Chapter 13

EFFECTS OF TILLAGE PRACTICES ON FOLIAR DISEASES

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Tillage practices influence survival of foliar diseases mainly through effects on the amount, position and rate of breakdown of crop residues. Survival of some pathogens is also influenced through effects of tillage practices on self-sown or regrowth crop plants. Other, less explored, influences of tillage on foliar diseases may be through modification of the susceptibility of the host crop and of the micro-environment within the crop.

Most studies of the effect of tillage on foliar diseases in Australia have involved cereals. Accordingly, the emphasis in this chapter is on cereals. Several diseases of wheat and barley are examined in some detail to establish principles with wider application. For convenience, foliar diseases are defined as those affecting above-ground parts of plants and caused by pathogens with primary propagules that are air-borne and dispersed by wind, water splash, or insect or mechanical vectors.

SURVIVAL OF FOLIAR PATHOGENS

Survival from crop to crop is of prime importance for foliar pathogens particularly those of annual crops. Pathogens may survive in one or more of a number of ways:

* Crop residues - Tillage has a major effect on diseases caused by the many facultative pathogens that survive primarily in crop residues. Facultative pathogens are able to live saprophytically and include most leaf-spotting fungi of cereals. Occupancy of tissues prior to death of the host plant usually provides facultative pathogens with a considerable advantage during the saprophytic phase.

* Living host plants - Pathogens surviving in this way are frequently biotrophs, such as rusts and viruses, and are unable to survive saprophytically in crop residues or soil. Facultative pathogens may also survive from crop to crop on living plants but this is generally secondary to other means of survival. Weeds may also be prevalent in poorly managed conservation farming situations and can act as potential hosts for pathogens and vectors.

* Seed or soil - Some pathogens with symptoms expressed in above-ground parts of crop plants can survive in or on seed, for example the various smut fungi of cereals. Tillage, naturally, does not appear to have any role in the survival of seed-borne pathogens of this type. Some cereal smuts, such as flag smut and possibly bunt, may also survive in soil. Generally, however, survival in soil either does not occur or is incidental for most foliar pathogens. Two exceptions to this are ergot (*Claviceps*) and *Sclerotinia* where the fruiting structures arising from sclerotia on or just below the soil surface are extended on stalks, enabling aerial dispersal of spores. Tillage that

results in deeper-burial of these structures may result in some control, at least in the short term.

The influence of crop residues on plant diseases has been covered more extensively by Cook *et al.* (1978).

CROP SUSCEPTIBILITY AND MICRO-ENVIRONMENT

A second, often less conspicuous effect of tillage practice on foliar diseases can be through modification of crop susceptibility and micro-environment (Yarham, 1975; Palti, 1981; Yarham and Norton, 1981).

The severity of foliar diseases may be modified where tillage practices alter crop vigour. For instance, powdery mildew (*Erysiphe graminis*) and leaf rust (*Puccinia recondita*) of wheat were more severe in tilled than in untilled land (Yarham and Norton, 1981). This effect appears to be associated with reduced mineralisation of nitrogen in untilled soil leading to less vigorous, and hence less susceptible growth as well as a less favourable micro-environment within the crop (Palti, 1981). Nitrogen fertilisation appears to increase the severity of barley scald (Jenkyn and Griffiths, 1978). Accordingly, tillage that increases mineralisation of nitrogen may lead to increased levels of scald (Yarham and Norton, 1981).

Direct drilling of cereals generally results in relatively shallow planting and plants that are more prostrate in habit (Palti, 1981). This again produces a less humid environment within young crops. In addition, crops sown into uncultivated seedbeds tend to establish more slowly (Chapters 2 and 3) and the micro-environment is initially less favourable for foliar diseases than in crops planted after conventional tillage.

In conservation farming, increased row spacings are often needed to handle the large quantities of crop residues. With wider rows, the micro-environment is often less humid and therefore less favourable for infection by foliar pathogens. As row spacings are increased, row direction may also become important. North-south orientation of rows has reduced losses from blue mould (*Peronospora hyoscyami*) in tobacco, probably because of better penetration of sunlight (Pont and Hughes, 1961).

Reduced tillage in conservation farming may also modify planting opportunities for crops (Chapters 2 and 3). In some situations earlier planting may be possible, but this has been shown to lead to higher levels of scald (*Rhynchosporium secalis*) in barley (Janakiram and Boyd, 1980) and septoria diseases (*Leptosphaeria nodorum* and *Mycosphaerella graminicola*) in wheat (Brown and Rosielle, 1980). In other situations, colder soil in spring associated with reduced tillage may delay planting of crops such as sorghum and cotton. At the other end of the crop season, early planting of cereals may result in earlier maturity of the crop and associated escape from diseases such as stem rust (*Puccinia graminis*). Later planting, however, might increase the likelihood of problems from these diseases.

DISPERSAL OF FOLIAR PATHOGENS

Unlike soil-borne diseases, most foliar diseases spread widely during a cropping season and many may develop irrespective of tillage practices in a particular field or farm. For instance, under favourable conditions cereal rusts may occur in susceptible crops largely irrespective of tillage practice. However, even diseases such as cereal rusts will be affected if tillage practices allow continued growth of out-of-season self-sown crop plants.

The severity of foliar disease in a susceptible crop is closely related to the proximity of inoculum to that crop. Generally, a small quantity of inoculum produced in or near a crop is more likely to result in infection in that crop than large amounts of inoculum produced at a considerable distance. Hence, a source of inoculum within a crop, such as infected crop residues, is more important with most diseases than inoculum produced elsewhere.

Dry fungal spores such as dry conidia (e.g. of *Drechslera* spp.) and rust uredospores are designed to act as dispersal spores. As well as increasing an epidemic in a source area their dispersal by wind spreads the disease to other crops and areas. Wet fungal spores such as pycnidiospores, many ascospores and some conidia are splash-dispersed or produced under wet conditions and are generally less likely to move very far. This does not mean that some spores of this type are not dispersed widely, but the majority travel only short distances. It could be expected, therefore, that tillage would have its greatest effect on foliar pathogens that produce wet spores in crop residues as the primary source of inoculum. Yellow spot (*Pyrenophora tritici-repentis*) in wheat and scald in barley are well known examples in Australia.

EXAMPLES OF DISEASES AFFECTED BY TILLAGE PRACTICE

YELLOW SPOT OF WHEAT

Since the early 1970s yellow spot has increased markedly and become the major leaf-spotting disease in wheat crops in Queensland and northern New South Wales (Rees and Platz, 1979). When first recorded during the wet 1950 season (Valder and Shaw, 1952) the disease was widespread in northern New South Wales and was present in southern Queensland and central New South Wales, indicating that it had been present for some time. For the next two decades yellow spot attracted little attention and was considered to be of minor importance.

Surveys through central and southern New South Wales in 1979 and 1980 showed that yellow spot was common in crops where wheat residues were present (Murray, 1981). In the wet 1983 season there was a substantial upsurge in yellow spot in these areas (G.M. Murray, personal communication).

Yellow spot was first noted in South Australia and Western Australia in about 1970 (Khan *et al.*, 1971) but was thought to have been present in Western Australia for some time. It was recognised in Western Australia only as a minor disease of seedlings until 1978 when the first crop severely affected at heading was reported and, by the 1983 season, it was one of the major foliar disease of wheat (A.G.P. Brown, personal communication).

Thus, yellow spot has emerged from a disease of little consequence to an important problem in a number of wheat areas of Australia.

Effect of crop residues

Two changes have contributed to the increased severity of yellow spot in northern New South Wales and Queensland (Rees and Platz, 1979 and unpublished data). Firstly, the high-yielding cultivars now grown in the prime-hard wheat area appear to be generally more susceptible to the disease than many of those grown previously. Of greater importance, however, has been the move away from burning to retention of wheat residues on the soil surface.

The role of crop residues and tillage was demonstrated in 1974 in a long-term residue-management experiment conducted by J.W. Littler and J.M.T. Marley at Hermitage on the southern Darling Downs (Rees and Platz, 1979) (Table 13.1). Practices that resulted in higher amounts of residue increased disease severity on the primary leaves. Although smaller, differences in severity of yellow spot between treatments remained as the crop approached maturity, despite the close proximity of the relatively narrow plots.

Table 13.1 Effect of residue management and tillage on severity of yellow spot (Rees and Platz, 1979)

Treatment		Surface Residue (g m^{-2})	Lesions per leaf	
Residues	Tillage		Primary leaf	Leaf below flag
Retained	Nil	152.9 a*	11.8 a	51.3 a
Retained	Conventional	32.2 b	2.4 b	33.3 b
Burnt	Nil	12.9 c	0.8 c	27.7 c
Burnt	Conventional	8.7 c	0.6 c	26.5 c

*The logarithmic transformation was applied to data before analysis; equivalent means are given. Values in each column followed by the same letter do not differ significantly ($P > 0.05$).

Surveys through northern New South Wales early in the 1979 season showed yellow spot to be most severe in young crops where wheat residues were present on the soil surface; it was virtually absent where residues had been burnt or where an 18 month long-fallow had been used (T.A. Klein and L.W. Burgess, unpublished data; Klein and Ellison, 1982). In Western Australia, wheat residues are also implicated, but increased numbers of self-sown plants in ungrazed stubbles due to reduced sheep numbers and some additional climatological factors may have contributed to the upsurge in yellow spot (A.G.P. Brown, personal communication).

During summer or autumn, small black fruiting bodies (pseudothecia) develop on infected wheat stubble (Figure 13.1). Under moist conditions, these pseudothecia produce ascospores, which are ejected several centimetres and then move short distances in air currents before possibly being deposited on wheat plants. Further moist conditions are required for infection to occur, with disease symptoms being evident in about a week. In time, large numbers of conidia are produced on old lesions and dead tissues in the crop. These dry conidia are blown about by the wind and may result in the rapid development of the epidemic and spread of the disease to other crops.

In two surface-management experiments at Greenwood and Greenmount on the Darling Downs (Freebairn and Boughton, 1981), severity of yellow spot was again influenced by tillage practice and associated levels of wheat residue (Table 13.2). The relationship between wheat-residue levels and disease severity was shown by Rees *et al.* (1982) to be initially linear but to become noticeably logarithmic as the epidemic progressed (Figure 13.2). The apparent linear relationship early in the growing season probably reflected the predominance of ascospore inoculum at that time and little interplot interference. The logarithmic phase occurred as conidial production increased on old lesions in the crop and the role of infected residues diminished. If a similar logarithmic relationship applies in crop situations free from interplot interference, a relatively small amount of infected residue could result in substantial yellow spot under environmental conditions favouring disease development.

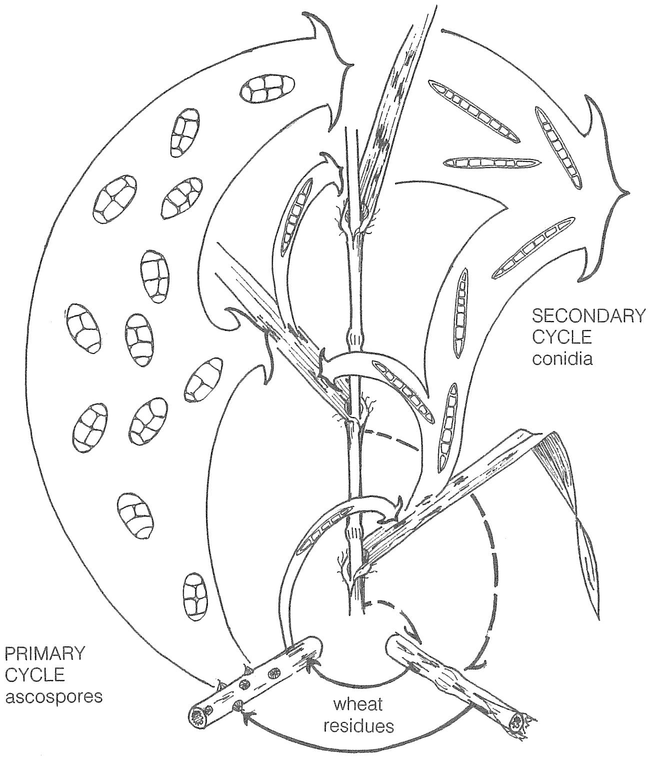

Figure 13.1 Disease cycle of yellow spot showing production of ascospores of *P. tritici-repentis* on wheat residues and conidia on diseased plant tissues. Ascospores, and to a lesser extent conidia, produced on wheat residues initiate the epidemic, while conidia produced on diseased plant tissues promote rapid development of the epidemic and spread to other crops

(Drawing by G.R. Scott)

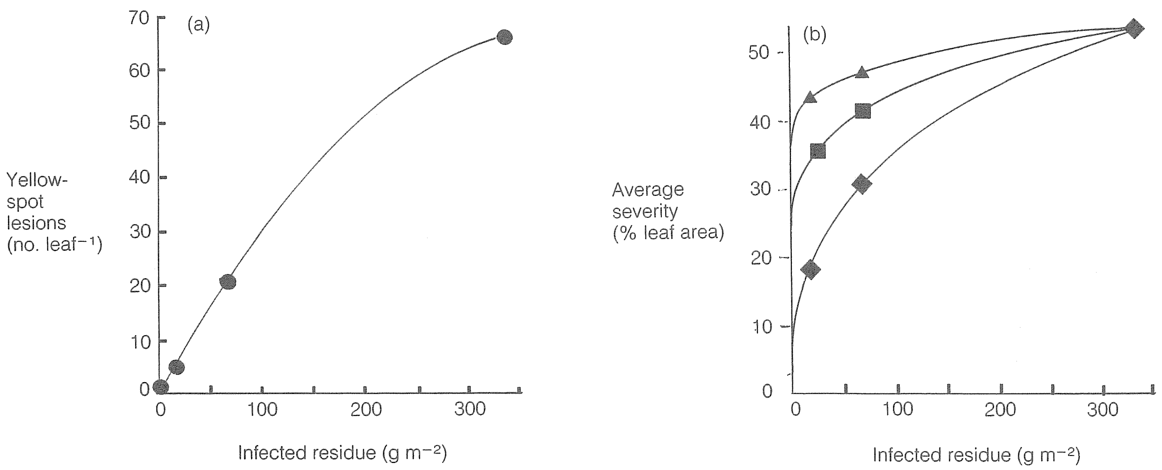

Figure 13.2 (a) Relationship between average number of yellow-spot lesions on leaf 2 at growth stage 14 and amount of infected wheat residue applied
(b) Relationship between average severity of yellow spot (% leaf area affected) and amount of infected wheat residue applied. Separate relationships for average disease severity over three dates to growth stage 39–41 (◆), seven dates from growth stage 69 (▲), and over the ten dates (■) are shown (Rees *et al.*, 1982)

Table 13.2 Effect of residue-management practice on severity of yellow spot (Rees, 1982)

Treatment		Yellow spot on primary leaf (%)[a]	
Residues	Tillage	Greenwood	Greenmount
Burnt	Disc plough	0.5	0.2
Incorporated	Disc plough	29.1	1.2
Retained	Sweep plough	80.5	36.3
Retained	Nil	90.0	56.3

[a] Percentage leaf area affected using the key of James (1971).

Cropping history

Yellow spot may become severe in the second or subsequent successive wheat crop in a rotation (Rees and Platz, 1979). At Formartin on the central Darling Downs, in an area where strip cropping is commonly practised, neighbouring strips were planted to the first, second or third wheat crops following a 15 month long-fallow from sorghum. The severity of yellow spot was greatest in the second wheat crop after the long-fallow and least in the initial crop (Table 13.3).

Table 13.3 Effect of cropping history on severity of yellow spot (Rees and Platz, 1979)

Cropping history	Yellow-spot severity (%)[a]		
	Flag	Flag–1	Flag–2
First wheat crop after 15-month long fallow	0.2	0.9	3.9
Second wheat crop after 15-month long fallow	15.8	49.0	97.8
Third wheat crop after 15-month long fallow	3.5	13.6	50.1

[a] Severity, or percentage of leaf area affected, measured using the key of James (1971).

Infectivity of residues

Crops other than wheat and some triticale cultivars are resistant to yellow spot. Small dark resistant lesions may occur in barley and, under favourable conditions, low numbers of pseudothecia may develop on barley residues. In one instance, pseudothecia on barley residues were associated with yellow spot in wheat (R.G. Rees and G.J. Platz, unpublished data). In general, however, pseudothecia of the yellow spot fungus develop abundantly only on wheat and possibly triticale residues. Residues of other crops are not important as sources of inoculum.

Soil incorporation of wheat residue prevents the residue from being an effective source of primary inoculum. This may be purely physical in that the ascospores, if produced, are unable to reach the foliage of the crop. In addition, in buried residues antagonists may overwhelm the fungus. Tillage frequently leaves the less readily decomposed crown and basal internodes of residues on the soil surface, but few pseudothecia generally develop in these tissues.

The fungus or its substrate in wheat residues on or above the soil surface gradually becomes depleted, the rate depending largely on weather conditions. During a single-crop season the number of pseudothecia increased during late summer (February) to late autumn (May) (Rees and Platz, 1980). By late spring (November), numerous pseudothecia were damaged, probably by insects and mites, and many appeared ineffective. Numbers of ascospores trapped above the crop residue were very low, and appeared to decline later in the growing season. In the laboratory, pseudothecia on dry wheat residues stored for 2 years still produced viable ascospores after the residues were wetted.

Samples of wheat residues from the surface-management trial at Greenmount (Freebairn and Boughton, 1981) were collected during July 1983 and counts made of pseudothecia of *P. tritici-repentis* (Table 13.4) (R.G. Rees and G.J. Platz, unpublished data). Where a no-till fallow since the 1982 crop was preceded by burning the 1981 wheat residues, pseudothecial numbers were low compared with the no-till fallowing in 1981. The influence of the 1981 crop residues probably carried through for 2 years, because of the dry year in 1982. Burning after the 1981 crop apparently resulted in very low levels of inoculum. Very little yellow spot developed in the 1982 crop because of the low initial inoculum levels and unfavourable conditions for disease development.

Table 13.4 Effect of previous residue management on infectivity of wheat residues

Residue treatment		Pseudothecia g^{-1} of wheat residue
Following 1981 crop	Following 1982 crop	
Incorporated (disc)	Mulched (sweep)	23
Burnt	Nil	24
Nil	Nil	321

Spore dispersal and disease gradients

Ascospores and, to a lesser extent, conidia produced on wheat residues on or above the soil surface form the bulk of the primary inoculum of yellow spot (Rees and Platz, 1980). Ascospores of *P. tritici-repentis* are usually produced at night under damp and often relatively still conditions and most are dispersed over short distances only. Gradients in the severity of yellow spot are frequently evident in Queensland wheat crops planted in fallow ground, free of wheat residues, but adjacent to infected wheat residues. Data from three such occurrences in 1979 are given in Table 13.5.

Table 13.5 Gradients of yellow spot from infected wheat residues (Rees, 1982)

Site	Lesions per leaf at distance (m) from residues							
	0	10	20	40	60	100	200	300
1	126	11.3	9.6	6.0	4.5	3.3	1.7	1.3
2	33.3	12.9	9.4	7.6	4.7	3.9	–	–
3	26.2	13.0	9.5	3.8	3.3	3.2	–	–

Similarly, the importance of ascospores produced on residues adjacent to target plants is illustrated by the data in Table 13.1. The plots concerned were about 5 m wide and yet marked differences in disease levels occurred in seedlings in different plots, indicating minimal movement of inoculum from plot to plot.

As epidemics of yellow spot progress, large numbers of conidia are produced on old lesions and dead infected tissues in diseased crops (Rees and Platz, 1980). These conidia result in rapid development of the epidemic. The role of ascospores and crop residues accordingly diminishes as the crop grows. Because these dry conidia are dispersal spores, all wheat in an area may be infected by the end of the season, but the level of infection in fields free of wheat residues will not generally approach the severity of that in crops planted through wheat residues. The data in Table 13.1 indicate significant differences between treatments as the crop approached maturity despite the narrow plots and movement of conidia from plot to plot.

Effect on grain yield

As well as the strong association between severity of yellow spot and amount of wheat residues (Figure 13.2), there are similarly strong relationships between loss in grain yield and level of yellow spot (Figure 13.3) and the amount of infected wheat residue on the soil surface (Figure 13.4). It is only in an occasional very favourable wet year, however, that losses in commercial crops would approach the maximum levels indicated in Figure 13.4. In commercial crops, yellow spot is generally only a problem where wheat residues are on the soil surface and reasonable rain falls during the growing season. Yield losses in these situations, in Queensland at least, would usually be of the order of 10-15% (Rees *et al.*, 1981) but exceeded 40% in at least some crops in 1984 (R.G. Rees, L.D. Ward and G.J. Platz, unpublished data).

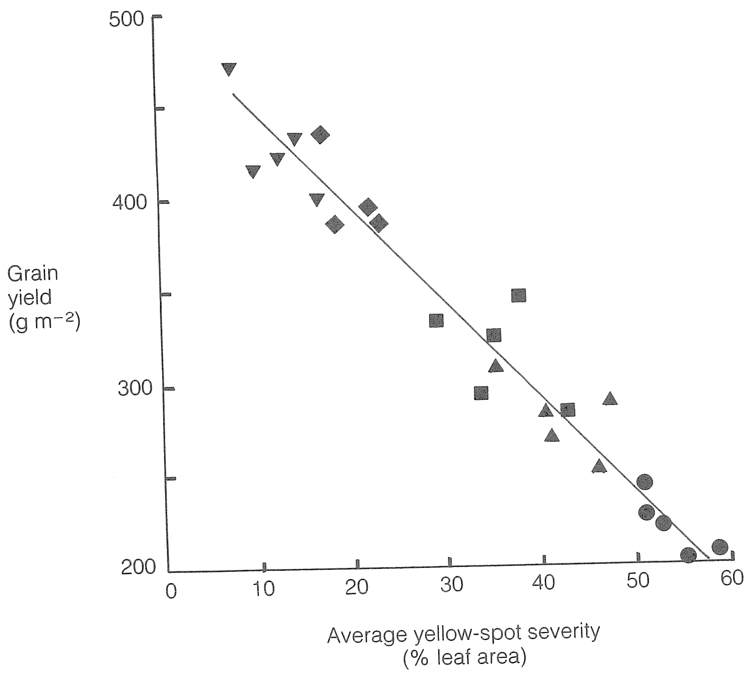

Figure 13.3 Regression of grain yield on average severity of yellow spot (% leaf area affected) over ten dates (Rees *et al.*, 1982). Rates of infected residue applied:
▼ nil plus fungicide ◆ nil
■ 16.8 g m^{-2} ▲ 67.0 g m^{-2}
● 335 g m^{-2}

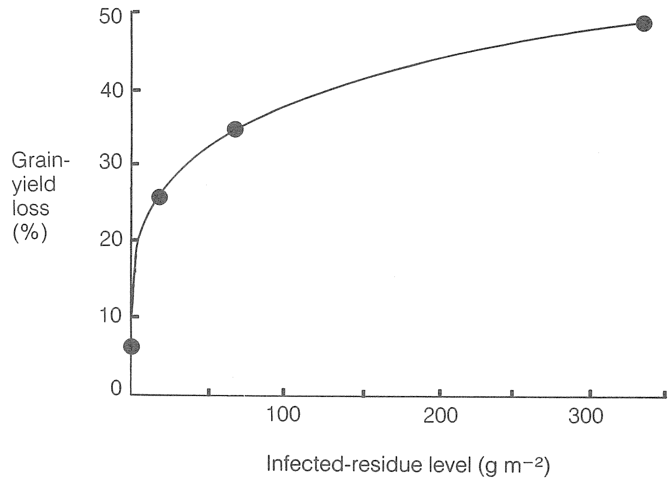

Figure 13.4 Relationship between loss in grain yield (%) and amount of infected residues applied to the soil surface (Rees *et al.*, 1982).

Yellow spot later in the season generally has a greater effect on grain yield than disease in juvenile plants. In one experiment, severe yellow spot in young crops through to jointing reduced grain yield by about 13%, while severe disease starting at jointing reduced yield by about 35% (Rees and Platz, 1983).

The value of reducing the amount of wheat residues on the soil surface has also been shown in the surface management trial at Greenmount. In an area of no-till fallow, wheat residues on some plots were burnt immediately before planting wheat, while on adjacent plots the residues were left intact. As would be expected, considerably less yellow spot developed in the burnt treatments and the grain yield in these areas was 27% higher than where the wheat residues had been left (D.M. Freebairn and R.G. Rees, unpublished data).

Control measures

Because the severity of yellow spot is closely associated with the amount of infected wheat residues on the soil surface in most Australian wheat areas, control of the disease is largely in the hands of the individual farmer. How he handles his own wheat residues will largely determine the subsequent severity of yellow spot. This is not necessarily the case with other foliar diseases, some of which are described below. Avoidance of planting wheat through wheat residues should give reasonable control of yellow spot in most situations. As most other crops are resistant to the disease, crop rotation is usually effective. Removing surface residues provides adequate control. Burning residues, possibly delayed to near planting, gives the greatest reduction in inoculum levels. Cultivation also reduces inoculum but the effectiveness depends on the extent of residue incorporation.

In Western Australia, in the dry eastern wheatbelt, yellow spot is clearly associated with wheat residues, but in the northern wheatbelt wind movement of crop residues and secondary inoculum may be sufficient to produce early infection in rotated crops (A.G.P. Brown, personal communication). Therefore, in this latter region crop rotation and residue management probably provide less control than that achieved in other Australian wheat areas.

It is expected that in the future resistant cultivars will become available, thus reducing the need to adapt cultural practices to the control of yellow spot. Sources of resistance to yellow spot are available and programmes are underway to incorporate resistance into cultivars adapted to Australian conditions.

SEPTORIA DISEASES OF WHEAT

Septoria tritici blotch (also known as speckled leaf blotch), caused by *Mycosphaerella graminicola*, is a widespread disease of wheat crops in the winter-rainfall areas of Australia. Before the arrival of stripe rust (*Puccinia striiformis*), septoria tritici blotch was the most important disease of wheat in Victoria (Brown and Paddick, 1980) where it occurs regularly with overall losses of up to 20%. Septoria tritici blotch is a serious problem in southern and central New South Wales (Murray, 1978) where control of the disease has more than doubled grain yields in field plots of highly susceptible cultivars (Kuiper, 1978).

Septoria nodorum blotch (also known as glume blotch), caused by *Leptosphaeria nodorum*, is a lesser problem in most areas of Australia but is particularly conspicuous in parts of the Western Australian wheatbelt (Brown and Rosielle, 1980). Comprehensive reviews of the literature on the septoria diseases have been prepared by Shipton *et al.* (1971) and King *et al.* (1983).

Effect of crop residues

Infected wheat residues are generally accepted as being the main survival site for the fungi causing the septoria blotches (Shipton *et al.*, 1971; King *et al.*, 1983) and pycnidiospores produced on these residues have been thought to be the main primary inoculum. Pycnidiospores are splash dispersed and, while some may become wind-borne, most are usually dispersed short distances only. Thus, with primary inoculum of this type, management of crop residues in particular fields is likely to be important. Accordingly, crop rotation or removal of wheat residues from a field should reduce the severity of septoria diseases initiated by pycnidiospores in a wheat crop planted in that field.

Studies in New Zealand and Australia, however, have demonstrated that ascospores may have an important role as primary inoculum (Sanderson, 1974; Brown *et al.*, 1978; Sanderson and Hampton, 1978). Collections of wheat residues from throughout the Victorian wheatbelt over a 3-year period showed that septoria tritici blotch was often present and frequently close to the new season's crop (Brown *et al.*, 1978). In this study, ascospore production increased during late autumn to a high level during winter and declined during early spring. The discovery of the role of ascospores has important epidemiological and control implications. Ascospores of these pathogens are more likely to be wind-borne for greater distances than pycnidiospores, infecting crops some distance from wheat residues (Brown *et al.*, 1978; Sanderson and Hampton, 1978). Thus, some infection of young crops would be expected under favourable conditions even in a field free of wheat residues.

It is not clear why there are differences in behaviour between ascospores of these fungi and those of the yellow spot pathogen. The apparently smaller numbers and larger size of ascospores produced by the yellow spot fungus may restrict their importance as dispersal spores.

SCALD OF BARLEY

Scald is one of the major diseases of barley in the winter rainfall areas of Australia (Chambers, 1960; Mayfield *et al.*, 1974; Khan and Portman, 1979). Yield losses up to 25% have occurred in trials conducted since 1962 by the Western Australian Department of Agriculture (Khan and Portman, 1979), with the main effect being reduced grain size. The literature on scald has been reviewed by Shipton *et al.* (1974).

Effect of crop residues

The scald fungus is able to survive in barley residues through the hot dry summer of southern Australia and then infect the following barley crop (Chambers, 1960; Ayesu-Offei and Carter, 1971; Mayfield *et al.*, 1974; Mayfield and Clare, 1984a). Viable conidia of the pathogen have been recovered from barley leaves retained on the soil surface for up to 30 weeks after crop maturity in a range of barley-growing environments in South Australia (Mayfield and Clare, 1984a). Suspending the leaves 30 cm above the soil extended survival of the fungus to 37 weeks. Burying leaves 6 cm below the soil surface reduced survival of the pathogen to around 20 weeks.

The effect of barley residues on barley leaf diseases was examined in ten experiments at six locations in Western Australia in 1981 and 1982 (T.N. Khan, personal communication). Scald was the major pathogen except at one location where spot-type net blotch (*Pyrenophora teres*) predominated. Significantly more leaf disease was measured in nine of the ten experiments where barley residues were present. Grain yield was significantly greater in residue-free treatments in five experiments.

Since the release and dispersal of conidia of *R. secalis* is mainly a result of raindrop splash, scald spreads most readily between adjacent plants, with satellite areas of infection occurring several metres from sources of infection (Ayesu-Offei and Carter, 1971). Thus, unless barley crops are grown in adjacent fields, scald is unlikely to spread by natural agencies from field to field in a single growing season (Ayesu-Offei and Carter, 1971). Exceptions might occur where wind movement of infected residues disperses the pathogen over greater distances (Khan and Portman, 1979).

Residue management

Management of barley residues within a field should have a large influence on the level of scald in that field since the pathogen shows only limited movement from barley residues with which it is closely associated. Burning or incorporation of barley residues into the soil has been recommended in Western Australia to reduce scald (Chambers, 1960). Burning or grazing barley residues reduced the amount of primary inoculum and resulted in less scald during seedling growth of the following barley crop (Mayfield and Clare, 1984b). In this experiment, the treatment effect had disappeared by grain filling, possibly due to interplot interference. The effects of residue management should last longer in a crop situation where external inoculum would have less influence. Residue management may affect crop nutrition and density, thus modifying the persistence of any reduction in scald during the growing season (Mayfield and Clare, 1984b). In areas where crop residues are frequently transported by wind, management of barley residues may not be fully effective in controlling scald (Khan and Portman, 1979).

Crop rotation affects the severity of scald, with less disease in seedling barley following wheat or pasture than in barley following barley. Scald was absent where its hosts had been absent for at least 18 months (Mayfield and Clare, 1984b).

OTHER FOLIAR DISEASES

Many other foliar diseases may be influenced by tillage. The majority of these are leaf spots, and blights or head diseases where the pathogens survive in crop residues. Some of these diseases that may be found in Australian crops of wheat, barley, maize or sorghum are given in Table 13.6. For information on the particular diseases the compendiums of diseases of wheat (Wiese, 1977), barley (Mathre, 1982), and maize (Shurtleff, 1980) and the text by Nyvall (1979) should be consulted.

Table 13.6 Some foliar diseases of Australian grain crops that may be affected by residue management

Crop	Disease	Pathogen
Wheat	Head scab	*Gibberella zeae*
	Septoria nodorum blotch	*Leptosphaeria nodorum*
	Septoria tritici blotch	*Mycosphaerella graminicola*
	Yellow spot	*Pyrenophora tritici-repentis*
Barley	Spot blotch	*Bipolaris sorokiniana*
	Powdery mildew	*Erysiphe graminis*
	Net blotch	*Pyrenophora teres*
	Scald	*Rhynchosporium secalis*
Maize	Anthracnose	*Colletotrichum graminicola*
	Maydis leaf blight	*Drechslera maydis*
	Turcicum leaf blight	*Exserohilum turcicum*
	Cob rot	*Gibberella zeae*
	Brown spot	*Physoderma maydis*
Sorghum	Grey leaf spot	*Cercospora sorghi*
	Anthracnose	*Colletotrichum graminicola*
	Leaf blight	*Exserohilum turcicum*
	Mouldy head	*Fusarium moniliforme*
	Zonate leaf spot	*Gloeocercospora sorghi*
	Sooty stripe	*Ramularia sorghi*
	Bacterial leaf stripe	*Pseudomonas andropogonis*
	Bacterial leaf spot	*Pseudomonas syringae*
	Bacterial leaf streak	*Xanthomonas holcicola*

EXOTIC DISEASES INFLUENCED BY CROP RESIDUE MANAGEMENT

Most of the important foliar pathogens of wheat, barley and sorghum that survive in crop residues already occur in Australia and few exotic diseases of this type are yet to be introduced (Table 13.7). The main exceptions are the downy mildews of sorghum and maize, but as germination of the oospores of these fungi generally results in initial infection of roots, these diseases are outside the definition of foliar pathogens in this book. The list of exotic foliar diseases of maize is extensive (Table 13.7) and problems from the introduction of these diseases might be expected in maize grown with reduced tillage. Other exotic foliar diseases of these grain crops may be influenced by crop-residue management, but they appear to be of little importance. It is always possible, however, that a minor pathogen in one continent may be of greater significance when introduced into another continent.

Table 13.7 Some exotic foliar diseases of grain crops that may be affected by residue management[a]

Crop	Disease	Pathogen
Wheat	Ascochyta leaf spot	*Ascochyta tritici*
Barley	–	–
Maize	Grey ear rot	*Botryosphaeria festucae*
	Grey leaf spot	*Cercospora zeae-maydis*
	Eyespot	*Kabatiella zeae*
	Phaeosphaeria leaf spot	*Phaeosphaeria maydis*
	Yellow leaf blight	*Phyllosticta maydis*
	Leaf freckle and wilt	*Corynebacterium nebraskense*
	Holcus spot	*Pseudomonas syringae*
Sorghum	–	–

[a] Prepared from information in Jones (1982), Mathre (1982), Nyvall (1979), Shurtleff (1980) and Wiese (1977).

HERBICIDES AND FOLIAR PATHOGENS

Herbicides are an important component of most reduced tillage systems and might be expected to influence survival of foliar pathogens. Any such influence could be through the following:

* Destruction of self-sown crop plants or crop regrowth - Judicious use of herbicides to control self-sown crop plants or crop regrowth can significantly reduce foliar diseases. The use of herbicides for this purpose may be justified during reduced-tillage fallows or in double-cropped situations.

* Direct effect on the pathogen - While certain herbicides may exhibit fungicidal effects, there appears to be little evidence of any direct effect of herbicides on the survival of foliar pathogens in crop residues. For example, paraquat has little effect either on conidial production by *R. secalis* on barley residues (Stedman, 1977) or pycnidiospore production by *L. nodorum* on wheat residues (Harris, 1979).

* Rate of decomposition of residues - Herbicides may have an effect on the microflora normally responsible for decomposition of crop residues (Grossbard and Harris, 1979). Paraquat decreases the rate of residue breakdown while glyphosate may stimulate (Grossbard and Harris, 1979) or retard (Pollard, 1979) decomposition of residues under different conditions. Paraquat and aminotriazole may inhibit some of the normal residue-decomposing saprophytes, but their use may lead to increased populations of herbicide-tolerant fungi including various species of *Fusarium* (Grossbard and Harris, 1979).

* Modification of antagonists or competitors - There appears to be little information on this aspect. However, as residue-decomposing fungi may be affected by herbicides, it is likely that species competitive or antagonistic to foliar pathogens could also be affected.

The review by Altman and Campbell (1977) provides a broader coverage of the effect of herbicides on diseases.

CONCLUSIONS

Some general principles can be developed to predict the effects on foliar diseases of changes in residue management associated with different tillage systems. As with most generalisations, exceptions may be encountered.

Role of crop residues Most foliar diseases affected by tillage survive in crop residues. Tillage may also influence survival of self-sown crop plants or crop regrowth acting as survival sites for some pathogens.

Type of residues Residues of the same crop are generally of greater importance than residues of unrelated crops. In addition, some pathogens are more likely to survive in particular parts of crop residues than in others. For example, *R. secalis* is generally found in leaves of barley while pseudothecia of *P. tritici-repentis* are more likely to develop in upper internodes of wheat stems than in the basal internodes.

Position of residues The position of crop residues may be of considerable importance. As air-borne foliar pathogens spread from crop residues to susceptible plants by rain splash or wind dispersal of spores, spread is largely prevented by incorporation of residues into the soil. Burying may also reduce the infectivity of residues.

Quantity of residues Given favourable environmental conditions and a susceptible crop, the amount of foliar disease originating from residues frequently depends on the amount of crop residue. Thus, cultural practices aimed at conserving increased quantities of crop residues on the soil surface are likely to increase the severity of these diseases.

Ease of dispersal of propagules Residue-surviving pathogens that produce primary propagules of a type not readily dispersed widely should be more closely associated with residue management in a particular field than pathogens with primary propagules that are widely dispersed. For instance, ascospores of *P. tritici-repentis* or the splash-dispersed conidia of *R. secalis* are generally not dispersed widely and accordingly there is a close association between the level of infection and crop residues within fields.

It is evident that tillage practices may have large effects on foliar diseases, especially those that survive in crop residues. Despite the enhancement of some diseases by reduced tillage, it is generally a desirable practice with over-riding benefits. Any increased problems from foliar diseases can probably be solved in the long term, but control of diseases may require more attention than is generally afforded to them in conventional cultivation practices in Australia. The most suitable control strategies can frequently be derived from an adequate understanding of the pathogen and may involve wider use of crop rotations, careful management of crop residues and development of resistant cultivars.

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