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The Current and Potential Costs from Diseases of Wheat 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 wheat 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 wheat disease losses have been updated by a survey of wheat pathologists across Australia. An examination has been made of the present costs of wheat diseases and the potential costs if current control measures were not in place, as well as the value of controls including fungicide use and levels of disease resistance in the varieties grown. These figures provide key insights into the importance of wheat diseases in Australia.

Wheat diseases cause an estimated current average annual loss of $913 million, or $76.64 per hectare, to the Australian wheat industry. This loss is 19.5 per cent of the average annual value of the wheat crop over the past decade. Nationally, five diseases dominate these losses:

DISEASE	$/ha	$ million
Yellow spot	17.82	212
Stripe rust	10.62	127
Septoria nodorum blotch	9.07	108
Crown rot	6.63	79
Pratylenchus neglectus	6.13	73
Total losses from others	26.37	314
TOTAL PRESENT LOSS	76.64	913

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

DISEASE	$/ha	$ million
Stripe rust	83.43	994
Yellow spot	56.71	676
Cereal cyst nematode	48.04	572
Stem rust	40.09	478
Crown rot	36.44	434

This study provides up-to-date information on the potential and present losses from wheat diseases. The last such study was undertaken in 1998. Since then, there have been changes in wheat production methods and areas, and there is a possibility that the changes to climate particularly in the past 10 years have affected disease development.

The loss estimates were derived from a national survey of the incidence and severity of 41 wheat diseases. The information was collected from the 14 agro-ecological zones where wheat is grown in Australia, with the incidence and severity data in each zone supplied by 18 plant pathologists familiar with the diseases. These data were combined with data on area, production and value of the wheat crop to estimate the economic value of the losses.

The relative importance of different diseases varies from one part of the wheatbelt to another and from ranking by potential loss and ranking by present loss. Ten diseases make up the top five by loss across each of the three GRDC Regions ranked by potential and present loss. Table 1 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.

Table 1 Ranking of disease losses (1 = highest loss)

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Potential	Present	Potential	Present	Potential	Present	Potential	Present
Yellow spot	3	1	6	7	1	1	2	1
Stripe rust	1	2	2	1	5	5	1	2
Septoria nodorum	24	24	25	18	2	2	7	3
Crown rot	4	4	3	4	10	8	5	4
Root les. nem. neglectus	9	6	4	5	3	3	6	5
Rhizoctonia barepatch	26	26	10	3	4	4	10	6
Cereal cyst nematode	26	26	1	2	12	17	3	7
Root les. nem. thornei	5	3	13	10	15	14	9	8
Common bunt	11	14	5	12	9	12	11	16
Stem rust	2	9	7	21	7	10	4	17

Effective control means that, at the national level, stem rust changes from fourth place by potential loss to 17th place by present loss, while stripe rust is important in all Regions both by potential and present losses.

Septoria nodorum blotch, ranked second in both potential and present losses in the Western Region, is unimportant in the other Regions.

Common bunt ranks highly in the Southern Region 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 yellow spot and several other, generally more minor, diseases.

The current average loss of $913 million or 19.5 per cent of the value of production compares with the estimate of $438 million or 15.1 per cent of production made in 1998. This difference in percentage loss is likely to be within the error of the estimations. However, there have been some large differences in the average potential loss estimated for eight of 27 diseases that were assessed in both surveys.

We postulate that the potential loss from six diseases can be associated with changes in climatic conditions since the last survey. The increases in potential loss from stem rust and stripe rust could be caused by temperature increases that have occurred over much of the wheatbelt, while drier conditions could be associated with increased losses from crown rot. The drier conditions could be associated with a decline in potential loss by Septoria tritici blotch and take-all while warmer winter conditions may be associated with a decline in common bunt.

Climate change does not seem to be associated with the increase in yellow spot in the Western Region and cereal cyst nematode in the Southern Region and changes in these estimates may reflect new knowledge.

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, stem rust is controlled largely by breeding; crown rot and cereal cyst nematode by breeding and cultural methods; stripe rust by a combination of breeding and pesticides; and yellow spot by a combination of all three methods:

DISEASE	CONTROL VALUE	CONTRIBUTION TO CONTROL ($ million) BY:		
	($ million)	Breeding	Cultural	Pesticides
Stem rust	470	438	24	8
Crown rot	355	83	272	0
Cereal cyst nematode	514	377	137	0
Stripe rust	868	431	78	359
Yellow spot	463	200	155	108

As a control measure, the use of fungicides has increased in the past 10 years. Seed treatments are applied to 73 per cent of the national crop, in-furrow to 10 per cent and foliar sprays to 39 per cent, while 9 per cent receive no fungicides.

Genetic resistance to 12 diseases is used in one or more of the wheat breeding programs in Australia. Data on wheat variety deliveries and their disease reactions were used to calculate the proportions of the crop harvested in 2005-06 in each disease reaction class. In general, varieties with moderate to high levels of resistance to the diseases with higher potential loss were grown in each Region.

Overall, wheat 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 wheat production in Australia. Even after these measures have been taken to reduce losses, Australian farmers still suffer significant losses each year from wheat 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 judgments about the type and levels of controls to apply in their district.

This report estimates the status of wheat disease losses in the first decade of the 21st century. It demonstrates changes that have occurred and 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 wheat. 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.

Professor Richard Oliver provided the reactions of cultivars to toxins of *Phaeosphaeria nodorum* and *Pyrenophora tritici-repentis*. Dr Peter Martin provided disease resistance data for several older cultivars.

Our methodology draws on our previous work (Brennan and Murray 1989, 1998), which 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

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. In 1998, the losses from wheat diseases with controls being applied were estimated to average $438 million per year, while the potential losses from nine separate diseases, if there had been no controls, would each exceed $100 million per year (Brennan and Murray 1998).

Wheat is the most important crop in Australia in terms of the gross value of production. Consequently, it attracts a large proportion of 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).

The 1998 estimates of wheat disease losses have been used by the GRDC to decide on priorities for funding since that time. However, as the disease spectrum and the economic environment change in time, the estimates and the data on which they are made should be updated regularly. Since 1998, the area and value of the wheat crop have changed. Other factors that could have affected disease development and consequent losses include:

1. Introduction of new pathogens
2. Development of new pathogenic races
3. Changes in crop management practices
4. Changes in climate and/or seasonal conditions

In response to these concerns, the GRDC requisitioned this updating of the estimates of wheat disease losses. The following sections of this report describe the methodology, present the survey summarised 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 41 diseases included in the survey and their pathogens.

Section 3 – Production and climate in wheat growing areas of Australia Examines the reliability of the selected time period as representative of the longer-term wheat production and climate, and the observed changes in climate over the past decade.

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

Section 5 – Losses from wheat diseases in Australia Potential and present yield loss (%); effects on quality and its cost; value of the losses; comparison of these findings with those of the 1998 survey.

Section 6 – Value of control of wheat diseases The value of control by breeding, cultural methods and pesticides; comparison of the contribution to control of these three methods between 1998 and this survey.

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

Section 8 – Use of resistant cultivars in Australian wheat production A 'snapshot' of the proportion of wheat deliveries in 2005-06 with differing levels of resistance to 12 diseases.

Section 9 – Conclusions

Section 10 – References

Appendix A – Wheat production and seasonal rainfall data, 1998-99 to 2007-08

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

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

Appendix D – Fungicide costs

Appendix E – Varietal reactions to 12 diseases by GRDC region, 2005-06

The aim was to update the estimates of the importance of wheat 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.

James (1974) summarised two phases in disease-loss appraisal. The first is field experiments that characterise the relationship between disease and yield loss so that loss can be reliably estimated over a range of conditions. For example, Murray *et al*. (1994) estimated losses from stripe rust to wheat at two locations over four years and used fungicide treatments and cultivars varying in reaction to stripe rust to develop a yield loss relationship. Such relationships generally are only derived for diseases that are severe, and are usually specific to the location; reported relationships between stripe rust severity and yield vary widely between locations (Murray *et al.* 1994).

The second phase is assessment of disease with surveys over a number of fields. This phase requires considerable resources to provide information over a large area and over time. It is done in England for several major crops. Samples are collected in a frequency corresponding to the proportion of the district's crop area, in the case of wheat, at the early to medium milk stage of grain development. Diseases present are identified and their incidence and severity recorded, and the relationship between disease level and yield used to estimate yield loss each year. Changes in disease loss between years can be related to region, seasonal conditions, cultivars, cropping history and crop management, and use of fungicides (Hardwick *et al*. 2001).

The English survey began in 1970 and provides highly detailed and precise information on losses from crop diseases (Hardwick *et al.* 2001) but such comprehensive assessments are rarely done in most countries because of the resources required. Quite simply, the experiments and observations required to fully satisfy James (1974) are frequently incomplete. In these cases, Zadoks and Schein (1979) argue that it is necessary to use the estimates of experts who "have built up enough experience to have some feeling for the effects of injuries and the resulting damages to the crop".

Brennan and Murray (1989, 1998) and Dubin and Van Ginkel (1990) used surveys and opinions of experts in the field to estimate wheat disease losses from national and international crop areas. Although this approach lacks the high precision of the detailed experimental method, it permits estimates over large areas and comparison of the likely losses from each disease.

The key processes involved in estimating the value of loss from diseases for a crop in Australia 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 first economic estimates of all wheat disease losses in Australia were made by Brennan and Murray (1989). These were estimated at the state level with the exception of NSW, which was divided into north and south. This level of aggregation meant that the geographic distribution of each disease was imprecise, particularly for those pathogens that affect particular areas within a state. Those estimates were extended and updated in Brennan and Murray (1998). For the 1998 estimates, respondents were asked to use their preferred regions within a state, which gave 23 regions for the Australian

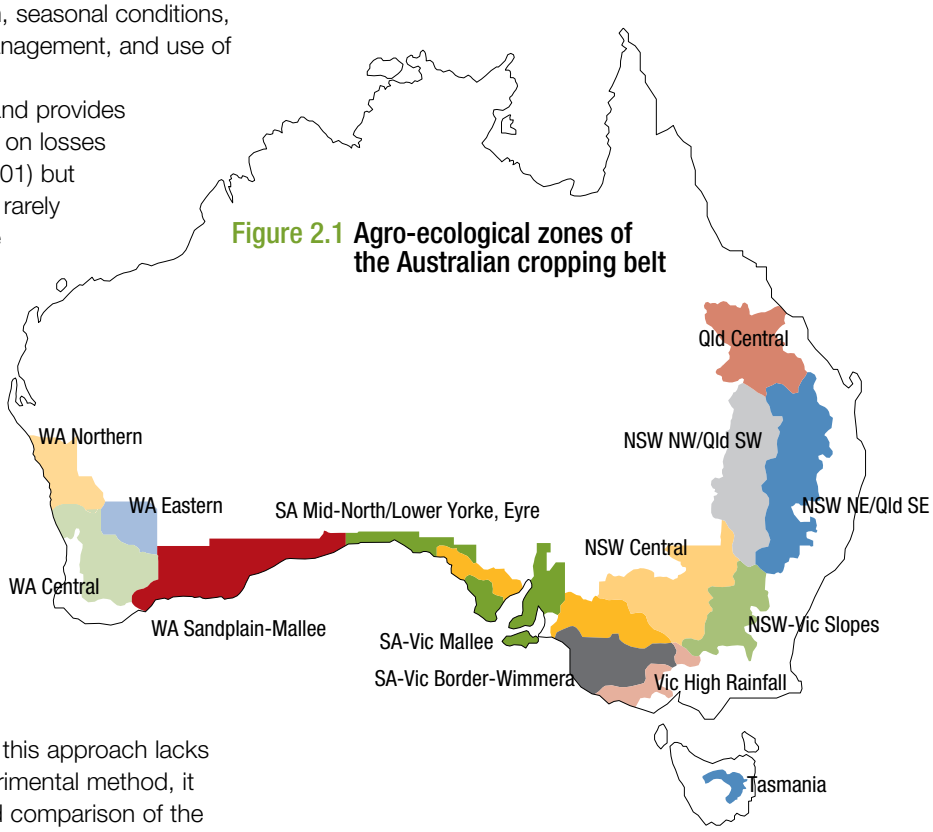


Figure 2.1 Agro-ecological zones of the Australian cropping belt

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

wheatbelt. The use of these regions allowed a more sensitive estimate of the losses caused by the different pathogens.

Subsequently, GRDC has adopted 'agro-ecological zones' to divide the cropping belt of Australia into areas of similar climate. There are 14 such zones growing wheat, which are grouped into three production regions (Figure 2.1, Table 2.1), and these zones and regions are used in this study. The agro-ecological zones broadly correspond with the regions used for the 1998 estimations.

2.3 Crop production data

In this study, we estimate disease losses to wheat for current production environments. Data for wheat 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.

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. However, the same disease may be called by different names and so 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 wheat 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 wheat 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 wheat growing zones of Australia. However, the frequency that they cause visible disease damage varies between zones and regions. Pathogens can be and frequently are present in an area without causing significant disease. This report seeks to estimate these frequencies and losses under the present 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).

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.

Severity is the loss caused by the disease in a year

favourable for its development. It is assessed on a per paddock basis.

The previous surveys (Brennan and Murray 1989, 1998) used classification scores to rate the incidence and severity of damage. These were then converted to frequency of years of damage and likely losses in those years.

Tables 2.3 and 2.4 show how class data for incidence and severity are transformed to frequency of years, proportion of area and disease loss.

With improved data on yield loss relationships and more recent field surveys, improved knowledge of the actual losses caused by some pathogens has become available, so that quantitative data are now available for some diseases.

Table 2.2 Wheat diseases and their pathogens in Australia

PATHOGEN	DISEASE
NECROTROPHIC LEAF FUNGI	
Cochliobolus sativus	Bipolaris leaf spot
Drechslera wirreganensis	Wirrega blotch
Mycosphaerella graminicola	Septoria tritici blotch
Phaeosphaeria avenaria f.sp. *triticea*	Septoria avenae blotch
Phaeosphaeria nodorum	Septoria nodorum blotch
Pyrenophora semeniperda	Ring spot
Pyrenophora tritici-repentis	Yellow spot
BIOTROPHIC LEAF FUNGI	
Blumeria graminis f.sp. *tritici*	Powdery mildew
Puccinia graminis f.sp. *tritici*	Stem rust
Puccinia triticina	Leaf rust
Puccinia striiformis	Stripe rust
Sclerophthora macrospora	Downy mildew
Urocystis agropyri	Flag smut
ROOT AND CROWN FUNGI	
Fusarium culmorum	Foot rot
Fusarium pseudograminearum	Crown rot
Gaeumannomyces graminis var. *tritici*	Take-all
Pythium spp.	Damping off/root rot
Rhizoctonia solani	Barepatch
Tapesia yallundae	Eyespot
Wojnowicia graminis	Basal rot
Cochliobolus sativus	Common root rot
INFLORESCENCE FUNGI	
Claviceps purpurea	Ergot
Fusarium graminearum	Fusarium head blight (scab)
Tilletia laevis, Tilletia caries	Common bunt
Ustilago tritici	Loose smut
NEMATODES	
Anguina tritici	Seed gall nematode
Heterodera avenae	Cereal cyst nematode
Merlinius brevidens	Stunt nematode
Pratylenchus crenatus	Root lesion nem. crenatus
Pratylenchus neglectus	Root lesion nem. neglectus
Pratylenchus penetrans	Root lesion nem. penetrans
Pratylenchus teres	Root lesion nem. teres
Pratylenchus thornei	Root lesion nem. thornei
Radopholus nativus	Burrowing nem. nativus
Radopholus vangundyi	Burrowing nem. vangundyi
BACTERIA	
Pseudomonas syringae pv. *atrofaciens*	Basal glume rot
Pseudomonas syringae pv. *syringae*	Bacterial leaf blight
Xanthomonas campestris pv. *translucens*	Black chaff
VIRUSES	
Barley yellow dwarf virus	Barley yellow dwarf
High Plains virus	High Plains disease
Wheat streak mosaic virus	Wheat streak mosaic

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

In contrast to the 1998 survey, the 2008 survey allowed the respondent to enter data of incidence and severity either as a class score (Tables 2.3 and 2.4) or as quantitative values where they consider this information to be more reliable than the score assessment. In the 2008 survey, respondents were asked to consider any recent changes in rainfall and temperature patterns in assessing incidence and severity (see Section 3 for a discussion of recent temperature and rainfall trends).

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

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, for example, 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. 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 40 per cent while current loss where most varieties grown are resistant is 5 per cent. Thus, potential severity is 40 per cent while current severity is 5 per cent. The average potential yield loss is (9 per cent incidence × 40 per cent severity) or 3.6 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, severe disease may develop following wet winters, which occur in 25 per cent of years, affecting early sown crops, once again occupying

Table 2.5 Relationship between severity and grade of wheat

DISEASE	SEVERITY %					
	0.0%	>0.0%–0.2%	>0.2%–1.0%	>1.0%–5.0%	>5.0%–20.0%	>20.0%
Yellow spot	ASW[a]	ASW	ASW	ASW	GP[b]	Feed[c]
Ergot	ASW	ASW	GP	Farm[d]	Farm	Farm
Scab	ASW	ASW	GP	Feed	Farm	Farm
Common bunt	ASW	GP	Farm	Farm	Farm	Farm
Loose smut	ASW	ASW	ASW	ASW	Farm	Farm
Seed gall nematode	ASW	GP	Feed	Farm	Farm	Farm

a ASW = Australian Standard White
b GP = General Purpose
c Feed = feed grade
d Farm = Not received in any grade, but usable as feed on farm. Valued at 25% below feed grade.

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). 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 reduce yield. In cases such as common bunt and ergot, a detectable level of disease can result in the grain being rejected from delivery with a high monetary loss even though the yield loss from the pathogen is negligible. 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 wheat 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).

Table 2.6 Relationship between severity and price discount ($/t) for wheat

DISEASE	SEVERITY %					
	0.0%	>0.0%–0.2%	>0.2%–1.0%	>1.0%–5.0%	>5.0%–20.0%	>20.0%
Yellow spot	0.00	0.00	0.00	0.00	8.22	33.34
Ergot	0.00	0.00	8.22	63.66	63.66	63.66
Scab	0.00	0.00	8.22	33.34	63.66	63.66
Common bunt	0.00	8.22	63.66	63.66	63.66	63.66
Loose smut	0.00	0.00	0.00	0.00	63.66	63.66
Seed gall nematode	0.00	8.22	63.66	63.66	63.66	63.66

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.

For the pesticides category, the survey sought information 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 were collected from plant pathologists familiar with wheat diseases in the agro-ecological zones. In all, 28 responses from 18 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

2.8.1 Size of yield losses from a disease

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 percentage disease loss from a disease is measured from the notional without-disease yield. Thus a 10 per cent yield loss from a disease means that current yields are 90 per cent (that is, 100 per cent – 10 per cent) of the yield that would have been achieved without that disease.

Algebraically, for each disease we have:

$$(1)\quad Y_c = Y_0\,(100 - K_c)/100,$$

where Y_c is the current observed yield (t/ha) in the presence of disease and current controls; Y_0 is the yield (t/ha) without the disease; and K_c is the percentage current loss caused by the disease.

Since we have data on Y_c and K_c, we calculate Y_0 as follows:

$$(2)\ Y_0 = Y_c / ((100 - K_c)/100),$$

From these, we have the quantity of the loss from a disease, on a per-hectare basis, is

$$(3)\ L_c = Y_0 - Y_c$$
$$= Y_c / ((100 - K_c)/100) - Y_c$$
$$= Y_c (K_c / (100 - K_c)),$$

where Y_c is the yield loss (t/ha) in the presence of current controls.

2.8.2 Value of current yield losses

The value of the current yield loss is calculated as:

$$(4)\ V_c = P L_c ,$$
$$= P Y_c (K_c / (100 - K_c))$$

where V_c is the value of the yield loss per hectare ($/ha); and P is the price ($/t).

2.8.3 Value of potential yield losses

The potential yield loss is also measured from the disease-free yield (Y_0). Thus we have:

$$(5)\ L_p = Y_0 (100 - K_p)/100,$$

where L_p is the potential yield loss (t/ha) without any controls; and K_p is the percentage potential loss caused by the disease. Substituting for Y_0 from equation (2) above, and simplifying, we have:

$$(6)\ L_p = Y_c ((100 - K_p)/100) / ((100 - K_p)/100)$$
$$= Y_c (100 - K_p)/(100 - K_c).$$

Correspondingly, the value of the potential loss per hectare

$$(7)\ V_p = P L_p$$
$$= P Y_c (100 - K_p)/(100 - K_c),$$

where V_p is the value of the potential yield loss per hectare ($/ha).

2.8.4 Value of quality losses from a disease

Some diseases can affect the quality or marketability of the output (and therefore price), as well as (or rather than) the quantity produced. Grain receival standards using in grain marketing mean that the presence of diseased kernels or spores in harvested grain can lead to the grain being down-graded to a lower grade (and therefore receive a lower price) or sometimes to a refusal to allow the grain to be marketed (see Section 2.5).

Where a disease results in a lower price per tonne (see Section 2.5), the price discount can be calculated from the difference in the prices for the different grades. The loss in value is calculated as follows:

$$(8)\ Q_c = D_c Y_c ,$$

where Q_c is the value of current quality losses ($/ha); and D_c is the price discount ($/t) due to the disease with current levels of severity.

Similarly, potential loss in value from quality is calculated as

$$(9)\ Q_p = D_p Y_p ,$$

where Q_p is the value of current quality losses ($/ha); and D_p is the price discount ($/t) due to the disease with current levels of severity.

In addition, any widespread disease control can also have an impact on the price received, if the demand curve faced by the producers is less than perfectly elastic (that is, if the producers are not pure price takers). If that were the case, the price received for all output after the disease was controlled would be lower than that received for a smaller output in the presence of disease, since the extra quantity available on the market would depress the price received. In this study, the market is assumed to have perfectly elastic demand, so that the only price effects taken into account are those resulting from the direct quality effects on marketability.

2.8.5 Value of economic losses

The total losses from a disease are then the combination of the yield and quality losses. We have:

$$(10)\ F_c = V_c + Q_c ,$$

$$(11)\ F_p = V_p + Q_p ,$$

where F_c and F_p are, respectively, the current and potential economic losses ($/ha) from a disease.

The aggregate value of the losses from a disease in a production zone is calculated by relating the per-hectare cost to the number of hectares of the crop sown in that production zones. Thus, the aggregate value is:

$$(12)\ G_c = A F_c ,$$

$$(13)\ G_p = A F_p ,$$

where Gc and G_p are, respectively, the current and potential aggregate losses (in $) of the disease across a production zone; and A is the area of the crop in the production zone (hectares).

2.8.6 Value of current disease control measures

The value of the current control measures is shown by the difference between the outcome if there were no controls and the outcome with current controls in place. Thus:

$$(14)\quad C = G_c - G_p ,$$

where C is the aggregate value ($) of current control measures.

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.

2.8.7 Summation of disease losses

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 AND CLIMATE IN WHEAT GROWING AREAS OF AUSTRALIA

3.1 Introduction

Wheat is grown throughout the annual 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 following 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 wheat 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.

The previous estimates of wheat disease losses (Brennan and Murray 1989, 1998) were based on average climatic conditions at the time. There is now conclusive evidence showing major changes in rainfall and temperature throughout the wheat growing areas. Rainfall data for each zone from 1998 to 2008 were provided by Neil Clark and Associates. The Commonwealth Bureau of Meteorology (2009) states:

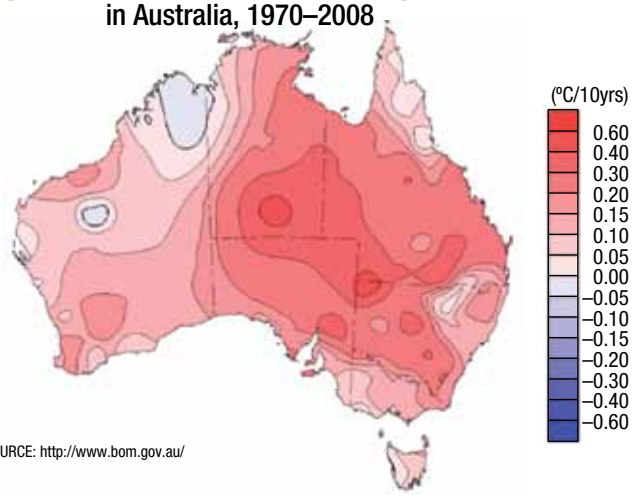
> "Australia and the globe are experiencing rapid climate change. Since the middle of the 20th century, Australian temperatures have, on average, risen by about 1°C with an increase in the frequency of heatwaves and a decrease in the numbers of frosts and cold days. Rainfall patterns have also changed – the northwest has seen an increase in rainfall over the past 50 years while much of eastern Australia and the far southwest have experienced a decline."

This section describes in brief the changes in climatic conditions, particularly those that could influence the development of wheat and its diseases. We evaluated the wheat production data from 1998-99 for its suitability as 'baseline data' on which to estimate the value of disease losses.

3.2 Temperature trends

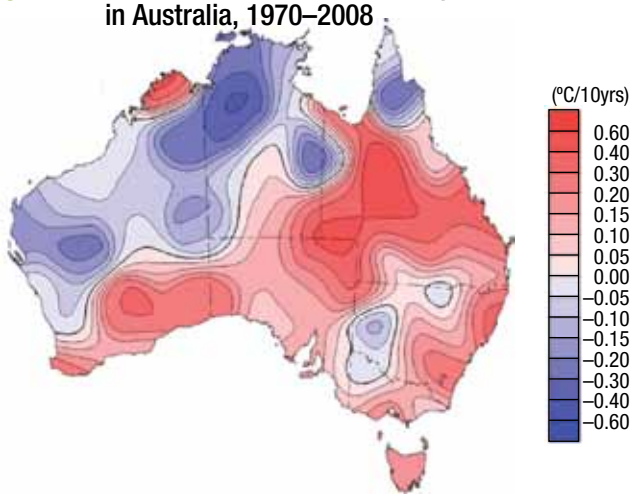
Maximum and minimum temperatures for each season have increased throughout the Australian wheatbelt since 1970 (Australian Bureau of Meteorology 2009). Overall, the mean annual temperature has increased by 0.05 to 0.30°C per decade since 1970 (Figure 3.1). Such temperature rises would be expected to affect the rates of development of

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



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 wheatbelt (Figure 3.2). Since the rate of development of stripe rust increases at temperatures below about 16°C (Ellison and Murray 1992), this rise may increase the incidence and severity of this disease. The warmer winter may also increase the survival and activity of virus vectors, and thus affect the development of diseases such as barley yellow dwarf and wheat streak mosaic virus.

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, but that this may have changed after 2000. Since 1970, annual rainfall has decreased in the eastern and most south-western wheat 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 wheatbelt.

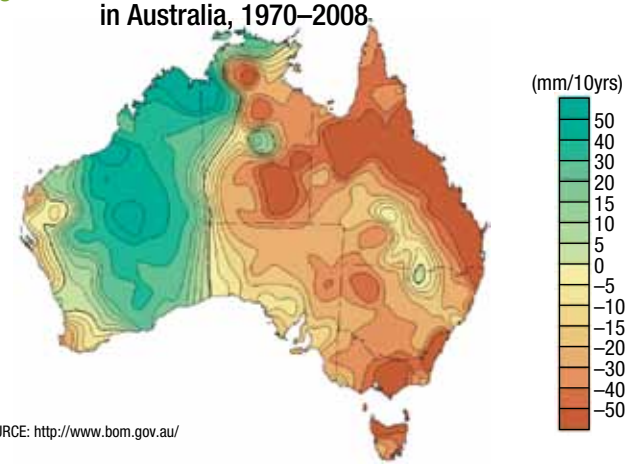
Changes in the distribution of rainfall could also be important for disease development. For example, there has been a reduction in autumn rainfall in much of the eastern wheatbelt (Figure 3.4). This is likely to affect the sowing date for crops, generally resulting in later sowing. This in turn would affect such diseases as Septoria tritici blotch, which decreases in severity with later sowing (Murray *et al.* 1990) and take-all, which requires 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 Wheat production data

Wheat 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

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

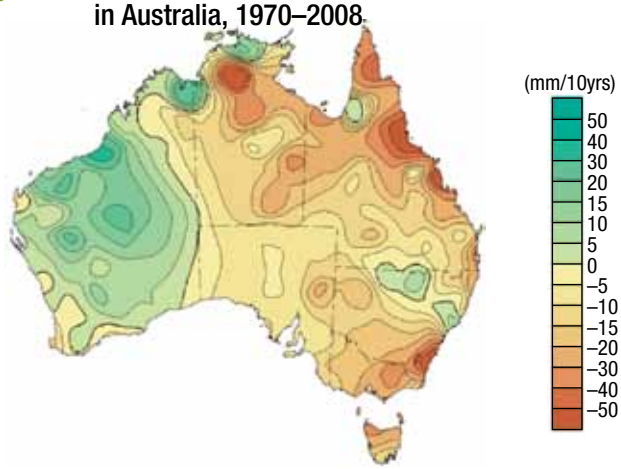


Table 3.1 Mean wheat area, yield, production and value, by agro-ecological zone, 1998-99 to 2007-08

	AREA ('000 ha)	YIELD (t/ha)	PRODUCTION ('000 t)	GROSS VALUE ($ million)
Queensland Central	159	1.65	262	63
NSW North-East/Queensland South-East	1199	1.88	2258	539
NSW North-West/Queensland South-West	878	1.34	1177	281
TOTAL NORTHERN REGION	**2236**	**1.65**	**3697**	**883**
NSW Central	983	1.52	1490	356
NSW–Victoria Slopes	1117	2.04	2275	543
Victoria High Rainfall	75	2.61	197	47
Tasmania	5	3.43	17	4
SA–Victoria Border–Wimmera	521	1.97	1028	245
SA–Victoria Mallee	1651	1.24	2054	490
SA Mid-North/Lower Yorke, Eyre	849	2.00	1701	406
TOTAL SOUTHERN REGION	**5202**	**1.68**	**8763**	**2092**
WA Sandplain–Mallee	342	1.84	631	151
WA Central	2099	1.72	3611	862
WA Northern	1054	1.56	1642	392
WA Eastern	983	1.28	1259	301
TOTAL WESTERN REGION	**4478**	**1.60**	**7143**	**1705**
TOTAL AUSTRALIA	**11,916**	**1.65**	**19,603**	**4680**

one individual year's data. To provide a representative set of data, the average of the ten years to 2007-08 were selected from the available data. 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 wheat in each agro-ecological zone where the crop is grown are shown in Appendix A, Table A1 for each year from 1998-99 to 2007-08.

The average area, yield and production of wheat in each zone are shown in Table 3.1, calculated from those annual data. In the period 1998-99 to 2007-08, the average wheat area sown in Australia was 11.9 million hectares, and average production was 19.6 million tonnes, giving an overall average yield of 1.65 t/ha. The production was spread unevenly throughout the 14 zones, with production ranging from 17,000 tonnes in Tasmania to 3.6 million tonnes in the WA Central zone. On average, the Southern Region (8.8 million tonnes) produced more than the Western Region (7.1 million tonnes), while the Northern Region produced 3.7 million tonnes each year (Table 3.1). The mean unit value of wheat over that period was $238.71/t (see Appendix A, Table A2 for annual data), giving an average gross value of production of $4680 million.

3.5 Representativeness of selected period based on rainfall deciles

To assess how representative the selected period is of conditions over the longer term, the annual rainfall for the period 1998 to 2007 was expressed as a decile range based on long-term data (1900 to 2008). A decile of 2, for example, indicates that annual rainfall will be less than that year in only two years out of 10; thus a decile of 5 means that year's rainfall was at or close to average. This showed that the mean annual rainfall for each of the agro-ecological zones for the period 1998 to 2007 lies in deciles 5-6 in each zone except for southern and western Victoria and eastern SA, where it was in decile 4, and in WA Sandplain-Mallee and WA Eastern where it was above average in decile 7 (Appendix A, Table A4). At the regional level, 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. More detailed rainfall data and rainfall deciles for the selected years are shown in Appendix A, Table A4.

Table 3.2 Annual rainfall deciles by GRDC Region, 1998 to 2007*

REGION	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	MEAN 98-07
Northern Region	10	9	7	4	1	4	8	4	1	6	5
Southern Region	7	7	8	5	1	6	4	6	1	5	5
Western Region	7	10	6	5	1	7	3	6	5	3	5

* Calculated as a weighted mean of the deciles for the zones in each region (see Appendix A, Table A4), weighted by average area sown.

4. INCIDENCE AND SEVERITY OF WHEAT DISEASES IN AUSTRALIA

4.1 Distribution of the pathogens

This survey studied the distribution of 25 fungal diseases, 10 pathogenic nematodes, three bacterial diseases and three viral diseases of wheat in the 14 agro-ecological zones where wheat is grown in Australia.

Some of the pathogens were widely distributed, with 10 being reported present in all zones and a further 12 present in more than 10 zones. Others had a much more restricted reporting, 11 being reported present in 4 or fewer zones (Appendix B, Tables B2 to B15). Within the GRDC regions, the Southern Region had the largest number of pathogens with 36 reported, while there were 32 of the 41 assessed present in the Northern and Western Regions (Table 4.1)

Across zones, the widely reported diseases included the readily observable and identifiable foliar diseases stem, leaf and stripe rust, powdery mildew, Septoria tritici and Septoria nodorum blotches, yellow spot and flag smut. 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 damping off/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, while eyespot and basal rot seem to be restricted to some areas of southern Australia (Appendix C, Table C1).

The seed-replacing diseases common bunt and loose smut were reported in all zones while ergot 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. The seed gall nematode is restricted to Western Australia and portions of South Australia but is now seldom recorded (Appendix C, Table C1). Projects specifically targeting root attacking nematodes are finding additional root lesion nematodes in Western Australia and burrowing nematodes in Queensland.

Although three 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. The next two virus diseases were not identified as present in Australia until 2003. Wheat streak mosaic is now known to occur in all zones except Queensland Central, while High Plains disease, which often occurs with wheat streak mosaic, has only been reported in four eastern zones (Appendix C, Table C1).

4.2 Incidence of wheat 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 wheat 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 wheat 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 15 diseases occurred over 25 per cent or more of the crop area in years favourable for their development (Table 4.2). The root lesion nematode *Pratylenchus neglectus* occurred with highest yearly incidence, 73.6 per cent, with crown rot, stripe rust and yellow spot also over 70 per cent. *P. neglectus*, stripe rust and yellow spot also affected more than 70 per cent of the crop area while crown rot affected 42 per cent of the crop area.

Within regions, crown rot occurred with highest frequency of years in the Northern Region, stripe rust in the Southern Region, and Septoria nodorum blotch, yellow spot, *P. neglectus* and *P. teres* in the Western Region. Yellow spot affected the largest proportion of the area in the Northern Region, *P. neglectus* in the Southern Region, and Septoria nodorum blotch and yellow spot in the Western Region (Table 4.2).

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

For Australia, the disease with maximum potential severity in the year favourable for its development was stem rust, with a potential yield loss of 46.3 per cent, followed by stripe rust with 34.6 per cent and crown rot with 24.6 per cent. In contrast, with current disease controls in place, the disease with the highest present severity was wheat streak mosaic, causing an average 6.0 per cent yield loss in years favourable for its development. This was followed by *P. thornei* with 5.3 per cent and Septoria nodorum blotch with 5.2 per cent

Stem rust also had the highest potential yield loss in each region, with 78.4 per cent in the Northern, 50.8 per cent in the Southern and 25.0 per cent in the Western. However, for current severity, the highest in the Northern Region was *P. thornei* (17.9 per cent), in the Southern, wheat streak mosaic (11.1 per cent), and in the Western, Septoria nodorum blotch and yellow spot, both with 9.0 per cent (Table 4.3).

Table 4.1 Presence[a] of pathogens causing wheat disease in the GRDC Regions and Australia

DISEASE[b]	NORTHERN	SOUTHERN	WESTERN	AUSTRALIA
NECROTROPHIC LEAF FUNGI				
Bipolaris leaf spot	Y	Y	Y	Y
Wirrega blotch	U	Y	U	Y
Septoria tritici blotch	Y	Y	Y	Y
Septoria avenae blotch	N	Y	Y	Y
Septoria nodorum blotch	Y	Y	Y	Y
Ring spot	Y	Y	Y	Y
Yellow spot	Y	Y	Y	Y
BIOTROPHIC LEAF FUNGI				
Powdery mildew	Y	Y	Y	Y
Stem rust	Y	Y	Y	Y
Leaf rust	Y	Y	Y	Y
Stripe rust	Y	Y	Y	Y
Downy mildew	Y	Y	Y	Y
Flag smut	Y	Y	Y	Y
ROOT AND CROWN FUNGI				
Foot rot	Y	Y	Y	Y
Crown rot	Y	Y	Y	Y
Take-all	Y	Y	Y	Y
Damping off/root rot	Y	Y	Y	Y
Rhizoctonia barepatch	U	Y	Y	Y
Eyespot	N	Y	N	Y
Basal rot	Y	Y	U	Y
Common root rot	Y	Y	Y	Y
INFLORESCENCE FUNGI				
Ergot	Y	Y	Y	Y
Fusarium head blight	Y	Y	Y	Y
Common bunt	Y	Y	Y	Y
Loose smut	Y	Y	Y	Y
NEMATODES				
Seed gall nematode	Y	Y	Y	Y
Cereal cyst nematode	U	Y	Y	Y
Stunt nematode	Y	U	U	Y
Root lesion nem. crenatus	Y	Y	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	Y	U	Y	Y
BACTERIA				
Basal glume rot	U	Y	N	Y
Bacterial leaf blight	Y	Y	N	Y
Black chaff	Y	Y	N	Y
VIRUSES				
Barley yellow dwarf	Y	Y	Y	Y
High Plains disease	Y	Y	N	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

Table 4.2 Incidence of wheat 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 leaf spot	20.0	25.0	5.8	3.0	0.0	0.0	6.3	6.0
Wirrega blotch	0.0	0.0	48.1	0.5	0.0	0.0	21.0	0.2
Septoria tritici blotch	0.0	0.0	24.3	17.1	1.5	1.9	11.2	8.2
Septoria avenae blotch	0.0	0.0	2.0	2.0	0.0	0.0	0.9	0.9
Septoria nodorum blotch	18.6	23.2	5.1	4.3	66.7	100.0	30.8	43.8
Ring spot	0.0	0.0	69.7	24.7	20.0	25.0	38.0	20.2
Yellow spot	55.8	84.3	79.8	39.1	66.7	100.0	70.4	70.5
BIOTROPHIC LEAF FUNGI								
Powdery mildew	37.3	25.0	68.2	5.4	59.0	25.0	58.9	16.4
Stem rust	66.9	75.7	18.4	52.2	35.3	25.0	33.9	46.4
Leaf rust	66.9	53.2	30.4	56.5	24.7	25.0	35.1	44.0
Stripe rust	91.2	79.2	84.2	80.7	46.9	60.2	71.5	72.7
Downy mildew	20.0	25.0	3.0	0.2	4.4	5.5	6.7	6.8
Flag smut	38.6	25.0	25.7	8.4	29.1	25.0	29.4	17.7
ROOT AND CROWN FUNGI								
Foot rot	37.1	23.2	62.6	13.9	15.3	19.1	40.0	17.6
Crown rot	99.3	37.4	81.2	58.2	49.8	25.0	72.8	41.8
Take-all	37.1	23.2	74.9	32.1	49.1	25.0	58.1	27.8
Damping off/root rot	35.9	25.0	68.2	63.2	49.1	25.0	55.0	41.7
Rhizoctonia barepatch	0.0	0.0	76.0	50.5	60.8	65.9	56.0	46.8
Eyespot	0.0	0.0	11.9	9.5	0.0	0.0	5.2	4.1
Basal rot	0.0	0.0	2.0	4.0	0.0	0.0	0.9	1.8
Common root rot	83.0	43.4	69.9	65.6	4.7	5.9	47.9	39.0
INFLORESCENCE FUNGI								
Ergot	7.9	9.8	12.3	10.1	1.5	1.9	7.4	7.0
Fusarium head blight	27.9	25.0	2.8	7.1	1.5	1.9	7.0	8.5
Common bunt	20.0	25.0	55.6	11.8	20.0	25.0	35.5	19.2
Loose smut	40.0	70.6	58.6	26.6	20.0	25.0	40.6	34.2
NEMATODES								
Seed gall nematode	0.0	0.0	0.5	0.2	18.5	23.1	7.2	8.8
Cereal cyst nematode	0.0	0.0	79.0	58.5	53.6	25.0	54.7	34.9
Stunt nematode	83.6	10.4	0.0	0.0	0.0	0.0	15.7	2.0
Root lesion nem. crenatus	0.0	0.0	0.5	0.0	0.0	0.0	0.2	0.0
Root lesion nem. neglectus	77.4	12.5	78.0	84.7	66.7	97.1	73.6	75.8
Root lesion nem. penetrans	0.0	0.0	0.0	0.0	20.0	25.0	7.5	9.4
Root lesion nem. teres	0.0	0.0	0.0	0.0	66.7	25.0	25.1	9.4
Root lesion nem. thornei	83.8	28.2	78.0	39.1	20.0	25.0	57.3	31.7
Burrowing nem. nativus	0.0	0.0	0.0	0.0	38.5	25.0	14.5	9.4
Burrowing nem. vangundyi	0.0	0.0	0.0	0.0	9.4	5.9	3.5	2.2
BACTERIA								
Basal glume rot	0.0	0.0	2.0	2.0	0.0	0.0	0.9	0.9
Bacterial leaf blight	20.0	25.0	2.0	2.0	0.0	0.0	4.6	5.6
Black chaff	0.0	0.0	2.0	2.0	0.0	0.0	0.9	0.9
VIRUSES								
Barley yellow dwarf	43.6	25.0	78.2	11.7	47.3	27.9	60.1	20.3
High Plains disease	18.6	23.2	16.1	5.1	0.0	0.0	10.5	6.6
Wheat streak mosaic	37.1	23.2	70.2	12.0	35.3	41.5	50.9	25.2

Table 4.3 Potential and present severity of wheat 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 leaf spot	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Wirrega blotch	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.0
Septoria tritici blotch	0.0	0.0	18.0	1.0	0.0	0.0	7.9	0.4
Septoria avenae blotch	0.0	0.0	4.0	4.0	0.0	0.0	1.8	1.8
Septoria nodorum blotch	0.1	0.1	11.3	4.0	19.3	9.0	12.2	5.2
Ring spot	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Yellow spot	41.7	9.4	11.2	3.3	19.3	9.0	20.0	6.6
BIOTROPHIC LEAF FUNGI								
Powdery mildew	10.2	2.6	4.0	0.1	2.9	0.4	4.7	0.7
Stem rust	78.4	0.7	50.8	0.0	25.0	3.0	46.3	1.3
Leaf rust	31.4	2.2	22.5	0.1	22.1	3.0	24.0	1.6
Stripe rust	63.1	7.5	38.5	4.1	15.8	5.0	34.6	5.1
Downy mildew	0.1	0.1	5.4	5.4	0.0	0.0	2.4	2.4
Flag smut	24.1	0.1	29.0	0.0	7.1	0.1	19.8	0.1
ROOT AND CROWN FUNGI								
Foot rot	11.1	2.8	8.4	3.3	0.1	0.1	5.8	2.0
Crown rot	60.1	12.0	21.8	4.4	10.2	1.8	24.6	4.8
Take-all	0.5	0.5	17.8	2.0	10.5	1.8	11.8	1.6
Damping off/root rot	0.8	0.8	4.4	3.7	2.9	1.0	3.1	2.2
Rhizoctonia barepatch	0.0	0.0	8.4	3.3	7.9	1.9	6.6	2.2
Eyespot	0.0	0.0	12.9	1.2	0.0	0.0	5.6	0.5
Basal rot	0.0	0.0	4.0	0.4	0.0	0.0	1.8	0.2
Common root rot	10.5	2.6	12.5	2.8	0.0	0.0	7.4	1.7
INFLORESCENCE FUNGI								
Ergot	0.2	0.2	10.7	0.0	0.0	0.0	4.7	0.0
Fusarium head blight	0.3	0.3	0.3	0.0	0.0	0.0	0.2	0.1
Common bunt	16.4	0.1	32.4	0.0	12.0	0.1	21.7	0.1
Loose smut	19.9	0.1	9.0	0.0	0.4	0.0	7.8	0.0
NEMATODES								
Seed gall nematode	0.0	0.0	0.5	0.0	0.1	0.0	0.2	0.0
Cereal cyst nematode	0.0	0.0	30.1	4.9	9.3	0.5	16.6	2.3
Stunt nematode	0.6	0.6	0.0	0.0	0.0	0.0	0.1	0.1
Root lesion nem. crenatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Root lesion nem. neglectus	23.1	9.4	6.3	1.8	12.0	3.0	11.6	3.7
Root lesion nem. penetrans	0.0	0.0	0.0	0.0	11.3	2.8	4.3	1.1
Root lesion nem. teres	0.0	0.0	0.0	0.0	12.0	3.0	4.5	1.1
Root lesion nem. thornei	49.3	17.9	10.3	1.8	12.0	3.0	18.3	5.3
Burrowing nem. nativus	0.0	0.0	0.0	0.0	12.0	3.0	4.5	1.1
Burrowing nem. vangundyi	0.0	0.0	0.0	0.0	2.8	0.7	1.1	0.3
BACTERIA								
Basal glume rot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bacterial leaf blight	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Black chaff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
VIRUSES								
Barley yellow dwarf	0.8	0.8	3.0	1.1	3.3	0.1	2.7	0.7
High Plains disease	0.1	0.1	2.0	2.0	0.0	0.0	0.9	0.9
Wheat streak mosaic	2.0	1.7	11.7	11.1	18.1	2.2	12.3	6.0

5. LOSSES FROM WHEAT 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 20.8 per cent was from stripe rust. Within GRDC regions, stripe rust also caused the highest potential loss of 44.3 per cent in the Northern Region. Cereal cyst nematode caused the highest potential loss of 28.1 per cent in the Southern Region while Septoria nodorum blotch and yellow spot were highest at 12.9 per cent in the Western Region (Table 5.1, see p. 22).

Other diseases that potentially can cause losses of more than 5 per cent in one or more regions are the fungal leaf diseases stem rust and leaf rust, the root and crown fungal disease crown rot, and the root lesion nematodes *Pratylenchus neglectus* and *P. thornei* (Table 5.1, see p. 22).

Within individual agro-ecological zones, some other diseases can cause potential losses of more than 5 per cent. Common bunt exceeds this in the NSW Central zone, take-all in the NSW-Victoria Slopes, Victoria High Rainfall and Tasmania zones, foot rot in the Victoria High Rainfall and Tasmania zones, Rhizoctonia barepatch in the SA-Victoria Mallee, SA Mid-North/Lower Yorke, Eyre, WA Sandplain-Mallee, and WA Central zones, common root rot in the SA-Victoria Mallee and SA Mid-North zones, and wheat streak mosaic in the WA Eastern zone (Appendix C, Table C6).

Nationally, the highest average annual present yield loss was 3.5 per cent, caused by yellow spot. Within the regions, stripe rust caused greatest current loss of 5.3 per cent in the Northern Region, cereal cyst nematode was highest in the Southern Region at 2.9 per cent and Septoria nodorum blotch and yellow spot were 6.0 per cent in the Western Region (Table 5.1, see p. 22). Present yield loss in the agro-ecological zones is in Appendix C, Table C7.

The present average annual yield loss from all diseases was 18.0 per cent, with foliar diseases contributing 8.9 per cent, root and crown diseases 4.2 per cent, nematodes 4.3 per cent and viruses 0.6 per cent.

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

5.2 Quality effects of diseases

Several diseases affect the quality of wheat grain and may reduce its market value. The relationships between severity and grade of wheat (Tables 2.5 and 2.6) and thus the price discount that may be incurred were used to calculate the value of the effect on quality (see Section 2.8.4). These diseases can lead to considerable economic losses. For Australia, the average annual potential cost due to quality loss from yellow spot was $16.83/ha; however, with current controls, the loss is negligible, 3 cents/ha (Table 5.2). Other diseases with potentially high quality losses are loose smut, common bunt, Fusarium head blight and ergot.

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 $4.64/ha, where Fusarium head blight makes the largest contribution of $3.80/ha. Elsewhere, the current losses are due solely to common bunt (Table 5.2).

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

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	POT.	PRES.	POT.	PRES.	POT.	PRES	POT.	PRES.
Yellow spot	25.30	0.16	4.57	0.00	26.84	0.00	16.83	0.03
Ergot	0.63	0.00	2.32	0.00	0.00	0.00	1.13	0.00
Fusarium head blight	3.80	3.80	0.48	0.00	0.00	0.00	0.92	0.71
Common bunt	5.26	0.68	8.77	0.71	5.08	0.66	6.72	0.68
Loose smut	12.76	0.00	10.35	0.00	0.00	0.00	6.91	0.00
Seed gall nematode	0.00	0.00	0.00	0.00	0.60	0.00	0.23	0.00
Total		**4.64**		**0.71**		**0.66**		**1.43**

5.3 Value of potential and present losses

The value of these yield and market losses were calculated by relating the yield losses and the quality losses to the gross value of wheat production in each zone, using the average value of wheat over a 10-year period (see Section 3.4). These losses were calculated on a per hectare basis and on a crop area 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
Stripe rust	83.43	994
Yellow spot	56.71	676
Cereal cyst nematode	48.04	572
Stem rust	40.09	478
Crown rot	36.44	434

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

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Potential	Present	Potential	Present	Potential	Present	Potential	Present
NECROTROPHIC LEAF FUNGI								
Bipolaris leaf spot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wirrega blotch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Septoria tritici blotch	0.0	0.0	0.9	0.1	0.0	0.0	0.4	0.0
Septoria avenae blotch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Septoria nodorum blotch	0.0	0.0	0.0	0.0	12.9	6.0	4.9	2.3
Ring spot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow spot	19.0	4.3	3.9	1.0	12.9	6.0	10.1	3.5
SUB-TOTAL		4.3		1.1		12.1		5.8
BIOTROPHIC LEAF FUNGI								
Powdery mildew	0.9	0.2	0.1	0.0	0.4	0.1	0.4	0.1
Stem rust	39.6	0.4	4.0	0.0	2.2	0.3	10.0	0.2
Leaf rust	11.0	0.8	3.6	0.1	1.4	0.2	4.1	0.2
Stripe rust	44.3	5.3	25.5	2.8	3.7	1.1	20.8	2.6
Downy mildew	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flag smut	2.4	0.0	1.7	0.0	0.6	0.0	1.4	0.0
SUB-TOTAL		6.7		2.9		1.6		3.1
ROOT AND CROWN FUNGI								
Foot rot	1.1	0.3	0.4	0.1	0.0	0.0	0.4	0.1
Crown rot	22.2	4.4	10.5	1.8	1.5	0.3	9.3	1.7
Take-all	0.0	0.0	3.6	0.4	1.4	0.2	2.1	0.3
Damping off/root rot	0.1	0.1	1.0	0.4	0.4	0.1	0.6	0.2
Rhizoctonia barepatch	0.0	0.0	4.1	2.0	4.5	1.1	3.5	1.3
Eyespot	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.0
Basal rot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common root rot	3.2	0.8	4.0	1.2	0.0	0.0	2.4	0.7
SUB-TOTAL		5.5		5.7		1.7		4.2
INFLORESCENCE FUNGI								
ergot	0.0	0.0	0.5	0.0	0.0	0.0	0.2	0.0
Fusarium head blight	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
common bunt	0.2	0.0	2.8	0.0	0.6	0.0	1.5	0.0
loose smut	1.8	0.0	1.3	0.0	0.0	0.0	0.9	0.0
SUB-TOTAL		0.1		0.0		0.0		0.0
NEMATODES								
Seed gall nematode	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cereal cyst nematode	0.0	0.0	28.1	2.9	1.5	0.1	12.8	1.3
Stunt nematode	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Root lesion nem. crenatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Root lesion nem. neglectus	2.4	1.0	5.6	1.6	7.8	1.9	5.8	1.6
Root lesion nem. penetrans	0.0	0.0	0.0	0.0	0.6	0.1	0.2	0.1
Root lesion nem. teres	0.0	0.0	0.0	0.0	2.0	0.5	0.8	0.2
Root lesion nem. thornei	11.6	4.3	2.4	0.4	0.6	0.2	3.5	1.0
Burrowing nem. nativus	0.0	0.0	0.0	0.0	1.2	0.3	0.4	0.1
Burrowing nem. vangundyi	0.0	0.0	0.0	0.0	0.3	0.1	0.1	0.0
SUB-TOTAL		5.3		4.9		3.2		4.3
BACTERIA								
Basal glume rot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bacterial leaf blight	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Black chaff	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	0.2	0.1	0.5	0.0	0.3	0.1
High Plains disease	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Wheat streak mosaic	0.2	0.2	0.7	0.6	3.4	0.4	1.6	0.5
SUB-TOTAL		0.3		0.9		0.4		0.6
TOTAL		**22.2**		**15.5**		**18.9**		**18.0**

The total potential losses were not summed because there would be significant interaction between diseases if all developed (see Section 2.8.7).

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

Northern Region

DISEASE	$/ha	$ million
Stripe rust	177.24	396
Stem rust	157.46	352
Yellow spot	100.75	225
Crown rot	86.45	193
Pratylenchus thornei	46.49	104

The potential losses per hectare in the Northern Region are generally greater than those averaged nationally. Cereal cyst nematode is of negligible importance in the Northern Region while the nematode *P. thornei* enters the top five.

Southern Region

DISEASE	$/ha	$ million
Cereal cyst nematode	105.08	547
Stripe rust	102.69	534
Crown rot	41.10	214
Pratylenchus neglectus	21.75	113
Rhizoctonia barepatch	15.68	82

In general, the potential losses per hectare in the Southern Region are less than those averaged nationally. The nematode *Pratylenchus neglectus* and Rhizoctonia barepatch move into the top five potential losses while yellow spot and stem rust are lower.

Western Region

DISEASE	$/ha	$ million
Yellow spot	77.99	349
Septoria nodorum blotch	51.15	229
Pratylenchus neglectus	29.45	132
Rhizoctonia barepatch	18.73	84
Stripe rust	14.21	64

The potential losses per hectare in the Western Region are the lowest of the three regions. Yellow spot is the highest; Septoria nodorum blotch is a major threat in contrast to its low threat in the other regions.

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.

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 $913 million. The rusts contribute $147 million, other foliar diseases $325 million, root and crown diseases $196 million, inflorescence $19 million, nematodes $199 million and viruses $28 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
Yellow spot	17.82	212
Stripe rust	10.62	127
Septoria nodorum blotch	9.07	108
Crown rot	6.63	79
Pratylenchus neglectus	6.13	73
Total losses from others	26.37	314
TOTAL PRESENT LOSS	**76.64**	**913**

The present losses are far less than the potential losses, showing the effectiveness and value of present controls. The value of disease control is considered in Section 6.

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

Northern Region

DISEASE	$/ha	$ million
Yellow spot	23.43	52
Stripe rust	20.91	47
Pratylenchus thornei	17.03	38
Crown rot	16.87	37
Fusarium head blight	4.13	9
Total losses from others	16.89	38
TOTAL PRESENT LOSS	**99.26**	**222**

As with the potential losses, the present losses per hectare in the Northern Region are generally greater than those averaged nationally. The present losses from the nematode *P. thornei* and Fusarium head blight are relatively more important than the potential losses.

Southern Region

DISEASE	$/ha	$ million
Stripe rust	11.86	62
Cereal cyst nematode	11.02	57
Rhizoctonia barepatch	7.37	38
Crown rot	6.93	36
Pratylenchus neglectus	6.03	31
Total losses from others	18.89	98
TOTAL PRESENT LOSS	**62.10**	**323**

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

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Potential	Present	Potential	Present	Potential	Present	Potential	Present
NECROTROPHIC LEAF FUNGI								
Bipolaris leaf spot	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Wirrega blotch	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Septoria tritici blotch	0.00	0.00	4.07	0.19	0.00	0.00	1.78	0.08
Septoria avenae blotch	0.00	0.00	0.04	0.04	0.00	0.00	0.02	0.02
Septoria nodorum blotch	0.02	0.02	0.14	0.09	51.15	24.02	19.29	9.07
Ring spot	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.01
Yellow spot	100.75	23.43	19.45	3.87	77.99	31.22	56.71	17.82
SUB-TOTAL		23.46		4.20		55.27		27.01
BIOTROPHIC LEAF FUNGI								
Powdery mildew	3.65	0.94	0.42	0.01	1.66	0.25	1.49	0.28
Stem rust	157.46	1.47	16.91	0.03	8.42	1.01	40.09	0.67
Leaf rust	42.54	3.01	15.02	0.46	5.42	0.70	16.57	1.03
Stripe rust	177.24	20.91	102.69	11.86	14.21	4.05	83.43	10.62
Downy mildew	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.01
Flag smut	9.34	0.04	7.07	0.00	2.20	0.03	5.66	0.02
SUB-TOTAL		26.39		12.37		6.04		12.62
ROOT AND CROWN FUNGI								
Foot rot	4.40	1.10	1.81	0.28	0.01	0.01	1.62	0.34
Crown rot	86.45	16.87	41.10	6.93	6.06	1.17	36.44	6.63
Take-all	0.18	0.18	15.86	1.82	5.83	0.66	9.15	1.08
Damping off/root rot	0.31	0.30	4.08	1.50	1.40	0.32	2.37	0.83
Rhizoctonia barepatch	0.00	0.00	15.68	7.37	18.73	4.63	13.88	4.95
Eyespot	0.00	0.00	0.76	0.05	0.00	0.00	0.33	0.02
Basal rot	0.00	0.00	0.09	0.01	0.00	0.00	0.04	0.00
Common root rot	12.49	3.06	15.48	4.54	0.00	0.00	9.10	2.55
SUB-TOTAL		21.52		22.49		6.79		16.41
INFLORESCENCE FUNGI								
Ergot	0.72	0.72	4.49	0.00	0.00	0.00	2.10	0.14
Fusarium head blight	4.68	4.13	0.53	0.00	0.00	0.00	1.11	0.78
Common bunt	6.16	0.70	20.08	0.73	7.36	0.67	12.69	0.70
Loose smut	19.96	0.05	15.84	0.02	0.07	0.00	10.69	0.02
SUB-TOTAL		5.60		0.75		0.67		1.63
NEMATODES								
Seed gall nematode	0.00	0.00	0.00	0.00	0.62	0.00	0.23	0.00
Cereal cyst nematode	0.00	0.00	105.08	11.02	5.78	0.26	48.04	4.91
Stunt nematode	0.21	0.21	0.00	0.00	0.00	0.00	0.04	0.04
Root lesion nem. crenatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Root lesion nem. neglectus	9.46	3.88	21.75	6.03	29.45	7.36	22.34	6.13
Root lesion nem. penetrans	0.00	0.00	0.00	0.00	2.13	0.53	0.80	0.20
Root lesion nem. teres	0.00	0.00	0.00	0.00	7.62	1.90	2.86	0.72
Root lesion nem. thornei	46.49	17.03	10.07	1.72	2.28	0.57	13.98	4.16
Burrowing nem. nativus	0.00	0.00	0.00	0.00	4.37	1.09	1.64	0.41
Burrowing nem. vangundyi	0.00	0.00	0.00	0.00	1.05	0.26	0.39	0.10
SUB-TOTAL		21.11		18.78		11.98		16.66
BACTERIA								
Basal glume rot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bacterial leaf blight	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Black chaff	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUB-TOTAL		0.02		0.00		0.00		0.00
VIRUSES								
Barley yellow dwarf	0.38	0.38	1.07	0.56	1.89	0.07	1.25	0.34
High Plains disease	0.02	0.02	0.45	0.45	0.00	0.00	0.20	0.20
Wheat streak mosaic	0.88	0.75	2.72	2.50	11.76	1.42	5.77	1.77
SUB-TOTAL		1.15		3.51		1.49		2.31
TOTAL		**99.26**		**62.10**		**82.24**		**76.64**

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

DISEASE	NORTHERN		SOUTHERN		WESTERN		AUSTRALIA	
	Potential	Present	Potential	Present	Potential	Present	Potential	Present
NECROTROPHIC LEAF FUNGI								
Bipolaris leaf spot	0	0	0	0	0	0	0	0
Wirrega blotch	0	0	0	0	0	0	0	0
Septoria tritici blotch	0	0	21	1	0	0	21	1
Septoria avenae blotch	0	0	0	0	0	0	0	0
Septoria nodorum blotch	0	0	1	0	229	108	230	108
Ring spot	0	0	0	0	0	0	0	0
Yellow spot	225	52	101	20	349	140	676	212
SUB-TOTAL		52		22		248		322
BIOTROPHIC LEAF FUNGI								
Powdery mildew	8	2	2	0	7	1	18	3
Stem rust	352	3	88	0	38	5	478	8
Leaf rust	95	7	78	2	24	3	197	12
Stripe rust	396	47	534	62	64	18	994	127
Downy mildew	0	0	0	0	0	0	0	0
Flag smut	21	0	37	0	10	0	67	0
SUB-TOTAL		59		64		27		150
ROOT AND CROWN FUNGI								
Foot rot	10	2	9	1	0	0	19	4
Crown rot	193	38	214	36	27	5	434	79
Take-all	0	0	83	9	26	3	109	13
Damping off/root rot	1	1	21	8	6	1	28	10
Rhizoctonia barepatch	0	0	82	38	84	21	165	59
Eyespot	0	0	4	0	0	0	4	0
Basal rot	0	0	0	0	0	0	0	0
Common root rot	28	7	81	24	0	0	108	30
SUB-TOTAL		48		117		30		196
INFLORESCENCE FUNGI								
Ergot	2	2	23	0	0	0	25	2
Fusarium head blight	10	9	3	0	0	0	13	9
Common bunt	14	2	104	4	33	3	151	8
Loose smut	45	0	82	0	0	0	127	0
SUB-TOTAL		13		4		3		19
NEMATODES								
Seed gall nematode	0	0	0	0	3	0	3	0
Cereal cyst nematode	0	0	547	57	26	1	572	58
Stunt nematode	0	0	0	0	0	0	0	0
Root lesion nem. crenatus	0	0	0	0	0	0	0	0
Root lesion nem. neglectus	21	8	113	31	132	33	266	73
Root lesion nem. penetrans	0	0	0	0	10	2	10	2
Root lesion nem. teres	0	0	0	0	34	9	34	9
Root lesion nem. thornei	104	38	52	9	10	3	167	50
Burrowing nem. nativus	0	0	0	0	20	5	20	5
Burrowing nem. vangundyi	0	0	0	0	5	1	5	1
SUB-TOTAL		47		98		54		199
BACTERIA								
Basal glume rot	0	0	0	0	0	0	0	0
Bacterial leaf blight	0	0	0	0	0	0	0	0
Black chaff	0	0	0	0	0	0	0	0
SUB-TOTAL		0		0		0		0
VIRUSES								
Barley yellow dwarf	1	1	6	3	8	0	15	4
High Plains disease	0	0	2	2	0	0	2	2
Wheat streak mosaic	2	2	14	13	53	6	69	21
SUB-TOTAL		3		18		7		28
TOTAL		**222**		**323**		**368**		**913**

In general, the present losses per hectare in the Southern Region are less than those in the other two regions. Cereal cyst nematode and Rhizoctonia barepatch move into the top five present losses while yellow spot and Septoria nodorum blotch are lower in relative importance than for potential losses.

Western Region		
DISEASE	$/ha	$ million
Yellow spot	31.22	139
Septoria nodorum blotch	24.02	108
Pratylenchus neglectus	7.36	33
Rhizoctonia barepatch	4.63	21
Stripe rust	4.05	18
Total losses from others	10.96	49
TOTAL PRESENT LOSS	**82.24**	**368**

The present losses per hectare in the Western Region are dominated by yellow spot and Septoria nodorum blotch, which is a major threat in contrast to its low threat in the other regions.

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 Comparison of yield losses estimated in 1988,1998 and 2008

Previous estimates of the importance of wheat diseases in Australia were made in 1988 (Brennan and Murray 1989) and 1998 (Brennan and Murray 1998). Those estimates related to 24 and 27 of the 41 diseases considered in the 2008 survey, respectively. Although the areas used to compile the data were slightly different to the agro-ecological zones used in the current survey, the 1998 survey produced yield loss estimates for the GRDC regions, while the state-based estimates of 1988 can be used to estimate the losses in each region. Although the unit value of production and the area sown to wheat has changed since the previous surveys, the yield losses as a percentage of the production value enable a comparison of the three surveys on an equal units basis.

5.4.1 Changes in potential losses

Table 5.1 and 5.5 give the average potential annual yield loss for the wheat diseases for the three GRDC regions from Brennan and Murray (1989, 1998) and Table 5.1. Nine diseases had an average potential loss of less than 1 per cent in each survey in all three regions: these were Bipolaris leaf spot, Septoria avenae blotch, ring spot, powdery mildew, downy mildew, eyespot, ergot, Fusarium head blight and seed gall nematode.

Four diseases had similar loss estimates of 1 per cent or greater for the three surveys within one or more regions: Septoria nodorum blotch, Pythium root rot, loose smut and barley yellow dwarf.

However, 14 diseases showed a marked change in potential loss between the surveys in one or more regions. Some changes occurred steadily from one survey to the next while others occurred between 1988 and 1998 or between 1998 and 2008.

Why are there differences between the three surveys? The methodology of data collection and the calculation of losses were similar in each, while the close agreement for most diseases either between the first and second survey or between the second and third suggests that errors in data collection are not the most likely cause of the differences.

Some differences are the result of greater knowledge of the disease. Such studies have led to the greater understanding of the importance of *Pratylenchus* spp. in Western Australia, South Australia and western Victoria (Holloway *et al*. 2008, Vanstone *et al.* 2008) and Queensland. The increase in recognised importance of *P. thornei* in the Northern Region from 1988 to 1998 and that of *P. neglectus* in the Southern and Western Regions since 1998 has resulted from greater knowledge. Ongoing work indicates that other nematodes may be important in some parts of the wheatbelt so the nematode ratings is likely to change.

Cereal cyst nematode has been important in western Victoria and South Australia for many years. The reason for the large increase from near 10 per cent to near 30 per cent from 1998 to 2008 is unclear but may reflect a greater appreciation of its potential. Yellow spot shows a steady rise in its assessed potential in the Northern and Western Regions. This may reflect greater knowledge gained from fungicide experiments and the increase in stubble retention.

Flag smut has been stable in the Northern and Southern Regions but declined in the Western Regions from 1988 to 1998.

Septoria tritici blotch and take-all have declined in potential severity in the Southern and Western Regions while common bunt has declined in all regions. Septoria tritici blotch is favoured by early sowing (early autumn rains) and by wet springs (Murray *et al.* 1990). Take-all requires continuously wet surface soil from sowing to early spring for infection of the roots (Murray *et al.* 1991). Thus, the drier seasons of the past decade (Section 3) would not favour these two diseases and is the likely cause of their reduction in importance. Common bunt is more severe when wheat is sown into cold soil (Wallwork 2000a) so the warmer winters (Section 3) may have contributed to its reduction.

Stem rust has increased in potential importance in the Northern Region since 1998, leaf rust shows a steady increase in the Northern and Southern Regions since 1988, and stripe rust increased since 1998 in the Northern and Southern Regions. Warmer late autumn, winter and early spring temperatures of the past decade (Section 3) would favour more rapid development of stripe rust and stem rust. For stripe rust, most wheat cultivars are susceptible to varying degrees until about the booting stage. These warmer temperatures may have allowed stripe rust to develop to a greater extent during winter and so cause greater

loss. Greater loss from early epidemics was described by Murray *et al.* (1994). Similarly, it may be that the warmer early spring temperatures have allowed stem rust to develop earlier than previously. The increased use of varieties (such as H45) with lower levels of stripe rust resistance but higher yield potential, coupled with the increasing use of fungicides (see Section 7) is likely to have enhanced the levels of stripe rust encountered in recent years, and may also have influenced the perception of increased potential yield losses.

Crown rot is favoured by drier soils with intermittent wetting and by warmer conditions (Wallwork 2000b). These changes in the past decade may have contributed to this disease becoming more important in the Northern and Southern Regions. In addition, detailed survey work has better quantified the distribution and severity of this disease (Backhouse *et al.* 2004).

The comparison of the potential importance of the diseases between 1998 and 2008 strongly suggest that climate change has played a role in the altered importance of several diseases. This is not surprising, because a disease is the result of the interaction between a host and the pathogen as influenced by the environment.

The increased temperature and drier seasons are consistent with models of climate change and these changes are likely to continue (see Flannery 2005). Changes in disease severity may be an important indicator of climate change.

Table 5.5 Average potential annual yield loss (%) of 27 wheat diseases assessed in 1988, 1998 and 2008 by GRDC Region

PATHOGEN	NORTHERN			SOUTHERN			WESTERN		
	1988	1998	2008	1988	1998	2008	1988	1998	2008
NECROTROPHIC LEAF FUNGI									
Bipolaris leaf spot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Septoria tritici blotch	0.1	0.2	0.0	12.6	7.8	0.9	2.0	4.6	0.0
Septoria avenae blotch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Septoria nodorum blotch	0.1	0.1	0.0	0.6	0.3	0.0	8.0	12.1	12.9
Ring spot	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
Yellow spot	3.3	2.0	19.0	1.0	1.6	3.9	5.0	9.3	12.9
BIOTROPHIC LEAF FUNGI									
Powdery mildew	0.0	0.5	0.9	0.4	0.1	0.1	0.0	0.0	0.1
Stem rust	10.0	9.2	39.6	6.0	2.3	4.0	2.5	2.1	2.2
Leaf rust	4.8	7.4	11.0	0.6	2.8	3.6	0.1	3.4	1.4
Stripe rust [A]	4.8	5.9	44.3	13.7	11.8	25.5	–	–	3.7
Downy mildew	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flag smut	2.0	1.3	2.4	1.6	2.3	1.7	4.2	0.9	0.6
ROOT AND CROWN FUNGI									
Crown rot	3.0	13.0	22.2	0.4	6.6	10.5	0.1	0.3	1.5
Take-all	0.8	0.6	0.0	9.5	13.6	3.6	10.0	3.0	1.4
Damping off/root rot	0.0	0.1	0.1	0.1	0.3	1.0	0.0	0.0	0.4
Rhizoctonia barepatch	0.2	0.1	0.0	3.7	4.7	4.1	0.5	1.4	4.5
Eyespot	0.0	0.0	0.0	0.9	0.2	0.2	0.0	0.0	0.0
Common root rot	4.2	3.4	3.2	0.8	3.6	4.0	0.5	0.3	0.0
INFLORESCENCE FUNGI									
Ergot [B]	–	0.0	0.0	–	0.0	0.5	–	0.0	0.0
Fusarium head blight [B]	–	0.0	0.2	–	0.0	0.0	–	0.0	0.0
Common bunt	2.5	4.1	0.2	10.0	6.5	2.8	2.5	1.3	0.6
Loose smut	1.7	1.2	1.8	1.0	1.6	1.3	0.5	0.1	0.0
NEMATODES									
Seed gall nematode [B]	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0
Cereal cyst nematode	0.0	0.0	0.0	9.9	6.7	28.1	2.0	1.4	1.5
Root lesion nem. neglectus	0.0	1.0	2.4	0.0	2.8	5.6	0.0	0.3	7.8
Root lesion nem. thornei	2.8	12.3	11.6	0.0	0.9	2.4	0.0	0.0	0.6
VIRUSES									
Barley yellow dwarf	0.1	0.0	0.1	0.4	1.2	0.2	0.0	0.7	0.5

A not present in Western Australia until 2002
B not assessed in 1988

5.4.2 Changes in losses when controlled

Table 5.1 and 5.6 give the average present annual yield loss for wheat diseases for the three GRDC regions from Brennan and Murray (1989, 1998). Sixteen diseases had an average present loss of less than 1 per cent in each survey in all three Regions.

One disease, Septoria nodorum blotch, had similar loss estimates for the three surveys, nil or insignificant in the Northern and Southern Regions, and 8.0, 4.9 and 6.0 per cent for 1988, 1998 and 2008, respectively, in the Western Region.

The remaining 10 diseases showed a marked increase or decrease over time in one or more of the regions (Table 5.6).

Septoria tritici blotch decreased in present loss from 1988 to 1998 and from 1998 to 2008 in both the Southern and Western Regions. In the Southern Region, the initial decrease was probably the result of widespread growing of less susceptible cultivars, since this reduces the disease potential in the following year (Murray *et al.*, 1990). The subsequent decrease in the Southern and Western Regions reflect drier seasonal conditions, as discussed for this disease in Section 5.4.1.

Yellow spot shows an increase in present loss in all Regions, particularly in the Northern and Western Regions. This may reflect a greater appreciation of its effect, as discussed in Section 5.4.1.

Table 5.6 Average annual yield loss (%) with control of 27 wheat diseases assessed in 1988, 1998 and 2008 by GRDC Region

PATHOGEN	NORTHERN			SOUTHERN			WESTERN		
	1988	1998	2008	1988	1998	2008	1988	1998	2008
NECROTROPHIC LEAF FUNGI									
Bipolaris leaf spot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Septoria tritici blotch	0.0	0.0	0.0	4.1	1.0	0.1	2.0	1.3	0.0
Septoria avenae blotch	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Septoria nodorum blotch	0.0	0.0	0.0	0.6	0.0	0.0	8.0	4.9	6.0
Ring spot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow spot	1.3	0.5	4.3	0.2	0.3	1.0	2.4	3.7	6.0
BIOTROPHIC LEAF FUNGI									
Powdery mildew	0.0	0.0	0.2	0.3	0.1	0.0	0.0	0.0	0.1
Stem rust	0.6	0.0	0.4	0.1	0.0	0.0	0.0	0.1	0.3
Leaf rust	0.6	0.2	0.8	0.2	0.2	0.1	0.0	0.5	0.2
Stripe rust [A]	0.6	0.1	5.3	1.8	0.8	2.8	–	–	1.1
Downy mildew	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flag smut	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ROOT AND CROWN FUNGI									
Crown rot	2.1	3.9	4.4	0.2	2.7	1.8	0.1	0.0	0.3
Take-all	0.8	0.1	0.0	4.1	3.6	0.4	4.8	0.5	0.2
Damping off/root rot	0.0	0.0	0.1	0.0	0.3	0.4	0.0	0.0	0.1
Rhizoctonia barepatch	0.1	0.0	0.0	0.5	2.4	2.0	0.1	0.4	1.1
Eyespot	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Common root rot	3.1	1.7	0.8	0.2	1.0	1.2	0.5	0.1	0.0
INFLORESCENCE FUNGI									
Ergot [B]	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0
Fusarium head blight [B]	–	0.0	0.1	–	0.0	0.0	–	0.0	0.0
Common bunt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Loose smut	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
NEMATODES									
Seed gall nematode [B]	–	0.0	0.0	–	0.0	0.0	–	0.0	0.0
Cereal cyst nematode	0.0	0.0	0.0	4.7	2.8	2.9	0.1	0.1	0.1
Root lesion nem. neglectus	0.0	0.3	1.0	0.0	0.5	1.6	0.0	0.3	1.9
Root lesion nem. thornei	0.8	5.9	4.3	0.0	0.2	0.4	0.0	0.0	0.2
VIRUSES									
Barley yellow dwarf	0.0	0.0	0.1	0.4	0.5	0.1	0.0	0.2	0.0

A not present in Western Australia until 2002
B not assessed in 1988

Stripe rust shows an increase in the two eastern regions and its appearance since 2002 in the Western Region. Temperature rises may have favoured its development as well (See Section 5.4.1), and the appearance of new pathogenic races and the growing of more susceptible cultivars (See Section 8).

Crown rot showed an increase from 1988 to 1998 in the Northern and Southern Regions. This early increase in present loss parallels the increase in potential loss, but while potential loss continued to rise, the actual loss did not. It is tempting to suggest that improved disease management prevented further losses from crown rot. Similarly, actual loss from common root rot decreased in the Northern Region while potential loss remained similar, again suggesting improved disease management.

The decline in actual losses from take-all parallels the decrease in potential loss, linked to warmer and drier conditions in Section 5.4.1.

The actual loss from cereal cyst nematode decreased from 1988 to 1998 and has remained similar to 2008, even though the potential loss has increased in the Southern Region. There has been wide adoption of cultivars with resistance to cereal cyst nematode in the Southern Region (see Section 8) and this may have prevented the increase in actual loss.

Actual losses from *Pratylenchus* species has increased since 1988 along with potential losses. Reasons for changes in these nematodes are discussed in Section 5.4.1.

6. VALUE OF CONTROL OF WHEAT DISEASES

6.1 Value of controlling wheat 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. 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: stripe rust, $868 million per year; cereal cyst nematode, $514 million; stem rust, $470 million; yellow spot, $464 million; and crown rot $355 million (Table 6.1).

Even the tenth ranked control, that of Rhizoctonia barepatch, is valued at $106 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 per hectare value for controlling stripe rust is $156 per hectare, 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 $10.67 per hectare, 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 fertilisers 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

Wheat breeding and the use of genetic resistance provided more than 50 per cent of the control for eight diseases and more than 25 per cent of the control for a further four. The top five average annual values for this control were: stem rust, $438 million; stripe rust, $431 million; cereal cyst nematode, $377 million; yellow spot, $200 million; and leaf rust, $152 million (Table 6.2).

Table 6.1 Value of current wheat 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 leaf spot	0.00	0.00	0.00	0.00	0	0	0	0
Wirrega blotch	0.00	0.01	0.00	0.00	0	0	0	0
Septoria tritici blotch	0.00	3.88	0.00	1.69	0	20	0	20
Septoria avenae blotch	0.00	0.00	0.00	0.00	0	0	0	0
Septoria nodorum blotch	0.00	0.05	27.12	10.21	0	0	121	122
Ring spot	0.00	0.00	0.00	0.00	0	0	0	0
Yellow spot	77.32	15.58	46.77	38.89	173	81	209	463
BIOTROPHIC LEAF FUNGI								
Powdery mildew	2.71	0.40	1.41	1.21	6	2	6	14
Stem rust	155.98	16.87	7.41	39.42	349	88	33	470
Leaf rust	39.53	14.56	4.71	15.55	88	76	21	185
Stripe rust	156.33	90.84	10.16	72.81	350	472	45	868
Downy mildew	0.00	0.00	0.00	0.00	0	0	0	0
Flag smut	9.30	7.07	2.17	5.65	21	37	10	67
ROOT AND CROWN FUNGI								
Foot rot	3.30	1.53	0.00	1.29	7	8	0	15
Crown rot	69.58	34.17	4.89	29.81	156	178	22	355
Take-all	0.00	14.04	5.17	8.07	0	73	23	96
Damping off/root rot	0.01	2.59	1.09	1.54	0	13	5	18
Rhizoctonia barepatch	0.00	8.31	14.10	8.93	0	43	63	106
Eyespot	0.00	0.71	0.00	0.31	0	4	0	4
Basal rot	0.00	0.08	0.00	0.03	0	0	0	0
Common root rot	9.43	10.94	0.00	6.55	21	57	0	78
INFLORESCENCE FUNGI								
Ergot	0.00	4.49	0.00	1.96	0	23	0	23
Fusarium head blight	0.54	0.53	0.00	0.33	1	3	0	4
Common bunt	5.46	19.36	6.69	11.99	12	101	30	143
Loose smut	19.92	15.82	0.07	10.67	45	82	0	127
NEMATODES								
Seed gall nematode	0.00	0.00	0.62	0.23	0	0	3	3
Cereal cyst nematode	0.00	94.06	5.51	43.13	0	489	25	514
Stunt nematode	0.00	0.00	0.00	0.00	0	0	0	0
Root lesion nem. crenatus	0.00	0.00	0.00	0.00	0	0	0	0
Root lesion nem. neglectus	5.58	15.71	22.09	16.21	12	82	99	193
Root lesion nem. penetrans	0.00	0.00	1.60	0.60	0	0	7	7
Root lesion nem. teres	0.00	0.00	5.71	2.15	0	0	26	26
Root lesion nem. thornei	29.47	8.34	1.71	9.82	66	43	8	117
Burrowing nem. nativus	0.00	0.00	3.28	1.23	0	0	15	15
Burrowing nem. vangundyi	0.00	0.00	0.79	0.30	0	0	4	4
BACTERIA								
Basal glume rot	0.00	0.00	0.00	0.00	0	0	0	0
Bacterial leaf blight	0.00	0.00	0.00	0.00	0	0	0	0
Black chaff	0.00	0.00	0.00	0.00	0	0	0	0
VIRUSES								
Barley yellow dwarf	0.00	0.51	1.83	0.91	0	3	8	11
High Plains disease	0.00	0.00	0.00	0.00	0	0	0	0
Wheat streak mosaic	0.12	0.22	10.34	4.00	0	1	46	48

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

DISEASE	COST/VALUE ($ million)			CONTRIBUTION (%)			CONTRIBUTION ($ million)		
	Potential	Present	Control	Breeding	Cultural	Pesticide	Breeding	Cultural	Pesticide
NECROTROPHIC LEAF FUNGI									
Bipolaris leaf spot	0	0	0	0	0	0	0	0	0
Wirrega blotch	0	0	0	0	100	0	0	0	0
Septoria tritici blotch	21	1	20	75	6	19	15	1	4
Septoria avenae blotch	0	0	0	0	0	0	0	0	0
Septoria nodorum blotch	230	108	122	30	42	29	36	51	35
Ring spot	0	0	0	0	0	0	0	0	0
Yellow spot	676	212	463	43	33	23	200	155	108
BIOTROPHIC LEAF FUNGI									
Powdery mildew	18	3	14	36	28	35	5	4	5
Stem rust	478	8	470	93	5	2	438	24	8
Leaf rust	197	12	185	82	9	9	152	16	17
Stripe rust	994	127	868	50	9	41	431	78	359
Downy mildew	0	0	0	0	0	0	0	0	0
Flag smut	67	0	67	76	2	22	51	1	15
ROOT AND CROWN FUNGI									
Foot rot	19	4	15	17	83	0	3	13	0
Crown rot	434	79	355	23	77	0	83	272	0
Take-all	109	13	96	0	90	10	0	86	10
Damping off/root rot	28	10	18	0	95	5	0	17	1
Rhizoctonia barepatch	165	59	106	0	94	6	0	100	6
Eyespot	4	0	4	1	91	8	0	3	0
Basal rot	0	0	0	0	100	0	0	0	0
Common root rot	108	30	78	59	41	0	46	32	0
INFLORESCENCE FUNGI									
Ergot	25	2	23	0	100	0	0	23	0
Fusarium head blight	13	9	4	20	80	0	1	3	0
Common bunt	151	8	143	2	2	95	3	3	136
Loose smut	127	0	127	1	1	98	2	1	124
NEMATODES									
Seed gall nematode	3	0	3	0	100	0	0	3	0
Cereal cyst nematode	572	58	514	73	27	0	377	137	0
Stunt nematode	0	0	0	0	0	0	0	0	0
Root lesion nem. crenatus	0	0	0	0	100	0	0	0	0
Root lesion nem. neglectus	266	73	193	25	75	0	48	146	0
Root lesion nem. penetrans	10	2	7	0	100	0	0	7	0
Root lesion nem. teres	34	9	26	0	100	0	0	26	0
Root lesion nem. thornei	167	50	117	51	49	0	60	57	0
Burrowing nem. nativus	20	5	15	0	100	0	0	15	0
Burrowing nem. vangundyi	5	1	4	0	100	0	0	4	0
BACTERIA									
Basal glume rot	0	0	0	0	0	0	0	0	0
Bacterial leaf blight	0	0	0	0	0	0	0	0	0
Black chaff	0	0	0	0	0	0	0	0	0
VIRUSES									
Barley yellow dwarf	15	4	11	3	22	74	0	2	8
High Plains disease	2	2	0	0	0	0	0	0	0
Wheat streak mosaic	69	21	48	0	100	0	0	48	0

6.3 Value of cultural methods

Cultural practices contributed more than 50 per cent of the control for 17 wheat diseases and more than 25 per cent for a further five. The top five average annual values for this control were: crown rot, $272 million; yellow spot, $155 million; *Pratylenchus neglectus*, 146 million; cereal cyst nematode, $137 million; and Rhizoctonia barepatch, $100 million (Table 6.2).

6.4 Value of pesticides

Pesticides, mainly fungicides, contributed more than 50 per cent of the control for two diseases and more than 25 per cent for a further three. The top five average annual values for this control were: stripe rust, $359 million; common bunt, $136 million; loose smut, $124 million; yellow spot, $108 million; and Septoria nodorum blotch, $35 million (Table 6.2).

6.5 Comparison of control methods between the 1998 and 2008 surveys

A similar study of the control practices in use was undertaken in 1998 (Brennan and Murray 1998). The diseases that were studied in both surveys and for which active control was undertaken are shown in Table 6.3, with the contributions made by breeding, cultural methods and pesticides listed for both surveys.

In the 1998 survey, pesticides were only used extensively for control of flag smut, common bunt and loose smut. Now they form important controls for an additional six: Septoria tritici blotch, Septoria nodorum blotch, yellow spot, powdery mildew, stripe rust and barley yellow dwarf (Table 6.3).

The increase in their use is particularly evident for stripe rust. It reflects the effects of the introduction of a highly pathogenic race in 2002 in Western Australia, where stripe rust had not previously occurred. This race was highly virulent and pathogenic to many cultivars. It quickly spread

Table 6.3 Contribution (%) of different forms of control of wheat diseases in 1998 (Brennan and Murray 1998) and in this 2008 survey

DISEASE	BREEDING		CULTURAL		PESTICIDE	
	1998	2008	1998	2008	1998	2008
NECROTROPHIC LEAF FUNGI						
Septoria tritici blotch	100	75	0	6	0	19
Septoria nodorum blotch	100	30	0	42	0	29
Yellow spot	5	43	95	33	0	23
BIOTROPHIC LEAF FUNGI						
Powdery mildew	0	36	100	28	0	35
Stem rust	100	93	0	5	0	2
Leaf rust	95	82	0	9	5	9
Stripe rust	95	50	0	9	5	41
Flag smut	40	76	0	2	60	22
ROOT AND CROWN FUNGI						
Crown rot	20	23	80	77	0	0
Take-all	0	0	95	90	5	10
Damping off/root rot	0	0	100	95	0	5
Rhizoctonia barepatch	0	0	100	94	0	6
Eyespot	0	1	90	91	10	8
Common root rot	20	59	80	41	0	0
INFLORESCENCE FUNGI						
Ergot	0	0	100	100	0	0
Fusarium head blight	0	20	100	80	0	0
Common bunt	0	2	0	2	100	95
Loose smut	0	1	0	1	100	98
NEMATODES						
Seed gall nematode	0	0	100	100	0	0
Cereal cyst nematode	60	73	40	27	0	0
Root lesion nem. neglectus	0	25	100	75	0	0
Root lesion nem. thornei	20	51	80	49	0	0
VIRUSES						
Barley yellow dwarf	95	3	0	22	5	74

throughout Western Australia and to the eastern regions, with the subsequent appearance of new races that affected more cultivars.

Breeding for resistance remains a major means of control for 13 of the diseases where sources of resistance are available. The recent attention given to Fusarium head blight has seen some resistance now becoming available. Increases in the contribution of resistance also occurred for powdery mildew, flag smut, common root rot, and the three root attacking nematodes.

Cultural methods are important controls for most of the diseases. Methods include crop rotation, destruction of over-summering hosts, stubble management and tillage systems. They are a main form of control for the root diseases caused by fungi and nematodes, have a role for the necrotrophic leaf fungi, and a smaller role for rust diseases.

7. USE OF FUNGICIDES IN AUSTRALIAN WHEAT PRODUCTION

7.1 Introduction

Fungicides to control smut and bunt have been applied to seed used for wheat crops for decades. Until recent years, fungicides were not applied routinely to wheat crops in Australia except in epidemics. However, in-crop applications of fungicides have recently become common as yields have increased over time, improved fungicides have been developed and the cost of fungicide applications has fallen in real terms. This has been enhanced by the recent breakdown of resistance to stripe rust in particular in the mix of wheat varieties grown across Australia. The outcome is a much more frequent and routine use of fungicides in wheat crops (see Section 6.5).

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. As part of this study, information was collected that enables estimates of the aggregate expenditure on different forms of fungicides for 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 wheat crops, and a broad estimate of the amounts spent each year by farmers in controlling fungal diseases in wheat.

Fungicide can be applied to cereal crops in three ways:
(a) seed treatment;
(b) in-furrow (that is, soil) application at sowing; and
(c) 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 wheat 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 when 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 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'). 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 for each zone was estimated by the relevant crop experts and from extension advice from 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.

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

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 ha (see Appendix D, Table D1 for fungicide costs in each agro-ecological zone). As an illustration, using the national average sowing rates of 47kg/ha for wheat, the costs of each strategy are shown in Table 7.2. On that basis, the low rates of seed treated with fungicide cost $1.41/ha, while the higher rate cost an average of $3.29/ha.

Table 7.2 Average costs of fungicide strategies for wheat*

SEED RATE (kg/ha)	47
COSTS OF FUNGICIDE APPLICATION ($/ha)	
Seed (low rate)	1.41
Seed (high rate)	3.29
In-furrow only	20.00
Foliar only	22.00
Seed (low rate) + in-furrow	21.41
Seed (low rate) + foliar	23.41
Seed (low rate) + 2 foliar	45.41
Seed + in-furrow + foliar	43.41

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

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 regions. The proportion of wheat crops in each region receiving the different fungicide treatments is shown in Table 7.3. Across all regions, 73 per cent of wheat crops (covering 8.7 million ha on average) were sown with seed treated by fungicide, 10 per cent (1.2 million ha) received in-furrow fungicide treatment. Overall, 39 per cent of crops were given at least one fungicide spray. Only 9 per cent of wheat crops did not receive any fungicide control for fungal diseases. Seed treatment (90 per cent of crops) was relied on more in the Southern Region than in the other two regions, while foliar sprays were relied on more in the Northern (53 per cent) and Western (43 per cent) regions.

Table 7.3 Fungicide treatments for wheat crops in the GRDC Regions and Australia

Area treated (%)	Northern	Southern	Western	Australia
Seed treatment	63	90	58	73
In-furrow application	1	12	13	10
Foliar application	53	29	43	39
No fungicide	19	0	16	9
Area treated ('000 ha)*				
Seed treatment	1411	4691	2585	8687
In-furrow application	28	603	579	1210
Foliar application	1193	1502	1919	4613
No fungicide	422	0	697	1119

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

The estimated cost to farmers of these fungicide applications for wheat is shown in Table 7.4. The total expenditure (including application costs) is estimated at $154 million per year, of which $30 million, $62 million and $62 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 wheat is estimated at $102 million per year. This implies that farmers spent an average of $52 million per year applying foliar fungicides to their wheat crops.

The costs of fungicide applications to wheat crops averaged $12.89 per-hectare across Australia (Table 7.5), varying within a narrow range across the different regions: the cost was $13.53 in the Northern Region, $11.86 in the Southern and $13.75 in the Western.

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

	INCLUDING APPLICATION COSTS				EXCLUDING APPLICATION COSTS			
	Northern	Southern	Western	Australia	Northern	Southern	Western	Australia
Seed (low rate)	0.5	3.8	1.0	5.3	0.5	3.8	1.0	5.3
Seed (high rate)	0.5	3.5	1.8	5.9	0.5	3.5	1.8	5.9
In-furrow only	0.6	3.0	6.9	10.4	0.6	3.0	6.9	10.4
Foliar only	8.3	7.9	18.8	34.9	4.5	4.3	10.2	19.0
Seed (low) + in-furrow	0.0	7.6	1.5	9.0	0.0	7.6	1.5	9.0
Seed (low) + foliar	17.3	17.5	17.0	51.8	9.8	10.1	9.7	29.6
Seed (rate)+ 2 foliar	3.1	13.8	7.5	24.4	1.7	7.8	4.2	13.7
Seed + in-furrow + foliar	0.0	4.5	7.2	11.7	0.0	3.5	5.5	9.0
Total	**30.2**	**61.7**	**61.6**	**153.5**	**17.6**	**43.7**	**40.7**	**102.0**

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

	$/ha
Northern Region	13.53
Southern Region	11.86
Western Region	13.75
Australia	12.89

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 wheat crops in Australia. They show that, on average, the main treatment was seed treatment (73 per cent of wheat crops), though 50 per cent of wheat crops received subsequent applications (in the form of in-furrow or foliar applications). Some 9 per cent of wheat crops received no fungicides.

There are some significant differences between regions in the proportion of crops receiving different fungicide treatments. In particular, in the Western Region there is a greater reliance on foliar sprays and a lesser reliance on seed treatment. In the Southern Region there is a strong reliance on seed dressing to control wheat diseases. One reason for regional differences in the use of foliar fungicide applications is likely to be differences in the levels of genetic resistance to foliar diseases in the varieties grown in the different regions. For instance, in Section 8, significant differences between regions in the levels of resistance to rust diseases in wheat are indicated.

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 wheat diseases provided by fungicides totals $836 million. On that basis, the ratio of benefits to costs from fungicide applications is estimated to be over 5:1 for wheat. 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 wheat so these figures are the only estimate available and provide a baseline estimate for further work in this area.

8. USE OF RESISTANT CULTIVARS IN AUSTRALIAN WHEAT PRODUCTION

8.1 Introduction

Wheat varieties have genetic levels of tolerance and resistance to a number of diseases. A key objective of breeders is to incorporate suitable levels of resistance into varieties that are bred for particular areas. They use information about the likely disease problems in the area to decide which forms of resistance should be included in breeding.

Farmers then decide to grow varieties best suited to their farming system, that will provide the best economic return. If certain disease resistances offer perceived advantages to the grower, we would expect varieties with such resistances to dominate in that area.

Knowledge of the distribution of different levels of disease response provides another source of information on the likelihood of outbreaks of those diseases.

Data on the reaction of most wheat varieties are known for a number of diseases, as a result of pre-release and post-release screening in various disease reaction nurseries. Because not all diseases are relevant in all regions, some varieties are released without having been tested for diseases that are thought not likely to be present in the Regions in which the variety is expected to be grown. However, in most cases, data for the key diseases are available for most varieties.

8.2 Varietal reactions to selected diseases

As a separate exercise from the survey described in previous sections, data on disease reactions were obtained from the various state departments of agriculture/primary industries for the varieties grown in 2005-06. A standardised scoring system has been adopted for the reactions found in the screening nurseries, as follows:

Resistant
Resistant - Moderately resistant
Moderately resistant
Moderately resistant - Moderately susceptible
Moderately susceptible
Moderately susceptible - Susceptible
Susceptible
Susceptible - Very susceptible
Very susceptible

Available data were collated for reactions to the following 12 wheat diseases (abbreviations of the diseases used in Figures 8.1 to 8.4 in brackets):

- stem rust;
- stripe rust;
- leaf rust;
- cereal cyst nematode (CCN Res);
- yellow spot (Yellow L S);
- Septoria tritici blotch (STB);
- Septoria nodorum blotch (S nodorum);
- *Pratylenchus neglectus* (P neg res);
- *Pratylenchus thornei* (P thor res);
- crown rot;
- common root rot (CR rot); and
- flag smut.

Where possible, the reaction to the pathotypes present in the area in early 2005, when varieties were chosen for sowing by farmers, was used. For some varieties released several years or decades earlier, current data were not available; in these cases the most recent data were used. Data on stripe rust posed the greatest dilemma. The rapid appearance of new pathotypes over the past decade and their slightly different distributions means that the choice of reaction to the most common pathotypes in 2004-05 may not reflect the reaction of wheat varieties to stripe rust in all zones. For this reason, WA scores were used in WA zones, and other scores recognising the Yr17 pathotypes were used for the other zones. For all other diseases, the reaction scores were the same across all zones.

8.3 Levels of disease resistance across regions

The proportion of the production in each region with the different disease reactions was calculated for 12 diseases by weighting the disease reaction scores by the relative importance of each variety in production in a region. While varietal shares in production are not available, confidential data were obtained from AWB Ltd on the quantities (tonnages) of each of 115 varieties delivered to each of the major ports in Australia from the 2005-06 harvest. These tonnages were aggregated to provide an estimate of variety shares of deliveries for each of three major production regions developed and used by the GRDC, the Northern, Southern and Western Regions. From these data, the percentage variety shares in each region were calculated. These percentage shares were then used to weight the variety disease reactions to develop an estimate of the proportion of the crop in each region that has the different variety reaction scores. These were analysed without compromising the confidentiality of the initial variety data from AWB Ltd.

Of the 115 varieties delivered to AWB Ltd in 2005-06, reaction scores for only nine varieties were available for all 12 diseases. Some 11 more varieties had diseases reaction scores available for at least ten diseases, while a further 51 had available reaction scores for between seven and nine diseases. For 12 varieties, there were no data, and 16 varieties had reaction scores of between one and three diseases.

The proportion of the production in each region with

Figure 8.1 Disease reactions, selected diseases Northern Region

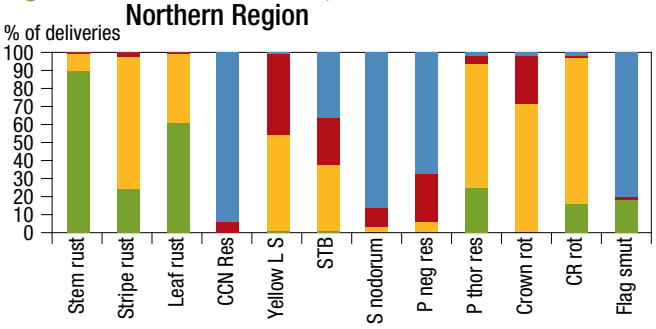


Figure 8.2 Disease reactions, selected diseases Southern Region

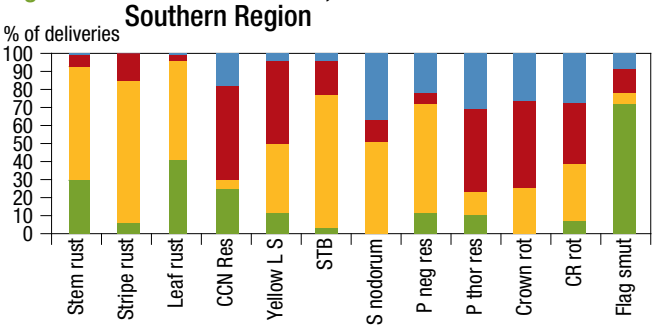


Figure 8.3 Disease reactions, selected diseases Western Region

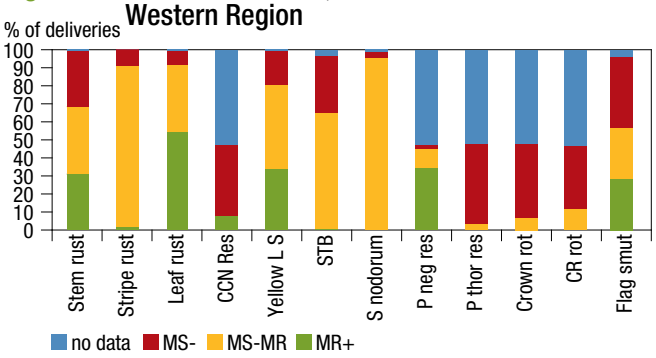
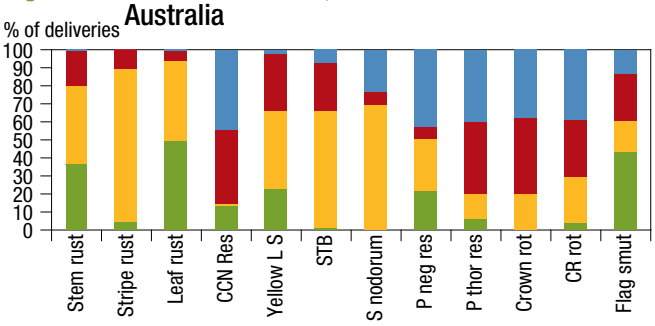


Figure 8.4 Disease reactions, selected diseases Australia



each of the nine separate disease reaction categories was calculated for each of the 12 diseases (see Appendix E). For simplicity, in the above graphs the reactions are combined into three categories, namely:

- MR+ (includes R, R-MR and MR);
- MS-MR (includes MR-MS, MS, MS-S); and
- MS- (S, S-VS, VS).

As data for reactions to some diseases are not available for all varieties, a proportion of the area in each region was sown to varieties for which there were no data for that disease. For diseases that were important across all regions, such as the rust diseases and yellow spot, that proportion was close to zero. For diseases important in only one or two regions, the proportion of the area sown to varieties with no data was sometimes relatively high. For example, for cereal cyst nematode (CCN) (which is only important in southern zones), only 6 per cent of the area in the Northern Region and 47 per cent of the area in the Western Region have data available on reaction to CCN. Other diseases with relatively lower data coverage include *P. thornei*, crown rot, common root rot and Septoria nodorum blotch.

The results for the key diseases are shown for each region in Figures 8.1, 8.2 and 8.3, and at the national level in Figure 8.4.

For stem rust and leaf rust, there are relatively high levels of resistance across most regions, especially in the Northern Region where those diseases pose the greatest threat. In contrast, stripe rust generally has moderate levels in the varieties grown, especially in the Western Region. The lower level of resistance shown to stripe rust is a result of the appearance of several new pathogenic races since 2002.

Flag smut is the other disease for which there are higher levels of resistance across all regions. For the remaining diseases, the levels of resistance tend to be moderate overall, but with higher levels in the regions where those diseases are most threatening.

There is a higher proportion of varieties resistant to cereal cyst nematode in the Southern Region where this nematode causes high potential losses, and lower resistance in the other regions where the potential loss is less. This is also seen for Septoria nodorum blotch in the Western Region, *Pratylenchus neglectus* in the Southern and Western Regions, and *P. thornei* and crown rot in the Northern Region.

Interestingly there is some resistance to Septoria tritici blotch in the Southern Region, where historically this disease was severe (see Section 5.4). There are also high proportions of resistance to flag smut in the Southern Region and common root rot in the Northern Region even though their potential losses are rated relatively low.

8.4 Conclusions

There is a general relationship between the growing of varieties resistant to a disease and the potential for the disease to cause loss in an area, where resistance is available. In general, the use of resistance is greater for diseases that cause large losses when they develop, even when the incidence of such severe disease is low.

It is clear from this analysis that there is considerable scope for both increasing the levels of resistance to key diseases in the varieties released, and in farmers looking to choose resistant rather than susceptible varieties as part of their risk-management strategies for their wheat crops. There may be a case for minimum disease resistance standards in the varieties released for commercial production.

9. CONCLUSIONS

Diseases remain a major threat to wheat production in Australia but are generally well controlled at present. The current average annual loss from wheat diseases was estimated to be $913 million, made up of $222 million in the Northern Region, $323 million in the Southern, and $368 million in the Western Region. This compares with a potential average loss nationally of $994 million from a single disease, stripe rust, which is reduced to $127 million by current controls.

On average, the current national average losses from diseases are $76.64 per hectare. In the Northern Region, the losses represent $99.26 per ha, while they are $62.10 in the Southern Region and $82.24 in the Western Region.

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

RANK	BY POTENTIAL LOSS	BY PRESENT LOSS
1	Stripe rust	Yellow spot
2	Yellow spot	Stripe rust
3	Cereal cyst nematode	Septoria nodorum blotch
4	Stem rust	Crown rot
5	Crown rot	*Pratylenchus neglectus*

The rankings of all diseases for potential and present losses are shown in Table 9.1 for each GRDC region and for Australia. There are 14 diseases with the potential to cause more than $100 million average potential loss in Australia; a further two can cause potential losses of more than $50 million.

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
Stripe rust	868	431	78	359
Stem rust	470	438	24	8
Cereal cyst nematode	514	377	137	0
Yellow spot	463	200	155	108
Crown rot	355	83	272	0

Most of the pathogens causing the 41 diseases surveyed occur throughout the wheatbelt of Australia. However, the severity of the diseases varies between the agro-ecological zones so that the potential and present disease losses vary widely.

For example, Septoria nodorum blotch causes major loss in the Western Region (potential loss $230 million per year, present loss $108 million, on average) but has negligible effect in the other regions. This high regional loss ranks it third nationally.

Within the Southern Region, cereal cyst nematode causes potential losses of 40 to 50 per cent in the South Australian/western Victorian zones but virtually 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. Common bunt and ergot can downgrade wheat to feed or below even when at low levels, so that their potential average annual losses are $151 million and $25 million, respectively. High levels of yellow spot, in addition to reducing yield, can cause 'pink grain' and affect grain quality so that $16.80/ha of its $56.70/ha potential loss can be attributed to quality loss.

The potential losses of several diseases have changed appreciably since the last national survey in 1998. Climate change, specifically drier seasons with higher temperatures, can be implicated in the reduction in importance of some diseases and the increase in others.

As a control measure, the use of fungicides has increased in the past 10 years. Seed treatments are applied to 73 per cent of the national crop, in-furrow to 10 per cent and foliar sprays to 39 per cent, while 9 per cent receive no fungicides.

Growing resistant cultivars remains a major means of control of these 12 diseases. Wheat cultivars with resistance to important diseases in the region dominate the share of deliveries for each region.

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 wheat sown. For example, if an alternative to control for soil-borne diseases by rotation were available, it may increase the area of wheat. Conversely, the appearance of a new rust race may reduce the area sown, with wheat 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".

Table 9.1 Ranking of wheat 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 leaf spot	21	21	32	29	28	24	37	35
Wirrega blotch	26	26	29	27	28	24	36	37
Septoria tritici blotch	26	26	17	17	28	24	20	26
Septoria avenae blotch	26	26	27	20	28	24	33	29
Septoria nodorum blotch**	24	24	25	18	2	2	7	3
Ring spot	26	26	32	29	24	22	35	33
Yellow spot**	3	1	6	7	1	1	2	1
BIOTROPHIC LEAF FUNGI								
Powdery mildew	14	11	24	23	19	19	23	21
Stem rust**	2	9	7	21	7	10	4	17
Leaf rust**	6	8	12	14	13	11	8	12
Stripe rust**	1	2	2	1	5	5	1	2
Downy mildew	21	21	28	24	28	24	34	32
Flag smut*	10	20	14	29	16	21	16	31
ROOT AND CROWN FUNGI								
Foot rot	13	10	19	16	25	23	22	20
Crown rot**	4	4	3	4	10	8	5	4
Take-all**	20	18	8	9	11	13	13	11
Damping off/root rot	18	16	16	11	20	16	18	13
Rhizoctonia barepatch**	26	26	10	3	4	4	10	6
Eyespot	26	26	21	19	28	24	28	28
Basal rot	26	26	26	25	28	24	32	34
Common root rot**	8	7	11	6	28	24	14	9
INFLORESCENCE FUNGI								
Ergot	16	13	15	29	26	24	19	24
Fusarium head blight	12	5	22	26	26	24	25	14
Common bunt**	11	14	5	12	9	12	11	16
Loose smut**	7	19	9	22	23	24	12	30
NEMATODES								
Seed gall nematode	26	26	31	29	22	24	29	39
Cereal cyst nematode**	26	26	1	2	12	17	3	7
Stunt nematode	19	17	32	29	28	24	31	27
Root lesion nem. crenatus	26	26	30	28	28	24	39	38
Root lesion nem.neglectus**	9	6	4	5	3	3	6	5
Root lesion nem. penetrans	26	26	32	29	17	15	26	23
Root lesion nem. teres	26	26	32	29	8	6	17	15
Root lesion nem. thornei**	5	3	13	10	15	14	9	8
Burrowing nem. nativus	26	26	32	29	14	9	21	18
Burrowing nem. vangundyi	26	26	32	29	21	18	27	25
BACTERIA								
Basal glume rot	26	26	32	29	28	24	40	39
Bacterial leaf blight	21	21	32	29	28	24	37	35
Black chaff	26	26	32	29	28	24	40	39
VIRUSES								
Barley yellow dwarf	17	15	20	13	18	20	24	19
High Plains disease	24	24	23	15	28	24	30	22
Wheat streak mosaic*	15	12	18	8	6	7	15	10

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

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. This should reduce this error over that in Brennan and Murray (1989), when the state was the level of aggregation. 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, wheat 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 wheat production in Australia. Even after these measures have been taken to reduce losses, Australian farmers still suffer significant losses each year from wheat diseases.

As diseases change, whether through changing climatic conditions or as a result of changing technologies and costs of available options, the wheat 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 wheat 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: WHEAT PRODUCTION AND SEASONAL RAINFALL DATA, 1998-99 TO 2007-08

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

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

The rainfall data (Table A4) was supplied by Neil Clark and Associates.

Table A1 Wheat data by agro-ecological zone

	NORTHERN REGION			SOUTHERN REGION							WESTERN REGION				
AREA SOWN ('000 hectares)															
	Q CEN	NNEQSE	NNWQSW	N CEN	NV SLP	Vic HR	TAS	SV BWIM	SV MALL	SMNLYE	W SANDM	WA CEN	WA N	WA E	TOTAL
1998-99	319	1505	864	775	809	42	3	451	1333	803	338	2079	1049	927	**11,296**
1999-00	212	1596	938	845	881	68	4	559	1489	863	336	2143	1064	919	**11,917**
2000-01	239	1281	968	1021	1020	68	5	529	1554	874	345	2096	1037	893	**11,932**
2001-02	75	1119	766	961	1104	75	5	506	1568	875	338	1959	1074	921	**11,346**
2002-03	107	746	598	959	1092	80	6	517	1626	861	319	1987	1158	932	**10,989**
2003-04	68	1258	990	1141	1286	86	6	570	1756	841	309	2276	1182	1089	**12,857**
2004-05	34	1305	1,058	1183	1358	91	6	519	1711	866	359	2398	1181	1117	**13,186**
2005-06	152	1130	898	935	1201	88	6	506	1828	818	381	2074	1197	1071	**12,284**
2006-07	276	909	819	973	1246	79	6	524	1974	839	353	1852	840	962	**11,650**
2007-08	112	1137	880	1033	1177	77	4	524	1674	854	342	2130	754	1004	**11,703**
Mean	**159**	**1199**	**878**	**983**	**1117**	**75**	**5**	**521**	**1651**	**849**	**342**	**2099**	**1054**	**983**	11,916
PRODUCTION ('000 tonnes)															
1998-99	523	2462	1479	1562	2372	108	12	807	1825	1858	679	3899	1966	1426	**20,978**
1999-00	253	3849	1693	1885	2699	186	14	1323	1979	1510	648	4610	2042	1507	**24,197**
2000-01	502	1699	1174	2304	3296	219	19	1442	3026	2305	520	2772	1420	965	**21,661**
2001-02	104	2654	1363	1798	2971	235	20	1393	2906	2753	795	3868	1713	1268	**23,842**
2002-03	123	829	343	680	1101	167	19	484	1009	1181	326	1958	1088	598	**9907**
2003-04	100	2485	1299	1849	2703	300	19	1443	2758	1807	790	5577	2528	2028	**25,683**
2004-05	42	3201	1546	1522	2378	238	23	914	1609	1516	674	4280	1979	1564	**21,486**
2005-06	256	2184	1602	1856	3387	273	27	1270	2889	2019	893	4173	2386	1558	**24,771**
2006-07	519	1281	353	464	723	77	12	323	1073	769	588	2737	747	1003	**10,669**
2007-08	201	1938	920	980	1123	168	6	882	1466	1293	396	2235	553	677	**12,839**
Mean	**262**	**2258**	**1177**	**1490**	**2275**	**197**	**17**	**1028**	**2054**	**1701**	**631**	**3611**	**1642**	**1259**	19,603
YIELD (t/ha)															
1998-99	1.64	1.64	1.71	2.02	2.93	2.58	4.46	1.79	1.37	2.31	2.01	1.88	1.87	1.54	**1.86**
1999-00	1.19	2.41	1.80	2.23	3.06	2.75	3.24	2.37	1.33	1.75	1.93	2.15	1.92	1.64	**2.03**
2000-01	2.10	1.33	1.21	2.26	3.23	3.20	4.01	2.72	1.95	2.64	1.51	1.32	1.37	1.08	**1.82**
2001-02	1.40	2.37	1.78	1.87	2.69	3.13	4.38	2.75	1.85	3.15	2.35	1.97	1.59	1.38	**2.10**
2002-03	1.15	1.11	0.57	0.71	1.01	2.08	3.36	0.94	0.62	1.37	1.02	0.99	0.94	0.64	**0.90**
2003-04	1.46	1.97	1.31	1.62	2.10	3.47	3.24	2.53	1.57	2.15	2.56	2.45	2.14	1.86	**2.00**
2004-05	1.23	2.45	1.46	1.29	1.75	2.62	4.07	1.76	0.94	1.75	1.88	1.78	1.68	1.40	**1.63**
2005-06	1.68	1.93	1.78	1.98	2.82	3.09	4.25	2.51	1.58	2.47	2.34	2.01	1.99	1.45	**2.02**
2006-07	1.88	1.41	0.43	0.48	0.58	0.97	2.04	0.62	0.54	0.92	1.67	1.48	0.89	1.04	**0.92**
2007-08	1.79	1.70	1.05	0.95	0.95	2.19	1.47	1.68	0.88	1.51	1.16	1.05	0.73	0.67	**1.10**
Mean	**1.65**	**1.88**	**1.34**	**1.52**	**2.04**	**2.61**	**3.43**	**1.97**	**1.24**	**2.00**	**1.84**	**1.72**	**1.56**	**1.28**	1.65

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

YEAR	UNIT GVP ($/t)
1998-99	$181
1999-00	$193
2000-01	$231
2001-02	$262
2002-03	$266
2003-04	$216
2004-05	$197
2005-06	$203
2006-07	$242
2007-08	$396
Mean 1998-99 to 2007-08	$239

SOURCE: AUSTRALIAN BUREAU OF AGRICULTURAL AND RESOURCE ECONOMICS *COMMODITY STATISTICS*

Table A3 Price discounts for wheat grades ($/t)

GRADE	PRICE	DISCOUNT
ASW	238.71	0.00
GP	230.49	8.22
Feed	205.37	33.34
Farm	175.06	63.66

Table A4 Annual rainfall deciles by agro-ecological zone, 1998 to 2007*

Agro-ecological zone	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Mean 1998 to 2007
Queensland Central	10	5	9	2	1	4	3	4	2	7	**5**
NSW North-East/Queensland South-East	10	9	6	4	1	4	8	4	1	6	**5**
NSW North-West/Queensland South-West	10	10	9	4	1	4	8	4	1	7	**6**
NSW Central	9	10	10	3	1	6	3	6	1	6	**6**
NSW–Victoria Slopes	8	9	7	3	1	5	4	7	1	4	**5**
Victoria High Rainfall	4	4	6	5	1	5	5	4	1	5	**4**
Tasmania	5	3	5	7	3	8	6	9	1	2	**5**
SA–Victoria Border–Wimmera	3	5	6	5	1	7	4	3	1	6	**4**
SA–Victoria Mallee	6	6	9	6	1	6	3	7	1	5	**5**
SA Mid–North/Lower Yorke, Eyre	6	4	8	9	2	6	5	6	2	6	**5**
WA Sandplain–Mallee	7	10	10	10	1	9	6	6	7	6	**7**
WA Central	6	10	4	3	1	7	2	7	3	3	**5**
WA Northern	7	10	6	4	2	4	3	5	3	1	**5**
WA Eastern	8	10	9	7	1	9	6	5	9	3	**7**

* Note: Deciles are calculated in relation to the period 1900 to 2008

SOURCE: BUREAU OF METEOROLOGY AND NEIL CLARK & ASSOCIATES

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

Table B1 lists the contributors to the survey of wheat diseases in the agro-ecological zones. The tables following (B2 to B15) summarise the estimates of the incidence and severity of diseases of wheat, 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 wheat 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
E. Colson*	+	+	+											
D. Herde	+	+												
S. Jones	+	+												
J. Thompson	+	+	+											
P. Wilkinson	+	+	+											
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 wheat 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 leaf spot	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Wirrega blotch	U						0.00	0.00	0	0	0
Septoria tritici blotch	N						0.00	0.00	0	0	0
Septoria avenae blotch	N						0.00	0.00	0	0	0
Septoria nodorum blotch	N						0.00	0.00	0	0	0
Ring spot	N						0.00	0.00	0	0	0
Yellow spot	Y	20	85	17	50.0	10.0	8.50	1.70	40	50	10
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	40	25	10	3.0	3.0	0.30	0.30	0	0	0
Stem rust	Y	67	67	45	100.0	1.0	44.89	0.45	90	10	0
Leaf rust	Y	67	50	34	40.0	3.0	13.40	1.01	80	10	10
Stripe rust	Y	100	60	60	80.0	10.0	48.00	6.00	50	30	20
Downy mildew	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Flag smut	Y	20	25	5	12.0	0.1	0.60	0.01	30	30	40
ROOT AND CROWN FUNGI											
Foot rot	U						0.00	0.00	0	0	0
Crown rot	Y	90	5	5	46.7	13.3	2.10	0.60	40	60	0
Take-all	N						0.00	0.00	0	0	0
Damping off/root rot	Y	20	25	5	0.5	0.1	0.03	0.01	0	90	10
Rhizoctonia barepatch	N						0.00	0.00	0	0	0
Eyespot	N						0.00	0.00	0	0	0
Basal rot	N						0.00	0.00	0	0	0
Common root rot	Y	100	20	20	15.0	4.3	3.00	0.87	45	55	0
INFLORESCENCE FUNGI											
Ergot	U						0.00	0.00	0	0	0
Fusarium head blight	Y	20	25	5	0.1	0.1	0.01	0.01	0	100	0
Common bunt	Y	20	25	5	25.0	0.1	1.25	0.01	0	10	90
Loose smut	Y	40	100	40	25.0	0.1	10.00	0.04	0	10	90
NEMATODES											
Seed gall nematode	N						0.00	0.00	0	0	0
Cereal cyst nematode	N						0.00	0.00	0	0	0
Stunt nematode	U						0.00	0.00	0	0	0
Root lesion nem. crenatus	U						0.00	0.00	0	0	0
Root lesion nem.neglectus	N						0.00	0.00	0	0	0
Root lesion nem. penetrans	U						0.00	0.00	0	0	0
Root lesion nem. teres	U						0.00	0.00	0	0	0
Root lesion nem. thornei	Y	90	12	11	60.0	20.7	6.48	2.23	45	55	0
Burrowing nem. nativus	U						0.00	0.00	0	0	0
Burrowing nem.vangundyi	N						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	U						0.00	0.00	0	0	0
Bacterial leaf blight	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Black chaff	U						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	40	25	10	0.1	0.1	0.01	0.01	0	50	50
High Plains disease	U						0.00	0.00	0	0	0
Wheat streak mosaic	U						0.00	0.00	0	0	0

Table B3 Incidence, severity and contribution to control estimates and derived disease loss of wheat 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 leaf spot	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Wirrega blotch	U						0.00	0.00	0	0	0
Septoria tritici blotch	N						0.00	0.00	0	0	0
Septoria avenae blotch	N						0.00	0.00	0	0	0
Septoria nodorum blotch	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Ring spot	N						0.00	0.00	0	0	0
Yellow spot	Y	58	83	47	43.8	10.5	20.45	4.91	50	18	33
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	35	25	9	9.8	2.3	0.85	0.20	60	35	5
Stem rust	Y	67	75	50	81.3	0.8	40.90	0.38	96	4	0
Leaf rust	Y	67	44	29	33.0	2.3	9.67	0.67	78	10	13
Stripe rust	Y	92	80	72	66.3	7.6	47.48	5.46	45	10	45
Downy mildew	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Flag smut	Y	40	25	10	25.0	0.1	2.50	0.01	90	0	10
ROOT AND CROWN FUNGI											
Foot rot	Y	40	25	10	12.0	3.0	1.20	0.30	25	75	0
Crown rot	Y	100	33	33	67.5	12.5	21.94	4.06	43	58	0
Take-all	Y	40	25	10	0.5	0.5	0.05	0.05	0	0	0
Damping off/root rot	Y	35	25	9	1.1	1.1	0.10	0.10	0	0	10
Rhizoctonia barepatch	N						0.00	0.00	0	0	0
Eyespot	N						0.00	0.00	0	0	0
Basal rot	N						0.00	0.00	0	0	0
Common root rot	Y	84	36	27	12.0	3.0	3.22	0.80	43	58	0
INFLORESCENCE FUNGI											
Ergot	Y	20	25	5	0.5	0.5	0.03	0.03	0	0	0
Fusarium head blight	Y	40	25	10	3.4	1.1	0.34	0.11	20	80	0
Common bunt	Y	20	25	5	3.0	0.1	0.15	0.01	20	0	80
Loose smut	Y	40	25	10	12.0	0.1	1.20	0.01	0	0	100
NEMATODES											
Seed gall nematode	N						0.00	0.00	0	0	0
Cereal cyst nematode	N						0.00	0.00	0	0	0
Stunt nematode	Y	90	11	10	0.3	0.3	0.03	0.03	0	0	0
Root lesion nem. crenatus	U						0.00	0.00	0	0	0
Root lesion nem.neglectus	Y	84	13	10	25.5	10.8	2.55	1.08	55	45	0
Root lesionnem.penetrans	U						0.00	0.00	0	0	0
Root lesion nem. teres	U						0.00	0.00	0	0	0
Root lesion nem. thornei	Y	84	30	25	50.5	18.8	12.78	4.75	58	43	0
Burrowing nem. nativus	U						0.00	0.00	0	0	0
Burrowing nem.vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	U						0.00	0.00	0	0	0
Bacterial leaf blight	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Black chaff	U						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	47	25	12	1.1	1.1	0.13	0.13	0	0	100
High Plains disease	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Wheat streak mosaic	Y	40	25	10	3.4	3.1	0.34	0.31	0	100	0

Table B4 Incidence, severity and contribution to control estimates and derived disease loss of wheat 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 leaf spot	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Wirrega blotch	U						0.00	0.00	0	0	0
Septoria tritici blotch	N						0.00	0.00	0	0	0
Septoria avenae blotch	N						0.00	0.00	0	0	0
Septoria nodorum blotch	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Ring spot	N						0.00	0.00	0	0	0
Yellow spot	Y	60	87	51	37.3	7.7	18.92	3.88	50	17	33
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	40	25	10	12.0	3.0	1.20	0.30	0	100	0
Stem rust	Y	67	78	52	70.7	0.7	36.85	0.35	97	3	0
Leaf rust	Y	67	67	45	27.7	2.0	12.33	0.89	83	10	7
Stripe rust	Y	89	82	71	55.7	6.8	39.28	4.82	40	10	50
Downy mildew	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Flag smut	Y	40	25	10	25.0	0.1	2.50	0.01	90	0	10
ROOT AND CROWN FUNGI											
Foot rot	Y	40	25	10	12.0	3.0	1.20	0.30	0	100	0
Crown rot	Y	100	50	50	52.5	11.0	26.25	5.50	35	65	0
Take-all	Y	40	25	10	0.5	0.5	0.05	0.05	0	0	0
Damping off/root rot	Y	40	25	10	0.5	0.5	0.05	0.05	0	0	0
Rhizoctonia barepatch	U						0.00	0.00	0	0	0
Eyespot	N						0.00	0.00	0	0	0
Basal rot	N						0.00	0.00	0	0	0
Common root rot	Y	78	58	40	7.8	1.8	3.11	0.70	45	55	0
INFLORESCENCE FUNGI											
Ergot	Y	20	25	5	0.5	0.5	0.03	0.03	0	0	0
Fusarium head blight	Y	40	25	10	0.5	0.5	0.05	0.05	0	0	0
Common bunt	Y	20	25	5	3.0	0.1	0.15	0.01	20	0	80
Loose smut	Y	40	25	10	12.0	0.1	1.20	0.01	0	0	100
NEMATODES											
Seed gall nematode	U						0.00	0.00	0	0	0
Cereal cyst nematode	U						0.00	0.00	0	0	0
Stunt nematode	Y	90	11	10	1.0	1.0	0.10	0.10	0	0	0
Root lesion nem. crenatus	U						0.00	0.00	0	0	0
Root lesion nem.neglectus	Y	82	14	11	24.0	9.3	2.63	1.02	57	43	0
Root lesionnem.penetrans	U						0.00	0.00	0	0	0
Root lesion nem. teres	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Root lesion nem. thornei	Y	82	29	24	45.7	16.3	11.03	3.95	60	40	0
Burrowing nem. nativus	U						0.00	0.00	0	0	0
Burrowing nem.vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	U						0.00	0.00	0	0	0
Bacterial leaf blight	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Black chaff	U						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	40	25	10	0.5	0.5	0.05	0.05	0	0	100
High Plains disease	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Wheat streak mosaic	Y	40	25	10	0.5	0.1	0.05	0.01	0	100	0

Table B5 Incidence, severity and contribution to control estimates and derived disease loss 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 leaf spot	Y	25	10	3	0.0	0.0	0.00	0.00	0	0	0
Wirrega blotch	U						0.00	0.00	0	0	0
Septoria tritici blotch	Y	20	25	5	30.0	5.0	1.50	0.25	60	0	40
Septoria avenae blotch	Y	5	5	0	10.0	10.0	0.03	0.03	0	0	0
Septoria nodorum blotch	Y	10	10	1	10.0	10.0	0.10	0.10	0	0	0
Ring spot	Y	25	10	3	0.0	0.0	0.00	0.00	0	0	0
Yellow spot	Y	58	25	15	13.5	4.0	1.97	0.58	40	40	20
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	23	18	4	2.5	0.6	0.09	0.02	40	5	55
Stem rust	Y	48	38	16	43.5	0.0	6.89	0.00	100	0	0
Leaf rust	Y	53	43	20	26.0	0.1	5.29	0.01	85	5	10
Stripe rust	Y	63	100	63	45.0	0.5	28.50	0.32	40	5	55
Downy mildew	Y	10	0	0	0.0	0.1	0.00	0.00	0	0	100
Flag smut	Y	60	20	12	35.0	0.0	4.20	0.00	80	0	20
ROOT AND CROWN FUNGI											
Foot rot	Y	10	1	0	20.0	10.0	0.02	0.01	0	100	0
Crown rot	Y	53	38	18	26.0	6.5	4.77	1.19	23	78	0
Take-all	Y	38	25	10	26.5	2.8	2.54	0.26	0	90	10
Damping off/root rot	Y	23	15	3	6.5	6.5	0.20	0.20	0	0	5
Rhizoctonia barepatch	Y	38	25	9	6.5	1.3	0.61	0.12	0	100	0
Eyespot	Y	5	10	1	20.0	5.0	0.10	0.03	0	100	0
Basal rot	Y	5	10	1	10.0	1.0	0.05	0.01	0	100	0
Common root rot	Y	40	88	35	11.5	2.8	4.03	0.96	35	65	0
INFLORESCENCE FUNGI											
Ergot	Y	20	10	2	25.0	0.0	0.50	0.00	0	100	0
Fusarium head blight	Y	15	38	5	1.5	0.1	0.08	0.00	20	80	0
Common bunt	Y	60	30	18	50.0	0.0	9.00	0.00	0	0	100
Loose smut	Y	80	80	64	5.0	0.0	3.20	0.00	0	0	100
NEMATODES											
Seed gall nematode	N						0.00	0.00	0	0	0
Cereal cyst nematode	Y	50	1	1	5.0	5.0	0.03	0.03	0	0	0
Stunt nematode	U						0.00	0.00	0	0	0
Root lesion nem. crenatus	U						0.00	0.00	0	0	0
Root lesion nem.neglectus	Y	50	50	25	3.0	1.0	0.75	0.25	50	50	0
Root lesion nem.penetrans	U						0.00	0.00	0	0	0
Root lesion nem. teres	U						0.00	0.00	0	0	0
Root lesion nem. thornei	Y	50	50	25	5.0	1.0	1.25	0.25	50	50	0
Burrowing nem. nativus	U						0.00	0.00	0	0	0
Burrowing nem.vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	Y	5	5	0	0.0	0.0	0.00	0.00	0	0	0
Bacterial leaf blight	Y	5	5	0	0.0	0.0	0.00	0.00	0	0	0
Black chaff	Y	5	5	0	0.0	0.0	0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	43	25	11	2.0	2.0	0.22	0.22	0	0	50
High Plains disease	Y	40	10	4	5.0	5.0	0.20	0.20	0	0	0
Wheat streak mosaic	Y	40	18	7	38.5	38.5	2.70	2.70	0	50	0

Table B6 Incidence, severity and contribution to control estimates and derived disease loss of wheat 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 leaf spot	Y	5	5	0	0.0	0.0	0.00	0.00	0	0	0
Wirrega blotch	U						0.00	0.00	0	0	0
Septoria tritici blotch	Y	33	25	8	23.5	0.3	1.91	0.02	75	5	20
Septoria avenae blotch	Y	5	5	0	10.0	10.0	0.03	0.03	0	0	0
Septoria nodorum blotch	Y	5	5	0	10.0	10.0	0.03	0.03	0	0	0
Ring spot	Y	25	10	3	0.0	0.0	0.00	0.00	0	0	0
Yellow spot	Y	50	25	13	10.0	5.0	1.25	0.63	30	70	0
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	20	5	1	0.0	0.0	0.00	0.00	0	0	100
Stem rust	Y	20	38	8	52.5	0.1	3.94	0.00	95	3	3
Leaf rust	Y	40	38	15	21.5	0.1	3.23	0.01	95	3	3
Stripe rust	Y	71	100	71	37.5	6.5	26.56	4.60	48	3	50
Downy mildew	Y	5	1	0	25.0	25.0	0.01	0.01	0	0	0
Flag smut	Y	40	20	8	50.0	0.0	4.00	0.00	80	0	20
ROOT AND CROWN FUNGI											
Foot rot	Y	5	40	2	10.0	5.0	0.20	0.10	0	100	0
Crown rot	Y	53	43	20	21.5	6.5	4.37	1.32	18	83	0
Take-all	Y	38	63	24	31.0	4.0	7.56	0.98	0	90	10
Damping off/root rot	Y	20	5	1	10.0	10.0	0.10	0.10	0	0	0
Rhizoctonia barepatch	Y	43	33	12	6.5	1.3	0.80	0.15	0	100	0
Eyespot	Y	10	25	3	20.0	1.0	0.50	0.03	0	100	0
Basal rot	Y	5	10	1	10.0	1.0	0.05	0.01	0	100	0
Common root rot	Y	20	25	5	30.0	5.0	1.50	0.25	20	80	0
INFLORESCENCE FUNGI											
Ergot	Y	20	35	7	25.0	0.0	1.75	0.00	0	100	0
Fusarium head blight	U						0.00	0.00	0	0	0
Common bunt	Y	71	28	20	25.0	0.1	4.90	0.02	3	0	98
Loose smut	Y	60	53	37	8.5	0.1	3.15	0.02	3	0	98
NEMATODES											
Seed gall nematode	N						0.00	0.00	0	0	0
Cereal cyst nematode	Y	50	1	1	5.0	5.0	0.03	0.03	0	0	0
Stunt nematode	U						0.00	0.00	0	0	0
Root lesion nem. crenatus	U						0.00	0.00	0	0	0
Root lesion nem.neglectus	Y	45	75	33	1.8	0.6	0.57	0.18	50	50	0
Root lesionnem.penetrans	U						0.00	0.00	0	0	0
Root lesion nem. teres	U						0.00	0.00	0	0	0
Root lesion nem. thornei	Y	45	75	33	2.8	0.6	0.89	0.18	50	50	0
Burrowing nem. nativus	U						0.00	0.00	0	0	0
Burrowing nem.vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	Y	5	5	0	0.0	0.0	0.00	0.00	0	0	0
Bacterial leaf blight	Y	5	5	0	0.0	0.0	0.00	0.00	0	0	0
Black chaff	Y	5	5	0	0.0	0.0	0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	48	25	12	4.0	2.8	0.48	0.33	0	75	25
High Plains disease	Y	40	15	6	5.0	5.0	0.30	0.30	0	100	0
Wheat streak mosaic	Y	20	18	4	17.6	17.6	0.61	0.61	0	100	0

Table B7 Incidence, severity and contribution to control estimates and derived disease loss of wheat diseases in the Victorian 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 leaf spot	U						0.00	0.00	0	0	0
Wirrega blotch	U						0.00	0.00	0	0	0
Septoria tritici blotch	Y	10	10	1	30.0	1.0	0.30	0.01	80	10	10
Septoria avenae blotch	U						0.00	0.00	0	0	0
Septoria nodorum blotch	Y	10	10	1	30.0	0.0	0.30	0.00	80	10	10
Ring spot	Y	100	20	20	0.0	0.0	0.00	0.00	0	100	0
Yellow spot	N						0.00	0.00	0	0	0
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	100	3	3	10.0	0.0	0.30	0.00	50	33	17
Stem rust	Y	30	90	27	80.0	1.0	21.60	0.27	50	20	30
Leaf rust	Y	100	90	90	20.0	5.0	18.00	4.50	50	10	40
Stripe rust	Y	100	90	90	60.0	10.0	54.00	9.00	50	10	40
Downy mildew	U						0.00	0.00	0	0	0
Flag smut	U						0.00	0.00	0	0	0
ROOT AND CROWN FUNGI											
Foot rot	Y	100	70	70	10.0	1.0	7.00	0.70	30	70	0
Crown rot	Y	100	50	50	10.0	1.0	5.00	0.50	30	70	0
Take-all	Y	100	70	70	20.0	2.0	14.00	1.40	0	70	30
Damping off/root rot	Y	100	80	80	5.0	0.0	4.00	0.00	0	90	10
Rhizoctonia barepatch	Y	100	30	30	10.0	2.0	3.00	0.60	0	100	0
Eyespot	U						0.00	0.00	0	0	0
Basal rot	U						0.00	0.00	0	0	0
Common root rot	U						0.00	0.00	0	0	0
INFLORESCENCE FUNGI											
Ergot	U						0.00	0.00	0	0	0
Fusarium head blight	U						0.00	0.00	0	0	0
Common bunt	Y	100	1	1	50.0	0.0	0.25	0.00	5	0	95
Loose smut	Y	100	1	1	30.0	0.0	0.15	0.00	5	0	95
NEMATODES											
Seed gall nematode	U						0.00	0.00	0	0	0
Cereal cyst nematode	Y	50	1	1	2.0	0.0	0.01	0.00	80	20	0
Stunt nematode	U						0.00	0.00	0	0	0
Root lesion nem. crenatus	Y	30	2	1	3.0	1.0	0.02	0.01	0	100	0
Root lesion nem.neglectus	Y	50	70	35	3.0	1.0	1.05	0.35	0	100	0
Root lesionnem.penetrans	U						0.00	0.00	0	0	0
Root lesion nem. teres	U						0.00	0.00	0	0	0
Root lesion nem. thornei	Y	50	30	15	3.0	1.0	0.45	0.15	0	100	0
Burrowing nem. nativus	U						0.00	0.00	0	0	0
Burrowing nem.vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	U						0.00	0.00	0	0	0
Bacterial leaf blight	U						0.00	0.00	0	0	0
Black chaff	U						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	100	30	30	10.0	2.0	3.00	0.60	30	30	40
High Plains disease	U						0.00	0.00	0	0	0
Wheat streak mosaic	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0

Table B8 Incidence, severity and contribution to control estimates and derived disease loss of wheat 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 leaf spot	U						0.00	0.00	0	0	0
Wirrega blotch	U										
Septoria tritici blotch	Y	10	10	1	30.0	1.0	0.30	0.01	80	10	10
Septoria avenae blotch	U						0.00	0.00	0	0	0
Septoria nodorum blotch	Y	10	10	1	30.0	0.0	0.30	0.00	80	10	10
Ring spot	Y	100	20	20	0.0	0.0	0.00	0.00	0	100	0
Yellow spot	N						0.00	0.00	0	0	0
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	100	3	3	10.0	0.0	0.30	0.00	50	33	17
Stem rust	Y	30	90	27	80.0	1.0	21.60	0.27	50	20	30
Leaf rust	Y	100	90	90	20.0	5.0	18.00	4.50	50	10	40
Stripe rust	Y	100	90	90	60.0	10.0	54.00	9.00	50	10	40
Downy mildew	U						0.00	0.00	0	0	0
Flag smut	U						0.00	0.00	0	0	0
ROOT AND CROWN FUNGI											
Foot rot	Y	100	70	70	10.0	1.0	7.00	0.70	30	70	0
Crown rot	Y	100	50	50	10.0	1.0	5.00	0.50	30	70	0
Take-all	Y	100	70	70	20.0	2.0	14.00	1.40	0	70	30
Damping off/root rot	Y	100	80	80	5.0	0.0	4.00	0.00	0	90	10
Rhizoctonia barepatch	Y	100	30	30	10.0	2.0	3.00	0.60	0	100	0
Eyespot	U						0.00	0.00	0	0	0
Basal rot	U						0.00	0.00	0	0	0
Common root rot	U						0.00	0.00	0	0	0
INFLORESCENCE FUNGI											
Ergot	U						0.00	0.00	0	0	0
Fusarium head blight	U						0.00	0.00	0	0	0
Common bunt	Y	100	1	1	50.0	0.0	0.25	0.00	5	0	95
Loose smut	Y	100	1	1	30.0	0.0	0.15	0.00	5	0	95
NEMATODES											
Seed gall nematode	U						0.00	0.00	0	0	0
Cereal cyst nematode	Y	50	1	1	2.0	0.0	0.01	0.00	80	20	0
Stunt nematode	U						0.00	0.00	0	0	0
Root lesion nem. crenatus	Y	30	2	1	3.0	1.0	0.02	0.01	0	100	0
Root lesion nem.neglectus	Y	50	70	35	3.0	1.0	1.05	0.35	0	100	0
Root lesionnem.penetrans	U						0.00	0.00	0	0	0
Root lesion nem. teres	U						0.00	0.00	0	0	0
Root lesion nem. thornei	Y	50	30	15	3.0	1.0	0.45	0.15	0	100	0
Burrowing nem. nativus	U						0.00	0.00	0	0	0
Burrowing nem.vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	U						0.00	0.00	0	0	0
Bacterial leaf blight	U						0.00	0.00	0	0	0
Black chaff	U						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	100	30	30	10.0	2.0	3.00	0.60	30	30	40
High Plains disease	U						0.00	0.00	0	0	0
Wheat streak mosaic	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0

Table B9 Incidence, severity and contribution to control estimates, and derived disease loss, of wheat 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 leaf spot	U						0.00	0.00	0	0	0
Wirrega blotch	U						0.00	0.00	0	0	0
Septoria tritici blotch	Y	30	20	6	20.0	0.0	1.20	0.00	90	10	0
Septoria avenae blotch	U						0.00	0.00	0	0	0
Septoria nodorum blotch	Y	2	2	0	20.0	0.0	0.01	0.00	80	20	0
Ring spot	Y	100	60	60	0.0	0.0	0.00	0.00	0	100	0
Yellow spot	Y	100	50	50	10.0	2.0	5.00	1.00	40	60	0
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	100	5	5	10.0	0.0	0.50	0.00	80	20	0
Stem rust	Y	15	70	11	60.0	0.0	6.30	0.00	90	10	0
Leaf rust	Y	30	70	21	30.0	0.0	6.30	0.00	90	8	2
Stripe rust	Y	90	70	63	50.0	7.0	31.50	4.41	60	10	30
Downy mildew	U						0.00	0.00	0	0	0
Flag smut	Y	10	1	0	20.0	0.0	0.01	0.00	20	0	80
ROOT AND CROWN FUNGI											
Foot rot	Y	100	10	10	15.0	1.0	1.50	0.10	10	90	0
Crown rot	Y	100	66	66	25.0	3.0	16.50	1.98	10	90	0
Take-all	Y	100	25	25	10.0	1.0	2.50	0.25	0	95	5
Damping off/root rot	Y	100	100	100	1.0	0.0	1.00	0.00	0	97	3
Rhizoctonia barepatch	Y	100	30	30	8.0	4.0	2.40	1.20	0	100	0
Eyespot	U						0.00	0.00	0	0	0
Basal rot	U						0.00	0.00	0	0	0
Common root rot	Y	100	60	60	5.0	1.0	3.00	0.60	80	20	0
INFLORESCENCE FUNGI											
Ergot	Y	10	2	0	1.0	0.0	0.00	0.00	0	100	0
Fusarium head blight	N						0.00	0.00	0	0	0
Common bunt	Y	100	0	0	40.0	0.0	0.02	0.00	5	5	90
Loose smut	Y	100	0	0	10.0	0.0	0.01	0.00	0	0	100
NEMATODES											
Seed gall nematode	U						0.00	0.00	0	0	0
Cereal cyst nematode	Y	100	100	100	40.0	5.0	40.00	5.00	60	40	0
Stunt nematode	U						0.00	0.00	0	0	0
Root lesion nem. crenatus	U						0.00	0.00	0	0	0
Root lesion nem.neglectus	Y	100	100	100	10.0	2.0	10.00	2.00	50	50	0
Root lesionnem.penetrans	U						0.00	0.00	0	0	0
Root lesion nem. teres	U						0.00	0.00	0	0	0
Root lesion nem. thornei	Y	100	50	50	15.0	2.0	7.50	1.00	50	50	0
Burrowing nem. nativus	U						0.00	0.00	0	0	0
Burrowing nem.vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	U						0.00	0.00	0	0	0
Bacterial leaf blight	U						0.00	0.00	0	0	0
Black chaff	U						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	100	2	2	3.0	0.1	0.06	0.00	0	100	0
High Plains disease	U						0.00	0.00	0	0	0
Wheat streak mosaic	Y	100	5	5	0.1	0.1	0.01	0.01	0	100	0

Table B10 Incidence, severity and contribution to control estimates and derived disease loss of wheat 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 leaf spot	N						0.00	0.00	0	0	0
Wirrega blotch	Y	100	1	1	0.1	0.1	0.00	0.00	0	100	0
Septoria tritici blotch	Y	7	10	1	10.0	0.0	0.07	0.00	85	15	0
Septoria avenae blotch	N						0.00	0.00	0	0	0
Septoria nodorum blotch	Y	3	2	0	10.0	0.0	0.01	0.00	75	25	0
Ring spot	Y	100	35	35	0.0	0.0	0.00	0.00	0	100	0
Yellow spot	Y	100	50	50	11.0	2.5	5.50	1.25	40	60	0
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	100	1	1	5.0	0.0	0.05	0.00	85	10	5
Stem rust	Y	7	75	5	50.0	0.0	2.43	0.00	90	10	0
Leaf rust	Y	15	75	11	20.0	0.0	2.25	0.00	85	12	4
Stripe rust	Y	95	75	72	35.0	4.0	25.03	2.86	65	10	25
Downy mildew	N						0.00	0.00	0	0	0
Flag smut	Y	10	1	0	20.0	0.0	0.01	0.00	20	0	80
ROOT AND CROWN FUNGI											
Foot rot	Y	100	6	6	1.5	0.5	0.09	0.03	10	90	0
Crown rot	Y	100	71	71	20.0	3.0	14.10	2.12	10	90	0
Take-all	Y	100	23	23	10.0	1.0	2.25	0.23	0	95	5
Damping off/root rot	Y	100	100	100	1.5	0.5	1.50	0.50	0	99	2
Rhizoctonia barepatch	Y	100	68	68	10.0	5.0	6.75	3.38	0	100	0
Eyespot	Y	2	5	0	10.0	0.0	0.01	0.00	60	40	0
Basal rot	U						0.00	0.00	0	0	0
Common root rot	Y	100	78	78	6.5	2.0	5.04	1.55	80	20	0
INFLORESCENCE FUNGI											
Ergot	Y	8	1	0	1.0	0.0	0.00	0.00	0	100	0
Fusarium head blight	N						0.00	0.00	0	0	0
Common bunt	Y	53	0	0	30.0	0.0	0.01	0.00	5	5	90
Loose smut	Y	55	0	0	10.0	0.0	0.01	0.00	0	0	100
NEMATODES											
Seed gall nematode	Y	1	1	0	1.0	0.0	0.00	0.00	0	100	0
Cereal cyst nematode	Y	100	100	100	50.0	5.0	50.00	5.00	80	20	0
Stunt nematode	0				0.0	0.0	0.00	0.00	0	0	0
Root lesion nem. crenatus	0				0.0	0.0	0.00	0.00	0	0	0
Root lesion nem. neglectus	Y	100	100	100	8.5	2.5	8.50	2.50	50	50	0
Root lesion nem. penetrans	0				0.0	0.0	0.00	0.00	0	0	0
Root lesion nem. teres	0				0.0	0.0	0.00	0.00	0	0	0
Root lesion nem. thornei	Y	100	13	13	15.0	2.5	1.88	0.31	50	50	0
Burrowing nem. nativus	0				0.0	0.0	0.00	0.00	0	0	0
Burrowing nem. vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	U						0.00	0.00	0	0	0
Bacterial leaf blight	U						0.00	0.00	0	0	0
Black chaff	U						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	100	2	2	2.5	0.1	0.05	0.00	0	100	0
High Plains disease	U						0.00	0.00	0	0	0
Wheat streak mosaic	Y	100	8	8	1.1	0.1	0.08	0.00	0	100	0

Table B11 Incidence, severity and contribution to control estimates and derived disease loss of wheat 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 leaf spot	N						0.00	0.00	0	0	0
Wirrega blotch	Y	100	1	1	1.0	0.0	0.01	0.00	0	100	0
Septoria tritici blotch	Y	50	10	5	10.0	0.0	0.50	0.00	80	20	0
Septoria avenae blotch	N						0.00	0.00	0	0	0
Septoria nodorum blotch	Y	5	2	0	10.0	0.0	0.01	0.00	70	30	0
Ring spot	Y	100	20	20	0.0	0.0	0.00	0.00	0	100	0
Yellow spot	Y	100	50	50	12.0	3.0	6.00	1.50	40	60	0
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	100	1	1	5.0	0.0	0.05	0.00	90	0	10
Stem rust	Y	6	30	2	50.0	0.0	0.90	0.00	90	10	0
Leaf rust	Y	15	50	8	20.0	0.0	1.50	0.00	80	15	5
Stripe rust	Y	100	50	50	30.0	3.0	15.00	1.50	70	10	20
Downy mildew	N						0.00	0.00	0	0	0
Flag smut	Y	10	1	0	20.0	0.0	0.01	0.00	20	0	80
ROOT AND CROWN FUNGI											
Foot rot	Y	100	7	7	2.0	0.5	0.14	0.04	10	90	0
Crown rot	Y	100	75	75	20.0	3.0	15.00	2.25	10	90	0
Take-all	Y	100	20	20	10.0	1.0	2.00	0.20	0	95	5
Damping off/root rot	Y	100	100	100	2.0	1.0	2.00	1.00	0	100	0
Rhizoctonia barepatch	Y	100	85	85	10.0	5.0	8.50	4.25	0	100	0
Eyespot	Y	50	4	2	10.0	0.5	0.20	0.01	0	60	40
Basal rot	U						0.00	0.00	0	0	0
Common root rot	Y	100	80	80	8.0	3.0	6.40	2.40	80	20	0
INFLORESCENCE FUNGI											
Ergot	Y	5	1	0	1.0	0.0	0.00	0.00	0	100	0
Fusarium head blight	N						0.00	0.00	0	0	0
Common bunt	Y	5	1	0	20.0	0.0	0.01	0.00	5	5	90
Loose smut	Y	10	1	0	10.0	0.0	0.01	0.00	0	0	100
NEMATODES											
Seed gall nematode	Y	1	1	0	1.0	0.0	0.00	0.00	0	100	0
Cereal cyst nematode	Y	100	100	100	50.0	5.0	50.00	5.00	80	20	0
Stunt nematode	U						0.00	0.00	0	0	0
Root lesion nem. crenatus	U						0.00	0.00	0	0	0
Root lesion nem.neglectus	Y	100	100	100	10.0	3.0	10.00	3.00	50	50	0
Root lesion nem. penetrans	U						0.00	0.00	0	0	0
Root lesion nem. teres	U						0.00	0.00	0	0	0
Root lesion nem. thornei	Y	100	25	25	15.0	3.0	3.75	0.75	50	50	0
Burrowing nem. nativus	U						0.00	0.00	0	0	0
Burrowing nem. vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	U						0.00	0.00	0	0	0
Bacterial leaf blight	U						0.00	0.00	0	0	0
Black chaff	U						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	100	2	2	3.0	0.4	0.06	0.01	0	100	0
High Plains disease	U						0.00	0.00	0	0	0
Wheat streak mosaic	Y	100	10	10	2.0	0.1	0.20	0.01	0	100	0

Table B12 Incidence, severity and contribution to control estimates and derived disease loss of wheat 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 leaf spot	U						0.00	0.00	0	0	0
Wirrega blotch	U						0.00	0.00	0	0	0
Septoria tritici blotch	Y	20	25	5	0.0	0.0	0.00	0.00	0	0	0
Septoria avenae blotch	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Septoria nodorum blotch	Y	67	100	67	14.0	6.3	9.33	4.17	25	50	25
Ring spot	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Yellow spot	Y	67	100	67	14.0	6.3	9.33	4.17	25	50	25
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	43	25	11	1.5	0.3	0.16	0.03	25	0	75
Stem rust	Y	40	25	10	25.0	3.0	2.50	0.30	60	10	30
Leaf rust	Y	20	25	5	25.0	3.0	1.25	0.15	80	10	10
Stripe rust	Y	53	25	13	25.0	3.0	3.33	0.40	50	10	40
Downy mildew	U						0.00	0.00	0	0	0
Flag smut	Y	20	25	5	3.0	0.1	0.15	0.01	35	10	55
ROOT AND CROWN FUNGI											
Foot rot	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Crown rot	Y	67	25	17	25.0	3.0	4.17	0.50	0	100	0
Take-all	Y	53	25	13	18.5	3.0	2.47	0.40	0	90	10
Damping off/root rot	Y	53	25	13	1.8	0.3	0.23	0.04	0	90	10
Rhizoctonia barepatch	Y	67	100	67	12.0	3.0	8.00	2.00	0	90	10
Eyespot	N						0.00	0.00	0	0	0
Basal rot	U						0.00	0.00	0	0	0
Common root rot	U						0.00	0.00	0	0	0
INFLORESCENCE FUNGI											
Ergot	Y	20	25	5	0.1	0.0	0.00	0.00	0	100	0
Fusarium head blight	Y	20	25	5	0.1	0.0	0.00	0.00	0	100	0
Common bunt	Y	20	25	5	12.0	0.1	0.60	0.01	0	10	90
Loose smut	Y	20	25	5	0.3	0.0	0.01	0.00	0	10	90
NEMATODES											
Seed gall nematode	N						0.00	0.00	0	0	0
Cereal cyst nematode	Y	30	25	8	3.0	0.5	0.23	0.04	10	90	0
Stunt nematode	U						0.00	0.00	0	0	0
Root lesion nem. crenatus	U						0.00	0.00	0	0	0
Root lesion nem.neglectus	Y	67	63	42	12.0	3.0	5.00	1.25	0	100	0
Root lesionnem.penetrans	Y	20	25	5	3.0	0.5	0.15	0.03	0	100	0
Root lesion nem. teres	Y	67	25	17	12.0	3.0	2.00	0.50	0	100	0
Root lesion nem. thornei	Y	20	25	5	12.0	3.0	0.60	0.15	0	100	0
Burrowing nem. nativus	Y	20	25	5	12.0	3.0	0.60	0.15	0	100	0
Burrowing nem.vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	N						0.00	0.00	0	0	0
Bacterial leaf blight	N						0.00	0.00	0	0	0
Black chaff	N						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	30	63	23	7.5	0.3	1.69	0.07	0	10	90
High Plains disease	N						0.00	0.00	0	0	0
Wheat streak mosaic	Y	40	25	10	3.0	0.5	0.30	0.05	0	100	0

Table B13 Incidence, severity and contribution to control estimates and derived disease loss of wheat 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 leaf spot	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Wirrega blotch	U						0.00	0.00	0	0	0
Septoria tritici blotch	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Septoria avenae blotch	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Septoria nodorum blotch	Y	67	100	67	25.0	12.0	16.67	8.00	30	40	30
Ring spot	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Yellow spot	Y	67	100	67	25.0	12.0	16.67	8.00	40	35	25
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	67	25	17	3.0	0.5	0.50	0.08	25	0	75
Stem rust	Y	40	25	10	25.0	3.0	2.50	0.30	80	10	10
Leaf rust	Y	20	25	5	25.0	3.0	1.25	0.15	80	10	10
Stripe rust	Y	40	100	40	12.0	3.0	4.80	1.20	40	10	50
Downy mildew	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Flag smut	Y	20	25	5	3.0	0.1	0.15	0.01	35	10	55
ROOT AND CROWN FUNGI											
Foot rot	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Crown rot	Y	67	25	17	12.0	3.0	2.00	0.50	0	100	0
Take-all	Y	67	25	17	12.0	0.5	2.00	0.08	0	90	10
Damping off/root rot	Y	67	25	17	3.0	0.5	0.50	0.08	0	90	10
Rhizoctonia barepatch	Y	67	100	67	12.0	3.0	8.00	2.00	0	90	10
Eyespot	N						0.00	0.00	0	0	0
Basal rot	U						0.00	0.00	0	0	0
Common root rot	U						0.00	0.00	0	0	0
INFLORESCENCE FUNGI											
Ergot	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Fusarium head blight	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Common bunt	Y	20	25	5	12.0	0.1	0.60	0.01	0	10	90
Loose smut	Y	20	25	5	0.5	0.0	0.03	0.00	0	10	90
NEMATODES											
Seed gall nematode	Y	20	25	5	0.1	0.0	0.01	0.00	0	100	0
Cereal cyst nematode	Y	67	25	17	12.0	0.5	2.00	0.08	10	90	0
Stunt nematode	U						0.00	0.00	0	0	0
Root lesion nem. crenatus	U						0.00	0.00	0	0	0
Root lesion nem.neglectus	Y	67	100	67	12.0	3.0	8.00	2.00	0	100	0
Root lesionnem.penetrans	Y	20	25	5	12.0	3.0	0.60	0.15	0	100	0
Root lesion nem. teres	Y	67	25	17	12.0	3.0	2.00	0.50	0	100	0
Root lesion nem. thornei	Y	20	25	5	12.0	3.0	0.60	0.15	0	100	0
Burrowing nem. nativus	Y	40	25	10	12.0	3.0	1.20	0.30	0	100	0
Burrowing nem.vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	N						0.00	0.00	0	0	0
Bacterial leaf blight	N						0.00	0.00	0	0	0
Black chaff	N						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	67	25	17	3.0	0.1	0.50	0.02	0	10	90
High Plains disease	N						0.00	0.00	0	0	0
Wheat streak mosaic	Y	40	25	10	25.0	3.0	2.50	0.30	0	100	0

Table B14 Incidence, severity and contribution to control estimates and derived disease loss of wheat 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 leaf spot	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Wirrega blotch	U						0.00	0.00	0	0	0
Septoria tritici blotch	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Septoria avenae blotch	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Septoria nodorum blotch	Y	67	100	67	25.0	12.0	16.67	8.00	30	40	30
Ring spot	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Yellow spot	Y	67	100	67	25.0	12.0	16.67	8.00	40	35	25
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	67	25	17	3.0	0.5	0.50	0.08	25	0	75
Stem rust	Y	20	25	5	25.0	3.0	1.25	0.15	80	10	10
Leaf rust	Y	40	25	10	25.0	3.0	2.50	0.30	80	10	10
Stripe rust	Y	40	25	10	12.0	3.0	1.20	0.30	50	10	40
Downy mildew	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Flag smut	Y	40	25	10	12.0	0.1	1.20	0.01	35	10	55
ROOT AND CROWN FUNGI											
Foot rot	U						0.00	0.00	0	0	0
Crown rot	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Take-all	Y	40	25	10	12.0	3.0	1.20	0.30	0	90	10
Damping off/root rot	Y	40	25	10	3.0	0.5	0.30	0.05	0	90	10
Rhizoctonia barepatch	Y	67	25	17	3.0	0.5	0.50	0.08	0	100	0
Eyespot	N						0.00	0.00	0	0	0
Basal rot	U						0.00	0.00	0	0	0
Common root rot	Y	20	25	5	0.0	0.0	0.00	0.00	0	0	0
INFLORESCENCE FUNGI											
Ergot	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Fusarium head blight	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Common bunt	Y	20	25	5	12.0	0.1	0.60	0.01	0	10	90
Loose smut	Y	20	25	5	0.5	0.0	0.03	0.00	0	10	90
NEMATODES											
Seed gall nematode	Y	20	25	5	0.1	0.0	0.01	0.00	0	100	0
Cereal cyst nematode	Y	67	25	17	12.0	0.5	2.00	0.08	10	90	0
Stunt nematode	U						0.00	0.00	0	0	0
Root lesion nem. crenatus	U						0.00	0.00	0	0	0
Root lesion nem. neglectus	Y	67	100	67	12.0	3.0	8.00	2.00	0	100	0
Root lesion nem. penetrans	Y	20	25	5	12.0	3.0	0.60	0.15	0	100	0
Root lesion nem. teres	Y	67	25	17	12.0	3.0	2.00	0.50	0	100	0
Root lesion nem. thornei	Y	20	25	5	12.0	3.0	0.60	0.15	0	100	0
Burrowing nem. nativus	Y	40	25	10	12.0	3.0	1.20	0.30	0	100	0
Burrowing nem.vangundyi	Y	40	25	10	12.0	3.0	1.20	0.30	0	100	0
BACTERIA											
Basal glume rot	N						0.00	0.00	0	0	0
Bacterial leaf blight	N						0.00	0.00	0	0	0
Black chaff	N						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	40	25	10	3.0	0.1	0.30	0.01	0	10	90
High Plains disease	N						0.00	0.00	0	0	0
Wheat streak mosaic	Y	20	25	5	3.0	0.5	0.15	0.03	0	100	0

Table B15 Incidence, severity and contribution to control estimates and derived disease loss of wheat 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 leaf spot	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Wirrega blotch	U						0.00	0.00	0	0	0
Septoria tritici blotch	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Septoria avenae blotch	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Septoria nodorum blotch	Y	67	100	67	3.0	0.5	2.00	0.33	30	65	5
Ring spot	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Yellow spot	Y	67	100	67	3.0	0.5	2.00	0.33	40	55	5
BIOTROPHIC LEAF FUNGI											
Powdery mildew	Y	40	25	10	3.0	0.1	0.30	0.01	25	0	75
Stem rust	Y	40	25	10	25.0	3.0	2.50	0.30	80	10	10
Leaf rust	Y	20	25	5	12.0	3.0	0.60	0.15	80	10	10
Stripe rust	Y	67	25	17	25.0	12.0	4.17	2.00	50	10	40
Downy mildew	Y	20	25	5	0.0	0.0	0.00	0.00	0	0	0
Flag smut	Y	40	25	10	12.0	0.1	1.20	0.01	35	10	55
ROOT AND CROWN FUNGI											
Foot rot	Y	20	25	5	0.1	0.1	0.01	0.01	0	0	0
Crown rot	Y	40	25	10	12.0	0.5	1.20	0.05	0	100	0
Take-all	Y	20	25	5	3.0	3.0	0.15	0.15	0	0	0
Damping off/root rot	Y	20	25	5	3.0	3.0	0.15	0.15	0	0	0
Rhizoctonia barepatch	Y	40	25	10	3.0	0.5	0.30	0.05	0	100	0
Eyespot	N						0.00	0.00	0	0	0
Basal rot	U						0.00	0.00	0	0	0
Common root rot	U						0.00	0.00	0	0	0
INFLORESCENCE FUNGI											
Ergot	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Fusarium head blight	Y	0	0	0	0.0	0.0	0.00	0.00	0	0	0
Common bunt	Y	20	25	5	12.0	0.1	0.60	0.01	0	10	90
Loose smut	Y	20	25	5	0.0	0.0	0.00	0.00	0	0	0
NEMATODES											
Seed gall nematode	Y	20	25	5	0.1	0.0	0.01	0.00	0	100	0
Cereal cyst nematode	Y	20	25	5	3.0	0.5	0.15	0.03	10	90	0
Stunt nematode	U						0.00	0.00	0	0	0
Root lesion nem. crenatus	U						0.00	0.00	0	0	0
Root lesion nem. neglectus	Y	67	100	67	12.0	3.0	8.00	2.00	0	100	0
Root lesion nem. penetrans	Y	20	25	5	12.0	3.0	0.60	0.15	0	100	0
Root lesion nem. teres	Y	67	25	17	12.0	3.0	2.00	0.50	0	100	0
Root lesion nem. thornei	Y	20	25	5	12.0	3.0	0.60	0.15	0	100	0
Burrowing nem. nativus	Y	40	25	10	12.0	3.0	1.20	0.30	0	100	0
Burrowing nem. vangundyi	U						0.00	0.00	0	0	0
BACTERIA											
Basal glume rot	N						0.00	0.00	0	0	0
Bacterial leaf blight	N						0.00	0.00	0	0	0
Black chaff	N						0.00	0.00	0	0	0
VIRUSES											
Barley yellow dwarf	Y	20	25	5	3.0	0.1	0.15	0.01	0	10	90
High Plains disease	N						0.00	0.00	0	0	0
Wheat streak mosaic	Y	40	100	40	25.0	3.0	10.00	1.20	0	100	0

APPENDIX C: SUMMARY OF PRESENCE, INCIDENCE AND SEVERITY OF WHEAT 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 wheat disease pathogens in the 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 leaf spot	Y	Y	Y	Y	Y	U	U	U	N	N	U	Y	Y	Y
Wirrega blotch	U	U	U	U	U	U	U	U	Y	Y	U	U	U	U
Septoria tritici blotch	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Septoria avenae blotch	N	N	N	Y	Y	U	U	U	N	N	Y	Y	Y	Y
Septoria nodorum blotch	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ring spot	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Yellow spot	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y
BIOTROPHIC LEAF FUNGI														
Powdery mildew	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Stem rust	Y	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
Stripe rust	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Downy mildew	Y	Y	Y	Y	Y	U	U	U	N	N	U	Y	Y	Y
Flag smut	Y	Y	Y	Y	Y	U	U	Y	Y	Y	Y	Y	Y	Y
ROOT AND CROWN FUNGI														
Foot rot	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	Y
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
Damping off/root rot	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Rhizoctonia barepatch	N	N	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
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	U	U	U	U	U	U
Common root rot	Y	Y	Y	Y	Y	U	U	Y	Y	Y	U	U	Y	U
INFLORESCENCE FUNGI														
Ergot	U	Y	Y	Y	Y	U	U	Y	Y	Y	Y	Y	Y	Y
Fusarium head blight	Y	Y	Y	Y	U	U	U	N	N	N	Y	Y	Y	Y
Common bunt	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														
Seed gall nematode	N	N	U	N	N	U	U	U	Y	Y	N	Y	Y	Y
Cereal cyst nematode	N	N	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Stunt nematode	U	Y	Y	U	U	U	U	U	0	U	U	U	U	U
Root lesion nem. crenatus	U	U	U	U	U	Y	Y	U	0	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	0	U	Y	Y	Y	Y
Root lesion nem. teres	U	U	Y	U	U	U	U	U	0	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	0	U	Y	Y	Y	Y
Burrowing nem. vangundyi	N	U	U	U	U	U	U	U	U	U	U	U	Y	U
BACTERIA														
Basal glume rot	U	U	U	Y	Y	U	U	U	U	U	N	N	N	N
Bacterial leaf blight	Y	Y	Y	Y	Y	U	U	U	U	U	N	N	N	N
Black chaff	U	U	U	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
High Plains disease	U	Y	Y	Y	Y	U	U	U	U	U	N	N	N	N
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 wheat 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 leaf spot	20	20	20	25	5							0	0	0
Wirrega blotch									100	100				
Septoria tritici blotch				20	33	10	10	30	7	50	20	0	0	0
Septoria avenae blotch				5	5						0	0	0	0
Septoria nodorum blotch		20	20	10	5	10	10	2	3	5	67	67	67	67
Ring spot				25	25	100	100	100	100	100	20	20	20	20
Yellow spot	20	58	60	58	50			100	100	100	67	67	67	67
BIOTROPHIC LEAF FUNGI														
Powdery mildew	40	35	40	23	20	100	100	100	100	100	43	67	67	40
Stem rust	67	67	67	48	20	30	30	15	7	6	40	40	20	40
Leaf rust	67	67	67	53	40	100	100	30	15	15	20	20	40	20
Stripe rust	100	92	89	63	71	100	100	90	95	100	53	40	40	67
Downy mildew	20	20	20	10	5							0	0	20
Flag smut	20	40	40	60	40			10	10	10	20	20	40	40
ROOT AND CROWN FUNGI														
Foot rot		40	40	10	5	100	100	100	100	100	20	20		20
Crown rot	90	100	100	53	53	100	100	100	100	100	67	67	20	40
Take-all		40	40	38	38	100	100	100	100	100	53	67	40	20
Damping off/root rot	20	35	40	23	20	100	100	100	100	100	53	67	40	20
Rhizoctonia barepatch				38	43	100	100	100	100	100	67	67	67	40
Eyespot				5	10				2	50				
Basal rot				5	5									
Common root rot	100	84	78	40	20			100	100	100			20	
INFLORESCENCE FUNGI														
Ergot		20	20	20	20			10	8	5	20	0	0	0
Fusarium head blight	20	40	40	15							20	0	0	0
Common bunt	20	20	20	60	71	100	100	100	53	5	20	20	20	20
Loose smut	40	40	40	80	60	100	100	100	55	10	20	20	20	20
NEMATODES														
Seed gall nematode									1	1		20	20	20
Cereal cyst nematode				50	50	50	50	100	100	100	30	67	67	20
Stunt nematode		90	90											
Root lesion nem. crenatus						30	30							
Root lesion nem. neglectus		84	82	50	45	50	50	100	100	100	67	67	67	67
Root lesion nem. penetrans											20	20	20	20
Root lesion nem. teres			0								67	67	67	67
Root lesion nem. thornei	90	84	82	50	45	50	50	100	100	100	20	20	20	20
Burrowing nem. nativus											20	40	40	40
Burrowing nem. vangundyi													40	
BACTERIA														
Basal glume rot				5	5									
Bacterial leaf blight	20	20	20	5	5									
Black chaff				5	5									
VIRUSES														
Barley yellow dwarf	40	47	40	43	48	100	100	100	100	100	30	67	40	20
High Plains disease		20	20	40	40									
Wheat streak mosaic	20	40	40	40	20	20	20	100	100	100	40	40	20	40

Table C3 Incidence (%) of wheat 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 Mall	SMNLYE	W SandM	WA Cen	WA N	WA E
NECROTROPHIC LEAF FUNGI														
Bipolaris leaf spot	25	25	25	10	5							0	0	0
Wirrega blotch									1	1				
Septoria tritici blotch				25	25	10	10	20	10	10	25	0	0	0
Septoria avenae blotch				5	5						0	0	0	0
Septoria nodorum blotch		25	25	10	5	10	10	2	2	2	100	100	100	100
Ring spot				10	10	20	20	60	35	20	25	25	25	25
Yellow spot	85	83	87	25	25			50	50	50	100	100	100	100
BIOTROPHIC LEAF FUNGI														
Powdery mildew	25	25	25	18	5	3	3	5	1	1	25	25	25	25
Stem rust	67	75	78	38	38	90	90	70	75	30	25	25	25	25
Leaf rust	50	44	67	43	38	90	90	70	75	50	25	25	25	25
Stripe rust	60	80	82	100	100	90	90	70	75	50	25	100	25	25
Downy mildew	25	25	25	0	1							0	0	25
Flag smut	25	25	25	20	20			1	1	1	25	25	25	25
ROOT AND CROWN FUNGI														
Foot rot		25	25	1	40	70	70	10	6	7	25	25		25
Crown rot	5	33	50	38	43	50	50	66	71	75	25	25	25	25
Take-all		25	25	25	63	70	70	25	23	20	25	25	25	25
Damping off/root rot	25	25	25	15	5	80	80	100	100	100	25	25	25	25
Rhizoctonia barepatch				25	33	30	30	30	68	85	100	100	25	25
Eyespot				10	25				5	4				
Basal rot				10	10									
Common root rot	20	36	58	88	25			60	78	80			25	
INFLORESCENCE FUNGI														
Ergot		25	25	10	35			2	1	1	25	0	0	0
Fusarium head blight	25	25	25	38							25	0	0	0
Common bunt	25	25	25	30	28	1	1	0	0	1	25	25	25	25
Loose smut	100	25	25	80	53	1	1	0	0	1	25	25	25	25
NEMATODES														
Seed gall nematode									1	1		25	25	25
Cereal cyst nematode				1	1	1	1	100	100	100	25	25	25	25
Stunt nematode		11	11											
Root lesion nem. crenatus						2	2							
Root lesion nem. neglectus		13	14	50	75	70	70	100	100	100	63	100	100	100
Root lesion nem. penetrans											25	25	25	25
Root lesion nem. teres			0								25	25	25	25
Root lesion nem. thornei	12	30	29	50	75	30	30	50	13	25	25	25	25	25
Burrowing nem. nativus											25	25	25	25
Burrowing nem. vangundyi													25	
BACTERIA														
Basal glume rot				5	5									
Bacterial leaf blight	25	25	25	5	5									
Black chaff				5	5									
VIRUSES														
Barley yellow dwarf	25	25	25	25	25	30	30	2	2	2	63	25	25	25
High Plains disease		25	25	10	15									
Wheat streak mosaic	25	25	25	18	18	25	25	5	8	10	25	25	25	100

Table C4 Potential severity of wheat 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 leaf spot	0.1	0.1	0.1	0.0	0.0							0.0	0.0	0.0
Wirrega blotch									0.1	1.0				
Septoria tritici blotch				30.0	23.5	30.0	30.0	20.0	10.0	10.0	0.0	0.0	0.0	0.0
Septoria avenae blotch				10.0	10.0						0.0	0.0	0.0	0.0
Septoria nodorum blotch		0.1	0.1	10.0	10.0	30.0	30.0	20.0	10.0	10.0	14.0	25.0	25.0	3.0
Ring spot				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Yellow spot	50.0	43.8	37.3	13.5	10.0			10.0	11.0	12.0	14.0	25.0	25.0	3.0
BIOTROPHIC LEAF FUNGI														
Powdery mildew	3.0	9.8	12.0	2.5	0.0	10.0	10.0	10.0	5.0	5.0	1.5	3.0	3.0	3.0
Stem rust	100.0	81.3	70.7	43.5	52.5	80.0	80.0	60.0	50.0	50.0	25.0	25.0	25.0	25.0
Leaf rust	40.0	33.0	27.7	26.0	21.5	20.0	20.0	30.0	20.0	20.0	25.0	25.0	25.0	12.0
Stripe rust	80.0	66.3	55.7	45.0	37.5	60.0	60.0	50.0	35.0	30.0	25.0	12.0	12.0	25.0
Downy mildew	0.1	0.1	0.1	0.0	25.0							0.0	0.0	0.0
Flag smut	12.0	25.0	25.0	35.0	50.0			20.0	20.0	20.0	3.0	3.0	12.0	12.0
ROOT AND CROWN FUNGI														
Foot rot		12.0	12.0	20.0	10.0	10.0	10.0	15.0	1.5	2.0	0.1	0.1		0.1
Crown rot	46.7	67.5	52.5	26.0	21.5	10.0	10.0	25.0	20.0	20.0	25.0	12.0	0.1	12.0
Take-all		0.5	0.5	26.5	31.0	20.0	20.0	10.0	10.0	10.0	18.5	12.0	12.0	3.0
Damping off/root rot	0.5	1.1	0.5	6.5	10.0	5.0	5.0	1.0	1.5	2.0	1.8	3.0	3.0	3.0
Rhizoctonia barepatch				6.5	6.5	10.0	10.0	8.0	10.0	10.0	12.0	12.0	3.0	3.0
Eyespot				20.0	20.0				10.0	10.0				
Basal rot				10.0	10.0									
Common root rot	15.0	12.0	7.8	11.5	30.0			5.0	6.5	8.0			0.0	
INFLORESCENCE FUNGI														
Ergot		0.5	0.5	25.0	25.0			1.0	1.0	1.0	0.1	0.0	0.0	0.0
Fusarium head blight	0.1	3.4	0.5	1.5							0.1	0.0	0.0	0.0
Common bunt	25.0	3.0	3.0	50.0	25.0	50.0	50.0	40.0	30.0	20.0	12.0	12.0	12.0	12.0
Loose smut	25.0	12.0	12.0	5.0	8.5	30.0	30.0	10.0	10.0	10.0	0.3	0.5	0.5	0.0
NEMATODES														
Seed gall nematode									1.0	1.0		0.1	0.1	0.1
Cereal cyst nematode				5.0	5.0	2.0	2.0	40.0	50.0	50.0	3.0	12.0	12.0	3.0
Stunt nematode		0.3	1.0						0.0					
Root lesion nem. crenatus						3.0	3.0		0.0					
Root lesion nem. neglectus		25.5	24.0	3.0	1.8	3.0	3.0	10.0	8.5	10.0	12.0	12.0	12.0	12.0
Root lesion nem. penetrans									0.0		3.0	12.0	12.0	12.0
Root lesion nem. teres			0.0						0.0		12.0	12.0	12.0	12.0
Root lesion nem. thornei	60.0	50.5	45.7	5.0	2.8	3.0	3.0	15.0	15.0	15.0	12.0	12.0	12.0	12.0
Burrowing nem. nativus									0.0		12.0	12.0	12.0	12.0
Burrowing nem. vangundyi													12.0	
BACTERIA														
Basal glume rot				0.0	0.0									
Bacterial leaf blight	0.1	0.1	0.1	0.0	0.0									
Black chaff				0.0	0.0									
VIRUSES														
Barley yellow dwarf	0.1	1.1	0.5	2.0	4.0	10.0	10.0	3.0	2.5	3.0	7.5	3.0	3.0	3.0
High Plains disease		0.1	0.1	5.0	5.0									
Wheat streak mosaic	0.1	3.4	0.5	38.5	17.6	0.1	0.1	0.1	1.1	2.0	3.0	25.0	3.0	25.0

Table C5 Present severity of wheat 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 leaf spot	0.1	0.1	0.1	0.0	0.0							0.0	0.0	0.0
Wirrega blotch									0.1	0.0				
Septoria tritici blotch				5.0	0.3	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Septoria avenae blotch				10.0	10.0						0.0	0.0	0.0	0.0
Septoria nodorum blotch		0.1	0.1	10.0	10.0	0.0	0.0	0.0	0.0	0.0	6.3	12.0	12.0	0.5
Ring spot				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Yellow spot	10.0	10.5	7.7	4.0	5.0			2.0	2.5	3.0	6.3	12.0	12.0	0.5
BIOTROPHIC LEAF FUNGI														
Powdery mildew	3.0	2.3	3.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.5	0.1
Stem rust	1.0	0.8	0.7	0.0	0.1	1.0	1.0	0.0	0.0	0.0	3.0	3.0	3.0	3.0
Leaf rust	3.0	2.3	2.0	0.1	0.1	5.0	5.0	0.0	0.0	0.0	3.0	3.0	3.0	3.0
Stripe rust	10.0	7.6	6.8	0.5	6.5	10.0	10.0	7.0	4.0	3.0	3.0	3.0	3.0	12.0
Downy mildew	0.1	0.1	0.1	0.1	25.0							0.0	0.0	0.0
Flag smut	0.1	0.1	0.1	0.0	0.0			0.0	0.0	0.0	0.1	0.1	0.1	0.1
ROOT AND CROWN FUNGI														
Foot rot		3.0	3.0	10.0	5.0	1.0	1.0	1.0	0.5	0.5	0.1	0.1		0.1
Crown rot	13.3	12.5	11.0	6.5	6.5	1.0	1.0	3.0	3.0	3.0	3.0	3.0	0.1	0.5
Take-all		0.5	0.5	2.8	4.0	2.0	2.0	1.0	1.0	1.0	3.0	0.5	3.0	3.0
Damping off/root rot	0.1	1.1	0.5	6.5	10.0	0.0	0.0	0.0	0.5	1.0	0.3	0.5	0.5	3.0
Rhizoctonia barepatch				1.3	1.3	2.0	2.0	4.0	5.0	5.0	3.0	3.0	0.5	0.5
Eyespot				5.0	1.0				0.0	0.5				
Basal rot				1.0	1.0									
Common root rot	4.3	3.0	1.8	2.8	5.0			1.0	2.0	3.0			0.0	
INFLORESCENCE FUNGI														
Ergot		0.5	0.5	0.0	0.0			0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fusarium head blight	0.1	1.1	0.5	0.1							0.0	0.0	0.0	0.0
Common bunt	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Loose smut	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEMATODES														
Seed gall nematode									0.0	0.0		0.0	0.0	0.0
Cereal cyst nematode				5.0	5.0	0.0	0.0	5.0	5.0	5.0	0.5	0.5	0.5	0.5
Stunt nematode		0.3	1.0						0.0					
Root lesion nem. crenatus						1.0	1.0		0.0					
Root lesion nem. neglectus		10.8	9.3	1.0	0.6	1.0	1.0	2.0	2.5	3.0	3.0	3.0	3.0	3.0
Root lesion nem. penetrans									0.0		0.5	3.0	3.0	3.0
Root lesion nem. teres			0.0						0.0		3.0	3.0	3.0	3.0
Root lesion nem. thornei	20.7	18.8	16.3	1.0	0.6	1.0	1.0	2.0	2.5	3.0	3.0	3.0	3.0	3.0
Burrowing nem. nativus									0.0		3.0	3.0	3.0	3.0
Burrowing nem. vangundyi													3.0	
BACTERIA														
Basal glume rot				0.0	0.0									
Bacterial leaf blight	0.1	0.1	0.1	0.0	0.0									
Black chaff				0.0	0.0									
VIRUSES														
Barley yellow dwarf	0.1	1.1	0.5	2.0	2.8	2.0	2.0	0.1	0.1	0.4	0.3	0.1	0.1	0.1
High Plains disease		0.1	0.1	5.0	5.0									
Wheat streak mosaic	0.1	3.1	0.1	38.5	17.6	0.1	0.1	0.1	0.1	0.1	0.5	3.0	0.5	3.0

Table C6 Potential average annual yield losses (%) from wheat 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 leaf spot	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wirrega blotch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Septoria tritici blotch	0.00	0.00	0.00	1.50	1.91	0.30	0.30	1.20	0.07	0.50	0.00	0.00	0.00	0.00
Septoria avenae blotch	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Septoria nodorum blotch	0.00	0.01	0.01	0.10	0.03	0.30	0.30	0.01	0.01	0.01	9.33	16.67	16.67	2.00
Ring spot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Yellow spot	8.50	20.45	18.92	1.97	1.25	0.00	0.00	5.00	5.50	6.00	9.33	16.67	16.67	2.00
BIOTROPHIC LEAF FUNGI														
Powdery mildew	0.30	0.85	1.20	0.09	0.00	0.30	0.30	0.50	0.05	0.05	0.16	0.50	0.50	0.30
Stem rust	44.89	40.90	36.85	6.89	3.94	21.60	21.60	6.30	2.43	0.90	2.50	2.50	1.25	2.50
Leaf rust	13.40	9.67	12.33	5.29	3.23	18.00	18.00	6.30	2.25	1.50	1.25	1.25	2.50	0.60
Stripe rust	48.00	47.48	39.28	28.50	26.56	54.00	54.00	31.50	25.03	15.00	3.33	4.80	1.20	4.17
Downy mildew	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flag smut	0.60	2.50	2.50	4.20	4.00	0.00	0.00	0.01	0.01	0.01	0.15	0.15	1.20	1.20
ROOT AND CROWN FUNGI														
Foot rot	0.00	1.20	1.20	0.02	0.20	7.00	7.00	1.50	0.09	0.14	0.01	0.01	0.00	0.01
Crown rot	2.10	21.94	26.25	4.77	4.37	5.00	5.00	16.50	14.10	15.00	4.17	2.00	0.01	1.20
Take-all	0.00	0.05	0.05	2.54	7.56	14.00	14.00	2.50	2.25	2.00	2.47	2.00	1.20	0.15
Damping off/root rot	0.03	0.10	0.05	0.20	0.10	4.00	4.00	1.00	1.50	2.00	0.23	0.50	0.30	0.15
Rhizoctonia barepatch	0.00	0.00	0.00	0.61	0.80	3.00	3.00	2.40	6.75	8.50	8.00	8.00	0.50	0.30
Eyespot	0.00	0.00	0.00	0.10	0.50	0.00	0.00	0.00	0.01	0.20	0.00	0.00	0.00	0.00
Basal rot	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common root rot	3.00	3.22	3.11	4.03	1.50	0.00	0.00	3.00	5.04	6.40	0.00	0.00	0.00	0.00
INFLORESCENCE FUNGI														
Ergot	0.00	0.03	0.03	0.50	1.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fusarium head blight	0.01	0.34	0.05	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common bunt	1.25	0.15	0.15	9.00	4.90	0.25	0.25	0.02	0.01	0.01	0.60	0.60	0.60	0.60
Loose smut	10.00	1.20	1.20	3.20	3.15	0.15	0.15	0.01	0.01	0.01	0.01	0.03	0.03	0.00
NEMATODES														
Seed gall nematode	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Cereal cyst nematode	0.00	0.00	0.00	0.03	0.03	0.01	0.01	40.00	50.00	50.00	0.23	2.00	2.00	0.15
Stunt nematode	0.00	0.03	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Root lesion nem. crenatus	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Root lesion nem. neglectus	0.00	2.55	2.63	0.75	0.57	1.05	1.05	10.00	8.50	10.00	5.00	8.00	8.00	8.00
Root lesion nem. penetrans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.60	0.60	0.60
Root lesion nem. teres	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.00	2.00	2.00
Root lesion nem. thornei	6.48	12.78	11.03	1.25	0.89	0.45	0.45	7.50	1.88	3.75	0.60	0.60	0.60	0.60
Burrowing nem. nativus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	1.20	1.20	1.20
Burrowing nem. vangundyi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00
BACTERIA														
Basal glume rot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bacterial leaf blight	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black chaff	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VIRUSES														
Barley yellow dwarf	0.01	0.13	0.05	0.22	0.48	3.00	3.00	0.06	0.05	0.06	1.69	0.50	0.30	0.15
High Plains disease	0.00	0.01	0.01	0.20	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wheat streak mosaic	0.00	0.34	0.05	2.70	0.61	0.01	0.01	0.01	0.08	0.20	0.30	2.50	0.15	10.00

Table C7 Present average annual yield losses (%) from wheat diseases with current controls 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 leaf spot	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wirrega blotch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Septoria tritici blotch	0.00	0.00	0.00	0.25	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Septoria avenae blotch	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Septoria nodorum blotch	0.00	0.01	0.01	0.10	0.03	0.00	0.00	0.00	0.00	0.00	4.17	8.00	8.00	0.33
Ring spot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Yellow spot	1.70	4.91	3.88	0.58	0.63	0.00	0.00	1.00	1.25	1.50	4.17	8.00	8.00	0.33
BIOTROPHIC LEAF FUNGI														
Powdery mildew	0.30	0.20	0.30	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.08	0.01
Stem rust	0.45	0.38	0.35	0.00	0.00	0.27	0.27	0.00	0.00	0.00	0.30	0.30	0.15	0.30
Leaf rust	1.01	0.67	0.89	0.01	0.01	4.50	4.50	0.00	0.00	0.00	0.15	0.15	0.30	0.15
Stripe rust	6.00	5.46	4.82	0.32	4.60	9.00	9.00	4.41	2.86	1.50	0.40	1.20	0.30	2.00
Downy mildew	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flag smut	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
ROOT AND CROWN FUNGI														
Foot rot	0.00	0.30	0.30	0.01	0.10	0.70	0.70	0.10	0.03	0.04	0.01	0.01	0.00	0.01
Crown rot	0.60	4.06	5.50	1.19	1.32	0.50	0.50	1.98	2.12	2.25	0.50	0.50	0.01	0.05
Take-all	0.00	0.05	0.05	0.26	0.98	1.40	1.40	0.25	0.23	0.20	0.40	0.08	0.30	0.15
Damping off/root rot	0.01	0.10	0.05	0.20	0.10	0.00	0.00	0.00	0.50	1.00	0.04	0.08	0.05	0.15
Rhizoctonia barepatch	0.00	0.00	0.00	0.12	0.15	0.60	0.60	1.20	3.38	4.25	2.00	2.00	0.08	0.05
Eyespot	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Basal rot	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common root rot	0.87	0.80	0.70	0.96	0.25	0.00	0.00	0.60	1.55	2.40	0.00	0.00	0.00	0.00
INFLORESCENCE FUNGI														
Ergot	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fusarium head blight	0.01	0.11	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common bunt	0.01	0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Loose smut	0.04	0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEMATODES														
Seed gall nematode	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cereal cyst nematode	0.00	0.00	0.00	0.03	0.03	0.00	0.00	5.00	5.00	5.00	0.04	0.08	0.08	0.03
Stunt nematode	0.00	0.03	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Root lesion nem. crenatus	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Root lesion nem. neglectus	0.00	1.08	1.02	0.25	0.18	0.35	0.35	2.00	2.50	3.00	1.25	2.00	2.00	2.00
Root lesion nem. penetrans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.15	0.15	0.15
Root lesion nem. teres	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50
Root lesion nem. thornei	2.23	4.75	3.95	0.25	0.18	0.15	0.15	1.00	0.31	0.75	0.15	0.15	0.15	0.15
Burrowing nem. nativus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.30	0.30	0.30
Burrowing nem. vangundyi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00
BACTERIA														
Basal glume rot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bacterial leaf blight	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black chaff	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VIRUSES														
Barley yellow dwarf	0.01	0.13	0.05	0.22	0.33	0.60	0.60	0.00	0.00	0.01	0.07	0.02	0.01	0.01
High Plains disease	0.00	0.01	0.01	0.20	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wheat streak mosaic	0.00	0.31	0.01	2.70	0.61	0.01	0.01	0.01	0.00	0.01	0.05	0.30	0.03	1.20

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 wheat, by GRDC Zone

% area treated	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	TOTAL
Seed (low rate)	40	20	13	30	25	30	30	40	60	60	23	20	10	20	**30**
Seed (high rate)	15	10	3	20	25	18	18	15	13	13	10	15	10	20	**14**
In-furrow only	0	1	1	0	0	1	1	5	5	5	10	5	10	10	**4**
Foliar only	0	17	20	20	9	1	1	2	2	2	20	20	30	5	**13**
Seed (low rate) + in-furrow	0	0	0	0	1	10	10	15	10	10	5	0	5	0	**4**
Seed (low rate) + foliar	10	37	33	25	20	20	20	15	7	7	18	20	10	15	**19**
Seed (low rate) + 2 foliar	0	3	3	5	20	10	10	4	0	0	3	5	5	0	**5**
Seed + in-furrow + foliar	0	0	0	0	0	10	10	4	3	3	3	5	5	0	**2**
No fungicide	35	12	25	0	0	0	0	0	0	0	10	10	15	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**				
	Q Cen	NNEQSE	NNWQSW	N Cen	NV Slp	Vic HR	Tas	SV BWim	SV Mall	SMNLYE	W SandM	WA Cen	WA N	WA E	TOTAL
Seed (low rate)	57	324	105	442	503	61	4	437	1783	612	92	504	126	236	**5287**
Seed (high rate)	50	378	61	688	1173	86	6	383	902	309	96	882	295	551	**5858**
In-furrow only	0	320	234	0	0	15	1	521	1651	849	684	2099	2107	1967	**10,449**
Foliar only	0	4395	3863	4323	2212	17	1	229	727	374	1505	9237	6954	1082	**34,919**
Seed (low rate) + in-furrow	0	0	0	0	244	171	11	1726	3600	1801	363	0	1117	0	**9032**
Seed (low rate) + foliar	365	10,263	6702	5773	5318	373	25	1882	2751	1379	1388	9741	2444	3422	**51,827**
Seed (low rate) + 2 foliar	0	1812	1314	2235	10,234	353	23	960	0	0	386	4745	2381	0	**24,444**
Seed + in-furrow + foliar	0	0	0	0	0	337	22	918	2170	1101	369	4535	2276	0	**11,728**
No fungicide	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
TOTAL	**473**	**17,492**	**12,280**	**13,462**	**19,684**	**1413**	**93**	**7055**	**13,584**	**6425**	**4883**	**31,743**	**17,700**	**7258**	**153,544**
Area treated ('000 ha)	**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	TOTAL
Seed (low rate)	64	240	117	295	279	23	1	208	991	510	77	420	105	197	**3526**
Seed (high rate)	24	120	29	197	v279	14	1	78	215	110	34	315	105	197	**1718**
In-furrow only	0	16	12	0	0	1	0	26	83	42	34	105	105	98	**522**
Foliar only	0	200	176	197	101	1	0	10	33	17	68	420	316	49	**1587**
Seed (low rate) + in-furrow	0	0	0	0	11	8	0	78	165	85	17	0	53	0	**417**
Seed (low rate) + foliar	16	440	293	246	223	15	1	78	116	59	60	420	105	148	**2219**
Seed (low rate) + 2 foliar	0	40	29	49	223	8	0	21	0	0	9	105	53	0	**537**
Seed + in-furrow + foliar	0	0	0	0	0	8	0	21	50	25	9	105	53	0	**270**
No fungicide	56	144	222	0	0	0	0	0	0	0	34	210	158	295	**1119**
TOTAL	**159**	**1199**	**878**	**983**	**1117**	**75**	**5**	**521**	**1651**	**849**	**342**	**2099**	**1054**	**983**	**11,916**
Cost per hectare	$3	$15	$14	$14	$18	$19	$19	$14	$8	$8	$14	$15	$17	$7	**$13**
Cost per hectare applied	$5	$17	$19	$14	$18	$19	$19	$14	$8	$8	$16	$17	$20	$11	**$14**
Sowing rate (kg/ha)	30	45	30	50	60	90	90	70	60	40	40	40	40	40	**47**

APPENDIX E: VARIETAL REACTIONS TO 12 DISEASES BY GRDC REGION, 2005-06

The percentages of the production in 2005-06 for cultivars with each levels of resistance are aggregated for the three GRDC Regions and for Australia in the following tables. For a more detailed explanation, see Section 8.

Table E1 Stem rust reactions (per cent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	0	6	3	4
Resistant - Moderately resistant	73	10	5	14
Moderately resistant	16	13	23	19
Moderately resistant - Moderately susceptible	2	19	2	8
Moderately susceptible	8	33	35	32
Moderately susceptible - Susceptible	1	10	0	4
Susceptible	0	3	26	15
Susceptible- Very susceptible	0	0	0	0
Very susceptible	0	4	5	4
No data	1	1	1	1

Table E2 Stripe rust reactions (per cent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	0	2	0	1
Resistant - Moderately resistant	8	0	0	1
Moderately resistant	16	4	2	4
Moderately resistant - Moderately susceptible	27	31	9	19
Moderately susceptible	43	21	39	33
Moderately susceptible - Susceptible	3	26	42	32
Susceptible	1	4	2	3
Susceptible- Very susceptible	0	4	7	5
Very susceptible	1	7	0	3
No data	0	0	0	0

Table E3 Leaf rust reactions (per cent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	2	23	34	27
Resistant - Moderately resistant	58	3	1	7
Moderately resistant	1	14	19	15
Moderately resistant - Moderately susceptible	33	2	20	15
Moderately susceptible	5	45	15	25
Moderately susceptible - Susceptible	0	8	1	4
Susceptible	0	3	8	5
Susceptible- Very susceptible	0	0	0	0
Very susceptible	0	0	0	0
No data	1	1	1	1

Table E4 Cereal cyst nematode reactions (per cent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	0	8	2	4
Resistant - Moderately resistant	0	0	0	0
Moderately resistant	0	17	5	9
Moderately resistant - Moderately susceptible	0	0	0	0
Moderately susceptible	0	4	0	2
Moderately susceptible - Susceptible	0	0	0	0
Susceptible	6	53	39	41
Susceptible- Very susceptible	0	0	0	0
Very susceptible	0	0	0	0
No data	94	17	53	44

Table E5 Yellow leaf spot reactions (percent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	0	0	0	0
Resistant - Moderately resistant	0	0	0	0
Moderately resistant	0	11	34	22
Moderately resistant - Moderately susceptible	24	8	21	16
Moderately susceptible	2	11	24	17
Moderately susceptible - Susceptible	28	20	1	10
Susceptible	44	43	16	29
Susceptible- Very susceptible	1	2	3	3
Very susceptible	0	0	0	0
No data	1	4	0	2

Table E6 Septoria tritici blotch reactions (per cent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	0	0	0	0
Resistant - Moderately resistant	0	0	0	0
Moderately resistant	0	4	1	2
Moderately resistant - Moderately susceptible	1	22	34	26
Moderately susceptible	13	48	12	25
Moderately susceptible - Susceptible	23	2	18	13
Susceptible	24	9	26	19
Susceptible- Very susceptible	0	4	5	4
Very susceptible	1	7	1	3
No data	37	4	3	7

Table E7 Septoria nodorum blotch reactions (per cent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	0	0	0	0
Resistant - Moderately resistant	0	0	0	0
Moderately resistant	0	0	0	0
Moderately resistant - Moderately susceptible	0	1	21	12
Moderately susceptible	3	33	35	31
Moderately susceptible - Susceptible	0	16	40	27
Susceptible	10	7	2	4
Susceptible- Very susceptible	0	5	1	2
Very susceptible	0	0	0	0
No data	87	37	2	23

Table E8 *Pratylenchus neglectus* reactions (per cent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	0	0	0	0
Resistant - Moderately resistant	0	0	0	0
Moderately resistant	0	11	34	22
Moderately resistant - Moderately susceptible	0	2	5	3
Moderately susceptible	2	18	2	8
Moderately susceptible - Susceptible	3	39	4	17
Susceptible	26	6	1	5
Susceptible- Very susceptible	0	1	2	1
Very susceptible	0	0	0	0
No data	68	22	53	43

Table E9 *Pratylenchus thornei* reactions (per cent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	0	4	0	2
Resistant - Moderately resistant	0	0	0	0
Moderately resistant	24	6	0	5
Moderately resistant - Moderately susceptible	24	2	0	3
Moderately susceptible	6	8	2	5
Moderately susceptible - Susceptible	40	2	1	5
Susceptible	4	45	42	39
Susceptible- Very susceptible	0	0	0	0
Very susceptible	0	1	2	1
No data	3	31	52	39

Table E10 Crown rot reactions (per cent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	0	0	0	0
Resistant - Moderately resistant	0	0	0	0
Moderately resistant	0	0	0	0
Moderately resistant - Moderately susceptible	23	0	0	3
Moderately susceptible	2	4	0	2
Moderately susceptible - Susceptible	46	21	5	15
Susceptible	27	47	42	42
Susceptible- Very susceptible	0	0	0	0
Very susceptible	0	0	0	0
No data	2	26	52	38

Table E11 Common root rot reactions (per cent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	0	0	0	0
Resistant - Moderately resistant	8	0	0	1
Moderately resistant	8	7	0	3
Moderately resistant - Moderately susceptible	40	3	0	5
Moderately susceptible	38	14	8	13
Moderately susceptible - Susceptible	4	14	3	7
Susceptible	0	29	35	29
Susceptible- Very susceptible	0	4	0	2
Very susceptible	0	0	0	0
No data	3	28	54	39

Table E12 Flag smut reactions (per cent of cultivars delivered in each category)

Resistance category	North	South	West	Australia
Resistant	5	30	1	12
Resistant - Moderately resistant	10	2	1	2
Moderately resistant	3	39	26	28
Moderately resistant - Moderately susceptible	0	2	5	3
Moderately susceptible	0	0	1	1
Moderately susceptible - Susceptible	0	4	23	14
Susceptible	1	13	39	26
Susceptible- Very susceptible	0	0	1	0
Very susceptible	0	0	0	0
No data	81	8	4	14

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