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The Current and Potential Costs from Diseases of Barley in Australia



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The current and potential costs of diseases of barley in Australia.

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“How can we expect practical men to be properly impressed with the importance of our work and to vote large sums of money for its support when in place of facts we have only vague guesses to give them and we do not take the trouble to make careful estimates.” Lyman (1918)

EXECUTIVE SUMMARY

The allocation of resources for the control of barley diseases, both at the grower level when deciding whether to control a particular disease and at the national level when allocating funds for research and development, depends on an assessment of the losses caused by those diseases. In this study, the estimates of barley disease losses have been obtained from a survey of barley pathologists across Australia. An examination has been made of the present costs of barley diseases and the potential costs if current control measures were not in place, as well as the value of controls used. These figures provide key insights into the importance of barley diseases in Australia.

Barley diseases cause an estimated current average annual loss of \$252 million, or \$66.49 per hectare, to the Australian barley industry. This loss is 19.5 per cent of the average annual value of the barley crop over the past decade. Nationally, five diseases dominate these losses:

DISEASE	\$/ha	\$ million
net blotch-spot form	11.42	43
powdery mildew	10.28	39
cereal cyst nematode	6.74	26
<i>Pratylenchus neglectus</i>	5.60	21
leaf rust	5.55	21
Total losses from others	26.90	102
TOTAL PRESENT LOSS	66.49	252

If the current control measures were not in place, losses would be far higher. The magnitude of potential losses is shown by the loss estimates for the top five diseases when uncontrolled:

DISEASE	\$/ha	\$ million
net blotch-spot form	50.60	192
cereal cyst nematode	40.39	153
net blotch-net form	30.76	117
powdery mildew	27.25	103
leaf rust	25.31	96

The loss estimates were derived from a national survey of the incidence and severity of 42 barley diseases. The information was collected from the 14 agro-ecological zones where barley is grown in Australia, with the incidence and severity data in each zone supplied by 16 plant pathologists familiar with the diseases. These data were combined with data on area, production and value of the barley crop to estimate the economic value of the losses.

The relative importance of different diseases varies from one part of the barley growing area to another and from ranking by potential loss and ranking by present loss. Eleven diseases make up the top five by loss across each of the three GRDC regions ranked by potential and present loss. The following table lists the diseases by ranking of present loss in Australia (where '1' represented the highest loss), and shows the ranking for losses in the three regions and for potential loss in Australia:

Effective control means that, at the national level, the net form of net blotch changes from third place by potential loss to eighth place by present loss, while the spot form of net blotch is important in all regions both by potential and present losses.

Cereal cyst nematode, ranked first in both potential and present losses in the Southern Region, is less important in the Western Region and unimportant in the Northern

Ranking of disease losses (1 = highest loss)

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Potential	Present	Potential	Present	Potential	Present	Potential	Present
net blotch-spot form	3	1	2	2	2	2	1	1
powdery mildew	4	5	13	10	1	1	4	2
cereal cyst nematode	30	30	1	1	11	17	2	3
root lesion nem neglectus	9	9	6	3	5	5	6	4
leaf rust	8	14	3	7	6	3	5	5
Rhizoctonia barepatch	30	30	10	4	4	6	8	6
crown rot	1	2	7	6	7	8	7	7
net blotch-net form	2	3	4	14	3	4	3	8
common root rot	5	6	11	5	23	23	12	9
covered smut	7	4	9	18	23	23	11	12
barley stripe	23	29	5	25	23	23	9	38

Region. Within the Southern Region, this nematode is very important in western Victoria and South Australia but not in other parts of the region.

Covered smut ranks highly in some areas not because of its effect on yield but by its effect on marketability and thus price received for contaminated grain. This effect on marketability can also be a component of the loss from several foliar diseases, which when severe can downgrade barley from malting to a less valuable grade.

The differences between potential and present losses reflect the value of current control measures. These show the considerable achievement of research, development and implementation of controls. Disease management is by the use of resistant cultivars (breeding), paddock preparation and management (cultural) and application of pesticides, and combinations of these.

For example, cereal cyst nematode is controlled largely by breeding with a contribution from cultural methods; barley stripe by cultural methods; covered smut by pesticides; powdery mildew by a combination of breeding and pesticides; and the spot form of net blotch by a combination of all three methods:

DISEASE	CONTROL VALUE	CONTRIBUTION TO CONTROL (\$ million) BY:		
	(\$ million)	Breeding	Cultural	Pesticides
cereal cyst nematode	155	109	46	0
barley stripe	62	0	62	0
covered smut	48	0	0	48
powdery mildew	72	11	3	59
net blotch-spot form	167	73	78	16

Fungicides are widely used for controlling several barley diseases. Nationally, seed treatments are applied to 79 per cent of the barley crop, in-furrow to 8 per cent and foliar sprays to 21 per cent, while 9 per cent of barley crops receive no fungicides.

Overall, barley diseases have the potential to cause very significant costs for farmers. Measures to overcome those potential costs, including varietal choice, cultural practices, crop rotations and the use of fungicides, play an important role in the location and nature of barley production in Australia. Even after these measures have been taken to reduce losses, Australian farmers still suffer significant losses each year from barley diseases.

In this report, detailed information on the present costs of diseases and the potential costs if current control measures are not maintained are presented. Awareness of those costs will allow decision-makers to allocate the research and development resources to most effective use, while farmers will also be in a position to make better-informed judgements about the type and levels of controls to apply in their district.

This report estimates the status of barley disease losses in the first decade of the 21st century. It provides a benchmark to judge future changes.

ACKNOWLEDGEMENTS

This survey could not have been done without the enthusiastic cooperation of a large number of cereal plant pathologists throughout Australia. We are fortunate to have these experienced specialists throughout the nation to support the health of Australian barley. They are listed in Appendix B, Table B1. We thank them for their contributions. The results of this survey show the value of their work and that of their colleagues in plant breeding, agronomy, applied plant pathology and related disciplines.

The methodology is the same as in our parallel study of wheat diseases (Murray and Brennan 2009) and draws on our previous work on wheat (Brennan and Murray 1989, 1998). This in turn owes its existence to a question from Dr Howard Dengate and a book chapter by Professor John F. Brown (1975). Dr Chris Upper described the basic methodology of estimating disease importance on a whole crop basis to Gordon Murray while he was a student at the University of Wisconsin.

We thank the GRDC for commissioning this report and providing the funding which gave us an opportunity to update the estimates previously published in our report of 1998.

1. INTRODUCTION

Barley is an important crop in Australia in terms of the gross value of production. Consequently, it attracts significant public funds for research and development. Part of these funds is raised from production levies that are matched by government funds and then invested by bodies such as the Grains Research and Development Corporation (GRDC).

Allocation of resources for the control of plant diseases depends on an assessment of the losses caused by those diseases. This applies both at the individual level, when a grower decides whether control of a particular disease is warranted, and at the national level, when funds are allocated for research on disease management. Murray and Brennan (2009) developed estimates of the current and potential costs from wheat diseases in Australia. The GRDC requisitioned this similar study of barley disease losses to provide equivalent information on the economic costs of barley diseases, to assist in the allocation of resources for disease control.

The following sections describe the methodology, present the survey results, derive the loss estimates, and discuss control measures and the overall findings. Appendices provide the detailed results.

Section 2 – Method Full description of the methods used for the survey and its analysis; list of the 42 diseases included in the survey and their pathogens.

Section 3 – Production in barley growing areas of Australia Examines the reliability of the selected time period as representative of the longer-term barley production and climate.

Section 4 – Incidence and severity of barley diseases in Australia Distribution of the pathogens, their incidence and severity.

Section 5 – Losses from barley diseases in Australia Potential and present yield loss (%); effects on quality and its cost; value of the losses.

Section 6 – Value of control of barley diseases The value of control by breeding, cultural methods and pesticides.

Section 7 – Use of fungicides in Australian barley production Survey results on the use of seed, soil and foliar fungicides on barley.

Section 8 – Conclusions

Section 9 – References

Appendix A – Barley production data, 1998-99 to 2007-08

Appendix B – Survey data on barley diseases in agro-ecological zones

Appendix C – Summary of presence, incidence and severity of barley diseases in the agro-ecological zones

Appendix D – Fungicide costs

The aim was to produce current estimates of the importance of barley diseases in a fully transparent manner to allow quick revision as new information becomes available. These estimates provide a benchmark to judge future changes.

2. METHOD

2.1 Introduction

Estimates of disease losses should be fully transparent and documented; that is, the processes by which the data, assumptions and calculations are used to produce the final estimates should be clearly spelled out. This enables a critical appraisal by others and a recalculation of the estimates when new information becomes available.

The key processes involved in estimating the value of loss from diseases for a crop in Australia (Murray and Brennan 2009) are:

1. Identification of areas within the cropping belt with similar growing conditions (climate, soils, etc.)
2. Estimation of the area, production and value of the crop within each area pertinent to the time period of the loss estimation
3. Development of a list of the pathogens and their diseases known to occur in at least one part of Australia (estimates for the potential losses caused by exotic pathogens are not part of this study)
4. Assessment of the potential losses caused in epidemics and the frequency of epidemics
5. Identification of the control methods used and their costs.

2.2 Geographical regions for survey

The geographical regions used for the survey are the GRDC’s 14 ‘agro-ecological zones’, which divide the cropping belt of Australia into areas of similar growing environments. These zones are grouped into three regions, the Northern Region, Southern Region and Western Region (Figure 2.1, Table 2.1). The zones and regions are fully discussed in Section 2.2 of Murray and Brennan (2009).

2.3 Crop production data

In this study, we estimate disease losses to barley for current production environments. Data for barley area, yield and production in recent years were collected for each agro-ecological zone, on the basis that recent averages would represent expected values over the next several years. The period 1998-99 to 2007-08 was selected to calculate the mean annual area and production (see Section 3 for a more detailed explanation).

Similarly, the value of production was estimated from past data on the average unit value (the unit gross value of production is effectively a weighted average of all prices applied across all grades). The price discounting that several pathogens can cause by affecting grain quality or marketability was estimated from past data on prices for different grades.

Table 2.1 Agro-ecological zones and GRDC Regions of the Australian cropping belt

	ZONE	ABBREVIATION
GRDC NORTHERN REGION		
1	Queensland Central	Q Cen
2	NSW North-East/Queensland South-East	NNEQSE
3	NSW North-West/Queensland South-West	NNWQSW
GRDC SOUTHERN REGION		
4	NSW Central	N Cen
5	NSW-Victoria Slopes	NV Slp
6	Victoria High Rainfall	Vic HR
7	Tasmania	Tas
8	SA-Victoria Border-Wimmera	SV BWim
9	SA-Victoria Mallee	SV Mall
10	SA Mid-North/Lower Yorke, Eyre	SMNLYE
GRDC WESTERN REGION		
11	WA Sandplain-Mallee	W SandM
12	WA Central	WA Cen
13	WA Northern	WA N
14	WA Eastern	WA E

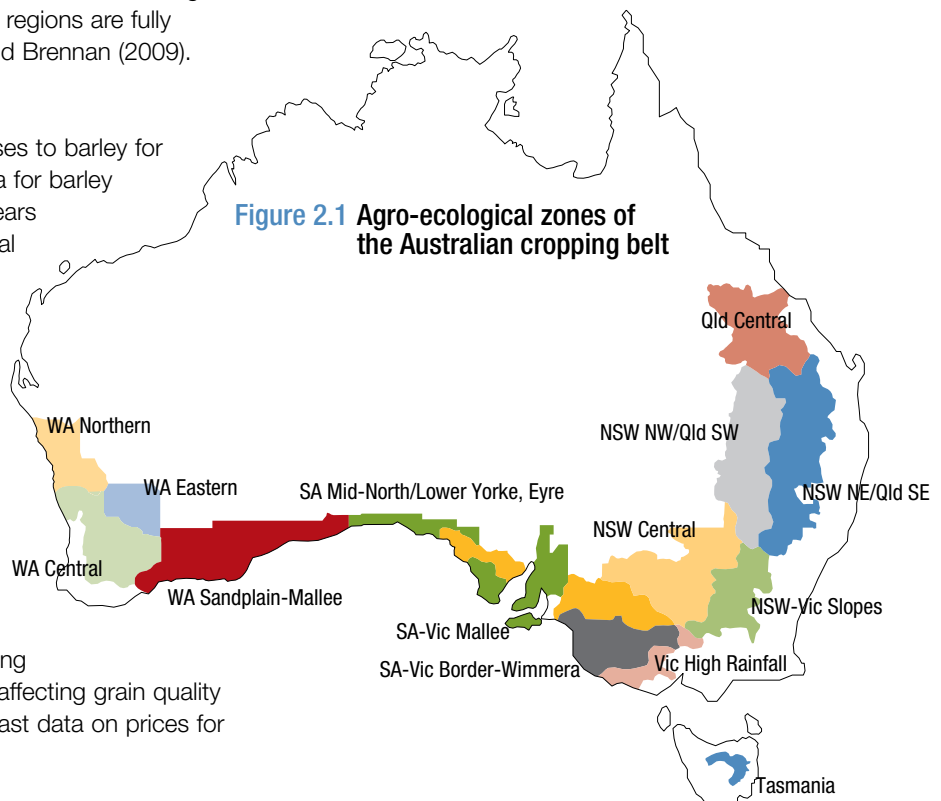


Figure 2.1 Agro-ecological zones of the Australian cropping belt

2.4 The diseases and their pathogens

Pathogens are the causes of disease. The extent of disease development depends on the host's response to the infection by the pathogen, how favourable are the seasonal conditions, overall climate and soil, and the management of the cropping system. This report deals with the losses caused by the diseases. Because the same disease may be called by different names, the name of the pathogen as well as the disease is given in Table 2.2.

The pathogens included in this study are those that have caused losses or have been of interest in one or more of the agro-ecological zones in Australia. It is not a complete

list of all barley pathogens recorded in Australia. Similarly, it does not include pathogens not yet recorded in Australia. Respondents to the survey recorded whether the pathogen was present in the zone and if present, provided the incidence and loss estimates (see below).

Naming of pathogens is subject to formal conventions and the name precisely defines the organism. The names in Table 2.2 are those generally accepted by taxonomists and plant pathologists in Australia. Names of diseases are not governed by such conventions: thus several common names may be in use in different locations. The names in Table 2.2 are those generally adopted by barley researchers in Australia (Wallwork 2000a, b). In some cases, for example the root lesion nematodes (*Pratylenchus* spp.), we have added an additional name for clarity.

Most of the pathogens are widely distributed throughout the barley growing zones of Australia. However, the frequency that they cause noticeable disease and the damage caused varies between zones and regions since pathogens can be and are frequently present in an area without causing significant disease. This report seeks to estimate these frequencies and losses under the current growing conditions.

The pathogens are grouped by the part of the plant affected by fungi, and then as nematodes, bacteria and viruses (Table 2.2).

Table 2.2 Barley diseases and their pathogens in Australia

PATHOGEN	DISEASE
NECROTROPHIC LEAF FUNGI	
<i>Cochliobolus sativus</i> <i>Drechslera wirreganensis</i> <i>Pseudoseptoria stomaticola</i> <i>Pyrenophora graminea</i> <i>Pyrenophora semeniperda</i> <i>Pyrenophora teres</i> f.sp. <i>maculata</i> <i>Pyrenophora teres</i> f.sp. <i>teres</i> <i>Rhynchosporium secalis</i> <i>Septoria passerinii</i>	Bipolaris spot blotch Wirrega blotch halo spot barley stripe ring spot net blotch-spot form net blotch-net form scald Septoria leaf blotch
BIOTROPHIC LEAF FUNGI	
<i>Blumeria graminis</i> f.sp. <i>tritici</i> <i>Puccinia graminis</i> f.sp. <i>tritici</i> <i>Puccinia triticina</i> <i>Puccinia striiformis</i> <i>Sclerophthora macrospora</i> <i>Urocystis agropyri</i> <i>Sclerophthora macrospora</i>	powdery mildew rye stem rust wheat stem rust stem rust leaf rust barley grass stripe rust downy mildew
ROOT AND CROWN FUNGI	
<i>Fusarium pseudograminearum</i> <i>Gaeumannomyces graminis</i> var. <i>tritici</i> <i>Pythium</i> spp. <i>Rhizoctonia solani</i> <i>Rhizoctonia</i> sp. <i>Tapesia yellundae</i> <i>Wojnowicia graminis</i> <i>Cochliobolus sativus</i>	crown rot take-all Pythium root rot Rhizoctonia barepatch Eradu patch eyespot basal rot common root rot
INFLORESCENCE FUNGI	
<i>Claviceps purpurea</i> <i>Fusarium graminearum</i> <i>Ustilago avenae</i> <i>Ustilago segetum</i> var. <i>hordei</i> <i>Ustilago tritici</i>	ergot Fusarium head blight (scab) semi-loose smut covered smut loose smut
NEMATODES	
<i>Heterodera avenae</i> <i>Merlinius brevidens</i> <i>Paratrichoidea</i> sp. <i>Pratylenchus neglectus</i> <i>Pratylenchus penetrans</i> <i>Pratylenchus teres</i> <i>Pratylenchus thornei</i> <i>Radopholus nativus</i> <i>Radopholus vangundyi</i>	cereal cyst nematode stunt nematode stubby root nematode root lesion nem. neglectus root lesion nem. penetrans root lesion nem. teres root lesion nem. thornei burrowing nem. nativus burrowing nem. vangundyi
BACTERIA	
<i>Xanthomonas campestris</i> pv. <i>translucens</i> <i>Pseudomonas syringae</i>	bacterial blight bacterial stripe blight
VIRUSES	
Barley yellow dwarf virus Wheat streak mosaic virus	barley yellow dwarf wheat streak mosaic

2.5 Potential and present disease losses

2.5.1 Incidence and severity of disease

Average loss in a zone is determined by the incidence and the severity of a disease. **Incidence** is the frequency with which environmental conditions enable the disease to reach its maximum severity in that zone. **Severity** is the level of damage caused when the environmental conditions are favourable for disease development. Often, only a proportion of the crop grown in a paddock will be affected in an outbreak.

Incidence as used in this report has two components: the frequency of years that favour development of the disease to damaging levels, and the proportion of the crop area affected in such a favourable year. The proportion of the crop area is defined on a per paddock basis. The proportion of the paddock affected is part of the severity assessment.

This survey assessed both potential severity, which is the severity reached in the absence of controls, and present severity, which is the severity that occurs with the current control methods of resistant varieties, cultural methods and pesticides. The difference between potential and present severity is a measure of the effectiveness of current controls.

Survey respondents were asked to provide information on both incidence and severity for each disease. In each case, they were able to provide either a qualitative score on a 0 to 5 scale, as used in Brennan and Murray (1998) for wheat diseases, or to estimate directly the incidence by years and area and the severity.

Thus, data from the respondents contained a mix of qualitative scores and quantitative assessments. The scores were transformed to values as in Tables 2.3 and 2.4.

Table 2.3 Incidence scores and associated frequency of losses

Score	Description	Incidence	
		Years (%)	Area (%)
0	Not recorded	0	0
1	Rare (about 1 year in 10, in scattered locations)	20	25
2	Localised, some seasons (2 years in 5 in 25% of area)	40	25
3	Localised, most seasons (2 years in 3 in 25% of area)	67	25
4	Widespread, some seasons (2 years in 5)	40	100
5	Widespread, most seasons (2 years in 3)	67	100

Table 2.4 Severity scores and associated percentage losses

Score	Classification	Percentage loss
0	No loss	0.0
1	Negligible	0.1
2	Light	0.5
3	Moderate	3.0
4	Severe	12.0
5	Very severe	25.0

2.5.2 Estimating average yield loss

This use of incidence and severity means that the following assessments could be made. For a foliar fungal disease such as scald, severe disease may develop in wet springs that occur in 30 per cent of years, affecting early sown crops that are 30 per cent of the crop area. Thus, incidence is 30 per cent frequency in 30 per cent of the area, so that the average incidence of the disease affecting the crop is 9 per cent. When severe, loss on a susceptible variety may be 30 per cent while current loss when most varieties grown are resistant is 5 per cent. Thus, potential severity is 30 per cent while current severity is 5 per cent. The average potential yield loss is (9 per cent incidence × 30 per cent severity) or 2.7 per cent, while average present yield loss is 0.45 per cent (9 per cent × 5 per cent).

On the other hand for a root disease such as take-all, severe disease may develop following wet winters, which

occur in 25 per cent of years, affecting early sown crops, once again occupying 30 per cent of the crop area. Average incidence is thus 25 per cent frequency in 30 per cent of the area (7.5 per cent). When severe, loss occurs in patches in the crop, with say 25 per cent of the paddock having patches where the loss is 80 per cent. In this case, severity in affected paddocks would be 20 per cent (25 per cent × 80 per cent). Thus, the average potential yield loss would be 1.5 per cent (7.5 per cent × 20 per cent).

2.5.3 Effects of quality loss

Some pathogens will reduce grain quality as well as reducing yield. In cases such as covered smut and ergot, a detectable level of disease can result in the grain being rejected from delivery or reduced from malting grade to feed, with a high monetary loss even though the yield loss from the pathogen is negligible. Most of the foliar diseases at higher severity will reduce grain filling and kernel mass, again reducing the quality of the grain. This loss in quality and value was estimated based on the standards adopted by the major grain traders (NACMA 2009 – now known as Grain Trade Australia). The likely effects of the detection of certain diseases in barley on grade are shown in Table 2.5.

Based on the prices received for each grade (Appendix A, Table A3), the severity will have an effect on the price received (Table 2.6).

2.6 Control methods

Three broad categories of controls are available:

- breeding (resistant cultivars);
- cultural practices including stubble management, tillage and crop rotations; and
- pesticides (fungicides applied as seed treatments, in-furrow and foliar sprays, and insecticides/miticides for vector control).

Survey respondents were asked to estimate the proportion of the current level of control obtained by each category, with the total being 100 per cent of the control achieved. This enabled a broad estimate to be made of the value of each form of control (see Section 7).

For the pesticides category, the survey sought information

Table 2.5 Relationship between severity and grade of barley

DISEASE	SEVERITY %					
	0.0%	>0.0%-0.2%	>0.2%-1.0%	>1.0%-5.0%	>5.0%-20.0%	>20.0%
Foliar diseases	Malt1	Malt1	Malt1	Malt2	Feed1	Feed2
Ergot	Malt1	Feed1	Farm	Farm	Farm	Farm
Fusarium head blight	Malt1	Feed1	Farm	Farm	Farm	Farm
Semi loose smut	Malt1	Malt1	Malt1	Feed1	Farm	Farm
Covered smut	Malt1	Malt1	Feed1	Farm	Farm	Farm
Loose smut	Malt1	Malt1	Malt1	Feed1	Farm	Farm

Farm: Not received in any grade, but usable as feed on farm. Valued at 25% below feed grade.
Malt1, Malt2: malting grade according to receival standards.
Feed1, Feed2: feed grade according to receival standards.

Table 2.6 Relationship between severity and price discount for barley

DISEASE	SEVERITY %					
	0.0%	>0.0%-0.2%	>0.2%-1.0%	>1.0%-5.0%	>5.0%-20.0%	>20.0%
Foliar diseases	0.00	0.00	0.00	5.00	20.00	30.00
Ergot	0.00	20.00	54.80	54.80	54.80	54.80
Fusarium head blight	0.00	20.00	54.80	54.80	54.80	54.80
Semi loose smut	0.00	0.00	0.00	20.00	54.80	54.80
Covered smut	0.00	0.00	20.00	54.80	54.80	54.80
Loose smut	0.00	0.00	0.00	20.00	54.80	54.80

on the proportion of the crop in each zone that receives fungicides applied as seed treatments, in-furrow and foliar sprays, and combinations of these treatments.

2.7 Survey

The data outlined above were collected from plant pathologists familiar with barley diseases in the agro-ecological zones. In all, 23 responses from 16 plant pathologists were received (Appendix B, Table B1). In most cases, individuals responded separately for the same zone. For Western Australia, a group of pathologists provided one consolidated assessment for their zones. The responses were collated, checked for consistency and returned to the survey respondents for final checking. The results were tabulated for all 14 agro-ecological zones and form the base data for calculating the costs of diseases. The collated data provided for each of the 14 agro-ecological zones are in Appendix B, Tables B2 to B15.

2.8 Calculating disease costs

In a production environment where a disease causes yield losses in the presence of current controls, there is an implied (higher) yield that would occur if that disease were fully controlled. From the observed current yield (with the disease) and the estimated yield reduction that has occurred, we can estimate the without-disease yield, and from that calculate the size and value of the losses occurring. The method used to estimate the size of the potential and current yield losses and the associated value of those losses is outlined in Murray and Brennan (2009).

Similarly, the method used for calculating the value of the quality losses from barley diseases is based on that outlined for wheat in Murray and Brennan (2009). Once the losses from yield and quality have been estimated on a per-hectare basis, they are converted to aggregate losses in each zone by relating the per-hectare losses to the number of hectares of barley in each zone. Both the potential and the present losses are average annual losses.

As in Murray and Brennan (2009), the value of the current control measures is the difference between the outcome if there were no controls and the outcome with current controls in place. The value of the controls across a production zone can be converted to a per-hectare basis by dividing by the number of hectares in the zone.

Implicit in these estimations is the assumption that there is no interaction between diseases. However, if all diseases developed uncontrolled, there would be significant interaction between them. The first to develop would be expected to have a greater effect on yield than subsequent diseases. Thus, the estimates of potential losses assume that for each disease, it is the only one that develops. Therefore, it is not appropriate to sum the total potential loss over all diseases.

For current losses, there would be far less interaction between diseases. In this case, we have assumed that it is possible to sum total current disease losses.

3. PRODUCTION IN BARLEY-GROWING AREAS OF AUSTRALIA

3.1 Introduction

Barley is grown throughout the annual winter cropping areas of Australia. Most of the crop is sown in autumn to early winter and harvested from mid spring to early summer, so that the delivery of the harvest mostly occurs from late in a calendar year to early in the next calendar year. Production data are collected on a seasonal basis, such that the crop sown in April-June 2006 and harvested in October 2006-January 2007 is identified as the 2006-07 season.

This report aims to provide estimates of the potential and current losses from barley diseases that are representative of present growing conditions. Base data necessary for this are the area, yield and value of the crop in each agro-ecological zone. These data from 1986–87 to 2007-08 were supplied by the GRDC.

Murray and Brennan (2009, Sections 3.2, 3.3) examine briefly the likelihood that climatic conditions are changing to bring about changes in the spectrum of wheat diseases. Those same trends are likely to be influencing the extent of barley diseases, though there is no earlier survey to which the current barley data can be compared. As a result, we can only use the current data to estimate a baseline of disease losses for barley given current conditions. No attempt is made to formally assess the likelihood of future changes from possible future climatic conditions.

We now consider the barley production data since 1998-99 and assess its suitability as 'baseline data' on which to estimate the value of disease losses.

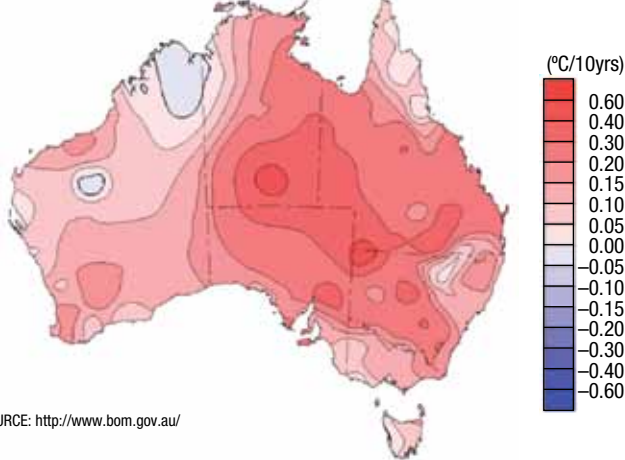
3.2 Temperature trends

Maximum and minimum temperatures for each season have increased throughout the Australian winter cropping area since 1970 (Australian Bureau of Meteorology 2009). Overall, the mean annual temperature has increased by 0.05 to 0.30°C per decade since 1970 (Figure 3.1).

Such temperature rises would be expected to affect the rates of development of many diseases and the activity of virus vectors, increasing the rate for some and decreasing it for others. For example, the average minimum winter temperature has increased in much of the cropping area (Figure 3.2).

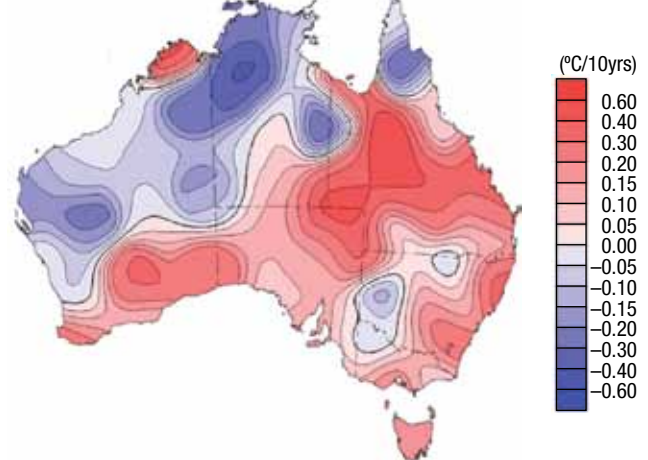
This may have increased the rate of development of some fungi and the activity of vectors, thereby affecting the development of the rusts and barley yellow dwarf virus.

Figure 3.1 Trend in annual mean temperature in Australia, 1970–2008



SOURCE: <http://www.bom.gov.au/>

Figure 3.2 Trend in winter minimum temperature in Australia, 1970–2008



3.3 Rainfall trends

There is evidence that rainfall had a relatively constant mean for the 50 years starting in the mid to late 1940s over much of Australia, and this underlying mean was higher than the previous 50 years. However, rainfall patterns may have altered in recent years. Since 1970, annual rainfall has decreased in the eastern and most south-western barley growing areas, with the largest reductions in Victoria and southern NSW (Figure 3.3). Conversely, there has been some increase in annual rainfall since 1970 in parts of the Western Australian barley area.

Changes in the distribution of rainfall could also be important for disease development. For example, there has been a reduction in autumn rainfall in much of the eastern cropping area (Figure 3.4). This is likely to affect the sowing date for crops, generally resulting in later sowing. This in turn would affect such diseases as scald, which decreases in severity with later sowing and requires good spring rainfall (Wallwork 2000a) and take-all, which requires high soil moisture in the surface layer through winter and early spring for development (Murray et al. 1991).

However, on average, rainfall over the decade 1998 to 2008 does not show any major abnormalities when

compared with rainfall since 1900 in any of the agro-ecological zones (see Section 3.5 below).

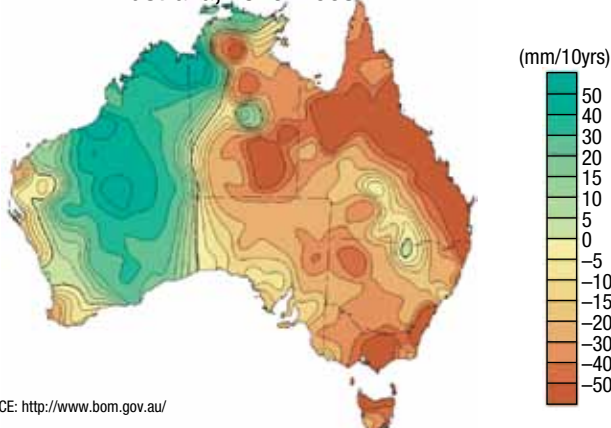
3.4 Barley production data

Barley area, yield and production vary considerably in each agro-ecological zone where the crop is grown. In this study, the aim is to assess disease losses for a representative set of production conditions, and not base those estimates on one individual year's data. To provide a representative set of data, the average of the 10 years to 2007-08 were selected from the available data, as in Murray and Brennan (2009). Using a 10-year period rather than a shorter period makes it less likely that extreme conditions in one or two years will skew the results away from a true representation of typical levels of production.

The area, yield and production of barley in each agro-ecological zone where the crop is grown are shown in Appendix A, Table A1 for each year in the period 1998-99 to 2007-08.

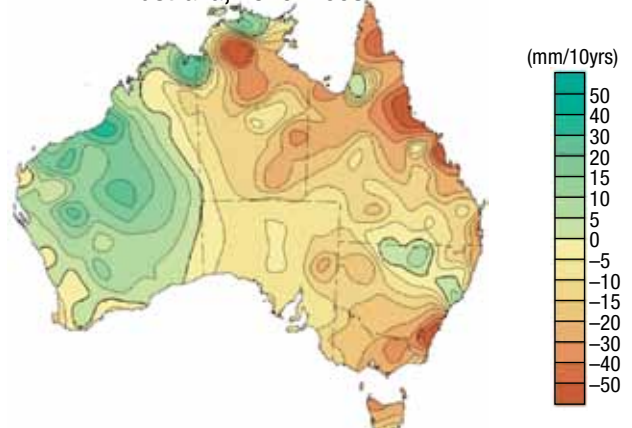
The average area, yield and production of barley in each zone are shown in Table 3.1, calculated from those annual data. In the period 1998-99 to 2007-08, the average barley area sown in Australia was 3.79 million hectares,

Figure 3.3 Trend in annual total rainfall in Australia, 1970–2008



SOURCE: <http://www.bom.gov.au/>

Figure 3.4 Trend in autumn total rainfall in Australia, 1970–2008



and average production was 6.55 million tonnes, giving an overall average yield of 1.73t/ha. The production was spread unevenly throughout the 14 zones, with production ranging from 6,000t in the Queensland Central zone to 1.29 million tonnes in the SA Mid-North/Lower Yorke, Eyre zone. On average, the Southern Region (4.00 million tonnes) produced more than the Western Region (1.82 million tonnes), while the Northern Region produced 0.73 million tonnes each year (Table 3.1). The mean unit value of barley over that period was \$196.73/t (see Appendix A, Table A2 for annual data), giving an average gross value of production of \$1289 million.

there is evidence that there has been a decrease in rainfall since 1970 (Murray and Brennan 2009, Section 3.3).

3.5 Representativeness of selected period based on rainfall deciles

To assess how representative the period 1998-99 to 2007-08 is of conditions over the longer term, Murray and Brennan (2009) examined the annual rainfall for the period 1998 to 2007 expressed as a decile range based on long-term data (1900 to 2008). That analysis showed that the mean annual rainfall for each of the agro-ecological zones for the period 1998 to 2007 lies in deciles 5 or 6 in each zone except for southern and western Victoria and eastern South Australia, where it was below average in decile 4, and in the WA Sandplain-Mallee and WA Eastern where it was above average in decile 7. The mean annual rainfall decile (weighted by area sown) for each of the three regions lies in decile 5, indicating that average annual rainfall in that period was at or near the long-term average at the region level.

Thus, average annual rainfall in the selected period is representative of the long term 1900 to 2008, even though

Table 3.1 Mean barley area, yield, production and value, by agro-ecological zone and GRDC Region, 1998-99 to 2007-08

	Area ('000 ha)	Yield (t/ha)	Production ('000 t)	Gross value (\$ million)
Queensland Central	4	1.58	6	1
NSW North-East/Queensland South-East	305	1.90	579	114
NSW North-West/Queensland South-West	107	1.34	143	28
TOTAL NORTHERN REGION	416	1.75	728	143
NSW Central	251	1.48	370	73
NSW-Victoria Slopes	256	1.62	415	82
Victoria High Rainfall	41	2.45	100	20
Tasmania	5	2.92	16	3
SA-Victoria Border-Wimmera	474	1.77	840	165
SA-Victoria Mallee	728	1.33	970	191
SA Mid-North/Lower Yorke, Eyre	610	2.12	1291	254
TOTAL SOUTHERN REGION	2365	1.69	4002	787
WA Sandplain-Mallee	273	1.93	528	104
WA Central	569	1.85	1051	207
WA Northern	83	1.59	131	26
WA Eastern	84	1.32	112	22
TOTAL WESTERN REGION	1009	1.81	1822	358
TOTAL AUSTRALIA	3790	1.73	6551	1289

4. INCIDENCE AND SEVERITY OF BARLEY DISEASES IN AUSTRALIA

4.1 Distribution of the pathogens

This survey studied the distribution of 42 diseases of barley, 29 caused by fungi, nine by nematodes, two by bacteria and two by viruses, in the 14 agro-ecological zones where barley is grown in Australia.

Some of the pathogens were widely distributed, with 11 being reported present in all zones and a further nine present in more than 10 zones. Others had a much more restricted reporting, 10 being reported present in four or fewer zones (Appendix C, Table C1). Within the GRDC regions, the Southern Region had 35 pathogens reported, while there were 31 and 29 present in the Western and Northern Regions, respectively (Table 4.1)

Across zones, the widely reported diseases included the readily observable and identifiable foliar diseases stem and leaf rust, powdery mildew, the spot and net forms of net blotch, and scald. Even though ring spot causes no yield loss (Table 4.3), it causes a distinctive leaf spot and has been recorded in all zones except those of the Northern Region (Appendix C, Table C1).

Widely distributed root diseases included crown rot, take-all and *Pythium* root rot. The first two cause distinctive symptoms and the pathogens are readily isolated. The last is caused by several *Pythium* spp. and it is likely that different species cause the disease in different locations. *Rhizoctonia* barepatch and common root rot have a slightly restricted distribution. Eyespot and basal rot seem to be restricted to some areas of southern Australia and Era du patch is restricted to two zones in the Western Region (Appendix C, Table C1).

The seed-replacing diseases covered smut and loose smut were reported from all zones while semi-loose smut had a more restricted distribution (this may reflect difficulties in distinguishing this disease from the other smuts). Ergot (mainly from grass weeds in the crop) and *Fusarium* head blight have been recorded in most zones (Appendix C, Table C1).

Cereal cyst nematode occurs in all except the northern zones, the root lesion nematode *Pratylenchus thornei* in all zones and *P. neglectus* in all except the Queensland Central zone. Projects specifically targeting root attacking nematodes are finding additional root lesion nematodes in Western Australia and burrowing nematodes in Queensland (Appendix C, Table C1) and defining the yield losses associated with them (Holloway *et al.* 2008, Vanstone *et al.* 2008).

Although two bacterial diseases have been recorded, they are seldom important and the identification of the bacteria is not often done with precision.

The virus disease barley yellow dwarf was first recorded over 50 years ago and is reported from all zones. Wheat

streak mosaic virus was not identified as present in Australia until 2003 and is now known to occur in all zones except Queensland Central where its status is unknown (Appendix C, Table C1).

4.2 Incidence of barley diseases

Incidence was assessed by one of two measures. The respondent could assess it as a single value score, or as a proportion of years that favoured development of the disease and the proportion of the area affected when the disease developed (see Section 2.5). If the score value was given, this was converted to a value for proportion of years and to a value for proportion of the area. The incidence values of years and area were multiplied together to provide a frequency for the annual average proportion of the crop affected (see Section 2.5).

The incidence of barley diseases by years and by crop area affected in years of occurrence is summarised in Table 4.2. These are the average values for each region and for Australia weighted by the barley area in each zone within the region. Individual zone data are in Appendix C, Tables C2 and C3.

Across Australia, there were 22 diseases that occurred with a yearly incidence of 25 per cent or greater, while 11 diseases occurred over 25 per cent or more of the crop area in years favourable for their development. The root lesion nematode *Pratylenchus neglectus* occurred with highest yearly incidence (82.4 per cent), with spot and net forms of net blotch, crown rot, *Rhizoctonia* barepatch, *Pratylenchus thornei* and barley yellow dwarf also over 70 per cent of years. *P. neglectus* affected the greatest area of crop (84.5 per cent) (Table 4.2).

Within Regions, crown rot occurred with highest frequency of years (91.0 per cent) in the Northern Region, *P. neglectus* and *P. thornei* (89.3 per cent) in the Southern Region, and *Rhizoctonia* barepatch, *P. neglectus* and *P. teres* in the Western Region. Common root rot affected the largest proportion of the area (59.5 per cent) in the Northern Region, *P. neglectus* (89.3 per cent) in the Southern Region, and powdery mildew and *P. neglectus* (100 per cent) in the Western Region (Table 4.2).

4.3 Severity of barley diseases in agro-ecological zones

Severity was assessed as the percentage yield loss that occurred in affected crops in the zone in years favourable for development of the disease (see Section 2.5). Two assessments were made. The first was the potential severity, that is, the severity that would occur if current controls were not applied. The second was the present severity, when current controls are in place. These severity assessments for

Table 4.1 Presence^a of pathogens causing barley disease in the GRDC Regions and Australia

Disease ^b	Northern	Southern	Western	Australia
NECROTROPHIC LEAF FUNGI				
Bipolaris spot blotch	Y	Y	Y	Y
Wirrega blotch	N	Y	Y	Y
halo spot	N	Y	Y	Y
barley stripe	Y	Y	Y	Y
ring spot	N	Y	Y	Y
net blotch-spot form	Y	Y	Y	Y
net blotch-net form	Y	Y	Y	Y
scald	Y	Y	Y	Y
Septoria leaf blotch	N	Y	U	Y
BIOTROPHIC LEAF FUNGI				
powdery mildew	Y	Y	Y	Y
rye stem rust	Y	Y	U	Y
wheat stem rust	Y	Y	Y	Y
stem rust	Y	Y	Y	Y
leaf rust	Y	Y	Y	Y
barley grass stripe rust	Y	Y	N	Y
downy mildew	Y	Y	N	Y
ROOT AND CROWN FUNGI				
crown rot	Y	Y	Y	Y
take-all	Y	Y	Y	Y
Pythium root rot	Y	Y	Y	Y
Rhizoctonia barepatch	N	Y	Y	Y
Eradu patch	U	U	Y	Y
eyespot	N	Y	N	Y
basal rot	N	Y	N	Y
common root rot	Y	Y	Y	Y
INFLORESCENCE FUNGI				
ergot	Y	Y	Y	Y
Fusarium head blight	Y	Y	Y	Y
semi-loose smut	Y	Y	N	Y
covered smut	Y	Y	Y	Y
loose smut	Y	Y	Y	Y
NEMATODES				
cereal cyst nematode	N	Y	Y	Y
stunt nematode	Y	U	U	Y
stubby root nematode	Y	U	U	Y
root lesion nem. neglectus	Y	Y	Y	Y
root lesion nem. penetrans	U	U	Y	Y
root lesion nem. teres	U	U	Y	Y
root lesion nem. thornei	Y	Y	Y	Y
burrowing nem. nativus	U	U	Y	Y
burrowing nem. vangundyi	U	U	Y	Y
BACTERIA				
bacterial blight	Y	Y	N	Y
bacterial stripe blight	Y	Y	N	Y
VIRUSES				
barley yellow dwarf	Y	Y	Y	Y
wheat streak mosaic	Y	Y	Y	Y

^a Y = present in zone; N = not recorded in zone; U = unknown status
^b see Table 2.2 for the pathogens that cause each disease

each agro-ecological zone are in Appendix C, Tables C4 and C5. The area weighted average severities for each region and for Australia are in Table 4.3.

For Australia, the disease with maximum potential severity in the years favourable for its development was the net form of net blotch, with a potential yield loss of 25.9 per cent, followed by scald with 22.9 per cent and leaf rust with 16.4 per cent. In contrast, with current disease controls in place, the disease with the highest present severity was crown rot, causing an average 3.3 per cent yield loss in years favourable for its development. This was followed by Rhizoctonia barepatch with 3.0 per cent and powdery mildew with 2.9 per cent (Table 4.3).

In the regions, the net form of net blotch had the highest potential yield loss in the Northern (36.5 per cent) and Southern (30.4 per cent), and powdery mildew in the Western (19.3 per cent). For current severity, the highest in the Northern Region was Bipolaris leaf spot (10.4 per cent), in the Southern, Rhizoctonia barepatch (3.7 per cent), and in the Western, powdery mildew (7.3 per cent) (Table 4.3).

Table 4.2 Incidence of barley diseases as a proportion of years when disease occurs (%) and as a proportion of the crop area affected when the disease develops (%) in the GRDC Regions and Australia

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Years	Area	Years	Area	Years	Area	Years	Area
NECROTROPHIC LEAF FUNGI								
Bipolaris spot blotch	31.8	11.3	1.9	2.9	0.0	0.0	4.7	3.1
Wirrega blotch	0.0	0.0	63.0	6.7	7.0	8.8	41.2	6.5
halo spot	0.0	0.0	15.7	16.6	5.4	6.8	11.3	12.2
barley stripe	9.9	1.0	15.0	19.3	13.0	16.2	13.9	16.4
ring spot	0.0	0.0	63.0	22.0	20.0	25.0	44.7	20.4
net blotch-spot form	86.1	39.9	87.7	81.1	64.5	83.6	81.3	77.2
net blotch-net form	53.5	45.2	87.7	22.2	60.8	89.9	76.8	42.7
scald	30.9	8.7	56.0	17.4	58.6	25.0	54.0	18.4
Septoria leaf blotch	0.0	0.0	4.3	5.4	0.0	0.0	2.7	3.3
BIOTROPHIC LEAF FUNGI								
powdery mildew	69.3	52.9	72.6	27.8	58.6	100.0	68.5	49.8
rye stem rust	19.8	24.8	41.4	19.7	0.0	0.0	28.0	15.0
wheat stem rust	18.1	21.9	41.4	19.7	20.0	25.0	33.2	21.3
stem rust	35.1	21.7	41.4	19.7	20.0	25.0	35.0	21.3
leaf rust	26.5	18.2	82.3	42.7	41.9	45.3	65.4	40.7
barley grass stripe rust	24.7	24.8	40.8	18.6	0.0	0.0	28.2	14.3
downy mildew	20.0	25.0	2.1	0.0	0.0	0.0	3.5	2.7
ROOT AND CROWN FUNGI								
crown rot	91.0	55.1	87.2	65.1	60.6	25.0	80.5	53.3
take-all	19.8	24.8	82.3	21.8	57.0	25.0	68.7	23.0
Pythium root rot	20.2	24.9	53.8	52.7	57.0	25.0	50.9	42.3
Rhizoctonia barepatch	0.0	0.0	86.3	42.2	66.7	87.6	71.6	49.6
Eradu patch	0.0	0.0	0.0	0.0	43.0	16.1	11.5	4.3
eyespot	0.0	0.0	1.1	1.1	0.0	0.0	0.7	0.7
basal rot	0.0	0.0	1.1	1.1	0.0	0.0	0.7	0.7
common root rot	82.6	59.5	88.6	69.5	1.6	2.0	64.8	50.5
INFLORESCENCE FUNGI								
ergot	19.8	24.8	7.9	4.2	2.7	3.4	7.8	6.2
Fusarium head blight	15.3	8.6	0.0	0.0	5.4	6.8	3.1	2.7
semi-loose smut	20.0	25.0	4.3	19.3	0.0	0.0	4.9	14.8
covered smut	41.3	21.9	16.5	17.5	20.0	25.0	20.2	20.0
loose smut	40.0	25.0	55.7	17.5	58.6	25.0	54.7	20.3
NEMATODES								
cereal cyst nematode	0.0	0.0	83.9	76.9	52.8	25.0	66.4	54.6
stunt nematode	63.5	16.7	0.0	0.0	0.0	0.0	7.0	1.8
stubby root nematode	5.1	6.4	0.0	0.0	0.0	0.0	0.6	0.7
root lesion nem. neglectus	81.5	19.9	89.3	89.3	66.7	100.0	82.4	84.5
root lesion nem. penetrans	0.0	0.0	0.0	0.0	20.0	25.0	5.3	6.7
root lesion nem. teres	0.0	0.0	0.0	0.0	66.7	25.0	17.7	6.7
root lesion nem. thornei	82.3	28.9	89.3	25.4	20.0	25.0	70.1	25.7
burrowing nem. nativus	0.0	0.0	0.0	0.0	34.6	25.0	9.2	6.7
burrowing nem. vangundyi	0.0	0.0	0.0	0.0	3.3	2.0	0.9	0.5
BACTERIA								
bacterial blight	20.0	25.0	0.5	0.5	0.0	0.0	2.5	3.1
bacterial stripe blight	39.8	25.0	1.1	1.1	0.0	0.0	5.0	3.4
VIRUSES								
barley yellow dwarf	48.8	25.0	84.8	8.6	51.7	35.1	72.1	17.4
wheat streak mosaic	24.7	24.8	57.3	16.4	38.4	25.0	48.7	19.6

Table 4.3 Potential and present severity of barley diseases (% yield loss in years suitable for disease development) in GRDC Regions and Australia

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Potential	Present	Potential	Present	Potential	Present	Potential	Present
NECROTROPHIC LEAF FUNGI								
Bipolaris spot blotch	31.5	10.4	0.0	0.0	0.0	0.0	3.5	1.1
Wirrega blotch	0.0	0.0	3.2	0.0	0.0	0.0	2.0	0.0
halo spot	0.0	0.0	1.6	0.0	0.0	0.0	1.0	0.0
barley stripe	4.4	0.2	8.6	0.0	0.0	0.0	5.8	0.0
ring spot	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0
net blotch-spot form	23.1	7.2	13.4	1.6	11.8	3.7	14.1	2.8
net blotch-net form	36.5	5.5	30.4	0.5	10.8	2.7	25.9	1.6
scald	25.3	1.5	30.2	1.6	5.0	0.5	22.9	1.3
Septoria leaf blotch	0.0	0.0	2.1	0.0	0.0	0.0	1.3	0.0
BIOTROPHIC LEAF FUNGI								
powdery mildew	7.2	3.4	11.9	1.0	19.3	7.3	13.4	2.9
rye stem rust	0.1	0.1	11.4	2.1	0.0	0.0	7.1	1.3
wheat stem rust	14.2	0.1	15.4	2.1	0.0	0.0	11.1	1.3
stem rust	6.4	0.1	11.4	2.1	0.0	0.0	7.8	1.3
leaf rust	20.8	0.9	17.0	2.4	13.0	3.8	16.4	2.6
barley grass stripe rust	0.8	0.1	7.2	0.0	0.0	0.0	4.6	0.0
downy mildew	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
ROOT AND CROWN FUNGI								
crown rot	34.3	9.5	10.8	2.5	13.8	2.6	14.2	3.3
take-all	0.1	0.1	6.7	1.6	13.0	1.6	7.7	1.4
Pythium root rot	0.9	0.9	3.3	1.8	2.7	0.7	2.9	1.4
Rhizoctonia barepatch	0.0	0.0	9.6	3.7	14.0	2.6	9.7	3.0
Eradu patch	0.0	0.0	0.0	0.0	7.7	1.9	2.1	0.5
eyespot	0.0	0.0	1.1	0.0	0.0	0.0	0.7	0.0
basal rot	0.0	0.0	0.6	0.0	0.0	0.0	0.4	0.0
common root rot	11.0	3.9	6.6	2.4	0.0	0.0	5.3	1.9
INFLORESCENCE FUNGI								
ergot	0.1	0.1	6.1	0.0	0.0	0.0	3.8	0.0
Fusarium head blight	2.4	0.8	0.0	0.0	0.0	0.0	0.3	0.1
semi-loose smut	0.1	0.1	4.3	0.0	0.0	0.0	2.7	0.0
covered smut	3.3	1.2	16.4	0.0	0.0	0.0	10.6	0.1
loose smut	2.5	0.4	8.1	0.0	2.1	0.1	5.9	0.1
NEMATODES								
cereal cyst nematode	0.0	0.0	20.0	3.3	8.8	0.5	14.8	2.2
stunt nematode	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0
stubby root nematode	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
root lesion nem. neglectus	9.2	2.8	6.5	1.7	12.0	3.0	8.3	2.2
root lesion nem. penetrans	0.0	0.0	0.0	0.0	9.6	2.7	2.5	0.7
root lesion nem. teres	0.0	0.0	0.0	0.0	12.0	3.0	3.2	0.8
root lesion nem. thornei	11.0	3.5	10.3	1.6	12.0	3.0	10.9	2.2
burrowing nem. nativus	0.0	0.0	0.0	0.0	12.0	3.0	3.2	0.8
burrowing nem. vangundyi	0.0	0.0	0.0	0.0	1.0	0.2	0.3	0.1
BACTERIA								
bacterial blight	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
bacterial stripe blight	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
VIRUSES								
barley yellow dwarf	1.1	1.1	3.9	1.1	11.1	0.5	5.5	0.9
wheat streak mosaic	0.2	0.2	1.2	0.0	0.1	0.1	0.8	0.1

5. LOSSES FROM BARLEY DISEASES IN AUSTRALIA

5.1 Potential and present percentage yield losses

The average annual yield loss was calculated from the incidence and severity data described in Section 4 (see Section 2.8 for the method). The potential severity was used to calculate the potential losses if current controls were not used and the current severity to calculate present losses with current control measures.

Nationally, the highest average annual potential yield loss of 12.1 per cent was from cereal cyst nematode. Within GRDC regions, cereal cyst nematode had the highest average potential loss in the Southern Region (18.9 per cent) but was much lower in the other regions. Within the Southern Region, cereal cyst nematode had high potential in the western Victorian and South Australian zones but was low in the remainder of the region. Crown rot had the highest potential in the Northern Region (15.8 per cent) and powdery mildew in the Western Region (11.9 per cent) (Table 5.1, see p. 20).

Other diseases that potentially can cause losses of more than 5 per cent in one or more regions are the fungal leaf diseases spot and net forms of net blotch, barley stripe and leaf rust, the root and crown fungal disease *Rhizoctonia*

barepatch, and the root lesion nematode *Pratylenchus neglectus* (Table 5.1, see p. 20).

Within individual agro-ecological zones, some other diseases can cause potential losses of more than 5 per cent. Scald reaches 27.0 per cent in the Victoria High Rainfall zone and possibly in Tasmania, while common root rot exceeds 5 per cent potential loss in the Queensland Central and NSW North-East/Queensland South-East zones, covered smut in the NSW Central and NSW-Victoria Slopes, and barley yellow dwarf in the Victoria High Rainfall and Tasmanian zones (Appendix C, Table C6).

Nationally, the highest average annual present yield loss was 2.0 per cent, again caused by cereal cyst nematode. Within the regions, crown rot caused greatest current loss of 4.4 per cent in the Northern Region, cereal cyst nematode was highest in the Southern Region at 3.1 per cent and powdery mildew was highest at 4.8 per cent in the Western Region (Table 5.1, see p. 20). Present yield loss in the agro-ecological zones is in Appendix C, Table C7.

The present average annual yield loss from all diseases was 13.5 per cent, with foliar diseases contributing 5.1 per cent, root and crown fungal diseases 4.2 per cent, and nematodes 4.1 per cent.

Table 5.2 Potential and present quality costs of barley diseases by GRDC Region and Australia (\$/ha)

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Potential	Present	Potential	Present	Potential	Present	Potential	Present
Bipolaris spot blotch	1.52	1.01	0.00	0.00	0.00	0.00	0.17	0.11
Wirrega blotch	0.00	0.00	0.60	0.00	0.00	0.00	0.37	0.00
halo spot	0.00	0.00	0.41	0.00	0.00	0.00	0.26	0.00
barley stripe	0.01	0.00	6.27	0.00	0.00	0.00	3.92	0.00
ring spot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
net blotch-spot form	16.62	11.08	24.87	3.87	19.38	8.09	22.50	5.78
net blotch-net form	14.70	9.18	6.29	0.55	19.47	4.87	10.72	2.64
scald	1.78	0.28	5.25	1.10	2.58	0.35	4.16	0.81
Septoria leaf blotch	0.00	0.00	0.34	0.00	0.00	0.00	0.21	0.00
powdery mildew	12.21	3.07	4.53	0.63	28.34	15.29	11.72	4.80
rye stem rust	0.00	0.00	0.91	0.60	0.00	0.00	0.57	0.37
wheat stem rust	1.65	0.00	0.96	0.60	0.00	0.00	0.78	0.37
stem rust	1.04	0.00	0.91	0.60	0.00	0.00	0.68	0.37
leaf rust	2.78	0.09	11.00	2.12	7.95	6.10	9.28	2.96
barley grass stripe rust	0.46	0.00	4.14	0.00	0.00	0.00	2.64	0.00
ergot	1.74	1.74	0.36	0.00	0.00	0.00	0.41	0.19
Fusarium head blight	1.50	1.50	0.00	0.00	0.00	0.00	0.16	0.16
semi-loose smut	0.00	0.00	3.27	0.00	0.00	0.00	2.04	0.00
covered smut	8.70	8.02	7.30	0.00	0.00	0.00	5.51	0.88
loose smut	3.50	0.00	0.22	0.00	3.82	0.00	1.54	0.00
Total		35.96		10.06		34.69		19.46

Table 5.1 Potential and present average annual yield losses (%) from barley diseases by GRDC Region and Australia

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Potential	Present	Potential	Present	Potential	Present	Potential	Present
NECROTROPHIC LEAF FUNGI								
Bipolaris spot blotch	0.9	0.3	0.0	0.0	0.0	0.0	0.1	0.0
Wirrega blotch	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.0
halo spot	0.0	0.0	0.3	0.0	0.0	0.0	0.2	0.0
barley stripe	0.0	0.0	5.4	0.0	0.0	0.0	3.4	0.0
ring spot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
net blotch-spot form	7.2	2.3	9.1	1.4	6.5	1.9	8.2	1.6
net blotch-net form	9.9	1.5	4.5	0.1	6.1	1.5	5.6	0.6
scald	0.8	0.1	3.2	0.3	0.7	0.1	2.3	0.2
Septoria leaf blotch	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
SUB TOTAL		4.1		1.8		3.5		2.5
BIOTROPIC LEAF FUNGI								
powdery mildew	2.5	1.2	1.5	0.2	11.9	4.8	4.4	1.5
rye stem rust	0.0	0.0	0.7	0.2	0.0	0.0	0.4	0.1
wheat stem rust	0.6	0.0	0.7	0.2	0.0	0.0	0.5	0.1
stem rust	0.4	0.0	0.7	0.2	0.0	0.0	0.5	0.1
leaf rust	1.1	0.0	5.2	0.6	3.5	1.3	4.3	0.7
barley grass stripe rust	0.1	0.0	2.7	0.0	0.0	0.0	1.7	0.0
downy mildew	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUB TOTAL		1.2		1.3		6.1		2.6
ROOT AND CROWN FUNGI								
crown rot	15.8	4.4	5.9	1.3	2.3	0.4	6.0	1.4
take-all	0.0	0.0	0.7	0.2	1.9	0.2	0.9	0.2
Pythium root rot	0.0	0.0	0.9	0.0	0.4	0.1	0.7	0.0
Rhizoctonia barepatch	0.0	0.0	3.8	1.6	9.1	1.7	4.8	1.5
Eradu patch	0.0	0.0	0.0	0.0	1.3	0.3	0.3	0.1
eyespot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
basal rot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
common root rot	4.7	1.7	3.7	1.4	0.0	0.0	2.9	1.0
SUB TOTAL		6.1		4.5		2.7		4.2
INFLORESCENCE FUNGI								
ergot	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
Fusarium head blight	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
semi-loose smut	0.0	0.0	0.8	0.0	0.0	0.0	0.5	0.0
covered smut	0.3	0.1	3.4	0.0	0.0	0.0	2.2	0.0
loose smut	0.3	0.0	0.1	0.0	0.3	0.0	0.2	0.0
SUB TOTAL		0.2		0.0		0.0		0.0
NEMATODES								
cereal cyst nematode	0.0	0.0	18.9	3.1	1.4	0.1	12.1	2.0
stunt nematode	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
stubby root nematode	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
root lesion nem. neglectus	1.5	0.5	6.2	1.6	8.0	2.0	6.2	1.6
root lesion nem. penetrans	0.0	0.0	0.0	0.0	0.5	0.1	0.1	0.0
root lesion nem. teres	0.0	0.0	0.0	0.0	2.0	0.5	0.5	0.1
root lesion nem. thornei	2.7	0.9	2.0	0.3	0.6	0.2	1.7	0.3
burrowing nem. nativus	0.0	0.0	0.0	0.0	1.0	0.3	0.3	0.1
burrowing nem. vangundyi	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
SUB TOTAL		1.3		5.1		3.1		4.1
BACTERIA								
bacterial blight	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
bacterial stripe blight	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SUB TOTAL		0.0		0.0		0.0		0.0
VIRUSES								
barley yellow dwarf	0.1	0.1	0.3	0.1	2.1	0.1	0.8	0.1
wheat streak mosaic	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
SUB-TOTAL		0.1		0.1		0.1		0.1
TOTAL		13.1		12.8		15.6		13.5

The large differences between the potential losses and present losses for potentially severe diseases clearly demonstrate the degree of disease control used by the industry.

5.2 Quality effects of diseases

Several diseases affect the quality of barley grain and may reduce its market value. The relationships between severity and grade of barley (Tables 2.5 and 2.6) and thus the price discount that may be incurred were used to calculate the value of the quality effect (see Section 2.8). These diseases can lead to considerable economic losses. For Australia, the average annual potential cost due to quality loss from the spot form of net blotch was \$22.50/ha; even with current controls, the loss is \$5.78/ha through downgrading from malting to lower grades (Table 5.2). Several other foliar diseases can cause yield and quality loss while the smuts reduce quality with little yield loss.

These quality losses are added to the yield loss to calculate the total economic loss.

Present quality losses are highest in the Northern Region at \$35.96/ha followed by the Western Region at \$34.69, where the spot form of net blotch makes the largest contribution of \$11.08/ha and \$8.09/ha, respectively. Quality losses are least in the Southern Region at \$10.06/ha (Table 5.2).

5.3 Value of potential and present losses

The value of these yield and market losses was calculated by relating the yield losses and the quality losses to the gross value of barley production in each zone, using the average value of barley over a 10-year period (see Section 3.4). These losses were calculated on a per hectare basis and on an aggregate basis for each zone, then for each GRDC region and nationally.

5.3.1 Value of potential losses

Details of the potential losses for all diseases surveyed for each Region and nationally are in Table 5.3 (\$ per hectare) and Table 5.4 (aggregate losses for the region).

At the national level, the five major diseases by potential loss on a per hectare basis and total cost to the industry are:

Australia		
Disease	\$/ha	\$ million
net blotch-spot form	50.60	192
cereal cyst nematode	40.39	153
net blotch-net form	30.76	117
powdery mildew	27.25	103
leaf rust	25.31	96

The total potential losses were not summed because there would be significant interaction between diseases if all developed (see Section 2.8).

For each region, the five major diseases by potential loss are:

Northern Region		
Disease	\$/ha	\$ million
crown rot	54.58	23
net blotch-net form	50.42	21
net blotch-spot form	42.40	18
powdery mildew	21.11	9
common root rot	16.49	7

The potential losses per hectare in the Northern Region for the top five diseases are broadly similar to the losses of the top five nationally. Cereal cyst nematode is of negligible importance in the Northern Region while crown rot and common root rot enter the top five.

Southern Region		
Disease	\$/ha	\$ million
cereal cyst nematode	62.64	148
net blotch-spot form	55.23	131
leaf rust	30.49	72
net blotch-net form	22.87	54
barley stripe	22.73	54

In general, the potential losses per hectare in the Southern Region are slightly higher than those nationally. Powdery mildew is much less important in this region and barley stripe enters the top five.

Western Region		
Disease	\$/ha	\$ million
powdery mildew	71.36	72
net blotch-spot form	43.12	43
net blotch-net form	41.15	42
Rhizoctonia barepatch	33.78	34
<i>Pratylenchus neglectus</i>	28.42	29

The potential losses per hectare in the Western Region of the top five diseases are the highest of the three regions. Rhizoctonia barepatch and the root lesion nematode *Pratylenchus neglectus* enter the top five.

Summarising the potential losses over regions loses some information. Some diseases are only important in one or two agro-ecological zones within a region, where they may be a major limit to local production. The regional average may not reflect this local importance or may in other cases suggest an importance in a zone when there is none in that zone. Potential losses (%) for each disease in each of the 14 agro-ecological zones are in Appendix B, Tables B2 to B15.

Table 5.3 Potential and present average annual costs (\$/ha) from barley diseases by GRDC Region and Australia

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Potential	Present	Potential	Present	Potential	Present	Potential	Present
NECROTROPHIC LEAF FUNGI								
Bipolaris spot blotch	4.74	2.10	0.00	0.00	0.00	0.00	0.52	0.23
Wirrega blotch	0.00	0.00	1.35	0.00	0.00	0.00	0.84	0.00
halo spot	0.00	0.00	1.23	0.00	0.00	0.00	0.77	0.00
barley stripe	0.02	0.00	22.73	0.00	0.00	0.00	14.19	0.00
ring spot	0.00	0.00	0.04	0.00	0.02	0.02	0.03	0.00
net blotch-spot form	42.40	19.25	55.23	8.44	43.12	15.19	50.60	11.42
net blotch-net form	50.42	14.58	22.87	1.01	41.15	10.25	30.76	4.96
scald	4.62	0.47	17.75	2.20	5.00	0.61	12.91	1.59
Septoria leaf blotch	0.00	0.00	0.68	0.00	0.00	0.00	0.42	0.00
SUB TOTAL		36.40		11.65		26.07		18.20
BIOTROPHIC LEAF FUNGI								
powdery mildew	21.11	7.13	9.51	1.25	71.36	32.74	27.25	10.28
rye stem rust	0.02	0.02	3.02	1.19	0.00	0.00	1.89	0.74
wheat stem rust	3.65	0.02	3.11	1.19	0.00	0.00	2.34	0.74
stem rust	2.42	0.03	3.02	1.19	0.00	0.00	2.15	0.74
leaf rust	6.60	0.24	30.49	4.22	20.90	10.85	25.31	5.55
barley grass stripe rust	0.66	0.02	12.74	0.00	0.00	0.00	8.02	0.01
downy mildew	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
SUB TOTAL		7.47		9.04		43.59		18.06
ROOT AND CROWN FUNGI								
crown rot	54.58	14.98	19.96	4.21	8.45	1.55	20.69	4.68
take-all	0.02	0.02	2.44	0.67	6.98	0.69	3.38	0.61
Pythium root rot	0.15	0.15	3.18	0.11	1.37	0.26	2.37	0.15
Rhizoctonia barepatch	0.00	0.00	12.68	5.10	33.78	6.20	16.90	4.83
Eradu patch	0.00	0.00	0.00	0.00	4.61	1.15	1.23	0.31
eyespot	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00
basal rot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
common root rot	16.49	5.80	12.60	4.55	0.00	0.00	9.67	3.47
SUB TOTAL		20.94		14.64		9.85		14.05
INFLORESCENCE FUNGI								
ergot	1.75	1.75	0.61	0.00	0.00	0.00	0.57	0.19
Fusarium head blight	1.62	1.54	0.00	0.00	0.00	0.00	0.18	0.17
semi-loose smut	0.02	0.02	5.63	0.01	0.00	0.00	3.51	0.01
covered smut	9.67	8.41	17.76	0.03	0.00	0.00	12.14	0.94
loose smut	4.36	0.14	0.56	0.01	4.87	0.05	2.13	0.04
SUB TOTAL		11.86		0.05		0.05		1.35
NEMATODES								
cereal cyst nematode	0.00	0.00	62.64	10.70	4.87	0.24	40.39	6.74
stunt nematode	0.13	0.08	0.00	0.00	0.00	0.00	0.01	0.01
stubby root nematode	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
root lesion nem. neglectus	5.21	1.58	21.58	5.67	28.42	7.10	21.60	5.60
root lesion nem. penetrans	0.00	0.00	0.00	0.00	1.67	0.47	0.44	0.12
root lesion nem. teres	0.00	0.00	0.00	0.00	7.10	1.78	1.89	0.47
root lesion nem. thornei	9.16	2.93	7.20	1.19	2.13	0.53	6.07	1.20
burrowing nem. nativus	0.00	0.00	0.00	0.00	3.65	0.91	0.97	0.24
burrowing nem. vangundyi	0.00	0.00	0.00	0.00	0.31	0.08	0.08	0.02
SUB TOTAL		4.60		17.55		11.11		14.41
BACTERIA								
bacterial blight	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
bacterial stripe blight	0.10	0.10	0.00	0.00	0.00	0.00	0.01	0.01
sub total		0.12		0.00		0.00		0.01
VIRUSES								
barley yellow dwarf	0.45	0.45	1.31	0.33	7.77	0.44	2.93	0.37
wheat streak mosaic	0.05	0.05	0.23	0.01	0.03	0.03	0.16	0.02
SUB-TOTAL		0.14		0.35		0.47		0.40
TOTAL		81.53		53.27		91.14		66.49

Table 5.4 Aggregate potential and present average annual costs (\$ million) from barley diseases by GRDC Region and Australia

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Potential	Present	Potential	Present	Potential	Present	Potential	Present
NECROTROPHIC LEAF FUNGI								
Bipolaris spot blotch	2	1	0	0	0	0	2	1
Wirrega blotch	0	0	3	0	0	0	3	0
halo spot	0	0	3	0	0	0	3	0
barley stripe	0	0	54	0	0	0	54	0
ring spot	0	0	0	0	0	0	0	0
net blotch-spot form	18	8	131	20	43	15	192	43
net blotch-net form	21	6	54	2	42	10	117	19
scald	2	0	42	5	5	1	49	6
Septoria leaf blotch	0	0	2	0	0	0	2	0
SUB TOTAL		15		28		26		69
BIOTROPHIC LEAF FUNGI								
powdery mildew	9	3	22	3	72	33	103	39
rye stem rust	0	0	7	3	0	0	7	3
wheat stem rust	2	0	7	3	0	0	9	3
stem rust	1	0	7	3	0	0	8	3
leaf rust	3	0	72	10	21	11	96	21
barley grass stripe rust	0	0	30	0	0	0	30	0
downy mildew	0	0	0	0	0	0	0	0
SUB TOTAL		3		21		44		68
ROOT AND CROWN FUNGI								
crown rot	23	6	47	10	9	2	78	18
take-all	0	0	6	2	7	1	13	2
Pythium root rot	0	0	8	0	1	0	9	1
Rhizoctonia barepatch	0	0	30	12	34	6	64	18
Eradu patch	0	0	0	0	5	1	5	1
eyespot	0	0	0	0	0	0	0	0
basal rot	0	0	0	0	0	0	0	0
common root rot	7	2	30	11	0	0	37	13
SUB TOTAL		9		35		10		53
INFLORESCENCE FUNGI								
ergot	1	1	1	0	0	0	2	1
Fusarium head blight	1	1	0	0	0	0	1	1
semi-loose smut	0	0	13	0	0	0	13	0
covered smut	4	3	42	0	0	0	46	4
loose smut	2	0	1	0	5	0	8	0
SUB TOTAL		5		0		0		5
NEMATODES								
cereal cyst nematode	0	0	148	25	5	0	153	26
stunt nematode	0	0	0	0	0	0	0	0
stubby root nematode	0	0	0	0	0	0	0	0
root lesion nem. neglectus	2	1	51	13	29	7	82	21
root lesion nem. penetrans	0	0	0	0	2	0	2	0
root lesion nem. teres	0	0	0	0	7	2	7	2
root lesion nem. thornei	4	1	17	3	2	1	23	5
burrowing nem. nativus	0	0	0	0	4	1	4	1
burrowing nem. vangundyi	0	0	0	0	0	0	0	0
SUB TOTAL		2		42		11		55
BACTERIA								
bacterial blight	0	0	0	0	0	0	0	0
bacterial stripe blight	0	0	0	0	0	0	0	0
SUB TOTAL		0		0		0		0
VIRUSES								
barley yellow dwarf	0	0	3	1	8	0	11	1
wheat streak mosaic	0	0	1	0	0	0	1	0
sub-total		0		1		0		1
TOTAL		34		126		92		252

5.3.2 Value of present losses

Details of the present losses for all diseases surveyed for each region and nationally are in Table 5.3 (\$ per hectare) and Table 5.4 (aggregate losses for the region). The present total average loss from diseases is \$252 million. Foliar diseases contribute \$137 million, root and crown diseases \$53 million, inflorescence \$5 million, nematodes \$55 million and viruses \$1 million average per year.

At the national level, the present losses from the five major diseases, the total from the other diseases and the total from all diseases on a per hectare basis and total cost to the industry are:

Australia		
Disease	\$/ha	\$ million
net blotch-spot form	11.42	43
powdery mildew	10.28	39
cereal cyst nematode	6.74	26
<i>Pratylenchus neglectus</i>	5.60	21
leaf rust	5.55	21
Total losses from others	26.90	102
TOTAL PRESENT LOSS	66.49	252

The present losses are far less than the potential losses, showing the effectiveness and value of present controls (see Section 6). The spot form of net blotch remains the top ranked disease but the subsequent ranking order changes with control. Powdery mildew moves to second and the root lesion nematode *Pratylenchus neglectus* moves to fourth.

For each region, the five major diseases, plus the total from the other diseases, and the total present losses are:

Northern Region		
Disease	\$/ha	\$ million
net blotch-spot form	19.25	8
crown rot	14.98	6
net blotch-net form	14.58	6
covered smut	8.41	3
powdery mildew	7.13	3
Total losses from others	17.18	8
TOTAL PRESENT LOSS	81.53	34

The present losses per hectare in the Northern Region are generally greater than those averaged nationally and second after the Western Region. Compared with the rankings by potential loss, the net form of net blotch moves to first and covered smut has moved to fourth while common root rot is less important with control.

Southern Region		
Disease	\$/ha	\$ million
cereal cyst nematode	10.70	25
net blotch-spot form	8.44	20
<i>Pratylenchus neglectus</i>	5.67	13
Rhizoctonia barepatch	5.10	12
common root rot	4.55	11
Total losses from others	18.81	45
TOTAL PRESENT LOSS	53.27	126

The present losses per hectare in the Southern Region are less than those in the other two regions. *Pratylenchus neglectus*, Rhizoctonia barepatch and common root rot are now in the top five while leaf rust, the net form of net blotch and barley stripe are less important than the potential loss rating.

Western Region		
Disease	\$/ha	\$ million
powdery mildew	32.74	33
net blotch-spot form	15.19	15
leaf rust	10.85	11
net blotch-net form	10.25	10
<i>Pratylenchus neglectus</i>	7.10	7
Total losses from others	15.01	49
TOTAL PRESENT LOSS	91.14	92

The total present losses per hectare are highest in the Western Region where powdery mildew dominates both the present and potential loss rankings.

As with potential losses, there are some diseases that cause major loss in some zones but not in others within a region. The regional average will not reflect this local importance. Present losses (%) for each disease in each of the 14 agro-ecological zones are in Appendix C, Table C7.

5.4 Possible changes in past decade

The fungal leaf disease scald is a notable omission from the top ranked diseases in the Western and Southern Regions. Yield differences between plots treated with routine fungicides sprays and untreated plots where scald developed were usually near 30 per cent in breeder's trials in southern NSW in the 1980s and early 1990s (Dr Barbara Read, personal communication). However, this disease seems to have been much less severe in the past decade. Field observations associated severe scald with early sowing and wet late winters and springs. As with *Septoria tritici* blotch of wheat (Murray and Brennan 2009), it is possible that the drier seasonal conditions prevailing over the past decade have reduced scald so that it is now rated less important.

6. VALUE OF CONTROL OF BARLEY DISEASES

6.1 Value of controlling barley diseases

The potential average annual loss is the estimate of the loss that would occur if current control practices were not in place, while the present average annual loss is the estimate of the loss that occurs with current controls in place. Thus, the difference between potential and the present loss is a measure of the average annual value of current controls for each disease.

For diseases with high potential loss and effective control, the value of control is high. Nationally, the leading five values for control are: spot form of net blotch, \$148 million per year; cereal cyst nematode, \$128 million; net form of net blotch, \$98 million; leaf rust, \$75 million; and crown rot and the root lesion nematode *Pratylenchus neglectus* \$61 million (Table 6.1). Even the tenth ranked control, that of scald, is valued at \$43 million per year.

The regional and national values are of primary consideration by funding bodies to judge the return on investment for development of the control. However, for farmers, the cost of using the control needs to be weighed against the return. Here, the per hectare value is useful. For example, within the Northern Region (see Table 6.1), the average annual value for controlling the net form of net blotch is \$35.84/ha, so on average a farmer can choose from a range of controls with relative security that the investment will be worthwhile. In contrast, for a disease such as loose smut with the average control value of \$4.22/ha, greater attention to the cost is required.

For this survey, control measures were grouped in three broad categories: breeding (resistant cultivars); cultural practices, including stubble management, tillage and crop rotation; and pesticides, including fungicides applied to the seed, in fertilizers and by spraying, and insecticides to control vectors. Data were collected on the contribution of each category to the proportion of control (see Section 2.6). These collated data for each zone are in Appendix B, Tables B2 to B15. The value of these different forms of control was then calculated on a national basis (Table 6.2).

6.2 Value of breeding for disease resistance

Breeding and the use of genetic resistance provided more than 50 per cent of the control for five diseases and more than 25 per cent of the control for a further nine barley diseases. The top five average annual values for this control were: cereal cyst nematode, \$90 million; spot form of net blotch, \$65 million; leaf rust, \$47 million; net form of net blotch, \$30 million; and scald, \$20 million (Table 6.2).

6.3 Value of cultural methods

Cultural practices contributed more than 50% of the control for 27 barley diseases and more than 25% for a further five. The top five average annual values for this control were: spot form of net blotch, \$70 million; crown rot, \$59 million; barley stripe, \$62 million; net form of net blotch, \$54 million; and *Rhizoctonia barepatch*, \$43 million (Table 6.2).

6.4 Value of pesticides

Pesticides, mainly fungicides, contributed more than 50% of the control for four barley diseases and more than 25% for a further two. The top five average annual values for this control were: powdery mildew, \$52 million; covered smut, \$42 million; spot form of net blotch, \$14 million; net form of net blotch, \$14 million; and semi-loose smut, \$13 million (Table 6.2).

More information on the use of fungicides on barley crops is in Section 7.

Table 6.1 Value of current barley control practices per hectare and per region by GRDC Region and Australia

DISEASE	PER HECTARE (\$)				TOTAL (\$ MILLION)			
	Northern	Southern	Western	Australia	Northern	Southern	Western	Australia
NECROTROPHIC LEAF FUNGI								
Bipolaris spot blotch	2.64	0.00	0.00	0.29	1	0	0	1
Wirrega blotch	0.00	1.35	0.00	0.84	0	3	0	3
halo spot	0.00	1.23	0.00	0.77	0	3	0	3
barley stripe	0.02	22.73	0.00	14.19	0	54	0	54
ring spot	0.00	0.04	0.00	0.02	0	0	0	0
net blotch-spot form	23.16	46.80	27.92	39.18	10	111	28	148
net blotch-net form	35.84	21.86	30.90	25.80	15	52	31	98
scald	4.15	15.54	4.39	11.33	2	37	4	43
Septoria leaf blotch	0.00	0.68	0.00	0.42	0	2	0	2
BIOTROPHIC LEAF FUNGI								
powdery mildew	13.99	8.25	38.62	16.97	6	20	39	64
rye stem rust	0.00	1.84	0.00	1.15	0	4	0	4
wheat stem rust	3.64	1.92	0.00	1.60	2	5	0	6
stem rust	2.39	1.84	0.00	1.41	1	4	0	5
leaf rust	6.36	26.26	10.05	19.76	3	62	10	75
barley grass stripe rust	0.64	12.73	0.00	8.01	0	30	0	30
downy mildew	0.00	0.00	0.00	0.00	0	0	0	0
ROOT AND CROWN FUNGI								
crown rot	39.60	15.75	6.90	16.01	16	37	7	61
take-all	0.00	1.76	6.28	2.77	0	4	6	11
Pythium root rot	0.00	3.08	1.12	2.22	0	7	1	8
Rhizoctonia bar patch	0.00	7.58	27.59	12.07	0	18	28	46
Eradu patch	0.00	0.00	3.46	0.92	0	0	3	3
eyespot	0.00	0.01	0.00	0.01	0	0	0	0
basal rot	0.00	0.00	0.00	0.00	0	0	0	0
common root rot	10.70	8.05	0.00	6.20	4	19	0	23
INFLORESCENCE FUNGI								
ergot	0.00	0.61	0.00	0.38	0	1	0	1
Fusarium head blight	0.08	0.00	0.00	0.01	0	0	0	0
semi-loose smut	0.00	5.61	0.00	3.50	0	13	0	13
covered smut	1.26	17.74	0.00	11.21	1	42	0	42
loose smut	4.22	0.55	4.82	2.09	2	1	5	8
NEMATODES								
cereal cyst nematode	0.00	51.94	4.64	33.65	0	123	5	128
stunt nematode	0.04	0.00	0.00	0.00	0	0	0	0
stubby root nematode	0.01	0.00	0.00	0.00	0	0	0	0
root lesion nem. neglectus	3.63	15.91	21.31	16.00	2	38	22	61
root lesion nem. penetrans	0.00	0.00	1.20	0.32	0	0	1	1
root lesion nem. teres	0.00	0.00	5.33	1.42	0	0	5	5
root lesion nem. thornei	6.23	6.02	1.60	4.86	3	14	2	18
burrowing nem. nativus	0.00	0.00	2.73	0.73	0	0	3	3
burrowing nem. vangundyi	0.00	0.00	0.23	0.06	0	0	0	0
BACTERIA								
bacterial blight	0.00	0.00	0.00	0.00	0	0	0	0
bacterial stripe blight	0.00	0.00	0.00	0.00	0	0	0	0
VIRUSES								
barley yellow dwarf	0.00	0.98	7.34	2.56	0	2	7	10
wheat streak mosaic	0.00	0.22	0.00	0.14	0	1	0	1

Table 6.2 Value of different forms of barley disease control in Australia

DISEASE	COST/VALUE (\$ million)			CONTRIBUTION (%)			CONTRIBUTION (\$ million)		
	Potential	Present	Control	Breeding	Cultural	Pesticide	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI									
Bipolaris spot blotch	2	1	1				0	1	0
Wirrega blotch	3	0	3	0	66	34	0	3	0
halo spot	3	0	3	0	100	0	0	3	0
barley stripe	54	0	54	0	100	0	0	54	0
ring spot	0	0	0	0	100	0	0	0	0
net blotch-spot form	192	43	148	0	100	0	65	70	14
net blotch-net form	117	19	98	44	47	9	30	54	14
scald	49	6	43	30	55	15	20	16	6
Septoria leaf blotch	2	0	2	48	38	15	0	2	0
BIOTROPHIC LEAF FUNGI									
powdery mildew	103	39	64	15	4	81	10	3	52
rye stem rust	7	3	4	49	51	0	2	2	0
wheat stem rust	9	3	6	38	62	0	2	4	0
stem rust	8	3	5	40	60	0	2	3	0
leaf rust	96	21	75	63	24	12	47	18	9
barley grass stripe rust	30	0	30	53	46	1	16	14	0
downy mildew	0	0	0	0	0	0	0	0	0
ROOT AND CROWN FUNGI									
crown rot	78	18	61	3	97	0	2	59	0
take-all	13	2	11	0	94	6	0	10	1
Pythium root rot	9	1	8	0	98	2	0	8	0
Rhizoctonia barepatch	64	18	46	0	94	6	0	43	3
Eradu patch	5	1	3	0	100	0	0	3	0
eyespot	0	0	0	0	100	0	0	0	0
basal rot	0	0	0	0	100	0	0	0	0
common root rot	37	13	23	68	32	0	16	7	0
INFLORESCENCE FUNGI									
ergot	2	1	1	0	100	0	0	1	0
Fusarium head blight	1	1	0	14	86	0	0	0	0
semi-loose smut	13	0	13	0	0	100	0	0	13
covered smut	46	4	42	0	0	100	0	0	42
loose smut	8	0	8	5	12	82	0	1	7
NEMATODES									
cereal cyst nematode	153	26	128	70	30	0	90	38	0
stunt nematode	0	0	0	10	90	0	0	0	0
stubby root nematode	0	0	0	0	100	0	0	0	0
root lesion nem. neglectus	82	21	61	32	68	0	19	41	0
root lesion nem. penetrans	2	0	1	0	100	0	0	1	0
root lesion nem. teres	7	2	5	0	100	0	0	5	0
root lesion nem. thornei	23	5	18	44	56	0	8	10	0
burrowing nem. nativus	4	1	3	0	100	0	0	3	0
burrowing nem. vangundyi	0	0	0	0	100	0	0	0	0
BACTERIA									
basal glume rot	0	0	0	0	0	0	0	0	0
black chaff	0	0	0	0	0	0	0	0	0
VIRUSES									
High Plains disease	11	1	10	38	24	38	4	2	4
wheat streak mosaic	1	0	1	59	41	0	0	0	0

7. USE OF FUNGICIDES IN AUSTRALIAN BARLEY PRODUCTION

7.1 Introduction

Fungicides to control smuts have been applied to seed used for barley crops for decades. Until recent years, fungicides were not applied routinely to barley crops in Australia except in epidemics. However, in-crop applications of fungicides have become common in recent years as yields have increased over time, improved fungicides have been developed and the cost of fungicide applications has fallen in real terms. The outcome is a much more frequent and routine use of fungicides in barley crops.

However, little information is available publicly on the amount of fungicide applied in its different forms, or on the cost to farmers of the applications. Murray and Brennan (2009) found that the cost of fungicide applications to wheat crops is \$154 million per year, or \$12.89/ha. As part of the present study, information was collected that enables estimates of the aggregate expenditure on different forms of fungicides for barley disease control in Australia. While not able to produce a precise estimate, these figures provide a broad estimate of the mix of fungicides used for disease controls in barley crops, and broad estimates of the amounts spent each year by farmers in controlling fungal diseases in barley.

Fungicide can be applied to cereal crops in three ways:

- seed treatment;
- in-furrow (that is, soil) application at sowing; and
- foliar sprays to growing crops.

These can be used separately or in combination to provide protection to a crop. The following fungicide options were identified through discussion with cereal pathologists:

- application of fungicide to seed (low rate);
- application of fungicide to seed (high rate);
- application of in-furrow fungicide only;
- foliar application only;
- seed application (low rate) + in-furrow application;
- seed application (low rate) + one foliar application;
- seed application (low rate) + two foliar applications;
- seed application (low rate) + in-furrow application + one foliar application; and
- no fungicide.

Survey respondents were asked to identify the percentage of the barley crop that receives each form of fungicide treatment in each agro-ecological zone with which they were familiar. Where precise data were not available, respondents were asked to provide their best estimates, after consultation with others as necessary. Given that the options were an exhaustive list, the total percentages for each zone summed to 100 per cent. The data for agro-ecological zones were then aggregated to the three major production regions.

The average cost of each of the fungicide treatments was

identified from industry sources, based on typical application rates and 2008 prices (Table 7.1). Seed treatment was estimated at \$3.00 per 100kg seed ('low rate') and \$7.00 per 100kg seed ('high rate'), the same as for wheat (Murray and Brennan 2009). Seed treatment costs are determined as a cost per 100kg of seed. To calculate the cost per hectare, the seeding rate (kg of seed per ha) for each zone is applied. The average seeding rate was estimated by the relevant crop experts for each zone and from extension advice from

Table 7.1 Costs of fungicide treatments

SEED DRESSING FUNGICIDE COSTS PER 100kg OF SEED	
Seed (low rate)	3.00
Seed (high rate)	7.00
OTHER COSTS	
In-furrow fungicide (\$/ha)	20.00
Foliar fungicide spray (\$/ha)	12.00
Application costs for foliar sprays (\$/ha)	10.00

Table 7.2 Average costs of fungicide strategies for barley*

SEED RATE (kg/ha)	60
COSTS OF FUNGICIDE APPLICATION (\$/ha)	
Seed (low rate)	1.80
Seed (high rate)	4.20
In-furrow only	20.00
Foliar only	22.00
Seed (low rate) + in-furrow	21.80
Seed (low rate) + foliar	23.80
Seed (low rate) + 2 foliar	45.80
Seed + in-furrow + foliar	43.80

* Based on national weighted average seeding rates; costs vary with different seeding rates for individual zones (see Appendix D, Table D1).

TABLE 7.3 FUNGICIDE TREATMENTS FOR BARLEY CROPS IN THE GRDC REGIONS AND AUSTRALIA

AREA TREATED (%)	NORTHERN	SOUTHERN	WESTERN	AUSTRALIA
Seed treatment	69	85	70	79
In-furrow application	0	9	7	8
Foliar application	19	11	46	21
No fungicide	21	7	9	9
AREA TREATED ('000 ha)*				
Seed treatment	288	2010	705	3003
In-furrow application	0	219	69	288
Foliar application	77	271	462	810
No fungicide	88	163	91	342

* Based on the average area sown, 1998-99 to 2007-08

Table 7.4 Aggregate costs of fungicide applications to barley crops (\$ million)

	INCLUDING APPLICATION COSTS				EXCLUDING APPLICATION COSTS			
	Northern	Southern	Western	Australia	Northern	Southern	Western	Australia
Seed (low rate)	0.3	1.6	0.5	2.4	0.3	1.6	0.5	2.4
Seed (high rate)	0.1	3.8	0.7	4.6	0.1	3.8	0.7	4.6
In-furrow only	0.0	1.3	0.8	2.1	0.0	1.3	0.8	2.1
Foliar only	0.9	2.8	3.8	7.4	0.5	1.5	2.1	4.0
Seed (low) + in-furrow	0.0	2.8	0.4	3.2	0.0	2.8	0.4	3.2
Seed (low) + foliar	0.9	2.5	5.2	8.6	0.5	1.5	3.0	5.0
Seed (rate) + 2 foliar	0.0	0.4	3.1	3.5	0.0	0.2	1.7	2.0
Seed+in-furrow + foliar	0.0	1.2	0.3	1.5	0.0	1.0	0.2	1.2
TOTAL	2.2	16.4	14.8	33.4	1.4	13.6	9.5	24.5

the various state departments of agriculture/primary industry. In-furrow applications and foliar sprays were estimated to cost \$20.00 and \$12.00 per ha, respectively.

The spraying cost for field application of fungicide was \$10.00/ha. In-furrow treatment had no direct field application cost, as it was applied as part of the sowing operation.

The costs of seed dressing per hectare varied between zones with the different seeding rates per hectare (see Appendix D, Table D1 for fungicide costs in each agro-ecological zone). As an illustration, using the national average sowing rates of 60kg/ha for barley, the costs of each strategy are shown in Table 7.2. On that basis, the low rates of seed applied fungicide cost \$1.80/ha, while the higher rate cost an average of \$4.20/ha.

7.2 Fungicide use

While the data were gathered on the basis of the agro-ecological zones, the results are reported here only on the basis of the three GRDC Regions. The proportion of barley crops in each region receiving the different fungicide treatments is shown in Table 7.3. Across all regions, 79 per cent of barley crops (covering 3.0 m ha on average) were sown with seed treated by fungicide, and 8 per cent (0.3 m ha) received in-furrow fungicide treatment. On average, 21 per cent of barley crops were given at least one fungicide spray, while 9 per cent of barley crops did not receive any fungicide control. Seed treatment (85 per cent of barley crops) was relied on more in the Southern Region than in the other two regions, while foliar sprays were relied on more in the Western Region (46 per cent).

The estimated cost to farmers of these fungicide applications for barley is shown in Table 7.4. The total expenditure (including application costs) is estimated at \$33 million per year for barley, of which \$2 million, \$16 million and \$15 million are in the Northern, Southern and Western Regions, respectively (Table 7.4). These costs include the cost of field application of foliar sprays. To obtain an estimate of the total expenditure on fungicides themselves (that is, without the field application costs), an estimate of the total costs with the field application costs set to zero is also shown in these tables. The total cost of the

fungicides applied to barley is estimated at approximately \$25 million per year. This implies that farmers spent an average of \$9 million per year applying foliar fungicides to their barley crops.

The costs of fungicide applications to barley crops averaged \$8.81/ha across Australia (Table 7.5), lower than the \$12.89/ha that Murray and Brennan (2009) found for wheat. Fungicide costs per hectare for barley were considerably higher in the Western Region (\$14.66/ha) than for the Northern (\$5.29/ha) and Southern (\$6.94/ha) regions.

7.3 Conclusions

The figures derived from the analysis undertaken in this study provide the first publicly-available estimate of the costs of fungicide application to barley crops in Australia. They show that, on average, the main treatment was seed treatment (79 per cent of barley crops), though 29 per cent of barley crops received subsequent applications (in the form of in-furrow or foliar applications). Some 9 per cent of barley crops received no fungicides. These figures reveal a higher reliance on seed treatment and lower reliance on other fungicide applications for barley than Murray and Brennan (2009) found for wheat.

There are some significant differences between regions in the proportion of crops receiving different fungicide treatments. In particular, in the Northern and Western Regions there is a greater reliance on foliar sprays and a lesser reliance on seed treatment for barley than in the Southern Region, where there is a particularly strong reliance on seed dressing to control barley diseases. Regional differences in the use of foliar fungicide applications are likely to be influenced by differences in the levels of genetic

Table 7.5 Expenditure on fungicides for barley crops (\$/ha)

	\$/ha
Northern Region	5.29
Southern Region	6.94
Western Region	14.66
Australia	8.81

resistance to foliar diseases in the varieties grown in the different regions.

Farmers clearly consider these applications to be economic and provide sufficient economic return to ensure that they are worthwhile. The estimates in Section 6 indicate that the total value of control for all barley diseases provided by fungicides totals \$166 million. Given that the cost of fungicide applications to barley crops is \$33 million, the ratio of overall benefits to costs from fungicide applications for barley is estimated to be almost 5:1. Of course, in individual cases, the return from fungicide applications will vary widely, given different circumstances and seasonal conditions.

The data collected by this survey should be treated with caution. Many of the respondents stated that their estimates were not precise. However, there is no publicly collected record of fungicide use on barley so these figures are the only estimate available, and provide a baseline estimate for further work in this area.

8. CONCLUSIONS

Diseases remain a major threat to barley production in Australia but are generally well controlled at present. The current average annual loss from barley diseases was estimated to be \$252 million, made up of \$34 million in the Northern, \$126 million in the Southern, and \$92 million in the Western Region. This compares with a potential average loss nationally of \$192 million from a single disease, spot form of net blotch, which is reduced to \$43 million by current controls.

On average, the current national average losses from diseases are \$66.49/ha. In the Western Region, the losses represent \$91.14/ha, while they are \$81.53/ha in the Northern Region and \$53.27/ha in the Southern Region.

When listed in order of potential and present losses, the five major diseases of barley in Australia are:

Australia		
Rank	By potential loss	By present loss
1	net blotch-spot form	net blotch-spot form
2	cereal cyst nematode	powdery mildew
3	net blotch-net form	cereal cyst nematode
4	powdery mildew	<i>Pratylenchus neglectus</i>
5	leaf rust	leaf rust

The rankings of all diseases for potential and present losses (where 1 = highest loss) are shown in Table 8.1 for each GRDC Region and for Australia. There are five diseases with the potential to cause more than \$100 million average annual potential loss in Australian barley production; a further six can cause more than \$50 million average annual potential loss.

The differences between potential and present losses reflect the value of current control measures. These show the considerable achievement of research, development and implementation of controls. Disease management is by the use of resistant cultivars (breeding), paddock preparation and management (cultural) and application of pesticides, and combinations of these. The following five diseases demonstrate this:

Disease	Control value (\$ million)	Contribution to control (\$ million) by:		
		Breeding	Cultural	Pesticides
cereal cyst nematode	155	109	46	0
barley stripe	62	0	62	0
covered smut	48	0	0	48
net blotch-spot form	167	73	78	16
powdery mildew	72	11	3	59

Overall, breeding contributes more than 25 per cent of the control for 14 diseases, cultural methods for 32 diseases, and pesticides for six barley diseases.

Most of the pathogens causing the 42 diseases surveyed occur throughout the barley growing area of Australia.

Table 8.1 Ranking of barley diseases by potential and present average annual costs for each GRDC Region and Australia (1 = highest loss)

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Potential	Present	Potential	Present	Potential	Present	Potential	Present
NECROTROPHIC LEAF FUNGI								
Bipolaris spot blotch	10	8	31	23	23	23	29	21
Wirrega blotch	30	30	22	25	22	22	26	37
halo spot	30	30	23	25	23	23	27	39
barley stripe*	23	29	5	25	23	23	9	38
ring spot	30	30	28	25	21	21	35	33
net blotch-spot form**	3	1	2	2	2	2	1	1
net blotch-net form**	2	3	4	14	3	4	3	8
scald*	11	13	8	8	13	12	10	10
Septoria leaf blotch	30	30	24	25	23	23	31	39
BIOTROPHIC LEAF FUNGI								
powdery mildew**	4	5	13	10	1	1	4	2
rye stem rust	27	25	18	11	23	23	23	14
wheat stem rust	13	27	17	11	23	23	19	15
stem rust	14	20	18	11	23	23	20	13
leaf rust**	8	14	3	7	6	3	5	5
barley grass stripe rust	17	21	12	22	23	23	13	32
downy mildew	24	22	32	24	23	23	40	34
ROOT AND CROWN FUNGI								
crown rot*	1	2	7	6	7	8	7	7
take-all	27	25	20	15	10	11	15	16
Pythium root rot	19	15	16	17	18	16	18	23
Rhizoctonia barepatch*	30	30	10	4	4	6	8	6
Eradu patch	30	30	33	25	12	9	24	19
eyespot	30	30	29	25	23	23	38	39
basal rot	30	30	30	25	23	23	39	39
common root rot	5	6	11	5	23	23	12	9
INFLORESCENCE FUNGI								
ergot	15	10	25	25	23	23	28	22
Fusarium head blight	16	11	33	25	23	23	33	24
semi-loose smut	24	22	15	21	23	23	16	30
covered smut*	7	4	9	18	23	23	11	12
loose smut	12	16	26	20	14	19	22	26
NEMATODES								
cereal cyst nematode**	30	30	1	1	11	17	2	3
stunt nematode	20	18	33	25	23	23	36	31
stubby root nematode	29	28	33	25	23	23	42	36
root lesion nem. neglectus*	9	9	6	3	5	5	6	4
root lesion nem. penetrans	30	30	33	25	17	14	30	25
root lesion nem. teres	30	30	33	25	9	7	21	17
root lesion nem. thornei	6	7	14	9	16	13	14	11
burrowing nem. nativus	30	30	33	25	15	10	25	20
burrowing nem. vangundyi	30	30	33	25	19	18	34	28
BACTERIA								
bacterial blight	24	22	33	25	23	23	41	35
bacterial stripe blight	21	17	33	25	23	23	37	29
VIRUSES								
barley yellow dwarf	18	12	21	16	8	15	17	18
wheat streak mosaic	22	19	27	19	20	20	32	27

** average annual potential loss in Australia > \$100 million
 * average annual potential loss in Australia > \$50 million

However, the severity of the diseases varies between the agro-ecological zones so that the potential and present disease losses vary widely around the country.

For example, powdery mildew causes major loss in the Western Region (potential loss \$72 million per year, present loss \$33 million, on average) but has much less effect in the Southern Region. This high regional loss ranks it fourth on potential and second on present loss nationally.

Within the Southern Region, cereal cyst nematode causes potential losses of 20 to 30 per cent in the South Australian/western Victorian zones but no potential loss in the other zones of the region.

Diseases that have effects on grain quality and marketability can also have a major impact on potential economic loss while having little effect on yield. Covered smut can downgrade barley to feed or below even when at low levels, so that its potential average annual loss is \$46 million. High levels of many foliar diseases, in addition to reducing yield, also increase screenings and so reduce the grain from malting to lower grades. For the spot form of net blotch, this grade reduction contributes \$22.50/ha of its \$50.60/ha average potential loss.

Fungicides are widely used for controlling several barley diseases. Nationally, seed treatments are applied to 79 per cent of the barley crop, in-furrow to 8 per cent and foliar sprays to 21 per cent, while 9 per cent receive no fungicides.

Caveats

There are four major cautions that need to be considered when using and assessing these findings.

1. The incidence and severity figures that form the basis of these estimates are assumed to be independent. No attempt was made to change the incidence value for different levels of severity. It is likely that for some diseases, an increase in level of disease will result in higher inoculum levels for the next season, and thus increase the incidence. Similarly, changing the severity may alter the area of barley sown. For example, if an alternative to control for the net blotch diseases by rotation were available, it may increase the area of barley. Conversely, the appearance of a new rust race may reduce the area sown, with barley replaced by a more profitable crop.
2. MacKenzie (1983) has cautioned that “the interpretation of information for several pests requires more sophisticated methods rather than just simple addition”. This is particularly so if no disease controls are applied when significant interaction between the diseases would occur. Thus, we did not sum the total potential loss, since each subsequent disease affecting the crop during its growth would have a reducing effect on yield. Such interaction is less likely with current controls in place, so on that basis we have summed the total present loss.

3. The level of aggregation of these estimates at the zone and then the regional levels will result in some errors if there are variations of incidence or severity within regions. The agro-ecological zones were selected to encompass areas within the cropping area of Australia with similar soils and climate. The danger remains that a disease that is severe in a small area of a zone could be overlooked. For example, cereal cyst nematode is unimportant in most of the NSW Central zone, but is a major limit to production in a small area along the Murray River. The other danger is that these estimates will only be used at the regional level, when diseases important in one or more zones will be undervalued over the whole region.
4. The loss estimates are for average annual losses. In years favourable to disease development the loss will be higher while in unfavourable seasons, the converse will apply.

Overall, barley diseases have the potential to cause very significant costs for farmers. Measures to overcome those potential costs, including varietal choice, cultural practices, crop rotations and the use of fungicides, play an important role in the location and nature of barley production in Australia. Even after these measures have been taken to reduce losses, Australian farmers still suffer significant losses each year from barley diseases. These present average annual losses of \$252 million are 19.5 per cent of the average value of the barley crop over the past decade (\$1289 million). Coincidentally, this relative loss is the same as that estimated for wheat diseases (Murray and Brennan 2009).

As diseases change, whether through changing climatic conditions or as a result of changing technologies and costs of available options, the barley industry also changes. In this report, detailed information on the present costs of diseases and the potential costs if current control measures are not maintained have been presented. Awareness of those costs will allow decision-makers to allocate the research and development resources to most effective use, while farmers will also be in a position to make better-informed judgments about the type and levels of controls to apply on their farms. Further work will be needed to ensure that these estimates do not become out-dated as circumstances change in the future.

This report presents estimates of the status of barley disease losses in the first decade of the 21st century. It demonstrates changes that have occurred and provides a benchmark to judge future changes.

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APPENDIX A: BARLEY PRODUCTION DATA, 1998-99 TO 2007-08

The barley production data (Table A1) was supplied by GRDC.

The value of barley (Table A2) is from the Australian Bureau of Agricultural and Resource Economics.

Table A1 Barley data by agro-ecological zone															
AREA SOWN ('000 hectares)															
	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION			TOTAL	
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mall	SMNLYE	W SandM	WA Cen	WA N		WA E
1998-99	3	314	73	199	195	18	6	352	603	537	260	414	49	42	3064
1999-00	1	220	47	167	164	21	5	360	564	449	191	284	23	24	2518
2000-01	2	252	55	233	181	32	6	425	662	577	267	546	72	56	3365
2001-02	1	273	86	207	183	33	5	446	684	645	295	570	100	84	3612
2002-03	4	233	74	219	210	41	6	485	735	663	300	609	100	90	3769
2003-04	5	406	121	280	275	43	6	548	816	635	312	703	109	108	4368
2004-05	1	365	136	300	307	59	5	538	852	702	309	724	121	113	4531
2005-06	5	363	180	319	361	53	6	511	792	624	267	620	99	107	4308
2006-07	13	264	115	264	320	57	6	562	784	647	262	602	69	114	4079
2007-08	5	362	180	319	361	50	4	510	792	623	267	618	82	107	4281
Mean	4	305	107	251	256	41	5	474	728	610	273	569	83	84	3790
PRODUCTION ('000 tonnes)															
1998-99	4	543	121	401	467	34	16	635	881	1312	491	738	77	61	5779
1999-00	1	459	77	353	384	48	12	737	866	878	354	612	37	36	4855
2000-01	3	358	66	507	433	91	17	987	1252	1555	402	713	109	64	6556
2001-02	1	635	131	351	400	98	19	1117	1279	1834	671	1200	166	122	8024
2002-03	7	247	40	127	136	85	15	377	444	948	334	746	124	67	3697
2003-04	6	868	190	554	574	150	20	1454	1542	1684	797	1777	247	207	10,068
2004-05	1	929	226	346	403	165	19	806	840	1342	612	1386	202	174	7451
2005-06	10	641	306	643	908	157	20	1248	1392	1614	658	1295	201	156	9250
2006-07	20	446	55	134	159	65	12	366	436	674	489	1036	65	142	4098
2007-08	8	659	219	284	289	102	6	676	772	1070	469	1010	83	90	5737
Mean	6	579	143	370	415	100	16	840	970	1291	528	1051	131	112	6551
YIELD (t/ha)															
1998-99	1.43	1.73	1.65	2.01	2.40	1.92	2.81	1.80	1.46	2.44	1.89	1.78	1.58	1.47	1.89
1999-00	1.50	2.09	1.65	2.12	2.34	2.31	2.54	2.05	1.54	1.96	1.86	2.15	1.62	1.49	1.93
2000-01	1.58	1.42	1.20	2.17	2.39	2.89	2.98	2.32	1.89	2.69	1.51	1.31	1.50	1.14	1.95
2001-02	0.40	2.33	1.52	1.70	2.18	2.95	3.76	2.51	1.87	2.84	2.27	2.11	1.65	1.46	2.22
2002-03	1.95	1.06	0.54	0.58	0.65	2.05	2.68	0.78	0.60	1.43	1.11	1.23	1.24	0.74	0.98
2003-04	1.22	2.14	1.57	1.98	2.09	3.49	3.13	2.65	1.89	2.65	2.55	2.53	2.25	1.90	2.30
2004-05	2.00	2.54	1.67	1.15	1.31	2.80	3.86	1.50	0.99	1.91	1.98	1.91	1.66	1.55	1.64
2005-06	2.07	1.76	1.70	2.02	2.51	2.96	3.32	2.44	1.76	2.59	2.47	2.09	2.03	1.45	2.15
2006-07	1.51	1.69	0.48	0.51	0.50	1.14	2.12	0.65	0.56	1.04	1.87	1.72	0.93	1.25	1.00
2007-08	1.66	1.82	1.22	0.89	0.80	2.06	1.64	1.33	0.97	1.72	1.76	1.63	1.00	0.83	1.34
Mean	1.58	1.90	1.34	1.48	1.62	2.45	2.92	1.77	1.33	2.12	1.93	1.85	1.59	1.32	1.73

Table A2 Unit gross value of production, 1998-99 to 2007-08

YEAR	UNIT GVP (\$/t)
1998-99	147
1999-00	172
2000-01	197
2001-02	208
2002-03	255
2003-04	169
2004-05	159
2005-06	149
2006-07	244
2007-08	267
Mean 1998-99 to 2007-08	197

Source: Australian Bureau of Agricultural and Resource Economics *Commodity Statistics***Table A3** Price discounts for barley grades (\$/t)

GRADE	PRICE	DISCOUNT
Malt1	196.73	0.00
Malt2	191.73	5.00
Malt3	186.73	10.00
Feed1	176.73	20.00
Feed2	166.73	30.00
Farm	141.93	54.80

APPENDIX B: SURVEY DATA ON BARLEY DISEASES IN AGRO-ECOLOGICAL ZONES

Table B1 lists the contributors to the survey of barley diseases in the agro-ecological zones. The tables following (B2 to B15) summarise the estimates of the incidence and severity of diseases of barley, the contribution to control by resistance, cultural methods and pesticides, in each agro-ecological zone. Where separate assessments were made by different people, the average was taken for each assessment.

No plant pathologists were contacted in Tasmania. The data in Table B8 for Tasmania assume that the conditions are similar to the Victorian High Rainfall zone (Table B7).

Table B1 Contributors to the survey of barley diseases in the agro-ecological zones

Contributor	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION			
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mall	SMNLYE	W SandM	WA Cen	WA N	WA E
Queensland Primary Industries and Fisheries														
E. Colson*	+	+	+											
D. Herde	+	+												
G. Platz	+	+	+											
NSW Department of Primary Industries														
S. Simpfendorfer		+	+	+										
G. Murray				+	+									
Victorian Department of Primary Industries														
G. Holloway					+	+		+	+					
South Australian Research and Development Institute														
H. Wallwork									+	+				
Department of Agriculture and Food, Western Australia														
R. Loughman*											+	+	+	+
A. Diggle											+	+	+	+
S. Gupta											+	+	+	+
K. Jayasena											+	+	+	+
R. Jones											+	+	+	+
W. McLeod											+	+	+	+
M. Shankar											+	+	+	+
G. Thomas											+	+	+	+
V. Vanstone											+	+	+	+

* Group coordinator

Table B2 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the Queensland Central Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	Y	50	5	3	5.0	5.0	0.1	0.1	0	50	0
Wirrega blotch	N						0.0	0.0	0	0	0
halo spot	N						0.0	0.0	0	0	0
barley stripe	N						0.0	0.0	0	0	0
ring spot	N						0.0	0.0	0	0	0
net blotch-spot form	Y	20	5	1	20.0	5.0	0.2	0.1	0	100	0
net blotch-net form	Y	20	5	1	40.0	5.0	0.4	0.1	40	60	0
scald	N						0.0	0.0	0	0	0
Septoria leaf blotch	N						0.0	0.0	0	0	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	50	50	25	5.0	3.0	1.3	0.8	100	0	0
rye stem rust	U						0.0	0.0	0	0	0
wheat stem rust	Y	20	25	5	0.1	0.1	0.0	0.0	0	0	0
stem rust	U						0.0	0.0	0	0	0
leaf rust	Y	10	5	1	1.0	0.2	0.0	0.0	90	10	0
barley grass stripe rust	N						0.0	0.0	0	0	0
downy mildew	Y	20	25	5	0.1	0.1	0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	92	30	29	35.0	9.0	10.2	2.6	0	100	0
take-all	N						0.0	0.0	0	0	0
Pythium root rot	Y	47	18	5	0.7	0.4	0.0	0.0	0	100	0
Rhizoctonia barepatch	N						0.0	0.0	0	0	0
Eradu patch	U						0.0	0.0	0	0	0
eyespot	N						0.0	0.0	0	0	0
basal rot	N						0.0	0.0	0	0	0
common root rot	Y	100	42	42	16.7	6.0	6.9	2.5	27	73	0
INFLORESCENCE FUNGI											
ergot	N						0.0	0.0	0	0	0
Fusarium head blight	Y	20	25	5	0.1	0.1	0.0	0.0	0	0	0
semi-loose smut	Y	20	25	5	0.1	0.1	0.0	0.0	0	0	0
covered smut	Y	40	25	10	3.0	0.5	0.3	0.1	0	0	100
loose smut	Y	40	25	10	3.0	0.5	0.3	0.1	0	0	100
NEMATODES											
cereal cyst nematode	N						0.0	0.0	0	0	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	N						0.0	0.0	0	0	0
root les. nem. penetrans	U						0.0	0.0	0	0	0
root lesion nem. teres	U						0.0	0.0	0	0	0
root lesion nem. thornei	Y	90	22	19	15.0	7.5	2.9	1.5	50	50	0
burrowing nem. nativus	U						0.0	0.0	0	0	0
burrowing nem.vangundyi	U						0.0	0.0	0	0	0
BACTERIA											
bacterial blight	Y	20	25	5	0.1	0.1	0.0	0.0	0	0	0
bacterial stripe blight	Y	20	25	5	0.1	0.1	0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	40	25	10	0.1	0.1	0.0	0.0	0	0	0
wheat streak mosaic	U						0.0	0.0	0	0	0

Table B3 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the NSW North-East/Queensland South-East Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)			
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide	
NECROTROPHIC LEAF FUNGI												
Bipolaris spot blotch	Y	33	12	3	33.5	11.7	1.0	0.4	0	65	35	
Wirrega blotch	N						0.0	0.0	0	0	0	
halo spot	N						0.0	0.0	0	0	0	
barley stripe	Y	10	1	0	5.0	0.2	0.0	0.0	40	20	40	
ring spot	N						0.0	0.0	0	0	0	
net blotch-spot form	Y	89	47	36	24.0	7.7	8.5	2.7	27	43	30	
net blotch-net form	Y	56	53	32	37.3	5.7	12.0	1.8	40	43	17	
sca ld	Y	33	11	4	24.0	1.7	1.0	0.1	27	40	33	
Septoria leaf blotch	N						0.0	0.0	0	0	0	
BIOTROPHIC LEAF FUNGI												
powdery mildew	Y	72	53	37	7.7	3.4	2.9	1.3	47	3	50	
rye stem rust	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0	
wheat stem rust	Y	20	25	5	12.0	0.1	0.6	0.0	0	100	0	
stem rust	Y	40	25	10	3.0	0.1	0.3	0.0	0	100	0	
leaf rust	Y	27	18	5	21.0	0.7	1.1	0.0	53	37	10	
barley grass stripe rust	Y	27	25	7	1.1	0.1	0.1	0.0	80	15	5	
downy mildew	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0	
ROOT AND CROWN FUNGI												
crown rot	Y	92	54	45	35.5	9.5	16.1	4.3	10	90	0	
take-all	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0	
Pythium root rot	Y	20	25	5	0.8	0.8	0.0	0.0	0	40	60	
Rhizoctonia barepatch	N						0.0	0.0	0	0	0	
Eradu patch	U						0.0	0.0	0	0	0	
eyespot	N						0.0	0.0	0	0	0	
basal rot	N						0.0	0.0	0	0	0	
common root rot	Y	83	63	46	11.3	3.9	5.2	1.8	45	55	0	
INFLORESCENCE FUNGI												
ergot	Y	20	25	5	0.1	0.1	0.0	0.0	0	0	0	
Fusarium head blight	Y	16	10	2	2.3	0.8	0.0	0.0	15	85	0	
semi-loose smut	Y	20	25	5	0.1	0.1	0.0	0.0	0	0	0	
covered smut	Y	40	25	10	3.0	1.3	0.3	0.1	0	0	100	
loose smut	Y	40	25	10	2.4	0.4	0.2	0.0	3	18	80	
NEMATODES												
cereal cyst nematode	N						0.0	0.0	0	0	0	
stunt nematode	Y	55	19	8	0.3	0.1	0.0	0.0	10	90	0	
stubby root nematode	U						0.0	0.0	0	0	0	
root les. nem. neglectus	Y	82	21	17	9.3	2.8	1.6	0.5	47	53	0	
root les. nem. penetrans	U						0.0	0.0	0	0	0	
root lesion nem. teres	U						0.0	0.0	0	0	0	
root lesion nem. thornei	Y	82	29	24	11.0	3.5	2.7	0.8	50	50	0	
burrowing nem. nativus	U						0.0	0.0	0	0	0	
burrowing nem.vangundyi	U						0.0	0.0	0	0	0	
BACTERIA												
bacterial blight	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0	
bacterial stripe blight	Y	40	25	10	0.3	0.3	0.0	0.0	0	100	0	
VIRUSES												
barley yellow dwarf	Y	49	25	12	1.1	1.1	0.1	0.1	0	10	90	
wheat streak mosaic	Y	27	25	7	0.2	0.2	0.0	0.0	0	100	0	

Table B4 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the NSW North-West/Queensland South-West Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)			
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide	
NECROTROPHIC LEAF FUNGI												
Bipolaris spot blotch	Y	27	11	3	26.8	7.0	0.7	0.2	0	70	30	
Wirrega blotch	N						0.0	0.0	0	0	0	
halo spot	N						0.0	0.0	0	0	0	
barley stripe	Y	10	1	0	3.0	0.2	0.0	0.0	40	20	40	
ring spot	N						0.0	0.0	0	0	0	
net blotch-spot form	Y	81	22	17	20.7	6.0	3.6	1.0	30	47	23	
net blotch-net form	Y	49	23	12	34.0	5.0	4.1	0.6	43	47	10	
scald	Y	25	4	1	30.0	1.0	0.3	0.0	20	40	40	
Septoria leaf blotch	N						0.0	0.0	0	0	0	
BIOTROPHIC LEAF FUNGI												
powdery mildew	Y	62	52	27	5.8	3.4	1.6	0.9	50	13	37	
rye stem rust	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0	
wheat stem rust	Y	13	13	3	21.0	0.1	0.5	0.0	0	100	0	
stem rust	Y	23	13	5	16.5	0.1	0.8	0.0	0	100	0	
leaf rust	Y	27	18	5	21.0	1.4	1.1	0.1	53	40	7	
barley grass stripe rust	Y	20	25	5	0.1	0.1	0.0	0.0	60	40	0	
downy mildew	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0	
ROOT AND CROWN FUNGI												
crown rot	Y	89	60	49	30.7	9.3	15.0	4.6	10	90	0	
take-all	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0	
Pythium root rot	Y	20	25	5	1.1	1.1	0.1	0.1	0	90	10	
Rhizoctonia barepatch	N						0.0	0.0	0	0	0	
Eradu patch	U						0.0	0.0	0	0	0	
eyespot	N						0.0	0.0	0	0	0	
basal rot	N						0.0	0.0	0	0	0	
common root rot	Y	80	52	32	10.2	4.0	3.2	1.3	47	53	0	
INFLORESCENCE FUNGI												
ergot	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0	
Fusarium head blight	Y	13	4	1	3.0	1.0	0.0	0.0	0	100	0	
semi-loose smut	Y	20	25	5	0.1	0.1	0.0	0.0	0	0	100	
covered smut	Y	45	13	5	4.0	0.8	0.2	0.0	0	5	95	
loose smut	Y	40	25	10	3.0	0.5	0.3	0.1	0	5	95	
NEMATODES												
cereal cyst nematode	N						0.0	0.0	0	0	0	
stunt nematode	Y	90	12	11	1.0	1.0	0.1	0.1	50	50	0	
stubby root nematode	Y	20	25	5	0.5	0.1	0.0	0.0	0	100	0	
root les. nem. neglectus	Y	82	18	14	9.3	2.8	1.3	0.4	47	53	0	
root les. nem. penetrans	U						0.0	0.0	0	0	0	
root lesion nem. teres	U						0.0	0.0	0	0	0	
root lesion nem. thornei	Y	82	29	24	11.0	3.5	2.7	0.8	50	50	0	
burrowing nem. nativus	U						0.0	0.0	0	0	0	
burrowing nem. vangundyi	U						0.0	0.0	0	0	0	
BACTERIA												
bacterial blight	Y	20	25	5	0.1	0.1	0.0	0.0	5	95	0	
bacterial stripe blight	Y	40	25	10	0.3	0.3	0.0	0.0	5	95	0	
VIRUSES												
barley yellow dwarf	Y	49	25	12	1.1	1.1	0.1	0.1	0	10	90	
wheat streak mosaic	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0	

Table B5 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the NSW Central Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	Y	13	18	3	0.3	0.1	0.0	0.0	0	95	5
Wirrega blotch	Y	30	30	9	10.0	0.0	0.9	0.0	0	100	0
halo spot	Y	30	70	21	5.0	0.0	1.1	0.0	0	100	0
barley stripe	Y	70	90	63	40.0	0.0	25.2	0.0	0	100	0
ring spot	Y	30	50	15	0.0	0.0	0.0	0.0	0	100	0
net blotch-spot form	Y	45	95	43	14.0	0.3	6.0	0.1	25	65	10
net blotch-net form	Y	45	95	43	19.0	0.3	8.1	0.1	25	65	10
scald	Y	33	30	9	26.0	1.5	2.4	0.1	45	40	15
Septoria leaf blotch	Y	10	25	3	10.0	0.0	0.3	0.0	0	100	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	58	95	56	6.5	1.6	3.6	0.9	20	5	75
rye stem rust	Y	10	90	9	30.0	10.0	2.7	0.9	50	50	0
wheat stem rust	Y	10	90	9	30.0	10.0	2.7	0.9	50	50	0
stem rust	Y	10	90	9	30.0	10.0	2.7	0.9	50	50	0
leaf rust	Y	25	58	10	14.0	5.1	1.3	0.5	65	30	5
barley grass stripe rust	Y	45	63	30	14.0	0.1	4.2	0.0	65	30	5
downy mildew	Y	10	0	0	0.0	0.0	0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	40	75	30	13.5	4.0	4.1	1.2	5	95	0
take-all	Y	25	25	6	14.0	2.6	0.9	0.2	0	100	0
Pythium root rot	Y	23	15	3	6.5	6.5	0.2	0.2	0	0	5
Rhizoctonia barepatch	Y	38	25	9	6.5	1.1	0.6	0.1	0	100	0
Eradu patch	U						0.0	0.0	0	0	0
eyespot	Y	5	5	0	5.0	0.0	0.0	0.0	0	100	0
basal rot	Y	5	5	0	3.0	0.0	0.0	0.0	0	100	0
common root rot	Y	53	63	38	6.5	2.8	2.5	1.1	30	70	0
INFLORESCENCE FUNGI											
ergot	Y	10	10	1	25.0	0.0	0.3	0.0	0	100	0
Fusarium head blight	Y	0	0	0	0.0	0.0	0.0	0.0	0	0	0
semi-loose smut	Y	20	90	18	20.0	0.1	3.6	0.0	0	0	100
covered smut	Y	50	80	40	40.0	0.1	16.0	0.0	0	0	100
loose smut	Y	50	80	40	1.0	0.1	0.4	0.0	0	0	100
NEMATODES											
cereal cyst nematode	Y	30	1	0	5.0	1.0	0.0	0.0	0	100	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	Y	50	50	25	2.0	0.5	0.5	0.1	0	100	0
root les. nem. penetrans	U						0.0	0.0	0	0	0
root lesion nem. teres	U						0.0	0.0	0	0	0
root lesion nem. thornei	Y	50	50	25	2.0	0.5	0.5	0.1	0	100	0
burrowing nem. nativus	U						0.0	0.0	0	0	0
burrowing nem.vangundyi	U						0.0	0.0	0	0	0
BACTERIA											
bacterial blight	Y			0	0.0	0.0	0.0	0.0	0	0	0
bacterial stripe blight	Y	5	5	0	0.0	0.0	0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	38	25	10	4.0	4.0	0.4	0.4	0	0	50
wheat streak mosaic	Y	40	18	7	2.8	0.1	0.2	0.0	50	50	0

Table B6 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the NSW–Victoria Slopes Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	Y	5	10	1	0.0	0.0	0.0	0.0	0	0	0
Wirrega blotch	Y	30	30	9	15.0	0.0	1.4	0.0	0	100	0
halo spot	Y	40	70	28	5.0	0.0	1.4	0.0	0	100	0
barley stripe	Y	70	90	63	40.0	0.0	25.2	0.0	0	100	0
ring spot	Y	30	50	15	0.0	0.0	0.0	0.0	0	100	0
net blotch-spot form	Y	40	50	20	25.0	0.0	5.0	0.0	0	100	0
net blotch-net form	Y	40	50	20	35.0	0.0	7.0	0.0	0	100	0
scald	Y	25	35	9	40.0	0.0	3.5	0.0	50	40	10
Septoria leaf blotch	Y	30	25	8	10.0	0.0	0.8	0.0	0	100	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	20	90	18	10.0	3.0	1.8	0.5	0	0	100
rye stem rust	Y	10	90	9	40.0	10.0	3.6	0.9	50	50	0
wheat stem rust	Y	10	90	9	40.0	10.0	3.6	0.9	50	50	0
stem rust	Y	10	90	9	40.0	10.0	3.6	0.9	50	50	0
leaf rust	Y	10	90	9	25.0	5.0	2.3	0.5	50	50	0
barley grass stripe rust	Y	60	100	60	35.0	0.0	21.0	0.0	50	50	0
downy mildew	Y	10	0	0	0.0	0.0	0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	40	35	14	15.0	5.0	2.1	0.7	0	100	0
take-all	Y	10	30	3	25.0	5.0	0.8	0.2	0	100	0
Pythium root rot	Y	25	5	1	10.0	10.0	0.1	0.1	0	0	0
Rhizoctonia barepatch	Y	35	25	9	10.0	2.0	0.9	0.2	0	100	0
Eradu patch	U						0.0	0.0	0	0	0
eyespot	Y	5	5	0	5.0	0.0	0.0	0.0	0	100	0
basal rot	Y	5	5	0	3.0	0.0	0.0	0.0	0	100	0
common root rot	Y	40	25	10	15.0	5.0	1.5	0.5	0	100	0
INFLORESCENCE FUNGI											
ergot	Y	10	20	2	25.0	0.0	0.5	0.0	0	100	0
Fusarium head blight	Y	0	0	0	0.0	0.0	0.0	0.0	0	0	0
semi-loose smut	Y	20	90	18	20.0	0.1	3.6	0.0	0	0	100
covered smut	Y	50	80	40	40.0	0.1	16.0	0.0	0	0	100
loose smut	Y	50	80	40	1.0	0.1	0.4	0.0	0	0	100
NEMATODES											
cereal cyst nematode	Y	20	1	0	5.0	1.0	0.0	0.0	0	100	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	Y	50	50	25	2.0	0.5	0.5	0.1	0	100	0
root les. nem. penetrans	U						0.0	0.0	0	0	0
root lesion nem. teres	U						0.0	0.0	0	0	0
root lesion nem. thornei	Y	50	50	25	2.0	0.5	0.5	0.1	0	100	0
burrowing nem. nativus	U						0.0	0.0	0	0	0
burrowing nem. vangundyi	U						0.0	0.0	0	0	0
BACTERIA											
bacterial blight	Y	5	5	0	0.0	0.0	0.0	0.0	0	0	0
bacterial stripe blight	Y	5	5	0	0.0	0.0	0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	20	25	5	5.0	5.0	0.3	0.3	0	0	0
wheat streak mosaic	Y	40	10	4	5.0	0.0	0.2	0.0	100	0	0

Table B7 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the Victoria High Rainfall Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	U						0.0	0.0	0	0	0
Wirrega blotch	U						0.0	0.0	0	0	0
halo spot	U						0.0	0.0	0	0	0
barley stripe	U						0.0	0.0	0	0	0
ring spot	U						0.0	0.0	0	0	0
net blotch-spot form	Y	100	95	95	30.0	4.0	28.5	3.8	70	30	0
net blotch-net form	Y	100	0	0	40.0	0.0	0.0	0.0	100	0	0
scald	Y	90	50	45	60.0	10.0	27.0	4.5	33	33	34
Septoria leaf blotch	U						0.0	0.0	0	0	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	70	20	14	25.0	2.0	3.5	0.3	15	15	70
rye stem rust	Y	50	1	0	5.0	0.0	0.0	0.0	0	100	0
wheat stem rust	Y	50	1	0	10.0	0.0	0.0	0.0	50	50	0
stem rust	Y	50	1	0	5.0	0.0	0.0	0.0	0	100	0
leaf rust	Y	100	80	80	30.0	5.0	24.0	4.0	70	30	0
barley grass stripe rust	Y	50	3	2	3.0	0.0	0.0	0.0	100	0	0
downy mildew	U						0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	100	60	60	5.0	1.0	3.0	0.6	0	100	0
take-all	Y	100	30	30	10.0	2.0	3.0	0.6	0	98	2
Pythium root rot	Y	20	25	5	2.0	0.0	0.1	0.0	0	98	2
Rhizoctonia barepatch	Y	100	10	10	8.0	3.0	0.8	0.3	0	100	0
Eradu patch	U						0.0	0.0	0	0	0
eyespot	U						0.0	0.0	0	0	0
basal rot	U						0.0	0.0	0	0	0
common root rot	Y	100	33	33	3.0	1.0	1.0	0.3	80	20	0
INFLORESCENCE FUNGI											
ergot	Y	10	2	0	1.0	0.0	0.0	0.0	0	100	0
Fusarium head blight	U						0.0	0.0	0	0	0
semi-loose smut	U						0.0	0.0	0	0	0
covered smut	Y	10	1	0	10.0	0.0	0.0	0.0	20	0	80
loose smut	Y	10	1	0	10.0	0.0	0.0	0.0	20	0	80
NEMATODES											
cereal cyst nematode	Y	100	0	0	0.5	0.0	0.0	0.0	40	60	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	Y	100	100	100	10.0	0.5	10.0	0.5	50	50	0
root les. nem. penetrans	U						0.0	0.0	0	0	0
root lesion nem. teres	U						0.0	0.0	0	0	0
root lesion nem. thornei	Y	100	30	30	10.0	0.5	3.0	0.2	50	50	0
burrowing nem. nativus	U						0.0	0.0	0	0	0
burrowing nem.vangundyi	U						0.0	0.0	0	0	0
BACTERIA											
bacterial blight	U						0.0	0.0	0	0	0
bacterial stripe blight	U						0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	100	60	60	15.0	2.0	9.0	1.2	10	60	30
wheat streak mosaic	Y	20	25	5	0.5	0.0	0.0	0.0	90	10	0

Table B8 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in Tasmania

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	U						0.0	0.0	0	0	0
Wirrega blotch	U						0.0	0.0	0	0	0
halo spot	U						0.0	0.0	0	0	0
barley stripe	U						0.0	0.0	0	0	0
ring spot	U						0.0	0.0	0	0	0
net blotch-spot form	Y	100	95	95	30.0	4.0	28.5	3.8	70	30	0
net blotch-net form	Y	100	0	0	40.0	0.0	0.0	0.0	100	0	0
scald	Y	90	50	45	60.0	10.0	27.0	4.5	33	33	34
Septoria leaf blotch	U						0.0	0.0	0	0	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	70	20	14	25.0	2.0	3.5	0.3	15	15	70
rye stem rust	Y	50	1	0	5.0	0.0	0.0	0.0	0	100	0
wheat stem rust	Y	50	1	0	10.0	0.0	0.0	0.0	50	50	0
stem rust	Y	50	1	0	5.0	0.0	0.0	0.0	0	100	0
leaf rust	Y	100	80	80	30.0	5.0	24.0	4.0	70	30	0
barley grass stripe rust	Y	50	3	2	3.0	0.0	0.0	0.0	100	0	0
downy mildew	U						0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	100	60	60	5.0	1.0	3.0	0.6	0	100	0
take-all	Y	100	30	30	10.0	2.0	3.0	0.6	0	98	2
Pythium root rot	Y	20	25	5	2.0	0.0	0.1	0.0	0	98	2
Rhizoctonia barepatch	Y	100	10	10	8.0	3.0	0.8	0.3	0	100	0
Eradu patch	U						0.0	0.0	0	0	0
eyespot	U						0.0	0.0	0	0	0
basal rot	U						0.0	0.0	0	0	0
common root rot	Y	100	33	33	3.0	1.0	1.0	0.3	80	20	0
INFLORESCENCE FUNGI											
ergot	Y	10	2	0	1.0	0.0	0.0	0.0	0	100	0
Fusarium head blight	U						0.0	0.0	0	0	0
semi-loose smut	U						0.0	0.0	0	0	0
covered smut	Y	10	1	0	10.0	0.0	0.0	0.0	20	0	80
loose smut	Y	10	1	0	10.0	0.0	0.0	0.0	20	0	80
NEMATODES											
cereal cyst nematode	Y	100	0	0	0.5	0.0	0.0	0.0	40	60	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	Y	100	100	100	10.0	0.5	10.0	0.5	50	50	0
root les. nem. penetrans	U						0.0	0.0	0	0	0
root lesion nem. teres	U						0.0	0.0	0	0	0
root lesion nem. thornei	Y	100	30	30	10.0	0.5	3.0	0.2	50	50	0
burrowing nem. nativus	U						0.0	0.0	0	0	0
burrowing nem.vangundyi	U						0.0	0.0	0	0	0
BACTERIA											
bacterial blight	U						0.0	0.0	0	0	0
bacterial stripe blight	U						0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	100	60	60	15.0	2.0	9.0	1.2	10	60	30
wheat streak mosaic	Y	20	25	5	0.5	0.0	0.0	0.0	90	10	0

Table B9 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the SA–Victoria Border–Wimmera Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	U						0.0	0.0	0	0	0
Wirrega blotch	U						0.0	0.0	0	0	0
halo spot	U						0.0	0.0	0	0	0
barley stripe	U						0.0	0.0	0	0	0
ring spot	U						0.0	0.0	0	0	0
net blotch-spot form	Y	100	95	95	15.0	3.0	14.3	2.9	70	30	0
net blotch-net form	Y	100	0	0	20.0	0.0	0.0	0.0	100	0	0
scald	Y	50	20	10	40.0	2.0	4.0	0.2	60	30	10
Septoria leaf blotch	U						0.0	0.0	0	0	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	70	20	14	20.0	1.0	2.8	0.1	15	15	70
rye stem rust	Y	50	1	0	5.0	0.0	0.0	0.0	0	100	0
wheat stem rust	Y	50	1	0	10.0	0.0	0.0	0.0	50	50	0
stem rust	Y	50	1	0	5.0	0.0	0.0	0.0	0	100	0
leaf rust	Y	100	40	40	20.0	1.0	8.0	0.4	70	30	0
barley grass stripe rust	Y	50	3	2	3.0	0.0	0.0	0.0	100	0	0
downy mildew	U						0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	100	60	60	10.0	2.0	6.0	1.2	0	100	0
take-all	Y	100	20	20	2.0	1.0	0.4	0.2	0	100	0
Pythium root rot	Y	20	25	5	2.0	0.0	0.1	0.0	0	98	2
Rhizoctonia barepatch	Y	100	30	30	10.0	5.0	3.0	1.5	0	100	0
Eradu patch	U						0.0	0.0	0	0	0
eyespot	U						0.0	0.0	0	0	0
basal rot	U						0.0	0.0	0	0	0
common root rot	Y	100	75	75	5.0	2.0	3.8	1.5	80	20	0
INFLORESCENCE FUNGI											
ergot	Y	10	2	0	1.0	0.0	0.0	0.0	0	100	0
Fusarium head blight	U						0.0	0.0	0	0	0
semi-loose smut	U						0.0	0.0	0	0	0
covered smut	Y	10	1	0	10.0	0.0	0.0	0.0	20	0	80
loose smut	Y	10	1	0	10.0	0.0	0.0	0.0	20	0	80
NEMATODES											
cereal cyst nematode	Y	100	100	100	30.0	3.0	30.0	3.0	60	40	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	Y	100	100	100	5.0	1.0	5.0	1.0	50	50	0
root les. nem. penetrans	U						0.0	0.0	0	0	0
root lesion nem. teres	U						0.0	0.0	0	0	0
root lesion nem. thornei	Y	100	15	15	10.0	1.0	1.5	0.2	50	50	0
burrowing nem. nativus	U						0.0	0.0	0	0	0
burrowing nem. vangundyi	U						0.0	0.0	0	0	0
BACTERIA											
bacterial blight	U						0.0	0.0	0	0	0
bacterial stripe blight	U						0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	100	2	2	4.0	0.1	0.1	0.0	0	90	10
wheat streak mosaic	Y	20	25	5	0.5	0.0	0.0	0.0	90	10	0

Table B10 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the SA–Victoria Mallee Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	N						0.0	0.0	0	0	0
Wirrega blotch	Y	100	1	1	1.0	0.0	0.0	0.0	0	100	0
halo spot	Y	10	2	0	1.0	0.0	0.0	0.0	50	50	0
barley stripe	N						0.0	0.0	0	0	100
ring spot	Y	100	20	20	0.1	0.0	0.0	0.0	0	100	0
net blotch-spot form	Y	100	95	95	10.0	2.0	9.5	1.9	60	40	0
net blotch-net form	Y	100	5	5	22.5	0.0	1.1	0.0	75	25	0
scald	Y	40	5	2	20.0	0.3	0.4	0.0	55	35	10
Septoria leaf blotch	N						0.0	0.0	0	0	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	75	8	5	10.0	0.5	0.5	0.0	18	18	65
rye stem rust	Y	50	1	0	5.0	0.0	0.0	0.0	0	100	0
wheat stem rust	Y	50	1	0	10.0	0.0	0.0	0.0	50	50	0
stem rust	Y	50	1	0	5.0	0.0	0.0	0.0	0	100	0
leaf rust	Y	100	23	23	10.0	1.5	2.3	0.3	75	25	0
barley grass stripe rust	Y	35	1	0	2.5	0.0	0.0	0.0	100	0	0
downy mildew	N						0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	100	68	68	10.0	2.0	6.8	1.4	0	100	0
take-all	Y	100	20	20	3.0	1.0	0.6	0.2	0	100	0
Pythium root rot	Y	60	63	53	2.0	0.0	1.1	0.0	0	99	1
Rhizoctonia barepatch	Y	100	58	58	10.0	5.0	5.8	2.9	0	100	0
Eradu patch	U						0.0	0.0	0	0	0
eyespot	Y	0	0	0	0.0	0.0	0.0	0.0	0	100	0
basal rot	N						0.0	0.0	0	0	0
common root rot	Y	100	78	78	5.5	2.0	4.3	1.6	80	20	0
INFLORESCENCE FUNGI											
ergot	Y	8	1	0	1.0	0.0	0.0	0.0	0	100	0
Fusarium head blight	N						0.0	0.0	0	0	0
semi-loose smut	U						0.0	0.0	0	0	0
covered smut	Y	8	1	0	10.0	0.0	0.0	0.0	20	0	80
loose smut	Y	55	1	0	10.0	0.0	0.0	0.0	20	0	80
NEMATODES											
cereal cyst nematode	Y	100	100	100	25.0	4.0	25.0	4.0	80	20	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	Y	100	100	100	7.5	2.0	7.5	2.0	50	50	0
root les. nem. penetrans	U						0.0	0.0	0	0	0
root lesion nem. teres	U						0.0	0.0	0	0	0
root lesion nem. thornei	Y	100	15	15	12.5	1.5	1.9	0.2	50	50	0
burrowing nem. nativus	U						0.0	0.0	0	0	0
burrowing nem. vangundyi	U						0.0	0.0	0	0	0
BACTERIA											
bacterial blight	U						0.0	0.0	0	0	0
bacterial stripe blight	U						0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	100	2	2	3.5	0.2	0.1	0.0	0	95	5
wheat streak mosaic	Y	60	18	8	0.5	0.1	0.0	0.0	45	55	0

Table B11 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the SA Mid-North/Lower Yorke, Eyre Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	N						0.0	0.0	0	0	0
Wirrega blotch	Y	100	1	1	1.0	0.0	0.0	0.0	0	100	0
halo spot	Y	20	4	1	1.0	0.0	0.0	0.0	50	50	0
barley stripe	N						0.0	0.0	0	0	100
ring spot	Y	100	20	20	0.1	0.0	0.0	0.0	0	100	0
net blotch-spot form	Y	100	60	60	10.0	1.0	6.0	0.6	50	50	0
net blotch-net form	Y	100	20	20	50.0	2.0	10.0	0.4	50	50	0
scald	Y	100	15	15	30.0	3.0	4.5	0.5	50	40	10
Septoria leaf blotch	N						0.0	0.0	0	0	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	100	5	5	10.0	0.5	0.5	0.0	20	20	60
rye stem rust	Y	50	1	0	5.0	0.0	0.0	0.0	0	100	0
wheat stem rust	Y	50	1	0	10.0	0.0	0.0	0.0	50	50	0
stem rust	Y	50	1	0	5.0	0.0	0.0	0.0	0	100	0
leaf rust	Y	100	40	40	20.0	2.0	8.0	0.8	80	20	0
barley grass stripe rust	Y	30	1	0	2.0	0.0	0.0	0.0	100	0	0
downy mildew	N						0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	100	75	75	10.0	2.0	7.5	1.5	0	100	0
take-all	Y	100	20	20	4.0	1.0	0.8	0.2	0	100	0
Pythium root rot	Y	100	100	100	2.0	0.0	2.0	0.0	0	100	0
Rhizoctonia barepatch	Y	100	50	50	10.0	3.0	5.0	1.5	0	100	0
Eradu patch	U						0.0	0.0	0	0	0
eyespot	Y	0	0	0	0.0	0.0	0.0	0.0	0	100	0
basal rot	N						0.0	0.0	0	0	0
common root rot	Y	100	80	80	6.0	2.0	4.8	1.6	80	20	0
INFLORESCENCE FUNGI											
ergot	Y	5	1	0	1.0	0.0	0.0	0.0	0	100	0
Fusarium head blight	N						0.0	0.0	0	0	0
semi-loose smut	U						0.0	0.0	0	0	0
covered smut	Y	5	1	0	10.0	0.0	0.0	0.0	20	0	80
loose smut	Y	100	1	1	10.0	0.0	0.1	0.0	20	0	80
NEMATODES											
cereal cyst nematode	Y	100	100	100	20.0	5.0	20.0	5.0	80	20	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	Y	100	100	100	10.0	3.0	10.0	3.0	50	50	0
root les. nem. penetrans	U						0.0	0.0	0	0	0
root lesion nem. teres	U						0.0	0.0	0	0	0
root lesion nem. thornei	Y	100	25	25	15.0	3.0	3.8	0.8	50	50	0
burrowing nem. nativus	U						0.0	0.0	0	0	0
burrowing nem. vangundyi	U						0.0	0.0	0	0	0
BACTERIA											
bacterial blight	U						0.0	0.0	0	0	0
bacterial stripe blight	U						0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	100	4	4	3.0	0.2	0.1	0.0	0	100	0
wheat streak mosaic	Y	100	10	10	0.5	0.1	0.1	0.0	0	100	0

Table B12 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the WA Sandplain-Mallee Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	U						0.0	0.0	0	0	0
Wirrega blotch	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
halo spot	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
barley stripe	U						0.0	0.0	0	0	0
ring spot	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0
net blotch-spot form	Y	67	63	42	14.0	6.3	5.8	2.6	8	65	28
net blotch-net form	Y	53	63	28	7.5	1.8	2.1	0.5	15	63	23
scald	Y	53	25	13	7.5	1.6	1.0	0.2	38	48	15
Septoria leaf blotch	U						0.0	0.0	0	0	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	53	100	53	12.0	1.8	6.4	0.9	10	0	90
rye stem rust	U						0.0	0.0	0	0	0
wheat stem rust	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
stem rust	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
leaf rust	Y	53	100	53	18.5	7.5	9.9	4.0	0	10	90
barley grass stripe rust	N						0.0	0.0	0	0	0
downy mildew	N						0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	67	25	17	25.0	3.0	4.2	0.5	0	100	0
take-all	Y	53	25	13	18.5	3.0	2.5	0.4	0	90	10
Pythium root rot	Y	53	25	13	1.8	0.3	0.2	0.0	0	90	10
Rhizoctonia barepatch	Y	67	100	67	25.0	3.0	16.7	2.0	0	90	10
Eradu patch	U						0.0	0.0	0	0	0
eyespot	N						0.0	0.0	0	0	0
basal rot	N						0.0	0.0	0	0	0
common root rot	U						0.0	0.0	0	0	0
INFLORESCENCE FUNGI											
ergot	Y	10	13	3	0.0	0.0	0.0	0.0	0	0	0
Fusarium head blight	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
semi-loose smut	N						0.0	0.0	0	0	0
covered smut	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
loose smut	Y	53	25	13	6.3	0.1	0.8	0.0	5	15	80
NEMATODES											
cereal cyst nematode	Y	30	25	8	3.0	0.5	0.2	0.0	10	90	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	Y	67	100	67	12.0	3.0	8.0	2.0	0	100	0
root les. nem. penetrans	Y	20	25	5	3.0	1.8	0.2	0.1	0	100	0
root lesion nem. teres	Y	67	25	17	12.0	3.0	2.0	0.5	0	100	0
root lesion nem. thornei	Y	20	25	5	12.0	3.0	0.6	0.2	0	100	0
burrowing nem. nativus	Y	20	25	5	12.0	3.0	0.6	0.2	0	100	0
burrowing nem.vangundyi	N						0.0	0.0	0	0	0
BACTERIA											
bacterial blight	N						0.0	0.0	0	0	0
bacterial stripe blight	N						0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	40	63	25	14.0	1.6	3.5	0.4	45	10	45
wheat streak mosaic	Y	40	25	10	0.1	0.1	0.0	0.0	0	0	0

Table B13 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the WA Central Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	U						0.0	0.0	0	0	0
Wirrega blotch	U						0.0	0.0	0	0	0
halo spot	U						0.0	0.0	0	0	0
barley stripe	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
ring spot	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0
net blotch-spot form	Y	67	100	67	12.0	3.0	8.0	2.0	5	55	40
net blotch-net form	Y	67	100	67	12.0	3.0	8.0	2.0	10	50	40
scald	Y	67	25	17	3.0	0.1	0.5	0.0	50	40	10
Septoria leaf blotch	U						0.0	0.0	0	0	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	67	100	67	25.0	12.0	16.7	8.0	10	0	90
rye stem rust	U						0.0	0.0	0	0	0
wheat stem rust	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
stem rust	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
leaf rust	Y	40	25	10	12.0	3.0	1.2	0.3	0	10	90
barley grass stripe rust	N						0.0	0.0	0	0	0
downy mildew	N						0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	67	25	17	12.0	3.0	2.0	0.5	0	100	0
take-all	Y	67	25	17	12.0	0.5	2.0	0.1	0	90	10
Pythium root rot	Y	67	25	17	3.0	0.5	0.5	0.1	0	90	10
Rhizoctonia barepatch	Y	67	100	67	12.0	3.0	8.0	2.0	0	90	10
Eradu patch	Y	67	25	17	12.0	3.0	2.0	0.5	0	100	0
eyespot	N						0.0	0.0	0	0	0
basal rot	N						0.0	0.0	0	0	0
common root rot	U						0.0	0.0	0	0	0
INFLORESCENCE FUNGI											
ergot	Y	0	0	0	0.0	0.0	0.0	0.0	0	0	0
Fusarium head blight	N						0.0	0.0	0	0	0
semi-loose smut	N						0.0	0.0	0	0	0
covered smut	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
loose smut	Y	67	25	17	0.5	0.1	0.1	0.0	5	15	80
NEMATODES											
cereal cyst nematode	Y	67	25	17	12.0	0.5	2.0	0.1	10	90	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	Y	67	100	67	12.0	3.0	8.0	2.0	0	100	0
root les. nem. penetrans	Y	20	25	5	12.0	3.0	0.6	0.2	0	100	0
root lesion nem. teres	Y	67	25	17	12.0	3.0	2.0	0.5	0	100	0
root lesion nem. thornei	Y	20	25	5	12.0	3.0	0.6	0.2	0	100	0
burrowing nem. nativus	Y	40	25	10	12.0	3.0	1.2	0.3	0	100	0
burrowing nem.vangundyi	N						0.0	0.0	0	0	0
BACTERIA											
bacterial blight	N						0.0	0.0	0	0	0
bacterial stripe blight	N						0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	67	25	17	12.0	0.1	2.0	0.0	50	10	40
wheat streak mosaic	Y	40	25	10	0.1	0.1	0.0	0.0	0	0	0

Table B14 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the WA Northern Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	Y	0	0	0	0.0	0.0	0.0	0.0	0	0	0
Wirrega blotch	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0
halo spot	U						0.0	0.0	0	0	0
barley stripe	U						0.0	0.0	0	0	0
ring spot	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0
net blotch-spot form	Y	40	100	40	12.0	3.0	4.8	1.2	5	85	10
net blotch-net form	Y	67	100	67	12.0	3.0	8.0	2.0	10	70	20
scald	Y	40	25	10	12.0	0.5	1.2	0.1	25	50	25
Septoria leaf blotch	U						0.0	0.0	0	0	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	40	100	40	12.0	0.5	4.8	0.2	10	0	90
rye stem rust	U						0.0	0.0	0	0	0
wheat stem rust	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
stem rust	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
leaf rust	Y	40	25	10	12.0	0.5	1.2	0.1	5	10	85
barley grass stripe rust	N						0.0	0.0	0	0	0
downy mildew	N						0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	20	25	5	0.1	0.1	0.0	0.0	0	0	0
take-all	Y	40	25	10	12.0	3.0	1.2	0.3	0	90	10
Pythium root rot	Y	40	25	10	3.0	0.5	0.3	0.1	0	90	10
Rhizoctonia barepatch	Y	67	25	17	3.0	0.5	0.5	0.1	0	100	0
Eradu patch	Y	67	25	17	12.0	3.0	2.0	0.5	0	100	0
eyespot	N						0.0	0.0	0	0	0
basal rot	N						0.0	0.0	0	0	0
common root rot	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
INFLORESCENCE FUNGI											
ergot	Y	0	0	0	0.0	0.0	0.0	0.0	0	0	0
Fusarium head blight	N						0.0	0.0	0	0	0
semi-loose smut	N						0.0	0.0	0	0	0
covered smut	Y	20	25	5	0.0	0.0	0.0	0.0	5	15	80
loose smut	Y	40	25	10	0.5	0.1	0.1	0.0	5	15	80
NEMATODES											
cereal cyst nematode	Y	67	25	17	12.0	0.5	2.0	0.1	10	90	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	Y	67	100	67	12.0	3.0	8.0	2.0	0	100	0
root les. nem. penetrans	Y	20	25	5	12.0	3.0	0.6	0.2	0	100	0
root lesion nem. teres	Y	67	25	17	12.0	3.0	2.0	0.5	0	100	0
root lesion nem. thornei	Y	20	25	5	12.0	3.0	0.6	0.2	0	100	0
burrowing nem. nativus	Y	40	25	10	12.0	3.0	1.2	0.3	0	100	0
burrowing nem. vangundyi	Y	40	25	10	12.0	3.0	1.2	0.3	0	100	0
BACTERIA											
bacterial blight	N						0.0	0.0	0	0	0
bacterial stripe blight	N						0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	20	25	5	3.0	0.1	0.2	0.0	0	10	90
wheat streak mosaic	Y	20	25	5	0.1	0.1	0.0	0.0	0	0	0

Table B15 Incidence, severity and contribution to control estimates and derived disease loss of barley diseases in the WA Eastern Zone

DISEASE	PRESENT	INCIDENCE (%)			SEVERITY (%)		DISEASE LOSS (%)		CONTRIBUTION TO CONTROL (%)		
		Years	Area	Frequency	No controls	Present controls	Potential	Present	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI											
Bipolaris spot blotch	U						0.0	0.0	0	0	0
Wirrega blotch	U						0.0	0.0	0	0	0
halo spot	U						0.0	0.0	0	0	0
barley stripe	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
ring spot	Y	20	25	5	0.1	0.1	0.0	0.0	0	100	0
net blotch-spot form	Y	67	25	17	3.0	0.5	0.5	0.1	5	85	10
net blotch-net form	Y	40	100	40	12.0	3.0	4.8	1.2	10	70	20
scald	Y	40	25	10	3.0	0.1	0.3	0.0	25	65	10
Septoria leaf blotch	U						0.0	0.0	0	0	0
BIOTROPHIC LEAF FUNGI											
powdery mildew	Y	40	100	40	12.0	0.5	4.8	0.2	10	0	90
rye stem rust	U						0.0	0.0	0	0	0
wheat stem rust	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
stem rust	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
leaf rust	Y	20	25	5	3.0	0.5	0.2	0.0	0	90	10
barley grass stripe rust	N						0.0	0.0	0	0	0
downy mildew	N						0.0	0.0	0	0	0
ROOT AND CROWN FUNGI											
crown rot	Y	40	25	10	3.0	0.5	0.3	0.1	0	100	0
take-all	Y	20	25	5	3.0	3.0	0.2	0.2	0	0	0
Pythium root rot	Y	20	25	5	3.0	3.0	0.2	0.2	0	0	0
Rhizoctonia barepatch	Y	67	25	17	3.0	0.5	0.5	0.1	0	100	0
Eradu patch	U						0.0	0.0	0	0	0
eyespot	N						0.0	0.0	0	0	0
basal rot	N						0.0	0.0	0	0	0
common root rot	U						0.0	0.0	0	0	0
INFLORESCENCE FUNGI											
ergot	Y	0	0	0	0.0	0.0	0.0	0.0	0	0	0
Fusarium head blight	N						0.0	0.0	0	0	0
semi-loose smut	N						0.0	0.0	0	0	0
covered smut	Y	20	25	5	0.0	0.0	0.0	0.0	0	0	0
loose smut	Y	40	25	10	0.5	0.1	0.1	0.0	5	15	80
NEMATODES											
cereal cyst nematode	Y	20	25	5	3.0	0.5	0.2	0.0	10	90	0
stunt nematode	U						0.0	0.0	0	0	0
stubby root nematode	U						0.0	0.0	0	0	0
root les. nem. neglectus	Y	67	100	67	12.0	3.0	8.0	2.0	0	100	0
root les. nem. penetrans	Y	20	25	5	12.0	3.0	0.6	0.2	0	100	0
root lesion nem. teres	Y	67	25	17	12.0	3.0	2.0	0.5	0	100	0
root lesion nem. thornei	Y	20	25	5	12.0	3.0	0.6	0.2	0	100	0
burrowing nem. nativus	Y	40	25	10	12.0	3.0	1.2	0.3	0	100	0
burrowing nem.vangundyi	N						0.0	0.0	0	0	0
BACTERIA											
bacterial blight	N						0.0	0.0	0	0	0
bacterial stripe blight	N						0.0	0.0	0	0	0
VIRUSES											
barley yellow dwarf	Y	20	25	5	3.0	0.1	0.2	0.0	0	10	90
wheat streak mosaic	Y	40	25	10	0.1	0.1	0.0	0.0	0	0	0

APPENDIX C: SUMMARY OF PRESENCE, INCIDENCE AND SEVERITY OF BARLEY DISEASES IN THE AGRO-ECOLOGICAL ZONES

The following tables present the data on presence, incidence (annual frequency and area affected), potential and present severity, and potential and present average annual yield loss.

These data are also in Appendix B where they are shown together for each agro-ecological zone.

However, the following tables show the factors in turn across the 14 zones, allowing comparison between zones.

Table C1 Presence of barley disease pathogens in 14 agro-ecological zones

Disease	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION			
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mall	SMNLYE	W SandM	WA Cen	WA N	WA E
NECROTROPHIC LEAF FUNGI														
Bipolaris spot blotch	Y	Y	Y	Y	Y	U	U	U	N	N	U	U	Y	U
Wirrega blotch	N	N	N	Y	Y	U	U	U	Y	Y	Y	U	Y	U
halo spot	N	N	N	Y	Y	U	U	U	Y	Y	Y	U	U	U
barley stripe	N	Y	Y	Y	Y	U	U	U	N	N	U	Y	U	Y
ring spot	N	N	N	Y	Y	U	U	U	Y	Y	Y	Y	Y	Y
net blotch-spot form	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
net blotch-net form	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
scald	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Septoria leaf blotch	N	N	N	Y	Y	U	U	U	N	N	U	U	U	U
BIOTROPHIC LEAF FUNGI														
powdery mildew	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
rye stem rust	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	U	U	U
wheat stem rust	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
stem rust	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
leaf rust	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
barley grass stripe rust	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N
downy mildew	Y	Y	Y	Y	Y	U	U	U	N	N	N	N	N	N
ROOT AND CROWN FUNGI														
crown rot	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
take-all	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Pythium root rot	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Rhizoctonia barepatch	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Eradu patch	U	U	U	U	U	U	U	U	U	U	U	Y	Y	U
eyespot	N	N	N	Y	Y	U	U	U	Y	Y	N	N	N	N
basal rot	N	N	N	Y	Y	U	U	U	N	N	N	N	N	N
common root rot	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	U	Y	U
INFLORESCENCE FUNGI														
ergot	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Fusarium head blight	Y	Y	Y	Y	Y	U	U	U	N	N	Y	N	N	N
semi-loose smut	Y	Y	Y	Y	Y	U	U	U	U	U	N	N	N	N
covered smut	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
loose smut	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
NEMATODES														
cereal cyst nematode	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
stunt nematode	U	Y	Y	U	U	U	U	U	U	U	U	U	U	U
stubby root nematode	U	U	Y	U	U	U	U	U	U	U	U	U	U	U
root lesion nem. neglectus	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
root lesion nem. penetrans	U	U	U	U	U	U	U	U	U	U	Y	Y	Y	Y
root lesion nem. teres	U	U	U	U	U	U	U	U	U	U	Y	Y	Y	Y
root lesion nem. thornei	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
burrowing nem. nativus	U	U	U	U	U	U	U	U	U	U	Y	Y	Y	Y
burrowing nem. vangundyi	U	U	U	U	U	U	U	U	U	U	N	N	Y	N
BACTERIA														
bacterial blight	Y	Y	Y	Y	Y	U	U	U	U	U	N	N	N	N
bacterial stripe blight	Y	Y	Y	Y	Y	U	U	U	U	U	N	N	N	N
VIRUSES														
barley yellow dwarf	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
wheat streak mosaic	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Y = present in zone; N = not recorded in zone; U = unknown status (see Table 2.2 for the pathogens that cause each disease)

Table C2 Incidence (%) of barley diseases as the proportion of years that favour disease development in 14 agro-ecological zones

Disease	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION			
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mall	SMNLYE	W SandM	WA Cen	WA N	WA E
NECROTROPHIC LEAF FUNGI														
Bipolaris spot blotch	50	33	27	13	5									0
Wirrega blotch				30	30				100	100	20		20	
halo spot				30	40				10	20	20			
barley stripe		10	10	70	70							20		20
ring spot				30	30				100	100	20	20	20	20
net blotch-spot form	20	89	81	45	40	100	100	100	100	100	67	67	40	67
net blotch-net form	20	56	49	45	40	100	100	100	100	100	53	67	67	40
scald		33	25	33	25	90	90	50	40	100	53	67	40	40
Septoria leaf blotch				10	30									
BIOTROPHIC LEAF FUNGI														
powdery mildew	50	72	62	58	20	70	70	70	75	100	53	67	40	40
rye stem rust		20	20	10	10	50	50	50	50	50				
wheat stem rust	20	20	13	10	10	50	50	50	50	50	20	20	20	20
stem rust		40	23	10	10	50	50	50	50	50	20	20	20	20
leaf rust	10	27	27	25	10	100	100	100	100	100	53	40	40	20
barley grass stripe rust		27	20	45	60	50	50	50	35	30				
downy mildew	20	20	20	10	10									
ROOT AND CROWN FUNGI														
crown rot	92	92	89	40	40	100	100	100	100	100	67	67	20	40
take-all		20	20	25	10	100	100	100	100	100	53	67	40	20
Pythium root rot	47	20	20	23	25	20	20	20	60	100	53	67	40	20
Rhizoctonia barepatch				38	35	100	100	100	100	100	67	67	67	67
Eradu patch												67	67	
eyespot				5	5				0	0				
basal rot				5	5									
common root rot	100	83	80	53	40	100	100	100	100	100			20	
INFLORESCENCE FUNGI														
ergot		20	20	10	10	10	10	10	8	5	10	0	0	0
Fusarium head blight	20	16	13	0	0						20			
semi-loose smut	20	20	20	20	20									
covered smut	40	40	45	50	50	10	10	10	8	5	20	20	20	20
loose smut	40	40	40	50	50	10	10	10	55	100	53	67	40	40
NEMATODES														
cereal cyst nematode				30	20	100	100	100	100	100	30	67	67	20
stunt nematode		55	90											
stubby root nematode			20											
root lesion nem. neglectus		82	82	50	50	100	100	100	100	100	67	67	67	67
root lesion nem. penetrans											20	20	20	20
root lesion nem. teres											67	67	67	67
root lesion nem. thornei	90	82	82	50	50	100	100	100	100	100	20	20	20	20
burrowing nem. nativus											20	40	40	40
burrowing nem. vangundyi													40	
BACTERIA														
bacterial blight	20	20	20		5									
bacterial stripe blight	20	40	40	5	5									
VIRUSES														
barley yellow dwarf	40	49	49	38	20	100	100	100	100	100	40	67	20	20
wheat streak mosaic		27	20	40	40	20	20	20	60	100	40	40	20	40

Table C3 Incidence (%) of barley diseases as the proportion of the area affected in years favouring development in 14 agro-ecological zones

Disease	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION			
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mal	SMNLYE	W SandM	WA Cen	WA N	WA E
NECROTROPHIC LEAF FUNGI														
Bipolaris spot blotch	5	12	11	18	10								0	
Wirrega blotch				30	30				1	1	25		25	
halo spot				70	70				2	4	25			
barley stripe		1	1	90	90							25		25
ring spot				50	50				20	20	25	25	25	25
net blotch-spot form	5	47	22	95	50	95	95	95	95	60	63	100	100	25
net blotch-net form	5	53	23	95	50	0	0	0	5	20	63	100	100	100
scald		11	4	30	35	50	50	20	5	15	25	25	25	25
Septoria leaf blotch				25	25									
BIOTROPHIC LEAF FUNGI														
powdery mildew	50	53	52	95	90	20	20	20	8	5	100	100	100	100
rye stem rust		25	25	90	90	1	1	1	1	1				
wheat stem rust	25	25	13	90	90	1	1	1	1	1	25	25	25	25
stem rust		25	13	90	90	1	1	1	1	1	25	25	25	25
leaf rust	5	18	18	58	90	80	80	40	23	40	100	25	25	25
barley grass stripe rust		25	25	63	100	3	3	3	1	1				
downy mildew	25	25	25	0	0									
ROOT AND CROWN FUNGI														
crown rot	30	54	60	75	35	60	60	60	68	75	25	25	25	25
take-all		25	25	25	30	30	30	20	20	20	25	25	25	25
Pythium root rot	18	25	25	15	5	25	25	25	63	100	25	25	25	25
Rhizoctonia barepatch				25	25	10	10	30	58	50	100	100	25	25
Eradu patch												25	25	
eyespot				5	5				0	0				
basal rot				5	5									
common root rot	42	63	52	63	25	33	33	75	78	80			25	
INFLORESCENCE FUNGI														
ergot		25	25	10	20	2	2	2	1	1	13	0	0	0
Fusarium head blight	25	10	4	0	0						25			
semi-loose smut	25	25	25	90	90									
covered smut	25	25	13	80	80	1	1	1	1	1	25	25	25	25
loose smut	25	25	25	80	80	1	1	1	1	1	25	25	25	25
NEMATODES														
cereal cyst nematode				1	1	0	0	100	100	100	25	25	25	25
stunt nematode		19	12											
stubby root nematode			25											
root lesion nem. neglectus		21	18	50	50	100	100	100	100	100	100	100	100	100
root lesion nem. penetrans											25	25	25	25
root lesion nem. teres											25	25	25	25
root lesion nem. thornei	22	29	29	50	50	30	30	15	15	25	25	25	25	25
burrowing nem. nativus											25	25	25	25
burrowing nem. vangundyi													25	
BACTERIA														
bacterial blight	25	25	25		5									
bacterial stripe blight	25	25	25	5	5									
VIRUSES														
barley yellow dwarf	25	25	25	25	25	60	60	2	2	4	63	25	25	25
wheat streak mosaic		25	25	18	10	25	25	25	18	10	25	25	25	25

Table C4 Potential severity of barley diseases (% loss when not controlled in season favourable for development) in 14 agro-ecological zones

Disease	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION			
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mall	SMNLYE	W SandM	WA Cen	WA N	WA E
NECROTROPHIC LEAF FUNGI														
Bipolaris spot blotch	5.0	33.5	26.8	0.3	0.0									0.0
Wirrega blotch				10.0	15.0				1.0	1.0	0.0		0.1	
halo spot				5.0	5.0				1.0	1.0	0.0			
barley stripe		5.0	3.0	40.0	40.0							0.0		0.0
ring spot				0.0	0.0				0.1	0.1	0.1	0.1	0.1	0.1
net blotch-spot form	20.0	24.0	20.7	14.0	25.0	30.0	30.0	15.0	10.0	10.0	14.0	12.0	12.0	3.0
net blotch-net form	40.0	37.3	34.0	19.0	35.0	40.0	40.0	20.0	22.5	50.0	7.5	12.0	12.0	12.0
scald		24.0	30.0	26.0	40.0	60.0	60.0	40.0	20.0	30.0	7.5	3.0	12.0	3.0
Septoria leaf blotch				10.0	10.0									
BIOTROPHIC LEAF FUNGI														
powdery mildew	5.0	7.7	5.8	6.5	10.0	25.0	25.0	20.0	10.0	10.0	12.0	25.0	12.0	12.0
rye stem rust		0.1	0.1	30.0	40.0	5.0	5.0	5.0	5.0	5.0				
wheat stem rust	0.1	12.0	21.0	30.0	40.0	10.0	10.0	10.0	10.0	10.0	0.0	0.0	0.0	0.0
stem rust		3.0	16.5	30.0	40.0	5.0	5.0	5.0	5.0	5.0	0.0	0.0	0.0	0.0
leaf rust	1.0	21.0	21.0	14.0	25.0	30.0	30.0	20.0	10.0	20.0	18.5	12.0	12.0	3.0
barley grass stripe rust		1.1	0.1	14.0	35.0	3.0	3.0	3.0	2.5	2.0				
downy mildew	0.1	0.1	0.1	0.0	0.0									
ROOT AND CROWN FUNGI														
crown rot	35.0	35.5	30.7	13.5	15.0	5.0	5.0	10.0	10.0	10.0	25.0	12.0	0.1	3.0
take-all		0.1	0.1	14.0	25.0	10.0	10.0	2.0	3.0	4.0	18.5	12.0	12.0	3.0
Pythium root rot	0.7	0.8	1.1	6.5	10.0	2.0	2.0	2.0	2.0	2.0	1.8	3.0	3.0	3.0
Rhizoctonia barepatch				6.5	10.0	8.0	8.0	10.0	10.0	10.0	25.0	12.0	3.0	3.0
Eradu patch												12.0	12.0	
eyespot				5.0	5.0				0.0	0.0				
basal rot				3.0	3.0									
common root rot	16.7	11.3	10.2	6.5	15.0	3.0	3.0	5.0	5.5	6.0			0.0	
INFLORESCENCE FUNGI														
ergot		0.1	0.1	25.0	25.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0
Fusarium head blight	0.1	2.3	3.0	0.0	0.0						0.0			
semi-loose smut	0.1	0.1	0.1	20.0	20.0									
covered smut	3.0	3.0	4.0	40.0	40.0	10.0	10.0	10.0	10.0	10.0	0.0	0.0	0.0	0.0
loose smut	3.0	2.4	3.0	1.0	1.0	10.0	10.0	10.0	10.0	10.0	6.3	0.5	0.5	0.5
NEMATODES														
cereal cyst nematode				5.0	5.0	0.5	0.5	30.0	25.0	20.0	3.0	12.0	12.0	3.0
stunt nematode		0.3	1.0											
stubby root nematode			0.5											
root lesion nem. neglectus		9.3	9.3	2.0	2.0	10.0	10.0	5.0	7.5	10.0	12.0	12.0	12.0	12.0
root lesion nem. penetrans											3.0	12.0	12.0	12.0
root lesion nem. teres											12.0	12.0	12.0	12.0
root lesion nem. thornei	15.0	11.0	11.0	2.0	2.0	10.0	10.0	10.0	12.5	15.0	12.0	12.0	12.0	12.0
burrowing nem. nativus											12.0	12.0	12.0	12.0
burrowing nem. vangundyi													12.0	
BACTERIA														
bacterial blight	0.1	0.1	0.1	0.0	0.0									
bacterial stripe blight	0.1	0.3	0.3	0.0	0.0									
VIRUSES														
barley yellow dwarf	0.1	1.1	1.1	4.0	5.0	15.0	15.0	4.0	3.5	3.0	14.0	12.0	3.0	3.0
wheat streak mosaic		0.2	0.1	2.8	5.0	0.5	0.5	0.5	0.5	0.5	0.1	0.1	0.1	0.1

Table C5 Present severity of barley diseases (% loss with current controls in season favourable for its development) in 14 agro-ecological zones

Disease	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION			
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mall	SMNLYE	W SandM	WA Cen	WA N	WA E
NECROTROPHIC LEAF FUNGI														
Bipolaris spot blotch	5.0	11.7	7.0	0.1	0.0								0.0	
Wirrega blotch				0.0	0.0				0.0	0.0	0.0		0.1	
halo spot				0.0	0.0				0.0	0.0	0.0			
barley stripe		0.2	0.2	0.0	0.0							0.0		0.0
ring spot				0.0	0.0				0.0	0.0	0.1	0.1	0.1	0.1
net blotch-spot form	5.0	7.7	6.0	0.3	0.0	4.0	4.0	3.0	2.0	1.0	6.3	3.0	3.0	0.5
net blotch-net form	5.0	5.7	5.0	0.3	0.0	0.0	0.0	0.0	0.0	2.0	1.8	3.0	3.0	3.0
scald		1.7	1.0	1.5	0.0	10.0	10.0	2.0	0.3	3.0	1.6	0.1	0.5	0.1
Septoria leaf blotch				0.0	0.0									
BIOTROPHIC LEAF FUNGI														
powdery mildew	3.0	3.4	3.4	1.6	3.0	2.0	2.0	1.0	0.5	0.5	1.8	12.0	0.5	0.5
rye stem rust		0.1	0.1	10.0	10.0	0.0	0.0	0.0	0.0	0.0				
wheat stem rust	0.1	0.1	0.1	10.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
stem rust		0.1	0.1	10.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
leaf rust	0.2	0.7	1.4	5.1	5.0	5.0	5.0	1.0	1.5	2.0	7.5	3.0	0.5	0.5
barley grass stripe rust		0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0				
downy mildew	0.1	0.1	0.1	0.0	0.0									
ROOT AND CROWN FUNGI														
crown rot	9.0	9.5	9.3	4.0	5.0	1.0	1.0	2.0	2.0	2.0	3.0	3.0	0.1	0.5
take-all		0.1	0.1	2.6	5.0	2.0	2.0	1.0	1.0	1.0	3.0	0.5	3.0	3.0
Pythium root rot	0.4	0.8	1.1	6.5	10.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.5	3.0
Rhizoctonia barepatch				1.1	2.0	3.0	3.0	5.0	5.0	3.0	3.0	3.0	0.5	0.5
Eradu patch												3.0	3.0	
eyespot				0.0	0.0				0.0	0.0				
basal rot				0.0	0.0									
common root rot	6.0	3.9	4.0	2.8	5.0	1.0	1.0	2.0	2.0	2.0			0.0	
INFLORESCENCE FUNGI														
ergot		0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fusarium head blight	0.1	0.8	1.0	0.0	0.0						0.0			
semi-loose smut	0.1	0.1	0.1	0.1	0.1									
covered smut	0.5	1.3	0.8	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
loose smut	0.5	0.4	0.5	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
NEMATODES														
cereal cyst nematode				1.0	1.0	0.0	0.0	3.0	4.0	5.0	0.5	0.5	0.5	0.5
stunt nematode		0.1	1.0											
stubby root nematode			0.1											
root lesion nem. neglectus		2.8	2.8	0.5	0.5	0.5	0.5	1.0	2.0	3.0	3.0	3.0	3.0	3.0
root lesion nem. penetrans											1.8	3.0	3.0	3.0
root lesion nem. teres											3.0	3.0	3.0	3.0
root lesion nem. thornei	7.5	3.5	3.5	0.5	0.5	0.5	0.5	1.0	1.5	3.0	3.0	3.0	3.0	3.0
burrowing nem. nativus											3.0	3.0	3.0	3.0
burrowing nem. vangundyi													3.0	
BACTERIA														
bacterial blight	0.1	0.1	0.1	0.0	0.0									
bacterial stripe blight	0.1	0.3	0.3	0.0	0.0									
VIRUSES														
barley yellow dwarf	0.1	1.1	1.1	4.0	5.0	2.0	2.0	0.1	0.2	0.2	1.6	0.1	0.1	0.1
wheat streak mosaic		0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1

Table C6 Potential average annual yield losses (%) from barley diseases if current controls were not applied in 14 agro-ecological zones

Disease	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION			
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mall	SMNLYE	W SandM	WA Cen	WA N	WA E
NECROTROPHIC LEAF FUNGI														
Bipolaris spot blotch	0.1	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wirrega blotch	0.0	0.0	0.0	0.9	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
halo spot	0.0	0.0	0.0	1.1	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
barley stripe	0.0	0.0	0.0	25.2	25.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ring spot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
net blotch-spot form	0.2	8.5	3.6	6.0	5.0	28.5	28.5	14.3	9.5	6.0	5.8	8.0	4.8	0.5
net blotch-net form	0.4	12.0	4.1	8.1	7.0	0.0	0.0	0.0	1.1	10.0	2.1	8.0	8.0	4.8
scald	0.0	1.0	0.3	2.4	3.5	27.0	27.0	4.0	0.4	4.5	1.0	0.5	1.2	0.3
Septoria leaf blotch	0.0	0.0	0.0	0.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BIOTROPHIC LEAF FUNGI														
powdery mildew	1.3	2.9	1.6	3.6	1.8	3.5	3.5	2.8	0.5	0.5	6.4	16.7	4.8	4.8
rye stem rust	0.0	0.0	0.0	2.7	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wheat stem rust	0.0	0.6	0.5	2.7	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
stem rust	0.0	0.3	0.8	2.7	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
leaf rust	0.0	1.1	1.1	1.3	2.3	24.0	24.0	8.0	2.3	8.0	9.9	1.2	1.2	0.2
barley grass stripe rust	0.0	0.1	0.0	4.2	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
downy mildew	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ROOT AND CROWN FUNGI														
crown rot	10.2	16.1	15.0	4.1	2.1	3.0	3.0	6.0	6.8	7.5	4.2	2.0	0.0	0.3
take-all	0.0	0.0	0.0	0.9	0.8	3.0	3.0	0.4	0.6	0.8	2.5	2.0	1.2	0.2
Pythium root rot	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.1	1.1	2.0	0.2	0.5	0.3	0.2
Rhizoctonia barepatch	0.0	0.0	0.0	0.6	0.9	0.8	0.8	3.0	5.8	5.0	16.7	8.0	0.5	0.5
Eradu patch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	0.0
eyespot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
basal rot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
common root rot	6.9	5.2	3.2	2.5	1.5	1.0	1.0	3.8	4.3	4.8	0.0	0.0	0.0	0.0
INFLORESCENCE FUNGI														
ergot	0.0	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fusarium head blight	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
semi-loose smut	0.0	0.0	0.0	3.6	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
covered smut	0.3	0.3	0.2	16.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
loose smut	0.3	0.2	0.3	0.4	0.4	0.0	0.0	0.0	0.0	0.1	0.8	0.1	0.1	0.1
NEMATODES														
cereal cyst nematode	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	25.0	20.0	0.2	2.0	2.0	0.2
stunt nematode	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
stubby root nematode	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
root lesion nem. neglectus	0.0	1.6	1.3	0.5	0.5	10.0	10.0	5.0	7.5	10.0	8.0	8.0	8.0	8.0
root lesion nem. penetrans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.6	0.6
root lesion nem. teres	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	2.0	2.0
root lesion nem. thornei	2.9	2.7	2.7	0.5	0.5	3.0	3.0	1.5	1.9	3.8	0.6	0.6	0.6	0.6
burrowing nem. nativus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.2	1.2	1.2
burrowing nem. vangundyi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0
BACTERIA														
bacterial blight	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
bacterial stripe blight	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VIRUSES														
barley yellow dwarf	0.0	0.1	0.1	0.4	0.3	9.0	9.0	0.1	0.1	0.1	3.5	2.0	0.2	0.2
wheat streak mosaic	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0

APPENDIX D: FUNGICIDE COSTS

The proportion of the crop treated by each fungicide method was estimated by the respondents to the disease survey.

These plant pathologists are listed in Appendix B, Table B1.

Table D1 Usage and cost of fungicides on barley, by agro-ecological zone

% AREA TREATED															
	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION				TOTAL
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mall	SMNLYE	W SandM	WA Cen	WA N	WA E	
Seed (low rate)	65	53	53	25	20	10	10	27	35	60	25	20	30	40	35
Seed (high rate)	15	7	7	15	30	40	40	58	53	13	13	15	20	20	28
In-furrow only	0	0	0	0	0	4	4	3	3	5	5	5	0	0	3
Foliar only	0	10	8	20	20	2	2	1	1	2	15	20	15	5	9
Seed (low rate) + in-furrow	0	0	0	0	0	10	10	5	5	10	8	0	0	0	4
Seed (low rate) + foliar	5	10	7	5	10	20	20	2	1	7	13	30	10	5	10
Seed (low rate) + 2 foliar	0	0	0	0	0	10	10	1	0	0	13	5	5	0	2
Seed + in-furrow + foliar	0	0	0	0	0	3	3	1	1	3	3	0	0	0	1
No fungicide	15	20	25	35	20	1	1	2	2	0	8	5	20	30	9
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
EXPENDITURE ON FUNGICIDES (\$'000)															
	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION				TOTAL
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mall	SMNLYE	W SandM	WA Cen	WA N	WA E	
Seed (low rate)	3	269	68	75	84	11	1	269	459	659	133	222	48	66	2368
Seed (high rate)	2	78	20	105	295	102	14	1346	1622	333	155	388	75	77	4613
In-furrow only	0	0	0	0	0	33	4	284	364	610	273	569	0	0	2137
Foliar only	0	671	196	1103	1125	18	2	104	160	269	901	2503	273	93	7418
Seed (low rate) + in-furrow	0	0	0	0	0	92	12	523	794	1331	449	0	0	0	3202
Seed (low rate) + foliar	4	722	165	291	605	201	27	228	173	1017	817	4087	198	101	8636
Seed (low rate) + 2 foliar	0	0	0	0	0	190	25	218	0	0	1568	1307	190	0	3498
Seed + in-furrow + foliar	0	0	0	0	0	54	7	209	160	802	300	0	0	0	1532
No fungicide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	9	1740	449	1574	2110	701	93	3182	3732	5021	4596	9077	784	337	33,404
AREA TREATED ('000 ha)															
	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION				TOTAL
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mall	SMNLYE	W SandM	WA Cen	WA N	WA E	
Seed (low rate)	3	163	57	63	51	4	1	128	255	366	68	114	25	34	1330
Seed (high rate)	1	20	7	38	77	16	2	275	386	79	34	85	17	17	1054
In-furrow only	0	0	0	0	0	2	0	14	18	31	14	28	0	0	107
Foliar only	0	31	9	50	51	1	0	5	7	12	41	114	12	4	337
Seed (low rate) + in-furrow	0	0	0	0	0	4	1	24	36	61	20	0	0	0	146
Seed (low rate) + foliar	0	31	7	13	26	8	1	9	7	43	34	171	8	4	362
Seed (low rate) + 2 foliar	0	0	0	0	0	4	1	5	0	0	34	28	4	0	76
Seed + in-furrow + foliar	0	0	0	0	0	1	0	5	4	18	7	0	0	0	35
No fungicide	1	61	27	88	51	0	0	9	15	0	20	28	17	25	342
TOTAL	4	305	107	251	256	41	5	474	728	610	273	569	83	84	3790
Cost per hectare (\$)	2	6	4	6	8	17	17	7	5	8	17	16	9	4	9
Cost per hectare applied (\$)	3	7	6	10	10	17	17	7	5	8	18	17	12	6	10
Sowing rate (kg/ha)	40	55	40	40	55	90	90	70	60	60	65	65	65	65	60



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