention and plump grain plus a slight increase in test weight values (Tables 10 and 11). Effects of the large grain size were observed as low values for percent screenings and high values for percent retention in NVT trials in northern New South

Wales (Table 12 and 13). The 2007 data from a drier season in the North Region demonstrate a larger advantage for the large seed trait of ND19119-5 (Figure 1). Climate change predictions indicate that crops and variety choices will need to be more adaptable to handle increasingly irregular rainfall patterns in the future. The stay-green trait, heat tolerance and long grain fill period, allows ND19119-5 to handle late planting and capitalize on spring rains, which are typical of the northern region environment. It provides a choice for growers if they receive rainfall in the late winter period before summer cropping is an option.

Table 9. Kernel weights and seed size measurements for selected barley varieties from samples grown at Aberdeen, Idaho under irrigation.

Variety	Test weight	Kernel weight	Kernel length		Kernel width		Kernel area	
	kg/hl	mg	mm	se[‡]	mm	se	mm	se
Rawson (2R)[†]	64.6	62.0	8.95	0.56	4.00	0.26	25.50	2.81
Conlon (2R)	61.9	56.1	8.96	0.58	3.78	0.24	24.13	2.50
Bowman (2R)	62.2	53.0	9.26	0.62	3.69	0.21	23.91	2.72
Harrington (2R)	59.7	52.1	9.29	0.52	3.65	0.26	23.53	2.49
Morex (6R)	58.3	41.0	8.49	0.65	3.30	0.26	19.89	2.59
Steptoe (6R)	56.9	57.0	10.53	0.93	3.48	0.28	25.46	3.77

[†] 2R = two-rowed spike type, 6R = six-rowed spike type. [‡] se = standard error.

Table 10. Feed quality comparisons for ND19119-5 and selected barley varieties based on yield trials grown in the northern region during 2008.

Variety	Plump grain >2.8mm	Retention >2.5mm	Test weight	Grain protein	Starch	Fibre (ADF)[†]	Husk	Faecal DE
	%	%	kg/hl	%	%	%	%	MJ/kg
Trials	14	14	14	14	14	14	14	14
ND19119-5	85.2	95.5	69.1	13.1	56.1	3.9	11.1	13.0
Grout	32.3	82.2	66.9	11.8	53.4	4.6	12.4	12.5
Gairdner	29.7	67.0	67.2	13.5	52.7	4.2	12.4	12.6
Commander	60.0	87.6	66.6	12.7	53.5	4.5	12.2	12.6
Shepherd	53.7	84.2	68.1	12.6	52.4	4.6	12.5	12.6
Fleet	65.3	89.2	64.4	12.9	50.7	5.0	13.2	12.4
Hindmarsh	34.8	80.2	67.9	12.9	52.5	4.4	11.8	12.8
Roe	70.1	92.3	68.5	12.6	52.3	4.7	12.8	12.7

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† ADF = acid detergent fibre.

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Table 11. Grain quality comparisons for ND19119-5 and selected barley varieties from drill strip trials grown in the northern region during 2008.

Variety	Screenings	Retention	Test weight	Protein	Husk	DE
	% <2.2 mm	% >2.5 mm	kg/hl	%	%	MJ/kg
Trials	8	8	8	8	8	8
Commander	15.9	49.9	64.8	14.3	13.0	12.7
Fitzroy	21.7	34.7	61.0	13.8	13.0	12.7
Fleet	7.6	66.2	62.6	14.2	13.3	12.4
Gairdner	22.7	28.0	66.4	15.2	12.9	12.7
Grout	11.2	51.2	66.0	13.2	12.7	12.6
Hindmarsh	10.8	50.1	67.7	14.3	11.9	12.9
ND19119-5	1.7	91.9	68.3	13.8	11.2	13.0
Shepherd	9.1	55.0	66.5	14.4	13.2	12.6
Skiff	33.9	24.0	64.5	15.4	12.8	12.9

Table 12. Percent screening (percent <2.2 mm) values for comparison of ND19119-5 and selected barley varieties based on 2008 NVT trials grown in northern New South Wales.

Region Nearest Town	N/W Coonamble	N/W Gilgandra	N/W Tulloona	N/W Walgett	N/E Tamworth	N/E Yallaroi	Average (%)
Variety Name	**%**	**%**	**%**	**%**	**%**	**%**	
Binalong	23.3	1.9	10.8	2	20.4	35.9	15.7
Buloke	3.3	1.3	6.9	1.5	8.4	7.8	4.9
Capstan	28.8	3.4	4.6	6.6	4.2	32.7	13.4
Commander	5.1	0.8	6.4	3	4.9	8.4	4.8
Cowabbie	15.7	0.9	5.4	1.4	2.4	20.0	7.6
Fitzroy	11.4	1.6	4.7	0.9	10	24.3	8.8
Flagship	6.2	2.3	7.3	1.1	6.6	22.8	7.7
Fleet	3.2	0.4	3.2	0.6	2.2	4.5	2.4
Gairdner	18.0	1.5	6.2	2.2	5.9	31.7	10.9
Grimmett	18.4	2.2	7.0	4.0	5.7	26.8	10.7
Grout	2.9	0.3	4.3	1.0	1.9	5.4	2.6
Hannan	6.8	0.4	4.6	2.2	5.4	23.6	7.2
Hindmarsh	4.6	1.1	4.4	1.9	2.5	6.9	3.6
Lockyer	18.1	0.8	7.6	2	8.7	26.2	10.6
Mackay	7.1	1.8	8.2	2.5	7.5	23.2	8.4
ND19119-5	0.7	0.2	1.9	0.2	0.6	0.3	0.7
Roe	1.8	0.6	3.6	0.5	3.0	4.8	2.4
Schooner	4.3	1.0	2.9	1.0	4.1	9.0	3.7
Shepherd	5.8	0.9	5.3	2.3	2.9	12.5	5.0
Tantangara	21.2	1.1	4.8	4	8.2	32.5	12.0
Urambie	-	-	-	-	5.4	25.6	15.5
Vlamingh	3.4	0.4	4.8	0.6	3.5	8.6	3.6
Yarra	-	-	-	-	1	21.5	11.3

Table 13. Percent retention (% >2.5 mm) values for comparison of ND19119-5 and selected barley varieties based on 2008 NVT trials grown in northern New South Wales.

Region	N/W	N/W	N/W	N/W	N/E	N/E	
Nearest Town	Coonamble	Gilgandra	Tulloona	Walgett	Tamworth	Yallaroi	Average
Variety Name	%	%	%	%	%	%	%
Binalong	19.9	84.1	66.2	77.3	37	9.4	49.0
Buloke	60.6	88.6	74.4	86.9	72.6	40.6	70.6
Capstan	20.2	81.1	85.4	67.3	81.9	11.4	57.9
Commander	73.4	95.5	83.9	87.5	84.7	54.4	79.9
Cowabbie	29.1	94.3	87.6	89.9	86.4	24.7	68.7
Fitzroy	51.9	88.6	85.1	91.4	63.3	32.9	68.9
Flagship	49.9	88.3	79.1	87.3	80.3	35.1	70.0
Fleet	76.7	95.8	90.6	95.3	90.7	67.7	86.1
Gairdner	19.4	88.5	79.2	77.5	68.5	11.3	57.4
Grimmett	20.2	82.6	78.9	71.2	78.5	25.7	59.5
Grout	75.8	95.2	87.4	91	90.5	64.3	84.0
Hannan	50.2	96.2	85.9	80.5	81.1	34.8	71.5
Hindmarsh	72.1	91	81.2	88.3	88.8	53.9	79.2
Lockyer	23.1	87.7	78.5	78	70.3	14.7	58.7
Mackay	48.1	87.2	79.3	82.3	70.7	23.3	65.2
ND19119-5	97	98.8	97.4	98.8	98.3	96.8	97.9
Roe	86.8	95.8	91.1	96.7	90.2	76.7	89.6
Schooner	57.2	92.6	90.4	88.6	84.2	41.9	75.8
Shepherd	58.2	93.5	84	86.5	85.8	43.5	75.3
Tantangara	17.4	84.7	85.8	64.3	60.8	9.5	53.8
Urambie	-	-	-	-	63.3	5.1	34.2
Vlamingh	68.6	97	87.6	94.3	85.3	47.3	80.0
Yarra	-	-	-	-	94.9	28.2	61.6

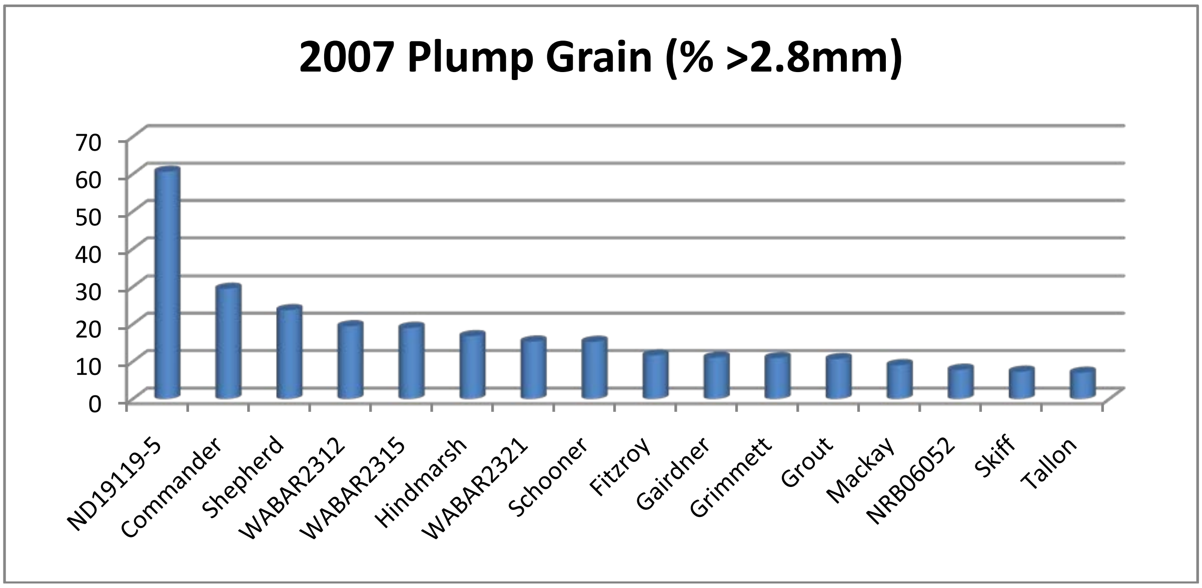

Figure 1. Summarized percentages of plump grain based grain samples from 14 barley yield trials grown in northern New South Wales and Queensland in 2007.

Grain quality comparisons: The potential feed quality of ND19119-5 was estimated for pigs were using NIR readings and conversion calibrations obtained from the Pork CRC. Comparisons among barley varieties grown during 2008 showed that ND19119-5 had high values starch content and digestible energy (DE) (Tables 10 and 11). The values for acid detergent fibre (ADF) and hull or husk were lower than those for other varieties. Although feeding trials for pigs have not been completed, ND19119-5 should be higher quality barley for feeding pigs.

Stress related responses: The above performance of ND19119-5 suggests that it could be more tolerant than other barley varieties in stressed environments. This was further demonstrated in a date of sowing trial at the Hermitage Research Station, which is representative of the inner downs and a production area where ND19119-5 probably should not be recommended. However, ND19119-5 was the high yielding entry in the July planting (Table 14). July planting are often affected by both moisture and heat stress, but in 2008 rain fall was not a limiting factor late in the season.

Table 14. Yield result from a time of sowing trial conducted at the Hermitage Research Station in 2008.*

Variety	Month of sowing*				
	April	May	June	July	Average
			t/ha		
Buloke	2.17	2.79	2.82	2.83	2.65
Commander	2.47	2.84	3.05	3.52	2.97
Fitzroy	2.35	3.16	3.29	3.16	2.99
Flagship	1.48	2.63	2.75	1.83	2.17
Fleet	2.74	2.99	2.46	3.03	2.81
Gairdner	1.77	1.35	1.65	1.95	1.68
Grimmett	1.62	2.14	2.64	2.39	2.20
Grout	1.39	2.36	2.82	2.15	2.24
Hindmarsh	1.99	3.43	3.56	3.02	3.00
Mackay	1.98	3.42	2.94	3.26	2.90
ND19119-5	2.01	2.90	2.56	3.78	2.81
Roe	1.57	2.03	2.52	2.37	2.12
Shepherd	1.91	2.86	3.36	3.53	2.92
Skiff	1.71	2.41	1.99	2.28	2.10
Mean	1.99	2.50	2.58	2.75	2.47
Gregory (wheat)	2.57	2.59	2.79	3.70	2.91

*Note: This trial was frosted to lows of minus 8-10 degree Celsius several times during the July –August period. This caused significant vegetative damage to the April and May plantings.

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Appendix 3: Review of Barley & Feed Grains Industry Value Chain

Complied by Kym McIntyre, DEEDI

Coarse grains in Queensland are an excellent value adding opportunity for agribusiness. Unlike most states the majority of grain in Queensland is value added before consumption or export. Queensland has strong markets for domestic milling (flour or malting) and intensive livestock production (mainly beef feedlots (62%) but also pigs, meat and egg chicken.

In a average production year Queensland produces slightly more grain than is currently required for domestic consumption. But Southern Queensland (SQ) has a high demand for feed grain, malting barley and milling wheat resulting in a deficit situation in all but high production years. This deficit is filled by grain from either central Queensland (CQ) or Northern New South Wales (NNSW). In a drought year the deficit is as high as 1.2 million tonne.

Thus the Queensland value added industries (flour milling, malting and intensive livestock) are highly reliant on the profitability of the northern grains region to supply reliable production of consistent quality grain to ensure their long term viability and underpin any plans for future expansion.

The barley market

Barley in Queensland has two major value chains as a primary source of grain into the malting and brewing industry. The value of the brewing industry to Queensland is estimated at 2.43 billion. (Barley Australia internal document)

Into the intensive livestock industry The value of the intensive livestock industry to Queensland is estimated at 2.5 billion dollars. (ALFA Lotfeeding Magazine July 2009)

Both of these industries have indicated significant potential growth in the future.

	Current demand (x ‘000 t)	Industry value (Farm gate grain)	Future growth	Increased Value to Queensland producers
Malting & Brewing	58	14 million	80,000 tonne *	19 million
Feed (Grain split between wheat sorghum and barley)	2200	440 million	Feedlot industry to double by 2025 + = another 1.6 million tonne	320 million

* Pinkenba Malt house, + Prediction by feed lot industry.

Australian malting Infrastructure and capacity

The Australian malt industry is dominated by two major players

- Joe White Maltings who are a division of ABB Grain (possibly to become a part of Canadian organisation Viterra.)
- Barrett Burston Malting which are owned by CHAMP (US Private equity group)
- A third player MaltEurop is the third largest malt producer worldwide with significant holdings in many European countries and China.

The malting industry is focussed on 2 markets domestic malt to supply domestic brewers and export malt which is generally exported to Asian in particular China.

These two markets require different quality characteristics which require

- The export market require varieties which produce a malt with high Diastatic Power (DP) high fermentability as they are using a solid adjunct eg rice
- The domestic market requires varieties with more moderate levels of DP & moderate levels of fermentability as they are using a liquid adjunct eg sugar. This market is approximately 220,000 mt and largely situated on the east coast. Melbourne to Brisbane.

State/Company	Capacity mt		Focus
	Barley	Malt	
Queensland			
Joe White Redbank	28,000	25,000	Domestic goes to Castlemaine Perkins Milton
Barrett Burston Toowoomba	30,000	26,000	Domestic supplies CUB Yatala
			Total 58,000 mt
New South Wales			
Joe White Tamworth	50,000	45,000	Domestic to supply Tooheys
Barrett Burston Thornleigh Sydney	40,000	34,000	Domestic supply Yatala
			Total = 90,000 mt
Victoria			
Joe White Ballarat	56,000	48,000	Domestic & Export
Barrett Burston Geelong & Burnley	140,000	123,000	50/50 domestic and export – supplies CUB brewery at Abbotsford Melbourne
MaltEurop Geelong	70,000	60,000	All export
Tasmania			
Joe White	7,000	6,000	Domestic for Boags brewery
Cascade	8,000	7,000	Domestic Cascade brewery
South Australia			
Joe White	205,000	176,000	Mainly export small amount to domestic market

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Cavan Port Adelaide			
Western Australia			
Joe White	230,000	200,000	Export – small amount to Swan Brewery
Kirin	53,000	46,000	Mainly export

The malting industry is currently planning further expansion with two new malt houses planned one in Queensland (Pinkenba) and one in NSW (Sydney) both this plants will put further demand into the northern grains region.

New malting investments in planning/construction

Location	Size	Ideal geographic region to draw grain from	Focus
Queensland Barrett Burston - Pinkenba	80,000 mt plus	Queensland	Domestic and export
New South Wales Joe White Minto (SW Sydney)	110,000 mt	NSW – southern part of northern region, central & southern NSW	Mainly export, but possibly some domestic for Tooheys.

The Australian Brewing Industry

Barley supplied to the malting and brewing industry attracts a premium at Farm Gate to feed quality barley.

Main breweries	State	% of Total Australian beer production	Amount of malt barley required	Farm gate value as malt (@$240)	Farm gate value as feed (@$200/tonne)
Castlemaine Perkins (Lion Nathan/Kirin)-Milton CUB - Yatala	QLD	40.5	90,000	21600000	18000000
Tooheys (Lion Nathan) Sydney	NSW	20	44,000	10560000	8800000
CUB – Abbotsford Melbourne	VIC	25	55,000	13200000	11000000
Coopers & Lion Nathan	SA	5.5	12100	2904000	2420000
Boags & Cascade	TAS	6	13200	3168000	2640000
Swan brewery- Lion Nathan	WA	3	6600	1584000	1320000

Current domestic beer market estimated worth of $6 billion QLD has approximately 40.5% = 2.43 billion dollars.

- By not producing the malt to supply malt houses for beer brewed in Queensland grain growers are losing up to 3.6 million dollars/annum at farm gate values.
- With an extra 80,000 mt capacity at the new planned Pinkenba plant this could be a further 3.2 million/annum dollars for Queensland grain growers due to a $40/tonne premium over feed grains.

Industry is paying this money (possibly more) in freight to access the grain from interstate. This is causing extra pressure on transport infrastructure which is already under pressure.

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Queensland Feed Grains Industry

Unlike malting or milling industries the intensive livestock industry can substitute one grain for another quite easily depending on availability or price.

In Queensland the intensive livestock industry is estimated to be worth 2.5 billion dollars. (ALFA Lotfeeding Magazine July 2009).

While the feed industries will use the grain which is easiest to source locally if they have a preference they will go for grain which is more easily processed and has a higher energy value for them. Thus if grain is to be brought up from the south preference in the beef feedlot industry is for white grain from as close a source as possible e.g. NNSW largely but also from as far afield as WA.

The relative digestibility of grains and processing impacts.

(Note only larger feedlots have the ability to steam flake and the cost of steam flaking increases with the cost of energy.)

Grain	Processing	Digestibility %			
		Rumen	Post Rumen	Total Tract	Mcal/kg
Sorghum	Dry rolled	59.8	62.5	87.2	1.19
	Steam flaked	78.4	89.9	98.0	1.50
Barley	Dry rolled	80.7	75.2	94.3	1.40
	Steam flaked	84.6	88.0	98.2	1.50
Wheat	Dry rolled	88.3	85.4	98.2	1.50
	Steam flaked	88.1	88.2	98.6	1.60
Corn	Dry rolled	76.2	68.9	92.2	1.55
	Steam flaked	84.8	92.6	98.9	1.62

Note barley is a good feed grain particularly in situations where processing is not economical. It also requires less energy to process barley due to good moisture uptake and easier processing energy.

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Australian Feed Grain Demand

Average year cereal grain usage within domestic demand regions (excludes export) x '000 tonnes. (Gold is QLD, Yellow is Northern region)

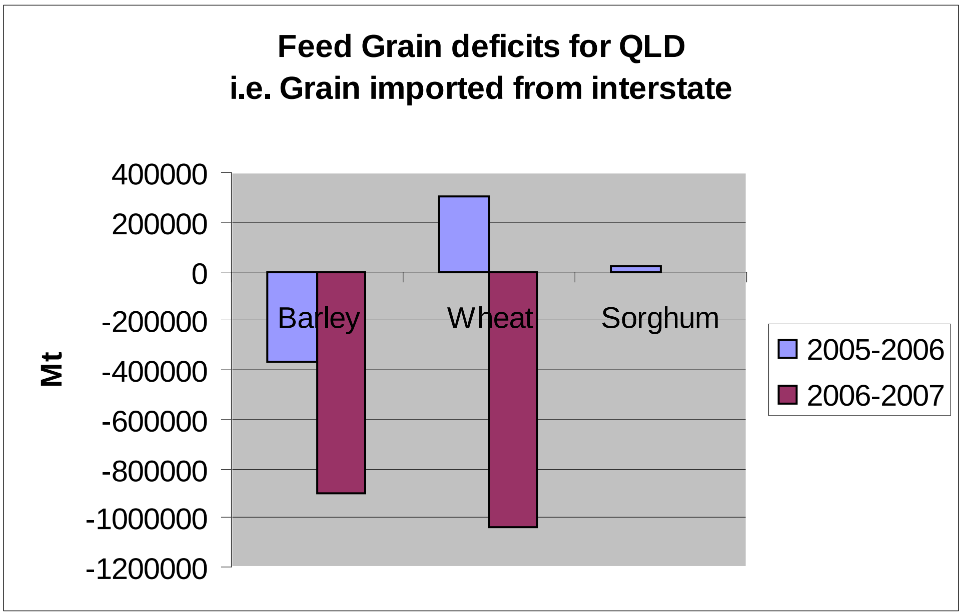
	Seed	Flour	Malt	Feed	Total
Northern & Central Qld	**22**	**--**		**357**	**379**
Southern Qld	**53**	**250**	**58**	**1,798**	**2,157**
North Eastern NSW	65	420	56	867	1,409
Western NSW	45	25	-	76	146
Sydney Newcastle NSW	0	420	44	472	936
Central NSW	106	780		820	1706
Murray & Northern Vic	141	115	60	1,364	1680
Melbourne & Gippsland Vic	4	320	63	944	1330
Western Districts Vic & SE SA	11			573	584
Adelaide, Mid North & Murraylands	66	200	220	649	1135
Eyre Peninsula & Northern SA	79	5		18	102
South West WA	193	140	313	748	1394
Central and Eastern WA	68			70	139
Tasmania	2	15	15	194	225
Northern Territory				30	30
Total					13353

Note that 83% of domestic feed demand is within the eastern states Queensland has about 24% of the feed grain demand and NSW also a similar amount in Victoria is slightly larger which is driven by dairy. The Queensland and New South Wales demand is largely driven by beef feedlots of which almost 80% are situated in QLD & NSW.

Value of production and consumption of feed grains in QLD consumption (figures based on Farm Gate Value not delivered value).

	Price of feed grain (April 09) $'s	Ave $ Value Produced in QLD '000,000 $'s	Ave$ Value Consumed in QLD '000,000 $'s
Barley	181	32.1	147.3
Wheat	210	161.4	238.7
Sorghum	166	143.8	142.3

This means in all but a surplus year of production Queensland is likely to be in a deficit situation.



Cost of transport is approx. $10/tonne/100 km therefore to bring 1 mt from Moree in NNSW to Toowoomba = approximately $40.00/tonne.

The largest amount of feed grain in QLD is consumed by the beef feed lot industry.

Average extra cost (to intensive livestock industry) per tonne over above values 2005-2007) about 40 million in transport $25 million barley, $15 million wheat.

Queensland regional grains supply and demand

	Wheat	Barley	Sorghum & maize	Other	Demand use	Surplus
Central Queensland	300,000	10,000	500,000	20,000	Feed – 357,000 mainly beef feed lot some pigs and dairy	456,000 tonnes exported or sent to supply demand from SQLD
Southern QLD	977,000	200,000	750,000	100,000	Feed 1.798 mill t beef feedlots, pigs, poultry, small dairy Export & milling wheat 350,000 mt Malt barley 58,000 mt	Deficit of approximatel y 150 000 mt

Where does barley fit in the farming system.

Barley is the third largest grown crop in QLD and second largest in Australia.

Currently the crop in Queensland is focussed in southern Queensland where it has strong markets into the domestic malt industry and the intensive feed lot industry.

It is generally grown for its rotational ability and flexibility of markets i.e. large number of local feed end users. Growers who are successful with barley see it as being a high yielding low input crop but which requires attention to marketing to ensure good pricing.

Favourable attributes of barley for balanced cropping system

- Not as susceptible to nematodes
- Different range of foliar diseases to wheat makes it a good rotation.
- Can handle earlier and later planting
- Lower frost risk
- High dry matter production gives it a dual purpose function – grain, silage, forage
- Lower cost of production than wheat or sorghum
    - Good weed smothering ability
    - Lower nitrogen requirement

Growth opportunities

There is considerable opportunity for barley to expand into other regions of QLD. Barley can be successfully grown wherever other broad acre crops are grown, and is often higher yielding with lower inputs than wheat. Access to markets and price of commodity is an issue for a number of growers.

From Benefit to Australian Grain Growers in the Feed Grain Market

John Spragg 2008 p 117

It is apparent that there is a strong reluctance by grain growers to grow feed grains; this especially applies across the traditional wheat and barley cropping areas. The following is a list of the main concerns growers raise when they look at why they do not plant feed grains:

- *Not having a market to sell to - will anyone buy the feed grain and how do they sell it.*
- *Lack of marketing skills or a desire to find markets for feed grain grown.*
- *Being dependent upon one buyer- the local feedlot or feed mill may take advantage of local growers.*
- *Lower price paid relative to growing milling wheat or malting barley.*
- *Loss of security as delivering wheat and barley to major accumulators is easier.*
- *A wet harvest and down graded wheat and barley makes feed grains worth less.*
- *A need to store on farm and control stored grain quality.*

Southern Queensland

Currently food grain prices (milling wheat and malting barley) make "feed only" varieties unattractive for many growers. The last widely adapted malting varieties released for QLD are Tallon (early 1990's and Grimmett (early 1980's). The development of a well adapted high yielding malting accredited variety would give growers a lot more confidence in this market. This would not have a detrimental impact on supply of feed grains as only a percentage of the crop generally makes malt quality and the increase in the area planted due to the improved price signal would compensate for increased amount of grain going to malting industry.

Need:

- ***Focus on development of high yielding malt variety acceptable to the domestic malting and brewing market. Demand in QLD alone expected to grown from current 58,000 tonne to 138,000 tonne at a $40 per tonne premium over feed barley this would be an extra $5.52 million farm gate value to Queensland Grain Growers***
- ***Also require more agronomic management work targeted at achieving malt quality to increase the likelihood of growers achieving malt quality.***

Central and western QLD.

Currently marketing in these areas has been based on delivering grain through bulk handling systems and focussed on export markets. The increase in on farm storage through these areas will give growers more marketing and storage options. As the intensive livestock industry expands into western and northern QLD it will require increased amounts of grain and by having on farm storage growers will be able to capitalise on this.

Need:

- ***Market development work needs to occur particularly in central Queensland for growers and end users to develop closer relations such as exist in southern Queensland.***
- ***Variety development work to fcus on high reliable yield which meets feed quality standards.***
- ***Dual purpose type varieties i.e. grain or forage could also be useful to maximise interaction between cropping and extensive livestock operations.***

Cane grower areas of coastal and northern QLD.

There has been considerable interest from growers in barley as a rotational crop with cane and a pulse or peanut crop. Some reasons for selecting barley.

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- a winter crop thus fits with soybean or peanut rotation
- good weed smothering ability – reduce need for chemical fallow (see photo)
- flexibility of end uses, grain, silage, hay or just a green manure crop.
- A good grain or forage option to support growth of both feedloting and dairy through the coastal regions.
- Lower inputs of both fertilizer and chemical required for production could assist in limiting potential reef run off issues.

Need:

- ***For barley to be truly successful in these areas work needs to be done on selection of varieties for quick maturity, disease resistance and forage production.***
- ***There also needs to be work done on developing local feed grain and forage markets and economic analysis of grain verse fodder production.***
- ***In NW QLD there is also an opportunity to development varieties which will assist extensive livestock operations in increasing productivity through either drought proofing, higher stocking rates or improved animal nutrition (ie. Dual purpose grain and graze type products).***

From Benefit to Australian Grain Growers in the Feed Grain Market

John Spragg 2008 p 115

The growth in demand for cereal hay and silage is lending itself to having cereal varieties better suited to the dual production of either hay or grain. These are potentially higher green matter production crops where the grower is targeting the production of hay with higher levels of protein and digestibility. Under differing climatic and market conditions, the grower may elect to not cut the crop and leave it for a grain harvest. The development of higher yielding dual purpose varieties of oats, barley, triticale and wheat would result in additional grain being targeted to feed grain markets. Increased dedicated cereal fodder production should result in less milling wheat and malting barley crops from being diverted into this market.

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Supporting Information

Improved Weed Control

Local research has shown that barley is much more competitive than wheat against a range of weed species. A series of field experiments showed that for wild oat (*Avena ludoviciana*) and paradoxa grass (*Phalaris paradoxa*), the yield loss from untreated weeds was 4-5 times greater in wheat than in barley (Fig. 1). Barley did not affect weed emergence but reduced weed seed production by suppressing weed tiller density and to a lesser extent, weed seed per tiller. Barley's competitive superiority was also evident when the weeds were treated with herbicides.

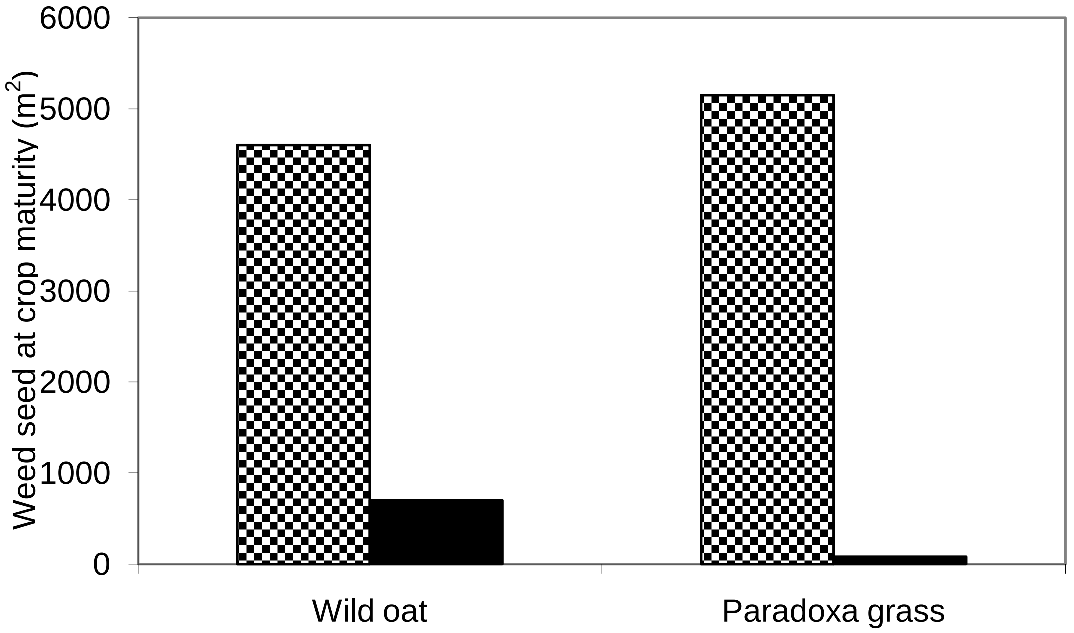

Figure 1. Weed seed production of wild oat and paradoxa grass in unsprayed wheat (checked bar) and barley (solid bar).
(Michael Widderick and Steve Walker 2009)

Where does the industry see R&D should focus?

From Benefit to Australian Grain Growers in the Feed Grain Market
John Spragg p138

1. Feed grains R&D should not be viewed in isolation as separate grains projects. There would seem to be great benefit in getting cereal chemists more actively involved with animal nutritionists to share in knowledge relating to the characteristics of grain and what is already recognised within other non feed industries.

2. The barley industry has made progress in shifting its focus to look at functional tests to predict barley maltability. This work includes looking at measuring diastatic power (DP) enzymes such as alpha amylase, beta amylase and limit dextrinase instead of the straight DP. In effect what is required is a measure of the potential fermentability of barley. This move in the malting industry has direct parallels with functional activity of barley when fed to animal species, with the characteristics of barley affecting rate of digestion in monogastrics and fermentability in ruminants. What would seem a logical step is for the barley industry to seek out common beneficial characteristics so that in selecting barley varieties better suited to malt production they also identify beneficial traits for animal feeding.

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3. Genetic X Environment interaction – there are recognised differences from season to season in how grain performs in animal feeding applications. Greater work is needed in defining the level of variation occurring as a result of genotype and environmental conditions. Climatic differences between seasons results in significant differences in grain yield, grain size and screenings as well as available energy content. Grain downgraded due to not meeting various receival standards is heavily discounted in value. PGLP work has shown that in most cases this downgrade is excessive and bears little correlation with how the grain us used by either the animal, or how it is used in the market. It is noted that the Pork CRC is conducting work in assessing effects of weather damage on grain quality. The grains industry should be looking at this area to seek means of preventing or reducing the level of downgrade occurring within the market.

4. Feed grain varieties – Lack of sufficient yield advantage has been identified by grain growers as the major reason why they do not grow feed grain varieties (wheat, barley and triticale). Growers generally need to see a minimum 15-20% yield advantage over either milling wheat or malting barley varieties before they will look to grow feed varieties. For malting barley this required yield advantage may be closer to 30%.
Lack of higher yielding varieties will continue to limit the development of a dedicated feed grain production base. If the grains industry is serious about meeting the feed grain needs of the domestic market and the livestock industries are equally serious about having feed grain security, then there should be a common interest in seeing the development and release of new higher yielding feed grain varieties. It would seem that unless both ends of the supply chain are supportive of this outcome, then there will only be slow progress to this end. In the eastern states, with increasing feed grain demand, it would seem to be an opportune time for the supply chain to more actively co-operate in this market development.

5. Milling Grain Varieties – having dedicated feed grain varieties would seem from an animal feed industry perspective as a good thing. Realistically, wheat breeding for milling and barley breeding for malt production is likely to remain the primary objectives for the Australian grains industry. The increasing volume of milling wheat and malting barley which is being used for pig, poultry and cattle feeding has in recent years shifted some of the planning within cereal breeding programs. In particular, there is opportunity to screen existing cereal grain genetic lines looking at available energy content. This process utilising PGLP NIR calibrations allows the cereal breeder to at least take into account what is available and eliminate any genetic lines which have obvious low energy characteristics. For the feed grain users, the most beneficial feature of milling grain breeding programs is a focus on increasing grain yield. This emphasis increases grain grower viability and increases grain supply security. Due to the high proportion of milling wheat and barley grown, this one R&D focus area is likely to be more beneficial to the feed grain supply chain than work in development of dedicated feed grain varieties.

6. Unique Quality Trait Characteristics – biotechnology has longer term potential to result in cereal grains carrying unique quality trait characteristics, which could add greater value to the grain in specific applications. Whilst many new and novel traits may be possible in the future, the greatest value for such traits may be within human consumption of cereal grains rather than within animal feeding. What is of importance is that biotechnology used to produce novel traits, for specific markets, does not result in unintended consequences for the animal feed end users. For example, work being undertaken looking at increasing fibre levels of some grains for human health benefits may be counter productive for animal feeding, should such grains be diverted to animal *feeding. There needs to be consideration of where such unique characteristics fit into the supply chain and what negative outcomes could result from their development.*

This, however, should not limit future work in development of new cereal grain traits which may offer benefits to the animal industries. Potentials include modification of the amino acids profile of grains, inclusion of higher levels of selected fatty acids such as omega 3, reduced fibre content, altered protein starch matrix to change rate of digestion and release of nutrients, provision of reduced phytate levels or enhancement of vitamin content of grains.

The livestock industries do not currently see these unique characteristics as a high priority. Nutritionists have capacity to formulate feeds using a wide range of raw materials to deliver the intended feed nutrient specification. This is very different to many food products which are reliant upon the single grain being processed.

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Appendix 4: Shepherd Barley (Tested as NRB03470)

A tall plant with good seedling vigour and vigorous early growth suited to all dryland regions of Queensland and the NW Slopes and Plains of NSW. Shepherd is a quick maturing line which displays improvements in foliar disease protection, grain size and hectolitre weight and reliable high yields across northern NSW & Queensland barley growing regions. It is a tall plant with good straw strength and has demonstrated the ability to maximise yields in high yielding sites.

Planting recommendations

As a quick maturing line Shepherd is showing wide adaptation to the northern grain growing region where heat during grain fill has been limiting yields of later maturing lines during the 2000's. While Shepherd is recommended for all parts of the region, best results will be obtained in situations with higher yield potential. In comparison to other quick maturing material (i.e. Grout & Fleet) Shepherd is to be able to hang onto high yields in favourable conditions and compete well against later maturing varieties. It also has leaf rust resistance which is a disease to which Grout has shown some susceptibility in 2008. It is recommended to try Shepherd against current commercial varieties.

Region	**Recommendation**
NQ & Coastal areas	A good choice for grain, silage or hay due to leaf rust resistance and quick maturity.
CQ	Recommended for all planting times, best into good soil moisture conditions.
SE Downs	Recommended for all but very early (April – 1st week May) planting where later maturing lines should be preferred. Opportunity for double cropping or late planting.
Dalby & Central Downs	Ideal for good moisture profiles mid May – end June planting. Good potential for earlier planting but some frost risk.
SW QLD	A good choice for most plantings in this region. Best in better moisture profiles. Grout should be preferred in lower moisture sites (yield potential > 2.00 t/ha) or for late planting.
NE Slopes & Coastal (NNSW)	Recommended for all but very early plantings (April) where frost could be a risk. Also later maturing lines could have a yield advantage in early planting
NW Plains (NSW)	A good choice for early planting and good sub soil moisture situations in this region. Grout should be preferred in lower moisture sites.
Tamworth and Liverpool Plains	Ideal for a quick rotation either into a double crop situation or as a later winter crop. In early plant high moisture situations later maturing lines could have a potential yield advantage. For plantings from mid June – end of July on would be an ideal choice.

Yield and grain quality

Shepherd has very good yield potential. On average yields across a number of sites it can be difficult to separate Grout and Shepherd however Shepherd tends to be able to capitalise on higher yielding sites and is more reliable across a range of sowing times. Shepherd also shows improved grain quality traits such as grain size and hectolitre weights.

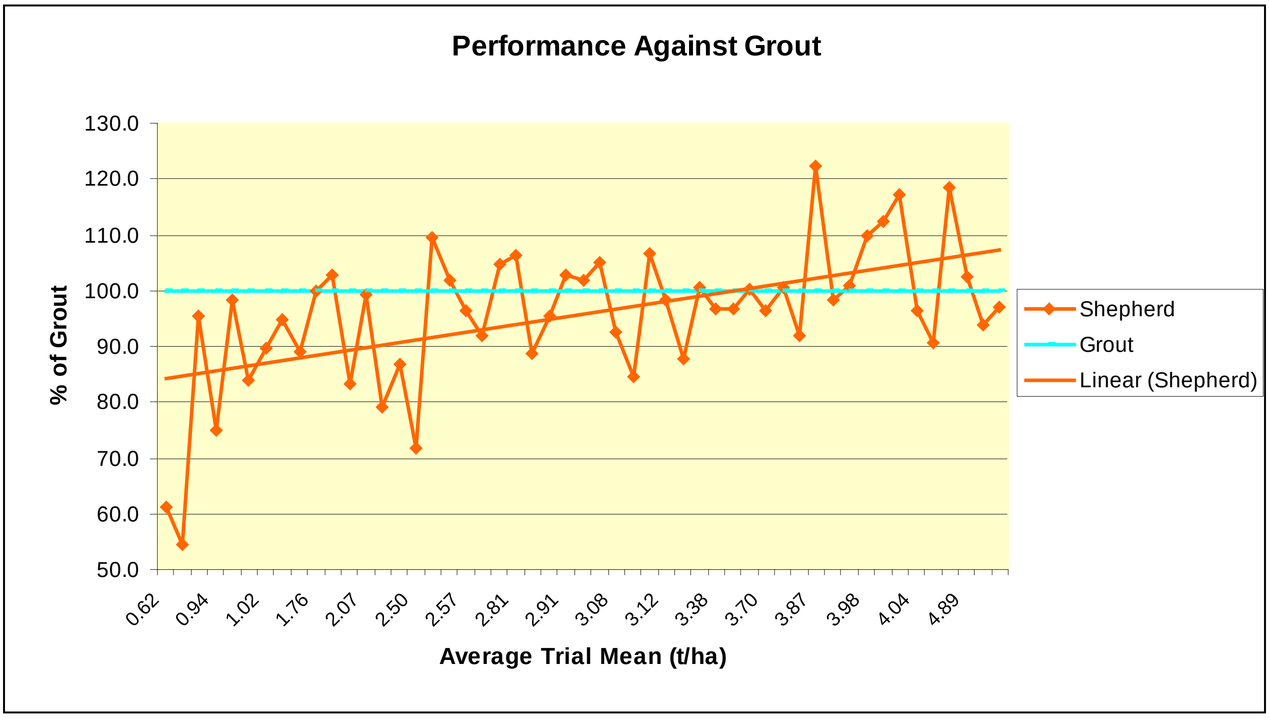
Table 1: Summary of yield and grain quality from 2008 Pork CRC strip trials (8 trials).

	Average yield	HLW	Screenings	Retention
Shepherd	3.31	66.5	9.1	55.0
Hindmarsh	3.63	67.7	10.8	50.1
Grout	3.46	66.0	11.2	51.2
Commander	3.41	64.8	15.9	49.9
Fitzroy	3.22	61.0	21.7	34.7
Fleet	3.05	62.6	7.6	66.2
Skiff	3.03	64.5	33.9	24.0
Gairdner	2.74	66.4	22.7	28.0

Table 2: Shepherd has demonstrated high yield potential across the region. In 39 trials conducted by Barley Breeding Australia (North) between 2006 and 2008 it has consistently been among the top performers.

Genotype	2008	2006-2008	No of trials
Grout	4.09	3.29	39
Commander	4.01	3.26	39
Shepherd	3.91	3.15	39
Mackay	3.67	2.95	39
Fitzroy	3.62	2.92	39
Skiff	3.50	2.83	39
Binalong	3.35	2.80	39
Grimmett	3.24	2.69	39
Tallon	3.20	2.66	39
Gairdner	3.20	2.62	39
Hindmarsh	3.96	3.22	37
Fleet	3.81	3.09	31

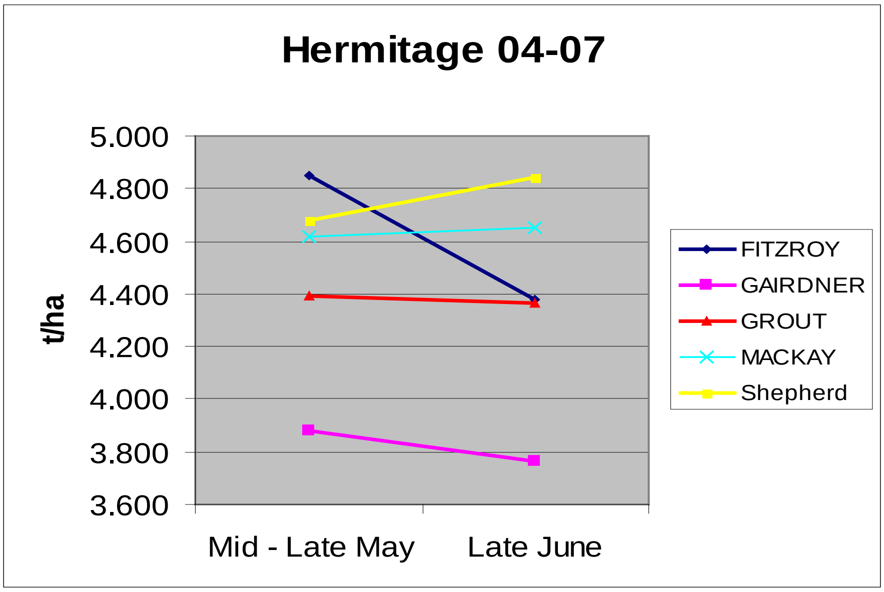
Figure 1: This graph shows the performance of Shepherd (NRB03470) against Grout in trials from 2005 - 2008. Although there is very little difference in average yield between the two varieties across the 52 trials Shepherd has an advantage in the higher yielding sites and Grout still demonstrates an advantage in the lower yielding sites (below 2-2.5 mt/ha). All trials are replicated trials in NNSW and QLD conducted between 2005-08.



Planting time

Shepherd is similar to Grout for maturity during the main planting times (Early May to Mid June) during the earlier and later parts of the season Shepherd tends to be later to flower than Grout. This makes it more suitable for earlier planting but less suitable for later planting in the western areas where Grout should be preferred for late planting. In eastern areas where heat during grain fill is less of a problem Shepherd has shown good yield potential on late plantings (see Figure 2).

Figure 2: Three years of time of sowing trials conducted at Hermitage Research Station near Warwick indicate that Shepherd barley is very stable in yield potential across sowing dates in this environment.



Note: In more western or northern environments where heat could be a problem during grain fill it is preferred that Grout be used on a later planting as Grout will reduce its days to flower and avoid heat during grain fill.

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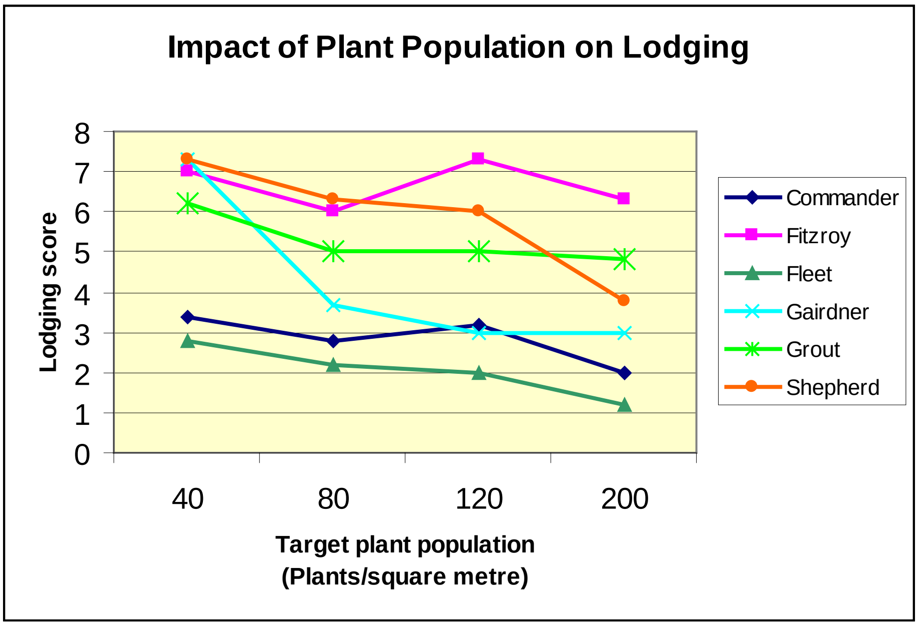
Plant Population & Planting Rate

Shepherd will produce best yields with established populations of between 1 million and 1.2 million plants per hectare, populations above 1.2 million plants per hectare could result in some lodging in favourable conditions.

Figure 3: Effect of seeding rate on lodging of a range of barley varieties at Spring Ridge in 2008 (Lodging score 1= all plants lodged 9= all plants standing). (Data from Barley Agronomy project 2008)



Deep Sowing

Shepherd has vigorous seedlings with good coleoptile length, 2007 and 2008 data indicates it is a good choice for deep sowing. Seed dressings containing triademenol will reduce coleoptile length and should be avoided if possible when deep sowing or alternatively increase planting rate to allow for lower establishment.

Nutrition

Shepherd is a high yielding variety and good nitrogen and phosphorus levels are important to maintain yield potential.

Disease resistance/susceptibility

Shepherd offers an advancement in disease resistance over most current varieties, to the major pathogens of barley in the Northern region. It has good resistance to powdery mildew (*Blumeria graminis* f. sp. *hordei*), leaf rust (*Puccinia hordei*), net form net blotch (*Pyrenophora teres* f. *teres*), covered smut (*Ustilago hordei*) and shows some resistance to spot blotch (*Cochliobolus sativus*). The value of these resistances in farming systems in the Northern region is given below.

The release of Shepherd will introduce a new leaf rust resistance gene into the commercial arena. This is highly desirable as most current cultivars (except Fitzroy and Mackay) are susceptible. Fitzroy is protected by *Rph3* which provided only ephemeral resistance to leaf rust in New Zealand and it is not expected to offer durable resistance here. Mackay is believed to have APR but it is not as effective as the APR in Shepherd. Having an alternative source of leaf rust resistance in the system is desirable as it will slow the development of virulence on *Rph3* and when *Rph3 does* becomes ineffective it will still provide protection from that pathotype.

Shepherd is highly resistant to powdery mildew.

Shepherd is resistant to the dominant pathotype of net form net blotch in eastern Australia. Its resistance is superior to Binalong, Grimmett, Skiff and Tallon. Shepherd is very susceptible to spot form of net blotch (*Pyrenophora teres* f. *maculata*) being similar to Hindmarsh, Mackay and Gairdner.

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Summary Table of Variety agronomic and disease comparisons.

Varieties in alphabetical order

	Commander	Hindmarsh	Fitzroy	Fleet	Gairdner	Grimmett	Grout	Mackay	Shepherd
Height	Tall	Short	Short	Tall	Medium - tall	Medium - tall	Medium - tall	Medium - tall	Tall
Standability	Medium - poor	Good	Good	Poor	Medium - good	Medium - poor	Medium	Medium	Medium
Post-ripe straw strength	Medium - poor	Medium	Medium	Poor	Good	Very good	Medium	Good	Good
Maturity (Days to flower)	Medium	Early – Medium	Medium - late	Early – medium	Late	Medium – Late	Early	Medium	Early medium
Net blotch (net form)	MR	MR-MS	MR	MR	MR	S-VS	R-MR	MR-MS	MR-MS
Net blotch (spot form)	MR-MS	S-VS	S	MR	S-VS	S	S	S-VS	S-VS
Leaf rust	S	MS	R	MS-S	S	S	VS	MR	MR
Stem rust	S	S	S	S	S	S	S	S	S
Spot blotch	S	S	S	S	S	S-VS	S	S	MS-S
Powdery mildew	MR-MS	MR	S	MR	S	S	R	MR	R

Foliar disease

R & MR = Management option: Very little to no disease found. No economic management decisions required.

MR -MS Monitor crops for disease development. In the presence of inoculum and in seasons conducive to disease, an economic management decision may be appropriate (eg preventable spray) Later occurrence of the disease may not require any action..

S-VS Management decisions will be required to reduce yield loss and will most probably be economic to do so.

(Foliar diseases have a wide range of pathotypes disease resistance ratings are based current knowledge of pathogen populations in the northern region.)

Shepherd has been released from the Northern node of Barley Breeding Australia and is marketed by AWB Seeds. Data provided in this leaflet is from trials conducted by BBA north and the Barley Agronomy project with funding from GRDC and the Pork CRC.

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