

Using on-farm research to refine management guidelines.

Jeff Russell¹, DAFWA; J. Eyres², G Fosbery² and A. Roe², ConsultAg.

¹Centre for Cropping Systems, PO Box 483, Northam, 6401. jrussell@agric.wa.gov.au

²ConsultAg, Northam.

Abstract:

Cereal crops are the mainstay of the cropping enterprise for farmers in the medium to low rainfall central wheatbelt of Western Australia. Barley grown for the premium malting and Shochu markets is a profitable crop in this district to the extent, that barley is increasingly being grown as consecutive crops which is a practice considered likely to be courting danger with disease. This has been allowed with the advent of fungicides that have application of economic merit given current barley yields and premiums for malting grade. Extended cereal crop sequences also have implications for crop nutrition with nitrogen management being prominent in this.

Developments in cropping technology over the last decade have enabled growers to have the ability to examine agronomic issues with greater precision. On farm research (OFR) is now easier to perform with confidence of relevant results applicable to the grower's environment. This allows growers to refine current intensive research findings through OFR to develop agronomic management packages of more relevance to their district.

Over the last three years members of the Kellerberrin Demonstration Group have conducted a number of OFR experiments to assist in the management of barley crops in their environment. These have been to determine the more appropriate application of foliar fungicides to combat leaf diseases and to fine tune crop nutrition. The results of this work are outlined along with the management practices developed to underpin productive and profitable barley crops in the central wheatbelt.

Keywords:

On-farm research, barley agronomy, nitrogen, fungicides, action learning

Introduction:

On-farm research (OFR) is the process by which research is conducted such that it is fully managed by growers. The research may be initiated by the grower or a second party such as researchers, agronomists or agri-industry consultants and may be aided by them to provide input and with the taking of specific measurements dealing with the specifics of the research. However, the defining feature is that OFR is implemented by growers using their own equipment to impose treatment effects in a realistic and practical fashion on their property and at a scale much larger than the usual intensive research conducted by researchers in agriculture.

The Kellerberrin Demonstration Group (KDG) is a small local grower group numbering 10 farming enterprises that has been in operation since 1999. The group has a general aim to understand local farming systems to improve their productivity and profitability on their farms (LFGN, 2007). Many members of the group have now become adept at conducting OFR and with the assistance of ConsultAg consultants and the Department of Agriculture and Food, Western Australia (DAFWA), have managed to build a profile of excellence in this area (Farm Weekly, 2007).

Within the confines of a group setting, OFR can become a useful learning process to help build the capacity of not just a grower's but also that of a researcher's or consultant's understanding of the issues being confronted. The KDG undertakes an action learning process (Weinstein, 1999) that transcends the growing season. An action learning cycle similar to that as developed by Kolb (1984) is employed within the structures of the group process. The great advantage of this process is that it also takes into account the breadth of learning styles (Honey and Mumford, 1982, *in* Mumford, 1993)

likely to be displayed by the members of the group. Through this process topics of importance to the KDG can be investigated. This usually involves some lower level preliminary OFR activity (Russell, 2001), then depending on the findings from this work, a more structured level of activity where greater design rigour is employed.

Profitable barley (*Hordeum vulgare*) production is just one of many cropping issues being investigated by the KDG and fine tuned to their environment by the group over the years. This work is conducted in a Mediterranean rain-fed environment that is described locally as being in the medium to low rainfall zone of the Western Australian cropping regions. Typically, annual rainfall is 333 mm with 72% falling in the growing season months of May to October.

Compared to wheat (*Triticum aestivum*), barley production in the Kellerberrin shire is small, at about a fifth the amount. However, barley production has almost doubled in the last 10 years from 14,000 tonnes to currently averaging about 22,000 tonnes, season depending (DAFWA internal sources). This has occurred as recognition for growing barley for the malt grade and if possible for the Japanese 'Shochu' market, where it can attract a premium price over growing barley for the feed market.

An impromptu survey of growers in the wider district (Russell, Merredin Crop Updates, 2007) confirmed assumed changes in barley cropping practices, when it was found that over half the barley growers double cropped barley and about a quarter were growing up to 3 consecutive crops of barley on a paddock. These are practices also being adopted by a number of the members of the KDG. Part of this has been brought about by a downward shift from the production of lupins (*Lupinus angustifolius*) and pastures within the district (and the whole state) and barley cropping has taken some of this paddock area along with the need to diversify from just wheat cropping. This has had consequences in changing the sequence of crops within the district. With the attractive margins for malt grade barley has come the imperative to get the crop agronomy right.

Consecutive cereal cropping including multiple barley crops grown on a paddock in successive years means increased risks of disease in following barley crops. The lowering of the legume input into the general crop sequences impacts on the grain protein and quality requiring the management of nitrogen to be more thoughtfully considered when growing cereals in general. As a result of this the KDG conducted a series of OFR activities to investigate disease management and nitrogen application to fine tune their local agronomic skill to the production of malt barley in their environment during the 2004 to 2006 seasons. Each activity while having separate aims a) To determine the effectiveness that applying a foliar fungicide has on leaf disease development in barley and to establish the optimum timing and rate for use of the fungicide and b) To determine the effect of different rates and timings of nitrogen have on barley yield and quality, have similar end purposes – to improve the profitability of barley cropping in their environment.

Methods:

Disease management

In 2004 a preliminary 'cris-cross' style of experiment was used to investigate the interaction of the rate and timing of applications of fungicide (ai propiconazole 250 g/L) for the control of leaf disease in barley cv Stirling. Rates of 0 and 180 ml of fungicide were applied at two different timings. The 4 to 6 leaf tillering stage (Z24) and prior to flag leaf emergence (Z36) to give replicated applications that totalled 0, 180, 360 and 540 ml of fungicide. Based on the results found from this activity and new knowledge in disease management in barley, the experiment was redesigned for greater rigour and repeated in 2005. The barley variety Stirling was used in all three years as it fits the current cropping system of consecutive cereal crops, and has market preference as a malting variety and for the 'Shochu' market.

In 2005 a "Level 4" experiment (Russell, 2001) was implemented to investigate the objective mentioned earlier. The barley crop was established as a conventional paddock following after a

previous wheat crop. Pre-sowing fungicide treatments were applied to the seed in line with normal grower practice. Nitrogen was applied at seeding to ensure no deficiencies were to occur, with the rate determined from crop history and management practice. Fungicide (ai propiconazole 250 g/L) treatments were applied by boomspray across the direction of seeding. The plots were very wide at 33m and 150m long. Three rates of fungicide (0, 125 and 250 ml/ha) were applied at the 4 to 6 leaf stage of the crop (Z24). Fungicide was then applied a second time at the same 3 rates just prior to flag leaf emergence (Z36).

Diagnosis of leaf disease within the nil fungicide plots were made about 8 weeks after seeding and used as a reference guide to the nature and level of infection. Visual ratings of disease were made prior to the application of the first spray regime. Visual ratings of disease in all treatments were then made before the second spray application and then before milky dough stage of the crop. Disease ratings were made on the F-2, F-1 and flag leaves at this final time.

From the observations made of the fungicide rate interactions with disease infection the KDG decided to repeat this experiment in 2006. This was done at two sites. One site was barley following wheat (site 1) the other a consecutive barley paddock (site 2). All methodology was the same as in 2005.

Crop yield in all three years was determined by harvesting the centres of the plots with a conventional harvester with the grain weighed in a weigh trailer. Samples of grain from each plot was taken to the local Cooperative Bulk Handling (CBH) receival sites for analysis and grading as is the convention for all grower deliveries within the state. Analysis of the results of all the experiments was performed using GENSTAT v7.0.

Nitrogen nutrition

In 2005 and 2006, "Level 4" (Russell, 2001) replicated and randomized experiments were performed in paddocks being sown to barley. Pre-sowing fungicides was applied to the seed at normal use rates for cropping. Barley cv Hamelin was grown in 2005 while in 2006 the variety Stirling was grown. A base level compound fertilizer was applied at seeding (14%N, 14%P, 9%S and TE; 70 kg/ha in 2005 and 50 kg/ha in 2006) along with conventional crop protection practices for weed control and disease as needed through the season. Nitrogen treatments were applied to plots in the form of liquid fertilizer (32% N) at three rates and two times of application, one at seeding and the other 7 weeks later. The rates of N in each year were determined from paddock soil testing history, soil type and likely seasonal projection of yields based on the paddock's previous cropping history. The rates were lower in 2006 due to the amount of summer rainfall that preceded that season. A nil treatment was included to be used as a benchmark and the treatments were set out in a randomized block structure and replicated twice. Plots were 33m wide and 150m long.

Plots were tissue tested for N at the 4 leaf stage (Z14), about 6 to 8 weeks after seeding, prior to the second application of N being applied (%PTA using commercial fertiliser industry nutrient analysis kit service). Crop yield was determined by harvesting the plots with a conventional harvester with the grain weighed in a weigh trailer. Samples of grain from each plot were collected and taken to CBH for analysis and grading as is the convention for grower deliveries in the state. Analysis of the results of all the experiments was performed using GENSTAT v7.0.

Results:

The seasons at Kellerberrin for the 3 years that this research was conducted were very different to each other (Table 1). The growing season for 2004 was slightly below average while 2005 was just above average. 2005 had a serious frost event in early September that critically affected cereal yields. 2006 had a very wet summer followed by a difficult start to an extremely dry winter.

Table 1. Rainfall at Kellerberrin for the years 2004 to 2006 (Post Office and BoM, 2006).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total	*GS
Ave	10	15	22	22	43	57	53	41	26	19	12	13	333	239
2004	23.4	7.2	7.2	22.1	34.8	65.0	30.3	38.9	18.0	18.8	5.7	2.5	274	206
2005	0	1	29.9	18.2	70.5	50.8	11.1	61.2	33.2	16.4	8.6	1.2	302	243
2006	100	41.2	17.2	23.9	10.3	10.8	19.6	28.2	33.9	2.8	17.6	12.0	317	106

*GS = growing season rainfall (May – Oct).

Disease management

Unfortunately operational issues occurred in 2004 that delivered an unbalanced design to the experiment which made it difficult to conduct a statistical analysis on the results with appropriate certainty. Never-the-less, observations occurred that implied there was still much to learn about determining the optimum rate and timing of fungicide. Leaf area affected by disease fell with the application of increasing rates of fungicide (Fig 1a) but this did not equate to the delivery of significantly ($p=0.05$) larger yield increases (Fig 1b).

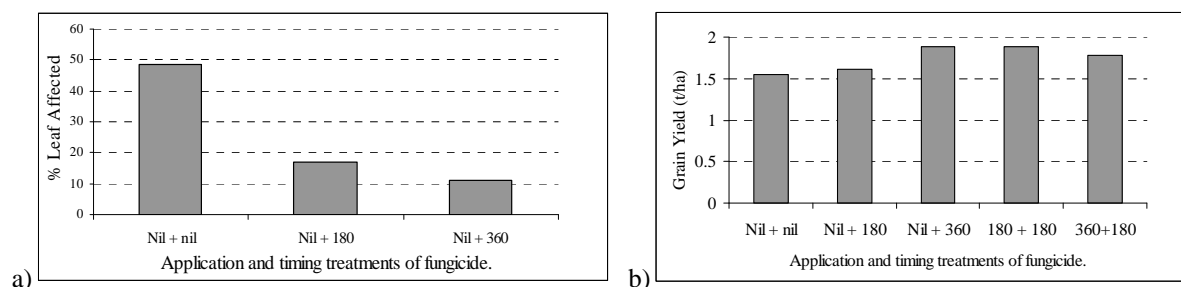


Figure 1. a) Leaf disease ratings taken at grain fill on the Flag -1 leaf and b) grain yield (t/ha) for the fungicide time x application rate treatments in 2004.

Grain yield and quality was measured with no significant differences ($p=0.05$) seen between the treatments. Malt grade was achieved by most treatments. The control had the lowest yield which then increased with increasing rates of fungicide and at the later application (Z36) time. It was observed that the level of screenings decreased with the higher rates of applied fungicide and at the second (Z36) application time. Grain weight was seen to increase at the later time of application (Z36) and with increasing rate of fungicide. A simple economic analysis showed the nil+360 treatment delivered a profit of about \$60/ha over the control.

The experiment conducted in 2005 was greatly affected by frost events that occurred that year rendering yield and grain quality measurements to be of questionable reliability. Significant reductions ($p=0.05$) in the leaf area affected by disease were noticed on the flag, flag-1 (fig 2) and to a lesser extent flag-2 leaves. The main effect on leaf disease gleaned from visual observations, appeared to be as a result of the second foliar application (Z36) and at a higher rate (250 ml/ha). This unfortunately was not translated to yield performance or grain quality at harvest as the frost caused some over riding interference of the results. All treatments went feed grade as a result.

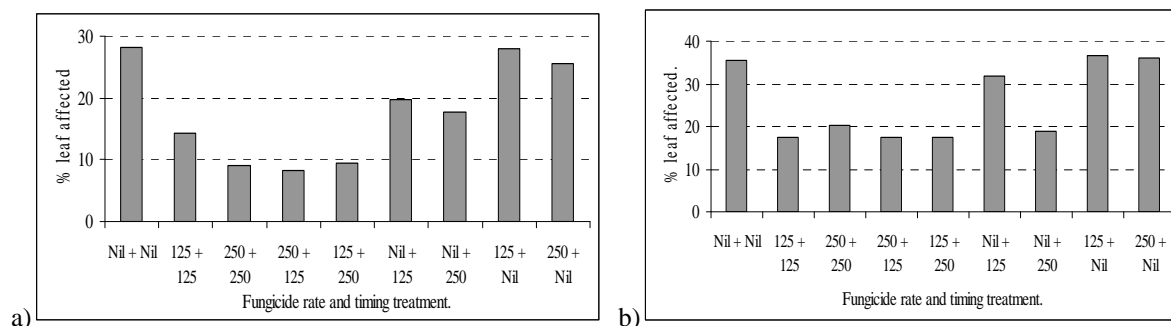


Figure 2. Area of the flag (a) and flag-1 (b) leaves of barley affected by disease as a result of the application rate and timing of fungicide in 2005.

The dry nature of the 2006 winter months (Table 1) was not conducive to leaf disease occurring at either of the two sites and the diagnostic tests and visual observations attests to this (Table 2).

Table 2. Disease observations in barley and fungicide application dates at the 2 sites in 2006.

Site	Visual sampling / observation dates			Fungicide application dates	
	1	2	Detailed measurements	First	Second
1 After wheat	10 th August Very low levels spot type net blotch	20 th August Low levels of spot type net blotch	1 st September	18 th August	2 nd September
2 After barley	na	28 th August Low levels of spot type net blotch	1 st September	10 th August	11 th September

Leaf disease measurements of observed leaf area affected were extremely low in 2006 (Table 3). At site 1 there was no significant effect of any of the fungicide treatments on the F-2 and F-1 leaves. Disease scores on the flag leaf and two lower leaves showed no significant effect ($p=0.05$) from the application of fungicide, at either rate or time of application. Site 2 had disease ratings only slightly greater than site 1 but there were no significant ($p=0.05$) effects of fungicide treatments in reducing the level of foliar disease in the crop overall.

Table 3. Leaf disease visual ratings (% of leaf area) taken at the 2 sites on the 1st September 2006.

Site	First\ Second	F-2 leaf			F-1 leaf			Flag leaf		
		0	125	250	0	125	250	0	125	250
1.	0	5.6	3.0	3.5	3.2	1.4	2.4	1.3	0.6	1.2
	125	3.4	2.6	2.9	1.6	1.2	1.9	0.9	0.4	0.6
	250	2.7	6.0	2.1	1.4	2.3	1.7	0.3	1.0	0.6
	lsd (5%)	4.2			2.5			0.8		
2.	First\ Second	0	125	250	0	125	250	0	125	250
	0	6.1	10.6	8.3	3.2	3.9	3.8	0.2	0.6	0.9
	125	7.4	10.4	9.8	3.5	3.5	3.5	1.0	0.9	0.6
	250	6.0	8.5	6.8	3.1	3.1	3.4	0.5	0.4	0.5
	lsd (5%)	5.1			1.4			0.8		

Harvest measurements from both sites do not show any convincing trends. The yield data (Table 4) shows no significant differences ($p = 0.05$) between the treatments. Likewise for the grain quality measurements there were no significant differences ($p = 0.05$) to be seen at each site.

Table 4. Grain yield and quality measurements of the barley at the 2 sites.

Site	First(Second)	Yield. (kg/ha)			Protein. (%)			Grain weight. (kg/hl)			Level of screenings.(%)			Grade
		0	125	250	0	125	250	0	125	250	0	125	250	
1.	0	2735	2550	2365	11.4	11.8	12.3	67.8	66.8	66.6	9.9	7.2	9.6	All malt
	125	2395	2595	2390	11.9	11.8	12.1	66.6	66.5	66.8	8.7	8.6	9.2	
	250	2445	2500	2460	12.0	12.2	12.2	68.6	67.8	66.3	8.6	8.1	8.2	
	lsd (5%)	263			0.7			1.4			2.5			
2.	First(Second)	0	125	250	0	125	250	0	125	250	0	125	250	All malt
	0	1975	1860	1895	10.9	10.9	11.1	66.2	67.8	66.5	13.0	12.6	12.9	
	125	1915	1855	2035	10.9	10.8	11.0	67.0	66.0	67.0	12.7	14.7	11.7	
	250	1940	1945	2045	11.0	10.7	10.8	66.2	66.5	67.0	14.4	13.7	13.3	
	lsd (5%)	639			0.8			2.0			5.7			

Nitrogen nutrition

In 2005 the damaging frosts were the most overriding feature of the season, so only limited weight can be placed on the harvest results. The 20 and 40 kg/ha N treatments were significantly ($p= 0.05$) higher yielding than the 80 kg/ha treatment at the first time of N application (Fig 3a). The yield of the 20+40 treatment was significantly ($p=0.05$) greater than the control (0+0) while the 80+40 was significantly ($p=0.05$) lower.

Protein was found to be significantly ($p=0.05$) impacted by increasing N rates at the two application times (Fig 3b). As applied N increased so did the grain protein. Only the control remained in the requirements for malt grade being less than 11.5%

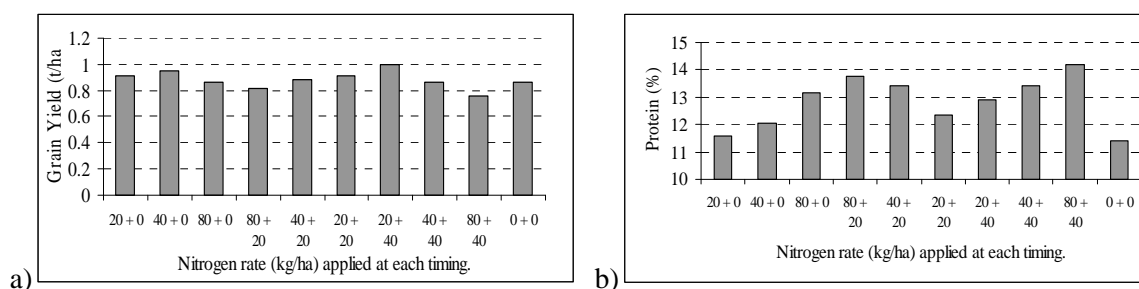


Figure 3. Grain yield (a) and grain protein (b) response in barley to the applied N treatments at the two times of application in 2005.

A combination of low grain weight (Fig 4a) and high screenings meant that all treatments were received into feed grade or went under grade. Applied N did not significantly ($p=0.05$) affect grain weight, however, increased applied N led to significantly ($p=0.05$) increased screenings (Fig 4b).

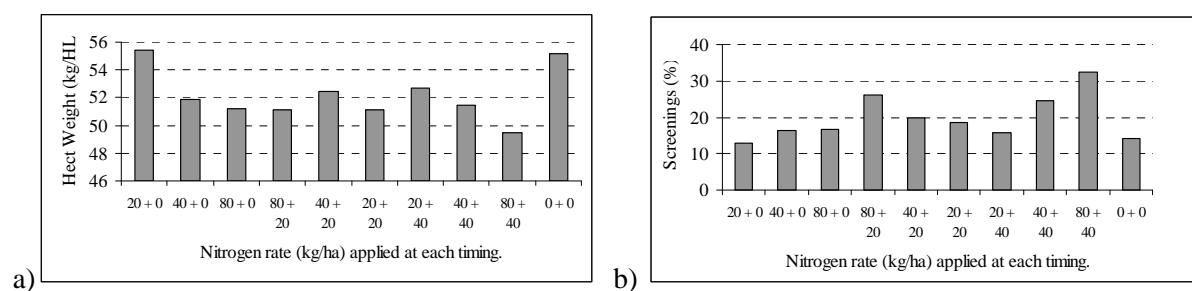


Figure 4. Grain weight (a) and level of screenings (b) response in barley to the applied N treatments at the two times of application in 2005.

Despite the dry growing season of 2006 (Table 1), barley yield was good (Fig 5a). All the treatments yielded higher than the control and this was the same for grain protein (Fig 5b). However, there was no significant ($p=0.05$) yield differences due to increased N at either of the two times of application. Grain protein was significantly ($p=0.05$) influenced by the treatments. As the N rate increased so did the grain protein. With the exception of the control, all protein levels were too high to make malt grade for shochu.

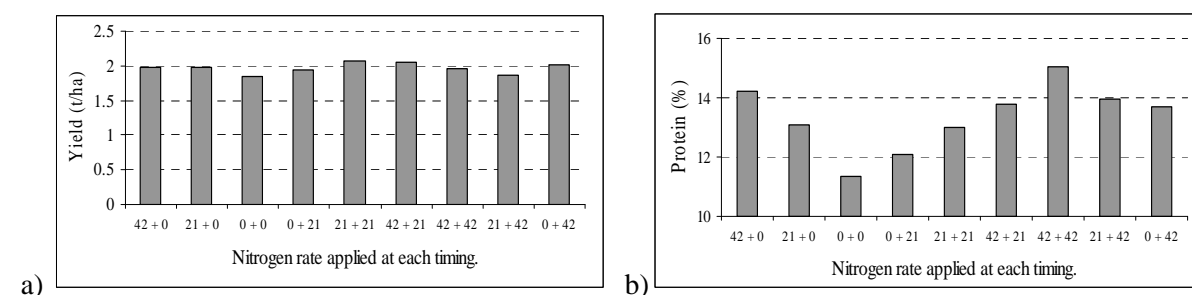


Figure 5. Grain yield (a) and grain protein (b) response in barley to the applied N treatments at the two times of application in 2006.

Grain weight was significantly ($p=0.05$) reduced by highest N rate at the second time of application but not by the first (Fig 6a). With the exception of the 21+21 treatment all grain weights were too low to go malt grade. As a result of high screenings all treatments were down graded to feed grade. Like grain weight, screenings were significantly ($p=0.05$) increased by the higher N rate at both times of application from the control.

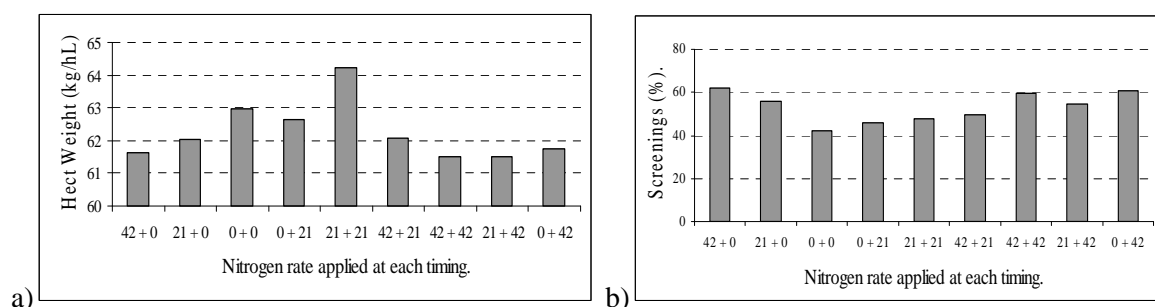


Figure 6. Grain weight (a) and level of screenings (b) response in barley to the applied N treatments at the two times of application in 2006.

A simple economic analysis found the control to be the most profitable treatment of all. While the 21+21 treatment was the most beneficial of all treatments applied in terms of yield and quality it did not cover the additional costs when compared to the control, costing the grower \$6.80/ha.

Discussion:

Disease management

The preliminary study conducted in 2004, suggested that 2 split applications of foliar fungicide would have a positive effect on yield and quality in barley. The general conclusion being that a late application of fungicide prior to flag leaf emergence (Z36) may be more effective than an earlier one at the 4 to 6 leaf stage (Z24).

From the visual ratings of leaf disease seen in 2005 (Fig 2) it can be generalised that the main effect in reducing the area of leaf disease is a result of the second time of application of fungicide (Z36), in particular the higher rate of fungicide. This did not carry through to yield and quality being most likely due to the influence of frost damage. However, the result of this work was similar to that seen in 2004.

The findings of the 2 experiments conducted in the very dry year of 2006, indicate that applying a foliar fungicide to barley, even when grown as consecutive barley crops as at site 2, is of no real advantage to the crop and so no economic benefit. The yields realised at both sites are an anomaly when compared to the season's rainfall. Normally to reach such yields in the order of 2 to 2.5 t/ha there would be more winter rainfall and a two fold effect on leaf disease – a bulky crop and wet canopy. In 2006 the crop grew on stored moisture rather than rainfall and this is a possible reason for no treatment effects to be seen. This suggests that if leaf disease levels are low less than 8% of the F-2 leaf and the canopy remains dry then a benefit from fungicide is less likely.

It should be noted that this work has been done on Stirling barley in the low rainfall central wheatbelt. Other varieties may respond differently, however, Stirling was used as it is still useful for meeting market demands and making money for growers.

Nitrogen nutrition

In 2005 yield was seen to decrease with the higher application of N. Given the frost effects this should not be too surprising. Research done by Knell (2003) suggested that a dense canopy can lead to the greater likelihood of damage in a frost event. It is possible that the 80 kg/ha of N at the first application time helped to contribute to this. Grain protein and screening levels reflected yield with undesirable responses to increasing N rates at either timing.

In 2006 the control was the financial best bet. However, the 21+21 treatment was the only one to make malt grade excepting for the screenings being above 30%. It had the lowest screenings for a treatment that received 42 kg/ha or more of N in total. This mirrors the results of 2005, where the 20+20 treatment was one of the better performers. There is a need to see how this treatment performs in an average season.

Conclusions:

Disease management

Fungicide applications in barley are often advocated where growing of barley is in a higher rainfall environment and with likely greater yield potentials of the crop (Jayasena and Loughman, 2001) However, the yield benefits seen in 2004 show that in some years it can be profitable in lower rainfall regions with crops yielding below 2t/ha.

An outcome of this work is the suggestion that a disease management plan for barley paddocks should be adopted by growers for their farm to make the tactical decisions required in the season for disease control. Rather than attempt to monitor all barley paddocks, especially if there is a large number of paddocks, growers should intensively monitor only a select number of barley paddocks on their property. The selection should be based on different crop histories but with similar yield potentials and highest likelihood of disease occurrence. Within these select paddocks, 2 to 3 sites should be

repeatedly and regularly monitored throughout the season. Decisions to then apply a foliar spray can then be made according to these observations of disease development taking into account the current weather conditions seasonal forecast and prevailing levels of disease in the district. This work shows that it is not an imperative to have applied fungicide early to get an advantage. Fungicide can then be applied across the whole barley program on the farm in a tactical manner where required.

Nitrogen nutrition

2005 shows that where frost conditions are likely to occur, it is better to not apply too much N upfront with the crop. Put a little on at the start then play the season. This was then reinforced in principle in the dry season of 2006. Research by Paynter and Hills (2007) with the variety Baudin and agronomic notes for the production of the variety Hamelin (Smith and Paynter, 2005), report on the need to be cautious with follow up applications of N so not to increase protein or screenings beyond the levels to meet malt grade.

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