SURVIVAL OF *GAEUMANNOMYCES GRAMINIS* VAR. *TRITICI* IN THE FIELD

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Abstract

Bioassays of wheat stubble were used to study the survival of *G. graminis* var. *tritici* in the field. There were marked differences in survival between the two localities investigated. At Ceduna the number of macro-sites with stubble (crowns) containing viable *G. graminis* var. *tritici* dropped from 90% in early February to 82% in mid-November, while at Turretfield the drop was from 96% in late January to 30% in late August. In another experiment at Ceduna, the survival of *G. graminis* var. *tritici* in field soil was studied using a bioassay of soil cores. There was only a small drop in the incidence of *G. graminis* var. *tritici* in cores removed at regular intervals from the take-all patch over a period of nearly one year.

I. Introduction

With few exceptions (Davis 1925; Russell 1934; Fellows 1941), studies on the survival of *Gaeumannomyces graminis* var. *tritici* Walker (hereafter referred to as *G. graminis*) in soil have been made with artificially colonized straws. Garrett (1938) established the use of this type of survival unit because of ease of standardization and convenience of preparation. Although this practice has led to uniformity of medium, Chambers and Flentje (1967) have shown that the virulence of the isolate used in survival studies has a marked effect on the results. Chambers (1971) also found that the method of sterilization of straws affects survival of *G. graminis*. Furthermore, there appears to be a discrepancy between the periods of survival of the fungus in artificially colonized straw and naturally infested material. In the longest period of survival in artificially colonized straw reported by Butler (1959), only 3% of straws contained viable *G. graminis* after 52 weeks burial in soil. However, Fellows (1941) found that *G. graminis* in naturally infested soil could survive for more than 2 years.

The experiments described in this paper investigate the survival of natural infestations of *G. graminis* in the field. Both the bioassay of stubble (Mac Nish 1973) and the bioassay of soil cores (Mac Nish *et al.* 1973) were employed in assessing the level of viable fungus in the field.

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II. Experimental Areas and Methods

(*a*) *Ceduna*

One experimental area was located on a farmer's property 22 km east of Ceduna. Details of the soil have been described previously (Mac Nish *et al.* 1973), and climatic details are given in Table 1. The block for the stubble removal experiment was situated in a take-all patch where most plants were stunted, although plants towards the eastern side of the block were more vigorous. The block was composed of 36 drill rows each 4·8 m long and was divided into 96 macro-sites each three drill rows wide by 60 cm. After harvesting, all macro-sites were divided into six sites which were each one drill row wide by 30 cm long. On five occasions in 1970 (February 3, April 14, June 23, September 1, and November 10) all wheat stubble from one randomly selected site per macro-site was removed and bioassayed for the presence of *G. graminis* (Mac Nish 1973). As the 1969 crop was harvested in the last week of November 1969, the above dates are 10, 20, 30, 40, and 50 weeks after harvest.

Table 1

Monthly mean maximum and mean minimum screen air temperatures and rainfall for Ceduna and Turretfield, and soil moisture values for Ceduna

Month	Ceduna				Turretfield		
	Mean temp. (°C) Max.	Mean temp. (°C) Min.	Rainfall (cm)	Soil moisture content (%)*	Mean temp. (°C) Max.	Mean temp. (°C) Min.	Rainfall (cm)
1969							
September	19·2	7·5	0·76		15·6	4·5	5·44
October	28·2	13·5	2·57		23·3	8·6	0·13
November	27·4	14·3	2·06		24·8	10·6	2·21
December	30·8	16·2	0		24·9	11·3	3·86
1970							
January	32·3	17·2	0·05		27·5	13·1	2·74
February	35·8	20·5	0	1·5 (6.ii.70)	31·8	14·6	0
March	29·4	16·0	0·03	1·5 (11.iii.70)	25·9	11·4	0·38
April	25·8	12·7	0·18	1·5 (17.iv.70)	23·4	11·5	6·15
May	19·6	9·2	0·56	9·3 (14.v.70)	16·9	8·0	4·88
June	19·0	6·9	0·53	7·5 (24.vi.70)	15·9	7·5	5·18
July	17·6	4·7	0·05	6·3 (29.vii.70)	14·7	4·7	4·11
August	17·5	5·6	2·18		14·1	4·1	9·68
September	19·8	8·1	2·62	9·8 (1.ix.70)	15·9	6·2	5·74
October	26·8	11·9	0·89	4·2 (5.x.70)	21·4	6·6	0·58
November	29·1	14·7	0·10	1·4 (10.xi.70)	25·5	11·2	3·18

* A soil moisture content of 8·8% is equivalent to a matric potential of −15·2 bars. The date of field sampling is given in parentheses.

The block used for the core removal experiment was the same size and directly south of that used in the above experiment. This block was also part of the take-all patch, but towards the eastern boundary there were several areas which contained relatively vigorous plants. As it was planned to remove samples at 5-weekly intervals throughout most of 1970, the 96 macro-sites were each divided into 12 core-sites (one drill row by 15 cm). One core (9·8 cm diam. by 10·5 cm deep) was taken on each occasion from the centre of one randomly selected core-site per macro-site and bioassayed for the presence of *G. graminis* (Mac Nish *et al.* 1973). The first cores were removed on February 3, 10 weeks after the 1969 harvest, and subsequent removals were made 15, 20, 25, 30, 35, 40, 45, and 50 weeks after harvest.

To prevent stock trampling the stubble, both experimental blocks were fenced. Due to the dry season (Table 1) there was poor growth of vegetation; the dominant species was harbinger medic (*Medicago littoralis* Rhode cv. Harbinger) with a few Wimmera ryegrass (*Lolium rigidum* Gaud.) and self-sown wheat plants.

(*b*) *Turretfield*

The other experimental area was on the Turretfield Research Station of the South Australian Department of Agriculture, 10 km north-east of Gawler. The soil in the experimental area is a hard-setting dull-reddish-brown loam, subject to cracking when dry. The climatic details for this location are given in Table 1. The block chosen from within the 1969 crop for the stubble removal experiment was part of a take-all patch. With the exception of three small areas, where the plants were relatively vigorous, the block contained mainly stunted plants. This experiment was conducted in a similar manner and with the same number and size of macro-sites as the experiment at Ceduna. Stubble was removed on four occasions during 1970 (January 28, March 19, May 28, and August 20). The above dates were 6, 13, 23, and 35 weeks after the 1969 harvest.

As previously, the block was fenced. During the winter of 1970 it became overgrown with a lush growth of African capeweed (*Cryptostemma calendula* Druce). There were also numerous self-sown wheat plants and a few of Wimmera ryegrass.

The core removal experiment at Turretfield was abandoned because the hardness of the soil during the summer months made it extremely difficult to remove cores.

III. Experimental Details and Results

(*a*) *Ceduna Location*

The results for the frequency distribution of the percentage of crowns containing viable *G. graminis* at each time of sampling are given in Table 2. "Survival" maps for 10, 30, 40, and 50 weeks after harvest are shown in Figure 1. The map for 20 weeks was very similar to that for 10 weeks and has not been included. For ease of observation, survival categories 1 and 2 have been grouped together, as have 3 and 4, and 5 and 6. Occasionally a few sites contained no stubble or only one crown. These sites have been eliminated from the calculations and are indicated on the maps with a black spot.

TABLE 2

FREQUENCY DISTRIBUTION OF THE PERCENTAGE OF CROWNS CONTAINING VIABLE *G. GRAMINIS* FOR EACH SAMPLING TIME AT CEDUNA, 1970

Sampling date*	No. of sites in survival category:						Total No. of sites†	No. of macro-sites with:	
	1	2	3	4	5	6			
	0–16%	17–33%	34–50%	51–67%	68–83%	84–100%		0%	100%
Feb. 3 (10)	10	4	6	4	5	60	89	9	55
Apr. 14 (20)	10	5	7	8	15	48	93	8	46
June 23 (30)	15	8	3	7	11	51	95	13	43
Sept. 1 (40)	19	5	8	15	15	30	92	16	28
Nov. 10 (50)	20	6	5	12	14	36	93	17	33

* Time from 1969 harvest (weeks) is given in parentheses.

† May be less than 96 due to sites which contained no stubble or only one crown (see text).

The results show that there was a reduction in the number of crowns containing viable *G. graminis* during the period of the experiment. From Figure 1(*a*) it can be

seen that a large proportion of the macro-sites in the block contained crowns carrying *G. graminis*. By 20 weeks after harvest the position had not changed markedly, nor by 30 weeks (Fig. 1*b*), though the number of macro-sites in categories 1 and 2 had increased. In particular, the area of low survival along the northern edge of the block had extended further south. An area of low survival had also developed along the southern boundary of the block. There was a considerable reduction in the number of macro-sites in the two highest survival categories between 30 and 40 weeks after harvest, but no further reduction between 40 and 50 weeks (Table 2).

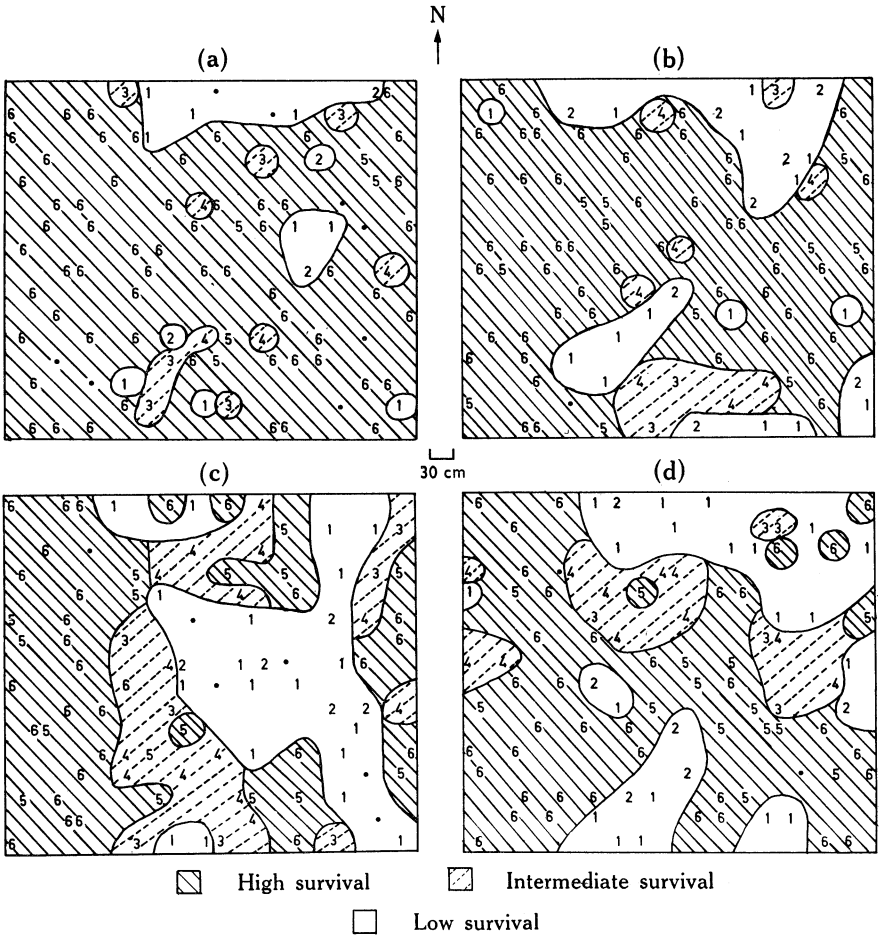

Fig. 1.—Survival maps for *G. graminis* at Ceduna, 1970, based on samples taken 10 (*a*), 30 (*b*), 40 (*c*), and 50 (*d*) weeks after harvest. Survival categories (percentage of crowns infected) are: 1, 0–16%; 2, 17–33%; 3, 34–50%; 4, 51–67%; 5, 68–83%; 6, 84–100%. In drawing the maps categories were grouped as low (categories 1 and 2), intermediate (3 and 4), and high (5 and 6) survival.

The frequency distribution for the percentage of infected roots of seedlings grown in the soil cores is shown in Table 3. "Incidence–survival" maps for 10, 25, 40, and 50 weeks after harvest are shown in Figure 2. The remaining maps (which

also show the same continuing pattern) have not been included. As the core bioassay determines the level of *G. graminis* in the soil, on the basis of disease incidence on seedlings, the maps have been called incidence–survival maps to differentiate them from the survival maps obtained by the crown bioassay. Incidence levels grouped in these maps were low, 0–25%; intermediate, 26–50%; and high, 51–100%. These

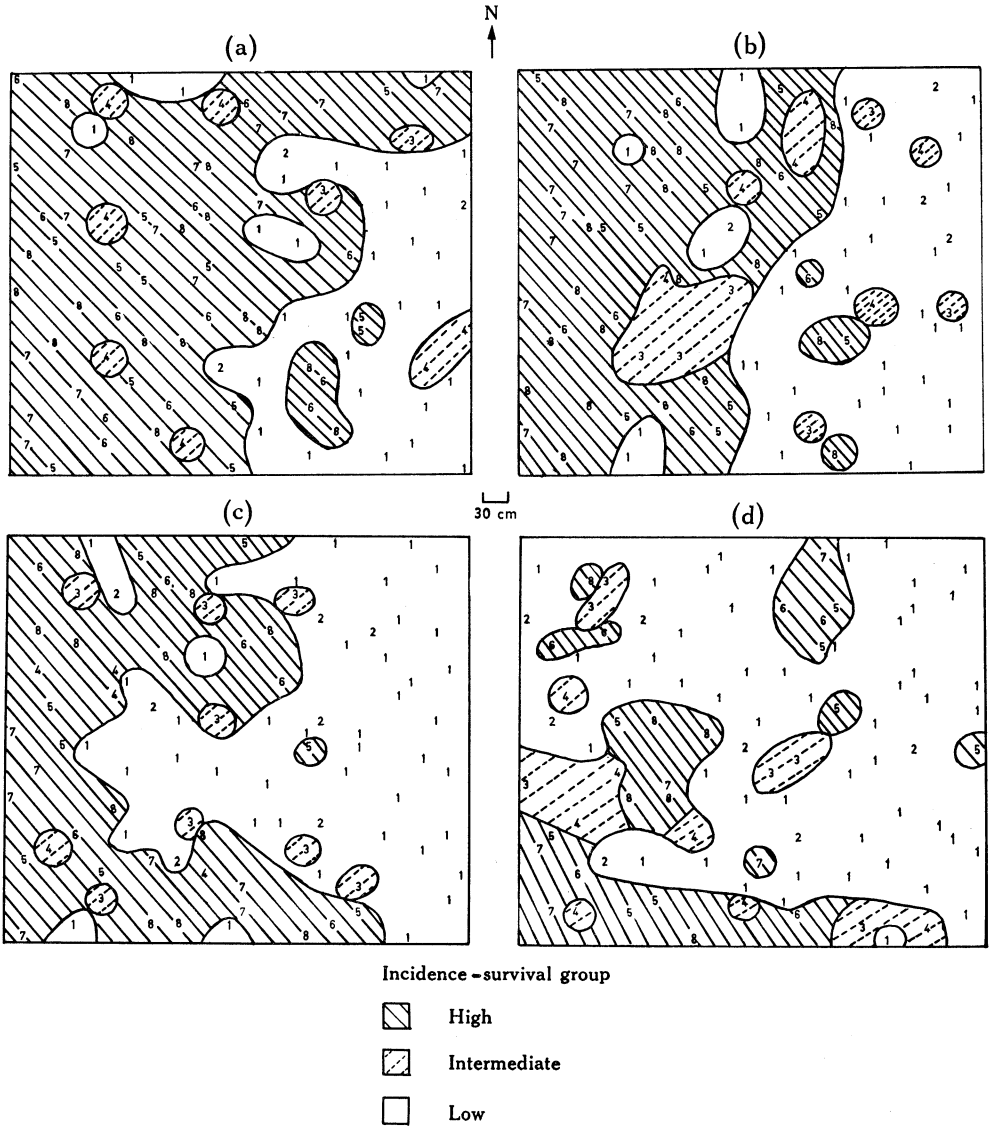

Fig. 2.—Incidence–survival maps for *G. graminis* at Ceduna, 1970, based on samples taken 10 (*a*), 25 (*b*), 40 (*c*), and 50 (*d*) weeks after harvest. Incidence categories (percentage of roots infected per soil core) are: 1, 0–12%; 2, 13–25%; 3, 26–37%; 4, 38–50%; 5, 51–62%; 6, 63–75%; 7, 76–87%; 8, 88–100%. In drawing the maps categories were grouped as low (categories 1 and 2), intermediate (3 and 4), and high (5–8) incidence–survival.

incidence categories are the same as those found in a previous experiment (at the same location, Mac Nish and Dodman 1973) to be the most appropriate for mapping the incidence of *G. graminis*.

TABLE 3

FREQUENCY DISTRIBUTION OF THE PERCENTAGE OF ROOTS INFECTED WITH *G. GRAMINIS* ON WHEAT SEEDLINGS GROWN IN SOIL CORES FOR EACH SAMPLING TIME AT CEDUNA, 1970

Sampling date*	No. of sites in incidence category: 1 0–12%	2 13–25%	3 26–37%	4 38–50%	5 51–62%	6 63–75%	7 76–87%	8 88–100%
Feb. 3 (10)	29	3	2	7	13	13	13	15
Mar. 9 (15)	23	5	3	5	8	13	9	29
Apr. 13 (20)	32	9	4	4	12	7	12	16
May 19 (25)	35	4	6	6	10	6	9	20
June 24 (30)	33	1	3	14	3	7	18	16
July 29 (35)	34	6	5	7	6	4	13	21
Sept. 1 (40)	43	7	8	4	8	6	7	13
Oct. 5 (45)	48	4	2	11	11	9	7	8
Nov. 10 (50)	51	7	6	7	8	6	5	6

* Time from 1969 harvest (weeks) is given in parentheses.

The results for the core removal experiment (Table 3) show that there was an overall decline in the level of *G. graminis* detected in the soil during the experiment. From 10 to 35 weeks after harvest there was no consistent change in incidence, but between 35 and 50 weeks after harvest there was a reduction in incidence. The

TABLE 4

FREQUENCY DISTRIBUTION OF THE PERCENTAGE OF CROWNS CONTAINING VIABLE *G. GRAMINIS* FOR EACH SAMPLING TIME AT TURRETFIELD, 1970

Sampling date*	No. of sites in survival category: 1 0–16%	2 17–33%	3 34–50%	4 51–67%	5 68–83%	6 84–100%	Total No. of sites†	No. of macro-sites with 0%	100%
Jan. 28 (6)	8	18	18	24	15	13	96	4	7
Mar. 19 (13)	12	10	21	21	26	6	96	5	2
May 28 (23)	31	29	17	10	7	0	94	16	0
Aug. 20 (35)	80	10	3	1	0	0	94	66	0

* Time from 1969 harvest (weeks) is given in parentheses.

† May be less than 96 due to sites which contained no stubble or only one crown (see text).

incidence–survival maps (Fig. 2) reveal that regions of low incidence appeared on the eastern edge and gradually expanded across the block during the period of the experiment. By 50 weeks after harvest the high-incidence area was confined to the south-western corner of the block.

(*b*) *Turretfield Location*

The frequency distribution for the percentage of crowns containing viable *G. graminis* for the various sampling times is given in Table 4. The survival maps for the four times of removal are shown in Figure 3. The results show that there was little change in survival between 6 and 13 weeks after harvest. During the remaining 5 months of the experiment there was a marked reduction in survival. From the survival maps it can be seen that the reduction in the percentage of crowns containing viable *G. graminis* was not associated with any particular part of the plot. There was a general disappearance of areas of both high- and intermediate-survival levels between 13 and 35 weeks after harvest.

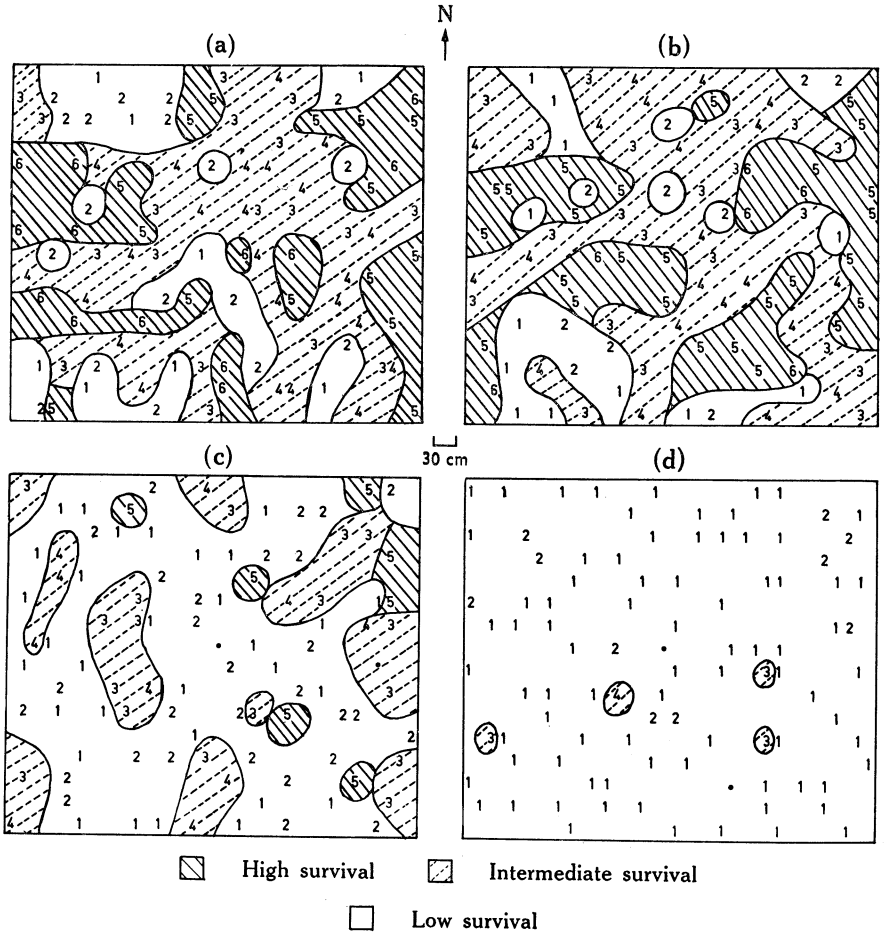

Fig. 3.—Survival maps for *G. graminis* at Turretfield, 1970, based on samples taken 6 (*a*), 13 (*b*), 23 (*c*), and 35 (*d*) weeks after harvest. Survival categories as for Figure 1.

IV. Discussion

It was hoped that changes in the proportion of stubble containing viable *G. graminis* would be detected by the crown bioassay, while the core bioassay would

detect changes in the level of viable *G. graminis* in soil. With time, due to exhaustion of nutrients within stubble or soil and the possibility of competition from other organisms, the amount of *G. graminis* could be expected to decline. However, the presence of grasses and self-sown wheat could lead to further growth of the fungus during the winter months. This increase in *G. graminis* should be detected in the soil cores but not in the stubble samples.

At Ceduna there was a gradual reduction in the number of crowns containing viable *G. graminis* during the period of the experiment. However, after 50 weeks in the field, stubble from 82% of the macro-sites still contained viable *G. graminis*, and in 35% of the macro-sites all crowns still carried viable fungus. This is in contrast to the results obtained at Turretfield, where the percentage of macro-sites with crowns containing viable *G. graminis* dropped from 96% at 6 weeks to 30% by 35 weeks after harvest, and in only one macro-site was there more than 50% of the crowns containing viable *G. graminis*. Although there was an overall reduction during the experiment, the rate of reduction at Turretfield accelerated between 23 and 35 weeks after harvest (Table 4).

In the core removal experiment at Ceduna there was an overall decrease in the level of viable *G. graminis* in the soil, with most reduction during mid-winter. It appears that environmental conditions were most unfavourable for the survival of *G. graminis* during the month of August. The expected increase in viable *G. graminis* during the late winter did not eventuate. The scarcity of grasses and self-sown wheat in the experimental block would not encourage a build-up of *G. graminis*.

The differences in survival between Ceduna and Turretfield may be attributed in part to differences both in the initial levels of *G. graminis* (Tables 2 and 4) and the climatic conditions at the two localities (Table 1). Soil was extremely dry at Ceduna until the middle of April and remained relatively dry during winter and spring (Table 1). At Turretfield, adequate rainfall and lush ground cover helped to maintain a moist soil surface, and this may have made conditions unfavourable for the survival of *G. graminis*. Although the decline in viable *G. graminis* was rapid at Turretfield, there would still have been a reservoir of fungus available to infect crops sown in late May or early June 1970.

We are unable to explain the marked difference in the central regions of the last two survival maps for Ceduna (Figs. 1*c* and 1*d*). It seems unlikely that there would be an increase in viable *G. graminis* within the stubble of the region; a more likely explanation is that the discrepancy is due to natural variability. In the central region, where the difference is most marked, the low-survival macro-sites in Figure 1(*c*) are in different drill rows from the high-survival macro-sites in Figure 1(*d*). As *G. graminis* tends to spread along the row (Adam and Colquhoun 1936) and infected plants tend to be clustered along the row (White 1945), it is possible that the plants in some rows would all be infected, while plants in adjacent rows could be free of *G. graminis*. This possibility may emphasize a technical problem associated with this type of mapping.

In both experiments at Ceduna, it was noted that the areas in the plot with consistently high levels of viable *G. graminis* were the same areas in which the least vigorous plants were observed in the previous season. This observation adds support to Gerlagh's (1968) contention that "take-all decline" is not due to a reduction in the

inoculum level in the soil caused by a rapid rate of decomposition of severely infected and less vigorous plants.

These survival experiments in the field at Ceduna and Turretfield have revealed some interesting contrasts between the survival of *G. graminis* at the two places. The reason for the differences was not established, but may have been due to factors like differences in climate or soil type. A similar study over a period of several years could give valuable information about the possibility of take-all decline being associated with factors affecting the survival of *G. graminis*. These studies could be profitably linked with a study of the type and condition of the fungus occupying the crown and root tissue of stubble remaining in the field.

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