Root-lesion nematode (*Pratylenchus thornei*) limits response of wheat but not barley to stored soil moisture in the Hermitage long-term tillage experiment

J. P. Thompson[A], *J. Mackenzie*[B] *and R. Amos*[C]

[A] Queensland Wheat Research Institute, Box 2282, Toowoomba, Qld 4350, Australia.
[B] Present address: 41 Clewley Crescent, Toowoomba, Qld 4350, Australia.
[C] Queensland Department of Primary Industries, Hermitage Research Station, via Warwick, Qld 4370, Australia.

Summary. The cumulative effects of factorial treatments of tillage (no tillage, conventional), stubble retention (burnt, retained), and nitrogen fertiliser (0, 23, 69 kg N/ha) on yield of continuous winter cereals and on soil properties have been tested in the Hermitage fallow management experiment since 1969. Despite increased soil water stored from the combination of no tillage and stubble retention, wheat responses to the extra water were disappointing in the first 11 years of the experiment.

Soil samples from the experiment were shown to be heavily infested with the root-lesion nematode (*Pratylenchus thornei* Sher and Allen), and therefore in 1980, the main plots were split for crop (wheat cv. Timgalen, barley cv. Clipper) and nematicide treatment (nil, aldicarb). Barley (maximum yield 3.2 t/ha) tolerated the nematodes and responded in this dry year to the extra stored water accumulated with no tillage and stubble retention, but wheat (maximum yield 1.22 t/ha) did not. Nematicide increased wheat yields by 42%.

The results from the changes to the Hermitage experiment in 1980 show the importance of considering root-lesion nematodes in interpreting results from long-term experiments involving wheat and in applying those results to farms. Control of root-lesion nematodes on farms by crop rotation and by growing tolerant and resistant wheat varieties is needed to obtain full yield benefits from improved tillage practices.

Introduction

Traditional practice for winter cereal production on the Darling Downs involved burning stubble and cultivating the fallow for weed control. In the mid 1960s, chemical companies provided local scientists with results from overseas studies indicating that herbicides like paraquat and diquat could effectively control fallow weeds without cultivation. Later, soil conservationists began to advocate retention of stubble to protect the highly erodible clay soils of this area. There was, however, no local information on the effects of these new practices on soil-water storage and nitrogen (N) supply, or on crop establishment, growth, and yield. Consequently, a long-term experiment to compare tillage and stubble management treatments for continuous winter cereal production was established in 1968 on a Vertisol at the Hermitage Research Station near Warwick (Marley and Littler 1989). All treatments were tested at 3 rates of N fertiliser because stubble was expected to immobilise N.

Although the combination of stubble retention and no tillage regularly increased soil water storage, it rarely increased wheat yield (Marley and Littler 1989). An investigation of factors influencing N nutrition in this experiment found high populations of the root-lesion nematode (*Pratylenchus thornei* Sher and Allen) in the topsoil before sowing in 1979 (Thompson 1992). This nematode species is a serious pathogen of wheat in the northern Australian grain region. It reduces root function, thereby limiting water and nitrate uptake from the soil (Thompson 1987), and results in stunting, chlorosis, reduced tillering, and decreased yield. Barley is much more tolerant of this nematode (Thompson *et al.* 1980), and when the Hermitage long-term plots were split to grow wheat and barley in 1979, barley outyielded wheat (Marley and Littler 1989). This paper reports an investigation in 1980 into the effects of *P. thornei* on wheat yields in this long-term experiment by comparing the yields of wheat and barley with and without nematicide.

Materials and methods

History

The long-term field experiment has been described in detail by Marley and Littler (1989). Briefly, it is located at the Hermitage Research Station (28°12'S, 152°06'E) on Warwick clay, a Udic Pellustert (Soil Survey Staff 1975). There are 4 fallow management treatments: mechanical tillage and stubble burnt; mechanical tillage and stubble retained; no tillage and stubble burnt; and no tillage and stubble retained. Each of these treatments is tested at 3 rates of N fertiliser (0, 23, 46 kg N/ha until 1976; 0, 23, 69 kg N/ha subsequently) applied as urea before sowing each year. The 12 treatments are tested in 4 randomised blocks. Plot size is 60 by 5.5 m. Wheat cv. Timgalen was grown from 1969 to 1974, barley cv. Clipper from 1975 to 1977, and wheat cv. Timgalen again in 1978. The plots were split longitudinally for growing both wheat and barley in 1979.

Methods in 1980

Sampling and analysis for soil water and nitrate. In 1980, the experiment was modified to provide split-plots for crop (wheat, barley) on the same longitudinal splits used in 1979 and for nematicide (nil, aldicarb) as transverse splits. Soil from the nil and 69 kg N/ha rates of all treatments was sampled to 150 cm depth with a hydraulically driven, thin-walled tube of 5 cm diameter (Foale 1980) on 29 May (before planting) and again on 2 December (after harvest). Two cores were taken from each subplot and subdivided into intervals (cm): 0–15, 15–30, 30–60, 60–90, 90–120, 120–150. Gravimetric moisture content was determined by drying subsamples at 105°C for 2 days. Values for bulk density and wilting point determined by Marley and Littler (1989) were used to calculate volumetric and available water contents of the soil from the gravimetric contents. Subsamples for chemical analysis were dried in a forced draft oven at 40°C for 5 days, ground to pass a 2-mm sieve, and stored in sealed jars. Subsamples of 10 g were extracted by shaking in 100 mL 2 mol KCl/L solution for 1 h, filtered through Whatman No. 40 filter paper, and analysed for nitrate-N by an autoanalysis Griess-Ilosvay technique (Best 1976).

Sampling and counting of soil nematodes. Topsoil for nematode counts was sampled on 23 June with a rapid soil corer (Thompson *et al.* 1988) of 43 mm diameter and 150 mm depth from 15 positions in each subplot. The bulked soil was broken manually to <10 mm aggregates before extracting nematodes by the Whitehead tray method (Whitehead and Hemming 1965) using a 2-day extraction time at 22°C and collecting nematodes on a 63-μm sieve. Numbers of *Pratylenchus thornei* in the extracts were counted on a Hawkesly slide under a compound microscope and expressed per 200 g oven-dried soil.

Sowing and crop measurements. Nitrogen fertiliser to provide 23 and 69 kg N/ha was drilled into the field plots as urea granules on 8 May. Wheat cv. Timgalen and barley cv. Clipper were sown at 35 and 38 kg/ha, respectively, on 24 June through an experimental planter equipped with rigid narrow points (Jahnke Brothers Pty Ltd, Mt Tyson) on 25-cm row spacing into the same wheat and barley subplots cropped in 1979. The nematicide aldicarb (2 kg/ha) was applied as granules (Temik 10G) to the appropiate subplots via a cone divider into the seed rows at sowing. The numbers of plants established in the experiment in each subplot were counted on 21 July in 2-m lengths of row from 4 grid positions in alternate drill rows. Severe frosting occurred due to a grass temperature of –9°C on 16 August. On 22 August, all subplots were rated for frost damage on a 0–4 scale, and a subset of plots was sampled to correlate the ratings with mass of leaf killed. Plants were sampled at anthesis (15 October) to determine biomass by cutting plants 2 cm aboveground from 2 adjacent rows in 2 m of drill row at 3 positions in each subplot. Dry matter was determined after drying at 75°C for 4 days. Grain was harvested by combine harvester on 21 November and weighed in the field. Moisture content was determined on a subsample of whole grain by drying at 75°C for 4 days. A ground subsample was analysed for N by an

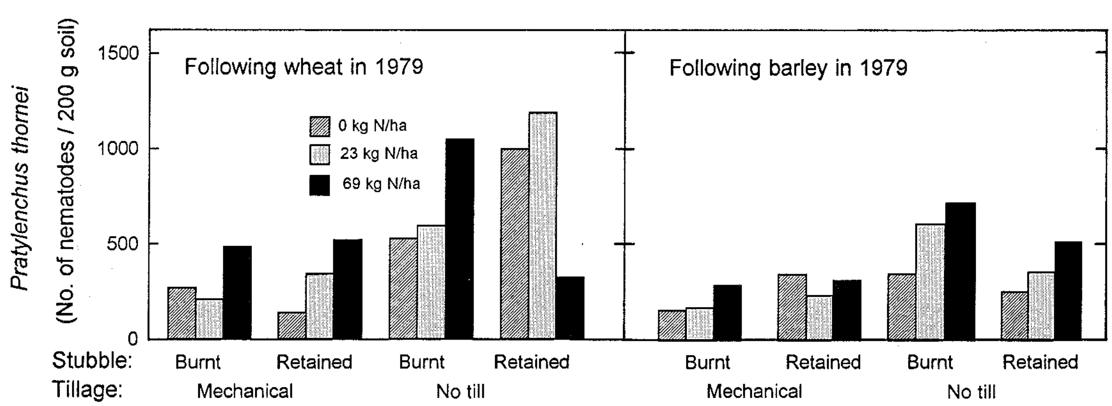

Figure 1. Populations of root-lesion nematode (*Pratylenchus thornei*) in topsoil (0–15 cm) before sowing in 1980. Significant factorial effects: tillage (P<0.01); nitrogen (P<0.05); crop (P<0.05).

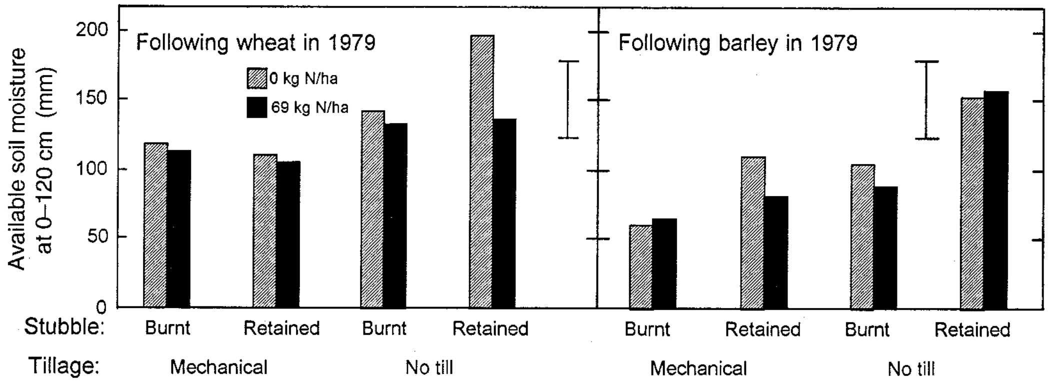

Figure 2. Available moisture (mm) in the soil profile (0–120 cm) before sowing in 1980. Vertical bars indicate l.s.d. at $P = 0.05$. Significant factorial effects: tillage ($P<0.01$); stubble ($P<0.01$); tillage x stubble ($P<0.05$); crop ($P<0.01$).

autoanalyser procedure (Best 1976) and protein calculated as 5.7 x N concentration for wheat and 6.25 x N for barley.

Statistical analysis. All variables were analysed by split-plot factorial analysis of variance with the factors tillage, stubble management, and N fertiliser, and subplots crop species and nematicide application. Numbers of root-lesion nematodes were transformed by $\ln(x + 1)$ before analysis of variance, and back-transformed equivalent means are presented in results. The soil profile for calculating available water and nitrate was taken as 0–120 cm because nitrate values had high coefficients of variation in the 120–150 cm interval, introducing errors that would mask treatment effects.

Rainfall. Rainfall totals recorded at the site during intervals between various operations were as follows: 1979 harvest to initial ploughing, 22.6 mm; inital ploughing to pre-sowing soil sampling, 157.2 mm; soil sampling to N fertiliser application, 1.6 mm; fertiliser application to sowing, 135.9 mm; sowing to dry matter assessment at flowering, 56.4 mm; flowering to grain harvest 52.8 mm; harvest to postharvest soil sampling, 22.0 mm.

Results

Soil nematodes, water, and nitrate before sowing

There were moderate to high populations of root-lesion nematodes in the topsoil of the various treatments before the crop was sown in 1980 (Fig. 1). The number of nematodes was much greater with no tillage than with mechanical tillage, greater following the use of N fertiliser in the preceding years, and greater after growing wheat than barley in the preceding winter season of 1979.

From harvest in 1979 until pre-planting soil-sampling in 1980, there was 180 mm of rain. The available water in the soil profile (Fig. 2) was greater with the combination of no tillage and stubble retention than with

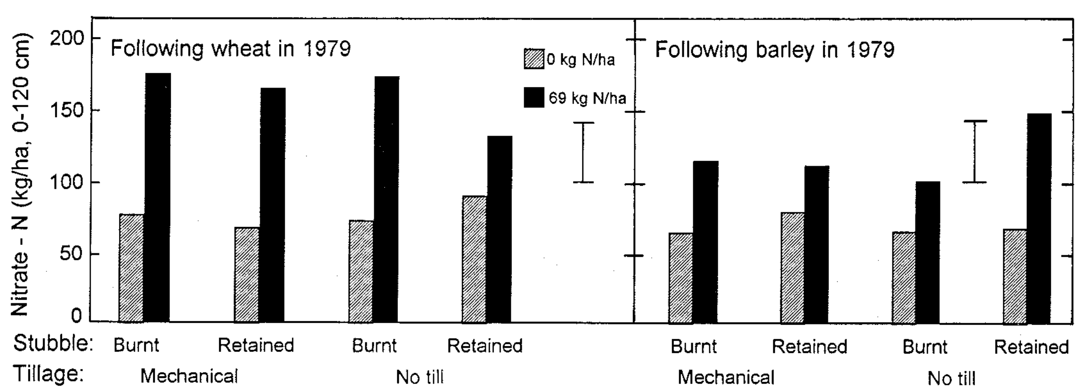

Figure 3. Nitrate-nitrogen (kg N/ha) in the soil profile (0–120 cm) before sowing in 1980. Vertical bars indicate l.s.d. at $P = 0.05$. Significant factorial effects: nitrogen ($P<0.01$); crop ($P<0.01$); nitrogen x crop ($P<0.05$); tillage x stubble x nitrogen x crop ($P<0.01$).

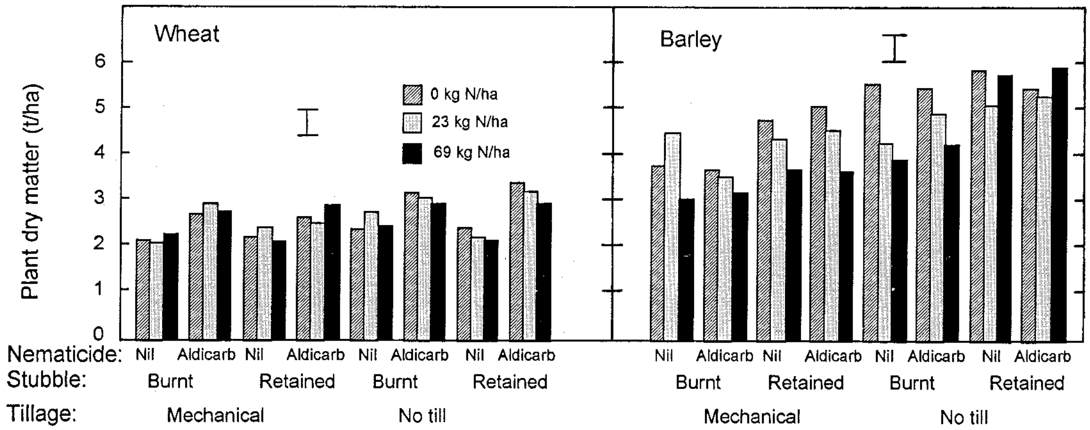

Figure 4. Plant dry matter (t/ha) at flowering in 1980. Vertical bars indicate l.s.d. at $P = 0.05$. Significant ($P<0.01$) factorial effects: tillage; stubble; nitrogen; crop; tillage x crop; stubble x crop; aldicarb; crop x aldicarb.

any other combination of tillage and stubble management. There was more soil water available after growing wheat than barley in the previous 1979 season.

Nitrate-N (Fig. 3) in the soil profile before sowing in 1980 was considerably greater where urea had been applied in previous years, and less where barley was grown than where wheat was grown in 1979. The difference between fertilised and unfertilised treatments (nitrate residual from fertiliser) was less after barley than after wheat except under no tillage with stubble retention.

Early crop growth

The mean number of plants established in the experiment was 69.8/m^2 with no significant difference between wheat and barley. Some treatments had small but significant ($P<0.01$) effects on establishment. The high rate of N fertiliser resulted in lower plant establishment (65.4 plants/m^2) than either the low rate of fertiliser or the nil fertiliser treatment, both with 72.0 plants/m^2. Nematicide increased mean plant establishment from 68.2 to 71.4 plants/m^2.

Frost damaged the leaves of the crop in its vegetative phase. Frost damage (data not shown) was greater to barley (mean rating 3.4 with 58% frosted leaf) than to wheat (mean rating 2.0 with 33% frosted leaf). Frost damage was also greater with stubble retained (mean rating 2.9 with 51% frosted leaf) than with stubble burnt (mean rating 2.5 with 41% frosted leaf) and somewhat greater with no tillage (mean rating 2.8 with 48% frosted leaf) than with mechanical tillage (mean rating 2.5 with 43% frosted leaf). The crop recovered from the frosting, and when sampled at flowering, the dry matter of the barley was greater than that of wheat (Fig. 4). No tillage and stubble retention both increased dry matter production in barley more than wheat. The nematicide aldicarb resulted in increased dry matter production by wheat but not by barley. Nitrogen fertiliser decreased

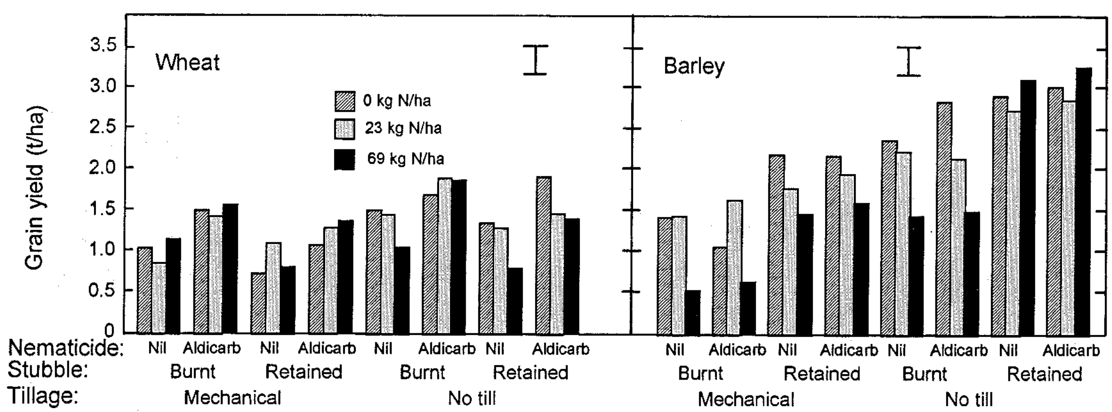

Figure 5. Grain yield (t/ha at 12% moisture) in 1980. Vertical bars indicate l.s.d. at $P = 0.05$. Significant ($P<0.01$) factorial effects: tillage; stubble; nitrogen; crop; tillage x crop; stubble x crop; aldicarb; crop x aldicarb.

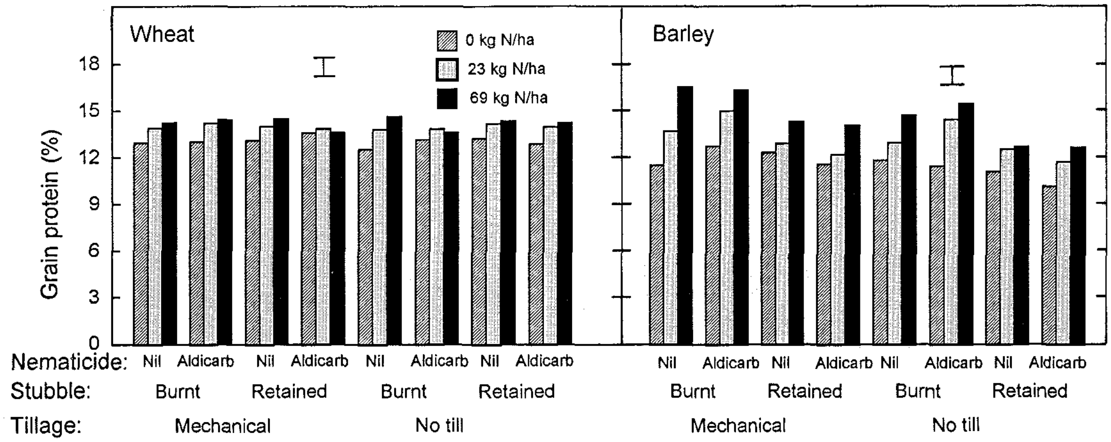

Figure 6. Grain protein (%) in 1980. Vertical bars indicate l.s.d. at $P = 0.05$. Significant ($P<0.01$) factorial effects: tillage; stubble; nitrogen; crop; tillage x crop; stubble x crop; aldicarb; crop x aldicarb.

overall dry matter production, although it is apparent that this was not the case for barley under no tillage and stubble retention, and affects on wheat were small.

Grain yield and nitrogen content

Grain yield (Fig. 5) of both wheat and barley was increased by both no tillage and stubble retention but the size of the increase was much greater for barley than for wheat. Application of the nematicide aldicarb resulted in a highly significant 42% increase in the yield of wheat but no increase in the yield of barley. Overall, N fertiliser depressed yield.

The grain protein of wheat (Fig. 6) in all treatments was above the 11.5% needed for prime hard quality. For barley, the protein content was just within the acceptable limit for malting quality (<12%) for most unfertilised treatments. Nitrogen fertiliser increased protein content of both wheat and barley.

Nitrogen uptake in the grain (Fig. 7) was considerably greater with barley than with wheat. Both no tillage and stubble retention resulted in more N uptake in barley than in wheat. On the other hand, nematicide increased N uptake in wheat grain but not in barley.

Postharvest soil water and nitrate

The available moisture in the soil profile after harvesting the crop (Fig. 8) was considerably less after barley than after wheat. With wheat, more water remained in the soil profile with no tillage and stubble retention than with other treatments. Nitrogen fertiliser resulted in less residual water with stubble retention but more with stubble burnt (especially for wheat) than in respective unfertilised treatments. The nematicide aldicarb increased water extraction by wheat but not barley.

Considerably more nitrate was present in the soil profile after harvest (Fig. 9) where N fertiliser had been applied than where it had not been applied. Less nitrate

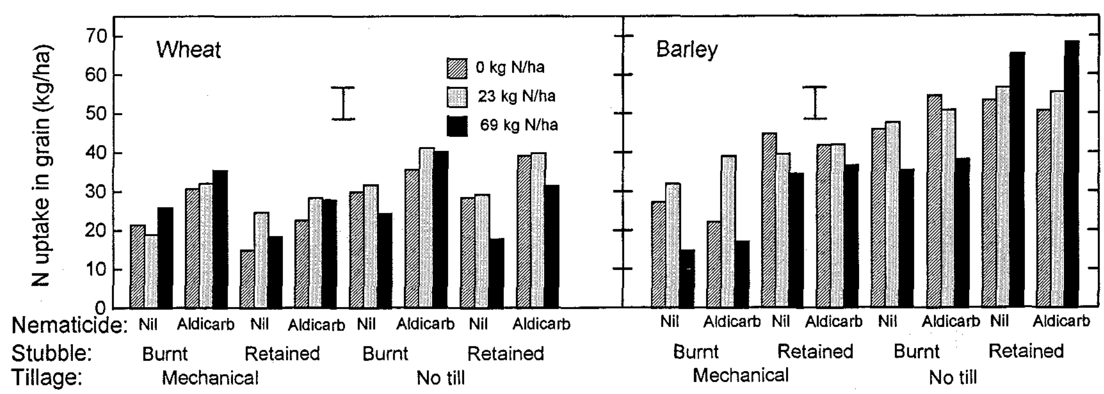

Figure 7. Nitrogen uptake (kg N/ha) in the grain in 1980. Vertical bars indicate l.s.d. at $P = 0.05$. Significant factorial effects: tillage ($P<0.01$); stubble ($P<0.01$); nitrogen ($P<0.05$); crop ($P<0.01$); tillage x crop ($P<0.05$); stubble x crop ($P<0.01$); aldicarb ($P<0.01$); crop x aldicarb ($P<0.01$).

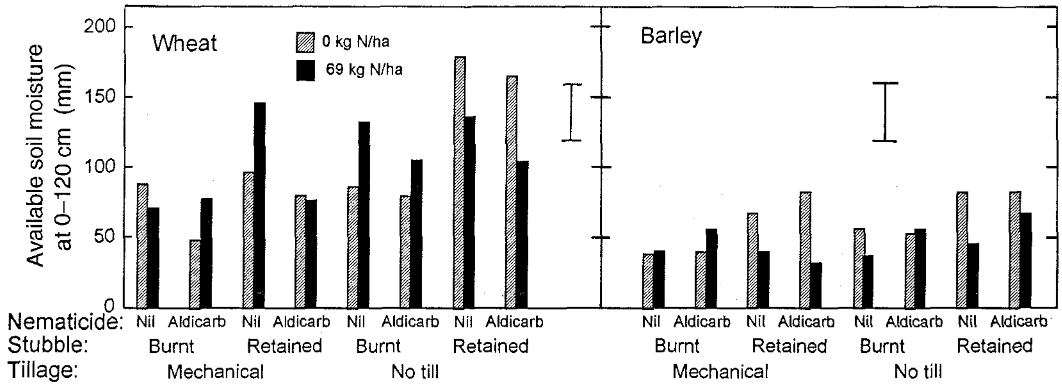

Figure 8. Available moisture (mm) in the soil profile (0–120 cm) after harvest of the 1980 crop. Vertical bars indicate l.s.d. at $P = 0.05$. Significant factorial effects: tillage ($P<0.01$); stubble ($P<0.01$); stubble x nitrogen ($P<0.01$); crop ($P<0.01$); tillage x crop ($P<0.01$); stubble x crop ($P<0.05$); tillage x stubble x nitrogen x crop ($P<0.01$); crop x aldicarb ($P<0.01$).

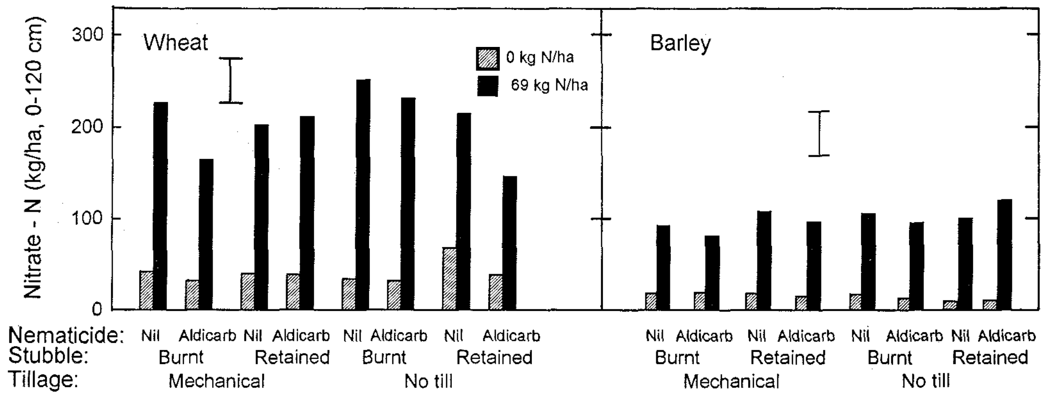

Figure 9. Nitrate-nitrogen (kg N/ha) in the soil profile (0–120 cm) after harvest of the 1980 crop. Vertical bars indicate l.s.d. at $P = 0.05$. Significant factorial effects: nitrogen ($P<0.01$); tillage x stubble x nitrogen ($P<0.05$); crop ($P<0.01$); nitrogen x crop ($P<0.01$); tillage x stubble x nitrogen x crop ($P<0.05$); aldicarb ($P<0.05$).

was present after growth of barley than wheat and less after application of aldicarb. There was less nitrate after growth of wheat on no tillage with stubble and aldicarb than on the same treatment without aldicarb.

Discussion

Barley cv. Clipper (highest yield of 3.2 t/ha) far outyielded wheat cv. Timgalen (highest yield of 1.22 t/ha); overall, the yield of barley was 161% that of wheat in this experiment in this year. Large differences have also been obtained on farms infested with high populations of *P. thornei* when wheat and barley have been compared in single-season experiments (Thompson *et al.* 1980). However, the yield advantage of Clipper barley over Timgalen wheat was only 18% on a nematode-free site on the Darling Downs (Thompson 1983). Clearly, Clipper barley is more tolerant of root-lesion nematode than is Timgalen wheat. This is confirmed here by the fact that wheat responded to the application of the nematicide aldicarb with a 42% yield increase, whereas barley did not. Although nematicide did not improve the best yield of wheat to equal the best yield of barley, this difference is likely to be still largely attributable to nematodes. Thompson *et al.* (1982) showed that the rate of aldicarb used in this experiment is suboptimal for maximum yield increases, and complete control of the nematode is rarely possible under dryland conditions even at optimal rates of nematicide. Marley and Littler (1989) partly attributed the poorer performance of wheat under retained stubble to the foliar disease yellow spot, caused by *Pyrenophora tritici-repentis* (Rees and Platz 1979). Yellow spot was not evident on the crop in 1980 because of the dry weather and is not a factor in the results obtained.

The crop on some of the treatments became severely stressed towards anthesis because only 56.4 mm of rain had been received since sowing. This was particularly noticeable in barley growing on the mechanical-tillage, stubble-burnt treatment with a high rate of N fertiliser, which produced a final yield of only 0.62 t/ha. However, barley on no tillage with stubble retention appeared relatively unstressed as it took advantage of the extra soil water stored in that treatment and produced a final yield of 3.2 t/ha. In contrast, wheat could not respond fully to the extra stored moisture under no tillage with stubble and was restricted to a maximum yield without nematicide of 1.22 t/ha because of its intolerance of the root-lesion nematodes.

There was much more residual soil water and fertiliser-derived nitrate after harvest of the wheat than after barley, indicating the lesser ability of the nematode-affected wheat roots to exploit the soil.

Conclusions

These results indicate that root-lesion nematode has probably been the most important factor limiting the yield of wheat and preventing it from responding to the extra stored water accumulated during fallows under no tillage with stubble retention (Marley and Littler 1989). Previously, I showed that the supply of nitrate was the limitation for barley yields on no tillage plus stubble treatment in the Hermitage experiment (Thompson 1992). This is a problem in years of higher rainfall than 1980, and increasing the highest N fertiliser rate from 46 to 69 kg/ha has largely overcome this limitation. Control of nematodes in this experiment by the use of nematicide or by growing tolerant varieties would allow wheat to exploit more thoroughly the soil profile for water and nitrate and to yield at a similar level to barley. If economical control of root-lesion nematode in wheat can be achieved, greater yields and profits should be obtained from no tillage, stubble retention, and N fertiliser useage. Better returns to farmers will encourage wider adoption of conservation tillage practices like no tillage with stubble retention in the nematode-infested areas of the northern Australian grain region, permitting more efficient use of rainfall for crop production and lessening the risk of soil erosion.

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