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# Root-lesion nematode (*Pratylenchus thornei*) reduces nutrient response, biomass and yield of wheat in sorghum–fallow–wheat cropping systems in a subtropical environment

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ABSTRACT

Wheat in winter and grain sorghum in summer are the most important crops of the subtropical grain region of eastern Australia, where they are often grown in sequences of 1–4 years of each crop species separated by a long fallow period of 11–14 months. Growers have observed that the second wheat crop in sequence can appear nutrient deficient with poor growth and grain yield compared with the first or subsequent crops. To investigate this problem, wheat was grown in various field experiments as the first–fourth wheat in sequence after long fallow from sorghum sequences of various lengths (one–four years) to test for responses in biomass production and grain yield to fertilisers, biocidal fumigants and nematicides. Populations of root-lesion nematodes (*Pratylenchus thornei*) were greatest in the soil before the second wheat crop was sown than before the first or third wheat crops. Greatest responses in wheat growth were obtained to the nematicide aldicarb in various wheat sequence positions up to the fourth (up to 137% increased yield of second wheat). Aldicarb best protected the roots from *P. thornei* allowing increased nutrient response. The fumigants chloropicrin and dazomet caused substantial changes in soil microbial populations and available nutrients, but the systemic nematicides fenamiphos and aldicarb did not. Responses in grain yield were also obtained to N fertiliser and less frequently to P and Zn (41% increase of second wheat to NPZn fertiliser), with best overall responses to a combination of aldicarb and fertiliser. A range of tolerance to *P. thornei*, as judged by both grain yield from nil treatment and response to aldicarb and/or fertiliser, was identified among wheat cultivars. In comparison, one barley cultivar yielded maximally without treatment (up to 3.7 and 1.3 times the yield of the most intolerant and the most tolerant wheat cultivars, respectively). Integrated management using crop rotation with sorghum to reduce *P. thornei* populations combined with growing tolerant wheat and barley cultivars supplied with adequate fertiliser are practical measures to reduce the impact of *P. thornei*.



## 1. Introduction

The subtropical grain region of Australia (Webb et al., 1997) is ~200–400 km inland of the east coast extending as a belt from the central Highlands of Queensland (~22°S) to the Liverpool Plains of New South Wales (~32°S) at an elevation of ~200–500 m above sea level. The region is unique in Australia with cropping on heavy-textured soils of high water-holding capacity at any time of the year dependent on a variable rainfall (median ~600–800 mm/year) ranging from summer-dominant in the north to equiseasonal in the south. The major rain-grown crops are wheat (*Triticum aestivum* L.) in a winter growing season (April–November) and sorghum (*Sorghum bicolor* L.) Moench) in a summer growing season (September–April) (Unkovich et al., 2009). In both winter and summer crop sequences, periods of fallow of about 6 months (called 'normal or short fallow') occur between successive crops. Changing from summer to winter crop sequences and vice versa is usually via a long fallow period of ~11–14 months, except when rainfall has recharged the soil profile and 'double-cropping' with little intervening fallow is possible. Grain growers aim to keep fallows weed-free in order to store soil moisture for subsequent crops.

Some grain growers in this region have reported very poor growth and yield of the second wheat crop in sequence compared with the first following a long fallow after sorghum. Because the second wheat often appeared to be nutrient deficient, the problem was considered to be zinc deficiency with somewhat

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atypical symptoms (Duncan, 1967) related to long fallow disorder (Thompson, 1987, 1994) that in wheat took an extra season to develop after the long fallow to cause the poor growth and grain yield. Some grain growers also observed that barley (*Hordeum vulgare*) sown instead of the second wheat yielded considerably better; however, barley is not a favoured crop because of its usually lower price/tonne than wheat. This paper reports research conducted on grain farms designed to understand the cause of this apparently nutritional problem and resultant poor growth of wheat in sorghum–fallow–wheat cropping systems. Experiments were conducted to test the effects of fertilisers, fumigants and nematicides on various sequences of wheat crops after long fallow from sorghum. A number of cultivars of wheat and one of barley were compared for tolerance to the problem in some of the experiments. Results showed the dynamic role of the root-lesion nematode *Pratylenchus thornei* in exacerbating nutrient deficiencies and reducing wheat yield in sorghum–fallow–wheat cropping systems.

## 2. Materials and methods

### 2.1. Selection of the Formartin site

A grain grower in the Formartin (Lat 27.46° S, Long. 151.43 E; 364 m elevation) district of the Darling Downs, Queensland, reported wheat crops suffering from the 'second-wheat crop after long fallow from sorghum disorder' on his farm, where rotational strip-cropping was practised for water management and soil conservation (Titmarsh and Stone, 1997). The second wheat crop in sequence, following long fallow from sorghum, was observed to be growing considerably worse than the first and somewhat worse than the third wheat crop on various rotation strips. Plants of the second wheat crop were stunted, with chlorotic older leaves and younger leaves that appeared reduced in size and erect. The second wheat crop exhibited some improvement in growth from nitrogen fertiliser up to 100 kg N/ha (applied as anhydrous ammonia by the grower before sowing), but even so the second wheat looked poorer than the first or third crops. All fields had been fertilised with 10 kg Zn/ha as $ZnSO4.H_2O$, a practice advocated for long-term correction of zinc deficiency in Vertosols.

### 2.2. Selection of the Macalister site

Many patches of poor growth of wheat, generally ~3–5 m in diameter with one area ~0.5 ha in extent, were noted in a field of about 50 ha near Macalister (Lat. 27.03° S, Long. 151.07° E). This was the second wheat crop in succession following long fallow from two crops of sorghum. Of two wheat cultivars in the field, cv. Gatcher was growing worse than cv. Oxley. Affected plants were stunted with chlorosis and necrosis of the lower leaves. The crop had been fertilised with 50 kg N/ha as urea before sowing, and 6 kg P/ha as triple superphosphate applied with the seed at sowing.

### 2.3. Soil properties

The soil at both the Formartin and Macalister sites is a self-mulching black Vertosol (Isbell, 1996) of the Waco Series (Beckmann and Thompson, 1960). The sites were characterised for particle size by the pipette method (Day, 1965), and for chemical properties by methods described by Rayment and Higginson (1992) under the code numbers 3A1 = electrical conductivity (1 soil: 5 water), 4A1 = pH (1 soil: 5 water), 6A1 = organic carbon, and 7A2 = total nitrogen. Analyses were performed in duplicate on ground air-dried soil samples from nine cores composited in depth intervals of 0–15, 15–30, 30–60, 60–90 and 90–120 cm. The soils at both sites were high in clay content (Formartin 16.5% sand, 15.9% silt and 67.6% clay at 0–15 cm, grading to 13.7% sand, 13.5% silt and 72.8% clay at 90–120 cm; Macalister 19.5% sand, 12.7% silt and 67.8% clay at 0–15 cm grading to 13.9% sand, 14.3% silt and 71.9% clay at 90–120 cm). The soils were alkaline (Formartin pH 8.5 at 0–15 cm grading to 9.2 at 0–120 cm; Macalister pH 8.6–9.0), low in organic matter (Formartin 0.96–0.61% organic C; Macalister 0.86–0.58%), and total N (Formartin 0.05–0.023%; Macalister 0.071–0.043). They were slightly saline below 60 cm (electrical conductivity at Formartin 0.283 at 0–15 cm to 1.212 dS/m at 90–120 cm; Macalister 0.269–0.873).

### 2.4. Experiments 1 and 2: Crop sequence × fertiliser × (fumigant and nematicide) trials at Formartin

For Experiment 1, similar field trials were conducted on neighbouring rotation strips (134 m wide) so that the experimental crops were either the first, second or third wheat in sequence following a long fallow after a sequence of three (strips 16 and 17) or four (strip 19) sorghum crops. Each trial consisted of plots 34 m long × 1.8 m wide (nine drill rows) with 12 fertiliser treatments in three randomised blocks. Fumigant and non-volatile nematicide treatments were applied across the fertiliser treatments in a split-plot design with sub-unit treatments in strips. The fertiliser treatments were N at rates of 0, 30, 60, 120 and 240 kg N/ha as urea, with additional treatments of P (30 kg P/ha as triple superphosphate) and Zn (15 kg Zn/ha as zinc sulphate monohydrate) in factorial combination with nil and N120. There was also one 'complete nutrient' treatment, consisting of N120P30Zn15 plus other essential nutrients at rates of K55, S77, Ca100, Mg9, Mn7, Cu2.5, B0.9, Mo0.25, Co0.02 and Cl50 kg/ha (Grundon et al., 1985). The three fumigant treatments were nil, chloropicrin (220 kg chloropicrin/ha as Larvicide®), and the dithiocarbamate compound dazomet (680 kg/ha Basamid® granules), which breaks down in moist soil to active volatile compounds, principally methyl isothiocyanate.

Experiment 2 consisted of similar trials conducted in the following year on two neighbouring rotation strips so that the experimental crops were first and second wheat after long fallow following one crop of sorghum. Fertiliser and fumigant treatments were similar to Experiment 1, but with the addition of two non-volatile nematicide treatments, namely the organophosphorus compound fenamiphos (10 kg fenamiphos/ha as Nemacur® 100G) and the oximecarbamate compound aldicarb (10 kg aldicarb/ha as Temik® 100G).

The fumigants and nematicides were applied before the fertilisers in a random design as strips (1.8 m wide with a 0.6 m gap between adjacent strips) grouped across the fertiliser plots towards one end to allow for machine harvest of grain from the remainder of the fertiliser plots. Chloropicrin was injected at 12.5 cm depth through nine narrow-point tynes at 20 cm spacing using a tractor-mounted soil fumigation rig. Dazomet, fenamiphos and aldicarb were drilled into the soil at 8 cm depth through nine tynes 18 cm apart, followed by harrows, then worked with the drill in the opposite direction for mixing with the soil. Both fumigant treatments were covered by thick polythene sheeting with edges inserted into trenches 15 cm deep then filled with soil. After 14 (Experiment 2) or 15 days (Experiment 1) the covers were removed and soil was sampled to a depth of 12.5 cm by taking 20 random cores per strip using a 28 mm diameter corer. Care was taken to avoid cross contamination of samples, which were sealed in sterile plastic bags and stored at 3 °C. Samples were broken up manually (hands covered with sterile gloves), mixed and sub-sampled for microbiological and chemical analyses.

From nine positions (three per replicate) across each trial area before sowing, deep soil cores (45 mm diameter) were obtained with a vehicle-mounted hydraulic soil corer and subdivided into