Effect of tillage on disease of cereals caused by *Gaeumannomyces graminis*, *Rhizoctonia solani* and *Heterodera avenae*: a review

S.M. Neate
Division of Soils, CSIRO, Private Bag 2, P.O., Glen Osmond, South Australia 5064

Summary

Both Australian and overseas research on the effect of tillage on three root diseases of cereals are reviewed. The effect of tillage on *Gaeumannomyces graminis* (Sacc.) Arx and Olivier was variable within and between countries. Tillage consistently reduced the effects of *Rhizoctonia solani* Kuhn on cereals. Little information is available on the effect of tillage on disease caused by *Heterodera avenae* Wollenweber (1924); however, in two studies in Australia, tillage increased the disease. Factors which may influence disease and which are affected by tillage are discussed. The large number of factors influenced by tillage may be the cause of the variable results especially with *G. graminis*.

Introduction

Three important root pathogens of small-grain cereals in southern Australia are *Gaeumannomyces graminis* (Sacc.) Arx and Olivier, the cause of take-all, *Rhizoctonia solani* Kühn which is associated with bare-patch disease, and *Heterodera avenae* Wollenweber (1924), the cereal cyst nematode. There are few reports of experimentally assessed losses in yield of cereals due to disease caused by *G. graminis, R. solani* and *H. avenae*. However, all three pathogens have often been observed causing serious losses on wheat in southern Australia (Richardson 1910; Samuel 1928; McKnight 1960; Winn 1965; Banyer 1966*a, b,c*; Brown 1982). Disease caused by *R. solani* had an estimated average annual yield loss in the years 1955 to 1960 of 5% (McKnight 1960) and *H. avenae* has had yield losses assessed experimentally as 25–43% (Rovira 1978; Rovira and Simon 1982).

Take-all

The effect of reduced cultivation on take-all has been investigated by workers in several countries, but without consistent results. In the United States, Sewell and Melchers (1925) found that with reduced cultivation there was less take-all of wheat and suggested that the burying of infested stubble in normal cultivation increased its survival. Moore (1978) and Moore and Cook (1984), however, found that reduced tillage increased take-all and attributed this to greater survival of inoculum because infected wheat crowns decomposed less rapidly in reduced tillage plots. In Great Britain, Brooks and Dawson (1968) found less take-all damage in direct-drilled wheat than in ploughed treatments. Early in the season more direct-drilled plants were infected, but toward the end of the season fewer were infected compared to plants from ploughed treatments. They considered that this was due to factors which limited the spread of *G. graminis* in undisturbed direct-drilled soil. Hood (1965) found higher take-all infection after direct drilling, with 20.4% of tillers infected in direct-drilled plots compared to 2.6% in ploughed plots, but grain yield did not differ significantly. Hornby (1975) obtained variable results. By using a seedling assay he showed that at one site (Boxworth) continuous direct-drilled plots had less take-all at depth than ploughed plots. Generally there were no differences between treatments. Lockhart *et al.* (1975) studying barley, found that for the first 5 years shallow ploughing resulted in greater infection by take-all compared to no-tillage.

In Germany, Debruck (1971) found fewer wheat plants infected with take-all in direct-drilled compared to ploughed plots and Schwerdtle (1971) found less take-all on direct-sown crops than crops sown with ploughing at two locations. Hesse (1970), however, obtained variable results, with increased take-all in direct-drilled wheat one year and decreased take-all the next. Other workers in Europe have reported no difference in severity of take-all on cereals under different tillage systems (Stetter 1971; Slope and Gutteridge 1974; Yarham and Hirst 1975; Prew 1976, 1977; Bowerman 1980; Rasmussen 1982).

In Australia, Neate *et al.* (1982), Neate (1984) and Rovira and Venn (1985), working at Avon in South Australia, found increased take-all in direct-drilled wheat following different rotations and on different soil types, but Kollmorgen *et al.* (1987) working on four trials in Victoria, generally found that disease was unaffected by tillage. They found that nil tillage increased disease severity compared to ploughing only at one site in one year out of three and decreased incidence of disease at only one site at one sampling time. This contrast in results may be due to the existence in South Australia of greater numbers of grassy weeds in pasture in the previous season and also after the first rains of the season before the crop is sown.

Rhizoctonia root rot

Although the effect of tillage on *R. solani* on non-cereal crops has been extensively investigated, there is little data published outside Australia on the effect of reduced cultivation on severity of disease of cereals caused by *R. solani* on small-grain cereals.

In the Pacific Northwest of the United States, patches caused by *R. solani* were found associated with reduced tillage sowing of cereals and there were more patches in no-tillage compared to ploughed plots (Weller *et al.* 1986). In Florida, with a soybeans–rye rotation, there were more propagules of *Rhizoctonia* spp. in the soil tilled to 15 cm than in untilled soil; however, no data were presented for disease or pathogenicity of the *Rhizoctonia* spp. (Ploetz *et al.* 1985). Other overseas work showed that deep ploughing to 20–25 cm compared to a more shallow ploughing or direct drilling reduced severity of disease of *R. solani* on some horticultural crops (Gumestad *et al.* 1978; Lewis and Papavizas 1980; Sumner *et al.* 1981; Lewis *et al.* 1983; Gurkin and Jenkins 1985); this effect was probably due to a dilution of inoculum in the surface layers with soil from deeper layers (Lewis and Papavizas 1980; Sumner *et al.* 1981).

For cereals in Australia, cultivation depth and disturbance is less than that used with horticultural crops and with cereals in the U.S. Most Australian cereal farmers cultivate with narrow-tined implements to a depth of 5–10 cm. Despite this, the effect of tillage on *Rhizoctonia* damage on cereals in Australia is the same as that reported for horticultural crops and cereals in the U.S. Cultivation consistently reduced *Rhizoctonia* attack on cereals under different rotations, soil types, seasons and sites (Neate *et al.* 1982; Neate 1984; MacNish 1985; Rovira and Venn 1985; Jarvis and Brennan 1986; Rovira 1986). One of the factors involved in the greater disease of cereals with direct drilling is grasses germinating after the first rains of the season in Autumn, which promote damage to roots by *R. solani* (Roget *et al.* 1987) as direct-drilled cereals may have greater numbers of pre-crop grass weeds than conventionally cultivated cereals (Neate 1984).

Cereal cyst nematode

The only reports on the effect of direct drilling on the cereal cyst nematode, *H. avenae*, are Australian work by Rovira and Simon (1982) and Roget and Rovira (1985) who reported less root damage and a reduction in number of female cysts of *H. avenae* per plant in wheat sown by direct drilling compared to wheat sown following cultivation.

Discussion

The variable effect of direct drilling on severity of root disease of cereals is probably due to differences in soil type, climate, cereal variety, depth and intensity of tillage and other management practices. A large number of factors are changed by cultivating soil and the degree of change will influence disease. Yarham (1975, 1981) and Yarham and Hirst (1975) have listed several factors that may affect *G. graminis* and most are also likely to affect *R. solani* and *H. avenae*.

1. Direct-drilling leaves larger fragments of infective wheat-root and stem-base debris near the soil surface rather than distributing them down the soil profile (Hornby 1975) and reduces the microbial and mechanical breakdown of the particles so that they remain more infective (Moore 1978). In southern Australia, grassy pasture is often grown in rotation with cereals and grass crowns and roots infected with *G. graminis* may act as inoculum.

2. Direct-drilling may result in increased biological activity (Dawson 1969) and increased microbial populations (Doran 1980) in the upper layers of soil and with the increased numbers of organisms will be more competitors and antagonists of *G. graminis*.

3. Direct-drilling increases bulk density and decreases pore size of soil (Cannell and Finney 1973). This effect, together with the increased biological activity, may result in changed levels of oxygen and ethylene in the soil which can be fungistatic (Fellows 1928; Cook 1981). Soil type will affect the degree of impact of reduced tillage on these factors. (Compaction of the soil can result in slower elongation of seminal roots after direct drilling than after ploughing (Finney and Knight 1973) and if rooting is sufficiently restricted take-all severity may be increased (Yarham 1981).)

4. Direct-drilling causes stratification of phosphorus in soil (Shear and Moschler 1969) and phosphorus nutrition influences take-all susceptibility (Garrett 1941).

5. Direct-drilling decreases mineralization of soil nitrogen (Davies *et al.* 1979; Huber *et al.* 1977) and low levels of nitrate nitrogen decrease the severity of take-all (Huber 1981). However, a nitrogen deficiency in the plant promotes take-all (Butler 1961).

Other factors influenced by direct drilling which were not considered by Yarham (1975, 1981) and Yarham and Hirst (1975) are:

i. Annual grasses which germinate after the first rains of autumn and grow until killed by herbicides before the crop is sown, may act as hosts to the pathogen. In southern Australia there can be up to 30 000 plants m^{-2} (Neate 1984) and the plants may be up to 10 weeks old.

ii. Herbicides used in association with direct drilling may have a direct effect on the pathogen in the soil and there may also be an indirect effect of the herbicide affecting the resistance of the host plant (Rovira and McDonald 1986; Sivasithamparam and Bolard 1985).

iii. Direct drilling can cause an increase in soil moisture particularly near the soil surface (van Ouwerkerk and Boone 1970; Finney and Knight 1973) and this may affect survival of the pathogen and disease expression.

The effect of tillage on root disease of cereals will, therefore, depend on the combination of pathogen and environment experienced at a site. Effect of tillage on disease caused by *R. solani* and possibly *H. avenae* appears to be predictable but this is not true of disease caused by *G. graminis*. More research on the interactions between the host, pathogen and environment is necessary before the effect of tillage on disease caused by *G. graminis* can be predicted.

References

Banyer, R. J. (1966) Cereal root diseases and their control. Part 1. *Journal of the Department of Agriculture of South Australia* **69**, 310–5.

Banyer, R. J. (1966). Cereal root diseases and their control. Part II. *Journal of the Department of Agriculture of South Australia* **69**, 372–6.

Banyer, R. J. (1966). Cereal root diseases and their control. Part III. *Journal of the Department of Agriculture of South Australia* **69**, 415–7.

Bowerman, P. (1980). Exploitation of take-all decline in wheat and barley. *Experimental Husbandry* **37**, 74–82.

Brooks, D. H., and Dawson, M. G. (1968). Influence of direct drilling of winter wheat on incidence of take-all and eye-spot. *Annals of Applied Biology* **61**, 57–64.

Brown, R. H. (1982) The ecology and control of cereal cyst nematode (*Heterodera avenae*) in southern Australia. *Journal of Nematology* **14**, 433.

Butler, F.C. (1961). Root and foot rot diseases of wheat. Department of Agriculture of New South Wales Scientific Bulletin No. 77, 98pp.

Cannell, R. Q., and Finney, J. R. (1973). Effects of direct-drilling and reduced cultivation on soil conditions for root growth. *Outlook on Agriculture* **7**, 184–9.

Cook, R. J. (1981). The effect of soil reaction and physical conditions. *In* 'Biology and Control of Take-all', eds M. J. C. Asher and P. J. Shipton, pp.343–52. (Academic Press: London.)

Davies, D. B., Vaidyanathan, L. V., Rule, J. S., and Jarvis, R. M. (1979). Effect of sowing date and timing and level of nitrogen application to direct-drilled winter wheat. *Experimental Husbandry* **35**, 122–31.

Dawson, M. G. (1969). The effect of minimum cultivation on take-all incidence. Ph.D. Thesis, University of Reading.

Debruck, J. (1971). Soil cultivation and direct sowing on weak pseudovergly para brown earth. *Lanwirtschaftliche Forschung* **26**, 230–44.

Doran, J. W. (1980). Soil microbial and biochemical changes associated with reduced tillage. *Journal of the Soil Science Society of America* **44**, 765–71.

Fellows, H. (1928). Some chemical and morphological phenomena attending infection of the wheat plant by *Ophiobolus graminis. Journal of Agricultural Research* **37**, 647–61.

Finney, J. R., and Knight, B. A. G. (1973). Effect of cultivation on wheat root development. *Journal of Agricultural Science, Cambridge* **80**, 435–42.

Garrett, S. D. (1941). Soil conditions and the take-all disease of wheat. VI. The effect of plant nutrition upon disease resistance. *Annals of Applied Biology* **28**, 14–18.

Gumestad, N. C., Hugelet, J. E., and Zink, R. T. (1978). The effect of cultural practices and straw incorporation into the soil on *Rhizoctonia* disease of potato. *Plant Disease Reporter* **62**, 985–9.

Gurkin, R. S., and Jenkins, S. F. (1985). Influence of cultural practices, fungicides and inoculum placement on southern blight and *Rhizoctonia* crown rot of carrots. *Plant Disease* **69**, 477–81.

Hesse, B. (1970). Measurement of cellulose mineralization and the appearance of *Ophiobolus graminis* Sacc. in direct drilling tests (Preliminary report). *Zeitschrift fur Pflanzenkrankheiten Pflanzenpathologie Pflanzenschutz Sonderheft* **V**, 147–50.

Hood, A. E. M. (1965). Ploughless farming using gramoxone. *Outlook on Agriculture* **4**, 286–94.

Hornby, D. (1975). Inoculum of the take-all fungus: nature, measurement, distribution and survival. *Bulletin Organisation Europeenne et Mediterranéenne pour la Protection des Plantes* **5**, 319–33.

Huber, D. M. (1981). The role of nutrients and chemicals. *In* 'Biology and Control of Take-all', eds M. J. C. Asher and P. J. Shipton, pp.317–41. (Academic Press: London.)

Huber, D. M., Warren, H. L., Nelson, D. W., and Tsai, C. Y. (1977). Nitrification inhibitors, new tools for food production. *Bio Science* **27**, 523–9.

Jarvis, R. J., and Brennan, R. F. (1986). Timing and intensity of surface cultivation and depth of cultivation affect rhizoctonia patch and wheat yield. *Australian Journal of Experimental Agriculture* **26**, 703–8.

Kollmorgen, J. F., Ridge, P. E., and de Boer, R. F. (1987). Effects of tillage and straw mulches on take-all of wheat in the Northern Wimmera of Victoria. *Australian Journal of Experimental Agriculture* **27**, 419–23.

Lewis, J. A., and Papavizas, G. C. (1980). Integrated control of *Rhizoctonia* fruit rot of cucumber. *Phytopathology* **70**, 85–9.

Lewis, J. A., Lumsden, R. D., Papavizas, G. C., and Kantzes, J. G. (1983). Integrated control of snapbean diseases caused by *Pythium* spp. and *Rhizoctonia solani. Plant Disease* **67**, 1241–4.

Lockhart, D. A. S., Heppel, V. A. F., and Holmes, J. C. (1975). Take-all (*Gaeumannomyces graminis* (Sacc.) Arx and Olivier) incidence in continuous barley growing and effect of tillage method. *Bulletin Organisation Europeenne et Mediterranéenne pour la Protection des Plantes* **5**, 375–83.

McKnight, T. (1960). Survey of present incidence, importance and causes of cereal root rots in Australia. *Proceedings of a Conference on Root Rots of Wheat, Wagga Wagga, New South Wales,* pp 1–12.

MacNish, G. C. (1985). Methods of reducing rhizoctonia patch of cereals in Western Australia. *Plant Pathology* **34,** 175–81.

Moore, K. J. (1978). The influence of no-tillage on take-all of wheat. Ph.D. Thesis, Washington State University.

Moore, K. J., and Cooke, R. J. (1984). Direct drilling increases take-all of wheat in the Pacific Northwest U.S.A. *Phytopathology* **74,** 1044–9.

Neate, S. M., Rovira, A. D., and Warcup, J. H. (1982). Minimum cultivation and root disease of wheat. *Biennial report of the Waite Agricultural Research Institute 1980–1981,* 142.

Neat, S. M. (1984). Minimum cultivation and root diseases of wheat. Ph.D. Thesis, University of Adelaide, 144 pp.

Ouwerkerk, C. van, and Boone, F. R. (1970). Soil-physical aspects of zero-tillage experiments. *Netherlands Journal of Agricultural Science* **18,** 247–61.

Ploetz, R. C., Mitchell, D. J., and Gallaher, R. N. (1985). Population dynamics of soilborne fungi in a field multicropped to rye and soybeans under reduced tillage in Florida. *Phytopathology* **75,** 1447–51.

Prew, R. D. (1976). Diseases in reduced cultivation systems. *Rothamstead Experimental Station Report, 1975 Part 1,* 256–8.

Prew, R. D. (1977). Diseases in reduced cultivation systems. *Rothamstead Experimental Station Report, 1976 Part 1* 261–2.

Rasmussen, K. J. (1982). Plant growth and soil physical properties by reduced tillage. *In* Proceedings of the 9th Conference of the Soil Tillage Organization, pp.526–31. (Institute for Soil Tillage and Soil Physics: Denmark.)

Richardson, A. E. V. (1910). 'Take-all'. Serious damage to crops. *Journal of the Department of Agriculture of South Australia.* **14,** 466–71.

Roget, D. K., and Rovira, A. D. (1985). Effect of tillage on *Heterodera avenae* in wheat. *In* 'Ecology and Management of Soil-borne Plant Pathogens', eds C. A. Parker, A. D. Rovira, K. J. Moore, P. T. W. Wong and J. F. Kollmorgen, pp.252–4. (American Phytopathological Society: St Paul.)

Roget, D. K., Venn, N. R., and Rovira, A. D. (1987). Reduction of *Rhizoctonia* root rot of direct-drilled wheat by short-term chemical fallow. *Australian Journal of Experimental Agriculture* **27,** 425–430.

Rovira, A. D. (1978). Assessment of yield losses in wheat due to cereal cyst nematode (*Heterodera avenae*) by the use of selective chemicals. *In* 'Epidemiology and Crop Loss Assessment', eds R. C. Close, R. E. Gaunt, I. C. Harvey, A. J. McCully, F. R. Sanderson and P.S. Teng. (Proceedings of the Australasian Plant Pathology Society Workshop: Lincoln College, New Zealand.)

Rovira, A. D. (1986). Influence of crop rotation and tillage on *Rhizoctonia* bare patch of wheat. *Phytopathology* **76,** 669–73.

Rovira, A. D., and McDonald, H. J. (1986). Effects of the herbicide chlorsulfuron on *Rhizoctonia* bare patch and take-all of barley and wheat. *Plant Disease* **70,** 879–82.

Rovira, A. D., and Simon, A. (1982). Integrated control of *Heterodera avenae. Bulletin Organisation Europeenne et Mediterranéenne pour la Protection des Plantes* **12,** 517–23.

Rovira, A. D., and Venn, N. R. (1985). Effect of rotation and tillage on take-all and *Rhizoctonia* root rot of wheat. *In* 'Ecology and Management of Soil-borne Plant Pathogens', eds C. A. Parker, A. D. Rovira, K. J. Moore, P. T. W. Wong and J. F. Kollmorgen, pp.255–8. (American Phytopathological Society: St Paul.)

Samuel, G. (1928). Two 'stunting' diseases of wheat and oats. *Journal of the Department of Agriculture of South Australia* **32,** 40–3.

Schwerdtle, F. (1971). Trials on direct sowing methods in comparison with conventional cultivation of various crops with particular regard to the weed flora. *KTBL Berichte uber Landtechnik* **149,** p.139.

Sewell, M. C., and Melchers, L. W. (1925). The effect of rotation and tillage on foot rot. *Journal of the American Society of Agronomy* **16,** 768–71.

Shear, G. M., and Moschler, W. W. (1969). Continuous corn by the no-tillage and conventional tillage methods: a six-year comparison. *Journal of Agronomy* **61,** 524–6.

Sivasithamparam, K., and Bollard, M. D. A. (1985). Effect of herbicide sprays on the infectivity and propagule numbers of take-all fungus (*Gaeumannomyces graminis* var. *tritici*) and the effect of propagule size and soil temperature on infectivity. *Australasian Plant Pathology* **14,** 22–5.

Slope, D. B., and Gutteridge, R. J. (1974). Reduced cultivation systems and plant diseases. *Rothamstead Experimental Station Report, 1973 Part 1,* 135–6.

Stetter, S. (1971). The effects of stubble treatments and ploughing quality on attacks of *Cercosporella herpotrichoides* and *Ophiobolus graminis* in barley. *Tidsskriftn Planteavl* **75,** 626–30.

Sumner, D. R., Doupnik, B., and Boosalis, M. G. (1981). Effects of reduced tillage and multiple cropping on plant diseases. *Annual Review of Plant Pathology* **19,** 167–87.

Sumner, D. R., Threadgill, E. D., Dowler, C. C., Phatak, S. C., Smittle, D., Young, J., Mitchell, G. A., and Johnson, A. W. (1981). Tillage practices, populations of soil fungi, and root diseases in irrigated, multiple-cropping sequences. *Phytopathology* **71,** 259.

Weller, D. M., Cook, R. J., MacNish, G., Bassett, E. N., Powelson, R. L., and Petersen, R. R. (1986). *Rhizoctonia* root rot of small grains favoured by reduced tillage in the Pacific Northwest. *Plant Disease* **70,** 70–3.

Winn, D. B. (1965). Agriculture in South Australia, Yorke Peninsula. *Journal of the Department of Agriculture of South Australia* **69,** 2–17.

Yarham, D. J. (1975). The effects of non-ploughing on cereal disease. *Outlook on Agriculture* **8,** 245–7.

Yarham, D. J. (1981). Practical aspects of epidemiology and control. *In* 'Biology and Control of Take-all', eds M. J. C. Asher and P. J. Shipton, p.353–84. (Academic Press: London.)

Yarham, D. J., and Hirst, J. M. (1975). Diseases in reduced cultivation and direct drilling systems. *Bulletin Organisation Europeenne et Mediterranéenne pour la Protection des Plantes* **5,** 287–96.