Field Crops Research 161 (2014) 1–10

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Pratylenchus thornei populations reduce water uptake in intolerant wheat cultivars

J.P.M. Whish[a,*], J.P. Thompson[b], T.G. Clewett[b], J.L. Lawrence[a], J. Wood[b]

[a] CSIRO Ecosystem Sciences, 203 Tor Street, Toowoomba, QLD 4350, Australia
[b] Agri-Science Queensland, Department of Agriculture, Fisheries and Forestry, Leslie Research Centre, P.O. Box 2282, Toowoomba, QLD 4350, Australia

ARTICLE INFO

Article history:
Received 5 September 2013
Received in revised form 7 February 2014
Accepted 9 February 2014
Available online 25 March 2014

Keywords:
Soil water
Water use efficiency
Water extraction
Root lesion nematode

ABSTRACT

Pratylenchus thornei is a major pathogen of wheat crops in the northern grain region of Eastern Australia with an estimated annual yield loss of $38 million. Damaged crops show symptoms of water and nutrient stress that suggest uptake is significantly affected. In order to understand the mechanisms involved in reducing water uptake and consequently plant yield, detailed measurements of water extraction and leaf area were conducted on a range of wheat cultivars with differing levels of tolerance and resistance to *P. thornei*.

Planting wheat into high populations of *P. thornei* reduced the extraction rate (*kl*) in the intolerant cultivars; this in turn caused a delay in the root extraction velocity and effectively changed the crop lower limit. The early season stress applied by the reduced extraction rate impeded canopy development that consequently reduced demand for water and nutrients, growth and yield potential. The resulting yield loss was consistent across both a wet and a dry wheat growing season with the intolerant cultivar yielding 34% less than the tolerant cultivar. Understanding the mechanism with which *P. thornei* reduces yield allows the impact of *P. thornei* to be included in simulation models to better understand how to manage this constraint to the Australian grain industry.

1. Introduction

Root lesion nematode (*Pratylenchus thornei*) has a worldwide distribution (Nicol and Rivoal, 2008) and broad range of hosts from cereals to cut flowers and including many vegetables (Castillo and Vovlas, 2007). Its impact on wheat and cereal crops has been extensively studied (Nicol et al., 2011) highlighting its economic importance to world cereal production. In wheat producing countries *P. thornei* has been identified as causing yield losses of up to 40% in Mexico (Nicol and Ortiz-Monasterio, 2004), 70% in Oregon USA (Smiley, 2009) and 44–85% in Australia (Thompson et al., 2012a, 2008). Within Australia *P. thornei* is found in the heavy-textured clay soils of the northern grains region of eastern Australia. Its occurrence on these soils was first reported in the 1960s (Baxter and Blake, 1968; Colbran and McCulloch, 1965) and later in the 1970s as one part of the soil biological basis for 'long fallow disorder (Thompson, 1987; Thompson et al., 2012a). Over the last 30 years *P. thornei*'s importance as a major constraint to wheat production in the northern grains region has significantly increased with surveys showing its presence in 59% of surveyed farms in Queensland and 77% in New South Wales (Thompson et al., 2010). More recently its occurrence has spread westward, mirroring the history of wheat production from the early production areas on the eastern side of the northern grain region to the more recent western plains. The cost of nematodes to the northern grains industry is rapidly increasing as a result of these new occurrences and was estimated at $38 million dollars per annum (Murray and Brennan, 2009).

Crop rotation is one option for management of this pathogen, but its broad host range makes finding crops to rotate difficult. The dominant winter crops grown in the northern cropping region of eastern Australia are wheat, barley and chickpea. The summer crops are sorghum, maize, cotton and mungbean, and of these only cotton and sorghum are non-hosts (Thompson et al., 2008, 1980).

Genetic control by breeding for resistance and tolerance is considered the best approach in the long-term, being the most economically effective and the only method that allows the regional yield potential to be achieved (Thompson et al., 1999). Tolerance with respect to nematode damage is defined as the ability of the plant to withstand nematode infection and maintain yield despite experiencing high nematode pressure (Roberts, 2002). However, the nematode population can continue to increase within the

* Corresponding author. Tel.: +61 7 46881419; fax: +61 7 46881193.
E-mail address: Jeremy.Whish@csiro.au (J.P.M. Whish).

http://dx.doi.org/10.1016/j.fcr.2014.02.002
0378-4290/

Table 1
Tolerance and resistance ratings of four wheat cultivars (from unpublished data base of J.P. Thompson, J.G. Sheedy and T.G. Clewett 2013 and Queensland Wheat Varieties 2013 (Lush, 2013)) where tolerance is based on % trial mean grain yield on sites heavily infested with *P. thornei*; T = tolerant; MT = moderately tolerant; MI = moderately intolerant; I = intolerant; VI = very intolerant and resistance is based on mean reproduction factor (=final population of *P. thornei* at 16 weeks/initial population) in glasshouse experiments MR = moderately resistant; MS = moderately susceptible; S = susceptible; VS = very susceptible.

Wheat cultivar	Tolerance			Resistance		
	Overall % trial mean yield	Tolerance rating	Number of trials	Mean reproduction factor	Resistance rating	Number of experiments
QT8447	139	T-MT	19	5.8	MR-MS	14
EGA Wylie	130	MT	13	14.9	S	8
EGA Gregory	122	MT	16	11.4	MS-S	8
Kennedy	105	MI	24	19.2	S-VS	13
EGA Bellaroi	103	MI	6	5.0	MR-MS	5
Sunvex	84	I	6	15.5	S	4
Strzelecki	77	I-VI	20	20.3	VS	9

roots of tolerant cultivars. Superior tolerance levels were found among modern wheat cultivars (Thompson et al., 1999), which have enabled the development of superior lines that yield as well in high nematode infested sites as they do in low.

Resistance is the ability of the crop to suppress development or reproduction of the nematode population (Roberts, 2002). Unfortunately, it has been more difficult to find superior resistance within modern wheats. However, some partial resistance has been identified and recently this has been combined with existing commercial releases (Thompson et al., 1999). Additionally, resistance and tolerance are not always coupled and have been shown to be under separate genetic control in some plant-nematode interactions (Roberts, 2002). Throughout this paper tolerance has been used to refer to differences in yield and growth, while resistance is used to refer to limitation of nematode population development.

Grain production in the semi-arid subtropical environments of eastern Australia is dependent on water, either as in-season rainfall or as stored reserves within the soil (Whish et al., 2007). Constraints or processes that impede a plant's ability to extract water and nutrients will significantly impede the growth and development of the plant. *P. thornei* is migratory and endoparasitic, feeding and reproducing within the cortex of plant roots (Fortuner, 1977). An individual nematode invades the wheat root in a non-random manner moving along the inner cortex to lay eggs (Baxter and Blake, 1967). The second stage juveniles that emerge within 14 days continue to feed close to where they hatch and create cavities within the cortex of the root, and this damage results in visible lesions (Dropkin, 1966). The plant symptoms of stunting, reduced tillering and leaf yellowing that are exhibited in intolerant plants are similar to those caused by water and nutrient deficiency. A nematicide experiment conducted as part of a long-term tillage trial was the first work to identify *P. thornei* as the cause of incomplete moisture extraction by intolerant wheat crops (Thompson et al., 1995).

We expanded on the idea that damage to the root system by nematodes would prevent complete water extraction from the soil. We hypothesised that intolerant wheat cultivars would have a different crop lower limit (LL crop), measured in the field as the lowest measured water content for crops experiencing terminal drought (Dalgliesh and Foale, 1998; Gardner, 1985; Gerakis and Ritchie, 2002) and reduced plant available water capacity (PAWC) when grown under a high nematode pressure than a low nematode pressure. Thus, wheat cultivars that are tolerant to nematodes would also have a greater plant available water capacity when grown on a soil with a high nematode population and the additional water would account for the additional yield.

It has been shown that plant biomass and grain yield have a near linear negative relationship with increasing populations of nematodes (Owen et al., 2005; Thompson et al., 2012a). The aim of this work was to quantify if the reduction in yield caused by *P. thornei* was as a result of:

(1) A reduction of plant root biomass, effectively decreasing the plant available water content (PAWC) and limiting yields by reducing the yield potential.
(2) Damage to root function, reducing the ability of roots to extract water resulting in reduced growth and development.

2. Methods

Experiments were conducted at one site (Formartin) in 2011 and two sites (Formartin and Yallaroi) in 2012.

2.1. Field sites

2.1.1. Formartin

A field experiment was conducted over two cropping cycles 2011 and 2012 at the Formartin research site (27.46401°S, 15142616° E). This 15-ha site is dedicated to *P. thornei* research. A four-year rotation used to manage the *P. thornei* population is sorghum followed by a 15-month weed free fallow, followed by a *P. thornei* susceptible wheat (Kennedy[1], S-VS, Table 1) used to build up the nematode population (∼2000 *P. thornei*/kg soil, Table 3), then a short 6-month fallow before use as the experimental site. Following the experimental phase there is a second 10 month weed-free long fallow to return to the sorghum phase. The sorghum crop and the two long fallows deplete the nematode population. The soil is a haplic, self-mulching endohypersodic black Vertosol (Isbell, 1996) of the Waco Series (Beckmann and C.H. Thompson, 1960). The plant available water capacity for a wheat crop (PAWC) was 288 mm to a depth of 1.8 m (Hochman et al., 2001) (Table 2).

2.1.2. Yallaroi

Experiments at the Yallaroi site (29.105481° S, 150.624619° E) were conducted in 2012 after the site had been managed in 2011 to create strips of high and low nematode populations. The site was selected because of its naturally high population of *P. thornei* of >2000/kg soil in the surface (0–0.3 m) layer. In 2011, strips of Sunvex (S) a bread wheat and EGA Bellaroi (MR-MS) a durum wheat (Table 1) were sown. Post-harvest testing of the soil revealed that Sunvex[A] had encouraged a high nematode population of ∼3000 *P. thornei*/kg soil (0–0.9 m) and the EGA Bellaroi had maintained the population at ∼200 *P. thornei*/kg soil 0–0.9 m (Table 3). The soil was a Black Vertosol (Australian soil

[1] Varieties used in this work are protected under the Plant Breeders Rights Act 1994.