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# FUSARIUM RHIZOME ROT OF GINGER IN QUEENSLAND

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SUMMARY

**A rhizome rot of ginger in Queensland is shown to be caused by a strain of *Fusarium oxysporum* Schlecht. emend. Snyd. and Hans. This fungus was non-pathogenic to gladiolus, onion and potato. Further, ginger was not attacked, or was attacked only weakly, by forms of *F. oxysporum* from aster, banana, cowpea, cucumber, gladiolus, onion, passion-fruit, pea, potato, tomato and watermelon. Because of its specific pathogenicity to ginger, the Queensland fungus is considered to be a distinct form of *F. oxysporum* and is referred to *F. oxysporum* f. *zingiberi* Trujillo.**

**Control of the disease in artificially inoculated ginger rhizomes was obtained with ethoxyethyl mercury chloride (6% Hg) at 1 lb in 40 gal for 30 min or 2 lb in 40 gal for 10 min. Control was not obtained with a dip treatment with captan, with dust treatments with captan or chloranil, or by curing rhizome pieces for five days before inoculation.**

**Shooting of healthy, uninoculated ginger rhizome pieces was stimulated by treatment with ethoxyethyl mercury chloride, methoxyethyl mercury chloride, or phenyl mercury acetate. An excessive number of small shoots was produced with treble-strength ethoxyethyl mercury chloride (3 lb in 40 gal) for 30 min.**

## I. INTRODUCTION

In Queensland, two types of rhizome rot of ginger have been studied by officers of the Department of Primary Industries. A severe form of the disease occurred in 1954 following the introduction from China of rhizomes infected with an unidentified species of *Fusarium* (Oxenham 1955; Simmonds 1955). When infected rhizomes were planted in the field, a severe rhizome rot, leaf chlorosis and pseudostem collapse resulted; a brown streaking of the vascular tissues in the rhizome and pseudostem was sometimes present. The disease spread rapidly in the field during wet weather. It was reproduced when either imported or local ginger rhizomes were inoculated in the laboratory or in the glasshouse with pure cultures of the *Fusarium*. This severe form of the disease apparently was

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eliminated from Queensland after two years by discarding the infected imported ginger as a source of planting material and by avoiding planting in or near infested soil (Simmonds 1956).

A less severe type of the disease has been present since 1930. It differs from the more severe type in rarely causing vascular streaking in the rhizome or pseudostem and in its less rapid spread in the field. Losses in storage occur by the progressive rotting of rhizomes retained for planting material (Figure 1).

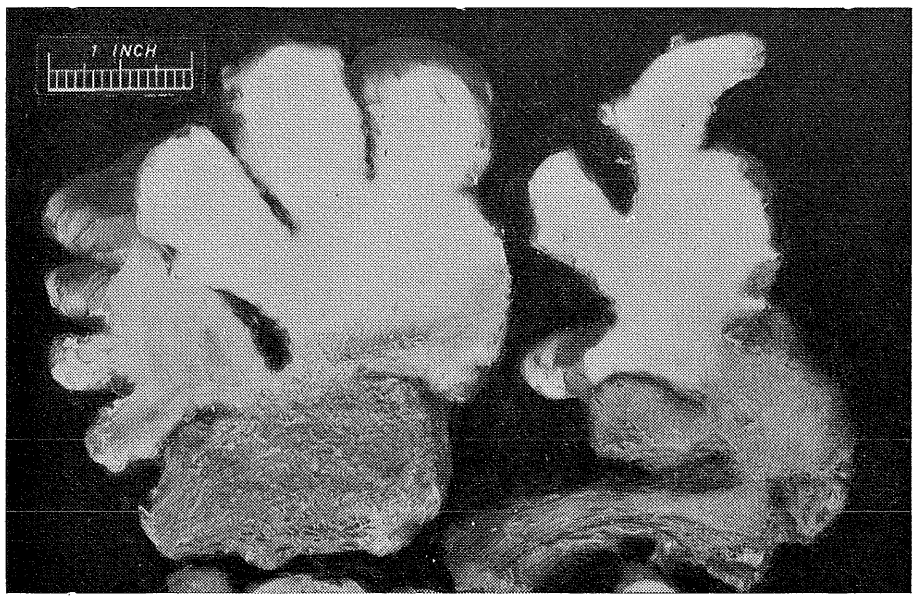


Fig. 1.—Ginger rhizomes sliced in half showing a brown rot caused by *Fusarium oxysporum*. The rot started at the cut surface of the rhizome stalk and progressed inwards.

In the field, infected planting material often fails to germinate or produces stunted yellow shoots which die prematurely. Infection occurs from the soil by way of cracks due to frosts or exposure to the sun, or by way of injuries caused by cultivating implements, soil-inhabiting insects or waterlogging of the soil. Control measures advocated have been rigid seed selection with the exclusion of rhizomes showing signs of rot, cracks, or injury; cultural practices aimed at avoiding damage to rhizomes by insects, frost, sunlight, waterlogging, and cultivating implements; and dipping selected planting material in solutions of mercuric chloride or organic mercury compounds after harvest (Veitch 1943, 1944; Smith 1945; Simmonds 1946; Officers of the Queensland Department of Agriculture and Stock 1951). The efficacy of the fungicidal treatments had not been demonstrated.

The present paper gives the results of recent work in Queensland on the cause and control of the less severe type of the disease. Abstracts of this work have been published (Simmonds 1958, 1959).

## II. CAUSE

Isolations from rotting ginger rhizomes revealed the presence of a number of fungi. As reported by previous workers (Officers of the Queensland Department of Agriculture and Stock 1951), the organism most commonly associated with the rot was a species of *Fusarium*. The fungus produced microconidia abundantly and 3- and 4-septate macroconidia less abundantly. Chlamydospores were numerous in 4-weeks-old cultures. In cultural and morphological characters the fungus agreed with the description of *F. oxysporum* Schlecht. emend. Synd. and Hans.

*Pathogenicity tests with ginger.*—The pathogenicity to ginger rhizomes of the ginger fungus and of other available forms of *F. oxysporum* was compared in both polythene bags and soil.

In the polythene bag studies, isolates of *F. oxysporum,* originally obtained from the stems of 12 different species of host plant (Table 1), were grown in petri dishes on potato dextrose agar. The cultures were cut into small pieces and each culture suspended separately in 100 ml of sterile water. Six 1-oz ginger rhizome pieces were dipped in each suspension; 6 rhizome pieces were dipped in sterile water only to serve as controls. The rhizome pieces were then placed, 3 per polythene bag, in an incubator at 26-28°C. The bags were opened daily to improve aeration.

**TABLE 1**

PATHOGENICITY TO GINGER RHIZOMES IN POLYTHENE BAGS OF FORMS OF *Fusarium oxysporum* FROM 12 HOSTS

| Original Host of *F. oxysporum* | Pathogenicity to Original Host | Number of Ginger Rhizomes Rotted out of 6 Inoculated |
|---|---|---|
| Aster | † | 1 |
| Banana | ? | 1 |
| Cowpea | † | 1 |
| Cucumber | † | 0 |
| Ginger | † | 6 |
| Gladiolus | † | 1 |
| Onion | † | 0 |
| Passion-fruit | † | 0 |
| Pea | ? | 1 |
| Potato | † | 0 |
| Tomato | † | 1 |
| Watermelon | † | 1 |
| Sterile water only | | 0 |

† Pathogenic to original host in tests by Officers of the Queensland Department of Primary Industries.

? Fungus obtained from plants showing symptoms typical of Fusarium wilt, but pathogenicity to original host not tested.

After 4 weeks, the rhizomes were sliced in half and the amount of rot determined. The results (Table 1) show that the ginger isolate of *F. oxysporum* caused appreciable rot in all 6 ginger rhizome pieces; 5 out of the 6 rhizome

pieces were a quarter or more rotted, whereas the sixth was slightly less than a quarter rotted. Rhizomes inoculated with the other isolates were healthy, except that slight rot (one-quarter or less) was present on 1 out of 6 rhizomes inoculated with *F. oxysporum* from aster, banana, cowpea, gladiolus, pea, tomato and watermelon.

In the soil studies, in one experiment lots of 9 ginger pieces were inoculated as above with cultures of *F. oxysporum* from ginger, gladiolus, onion or potato, and were planted in sterilized soils in pots; 9 ginger rhizome pieces were planted without treatment as controls. Three months after planting, the rhizomes had not germinated, presumably because they were planted during cool weather several months before the normal planting date. The rhizomes were removed from the soil and examined for rot. The results (Table 2) show that only the ginger form of *F. oxysporum* consistently caused a severe rhizome rot of ginger.

**TABLE 2**

PATHOGENICITY TO GINGER RHIZOMES IN SOIL OF *Fusarium oxysporum* FROM FOUR HOSTS

| Original Host of *F. oxysporum* | Variety of Ginger Inoculated | Number of Ginger Rhizomes Rotted out of 9 Inoculated |
|---|---|---|
| Ginger .. .. .. | Local | 9 (*a*) |
| | Chinese | 9 (*a*) |
| Gladiolus .. .. .. | Local | 0 |
| Onion .. .. .. | Local | 0 |
| Potato .. .. .. | Local | 4 (*b*) |
| No fungus .. .. .. | Local | 1 |

(*a*) Completely rotted.

(*b*) 1 completely rotted, 3 partly rotted.

In another experiment, lots of 5 ginger rhizome pieces were inoculated as above with *F. oxysporum* from either ginger or passion-fruit, and were planted in an unsterilized garden soil; 10 rhizome pieces were planted without treatment as controls. Five weeks after planting, all of the control rhizomes and the rhizomes inoculated with the isolate of *F. oxysporum* from passion-fruit had germinated, whereas none of the rhizomes inoculated with the isolate of *F. oxysporum* from ginger had germinated.

*Attempted infection of other plants.*—Attempts were made to infect gladiolus, onion and potato with *F. oxysporum* from ginger. In one experiment lots of 9 Picardy gladiolus corms were dipped in a culture macerate of either the gladiolus or the ginger isolate of *F. oxysporum* and were planted in soil; lots of 9 Sebago potato tubers were similarly inoculated with either the potato or the ginger isolate of *F. oxysporum* before planting. Nine gladiolus corms and 9 potato tubers were planted without treatment as controls. Control plants and gladioli and potato plants inoculated with the isolate of *F. oxysporum* from ginger germinated and grew normally. Gladioli plants inoculated with

*F. oxysporum* from gladiolus did not emerge from the soil. Potato plants inoculated with *F. oxysporum* from potato emerged, but became chlorotic and later died prematurely.

In another experiment, lots of 6 onions were cut with a knife so that a small portion of the bulb scales and stem on one side were removed. The onions were then dipped in culture macerates of either the onion or the ginger isolate of *F. oxysporum,* or were left uninoculated, before being placed in polythene bags in an incubator at 26°C. After 10 days, the cut surfaces of the bulbs inoculated with *F. oxysporum* from onions were covered with a copious growth of *F. oxysporum* and rot extended into the bulb scales and stem from these areas. The onions inoculated with *F. oxysporum* from ginger or left uninoculated remained healthy.

## III. CONTROL TRIALS

Ginger rhizome pieces with two or three cut surfaces were prepared from apparently healthy rhizomes. The pieces were then inoculated by dipping in a spore and mycelial suspension of *F. oxysporum* from ginger; the interval between cutting and inoculating was 1 day, except in the case of a curing treatment, in which case the interval was 5 days. The inoculum was allowed to dry briefly and then fungicidal treatments with ethoxyethyl mercury chloride (EMC) and captan were applied. EMC (6% Hg) was used as a dip for 30 min at 1 lb in 40 gal of water; captan (50% wettable powder) was used as a dip for 30 min at 1½ lb in 40 gal of water, or as a dust applied in a hessian bag with the excess dust being screened off. The treated rhizome pieces were planted in field plots, using a latin square design with 30 rhizome pieces per plot.

The results (Table 3) show that EMC treatment allowed good stands and high yields of healthy ginger, whereas captan and curing did not. Isolations from rotting rhizomes usually yielded *F. oxysporum.*

**TABLE 3**

EFFECT OF FUNGICIDAL TREATMENT OF RHIZOME PIECES PREVIOUSLY INOCULATED WITH *Fusarium oxysporum* FROM GINGER

| Treatment | Number of Stools After— | | Total Yield of Healthy Ginger (lb) After 30 Weeks |
|---|---|---|---|
| | 7 Weeks | 30 Weeks | |
| EMC dip (*a*) .. .. | 117 (*b*) | 123 | 128 |
| Captan dip .. .. .. | 22 | 23 | 12 |
| Captan dust .. .. | 32 | 30 | 14 |
| Curing for 5 days .. .. | 13 | 10 | 4 |
| Untreated .. .. .. | 3 | 7 | 4 |

(*a*) EMC = 6% mercury as ethoxyethyl mercury chloride.
(*b*) 150 rhizome pieces planted.

Subsequently two experiments with ginger planted in sawdust were done in order to determine if 1 lb EMC in 40 gal water for 30 min was the optimal

dosage. With rhizomes inoculated with *F. oxysporum,* decreased control of rot was obtained by dipping for less than 30 min in 1 lb EMC in 40 gal water.

Double-strength EMC (2 lb in 40 gal water) for 10 min was effective. Treble-strength EMC (3 lb in 40 gal water) for 30 min, although controlling rhizome rot, resulted in the production of about twice as many shoots as with normal strength, but these were only about half the size.

In another experiment, EMC (2 lb in 40 gal for 10 min) was compared with chloranil dust as a preplanting treatment. Ginger rhizomes were cut into pieces and inoculated by dipping in a suspension of macerated cultures of *F. oxysporum.* The rhizomes were then dipped in EMC, dusted with chloranil, or left untreated, and then planted in soil in a seed-box. There were 6 rhizomes per plot and each treatment was replicated three times. Emergence of shoots began $3\frac{1}{2}$ months after planting and emergence counts were made $6\frac{1}{2}$ months after planting.

Whereas emergence was 16 out of 18 with rhizome pieces treated with EMC, emergence was only two out of 18 for the chloranil-treated rhizomes and for the untreated rhizomes.

## IV. EFFECT OF FUNGICIDES ON SHOOTING OF GINGER

Experiments were done to determine if organo-mercurial fungicides stimulated germination in ginger rhizomes in the comparative absence of fungal pathogens.

In soil tests, ginger rhizome pieces were dipped for 30 min in fungicidal dips of mercury content equivalent to 1 lb EMC (6% Hg) in 40 gal water. The treatments were EMC, methoxyethyl mercury chloride (MMC), phenyl mercury fixtan (PMF), phenyl mercury urea (PMU), phenyl mercury acetate (PMA), methyl mercury dicyan diamide (MMDD), mercuric chloride ($HgCl_2$), and no treatment. No inoculation with *F. oxysporum* was made. There were 18 rhizome pieces per plot and treatments were replicated three times. Emergence counts were made $4\frac{1}{2}$ and $7\frac{1}{2}$ weeks after planting. The results (Table 4) show that EMC, MMC and, to a lesser extent, PMA stimulated early germination of ginger.

In polythene bag tests, ginger rhizome pieces were dipped for 30 min in EMC solution (1 lb in 40 gal water). Lots of 3 dipped seed pieces were placed in polythene bags, and one bag was placed in each of 10 compartments of a multiple-temperature incubator running between 12 and 29°C; undipped rhizome pieces were similarly bagged and incubated. Bags were opened daily to improve aeration. After 3 weeks, measurements were made of the longest shoot on each rhizome.

**TABLE 4**

STIMULATORY EFFECT OF ORGANO-MERCURIAL FUNGICIDES ON SHOOTING OF GINGER

| Treatment | Equivalent Percentage Emergence* after— | |
|---|---|---|
| | 4½ Weeks | 7½ Weeks |
| Ethoxyethyl mercury chloride (EMC) .. | 81 | 99 |
| Methoxyethyl mercury chloride (MMC) | 80 | 93 |
| Phenyl mercury acetate (PMA) .. | 67 | 86 |
| Methyl mercury dicyan diamide (MMDD) | 50 | 90 |
| Phenyl mercury fixtan (PMF) .. .. | 48 | 86 |
| Phenyl mercury urea (PMU) .. .. | 41 | 84 |
| Nil .. .. .. .. .. .. | 39 | 96 |
| Mercuric chloride ($HgCl_2$) .. .. | 35 | 88 |
| | EMC, MMC> > MMDD, PMF, PMU,Nil, $HgCl_2$. PMA> > $HgCl_2$. PMA> PMU, Nil, $HgCl_2$. | No significant differences |

*Equivalent percentages of transformed treatment means. Analysis for percentage emergence was carried out using the inverse sine transformation.

The results (Table 5) show that with both EMC-dipped and undipped ginger shooting was negligible or slight below 20°C, and was optimal at approximately 27°C. EMC-dipped ginger produced shoots which were usually two or more times longer than those produced by undipped ginger.

**TABLE 5**

EFFECT OF ETHOXYETHYL MERCURY CHLORIDE (EMC) ON SHOOTING OF GINGER RHIZOME PIECES HELD AT VARIOUS TEMPERATURES IN BAGS

| Average Temperature (°C) | Lengths of Longest Shoots on 3 Rhizomes after 3 Weeks (mm) | |
|---|---|---|
| | Dipped in EMC | Undipped |
| 12 | 0 | 0 |
| 14 | 0 | < 3 |
| 16 | < 3 | < 3 |
| 18 | < 3 | < 3 |
| 20 | 3–6 | < 3 |
| 21 | 6–12 | 3–6 |
| 23 | 12–25 | 3–6 |
| 25 | 12–25 | 6–12 |
| 27 | > 25 | 6–12 |
| 29 | 12–25 | 6–12 |

## V. DISCUSSION

The results given in Tables 1 and 2 show that *Fusarium oxysporum* from ginger consistently was pathogenic to ginger, whereas *F. oxysporum* from 11 other hosts was not. Further, *F. oxysporum* from ginger was non-pathogenic to three plant species other than ginger which were readily attacked by their respective forms of *F. oxysporum*. This provides experimental evidence for the suggestion (Trujillo 1963) that *F. oxysporum* from ginger is host-specific, and confirms the validity of the new form, f. *zingiberi* Trujillo, erected to contain the ginger *Fusarium*.

The results given in Table 3 show that a preplanting treatment with EMC substantially increased the stand and yield of ginger in the presence of abundant artificial contamination with *F. oxysporum* f. *zingiberi*; presumably treatment with EMC would also act against natural contamination of rhizome pieces with this fungus during the cutting-up process or following the planting of rhizomes in infested soil. Mercury treatment already has been shown to be effective against rhizome rot of ginger caused by species of *Pythium* and *Sclerotium rolfsii* Sacc. (Park 1935, 1937; Thomas 1940; Ramakrishnan 1952). Further, organo-mercurial compounds are effective against the forms of *F. oxysporum* attacking gladiolus (Magie 1955) and narcissus (Aycock 1959).

EMC and related organo-mercury compounds have been reported to stimulate early shooting in sugar-cane sets (Mungomery 1947; Steindl 1955; Mathuswamy and Aravamudhan 1957); a similar effect is caused in ginger (Tables 4 and 5). The reason for the stimulation in shooting is unknown, but possibly it is hormonal. This would be suggested by the fact that treatment of ginger with triple-strength EMC for 30 min resulted in the production of about twice the number of shoots of about half the size of those treated with single-strength EMC. The possibility that the stimulation in shooting is a result of control of pathogenic micro-organisms is unlikely, since the effect occurred in apparently healthy rhizome pieces placed in soil (Table 4) or in polythene bags in incubators (Table 5). However, EMC treatment causes changes in the surface microflora of ginger rhizomes held under moist conditions. *Penicillium brevicompactum* Dierckx (identified by J. J. Elphick, Commonwealth Mycological Institute, December 1958) was found growing abundantly on the cut ends of EMC-treated rhizome pieces, but was not obvious on the cut ends of undipped rhizome pieces. Further work is required to establish definitely the basis of the stimulatory effect.

EMC preplanting treatment of rhizome pieces has been used by most ginger growers in Queensland since 1957. Double-strength EMC (2 lb in 40 gal) for 10 min has been generally employed, since it is more economical of time than single-strength EMC for 30 min. This has involved no additional changes in practices except that the treated rhizome pieces, if harvested with the new rhizomes, cannot be processed for human consumption because of residues of mercury. The value of the treated rhizome piece is low, however, and in any case rhizome pieces sound at harvest time have been successfully replanted the following season (G. W. J. Agnew, private communication 1959). Translo-

cation of mercury compounds in ginger is apparently insignificant. In tests carried out in the Government Chemical Laboratory, Brisbane, mercury was present in appreciable amounts in $\frac{1}{8}$-in. deep slices across the cut surfaces of dipped rhizome pieces and $\frac{1}{16}$-in. deep slices of the skin of rhizome pieces, but not in deeper tissues of the dipped rhizome pieces or in the new rhizomes.

A preplanting treatment of ginger rhizome pieces with an organo-mercurial fungicide such as EMC would appear to be a useful practice in the culture of ginger in Queensland. The beneficial effects are the promotion of early germination and the protection given against the rhizome rot fungus, *F. oxysporum* f. *zingiberi*.

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