Influence of Crop Rotation and Tillage on Rhizoctonia Bare Patch of Wheat

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ABSTRACT

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In a 3-yr field study in calcareous sandy loam soil, Rhizoctonia bare patch was more severe in direct drilled wheat than in wheat sown into cultivated soil. The areas of patches of stunted seedlings in direct drilled crops ranged from 5 to 13% (1981), 11 to 22% (1982), and 20 to 45% (1983) with no patches when soil was cultivated. The area of affected crop was consistently larger when wheat followed a mixed annual pasture of grasses and *Medicago* spp. than when wheat followed wheat, peas, or grassfree pasture of *Medicago* spp. Several potential root pathogens were isolated from rotted roots, but only *Rhizoctonia*-like fungi produced severe cortical rot and brown-tipped truncated roots similar to the symptoms on fieldgrown plants. Isolates identified as *Rhizoctonia solani* and *Thanatephorus cucumeris* were the most pathogenic of the *Rhizoctonia*-like fungi. All isolates of *R. solani* were pathogenic on wheat, barley, peas, *Medicago* spp., annual ryegrass, and barley grass.

Rhizoctonia solani Kühn causes a "bare patch" disease of cereals in Australia (8,9,11,26,28–31). Studies of isolates of *R. solani* from roots of plants in patches in South Australia have shown them to be *Thanatephorus cucumeris* (Frank) Donk (4). In South Australia, bare patch disease occurs in highly calcareous sandy soils where patches range from 1 to 10 m across and occur in cultivated fields regardless of rotation (1,4,5,10). Cultivation in these soils is limited to one to three passes with tined cultivators penetrating 5–7 cm to control weeds germinated by the autumn rains after the long hot summer. Seeding is conducted with cultivator seed drills with rows of cultivating tines with 15-cm wide shares following the seeding tines.

Until recently, the only management strategy to reduce losses from this disease in cereals has been to increase soil fertility by applications of superphosphate and increased available nitrogen by improving legume content of pastures (1) and ammonium sulfate fertilizer (9).

With the development of suitable herbicides, conservation tillage has become a practical reality for rainfed cereal farming in Australia. Conservation tillage is a broad term that covers practices ranging from reduced tillage (fewer cultivation passes) to no-till or direct drilling. Reduced tillage practices offer the advantage of reduced erosion, reduced soil preparation costs, and grazing of the annual pasture of grasses and pasture legumes regenerated by autumn rains.

The study reported in this paper is part of a long-term field trial to investigate the influence of soil type, crop rotation, and tillage on root diseases of wheat, mineral nitrogen levels, root growth, plant development, and grain yield.

When this field trial began in 1979, the major root disease of wheat at the site was *Gaeumannomyces graminis* (Sacc.) Olivier and Von Arx. var. *tritici* Walker, although the symptoms of Rhizoctonia root rot were recorded on most root systems in 1979 and 1980. In 1981 stunted plants with a purple hue appeared in patches 0.25–1 m in diameter in the direct drilled wheat but not where wheat was sown after cultivation.

In view of the move away from cultivation by many farmers and the appearance of patches in direct drilled wheat, both in our trials and farmers' direct drilled crops in districts where Rhizoctonia bare patch has not been a problem, there was a need for further investigation. Recently, there have been reports of cultivation (13,29) and nitrogen fertilizers (14) reducing this disease.

The aims of this study were to investigate causes of bare or purple patch associated with this new agricultural practice and to develop management strategies to control the disease.

MATERIALS AND METHODS

Field experiments. *Experimental site*. The experimental plots were at Avon, South Australia (34°14′S, 138°18′E), 100 km north of Adelaide. The soil was an alkaline calcareous sandy loam, pH 8.4, classification Gcl.12 (23), or solonized brown soil or calcaric xerosol (6,7) with winter-dominant rainfall averaging 350 mm per year. The soil had a moderate amount of inoculum of *G. g. tritici* and *R. solani* with a barely detectable population of the cereal cyst nematode (*Heterodera avenae* Woll.) (27).

Experimental design. Six replicate plots, 100 m long and 1.6 m wide (10 rows), were established for each of the 2-yr rotations: annual mixed pasture/wheat, medic pasture/wheat, peas/wheat, and wheat/wheat, with two tillage systems for each rotation. Annual mixed pasture varied each year and consisted of 20–50% medic (*Medicago truncatula* Gaertn. 'Harbinger'), 40–60% barley grass (*Hordeum glaucum* Steud.), and 10–20% ryegrass (*Lolium rigidum* Gaudin) regenerated from seed after autumn rains. Medic pasture was *Medicago scutellata* L. Miller (snail medic) sown at 12 kg/ha in the autumn. Peas were *Pisum sativum* L. 'Dundale' sown at 90 kg/ha in early winter. One set of plots with these rotations commenced in 1978 and a second set in 1979, each rotation crop following wheat; this provided identical experiments 1 yr apart on adjacent areas with the same soil type. The results reported are for the wheat crops of 1981, 1982, and 1983.

Cultivation and seeding. The district practice or conventional cultivation consisted of three passes with a tine cultivator to 7-cm depth with 15-cm shares in April and May after the autumn rains. Seeding was done with a 10-row cultivator combined seed drill with a 15-cm tine share on each delivery tube.

Direct drilled plots were sprayed with paraquat (125 g/L) and diquat (75 g/L), a desiccant herbicide combination applied at 2 L/ha, 2 days before seeding with a Sirodrill designed to seed with minimum soil disturbance (Fig. 1) (35).

Wheat, *Triticum aestivum* L. 'Condor,' was sown when soil conditions were suitable in early winter (late May–early June) at 50 kg/ha with superphosphate at 120 kg/ha drilled in with the seed.

Disease assessment. At the early tillering stage of growth, between 8 and 11 wk after seeding, 10–15 plants were taken at 10-m intervals over the length of each plot. The roots were washed and rated for Rhizoctonia root rot on a 0–5 severity scale (0 = no disease, 5 = maximum disease) (15). The area of bare patch in each plot was assessed by the line intercept method (2) with measurements at 5-m intervals along the plot.

Plant growth and yield assessments. Plant dry weight at early tillering was obtained from the tops of plants used for disease assessment. The correlation between top weight and root disease was calculated from these plants. Grain yield of patches of poor growth and adjacent areas of good growth were assessed from quadrat cuts taken at maturity in 1981. The entire plot was harvested and the grain yields converted to tonnes per hectare.

Laboratory and controlled environment studies. *Pathogen identification.* Because the study was in soil not prone to the previously described Rhizoctonia bare patch, a range of fungi was isolated from diseased roots and tested for pathogenicity. Isolations were made from 4- to 6-wk-old plants showing typical root rot symptoms.

Roots were washed, cut into 1–5 mm segments, surface-sterilized in 3% sodium hypochlorite for 60 sec, washed in sterile distilled water, blotted on filter paper, and transferred to half-strength potato-dextrose agar containing 30 μg of tetracycline (Achromycin) per milliliter.

After 30 hr at 25 C, hyphal tips were transferred to half-strength potato-dextrose agar and incubated at 25 C. Fungi were identified according to culture characteristics and examination of reproductive structures.

Pathogenicity tests on fungal isolates from rotted roots. When the fungus had covered the petri dish, two 12-mm-diameter plugs were taken from the edge of the colony and used to test pathogenicity on wheat seedlings as shown in Figure 2 using a heat-sterilized (121 C for 35 min) calcareous sandy loam moistened to 15% w/w. No attempt was made to maintain sterile conditions after seeding. There were four test plants per isolate. Plants were grown in a controlled environment at 10 C with a 9-hr day.

Characterization and pathogenicity of isolates of Rhizoctonia. Isolates of *Rhizoctonia* were studied further for identification and pathogenicity testing.

For colony characterization, 5-mm-diameter plugs from edges of agar cultures were transferred to sixth-strength neutral Dox yeast agar (4) containing 0.33 g of $NaNO_3$, 0.16 g of KH_2PO_4, 0.08 g of $MgSO_4$, 0.08 g of KCl, 0.08 g of yeast extract, 5.0 g of sucrose, 15.0 g of agar, and 1.7 ml of $FeSO_4$ (0.1%) added to 1 L of water and incubated at 25 C.

Morphologic features were used to identify *R. solani* and the characteristics of the perfect stage were used to identify *T. cucumeris* (25,34). The anastomosis group (AG) of representative cultures of *R. solani* was determined by testing against representatives of AG2-1, AG2-2, AG3, AG4, and AG5 (24).

The pathogenicity of these isolates was tested against wheat, medic, peas, and ryegrass by de Beer's method (4). Each culture was grown in 100 ml of liquid neutral Dox yeast medium for 28 days at 25 C. The mycelial mat was washed in sterile distilled water and macerated in a small amount of distilled water for approximately 1 min in a Sorvall blender. The macerated culture was retained on filter paper in a Buchner apparatus, washed several times with sterile distilled water, and then mixed through 200 g of unsterilized, calcareous sandy soil. Fifty grams of the above was mixed with 300 g of unsterilized calcareous sandy soil, moistened to 10% w/w, dispensed into pots, and planted with wheat, peas, medic, or ryegrass with five seeds per plot. There were five replicate pots for each host. Pots were randomized in a root temperature tank at 10 C in a glasshouse and watered to 10% water (field capacity). Wheat and peas were harvested after 21 days and medic and ryegrass after 29 days, and roots were rated for Rhizoctonia root rot.

RESULTS

Pathogen identification. The fungi isolated from roots of plants from bare patches were *R. solani, Ceratobasidium* spp.,

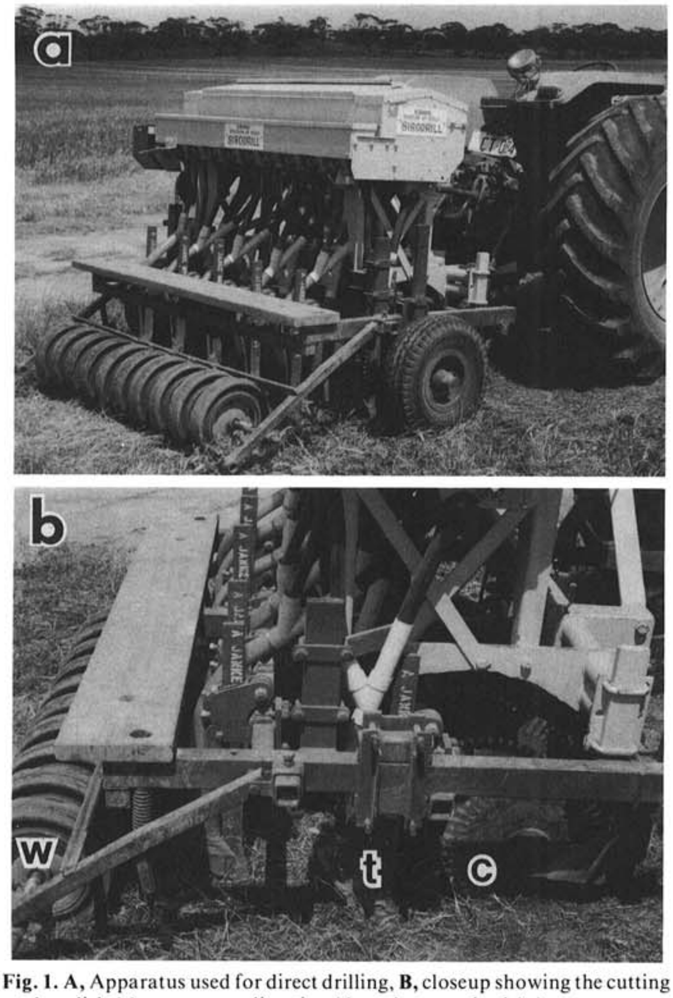

Fig. 1. A, Apparatus used for direct drilling, **B,** closeup showing the cutting coulter disk (c), narrow seeding tine (t), and press wheel (w).

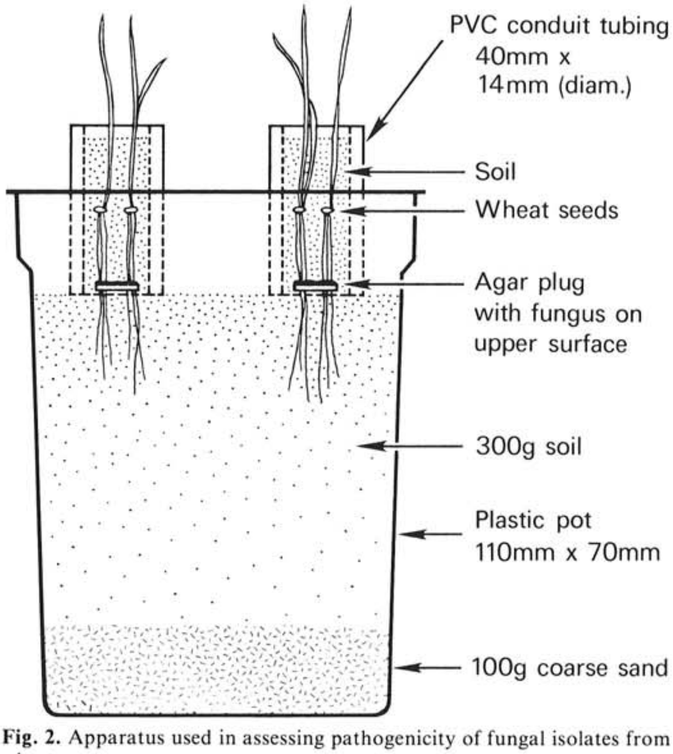

Fig. 2. Apparatus used in assessing pathogenicity of fungal isolates from wheat roots.

Ulocladium atrum Preuss, *Helminthosporium* spp., *Aureobasidium* spp., *Cylindrocarpon destructans* (Zins.) Scholten, *Alternaria* spp., *Fusarium graminearum* Schwabe, *Fusarium* spp., *Paecilomyces* sp., *Chaetomium* sp., and *Microdochium bolleyi* (Sprague) de Hoog & Herman. - Nijhof. The initial pathogenicity tests with plugs of agar culture showed that only *R. solani* produced symptoms similar to those on roots of plants from patches in the field (Fig. 3). *F. graminearum* caused browning of the cortex, but none of the other isolates was pathogenic. Further identification of fungi other than *R. solani* was not pursued because they obviously were not the cause of the patches of poor growth.

Of the 53 fungal cultures identified as *Rhizoctonia*, 38 were multinucleate, and 25 of these fulfilled the criteria for *R. solani* (25). Of these 25 isolates identified as *R. solani*, four formed the perfect stage of *T. cucumeris*. Seven of the 53 isolates were binucleate and probably *Ceratobasidium* sp. None of the cultures of *R. solani* anastomosed with AG2-1, AG2-2, AG3, AG4, or AG5 (24), which is consistent with other findings (20–22).

Of the 53 isolates, the *R. solani-T. cucumeris* group was highly pathogenic against wheat, peas, medic, and ryegrass, causing disease as severe as that found in patches of direct drilled crop and in pasture (Table 1). The other multinucleate *Rhizoctonia*-like fungi were generally less pathogenic, and the binucleate isolates were much less pathogenic than the cultures of *R. solani* but still caused significant root damage.

Disease assessments in field wheat. Each year the severity of disease on wheat roots was greater with direct drilling than with conventional cultivation. In the direct drilled wheat, the average rating (based on plants sampled on a random basis regardless of patches of poor growth) was between 1.9 and 3.2, whereas with cultivation, the disease rated between 0.5 and 1.2 (Fig. 4). There was less Rhizoctonia root rot with wheat following peas than wheat following sown medic or annual grass-medic pastures.

When the damage to the crop was assessed as patches of stunted plants, no patches occurred in the cultivated plots compared with 6–45% of the crop area in direct drilled wheat (Fig. 5). In all three years there was significantly less damage to the crop following peas and medic than following pasture.

Effects of Rhizoctonia root rot on early growth and grain yield of field wheat. There were large effects of both tillage and rotation on early growth of wheat (Fig. 6).

An analysis of the relationship between Rhizoctonia root damage and seedling top weight showed a highly significant correlation of $r = -0.84$ (Fig. 7).

Grain yields of quadrats taken from within and outside patches of direct drilled wheat in 1981 were 0.18 ± 0.04 and 1.91 ± 0.45 t/ha, respectively. The low yield within areas of patches was the result of root disease ratings of 4–5 for roots of plants within patches compared with average ratings of 2–4 in direct drilled wheat derived from the random samples taken over the whole plot.

In 1981 and 1982, grain yields were low due to drought; in 1982 and 1983 yields were significantly lower in wheat sown by direct drill than in wheat sown after cultivation, except in continuous wheat with cultivation in which cereal cyst nematodes heavily damaged roots and reduced yields. The rainfall in 1983 was adequate for good yields and to compare the yields of wheat in the

TABLE 1. Pathogenicity of *Rhizoctonia* fungi isolated from roots of plants from patches in direct drilled wheat

Categories	Isolates (no.)	Mean disease rating[a] Wheat	Peas	Medic	Ryegrass
R. solani and *Thanatephorus cucumeris*[b]	25	4.10	3.00	2.70	2.88
Multinucleate[c]	13	2.45**	2.33	2.57	1.75*
Binucleate[d]	7	1.63***	1.66	1.18	1.14***
Other	8	0.83***	1.12***	0.49***	0***

[a] Root disease rating on a 0–5 scale (15). *, **, and *** indicate significant differences from isolates of *R. solani* and *T. cucumeris* at $P = <0.05$, $P = <0.01$, and $P = <0.001$, respectively, as calculated by an analysis of variance.

[b] *T. cucumeris*, perfect stage of *R. solani*.

[c] These isolates were pale colored and their characteristics did not completely fulfill those for *R. solani* (20).

[d] Probably *Ceratobasidium* sp. but identification was not conclusive in the absence of perfect stage fructifications.

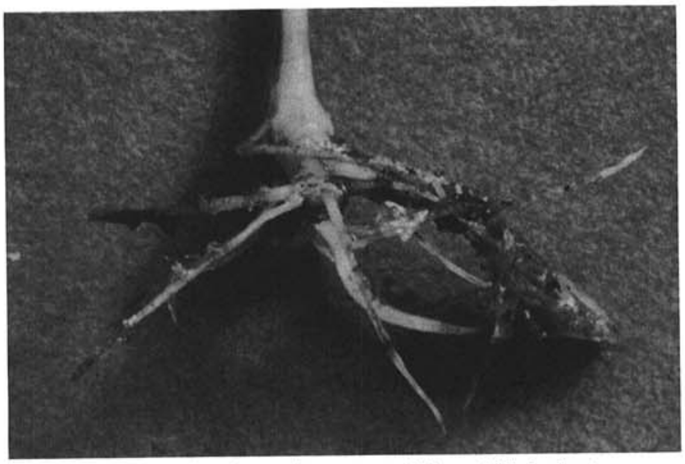

Fig. 3. Symptoms of Rhizoctonia root rot of direct drilled wheat.

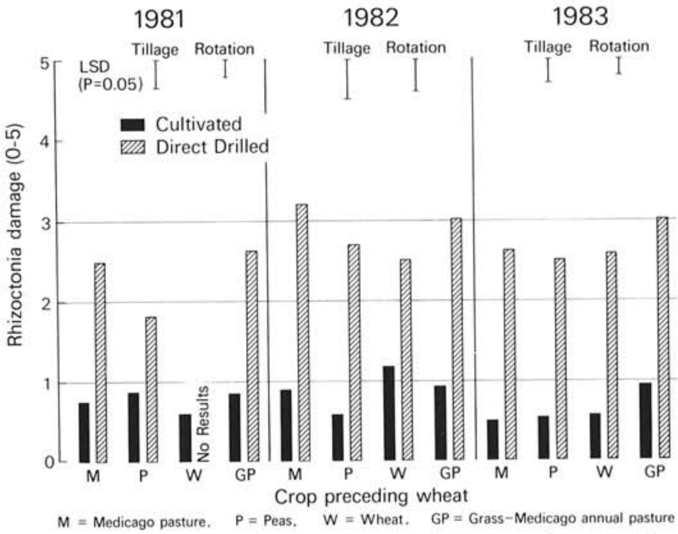

Fig. 4. Effect of rotation and tillage on the damage to wheat roots by *Rhizoctonia* sp. Root rot rating scale was 0–5 (5 = maximum disease).

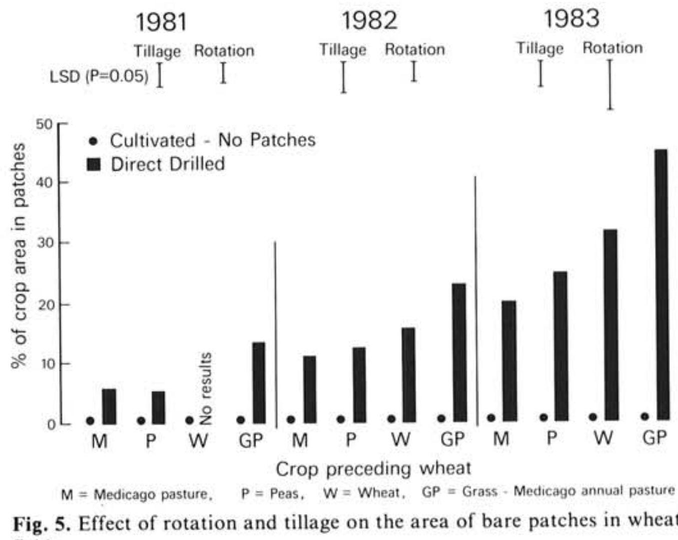

Fig. 5. Effect of rotation and tillage on the area of bare patches in wheat fields.

three rotations not affected by cereal cyst nematodes. This comparison showed increases in yield due to cultivation of 0.09, 0.42, and 1.10 t/ha for the peas-wheat, medic-wheat, and pasture-wheat rotations, respectively (Table 2).

DISCUSSION

This study has demonstrated that Rhizoctonia root rot of wheat was greater in wheat sown by direct drilling than in wheat planted into cultivated soil. The low level of disease in cultivated soil was not sufficient to produce bare patches but may still have affected yields.

In comparisons of these results with those from tillage experiments in other countries, differences in the cropping environment and cultivation practices should be noted. The calcareous sandy loam soil in this study represents the soils and climate that produce 60 and 30% of the wheat and barley of the states of South Australia and Victoria, respectively. These districts are subject to hot dry summers during which little or no decomposition of residues occurs. Considerable fragmentation of the residues occurs with the common practice of grazing sheep on the dry pastures and crop residues. Autumn rains occur after 4–5 mo of such conditions and cultivation is done after the rains in April and May. Farmers generally cultivate with two or three passes with tined implements with 15- to 17-cm wide shares to a depth of 7 cm. Such cultivations, undertaken for weed control and seed bed preparation, disturb the soil and fragment and incorporate much of the plant residues. The conservation tillage practice advocated for this farming system has been to graze the annual grass-legume pasture that regenerates after the autumn rains, spray with herbicide, and direct drill into this herbicide-treated pasture within 1–3 days. With this direct drill system, the residues from roots of the previous year's crop or pasture and the

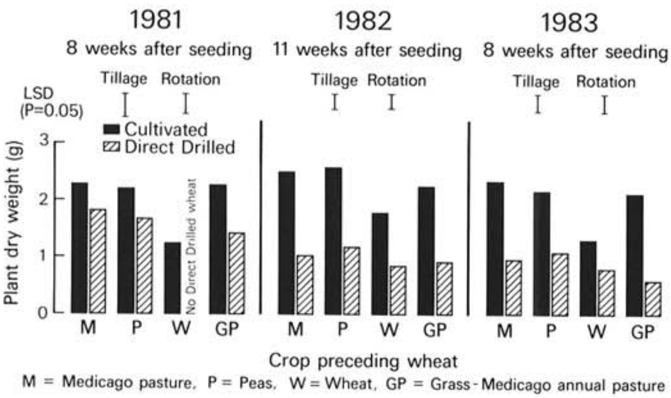

Fig. 6. Effect of rotation and tillage on seedling top dry weight of wheat.

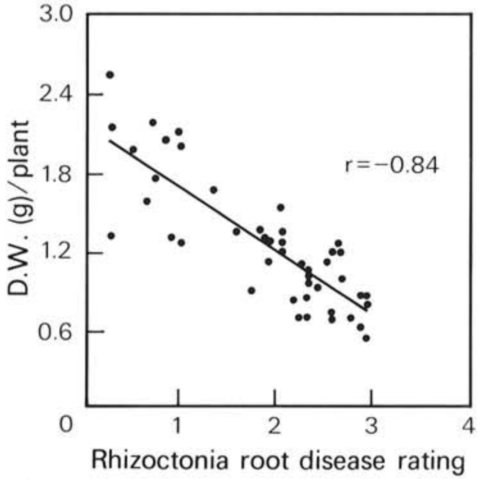

Fig. 7. Relationship between seedling top dry weight (DW) and root disease caused by *Rhizoctonia solani* in fieldgrown wheat.

roots of the newly regenerated pasture are concentrated in the surface 8 cm; the plant residues from the previous year would have been trampled by sheep into the top 2–3 cm, and the recently sprayed autumn-grown pasture covers the soil surface.

An independent study on nearby plots at the Avon site showed that, although the distribution of propagules of *Rhizoctonia* spp. was extremely variable in the plots, most propagules were associated with particulate organic matter in the soil (20).

The tillage methods used in this study differ from those in much of the United States where minimum tillage often consists of disk harrowing to a depth of 10–15 cm and cultivation involves subsoiling to 40 cm and turning with a moldboard plough to 30 cm. Also, moist soil conditions during autumn in most of the United States favor decomposition of residues (32,33). Despite these different conditions, the incidence of *R. solani* and *Ceratobasidium* spp. was significantly greater on roots of peas sown after minimum tillage than after the other two tillage systems; *R. solani* was the most pathogenic fungus isolated from diseased roots (32). These effects of tillage on Rhizoctonia root disease are attributed to differences in the distribution of propagules of *R. solani* in the profile; with disk cultivation, 91% of propagules were in the top 10 cm compared to 19% where the soil was deep ploughed.

I propose that during cultivation there is a fragmentation of the residues, which reduces propagule size and may affect the pathogenicity of hyphae that have ramified through the soil. For *G. g. tritici* in wheat, such fragmentation causes less take-all on wheat in cultivated soil than on no-till wheat (18).

The greater incidence of Rhizoctonia root rot with direct drilling also may be partly caused by the pathogen growing on the roots of the newly germinated pasture plants after the autumn rains. Although *R. solani* has been isolated from the roots of *Medicago* spp., ryegrass, and barley grass from the trial plots before spraying with paraquat-diquat herbicide, it is not known how long *R. solani* survives on roots of sprayed plants or how much this source of inoculum contributes to the disease compared with inoculum from older plant residues.

The importance of the direct effect of soil disturbance in the field on the disease has also yet to be assessed, but this effect could be important. MacNish (13,14) demonstrated that mixing patch soil reduces Rhizoctonia disease, and we showed, in inoculation experiments under controlled environment conditions in which 16 propagules of *R. solani* per kilogram of soil were incubated for 2 wk, that transferring to a second container reduces the root disease rating on wheat from 2.5 to 1.25 (A. D. Rovira and H. J. McDonald, *unpublished*).

It is not understood why the disease in the field takes the form of patches of poor growth; *Rhizoctonia* spp. were isolated from roots of wheat both inside and outside the patches. The lower disease rating of roots from apparently healthy plants outside the patches indicates lower inoculum levels.

It is not known whether the patches observed in this study recur in the same places each year. Disease assessments indicate that the pathogen is distributed over the entire plot, but there is no indication why the disease is sufficiently intense in some areas to

TABLE 2. Effect of rotation crop in previous year and tillage on grain yield (t/ha) of wheat

	Rainfall (mm)			Wheat grain yield (t/ha)				LSD ($P = 0.05$)	
Year	Annu.	Apr.-Oct.	Tillage[a]	Medic pasture[b]	Peas[b]	Wheat[b]	Annual pasture[b]	Tillage	Rotation
1981	240	172	CC	1.51	1.30	1.25	1.22	ns	0.21
			DD	1.30	1.34	···	1.16		
1982	164	136	CC	0.64	0.78	0.49	0.36	0.06	0.13
			DD	0.53	0.54	0.42	0.31		
1983	324	263	CC	2.63	2.59	1.31[c]	2.66	0.41	0.48
			DD	2.21	2.50	2.04	1.56		

[a] CC = conventional cultivation, DD = direct drill.
[b] Crop preceding wheat.
[c] Severe attack by *Heterodera avenae* (cereal cyst nematode) reduced yield in continuous wheat sown with cultivation.

cause patches. No differences in organic residues or soil have been observed between patches and surrounding areas. Field experiments in Australia (10) and Scotland (19) showed more propagules of *R. solani* in soil from patches than in surrounding healthy areas.

R. solani was the most pathogenic of the *Rhizoctonia*-like fungi associated with the bare patch in direct drilled wheat. The cultures of *R. solani* isolated from this field showed considerable variation in cultural features, but although selected cultures anastomosed with each other, they did not anastomose with known AG cultures, which supports the proposal that a new group, AG8, be formed (22).

Although fungi other than the *Rhizoctonia*-like group were isolated from diseased roots, they did not produce the field symptoms but may exacerbate the damage inflicted by *R. solani* (16). Damage by *R. solani* facilitates the entry of *Microdochium bolleyi* (19), which was recovered frequently from diseased roots, but in this study, isolates of *M. bolleyi* caused only slight lesions on the wheat coleoptile.

Although the wide host range of *R. solani* makes control by crop rotation difficult, the report that soil from a cereal-potato rotation had twice the number of propagules of *R. solani* per kilogram of soil as that from soil planted continuously to potatoes (3) indicates that rotation affects pathogen levels and that control by rotation may be possible. This study has demonstrated an effect of rotation; the area lost to patches in wheat after the annual grass-medic pasture was greater than in wheat after medic, peas, or wheat. This may have been due to the grass growth after the autumn rains in what had been pasture the previous year. Roots of grasses host *R. solani* and provide inoculum from readily metabolized roots, which may be more infective than inoculum from older particulate organic matter. The importance of partly decomposed plant residues as the base for propagules of *R. solani* has been demonstrated in other cropping systems (36). Another contributing factor from a grass-medic pasture is the large amount of dead root residues left from the grass component, which acts as substrate for the *Rhizoctonia*-like fungi (20). The practical implication of these results is that direct drilling of wheat could be a feasible proposition in these calcareous soils if annual grasses are controlled.

A report from the U.S. Pacific Northwest (37) describing Rhizoctonia bare patch in no-till or minimum tillage wheat and similar reports from Australia (11–13,17) indicate that this disease has the potential to become a serious problem with the trend away from cultivation. Thus, it will be necessary to develop management strategies and search for resistant cultivars and chemical controls to minimize the effects of Rhizoctonia root rot where conservation tillage is being introduced.

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