EXPERIMENT 8

THE EFFECT OF CANOLA RESIDUES AND GLUCOSINOLATE BREAKDOWN PRODUCTS ON THE GROWTH OF SOME FUNGI PATHOGENIC TO CEREALS IN SOUTHERN AUSTRALIA.

INTRODUCTION

Compounds prevalent in *Brassica* spp., including canola, the Isothiocyanates, have been reported to have anti-fungal activity (Greenhalgh and Mitchell 1976). Tagasugi *et al.* (1987) working with *B. oleracea* supported the earlier work of Lewis and Papavisas (1971) where the vapour of isothiocyanates inhibited the growth of a root rot fungus of peas. Mithen *et al.* (1987) believed sinigrin and other breakdown products could inhibit the fungus responsible for stem canker disease.

Other authors have also postulated that glucosinolate breakdown products from canola residues have anti-fungal activity, notably most recently Angus *et al.* (1994). These workers also identified potential compounds which could be implicated in any anti-fungal activity. Methyl Isothiocyanate and Phenyl ethyl isothiocyanate were identified as dominant in *Brassica* spp. residues and as being active against the fungus causing take-all of wheat (*Gaeumannomyces graminis* var *tritici*) (Ggt).

This experiment aimed to investigate the effect of canola residues and some glucosinolate breakdown products on the growth of a number of fungal root pathogens, *in vitro*. Indole Acetyl Nitrile (IAN) and Phenyl Ethyl Amine (PEA) are products produced from the further breakdown of Isothiocyanates and are postulated as possibly having activity in suppressing fungal pathogens.

METHODS

This experiment was carried out in mid 1992 at CSIRO Division of Soils in Adelaide.

Four fungal pathogens of cereal crops grown in Southern Australia were selected as test organisms to evaluate the inhibitory effects of Canola leachates and Glucosinolate breakdown products These pathogens were *Gaeumannomyces graminis* var *tritici* (Ggt) isolate 500, *Pythium spp.* strain BH40 and two *Rhizoctonia* species, strains AG8 and AG2-1. These were taken from stock cultures and

grown on 1/5 Potato Dextrose agar to produce colonies from which the experimental selections were made.

Plugs of agar with fungi 0.5 cm in diameter were taken from plates and placed in the centre of Petri dishes to which 1.3cm circles of Whatman No 41 filter paper were placed at four points around the circumference of the dishes. These filter paper circles had been dipped in different dilutions of canola leachates or different concentrations of glucosinolate breakdown products.

Test solutions of canola leachates and breakdown products were prepared as follows:

Residues from two varieties of canola was collected from breeders' plots at NSW Dept. of Agriculture Research Institute at Wagga Wagga, in NSW, within two days of harvest. The varieties were Maluka and Jumbuck. Both stem and root material were sampled and mixed together. The dried residues were hammermilled through a 2.5mm screen and stored in dry conditions and stored at 4°C until required. 1g of each sample was placed in bottles with 100ml of distilled water and incubated at 25°C in the dark for 72 hrs. This gave a dilution of residue leachate of 10mg/ml. Following incubation the bottles containing residue leachates were quite cloudy and smelled of organic compounds. Dilutions from all solutions were made to produce concentrations of 100µg/ml and 1µg/ml. Each dilution was filtered through 0.45µm millipore filters prior to dipping the filter paper discs which were placed on the Petri dishes. Calculations from these suggest that each disc absorbed 25µl of liquid, with this containing an equivalent amount of leachate to correspond to a residue level in the field of 0.18t/ha. This would be at the lower levels expected from crops grown, and higher levels would be more normal.

Each replicate dish contained a central plug of fungus with four filter paper discs arranged around the perimeter of the dish; one circle contained sterile water, and the others contained the three dilutions of leachate.

Two glucosinolate breakdown products were prepared, in varying concentrations, and used as test compounds in a similar manner. Indoleacetylnitrile (IAN) and Phenylethylamine (PEA) (Sigma Ltd.) were diluted in sterile water to concentrations of 10mM, 100µM and 1µM. These were also passed through 0.45µm millipore filters and discs of filter paper used to introduce all concentrations, as well as sterile water control to dishes containing central plugs of the fungi.

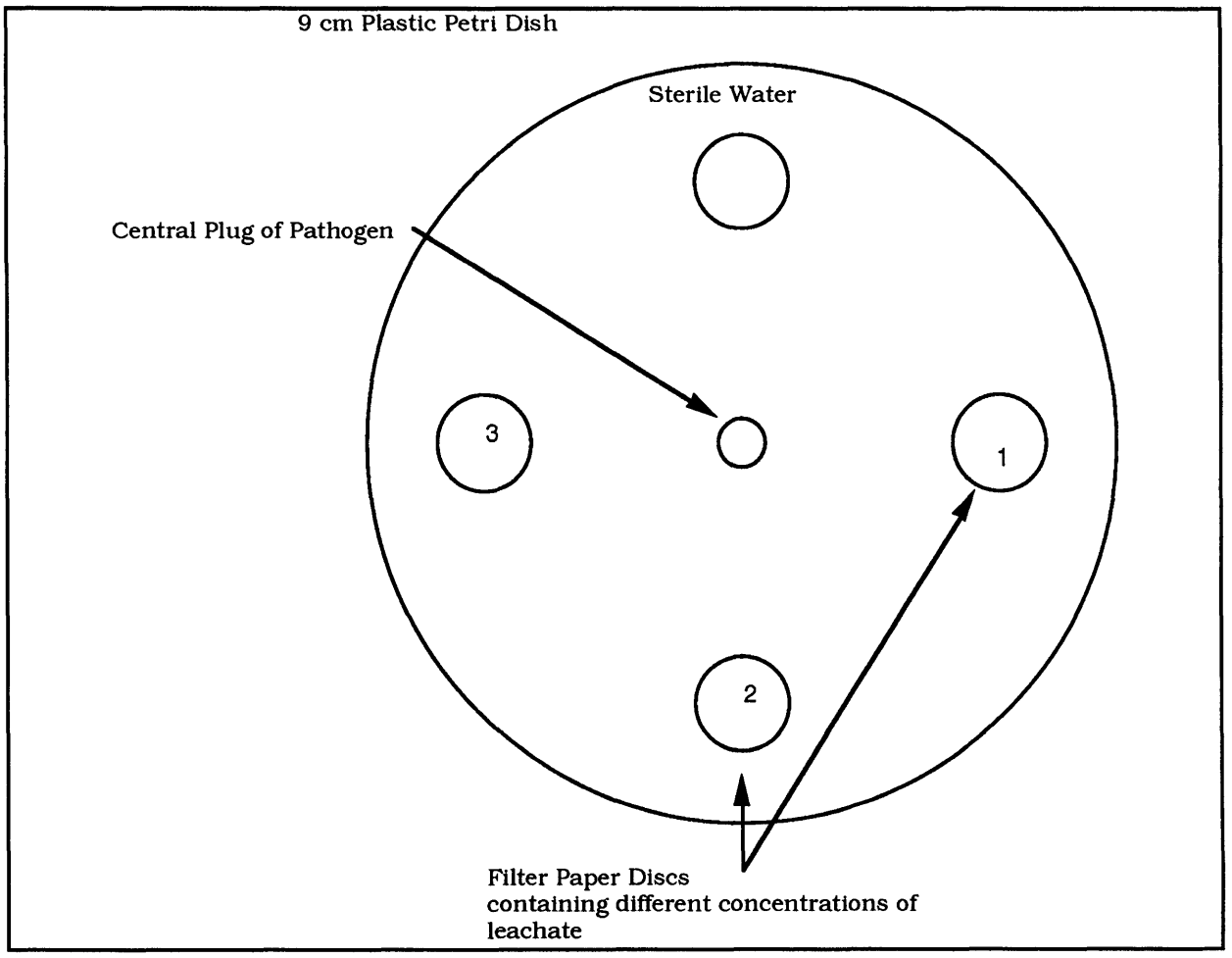


Figure E8.1. Outline of typical test plate.

Each disc of filter paper contained approximately 0.25ml of test leachate or solution of test compound.

The discss contained leachates, and compounds as follows:

Disc B:	10mg/ml Leachate	or	10mM Solution
Disc C:	100ug/ml Leachate	or	100um Solution
Disc D:	1ug.ml Leachate	or	1uM Solution
Disc A:	Sterile Distilled Water		

Four replicates were used and dishes were incubated in the dark at 25°C. Assessments were made on Day 6 after setting up, and photographs taken of each treatment and fungi growth pattern.

RESULTS

After 6 days growth inhibition of Ggt was seen only where canola residue leachates were used. No inhibition was observed with *Pythium* spp. BH40, nor *Rhizoctonia* spp., AG8 and AG2-1. See the plates, over.

None of the fungi were inhibited with either of the glucosinolate breakdown products at the concentrations used.

Inhibition of Ggt by the residue leachates was complete with no growth from the agar plug, not even in the direction of the filter paper disc containing sterile water. Such complete inhibition points to volatile agents emanating from the discs carrying canola residue extracts.

The Ggt500 plugs were removed from these dishes and placed in dishes containing only agar to determine if the fungus was alive. Both these dishes and the test dishes were incubated as per the experimental conditions.

After 17 days the colonies of Ggt500 taken from these dishes were alive and had developed across the agar which indicates thast the inhibitory compounds from the canola residues were fungistatic rather than fungicidal. Assessments of the dishes showed that Ggt500 had developed since Day 6, with some pattern evident whereby growth was less toward the areas where the filter paper circles containing the highest concentration of leachate (10mg/ml) were placed. See Plates E8.3 and E8.4.

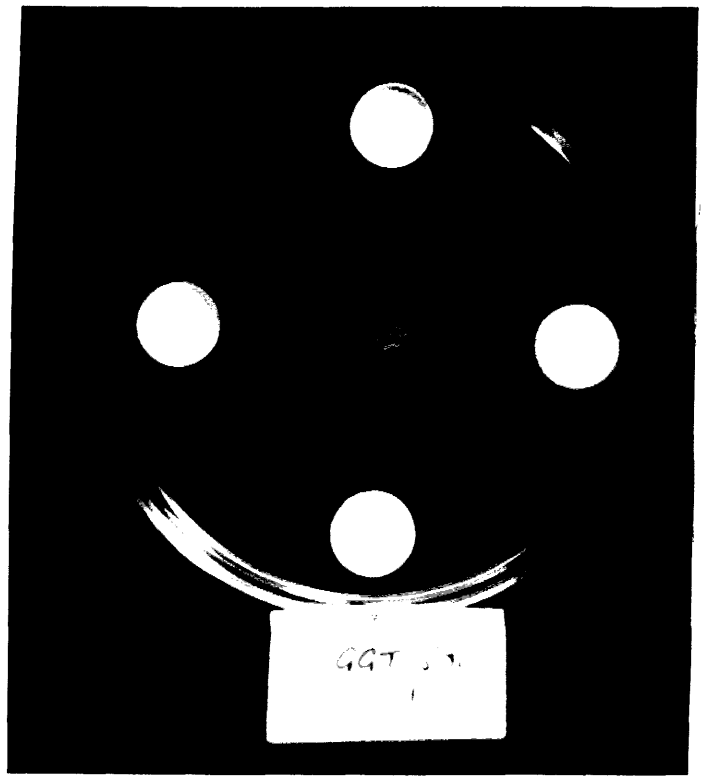


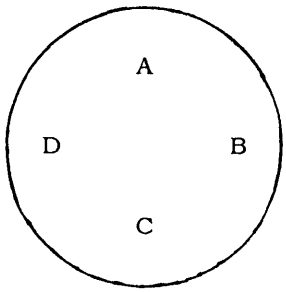
Plate E8.1:

6 Days after plating out:

Ggt500 in centre,

Leachates of canola cv. Maluka

Key to discs:



A: Sterile Water

B: 10mg/l leachate

C: 100μg/l leachate

D: 1μg/l leachate

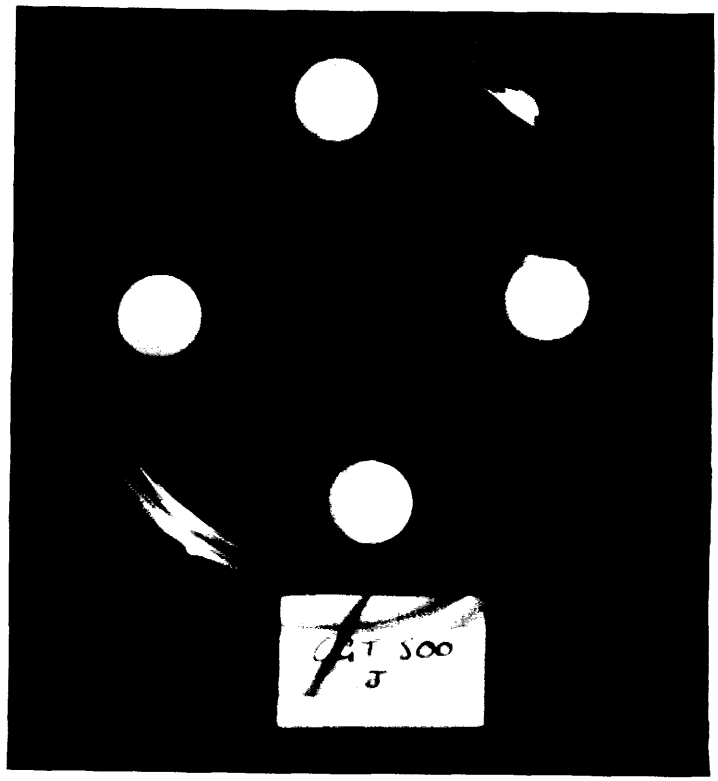


Plate E8.2:

6 Days after plating

Ggt500 in centre,

Leachate of canola

cv. Jumbuck

Plate E8.3. Growth of Ggt colony taken from plates containing canola (cv. Maluka) residue leachate Day 17 (11 days after removal from plates.)

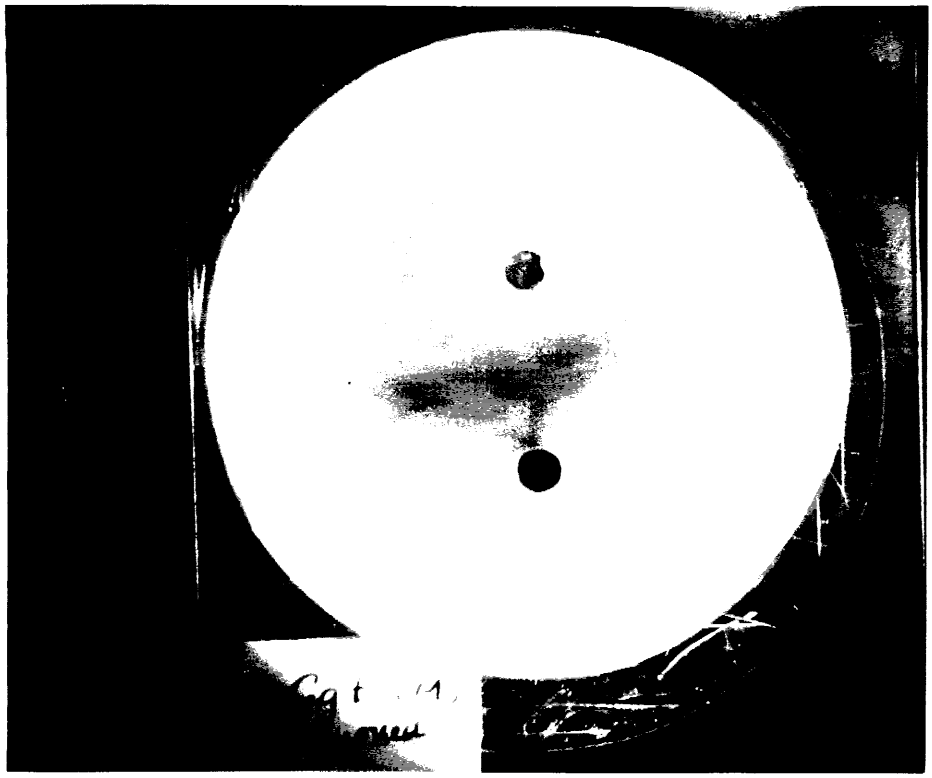
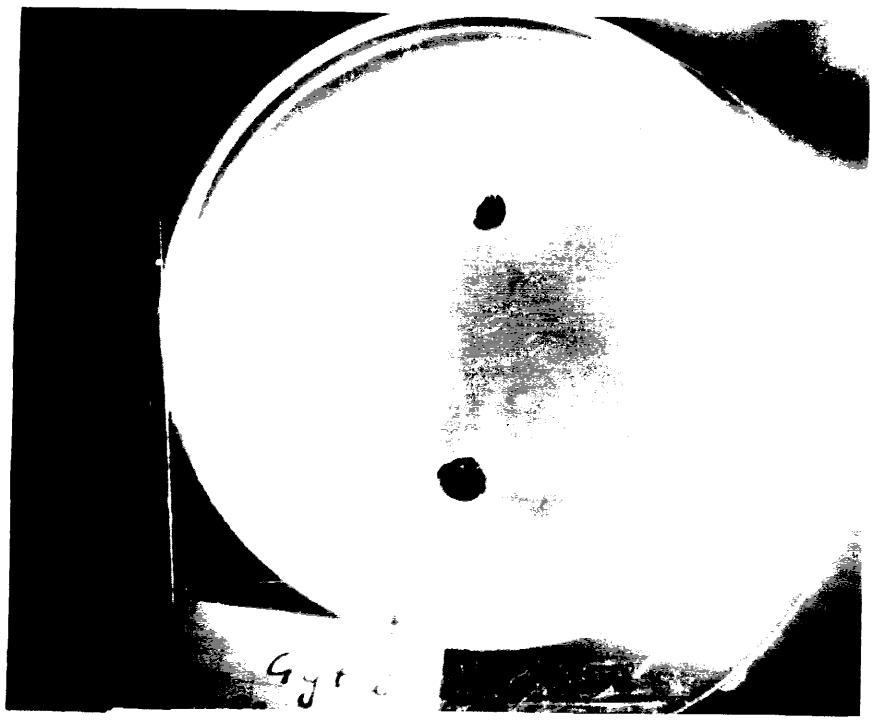


Plate E8.4. Growth of Ggt colony taken from plates containing canola (cv. Jumbuck) residue leachate . Day 17 (11 days after removal from plates.)

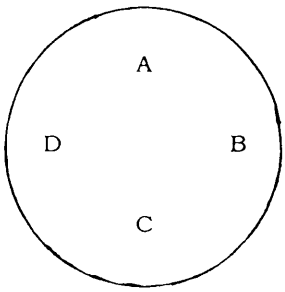


The plates from which the Ggt colonies had been removed were incubated and after 11 days the fungus had begun to grow from the remnants of the central plug. This is further evidence that the pathogen had been inhibited by canola residue leachates rather than killed, indicating that the inhibiting agents in the canola residues were volatile.

The growth of the Ggt remnant in the plate after removal of the central agar plug showed a pattern of growth away from disc A and B. These discs contained the strongest dilutions of leachate, which indicates that as well as being volatile, the inhibiting compounds were water soluble. See plate E8.5.

Plate E8.5: Ggt plate following central colony removal showing growth of pathogen from remnants of colony. 11 days after colony removal, 17 days after initial plating out.

Key to discs:

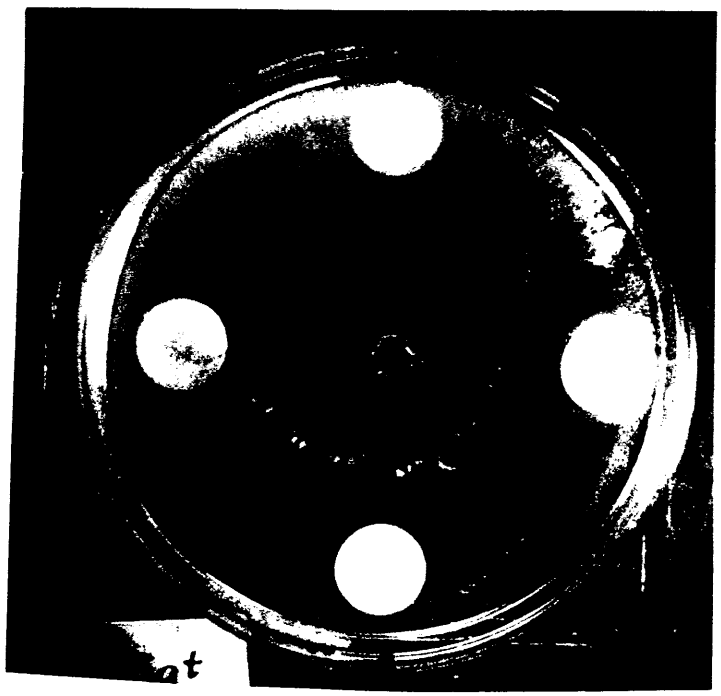


A: Sterile Water

B: 10mg/l leachate

C: 100μg/l leachate

D: 1μg/l leachate



DISCUSSION

From the observations of the plates it appears that neither of the candidate compounds, at the concentrations used, showed any activity in inhibiting the growth of any of the cereal pathogens under these conditions. This may have been due to the concentration of the solutions being too low, or that the compounds had no activity against the pathogens. The latter seems to be the case, since the range

experiments (Experiment 6) which inhibited germination of seeds. The reduction in disease levels expected following canola crops may be due to other compounds.

Angus *et al.* (1994) identifies methyl isothiocyanate and phenyl ethyl isothiocyanate as being active against Ggt, and it is possible that it is the isothiocyanate compound, not the breakdown products indole acetyl nitrile and phenyl ethyl amine used in this experiment, that are the compounds active against Ggt and possibly other pathogens.

The extracts from the canola residues had a striking effect on Ggt, with no growth at all out from the central plug. Growth of the fungus from the plug toward the filter paper discs containing sterile water would be expected if the inhibitory compounds in the residue extracts were water soluble, but growth was inhibited in all directions. This indicated that the inhibitory agent(s) in the extract could be volatile, leading to general inhibition of the fungus. These results suggest that canola residues may be active against Ggt at very low levels in the field, since the strongest dilution used here corresponded to a field residue level of only 0.18t/ha. Much higher levels in the field would be expected, and so any anti-fungal effects from canola residues could be expected to be significant under field conditions.

To test whether the inhibitory agents were fungistatic or funguicidal, the agar plugs with Ggt were transferred to new agar plates. Growth of the fungus from these plugs when removed from the dishes with residue extracts establishes the fungistatic nature of the inhibition (Plates E8.3 and E8.4).

This is consistent with the findings of Lewis and Papivasis (1971) that vapour from glucosinolate breakdown products to be able to inhibited the growth of root rot pathogen in peas. They identified allyl isothiocyanate and phenyl ethyl isothiocyanate as likely inhibitors.

It is possible that it is the Isothiocyanate that is active against fungi. In this case it may be that Indole glucosinolates are initially producing indole isothiocyanate, with this giving the anti fungal effect here. Further breakdown to produce nitriles (for example, IAN) may then occur, with these compounds not being active against fungi, but active against plant germination. Thus, there may be activity against fungi with early breakdown products, that is, the isothiocyanate, with these being volatile, followed by further breakdown to the nitrile with these compounds affecting plant germination.

After several days, the plates containing Ggt and canola extracts began to show growth of the pathogen. This growth was skewed toward the circles containing sterile water and the lowest concentration of extract (see Plate E8.5, growth is toward circles D and A). This indicates the active agent may be diminishing in concentration with time, such that growth was able to occur, however, sufficient activity remained in the circles of highest concentration to continue to inhibit growth. Alternatively the compounds active against the fungi may have been broken down to other less active compounds.

Two effects seem to have been displayed by the inhibitory compounds in the canola residue extracts. The effects where the fungus was prevented from making any growth outward from the central plug indicates that the compounds are volatile. Subsequent to this the fungus grew in a pattern away from the strongest dilutions of the residue extracts, indicating the the inhibitory agents responsible for this were not fungicidal, but fungistatic, and also water soluble. The inhibition may be due to volatile compounds produced early from residues, with further breakdown of these to, soluble compounds. There may be a number of compounds produced with volatiles being most active early giving a general fungistatic effect, followed by continued activity from other compounds as the volatiles dissipate.

These results suggest inhibitory activity by agents present in extracts of canola residue, active against Ggt. While no activity was observed with the other pathogens, this may be due to Ggt being more sensitive than other fungal organisms, the generally low levels of residue extract used, or because the agent has specific activity against only Ggt. Again, recent work by Kirkegaard *et al.* (1994b) agrees with these observations, that canola residues are strongly inhibitory to Ggt growth.

Further experiments are needed to confirm the inhibition of Ggt seen here, and to investigate different lengths of incubation of residue prior to extraction. This may help better describe the effects occurring and indicate further the causative agents.

EXPERIMENT 9

CONFIRMATION OF RESULTS SEEN IN EXPERIMENT 8, LENGTH OF INCUBATION OF CANOLA RESIDUE; EFFECT ON INHIBITION OF PATHOGENIC FUNGI

INTRODUCTION

Following the positive results in Experiment 8, where extracts of canola residue were implicated in inhibiting growth of cereal pathogenic fungi, it was thought necessary to check the repeatability of the findings and to look into the length of incubation as a factor affecting any inhibition observed.

Since no activity was detected with the compounds used, only canola residue was used in this experiment. A range of incubation times and dilutions were tested for any effect on inhibition of the fungal pathogens.

METHODS

This experiment was conducted in Adelaide at CSIRO Division of Soils in mid 1992.

As in Experiment 8 the following pathogens were used: *Gaeumannomyces graminis* var *tritici* (Ggt) 500, *Pythium* species. strain BH40 and two *Rhizoctonia* species, strains AG8 and AG2-1. These were taken from stock cultures and grown on 1/5 Potato Dextrose Agar to produce colonies from which the experimental selections were made.

0.5 cm diameter plugs of agar and fungi were taken from cultures and placed in the centre of Petri dishes to which 1.3cm discs of Whatman No 41 filter paper, dipped in different dilutions of canola residue extracts, incubated for a range of times prior to extraction, were placed near the outer edge of the dish.

These leachates were prepared, as follows.

Residues of canola cv. Maluka was used in this experiment, from the same source used in Experiment 8. The dried residues were hammermilled through a 2.5mm screen and stored in dry cold conditions until required.

8g of residue material was placed in bottles with 80ml of distilled water and incubated at 25°C in the dark for 1.5, 7, 28 and 96 hrs.

This gave a dilution of residue leachate of 100mg/ml. Further dilutions from this solution were made to produce dilutions of 50mg/ml and 10mg/ml. Sterile distilled water was used as nil concentration solution. Each dilution was filtered through 0.45µm millipore filters

A 25µl aliquot was taken from each millipore filtered leachate and added to the disc in each dish. This gave amounts of residue leachate contained in each filter paper circle equivalent to a maximum of 1.88t/ha of canola residue, an amount similar to what may be expected in field conditions from moderate to lower yielding crops

Thus, each replicate dish contained a central plug of fungus with one filter paper disc near the outside of the dish. Each dish was thus a single dilution or incubation period. Four replications were used.

Observations were made on day 2 (Pythium) and day 4 (Ggt and Rhizoctonia) Photographs were taken of dishes as in Experiment 8.

RESULTS

Of the treatments only the strongest dilution (100mg/ml) or the longest incubation (96 h) showed inhibition. Of the pathogens used the only substantial inhibition was seen with Ggt and Pythium. Neither of the Rhizoctonia strains seemed to be inhibited to any degree by any of the treatments, although strain AG2-1 showed some slight indications of inhibition with the strongest dilution of leachate or with longest incubation time.

The effect of general inhibition pointing to volatile compounds was not seen in this experiment.

Many of the filter paper circles showed a degree of contamination from bacteria. With further time this became more evident, such that to make any inferences from the inhibition of fungal growth in some of the plates would be difficult. Any inhibition of growth could be due to bacterial growth producing antibiotics.

As such it was decided to repeat the experiment, but to filter the extracts though a smaller millipore filter. This time a 0.22μm millipore filter was used and leachates were filtered twice before the aliquots were drawn off and placed on filter paper circles.

The treatments were also modified such that incubation times were 1, 25 and 75 h. The same concentrations of aliquots were used in each series.

In this series no inhibition was observed with any concentration or any period in incubation.

DISCUSSION

The first series of treatments showed some inhibition to growth of some of the pathogens, but due to suspected contamination of some of the filter paper discs this cannot be accurately attributed to the leachate. It is likely that some bacteria were still present in the leachate after millipore filtration (0.45μm millipore) and these may have been the cause of inhibition of fungal growth observed. Alternatively, any inhibitory agent present in the leachates may have passed throught the 0.45μm millipore filter and effected the inhibition observed. It seemed that more inhibition occurred where the longest incubation occurred (96hr) and/or where the highest concentration of leachate was used.

The pattern of inhibition seen was not of the general nature seen in Experiment 8, where volatility of the responsible compounds was indicated. It is likely here that the increased length of time of incubation of many of the treatments may have allowed some of the volatility to dissipate, or other further breakdown products products to be formed, or that where contamination was present the volatile compounds were not produced.

Dahiya *et al.* (1988) isolated a bacterium (*Pseudomonas fluorescens*) from the rhizosphere of canola. They identified three compounds produced by the bacteria which affected fungi, including Rhizoctonia, Pythium and Ggt. It may be that, in this experiment, any activity from residue extracts is

also due to production of compounds by bacteria associated with the residue and, perhaps, the compounds are contained within the bacterium. As such Millipore filtration may have not only removed the bacterium, but also the potentially active compounds they may contain. Lovett and Jackson (1980) identified this bacterium as potentially important in the production of allelopathic compounds from *Camelina sativa* leaf washings, with Lovett and Duffield (1981) hypothesising along these lines.

The second series of dishes showed little or no inhibition of fungal growth in any treatment. Filtration twice through 0.22µm millipore filter seems to have removed any bacteria, and perhaps also any active compounds associated with them.

Given that no inhibition of fungal growth was seen with extracts from canola residues in the second series of treatments it remains difficult to explain the inhibition observed in Experiment 8, where canola residue leachate was seen as inhibitory to Ggt. No similar inhibition was seen in this experiment, where the only major difference would seem to be the filtration through finer millipore filter. It may be possible that any inhibitory agents were unable to pass through the smaller millipore (0.22µm), and were present in the leachates filtered through 0.45µm millipore, but due to contamination their effect could not be reliably identified. If the experiment was, again, repeated it would be interesting to try filtering through 0.45µm millipore, but also employing a means of ensuring freedom from contamination, and also to filter through 0.22µm millipore.

It is interesting to note that inhibition of pathogen growth in the first series was seen with Pythium and Ggt mainly in dishes containing the highest concentration of leachate (that is, those with 100mg/ml of leachate). Little or no inhibition was seen with the Rhizoctonia pathogens even where contamination was evident. This may mean that Rhizoctonia is resistant to the inhibitory effect of contamination, or leachate compounds, while Pythium and Ggt are more susceptible. Alternatively, it may mean that the inhibition of Pythium and Ggt is not due to contamination, but rather to leachate compounds (perhaps bacterial in origin) which are not as active on Rhizoctonia. In the highest concentration leachates these compounds may have been freely in solution and so able to pass through millipore filter.

It could be expected that contamination was present in those dishes containing lower concentrations of leachate, but no inhibition was seen. This may also support the theory that inhibition at highest concentrations was due to compounds, with contamination being incidental, though possibly additive.

If the inhibition was due to leachate compounds being able to pass through the larger millipore, then inhibition (of Pythium and Ggt) seen with the first series of plates in this experiment may not necessarily have been due solely to contamination, but contamination occurred incidentally to inhibition caused by leachate compounds.

EXPERIMENT 10

THE EFFECT OF CANOLA RESIDUES ON WHEAT GROWTH AND PATHOGEN INFECTION IN POTS.

INTRODUCTION

To test the effect of canola residues on pathogenicity of fungal diseases in cereals in a soil an experiment was designed incorporating three pathogens and two levels of canola residue.

Earlier work (Experiment 7) indicated that canola residues inhibited the the take-all fungus (Ggt) *in vitro*, so this experiment was designed.

Evidence exists concerning the benefits of canola in a cereal based cropping rotation, in terms of reducing soil borne fungal pathogens (Mithen *et al.* 1987, Angus *et al.* 1991). Recent work in Australia (Angus *et al.* 1994) supports the idea that canola produces products upon breakdown that suppress some fungal pathogens of wheat. These authors believed this to be one of the factors involved in healthy wheat crops grown following canola crops.

This experiment aimed to investigate the affect of canola residues on the observed disease levels in cereal seedlings.

METHODS

This experiment was carried out in Adelaide at CSIRO Division of Soils in mid-late 1992.

A mallee sandy soil DY5 (Northcote 1965) from Avon in South Australia was used, taken from an area where no fungal pathogen, or alternate host plants occurred. The soil was sifted through a 1.0mm sieve.

The experiment was carried out in small pots, each holding 300g soil. Into each pot was placed 200g of soil, then inoculum of fungus was placed in each pot before a further 100g of soil was added. In the canola treatments, the residue was added and incorporated evenly through the top 100g of soil. The pots were incubated for 10 days in the light at 15°C, at 12% moisture.

Three fungal pathogens were used. Pythium (BH40) inoculum was 1cm diameter agar discs, with three of these placed in each pot. Ggt (Ggt500) inoculum was millet seed, with three propogules (seeds) placed in each pot. Rhizoctonia (AG8) inoculum was ryegrass seed and, again, three propogules (seeds) were placed in each pot before being topped up with the last 100g of soil. Control pots had no inoculum placed in them.

Three levels of canola residue were used; equivalent to 0, 1 and 5 tonne per hectare. These levels are what would be expected in the field from poor to high yielding crops. The residues were hammermilled and evenly mixed through the soil so that an evenly incorporated residue was present in the top layer of soil, placed on top of the pathogen inoculum in the pots. See Figure. E10.1.

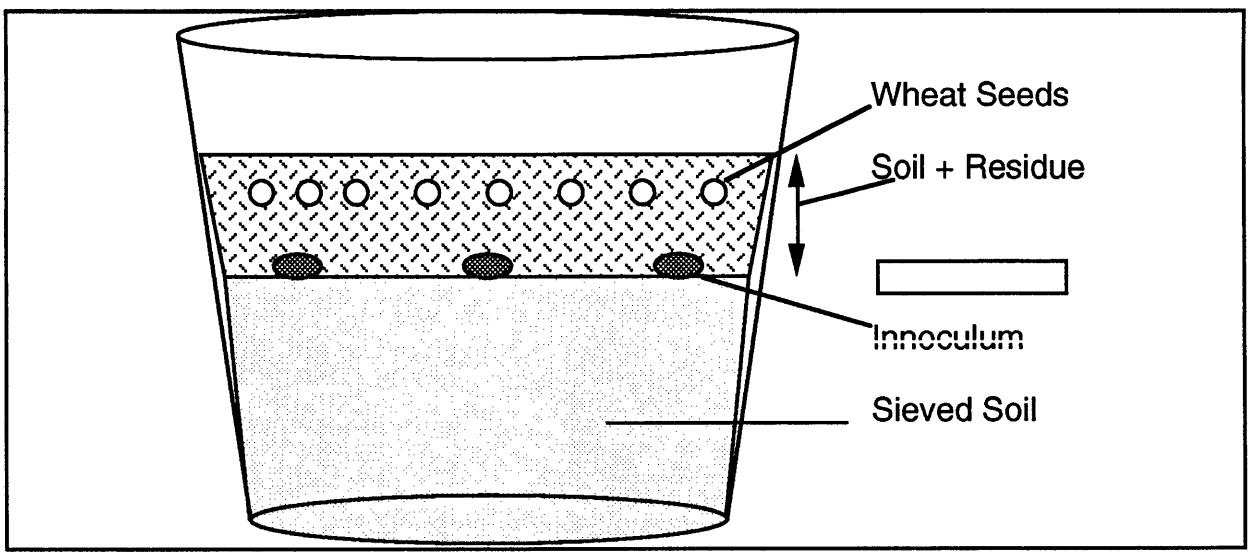


Figure E10.1: Pot Layout for Experiment.

Wheat seeds, cv Spear (7 per pot) were planted at depth of 4 cm.

Pots were maintained at 12% moisture and held in a growth cabinet at 15°C in a light / dark cycle (12hr/12hr) until assessment for germination and dry weight after 26 days. Germination was measured 14 days after planting and dry weights were taken a further 12 days later. Upon harvest rootsts were assessed for infection and damage by Rhizoctonia and Ggt.

RESULTS

All results were analysed using Analysis of Variance techniques, with the LSD's indicated calculated using this method.

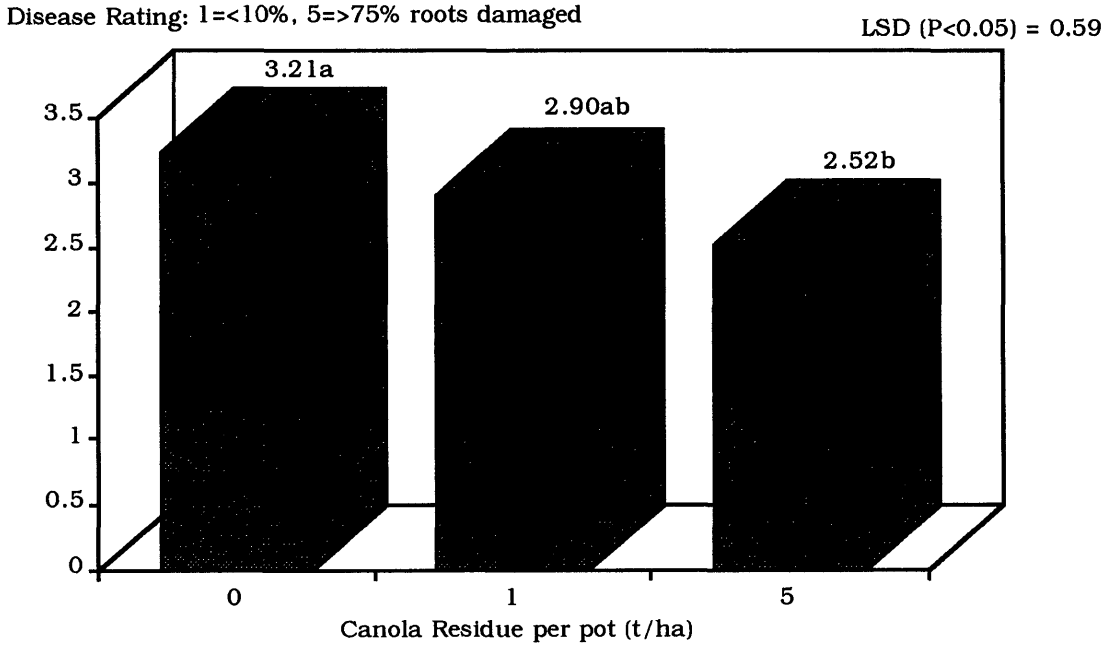
1. GERMINATION

The result for germination of wheat, while showing some interesting trends, showed no statistically significant differences.

Some depression of germination seemed evident where Pythium was added to pots, with improvement where canola residues were subsequently added. Similar effects were seen with the other pathogens but, again, results were non-significant.

2.. RHIZOCTONIA DAMAGE TO WHEAT ROOTS:

Figure E10.2: Effect of residue on Rhizoctonia infection of wheat.
Disease rating (1-5)



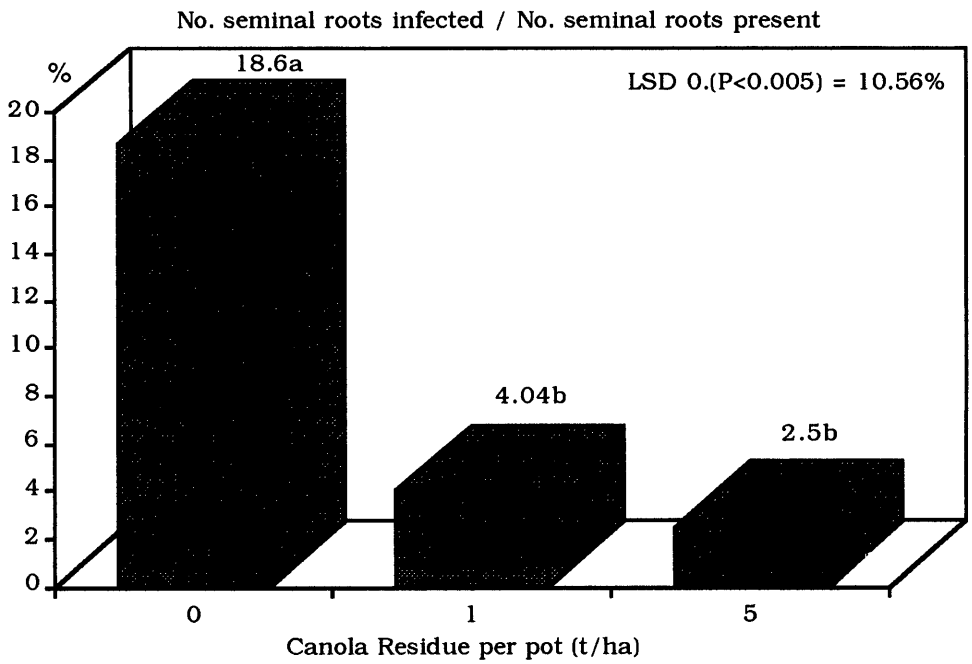
Means sharing the same letter are not significantly different (P<0.05).

Rhizoctonia damage was rated on a 1 - 5 scale, where 1=<10% damage, 2= 10-25% damage, 3= 50-75% damage, 4=>75% damage and 5= severely stunted root system.

Where canola residue was added to pots containing Rhizoctonia innoculum the severity of damage to the wheat was reduced. At the highest rate of residue addition (5 t/Ha) the level of damage to roots was significantly ($P < 0.05$) less than that where no residue was present (Figure E10.2 above).

3. GGT INFECTION OF WHEAT

Figure E10.3: The effect of canola residue on Ggt incidence in wheat.



Means sharing the same letter are not significantly different ($P<0.005$).

Figure E10.3 shows that canola residue resulted in a highly significant reduction ($P < 0.005$) in the level of infection of wheat roots by the take all fungus (Ggt) at both levels of residue addition.

4. DRY WEIGHT OF PLANTS.

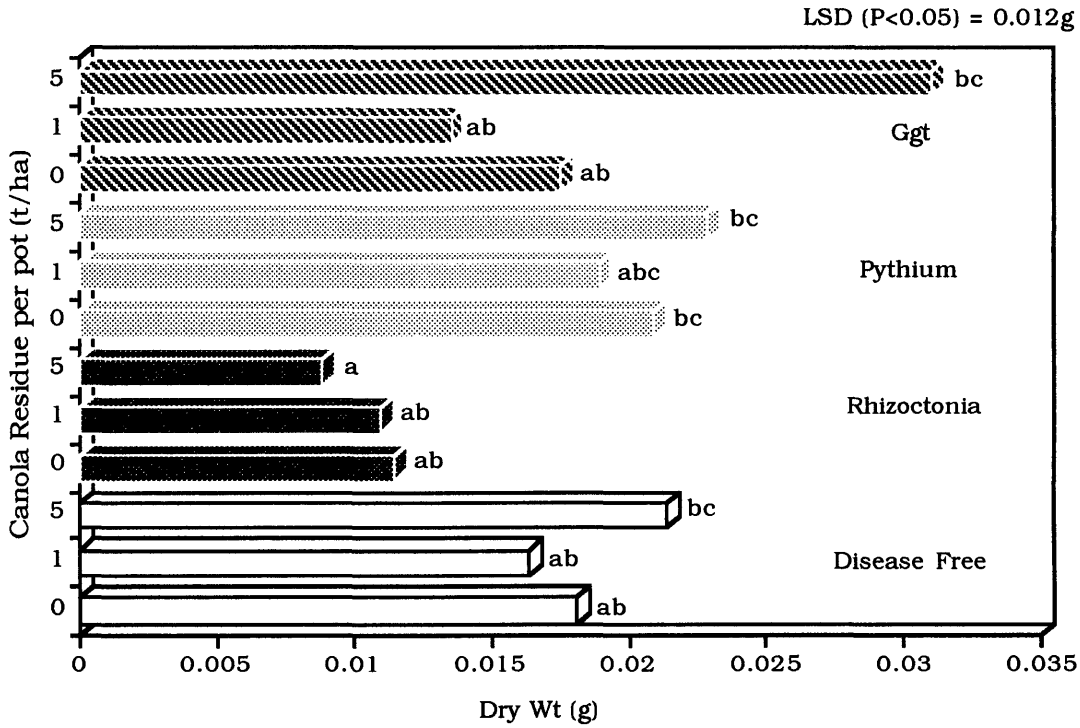
The results for dry weight of the shoots showed no statistically significant results, however differences in the dry weights of the roots were significant ($P < 0.05$), between any two treatments. Figure E10.4 shows the effect of pathogen infection and residue level on the dry weight of roots of the wheat plants in each treatment.

Within any group of like treatments, however, the results were not significant, thus, while some interesting trends are apparent, it is not possible to attribute statistical significance to these.

The trends observed were:

- a general depression in dry weight where Rhizoctonia inoculum was added to pots, with little or no recovery with addition of canola residue;
- a small depression and restoration of dry weight with Ggt. The high rate of canola residue overcame the effect of the pathogen;
- generally, root growth showed a greater degree of response to the treatments than top growth as measured by dry weight.

Figure E10.4: The effect of residues and pathogens on root dry weight of wheat



Means sharing the same letter are not significantly different (P<0.05).

DISCUSSION

Pythium often reduces seedling emergence and, so, % germination is a means of estimating the effect the pathogen. While non significant results were obtained in this experiment, the trend showed that pythium alone reduced germination and this improved with the addition of canola residue. This was

supported by the results for dry weight of the plants in each pot, where Pythium depressed dry weight and canola residue led to increased growth. These results indicate some activity of canola residues (or breakdown products from these residues) in reducing the damage caused by Pythium.

The results for Rhizoctonia disease damage rating showed statistically significant differences ($P<0.05$). Where no residue was present the damage was more severe than where residue was included, with the addition of the highest rate of residue (5 t/Ha) giving significantly less damage than the lower rate or no residue. The dry weight of roots do not show the same levels of differences.

The addition of canola residue dramatically reduced the damage caused by Ggt (see Figure E10.3). Dry weight results also support this positive effect of addition of canola residue. It would appear that canola residues, or breakdown products from them, are able to have a potent affect on the Ggt fungus, leading to a significant reduction in the take all disease where canola residues are present.

These results could have implications for crop rotations, such that a canola crop preceding a cereal may be beneficial in reducing either inoculum levels in the soil, or in reducing the virulence of the pathogen. This could help explain the anecdotal evidence of improved crop growth of cereals grown following canola crops.

The results reported here support evidence elsewhere of the ability of *Brassica* spp., either as living plants or as residues to have some anti-fungal activity. The work of Sturz and Bernier (1987, 1989, 1991) in Canada showed the the inclusion of canola in crop rotations with cereals could have considerable benefits in reducing the levels of disease in the cereal crop. They especially identified a role of canola in reducing the level of Ggt.

More recently Angus *et al.* (1991), Kirkegaard *et al.* (1993) and Angus *et al.* (1994) have reported, that canola residues can reduce the level of Ggt infection in wheat.

EXPERIMENT 11

THE EFFECT OF CANOLA RESIDUES AND PHENYL ETHYL AMINE ON GERMINATION AND EARLY GROWTH OF WHEAT.

INTRODUCTION

This experiment was designed to confirm the results from Experiment 10 and also to investigate the possible effect of one of the compounds identified in canola residue leachates in earlier work, namely Phenyl Ethyl Amine (PEA), as as possible agent to also suppress fungal pathogen growth. Phenyl ethyl amine is a possible breakdown product from the glucosinolate prevalent in root tissue of *Brassica* spp., phenylethyl glucosinolate (MacLeod *et al.* 1981).

METHODS

This experiment was also carried out at CSIRO Division of Soils, Adelaide, in late 1993, as defined in Experiment 10.

Four levels of canola residue were used: 0, 1, 5 and 10 tonne per hectare. The residues were hammermilled and evenly mixed through the soil so an evenly incorporated residue was present in the top layer of soil, placed on top of the pathogen inoculum in the pots.

Three dilutions of PEA were used added to pots via filter paper discs placed on top of the first 200g of soil prior to the last 100g being added. Dilutions prepared were 0.001M, 0.01M and 0.1M of PEA, and three 1.3cm diameter discs of Whatman No. 41 filter paper containing one these dilutions were added to each pot. Each discs contained 0.05ml of solution, thus a total of 0.15ml of each dilution was added to each pot.

Wheat seeds, cv Spear (7 per pot) were planted at depth of 4 cm.following pots being incubated for 10 days to allow the pathogen inoculum time to establish.

Pots were maintained at 12% moisture and held in a growth cabinet at 15°C in a light / dark cycle (12hr/12hr) until assessment for germination % and later dry weight. Germination was measured 14 days after planting and dry weights were taken a further 12 days later. Upon harvest plants were assessed for infection by Rhizoctonia and Ggt.

RESULTS

All results were statistically analysed using Analysis of Variance techniques.

1 EFFECT OF CANOLA RESIDUE ON DISEASE LEVEL IN WHEAT.

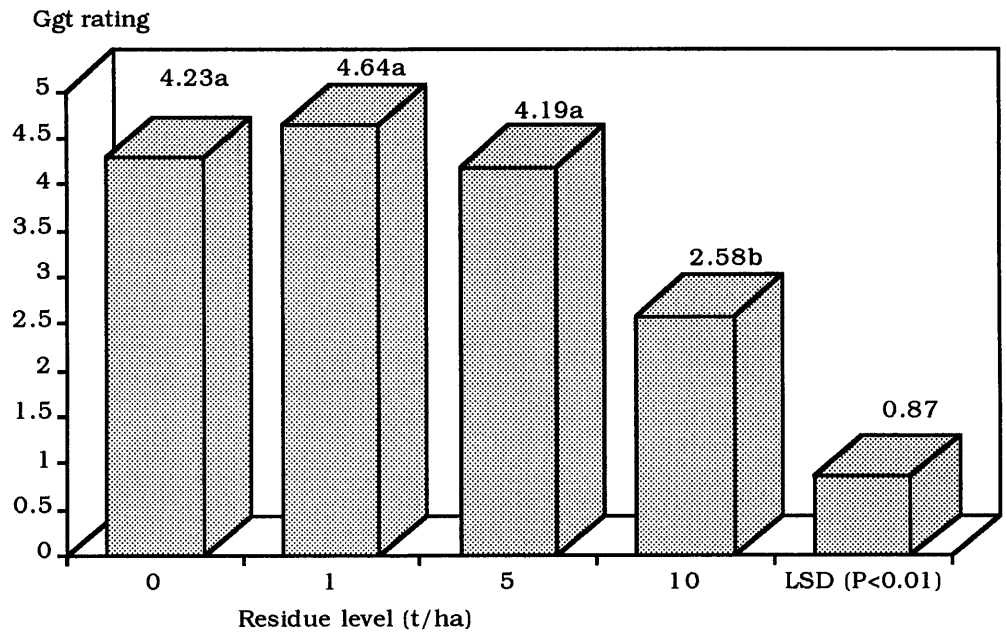
a) Ggt Infection:

Ggt infection of wheat was assessed by visually rating the amount of infection on the roots of plants. A scale from 0- 5 was used as follows:

Rating:	Description:
0	nil lesions
0.5	1 lesion, < 0.5 cm long
1	1-5% of roots carrying lesions
2	6-25% of roots carrying lesions
3	26-50% of roots carrying lesions
4	> 50% of roots carrying lesions

Figure E11.1 shows the effect of increasing levels of canola residue in pots and how this affected the level of Ggt damage to wheat. The highest level of residue reduced the Ggt damage significantly.

Figure E11.1: Ggt Rating as affected by canola residue level in pot

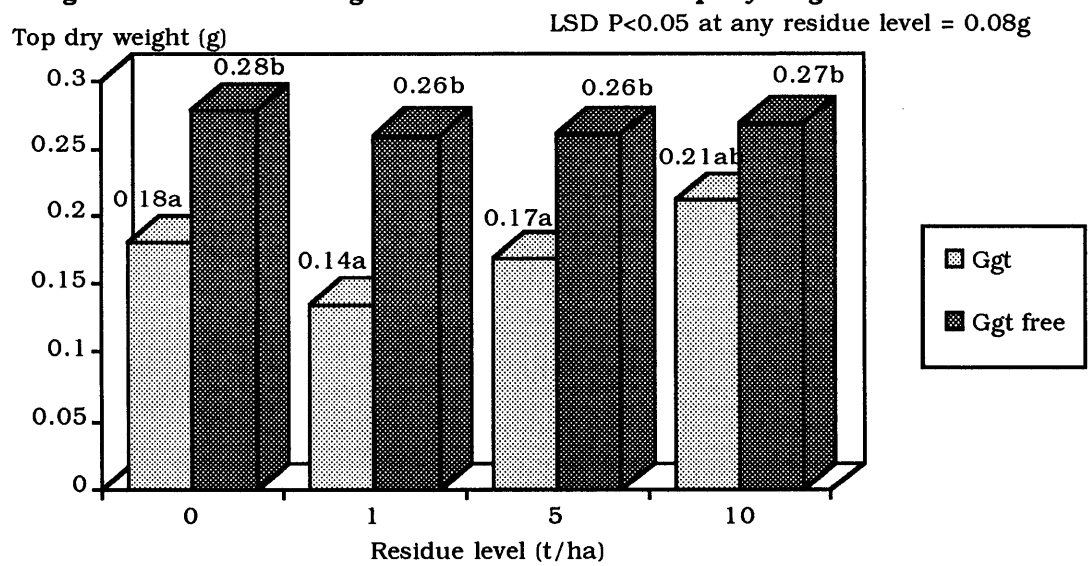


Means sharing the same letter are not significantly different (P<0.01).

Dry weight of wheat tops was also measured. Canola residue at up to 10t/ha had no effect on the growth of wheat as measured by dry weight.

Ggt, however, strongly reduced the dry weight of wheat tops. Adding canola residue restored dry weights toward that of pots where Ggt was not added. The highest level of canola residue (10t/ha) restored dry weight to a level approaching that in Ggt free pots, (Figure E11.2, below).

Figure E11.2: Effect of Ggt and canola residues on top dry weight



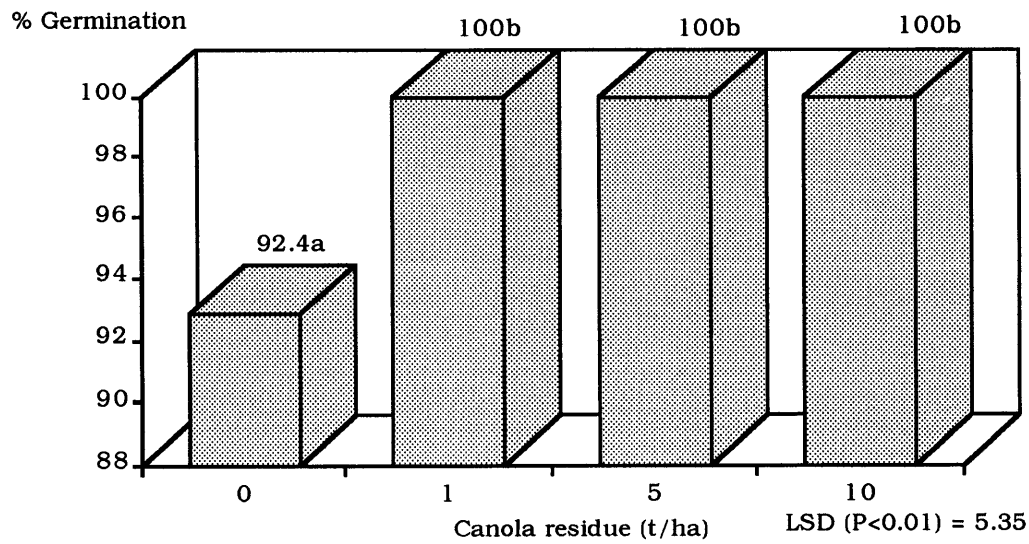
Means sharing the same letter are not significantly different (P<0.05).

b) Pythium Infection.

The effect of Pythium was measured by % germination and dry weight of tops.

Figure E11.3, shows canola residue as improving germination of wheat in the presence of Pythium.

Figure E11.3: The effect of canola residues on the germination of wheat in the presence of Pythium



Means sharing the same letter are not significantly different (P<0.1).

Although residue gave a positive effect in restoring germination, there was no significant difference in dry weights of the treatments.

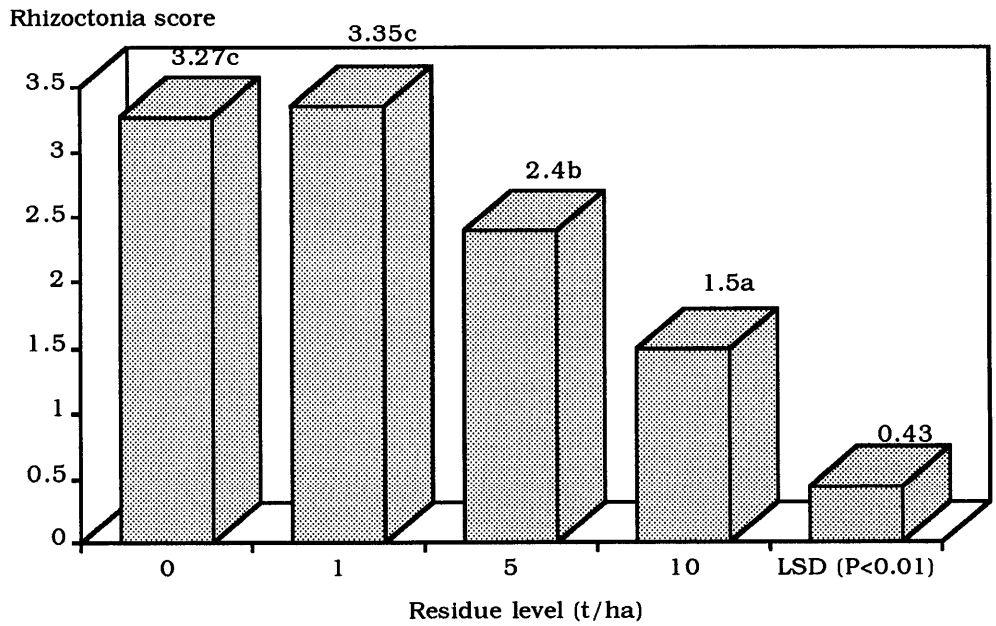
c) Rhizoctonia Disease Rating.

Rhizoctonia damage was visually ranked using a numeric scale:

Rank:	
1	5% of roots showing damage
2	15% of roots showing damage
3	30% of roots showing damage
4	45% of roots showing damage
5	>45% of roots showing damage

The higher levels of canola residue reduced the level of damage from Rhizoctonia (Figure E11.4).

Figure E11.4: Rhizoctonia infection of wheat as affected by canola residue



Means sharing the same letter are not significantly different (P<0.01).

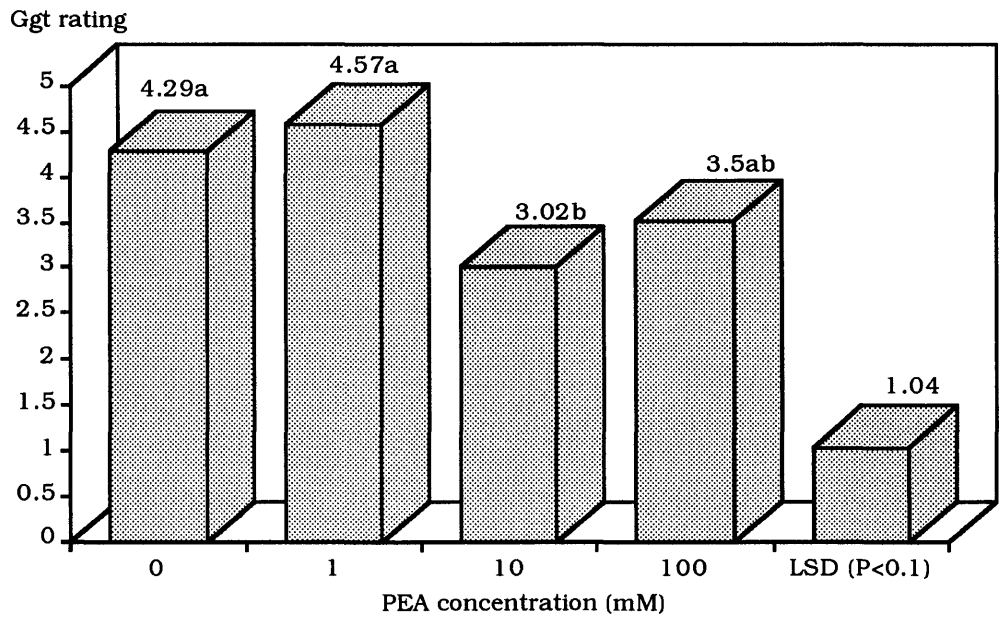
The results for dry weights of tops did not show any significant differences between amount of residue added to infected or rhizoctonia free pots. Thus, the results of disease rating above are the only ones showing effect of canola residue on the level of Rhizoctonia in this thesis.

2. EFFECT OF PHENYL ETHYL AMINE ON DISEASE IN WHEAT.

a) Effect of PEA on Ggt infection of wheat.

Figure E11.5, below, shows PEA at the two top concentrations reduced the level of Ggt infection, although the level of significance was at the (P<0.1) level.

Figure E11.5: Effect of PEA on Ggt infection in wheat.



Means sharing the same letter are not significantly different (P<0.1).

Ggt strongly reduced top dry weights (see Table E11.1), but the presence of PEA did not reduce the effect of Ggt.

Table E11.1: Ggt infection as influenced by presence of PEA.

Dry Weight of plant tops (g)

PEA Concentration (mM)	Ggt	Ggt free	
0	0.178a	0.279a	**
1	0.144b	0.260a	**
10	0.181a	0.261a	**
100	0.215a	0.269a	N.S.
Mean	0.719	1.069	

Means within a disease level sharing the same letter are not significantly different (P<0.05).

Results from PEA addition to other pathogen inoculated pots showed no effect on level of disease expression.

Where PEA was added to pots with Pythium and Rhizoctonia the disease level remained as in pots where no PEA was added. Only in the Rhizoctonia treatments was any trend apparent, however this was not statistically significant.

It would appear that PEA is not a strong inhibitor of fungal pathogens as tested in this experiment. It showed little or no activity in reducing the severity of diseases, especially Pythium and Rhizoctonia.

DISCUSSION

Canola residues were seen to strongly reduce the Ggt infection as rated by a visual inspection of wheat roots, especially at the higher levels of residue (10t/ha). This supports earlier experiments and also the work done by others recently (Angus *et al.* 1994). The results of dry weight analysis showed increased growth of wheat, also notably at the highest rates of residue, though this increase in growth was not statistically significant.

It is possible that the pots were harvested before the full effects of Ggt infection had been expressed in dry weights and, possibly, leaving the plants to grow longer may have given greater increases in dry weights where canola residue was added to Ggt pots.

If canola residues were able to reduce the level of Ggt infection in wheat plants this could well be reflected in plants being able to tolerate low moisture or nutrient levels more ably, resulting in marked improvement in growth.

The results presented here support the hypothesis that canola residues can play a role in reducing the ability of fungal pathogen Ggt to infect wheat, and to increase growth where Ggt is present.

The results of residues on Pythium indicate that, where canola residues were present. % germination was improved. Since Pythium exerts its effect mainly in reducing wheat germination, this indicates that canola may assist in reducing the severity of Pythium where it is present, resulting in better crop establishment. There was no difference in dry matter results, suggesting that any effect on Pythium was in improving germination, rather than early growth. It is to be expected that different pathogens would vary in their susceptibility to inhibitory compounds present in residue leachates or compounds used alone. In this case it is possible that Pythium is a more resistant pathogen to these treatments, with Ggt and Rhizoctonia being the most easily inhibited pathogens.

Canola residues showed a strong ability to reduce the level of Rhizoctonia damage in wheat roots, especially at levels of 5 and 10t/ha. This improves on the results in the last experiment where 5t/ha was insufficient to reduce Rhizoctonia damage.

Again, the dry weights did not show any effect of canola residue in improving growth of Rhizoctonia infected wheat. As before, this could be due to an insufficient time allowed for the plants to more fully express the effects of the disease and the stress free growing conditions.

Phenylethyl amine (PEA) showed only minor effects in inhibiting fungal diseases, with only the highest concentration showing any activity. This may be due to PEA being a weak inhibitor of fungal pathogens as compared to other glucosinloate breakdown products. For example, other glucosinolates may produce products of higher activity against fungal pathogens than PEA (for example, indole acetyl nitrile).

PEA is an alternate breakdown product to phenylethyl isothiocyanate, produced from phenylethyl glucosinolate under acidic conditions (basic conditions produces the isothiocyanate). Isothiocyanates have been widely reported as active in inhibiting pathogens (Angus *et al.* 1994, Chan and Close 1987, Mithen *et al.* 1987, Takasugi *et al.* 1987, Drobnica *et al.* 1967), and it seems that the nitrile breakdown products are of lower activity than isothiocyanates. Angus *et al.* (1994) found that phenylethyl isothiocyanate was less active than methyl isothiocyanate, and it is possible that PEA is less active than similar breakdown products from other glucosinolates;

it is possible, however, that PEA may be involved in inhibition of pathogen by canola residues, or where wheat follows canola. There is a number of glucosinolates in canola plants, including the root systems, including phenylethyl glucosinolate.

Many compounds may act together to produce the inhibitory effects. Thus, any one compound which shows inhibition in experiments may be far more active in soil in the present of many other compounds, such that only slight activity in experiments may reflect greater activity in soil in association with the possible many other compounds present, especially other breakdown products and other glucosinolates and their breakdown products;

The period of exposure of the pathogen to the inhibitory compound(s) may be important for compounds showing marginal activity *in vitro*.

The effects in this experiment, where canola residue leachates were seen as more active against pathogens compared to an individual candidate compound, may indicate one or more effects:

Residues, containing several glucosinolates, may be expected to produce a number of breakdown compounds, which may vary in activity towards plant pathogens. In soil this variety of compounds may provide considerably more activity than any single compound. Thus, the effect of residue leachates, in this experiment, may be due to a number of different glucosinolate breakdown products acting together, either additively or in synergy.

Similarly, residues may contain other compounds, not only glucosinolate breakdown products, which may contribute to any inhibitory activity.

Whatever the compound(s) involved, canola residues are inhibitory to cereal fungal root pathogens, notably Ggt and to a lesser extent Pythium and Rhizoctonia. It is also likely that glucosinolate breakdown compounds, for example, isothiocyanates or nitriles are involved. The use of canola in a cropping rotation may, thus, be expected to be beneficial in reducing the level of these pathogens in soil and increasing yields of cereals.

EXPERIMENT 12

EFFECT OF CANOLA RESIDUES AND FUNGAL PATHOGENS ON GERMINATION AND EARLY GROWTH OF WHEAT.

INTRODUCTION

The results from Experiments 10 and 11 showed that canola residues suppressed root pathogens of wheat, especially Ggt, as well as some possible effects on Rhizoctonia and Pythium. Canola residues at levels up to 10t/ha of dry matter were seen to inhibit the growth of Ggt, Rhizoctonia and Pythium and, possibly, to increase growth of wheat in the presence of these pathogens.

This experiment aimed to further confirm these results, using a fresh source of canola residues.

METHODS

The experiment was carried out in Adelaide at CSIRO Division of Soils in late 1993, as described for Experiments 10 and 11.

Canola residue was gathered at Trundle in NSW from a paddock following harvest and before rainfall had occurred on the canola stubble. Canola was cv. 'Oscar' and both roots and tops (stems and leaf residues) were collected. The residues were hammermilled and evenly mixed through the soil so an evenly incorporated residue was present in the top layer of soil, placed on top of the pathogen innoculum in the pots. Four levels of canola residue were used: 0, 1, 5 and 10 t/ha.

Wheat seeds, cv. Spear (7 per pot) were planted at depth of 4 cm following pots being incubated for 10 days to allow the pathogen inoculum time to establish.

Pots were maintained at 12% moisture and held in a growth cabinet at 15°C in a light / dark cycle (12hr/12hr) until assessment for germination % and later dry weight. % germination, disease rating and top dry weights were measured 28 days after planting.

RESULTS

As with earlier experiments results were statictically analysed using Analysis Of Variance techniques.

EFFECT OF CANOLA RESIDUE ON DISEASE LEVEL IN WHEAT.

a) Ggt Infection.

Ggt infection of wheat was assessed by visually rating the amount of infection on the roots of plants. A scale from 0- 5 was used as follows:

Rating:	Description:
0	nil lesions
1	1 lesion, < 0.5 cm long
2	1-5% of roots carrying lesions
3	6-25% of roots carrying lesions
4	26-50% of roots carrying lesions
5	> 50% of roots carrying lesions

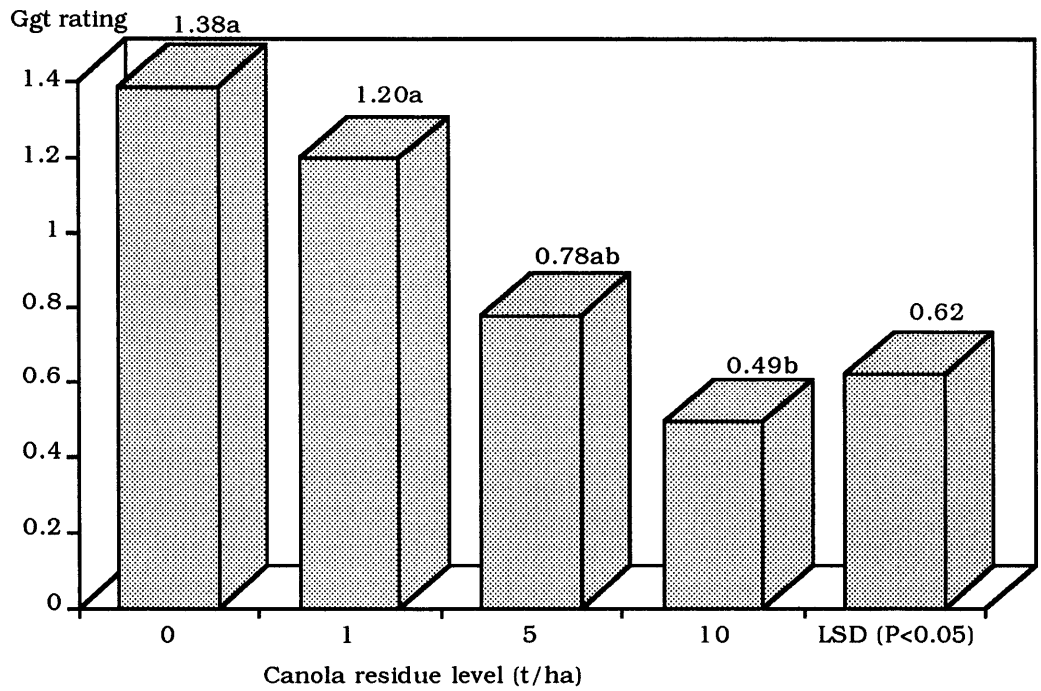
Table E12.1 and Figure E11.2 (over) show Ggt rating as affected by the presence of canola residue from 0 to 10t/ha dry matter. Ratings sharing the same letter are not significantly different (P<0.05).

Table E12.1: Effect of Residue on Ggt Infection Rating in wheat

Residue (t/Ha)	Ggt Rating	
0	1.39	a
1	1.20	ab
5	0.78	bc
10	0.49	c
LSD P<0.05	0.62	

The addition of canola residue at amounts of 5 t/ha and above reduced the level of Ggt infection as rated by the visual scale described, above.

Figure E12.1: The ffect of canola residue on Ggt infection of wheat



Dry weight of wheat shoots did not show a significant level of difference between residue level and Ggt (Table E12.2)

Table E12.2: Effect of Ggt and canola residue level on dry weight of wheat shoots.

Results are not statistically significant.

Dry Weight of Tops (g)

Residue Level (t/ha)	Ggt	Ggt free
0	0.099	0.115
1	0.103	0.122
5	0.104	0.115
10	0.101	0.102

b) Pythium Infection.

The effect of Pythium was measured by germination and dry weight of shoots. No statistically significant effects were found. There was no difference in % germination between pots containing Pythium and control, nor between pots containing varying levels of canola residue.

c) Rhizoctonia Disease Rating.

Like Ggt, Rhizoctonia infection was visually ranked using a numeric scale, as follows:

Rank:

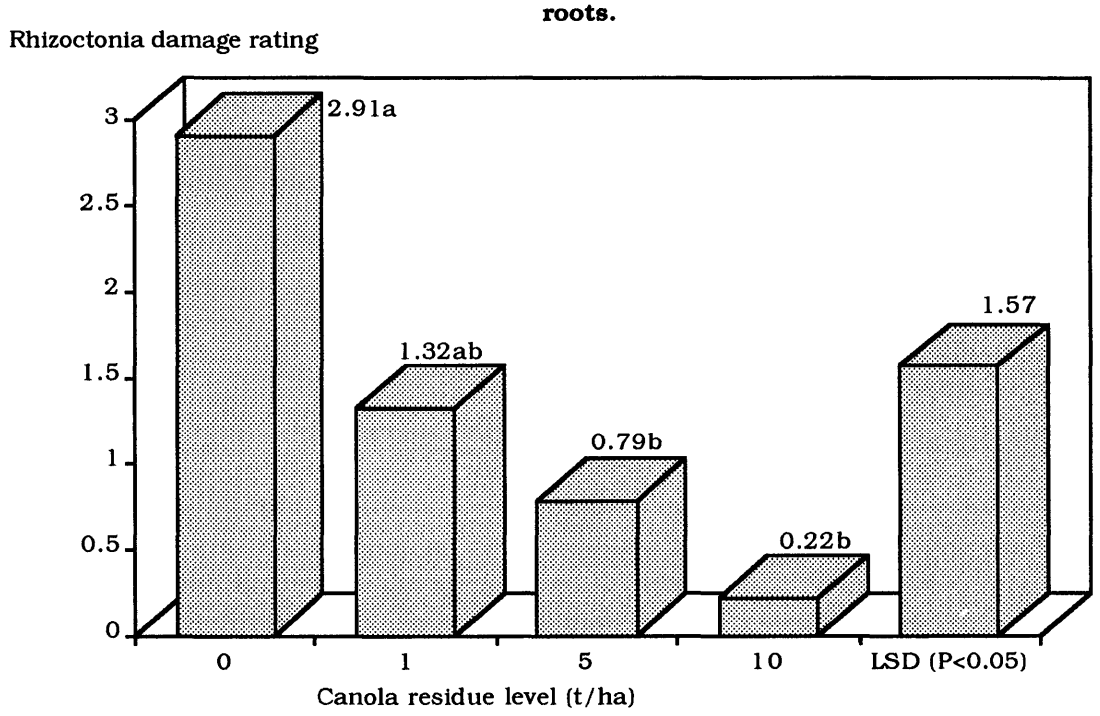
1 5% of roots damaged
2 15% of roots damaged
3 30% of roots damaged
4 45% of roots damaged
5 >45% of roots damaged

Canola residue reduced infection of Rhizoctonia as shown in Table E12.3 and Figure E12.2.

Table E12.3: Effect of Canola Residues on Rhizoctonia Rating in Wheat.

Residue (t/Ha)	Rhizoctonia Rating	
0	2.91	a
1	1.32	b
5	0.79	b
10	0.22	b
LSD P<0.05	1.57	

Figure E12.2: Effect of canola residue on Rhizoctonia damage to wheat roots.



Means sharing the same letter are not significantly different (P<0.05).

The results for dry weights of tops did not show any significant differences between amount of residue added to infected or Rhizoctonia free pots. Thus the results of disease rating above are the only ones in this series of experiments which show effect of canola residue on Rhizoctonia.

DISCUSSION

As in the prevoius experiments, canola residues strongly inhibited Ggt infection in wheat, even though the source of canola residue was different, it is a newer cultivar and a fresh stubble was used. This indicates that inhibition may not vary with cultivar and time after harvest.

Since glucosinolates are broken down as the plant senesces and glucosinolates and myrosinase come in contact with each other it is possible that inhibitory compounds are produced as canola plants reach maturity. In this case it is likely that, as leaves fall from the crop near maturity, compounds produced during breakdown may be being added to the soil over a period of time from before to after harvest.

Thus, inhibition of pathogens may occur over a period of time, possibly resulting in more effective reduction in pathogens than indicated in these short term experiments. Disease reduction by canola residues and their associated chemical compounds *in vivo* may be more effective than experimental results may indicate.

The level of inhibition of Ggt seen in the assessments of Ggt infection of wheat roots was not matched by an increase in wheat top dry weights. This is similar to results seen in experiment 10 and is likely to be explained by similar reasons; length of time that wheat was grown before harvest (28 days) may have not been sufficient to allow growth to adequately reflect the effect of the residues in their effect on Ggt.

Canola residues were not seen to inhibit Pythium in this experiment, possibly confirming that the compounds produced by canola residues are less active on Pythium.

Residues did, however, reduce the damage from Rhizoctonia in this, as in Experiment 11. Residue at 1t/ha was sufficient to reduce the infection of roots by Rhizoctonia. Again, this effect was not reflected in increased dry weights.

This experiment reaffirms the effect of canola residues in inhibiting the damage from fungal root pathogens to wheat and, thus, lends more weight to the hypothesis that canola can play a role in managing cereal diseases, notably Ggt and Rhizoctonia.

Further work could examine growing wheat in soil taken from paddocks where wheat, canola or no crop was recently grown. Pathogens could be added with canola residues, or candidate compounds to test the effect of soil where canola has grown in effecting the pathogenicity of disease organisms. Some of this type of work has recently been initiated by CSIRO workers in Canberra.

SUMMARY

The phenomenon of allelopathy and its role in plant-insect-fungal interactions is well known. Residues of canola, or compounds produced from them, have been demonstrated to be phytotoxic.

This work examined the hypothesis that canola plants and residues are able to affect growth of other plants and fungi (notably fungi pathogenic to following cereal crops) due to the production of compounds from glucosinolates, either during the life of the plant or from residues.

In a series of experiments the following results were found.

• Using rapeseed meal as a source of glucosinolates and breakdown products, the breakdown products were more phytotoxic than intact glucosinolates.

• Canola residue leachates were seen to be inhibitory to early growth of a number of test species (wheat, ryegrass, clover, linseed).

• Some differences between canola cultivars as sources of active residues were recorded in the degree of inhibition of plant growth observed.

• With both residue leachates and test compounds, very low concentrations or very high concentrations inhibition of test species was observed, while at intermediate concentrations stimulation of growth occurred. A number of possible reasons for this are advanced.

• 3 Candidate test compounds, glucosinolate breakdown products, were tested for effects on plant germination. The compounds indoleacetylnitrile (IAN), indoleacetylmethanol (IAM) and phenylethylamine (PEA) were all seen to inhibit germination and growth of test species, with IAN the most active. Again, concentration effects were observed, with very low concentrations showing some inhibition while at higher (intermediate) concentrations stimulation occurred, before inhibition at the highest levels. Reasons for these effects are discussed.

• Of the test species linseed was the most sensitive to residue leachates, with clover, ryegrass and wheat of lower susceptibility. However, with the test compounds (IAN, IAM, PEA) linseed and wheat were the least sensitive with clover and ryegrass the most. These differences are discussed.

• Residue leachates were analysed using High Performance Liquid Chromatography (HPLC) for the candidate compounds suggested as being active. IAN, IAM and PEA were identified in leachates, suggesting that canola residue leachates contain these compounds, and that they are responsible for the effects seen with the residue leachates. Differences in compound makeup in the leachates were estimated, with differences in compound makeup between cultivars of canola noted and discussed.

• A comparison between leachate and compound effects on the test species was made, which allowed a comparison of level of inhibition between leachate and compound concentration. This led to further estimates of compound concentration in the leachates.

• A discussion of possible relationships between the identified glucosinolate breakdown products and other plant compounds was canvassed, including some discussion of possible modes of action of these compounds. In this context a possible relationship between IAN and the auxin compound indol acetic acid is hypothesised.

• Canola residue leachates were shown to be inhibitory to fungal pathogens of cereals, notably *Gaeumannomyces graminis* var *tritici* (Ggt), Rhizoctonia and Pythium, with greatest activity on Ggt *in vitro*. IAN and PEA did not show activity against these fungi.

• Subsequent experiments confirmed the effect of canola residues in inhibiting Ggt, Rhizoctonia and Pythium. Wheat germination and root growth *in vivo* in the presence of the pathogens was improved by the addition of canola residues, with these residues having the strongest effect on Ggt.

Further work could examine the activity of the identified compounds against both other plants and fungi, and look at differences between varieties of canola and also between different species of the *Brassicae*. The compounds or derivatives could form the basis for commercially active products. Breeding, or genetic engineering could exploit these effects in existing crops. Knowledge of the effects of *Brassica* spp. crops could help better plan crop rotations for weed and disease management.

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