SURVIVAL OF *GAEUMANNOMYCES GRAMINIS* VAR. *TRITICI* IN FIELD SOIL STORED IN CONTROLLED ENVIRONMENTS

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Abstract

A bioassay was used to study the effect of various storage treatments on the survival of *G. graminis* var. *tritici* in soil cores removed from a take-all patch. There was no significant change in the incidence of the fungus when the soil was maintained either dry (−250 to −980 bars) and cool (15°C), or moist (−4·0 to −7·0 bars) and cool (15°C). When maintained very dry (−980 bars or less) and hot (35°C) or wet (−0·1 to −0·2 bar) and cool (15°C) there was a significant reduction in disease incidence, but considerable levels of viable fungus were still present after 45 weeks storage. Only in wet hot soil (−0·1 to −0·2 bar and 35°C) was the fungus eliminated rapidly.

I. INTRODUCTION

Studies on the survival of *Gaeumannomyces graminis* var. *tritici* Walker (hereafter referred to as *G. graminis*) in naturally infested soils have shown that this fungus remains viable for periods of two years or more (Russell 1934; Fellows 1941), although Clark (1942) reported that *G. graminis* disappeared after 3 months storage under "moisture and temperature conditions favourable for microbial activity". Clark did not specify what these conditions were. In field studies, Mac Nish and Dodman (1973) found marked differences in the survival of *G. graminis* at two locations in S.A. At Turretfield there was a considerable reduction in viable fungus within 35 weeks, while at Ceduna there was only a small reduction after 50 weeks. The effect of moisture and temperature on the survival of *G. graminis* in naturally infested soils was investigated with soil cores from the Ceduna site. These studies are reported below. Incidence of *G. graminis* after different periods of time was assessed by the core bioassay (Mac Nish *et al.* 1973).

II. MATERIALS AND METHODS

Cores were collected along the drill row from a take-all patch at Ceduna in February 1970. Details of the soil have been described previously (Mac Nish *et al.* 1973). The storage conditions chosen were soil matric potentials of −0·1 and −980 bars and temperatures of 15 and 35°C. These were used in all four combinations. The matric potential of −0·1 bar was chosen to represent the moisture conditions in field soil in midwinter. However, measurement of the soil moisture content at Ceduna revealed that this matric potential was too high (Mac Nish and Dodman 1973). For this

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reason a fifth experiment with a soil matric potential of −4·0 bars and a temperature of 15°C was later conducted using cores that had been collected at Ceduna in April 1970. The matric potential of −980 bars was the same as that in the field at Ceduna in midsummer (Mac Nish and Dodman 1973).

Winter temperature was represented by 15°C. Surface soil temperatures in South Australian wheat-growing areas are below 15°C for most of the time in midwinter (Table 1). Although it may have been preferable to have storage conditions with daily temperature fluctuations similar to those in the field, these conditions were not available. Summer temperature was represented by 35°C. In midsummer surface soil temperatures in the South Australian wheatbelt are above 35°C for a considerable part of the time (Table 1).

TABLE 1

SOIL TEMPERATURES AT WAITE AGRICULTURAL RESEARCH INSTITUTE IN BARE SOIL AT A DEPTH OF 2·5 CM

Days of the week are indicated by their first letter

Date	Hours above 35°C on:							Total No. of hours above 35°C for week
	M	T	W	T	F	S	S	
30 Dec. 1967–	6	0	6	8	8	9	10	47
2 Mar. 1968	10	9	7	7	8	9	8	58
	10	10	10	11	0	0	1	42
	7	9	8	8	9	10	10	61
	10	11	12	9	8	8	10	68
	9	8	8	6	8	8	8	55
	8	10	9	9	10	10	10	66
	10	0	3	7	8	9	8	45
	2	0	2	6	2	6	6	24
Date	Hours above 15°C on:							Total No. of hours above 15°C for week
	M	T	W	T	F	S	S	
3 June 1968–	4	0	4	6	7	5	4	30
29 July 1968	0	7	7	7	0	7	6	34
	7	0	0	0	0	3	4	14
	0	0	3	0	4	0	0	7
	0	0	0	0	4	6	5	15
	4	0	0	4	5	4	3	20
	3	0	0	5	6	1	0	15
	3	5	2	0	0	0	4	14

III. EXPERIMENTAL DETAILS AND RESULTS

(*a*) *Survival in Cores Maintained at a Matric Potential between −0·1 and −0·2 bar and at 15°C*

In this experiment the cores were watered fortnightly to a constant weight equivalent to a soil moisture content (gravimetric) of 22·4%. Average loss in weight per core during storage was 43 g per fortnight. This is equivalent to a change in matric potential from −0·1 to −0·2 bar. Seedlings that appeared in the cores during storage were removed. At intervals of 9 weeks, one set of cores (seven replicates) was removed and bioassayed. The results are shown in Table 2.

(*b*) *Survival in Cores Maintained at a Matric Potential between −250 and −980 bars and at 15°C*

Soil moisture content remained at about 1·5% for 6 months during 1969–70 at Ceduna (Mac Nish and Dodman 1973). This is equivalent to a matric potential of −980 bars. The combination of this matric potential and a temperature of 15°C may be encountered for short periods in most years, while in drought years very dry conditions could extend beyond the end of April into the cool winter months. During storage the cores received no treatment. The relative humidity in the place of storage was 70% or greater and consequently the soil absorbed a small amount of moisture. Each core gained an average of 5 g in weight during the 45 weeks of the experiment; this is equivalent to a change in matric potential from −980 to −250 bars. The results of the bioassay are shown in Table 2.

TABLE 2

EFFECT OF VARIOUS STORAGE TREATMENTS ON THE INCIDENCE OF *G. GRAMINIS* ON WHEAT SEEDLINGS GROWN IN SOIL CORES REMOVED FROM A TAKE-ALL PATCH

Soil was maintained wet (matric potential −0·1 to −0·2 bar), dry (−250 to −980 bars), or very dry (−980 bars or less) and either cool (15°C) or hot (35°C). Values (means of seven replicates) are expressed as percentage of roots infected per core or as arcsin (rad)

Storage time (weeks)	Wet cool soil		Dry cool soil		Very dry hot soil	
	Percentage	Arcsin	Percentage	Arcsin	Percentage	Arcsin
0	76	1·12	76	1·12	76	1·12
9	75	1·09	47	0·72	34	0·58
18	51	0·78	67	1·00	45	0·72
27	16	0·32	49	0·77	30	0·48
36	13	0·27	40	0·64	20	0·35
45	12	0·28	55	0·85	24	0·44
Standard error		0·107		0·125		0·128
L.S.D. ($P = 0·05$)		0·22		n.s.		0·26
($P = 0·01$)		0·29				0·35

(*c*) *Survival in Cores Maintained at a Matric Potential of −980 bars or less and at 35°C*

At the time of collection, the soil cores used in this experiment had a moisture content of about 1·5%. The average loss of moisture per core during the 45-week storage period was 9 g, and thus moisture content dropped from 1·5 to 0·7%. During storage the cores received no treatment. The results are recorded in Table 2.

(*d*) *Survival in Cores Maintained at a Matric Potential between −0·1 and −0·2 bar and at 35°C*

This combination of matric potential and temperature is unlikely to exist for more than a very short time in any part of the wheat-growing areas of S.A. However, attempts have been made to grow wheat in tropical parts of W.A. (Beech and Norman 1966) where such conditions may occur frequently. High soil moisture content and

soil temperatures are also experienced during summer in the wheat-growing areas of the Darling Downs in Queensland (Purss 1971). The cores were watered to a constant weight equivalent to a moisture content of 22·4% every third day. Average loss in weight per core during this period was 44 g. This is equivalent to a change in matric potential from −0·1 to −0·2 bar. All seedlings that appeared during storage were removed. A bioassay was performed on one set of cores after 4 weeks storage and on another after 9 weeks. As all seedlings were free of infection in both bioassays, the experiment was terminated.

(e) *Survival in Cores Maintained at a Matric Potential between −4·0 and −7·0 bars and at 15°C*

The cores used in this experiment were watered to constant weight (12% soil moisture content) once a fortnight. The average loss in weight per core was 16 g per fortnight. This is equivalent to a change in matric potential from −4·0 to −7·0 bars. The cores received no other treatment except removal of any seedlings that appeared. Cores were removed and bioassayed for the presence of *G. graminis* at 5-weekly intervals. Results are recorded in Table 3.

TABLE 3

EFFECT OF STORAGE UNDER COOL MOIST CONDITIONS ON THE INCIDENCE OF *G. GRAMINIS* ON WHEAT SEEDLINGS GROWN IN SOIL CORES REMOVED FROM A TAKE-ALL PATCH

Soil was maintained at a matric potential of −4·0 to −7·0 bars and at 15°C. Values are means of seven replicates

Storage time (weeks)	Percentage of roots infected per core	Value expressed as arcsin (rad)
0	76	1·10
5	65	0·94
10	91	1·33
15	83	1·27
20	82	1·18
25	59	0·87
31	73	1·11
Standard error		0·119
L.S.D. ($P = 0·05$)		n.s.

IV. DISCUSSION

Although there was a significant reduction in the incidence of *G. graminis* in the wet cool soil (−0·1 to −0·2 bar and 15°C), viable fungus was still present after 45 weeks of storage. In this experiment there was ample moisture for microbiological activity. Burgess and Griffin (1968) found that exposure to conditions favouring microbial activity adversely affected recovery of *Gibberella zeae* (Schw.) Petch from straw. They suggested that this was due to decomposition of the straw. Breakdown of infected root and crown tissue may account for the reduction in incidence of *G. graminis* in wet cool soil. However, without further investigation it is impossible to

determine whether the reduction in incidence is due to decomposition of infected tissue, microbial production of substances antagonistic to *G. graminis* (Gerlagh 1968), exhaustion of nutrient supply (Garrett 1963, 1966, 1967), or some other factor(s).

In the dry cool soil (−250 to −980 bars and 15°C) there was no significant change in the incidence of *G. graminis* during 45 weeks. Chen and Griffin (1966) found that microbiological activity in soil ceases when the matric potential is greater than −400 bars (relative humidity 75%). In this experiment, where the activity of other microorganisms would be minimal, the survival of *G. graminis* was probably prolonged by the cool conditions. Similarly, Burgess and Griffin (1968) found that there was a high recovery of *Gibberella zeae* from straw stored on dry (87 and 76% relative humidity) cool (10°C) soil. Bruehl and Lai (1968) demonstrated that *Cephalosporium gramineum* Nisikado & Ikata survived well in straws partially buried in dry (82% relative humidity) cool (15°C) soil. They attributed this survival to elimination of antagonistic *Penicillium* species, which compete with *C. gramineum* at relative humidities of 90 and 86%.

In the very dry hot soil (−980 bars or less and 35°C) there was a significant reduction in *G. graminis* during the period of the experiment. The reduction in incidence was greater than that observed by Mac Nish and Dodman (1973) in cores removed from the field at Ceduna during the summer months. In that field experiment there was only a small change in the level of viable *G. graminis* in soil during the summer months. Although the soil moisture conditions used in the present experiment were similar to those at Ceduna, temperatures in the field would not be as consistently high. This suggests that temperature was the main factor affecting survival in this experiment. It is unlikely that reduction in the level of viable *G. graminis* can be attributed to the activity of other microorganisms (Chen and Griffin 1966).

The cause of the rapid elimination of *G. graminis* in the wet hot soil (−0·1 to −0·2 bar and 35°C) is unknown. There is the possibility that a temperature of 35°C is lethal for *G. graminis* maintained in wet soil. It would be of interest to determine whether the poor survival of the fungus in hot wet soil is a contributing factor to the minor importance of *G. graminis* as a pathogen of wheat in Queensland (Butler 1955). Against this is the finding that wet (100% relative humidity) hot (35°C) storage conditions also adversely affected the survival of *Gibberella zeae* (Burgess and Griffin 1968); *G. zeae* is an important pathogen of wheat in Queensland (McKnight and Hart 1966). However, *G. graminis* failed to survive for 4 weeks in the present experiment, while some *Gibberella zeae* was still viable after 24 weeks in the experiment of Burgess and Griffin (1968).

In the moist cool soil (−4·0 to −7·0 bars and 15°C) there was no significant change in incidence of *G. graminis* throughout the 31 weeks of the experiment. This is in contrast to the results obtained when naturally infested soil was maintained between −0·1 and −0·2 bar and at 15°C. The relative dryness of the soil maintained at a matric potential of between −4·0 and −7·0 bars apparently had a restricting effect on the factor(s) reducing the survival of *G. graminis* in wet soil (−0·1 to −0·2 bar).

In general, the results of these survival studies confirm those of Fellows (1941). The levels of survival tend to be greater than those commonly reported with straws artificially colonized by *G. graminis* (Garrett 1938, 1940; Butler 1959; Chambers and Flentje 1967), although Petersen and Christensen (1968) report survival of longer than

three years using artificially colonized straws. My work and that of others (Russell 1934; Fellows 1941) indicates that more investigations of fungal survival should be conducted with naturally infested soil. There is also a need for comparison of the survival in soil of *G. graminis* in artificially colonized plant material and naturally infested debris.

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