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Yield Losses in Wheat from Yellow Spot: Comparison of Estimates Derived from Single Tillers and Plots

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Abstract

Losses in wheat yield associated with yellow spot (*Pyrenophora tritici-repentis*) have been examined in a field experiment where development of crop and disease were promoted with sprinkler irrigation. Different amounts of infected wheat stubble were applied to initiate epidemics in four treatments, while fungicide sprays were used to reduce the severity of yellow spot in a fifth treatment. The relationship between severity of yellow spot and the amount of infected stubble at first appeared to be linear but became more noticeably logarithmic as the epidemics progressed. Under conditions favouring disease development, a loss in grain yield of *c.* 49% was measured in the most severely diseased treatment relative to the sprayed treatment, with grain number per unit area and grain size both being reduced. The percentage loss in grain yield was less for main stems than for later heads.

Regression analyses of disease severity with grain yield and its components using 50 main stems in each plot gave different estimates of yield loss, depending on the growth stage at which disease severity was assessed. These estimates of yield loss and those provided by a previously developed disease-loss relationship severely underestimated the overall loss in grain yield. However, there was better agreement between estimates derived from the regressions and loss in grain yield on main stems. Possible reasons for the discrepancies in estimates of loss in grain yield are discussed.

Introduction

Yellow spot, caused by the fungus *Pyrenophora tritici-repentis* (Died.) Drechsler, has become an important disease in wheat crops in the north-eastern wheat areas of Australia (Rees and Platz 1979). Yield losses associated with yellow spot have been examined (Rees *et al.* 1981) by using a single tiller technique based on that of Richardson *et al.* (1975). While techniques of this type are convenient to use and have a number of advantages, there are some deficiencies associated with their use, including no allowance for the effects of severe disease on tillering or plant vigour and reliance on disease severity at a single growth stage (Rees *et al.* 1981). The single tiller approach has been criticized by James and Teng (1979), who suggested that any possible use would be restricted to late epidemics where only the weight of individual grains could be affected by the disease.

In developing their single tiller technique, Richardson *et al.* (1975) used randomly selected tillers. Wheat crops in the north-eastern parts of the Australian wheat belt are generally planted at comparatively low seeding rates because of unreliable rainfall. Under favourable conditions, late secondary tillers frequently develop, with grain numbers on late tillers being very variable. To avoid these late tillers and the associated high variability, Rees *et al.* (1981) used main tillers (main stems or their subtended tillers) to approximate the randomly selected tillers of Richardson *et al.* (1975). Grain yield and its components, however, are more consistent on main stems than on subsequent tillers (D. R. Woodruff, unpublished data). As main stems should provide more accurate estimates of relative yield between crops, these were used in the experiment reported here. In this experiment, yield losses from plots were compared with estimates determined by a single tiller technique to further examine losses from yellow spot and to evaluate the suitability of a single tiller technique.

Methods

Wheat, cv. Banks, was planted in plots 10 by 2 m in land free of wheat stubble at Toowoomba on 14 June 1979. Five replications of five treatments were used in a randomized block design. Three weeks before planting the wheat, buffer areas of oats (cv. Stout) 6 m wide were planted to separate the wheat plots.

Stubble from a 1978 wheat crop infected with *P. tritici-repentis* was collected and some was fumigated with methyl bromide to kill the pathogen. Before crop emergence, treatments were imposed by using different amounts of infected stubble: B, nil; C, 16·8 g m^{-2}; D, 67 g m^{-2}; and E, 335 g m^{-2}. Where necessary, fumigated stubble was used to bring the total stubble applied to 335 g m^{-2} for each treatment. A fifth treatment (A) involved 11 sprays of triadimefon (250 g ha^{-1} active ingredient) at 1–2 week intervals to plots to which only fumigated stubble was added. Disease and crop development were promoted by sprinkler irrigation (*c.* 3·1 mm h^{-1}) for 2–3 h, up to several evenings per week.

Yellow spot was assessed on a whole plot basis on eight occasions using the key for Septoria leaf blotch of James (1971). At each assessment, disease on 10 randomly selected main stems or their subtended (primary) tillers (here collectively called main tillers) in each plot was assessed independently by two operators. In addition, counts of lesions on leaf 2 were made on one replicate at growth stage (g.s.) 14 of Zadoks *et al.* (1974). To test a single tiller technique, 50 main stems in a similar single row in each plot were marked with numbered self-adhesive labels during the early tillering stage of crop development. After flowering, replacement labels were applied to the stem immediately below the flag-leaf node. Yellow spot levels on the flag leaf and penultimate leaf of each stem were assessed at medium milk (g.s. 75) and again at late milk-early dough (g.s. 77–83).

As the crop was nearing maturity, slight damage was caused by a hail storm. To determine the effects of the hail, the number of grains on the ground were counted in two quadrats of 0·5 m^2 in each plot before harvest.

At maturity, plants bearing the labelled main stems were hand-pulled ('50-plant samples') and the main stem and tillers on each plant threshed separately. Two quadrats, each of 0·5 m^2 ('area samples'), were also taken from each plot before machine harvesting the remainder of the plot.

For each plant in the '50-plant samples', determinations were made of grain yield and 1000-grain weight for both the main stem and tillers. Tiller number, grain yield and 1000-grain weight were also measured for the 'area samples'. Grain from the machine harvest was used for determinations of yield, test weight, 1000-grain weight and concentrations of grain nitrogen and phosphorus.

Analysis of variance and regression analysis were applied to all data where applicable. The linear regressions of yield variables against disease measurements for the labelled main stems were estimated as previously for main tillers (Rees *et al.* 1981). Loss estimates derived from these critical point models were also compared with estimates from multiple point models (James 1974) based on assessments on each of the top two leaves at two growth stages.

Results

Severe epidemics of yellow spot developed rapidly in plots where relatively large amounts of infected stubble were applied. For most of the growing season, little disease was evident in treatments where no infected stubble was present, but severe yellow spot developed in these as the crop approached maturity. The frequent sprays of triadimefon gave only limited control of the disease late in the growing season when inoculum pressure was high.

The average number of lesions on leaf 2 at g.s. 14 is plotted against the amount of infected stubble in Fig. 1*a*. The average severity of yellow spot over three assessments to around early boot (g.s. 39–41), over seven assessments (including the two series of single tiller assessments) from the end of anthesis (g.s. 69) and over the 10 assessment dates (including the single tiller assessments) are each plotted against the amount of infected stubble in Fig. 1*b*. The relationship between severity of yellow spot and the amount of infected stubble became more noticeably logarithmic as the epidemics progressed.

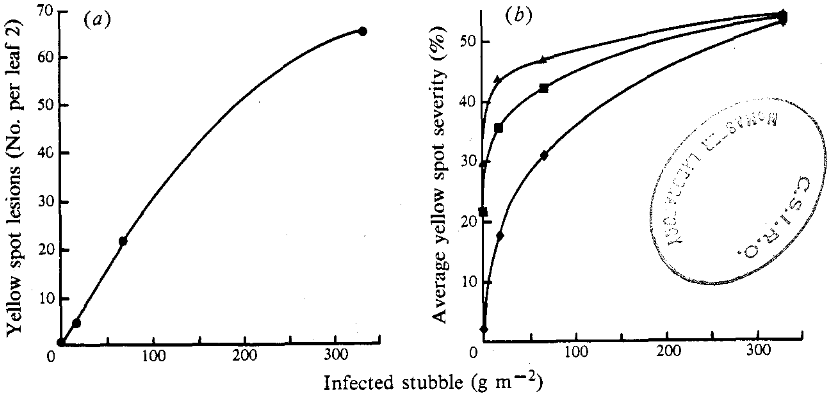

Fig. 1. (*a*) Relationship between average number of yellow spot lesions on leaf 2 at g.s. 14 and amount of infected stubble applied. (*b*) Relationship between average severity of yellow spot (percentage leaf area affected) and amount of infected stubble applied. Separate relationships for average disease severity over three dates to g.s. 39–41 (◆), seven dates from g.s. 69 (▲), and over the 10 dates (■) are shown.

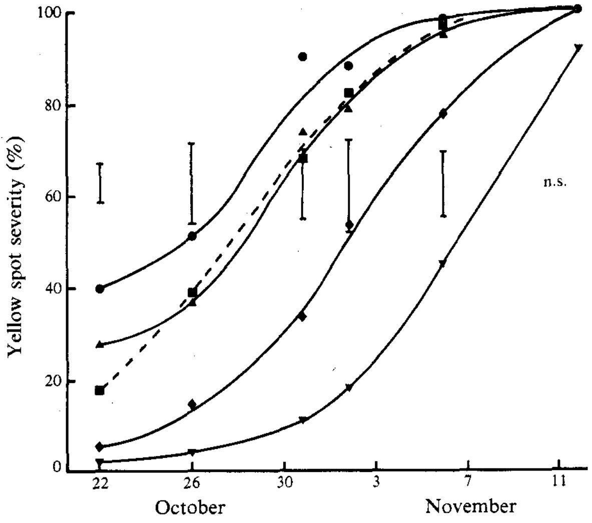

Fig. 2. Progress of epidemics of yellow spot on the penultimate leaf in five treatments. Assessments of percentage leaf area affected on main stems made on 26 October (g.s. 75) and 2 November (g.s. 77–83) are included. Rates of infected stubble applied: ▼ nil plus fungicide; ◆ nil; ■ 16·8 g m^{-2}; ▲ 67·0 g m^{-2}; ● 335 g m^{-2}. Vertical bars indicate least significant differences (P = 0·05).

The differences in epidemic development in the various treatments late in the season are illustrated by disease progress curves for the penultimate leaf (Fig. 2). While the average severity of disease on this leaf differed considerably with treatment on 22 October (around early milk, g.s. 73), the severities in all treatments were similar by 12 November (around early dough, g.s. 83).

Delays in head emergence and flowering were associated with increased early severity of yellow spot. For instance, on 2 October plants under treatments A and B were at the growth stage of $\frac{1}{2}$–$\frac{3}{4}$ inflorescence emerged (av. g.s. 56·8), treatment C at $\frac{1}{4}$–$\frac{1}{2}$ inflorescence emerged (av. g.s. 54·4), treatment D at $\frac{1}{4}$ inflorescence emerged (av. g.s. 52·8), and treatment E at first spikelet of inflorescence just visible (av. g.s. 51·2) (for av. g.s., l.s.d. ($P = 0{\cdot}05$) = 0·91).

Table 1. Measurements of grain yield and quality determined from machine harvest

Within columns, values followed by the same letter do not differ significantly ($P < 0{\cdot}05$)

Infected stubble (g m^{-2})	Grain yield (g m^{-2})	Hail loss (%)	Grain yield adjusted for hail (g m^{-2})	$10^{-3}\times$ number grains per m^2	1000-grain weight (%)	Test weight (kg hl^{-1})	Grain nitrogen (%)	Grain phosphorus (%)
A. 0, fungicide	428a	3·55a	443a	13·6a	31·1a	76·8a	2·17c	0·302b
B. 0	402a	3·38a	416a	13·2a	29·9a	75·6a	2·20c	0·304b
C. 16·8	315b	2·21b	322b	11·9b	25·9b	73·7b	2·29b	0·324a
D. 67·0	280c	1·99b	286c	11·2b	24·6bc	72·4c	2·40a	0·326a
E. 335	220d	1·97b	224d	9·4c	22·9c	71·0d	2·46a	0·340a
s.e. (mean)	8·9	0·207	9·4	0·30	0·61	0·41	0·024	0·0056

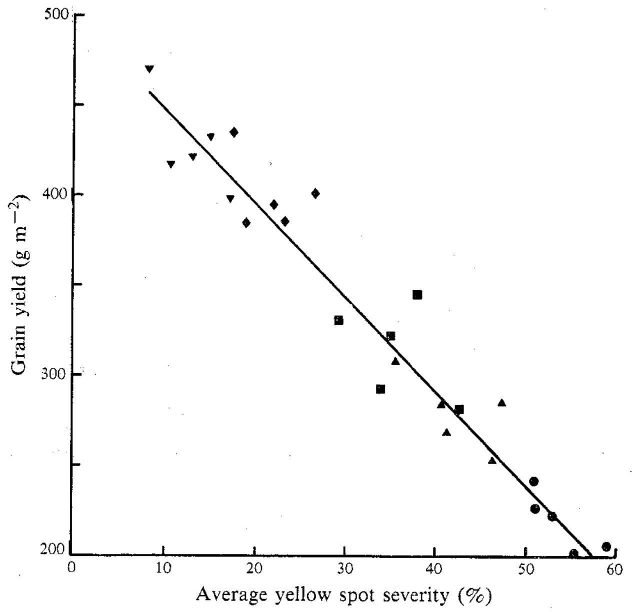

Fig. 3. Regression of grain yield (unadjusted for hail damage) on average yellow spot severity (percentage leaf area affected) over 10 dates. Disease severity was measured on randomly selected main tillers on eight dates and on tagged main stems on two occasions. Rates of infected stubble applied: ▼ nil plus fungicide; ◆ nil; ■ 16·8 g m^{-2}; ▲ 67·0 g m^{-2}; ● 335 g m^{-2}.

Estimates of Yield Loss Determined from Plots

Grain yields from the machine harvest differed considerably with treatment (Table 1). Grain losses from hail damage were greater in the high-yielding treatments, but overall these losses were small (Table 1). Adjusting plot yields for hail damage gave a yield loss of 49·4% in the high-disease treatment (E) relative to the sprayed treatment (A), or a loss of 48·6% if no adjustment was made. One thousand-grain weight was reduced by 26·4%, grain number m^{-2} by 30·9% and test weight by

7·6% in the high-disease treatment (E) compared with the sprayed treatment (A). Grain nitrogen and phosphorus concentrations were higher where infected stubble was applied (treatments C, D and E). However, total amounts of grain nitrogen and phosphorus per unit area were reduced by the disease. Despite the high levels of yellow spot in some treatments, no conspicuous pink grain was present.

The regression of grain yield (unadjusted for hail damage) with average severity of yellow spot over 10 dates is shown in Fig. 3. The regression is significant ($b = -5\cdot16 \pm 0\cdot30$, $r = 0\cdot966$, $P < 0\cdot01$) and illustrates the strong inverse relationship between grain yield and yellow spot severity. In contrast, a logarithmic relationship existed between grain yield and the amount of infected stubble and also between loss in grain yield and infected stubble (Fig. 4).

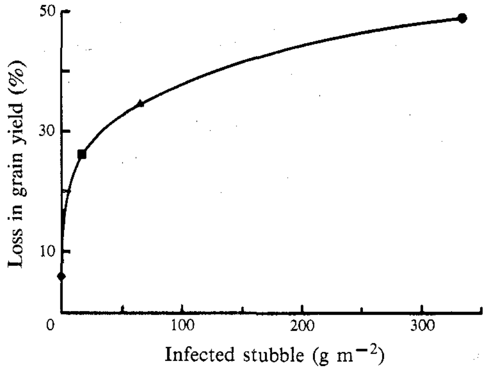

Fig. 4. Relationship between percentage loss in grain yield relative to sprayed treatment (A) and amount of infected stubble applied to the soil surface. Rates of infected stubble applied: ◆ nil; ■ 16·8 g m^{-2}; ▲ 67·0 g m^{-2}; ● 335 g m^{-2}.

Table 2. Measurements of grain yield and its components determined from 'area samples'
Within columns, values followed by the same letter do not differ significantly ($P < 0\cdot05$)

Infected stubble (g m^{-2})	Grain yield (g m^{-2})	Number plants per m^2	Number heads per plant	Number heads per m^2	$10^{-3}\times$ No. grains per m^2	1000-grain weight (g)
A. 0, fungicide	529a	123a	4·24ab	374a	17·9a	29·5a
B. 0	518a	129a	4·26a	394a	18·5a	28·0a
C. 16·8	412b	109a	4·57a	354ab	16·9ab	24·4b
D. 67·0	365c	118a	3·81c	324b	15·4bc	23·7b
E. 335	314d	114a	3·86bc	312b	13·9c	22·5b
s.e. (mean)	14·8	6·2	0·130	15·9	0·66	0·62

Grain yield and its components measured from the 'area samples' are given in Table 2. Loss in grain yield between the high-disease and sprayed treatments (E and A) was 40·6%, compared with 48·6% for the machine harvest (Tables 1 and 2). Loss of small grains associated with machine harvesting probably accounted for some of the difference. Similar data derived from the '50-plant samples' are given in Table 3. Loss in grain yield per main stem between the extreme treatments (E and A) (20·7%) was considerably less than the average for 'other heads' (30·8%) (Table 3). As the loss in grain yield of 36·1% calculated on a per plant basis is greater than that calculated on a per tiller basis, reduced head number apparently contributed to the overall yield loss.

Significant differences in 1000-grain weights occurred between treatments (Tables 2 and 3). Generally, individual grains from main stems were larger than those in the 'other heads', with a slightly greater percentage loss in grain size associated with yellow spot in the 'other heads' (Table 3).

Table 3. Measurements of grain yield and its components determined from '50-plant samples'
Within columns, values followed by the same letter do not differ significantly ($P < 0{\cdot}05$)

Infected stubble (g m^{-2})	Grain yield Per main stem (g)	 Per 'other head' (g)	 Per plant (g)	Heads per plant	Number of grains^{A} Per main stem	 Per 'other head'	 Per plant	1000-grain weight Main stem (g)	 'Other heads' (g)	 Per plant (g)
A. 0, fungicide	2·08a	1·59a	8·80a	5·23a	63·1b	52·5ab	285a	33·0a	30·4a	30·9a
B. 0	1·88b	1·40b	7·66ab	5·12a	59·9c	48·4c	259a	31·3a	29·1a	29·5a
C. 16·8	1·82b	1·27c	7·08b	5·13a	65·1ab	50·9abc	275a	28·3b	25·2b	25·8b
D. 67·0	1·76bc	1·23c	5·84c	4·35a	66·9a	53·6a	245a	26·6bc	23·0c	23·8c
E. 335	1·65c	1·10d	5·62c	4·60a	67·1a	50·0bc	248a	25·0c	22·1c	22·8c
s.e. (mean)	0·049	0·039	0·395	0·249	0·94	1·10	12·3	0·59	0·53	0·50

^{A} Only grains remaining after hail included.

Table 4. Regressions of yield measures on yellow spot severity at two growth stages
Average severity of yellow spot on top two leaves of main stems at g.s. 75 was 17·0% and at g.s. 77–83 was 41·8%
Regressions based on 1192 to 1195 points

	Grain yield per main stem (g) Unadjusted for hail	 Adjusted for hail	Number grains per head^{A}	Av. grain weight (mg)
Av. value	1·85	1·94	67·3	28·9
Assessments at g.s. 75				
a	2·02	2·16	68·1	31·8
$10^{2} \times b$	−0·979	−1·25	−4·77	−17·0
R^{2} (%)	21·0	31·7	1·03	41·5
Loss coefficient ± s.e.	0·485±0·025	0·581±0·022	0·070±0·020	0·535±0·017
Assessments at g.s. 77–83				
a	2·15	2·33	68·7	34·1
$10^{2} \times b$	−0·711	−0·926	−3·50	−12·4
R^{2} (%)	25·8	40·5	1·30	51·9
Loss coefficient ± s.e.	0·331±0·014	0·397±0·012	0·051±0·013	0·365±0·009

^{A} Counts of grains remaining plus florets emptied by hail.

Estimates of Yield Loss Determined from Single Tillers (Main Stems)

The regressions of the yield variables and coefficients of loss in these variables on yellow spot severity determined from the single tiller data are summarized in Table 4. All regressions were significant ($P < 0{\cdot}01$). Most of the estimated loss in grain yield per head was attributable to reduced grain weight.

Considerably different estimates of loss in grain yield per head in the high-disease treatment (E) were obtained from the critical-point and the multiple-point models, with a range of 14·7% to 20·1% (Table 5). The loss coefficient derived from data at g.s. 77–83 provided the closest estimates to losses calculated from the multiple-point model.

Comparison of Loss Estimates from Plots and Single Tillers (Main Stems)

The various estimates of loss in grain yield and its components have been brought together in Table 6 to facilitate comparison. While the loss in total grain yield is severely underestimated by the disease-loss relationships, the discrepancies are reduced if the relationships are taken as applying only to main stems. In particular, good agreement in losses in grain yield for main stems was obtained with the relationship at g.s. 77–83 and those measured on the '50-plant samples'. The loss in grain yield per main tiller is underestimated if the previously derived relationship (Rees *et al.* 1981) is used.

Table 5. Comparison of percentage losses (±s.e.) estimated by critical point and multiple point disease-loss relationships for the high-disease treatment (E) relative to the sprayed treatment (A)

Disease assessments at both growth stages were on the top two leaves of main stems and averaged 30·3% at g.s. 75 and 60·7% at g.s. 77–83 in the high-disease treatment (E)

Measure	Critical-point models Est. loss (%) using loss coefficient determined at: g.s. 75	g.s. 77–83	Multiple-point model Est. loss (%) using two assessments at each of two growth stages
Grain yield per head			
Unadjusted for hail	14·7±0·76	20·1±0·85	19·6±0·90
Adjusted for hail	17·6±0·67	24·1±0·73	23·9±0·75
No. grains per head	2·12±0·61	3·10±0·79	2·33±0·81
Av. grain weight	16·2±0·52	22·2±0·55	22·4±0·54

Table 6. Comparison of estimates of percentage loss (±s.e.) in grain yield and its components for the high-disease treatment (E) relative to the sprayed treatment (A)

n.s., not significant ($P > 0{\cdot}05$)

Source of loss estimate	Estimate applicable to	Estimated percentage loss in: Grain yield	Grain number	Grain size
	Plots			
Machine harvest	m^{-2}	48·6±2·34	30·9±2·68	26·4±2·44
'Area samples'	m^{-2}	40·6±3·25	22·3±4·67	23·7±2·64
	plant^{-1}	35·1±5·52	15·0±6·56	23·7±2·64
'50-plant samples'	plant^{-1}	36·1±5·33	n.s.	26·2±2·01
	main stem^{-1}	20·7±3·01	−6·3±2·17	24·2±2·24
	'other head'$^{-1}$	30·8±2·98	4·8±2·89	27·3±2·16
	Single Tillers			
Disease-loss relationship derived from:				
Severity at g.s. 75	main stem^{-1}	14·7±0·76	2·1±0·61	16·2±0·52
Severity at g.s. 77–83	main stem^{-1}	20·1±0·85	3·1±0·79	22·2±0·55
Multiple-point model	main stem^{-1}	19·6±0·90	2·3±0·81	22·4±0·54
Previous disease-loss relationship using severity at:				
g.s. 75	main tiller^{-1}	8·0±0·42	5·5±0·41	4·1±0·30
g.s. 77–83	main tiller^{-1}	16·0±0·83	11·0±0·82	8·3±0·60

When the disease-loss relationship developed at g.s. 77–83 is applied to the average disease level at that growth stage in each of the five treatments, estimates of loss in grain yield of 3·6, 11·2, 17·5, 17·0 and 20·1% are obtained for treatments A to E respectively. Measured losses in grain yield per main stem ('50-plant samples') were 9·6, 12·5, 15·4 and 20·7% for treatments B to E respectively relative to the sprayed treatment (A). The agreement is reasonable except for treatment C where loss in grain yield was overestimated by the disease-loss relationship.

Discussion

Distinctly different disease epidemics developed with the various treatments. Very early in the growing season, large differences in disease severity were present, with the relationship between disease severity and amount of infected stubble being apparently linear. This would have reflected the predominance of ascospore inoculum at that time (Rees and Platz 1980) and little apparent interplot interference. Subsequently, epidemic development became noticeably logarithmic as conidia were produced on old lesions in the crop. Near the end of the season, largely as a direct or indirect result of interplot interference, the various epidemics attained similar severities with the different treatments (Fig. 2). A logarithmic relationship appeared to be present between average yellow spot severity over the whole season and amount of infected stubble on the soil surface (Fig. 1). If a similar logarithmic relationship applies in situations free from interplot interference, then it is evident that, under environmental conditions favourable for disease development, a relatively small amount of infected stubble can result in considerable yellow spot with substantial reduction in grain yield. This has important control implications in that modification of cultural practice, such as partial incorporation of stubble into the soil, would likely provide inadequate control of the disease in wet seasons.

Yellow spot caused considerable losses in grain yield, with a machine-harvest loss of *c.* 49% in a highly susceptible cultivar under environmental conditions very favourable for development of both crop and disease (Table 1). The increased concentrations of grain nitrogen and phosphorus associated with severe yellow spot (Table 1) probably reflected in part the reduction of endosperm in the shrivelled grain. Similar increased concentrations of nitrogen and phosphorus have also been observed in grain from wheat plants severely affected by stem rust (*Puccinia graminis* Pers. f. sp. *tritici* Erikss. & Henn.) (Rees and Syme 1981).

Grain yield of main stems was relatively less affected by the disease than was the yield of subsequent tillers (Table 3). The effects of other foliar pathogens of wheat have also been found to differ between early and late tillers (Ziv and Eyal 1976; Wafford and Whitbread 1978). Although the grain yield of individual 'other heads' was lower than that of the main stem, the 'other heads' contributed around three-quarters of the total yield per plant (Table 3). Accordingly, the greater effect of the disease on the yield of 'other heads' than on the yield of main stems would be of considerable overall consequence.

No significant differences in plant numbers per unit area were detected (Table 2). However, significance might have been obtained with improved sampling precision. A small reduction in the number of heads per plant appeared to be associated with severe yellow spot, but this was significant ($P < 0{\cdot}05$) for only one of the two series of plant samples (Tables 2 and 3). Plants from the '50-plant samples' possessed an average of 4·86 heads (Table 3) compared with an average of 4·15 heads for plants from the 'area samples' (Table 2), possibly illustrating sampling bias in selecting the 50 plants in each plot. The reduction in heads per unit area (Table 2) probably was a combined result of fewer heads per plant and fewer plants per unit area.

The small losses of grain associated with the hail damage increase to some extent the difficulty in interpretation of grain number data. In addition, the compounding effects of errors associated with loss estimates for the various measurements of yield components result in considerable differences in estimates of loss in grain number obtained by different methods. Despite these limitations, reduced grain number per unit area accounted for about half the loss in grain yield in the machine harvest and 'area samples'.

Most of the variation in estimates of yield loss obtained by the different sampling procedures resulted from differences in grain number. Estimates of reduction in grain size from the machine harvest and plant samples agreed well (Table 6), illustrating that grain size measurements are subject to smaller errors than are grain number determinations.

Several disease-loss relationships can be derived from the single tiller data, and these relationships differ substantially from one another and from that developed previously (Rees *et al.* 1981). It is evident that large differences in disease severity occurring with relatively small changes in growth stage can result in large differences in loss estimates determined by the single tiller technique (Table 6). Also, distinctly different epidemics can result in similar disease severities near the end of the crop season. Naturally, yield reduction is increased where the epidemic is severe for an extended period rather than only at the end of the season. The R^2 values obtained with the single tiller technique (Table 4) were higher than those normally achieved with this approach, probably reflecting the more consistent nature of yield on main stems.

Losses in grain yield tend to be exaggerated by machine harvest as many small grains are lost through the harvester and these small grains comprise a large proportion of the grain from diseased plants. This is illustrated by the observed loss of 48·6% from the machine harvest compared with 40·6% from the plant samples (Table 6). Many of these small grains would be lost during commercial harvesting, however, and as yellow spot was present in the sprayed reference plots late in the season, all the estimates of yield loss would be conservative.

The disease-loss relationships derived from single tillers make no allowance for reduced grain number per unit area resulting from fewer heads. However, this problem can be accommodated to some extent by expressing loss data on a per head basis. As grain yield on main stems may be less-affected by yellow spot than that on subsequent heads, reliance on main stems further underestimates the effect of the disease on overall grain yield.

The value of a particular coefficient for estimating loss in grain yield varies with growing conditions. Losses from yellow spot would be expected to be greater in high-yielding situations than in those which are low-yielding because of inadequate rainfall. A severe, extended epidemic is able to develop under the wet conditions promoting high yields, and the additional late heads formed are likely to be affected more by the disease than are main tillers. In such a situation, the disease-loss relationship can be expected to give a substantial underestimate of yield loss. In the average crop situation in this region, however, tillering is frequently reduced by shortage of moisture and the underestimation of yield loss is probably not large. Rainfall normally occurs only infrequently during the crop season and the disease is rarely as severe as encountered in this experiment. Frequently, yellow spot may be evident early in the season and becomes noticeable again during grain filling. Under these conditions, grain size is probably the main yield component affected and the disease-loss relationship may still provide a useful guide at least to losses on main tillers. Accordingly, the disease-loss relationship may give an acceptable estimate of minimum losses in normal low-yielding situations, while the estimates of yield loss obtained from plots in this experiment more likely provide an estimate of maximum losses under high-yielding conditions.

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