Effects of the Herbicide Chlorsulfuron on Rhizoctonia Bare Patch and Take-All of Barley and Wheat

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ABSTRACT

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Measurements on two crops of direct-drilled barley in soil treated with chlorsulfuron at 15 g/ha 12 mo previously showed an increase in patches of poor growth and yield losses of 0.70 and 1.54 t/ha where the herbicide had been applied. Controlled-environment experiments with *Rhizoctonia solani* showed that chlorsulfuron at the equivalent of 2.5 g/ha significantly increased root disease caused by *R. solani* in wheat and barley. Chlorsulfuron had no effect on the incidence and severity of lesions caused by *Gaeumannomyces graminis* var. *tritici* on wheat.

The acceptance of conservation tillage (reduced tillage, nontillage, or direct drilling) by farmers as an alternative to cultivation is an important step in maintaining economically viable and sustainable farming systems in which the biological and physical properties of soils are improved and erosion losses reduced. In Australia, most cereals are grown in areas with low and unreliable rainfall and in soils prone to wind and water erosion—conditions that account for the introduction of conservation tillage to over 2 million hectares of cereal-growing land in southern Australia.

Conservation tillage differs from conventional cultivation practices in that herbicides rather than cultivation are used to destroy weed growth before planting. The major herbicides used in Australia for conservation tillage are paraquat-diquat mixture (Spray.Seed), glyphosate (Roundup), and chlorsulfuron (Glean). Recent studies in Australia (13,14,19,21) have demonstrated that root rot caused by *Rhizoctonia solani* Kühn is greater in cereals planted by direct drilling than in cereals sown in cultivated soil. This disease manifests itself as patches of stunted plants with purple stem and leaf coloration and truncated roots with dark tips and cortical rot (12). In direct-drilled crops, the patches range from 0.2 to 2 m across (19). In 1983, a number of farmers and district agronomists reported a high incidence of patches of poor growth in direct-drilled barley and wheat crops planted in alkaline soils that had been treated with chlorsulfuron 1 yr previously. The roots of plants from such patches showed symptoms typical of Rhizoctonia root rot, viz., cortical root rot and truncated roots with dark brown tips and also stelar lesions characteristic of infection by *Gaeumannomyces graminis* var. *tritici* (*G. g.* var. *tritici*).

The aims of this study were 1) to assess in two crops of barley the areas of patches and grain yields from parts of the fields with and without chlorsulfuron and 2) to assess the effect of a range of concentrations of chlorsulfuron in the soil on root rot caused by *R. solani* on wheat and barley and on the incidence and infection by *G. g.* var. *tritici* on wheat in experiments under controlled-environment conditions. Wheat was included in the controlled-environment experiments because chlorsulfuron is recommended as a preplant herbicide for wheat sown either by direct drilling or with conventional cultivation (10).

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MATERIALS AND METHODS

Field experiments. The two crops of spring barley (*Hordeum vulgare* L. 'Galleon') studied were planted at Avon, South Australia (34° 14′ S, 138° 18′ E), in May 1983 by direct drilling with a cultivating seed drill with 15-cm shares. Commercial-grade chlorsulfuron had been applied at 15 g/ha in April 1982 to control annual rye grass before planting spring wheat (*Triticum aestivum* L. 'Condor') in one field and oats (*Avena sativa* L. 'Avon') in the second field in May 1982. In each field, there were strips that had not received the herbicide; these strips provided the "check" or nil herbicide and facilitated comparisons of disease levels and yield in treated and untreated parts of the barley crops in 1983. The areas of barley crop made up of patches of poor growth were assessed using the line interception method (5) when the crops were flowering. Roots of these plants were examined for root diseases, and isolations were made from surface-sterilized roots (19). Grain yields were assessed from machine harvests of strips 70 × 7 m wide. There were six replicate strips from chlorsulfuron-treated areas and three replicate strips from untreated strips. The yields from patches of poor growth and from surrounding good areas were assessed by taking 10 1-m^2 quadrats from within and outside patches from that part of the field treated with chlorsulfuron. The soil in each field was a calcareous sandy loam, pH 8.3, classified as Gcl (18) or calcic xerosol (6,7).

Controlled-environment experiments. *Plant growth conditions.* These experiments were conducted in plant growth chambers with 8 hr of light per day and constant temperature of 10 C to simulate field conditions at the time of seedling cereal growth when the Rhizoctonia bare patch symptoms appear.

Soil. The soil was similar to that at Avon, where the field effects were assessed (calcareous sandy loam classified as Gcl [18] or calcic xerosol [6,7] with pH 8.3). The soil was collected from under a crop of peas sown after cultivation; the soil had low levels of *Rhizoctonia* and had never been treated with chlorsulfuron. It was air-dried and seived to remove organic residues >2 mm.

Herbicide treatments. A solution of chlorsulfuron was mixed through the soil during wetting up to give concentrations of 0.002, 0.004, 0.008, 0.016, and 0.032 μg/g, which are equivalent to 1.25, 2.5, 5, 10, and 20 g/ha (5 cm deep). This range was selected to cover recommended rates of applications, viz., 15–20 g/ha and probable residue levels in alkaline soils, viz., 1.25–5 g/ha.

Soil preparation and disease treatments. *R. solani* cultures isolated from diseased roots of wheat from the CSIRO Experimental Site at Avon, S.A. (19), were grown on millet seed sterilized by γ-radiation, soaked and autoclaved (15), and the number of propagules added to soil adjusted to give low root damage in the absence of chlorsulfuron. In experiment 1, isolate C was used at 16 millet seed propagules per kilogram of soil, and in experiment 2, isolate 21 was used at four propagules per kilogram of soil. Earlier experiments had shown that these two isolates differed in pathogenicity but belonged to the same anastomosis group and had the same electrophoretic isoenzyme patterns; a previous study (20) had shown that these two cultures belonged to a new anastomosis group, AG-8 (16).

The *R. solani* experiments were conducted in plastic containers 8 × 12 × 7 cm (Fig. 1). Moistened soil (500 g) was placed in each container, then propagules of *R. solani* were spread on this soil, covered with another 500 g soil, and incubated for 2 wk (15). Six wheat seeds (cultivar Condor) or barley (cultivar Galleon) were planted 1 cm below the soil surface in each container, and the soil was covered with 1 cm of polyethylene beads to reduce evaporation. There were five replicate pots for each treatment. Results were analyzed and compared by Duncan's multiple range test.

G. g. var. *tritici* grown on sterilized ryegrass seed (23) was mixed through moist soil at 12 and 24 propagules per 200 g of soil, and 200 g was dispensed into 300-ml conical plastic drink containers. A 1-cm layer of soil without inoculum was placed on the inoculated soil, and wheat seeds (cultivar Condor, five per pot) were planted and covered with 1 cm of soil. A cover of 1-mm polyethylene beads reduced evaporation. There were five replicate pots per treatment. An analysis of variance was conducted on the results.

Root disease ratings and root length measurements. Roots were rated for damage by *R. solani* after 3 wk on a scale of 0–5 (15). Root disease assessments for *G. g.* var. *tritici* were made on plants after 4 wk by assessing the percentage of main seminal roots with *G. g.* var. *tritici* lesions and the mean lesion length. The effects of *R. solani* and chlorsulfuron on root length of barley and wheat were assessed using the line intersect method (24).

RESULTS

Field crop assessments. The percentage of barley crop made up of patches of poor growth was two to three times greater where chlorsulfuron had been used (Table 1). The reductions in yield where chlorsulfuron had been applied were 1.54 and 0.70 t/ha in the two fields (Table 1).

The mean yield of grain in one crop from the more severe patches was 35 g/m^2 (SE = 15) compared with 254 g/m^2 (SE = 44) in the surrounding healthy crop. Examination of the roots of the barley from patches showed that most of the seminal and many of the nodal roots were truncated through cortical rotting and had dark "spear tips" characteristic of Rhizoctonia root rot (14,15,19,21,25).

Isolation from surface-sterilized roots showed a range of fungi including *G. g.* var. *tritici* but not *R. solani*. The inability to isolate *R. solani* was not surprising because isolation was done on roots of plants at flowering, when it is difficult to isolate *R. solani* from damaged roots (11,12).

The controlled-environment experiments were undertaken with added propagules of *R. solani* because the root rot symptoms on the barley plants in the fields were characteristic of *R. solani* and with *G. g.* var. *tritici* because it had been isolated from roots of plants from affected fields.

Controlled-environment experiments (experiment 1). *Rhizoctonia.* Addition of chlorsulfuron to soil significantly increased the *Rhizoctonia* root damage in wheat with both the natural (low) level of disease in the soil and where propagules of *R. solani* had been added (Table 2).

Take-all. There was no effect of chlorsulfuron on the incidence or severity of infection by *G. g.* var. *tritici* on wheat (Table 3).

Controlled-environment experiments (experiment 2). This study with extremely low rates of herbicide showed a consistent increase in root damage by *R. solani* on wheat and barley with increasing chlorsulfuron levels; this increase was statistically significant where *R. solani* had been added to soil (Table 4). Increased disease was significant with wheat at 0.004 μg/g of soil and with barley at 0.008 μg/g, although for both cereals, the trend was apparent even at 0.002 μg/g.

Figure 1 demonstrates that chlorsulfuron at 0.008 μg/g had no effect on the top growth of wheat in the absence of *R. solani*, but the effect of the pathogen on top growth (through its effect on root damage) was great when chlorsulfuron was added to the soil. Figure 2 shows that roots of barley seedlings were more severely damaged when both *R. solani* and chlorsulfuron were present.

Root length measurements on plants from experiment 2 further confirmed the damaging effect of *R. solani* on wheat and barley in the presence of chlorsulfuron (Table 5). Chlorsulfuron added to soil with a low (unamended) level of *R. solani* had no effect on wheat roots but did reduce the length of barley roots at the higher levels, indicating a phytotoxic effect on barley (the low value at 0.004 μg/g appears to be an anomoly). In the treatments without added *R. solani*, the

Table 1. Areas of *Rhizoctonia* patches and yields of barley in two fields, parts of which were treated with chlorsulfuron at 15 g/ha 12 mo before planting

Field	Chlorsulfuron	Area of crop with severe *Rhizoctonia* patches (%)	Grain yield (t/ha)
1	–	23 ± 3 SE[a]	3.33 ± 0.15 SE
	+	81 ± 5	1.79 ± 0.10
2	–	37 ± 2	2.23 ± 0.03
	+	78 ± 6	1.53 ± 0.05

[a]Standard errors of mean calculated from three replicate strips of crop (70 × 7 m wide) for no chlorsulfuron and from seven replicates where chlorsulfuron had been applied.

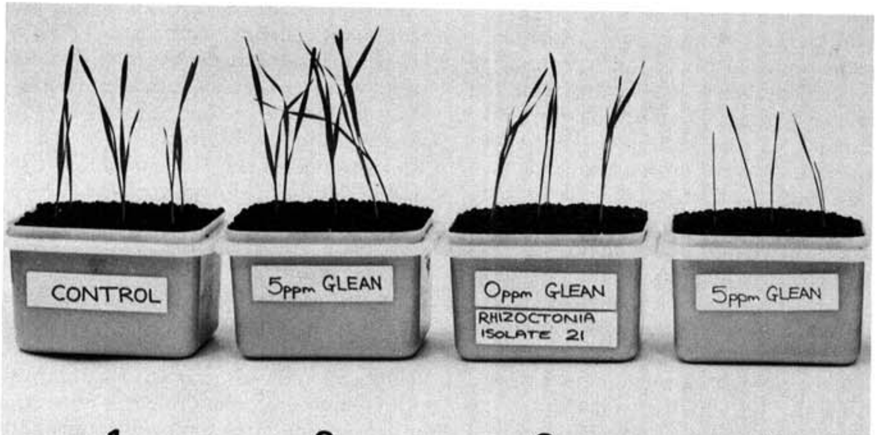

Fig. 1. Effects of chlorsulfuron and *Rhizoctonia solani* on growth of wheat. *R. solani* (isolate 21) was added to soil at four millet seed propagules per kilogram of soil. Chlorsulfuron was mixed through soil at 0.008 μg/g of soil. 1 = No chlorsulfuron, no added *R. solani*; 2 = chlorsulfuron, no added *R. solani*; 3 = no chlorsulfuron, added *R. solani*; and 4 = chlorsulfuron, added *R. solani*.

Table 2. Effect of chlorsulfuron on *Rhizoctonia* damage to roots of wheat

No. propagules of *R. solani* (isolate C)/kg soil	Chlorsulfuron (μg/g soil)	*Rhizoctonia* root damage rating[y]
0	0.000	0.14 a[z]
	0.008	0.51 ab
	0.016	1.01 abc
	0.032	1.72 cd
16	0.000	0.78 abc
	0.008	1.48 bcd
	0.016	1.96 d
	0 032	2.36 d

[y]Root damage rating on a scale of 0–5 (15).
[z]Values followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

damage from the natural population would be insufficient to affect root length, thus enabling the phytotoxic effect of chlorsulfuron to manifest itself with barley. There was a statistically significant interaction between the added *Rhizoctonia* inoculum and the addition of chlorsulfuron. The level of inoculum in this experiment was adjusted to give low to moderate root damage to facilitate the detection of the effect of chlorsulfuron.

DISCUSSION

Although there are reports of other herbicides increasing root disease by *R. solani*, e.g., trifluralin with cotton (17) and pebulate and pyrazone with sugar beet (1,3,4,22), this is the first report of chlorsulfuron increasing Rhizoctonia root rot. These reports suggest that the herbicides increase the susceptibility of the host plant rather than the virulence of the pathogen. Altman and Campbell (2) provided evidence with sugar beet that herbicide treatment increased the leakage of glucose and mineral ions and postulated that these exudates could stimulate the growth of *R. solani* and so increase disease. We did not study the direct effect of chlorsulfuron on *R. solani* in agar or in soil, and we did not study whether root exudation was affected by the herbicide. The controlled-environment experiments confirmed the field results by demonstrating that low levels of chlorsulfuron increase root damage by *R. solani*.

These findings have considerable significance in the development of conservation tillage practices. Chlorsulfuron is recommended as a tank mix with

Table 3. Effect of chlorsulfuron on the incidence and severity of infection of wheat roots by *Gaeumannomyces graminis* var. *tritici* (Ggt)[a]

No. propagules of Ggt/200 g soil	Chlorsulfuron (μg/g soil)	Incidence (% infected roots)	Severity (mm lesion/ seminal root system)
0	0.000	0	0.0
	0.008	0	0.0
	0.016	0	0.0
	0.032	0	0.0
12	0.000	9	1.8
	0.008	12	1.7
	0.016	11	1.1
	0.032	12	1.6
24	0.000	23	4.5
	0.008	25	2.5
	0.016	20	3.8
	0.032	11	1.9

[a]No significant effect of chlorsulfuron. Effect of Ggt inoculum significant at 0.1%.

Table 4. Effect of chlorsulfuron on *Rhizoctonia* damage to roots of wheat and barley

No. propagules of *R. solani* (isolate 21)/ kg soil	Chlorsulfuron (μg/g soil)	*Rhizoctonia* root damage rating[y]	
		Wheat	Barley
0	0.000	0.09 a[z]	0.23 a
	0.002	0.13 a	0.53 a
	0.004	0.00 a	0.79 a
	0.008	0.00 a	0.83 a
	0.016	0.20 a	0.74 a
4	0.000	1.29 ab	2.25 b
	0.002	2.05 bc	2.63 bc
	0.004	3.41 cd	2.92 bcd
	0.008	3.99 d	3.46 cd
	0.016	4.56 d	3.73 d

[y]Root damage rating on a scale of 0–5 (15).
[z]Values in each column followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

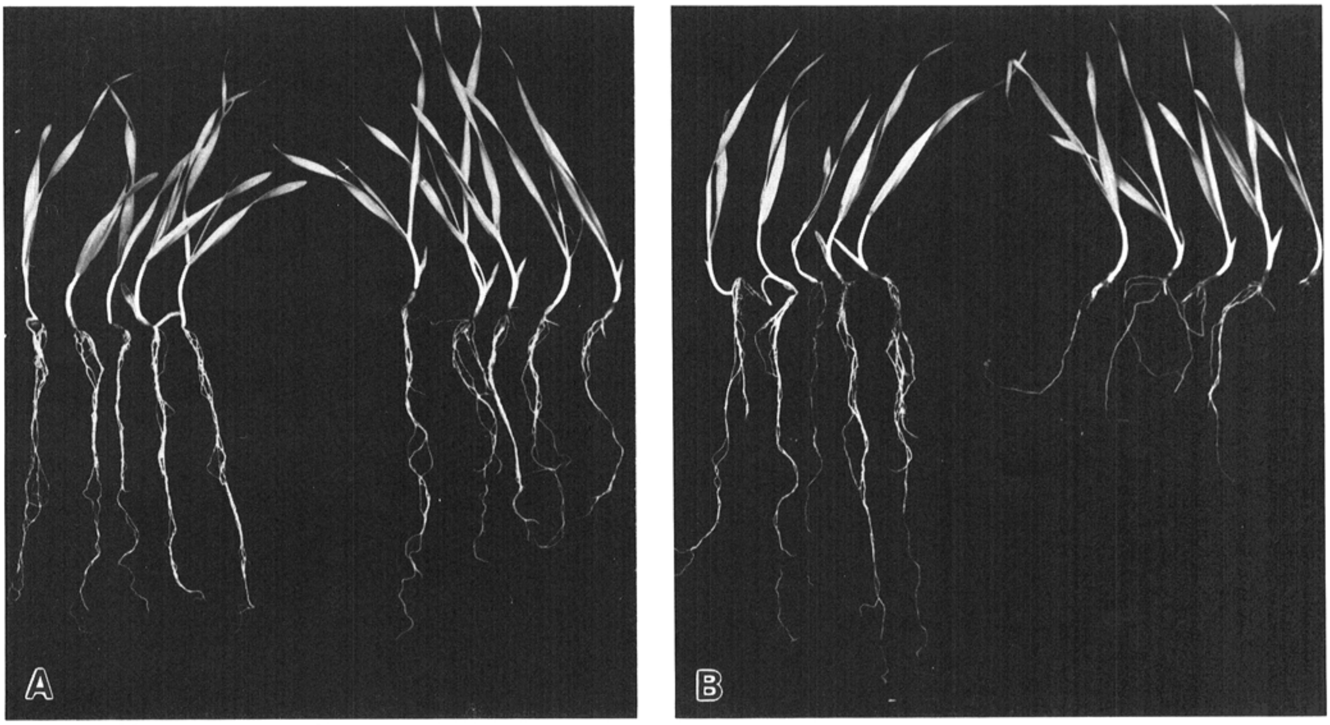

Fig. 2. Effects of chlorsulfuron and *Rhizoctonia solani* on growth of barley. **(A)** No *R. solani* added and **(B)** *R. solani* (isolate 21) added to soil at four millet seed propagules per kilogram of soil. Plants on left in each photograph received no chlorsulfuron; plants on right received chlorsulfuron mixed through soil at 0.008 μg/g of soil.

Table 5. Effects of chlorsulfuron and *Rhizoctonia* on lengths of wheat and barley roots

No. propagules of *R. solani* (isolate 21)/ kg soil	Chlorsulfuron (μg/g soil)	Mean root length/plant (cm)	
		Wheat	Barley
0	0.000	26 a[z]	75 a
	0.002	26 a	76 a
	0.004	24 a	43 b
	0.008	24 a	62 b
	0.016	23 a	27 c
4	0.000	22 a	73 a
	0.002	18 ab	41 b
	0.004	12 b	24 c
	0.008	11 b	27 c
	0.016	9 b	17 c

[z]Values in each column followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

either paraquat-diquat mixture or glyphosate before direct drilling of wheat. As the application of various conservation tillage practices increases, there is a distinct possibility of increased severity of Rhizoctonia root rot in areas where it has not been a problem before.

The efficiency of chlorsulfuron, at 15–20 g/ha, for the control of a wide range of weeds with consequent yield increases is not questioned, but our results indicate that some precautions should be taken in soils with a potential *Rhizoctonia* problem.

Rhizoctonia root rot of cereals is a problem associated with sandy soils, which in South Australia are generally calcareous with pH values of 8–8.5. In acid to neutral soils, chlorsulfuron has an average half-life of 4-8 wk, but in soils of pH 7.6–8.5, hydrolysis is slow and residues can persist for up to 2 yr at sufficient levels to affect legumes (8,9). One strategy in alkaline sandy soils would be to cultivate or rotate with crops or legume pasture, which reduce Rhizoctonia bare patch (19,20). Roget, Venn, and Rovira (*unpublished*) have shown in field and controlled-environment trials that the Rhizoctonia root rot in direct-drilled wheat is reduced if grasses are killed 3 wk before seeding, so where chlorsulfuron residues and high *Rhizoctonia* levels are suspected, removal of annual grasses 2–3 wk before seeding by either chemical fallowing or light cultivation would reduce the disease level. Rhizoctonia bare patch is essentially an early seedling disease; hence, delaying the application of chlorsulfuron until about 3 wk after crop emergence would be another alternative.

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