Rooting patterns in wheat differing in vigour are related to the early uptake of nitrogen in deep sandy soils.

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Abstract

Early vigour, and deep and fast root growth are desirable characteristics for wheat (*Triticum aestivum* L.) grown on the deep sandy soils of the Mediterranean climatic region of Western Australia, where large quantities of NO_3^- are moved rapidly down the soil profile before nitrogen uptake is possible. The difference between the vigour wheat lines, Vigor 18 and B18, and Janz, a current commercial cultivar widely adapted in Western Australia, on the growth and proliferation of roots was compared.. Plants were grown in a glasshouse in glass-walled boxes filled to a depth of 1 m with sandy soil, collected from a field site, and under non-limiting water and nutritional conditions. Root length, root number and distribution along the soil profile were non-destructively measured at 48 h intervals by a mapping technique. Shoot and root biomass and nitrogen uptake were measured destructively at stem elongation. Maximum rooting depth of the vigour wheat lines was not different to that of Janz. The vigour wheat lines branched earlier and considerably more prolifically in the top 0.7 m of the soil profile, resulting in higher root number, higher root length density and presumably improved the capture of nitrogen before it moved down the soil profile. Cumulative root length of the vigour wheat lines from the 1-leaf stage to stem elongation was 83% higher than that of Janz.

Media summary

Different rooting patterns between vigour wheat lines and a current commercial cultivar widely adapted in Western Australia were found. These differences may help to reduce the quantities of NO_3^- lost early in the season.

Key Words

Vigour wheat, root growth, root proliferation, nitrogen capture.

Introduction

Wheat (*Triticum aestivum* L.) is the most important crop in the Mediterranean climatic region of Western Australia with over 5 million ha sown each year. Wheat is normally sown on the first major rainfall from mid May through to the end of June. In this region, 75% of the annual rainfall occurs between May and October. Under these conditions, water and nitrogen are often lost by deep drainage in the winter months when crop growth and nitrogen uptake is slow due to low temperatures and low solar radiation (Turner and Nicolas 1988). Losses of nitrogen by leaching include the inorganic nitrogen, available in the soil profile at the break of the season, chiefly NO_3^- (Fillery, 2001), and the nitrogen applied as fertiliser (Anderson et al. 1998). A poor synchronisation between the availability of NO_3^- in the soil profile and the NO_3^- demand by the wheat crop is attributed to these losses of nitrogen (Angus 2001) and is responsible for the typical 30 to 50% recovery of the nitrogen fertiliser applied to the soil in wheat crops in Western Australia (Fillery and McIness 1992).

Nitrogen fertilizer is an expensive input representing one third of the costs of wheat production in many areas of the wheatbelt of Western Australia, where wheat crops are inefficient users of nitrogen (Fillery and McIness 1992). Measures to reduce the leakage of NO_3^- below the rooting zone by improving the nitrogen uptake efficiency by wheat crops are being sought. Agronomy practices that change the time of supply of nitrogen to match the availability of nitrogen in the soil with the demand by the crop are limited by the rapid mobilization of nitrogen within the soil profile and the time taken for the roots to grow and proliferate in response to the nitrogen availability. Improving the ability of root systems to recover soil NO_3^- by earlier and faster uptake of NO_3^- is a more effective strategy to minimize NO_3^- losses and improve nitrogen uptake efficiency (Liao et al. 2004). This strategy dictates that roots grow faster and proliferate earlier to intercept and capture the NO_3^- before it moves below the rooting depth of wheat crops. Correlation between root biomass, root length and uptake of NO_3^- have been reported in wheat (Liao et al. 2004) indicating that wheat crops with bigger and deeper root systems may be more effective in capturing nitrogen. Genotypic differences in the early uptake of nitrogen have been shown in wheat genotypes differing in vigour and they have been associated with differences in early root biomass (Liao et al. 2004). Vigour wheat genotypes have larger leaf area, larger shoot biomass (Rebetzke and Richards, 1999; Richards and Lukacs 2002), and larger root biomass (Liao et al. 2004) than current cultivars. While the early uptake of nitrogen by vigour wheat is presumably controlled by the crop growth (Liao et al. 2004), the important agronomic question concerns the relationship between early uptake of nitrogen and root growth and proliferation. We have commenced studies to examine the rooting patterns of vigour wheat and in this paper presents the general analysis of root growth and proliferation of wheat genotypes differing in vigour.

Methods

In order to examine in detail the early rooting patterns of vigour wheat, a glasshouse experiment was conducted in 2002 in Perth, Western Australia. Janz wheat and the vigour breeding lines Vigor 18 and B18 selected by Richard Richards and Greg Rebetzke at CSIRO Plant Industry were grown in glass-walled boxes filled to a depth of 1.0 m with soil. The soil was yellow sand (Typic, Xeric Psamment; Uc5.22; siliceous sand). The soil was packed to a bulk density of approximately 1.54 g cm^{-3}. At sowing, the equivalent of 5g N m^{-2} as urea and 1.8 g P m^{-2} as amended superphosphate (Cu, Mo, Zn) was mixed into the top 0.1 m of soil in each box. There were 4 seedlings per box (equivalent to150 plants/m^2). The 4 replicates for each genotype, and the boxes were arranged randomly at 0.05 m apart. The glass wall of each box was covered with a black PVC sheet to avoid any exposure to light. The plants were grown in a naturally-lit greenhouse with day/night temperatures of 20/10 ?C, and natural photoperiod about 10 h. The plants were watered daily by hand to maintain soil water content close to field capacity. Every 48 h from the time the seedlings were at the 1-leaf stage, until they were at stem elongation, the growth and proliferation of the roots were followed by tracing on a transparent plastic film all the visible new roots.

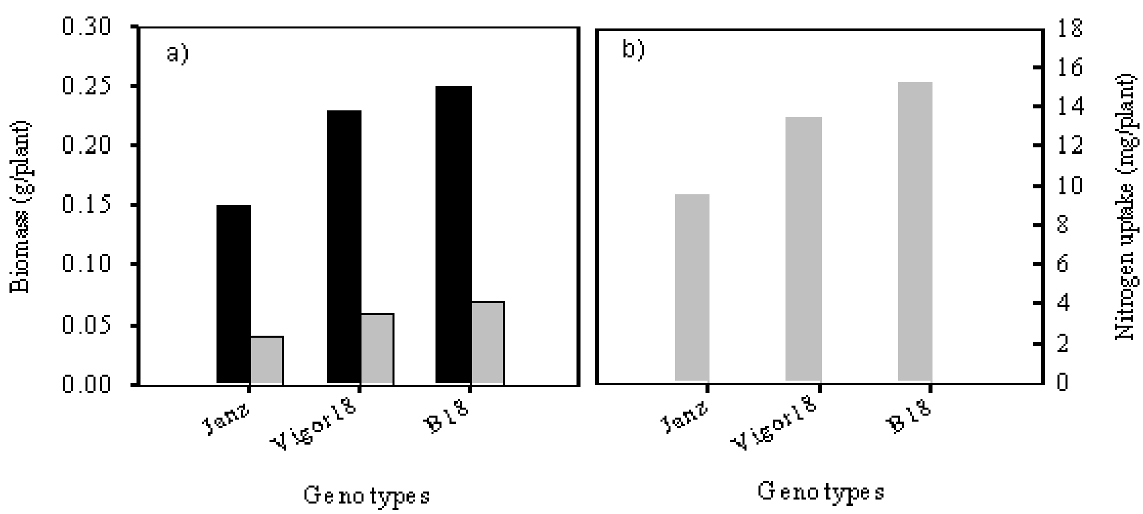

Figure 1. (a) Shoot biomass (black bars), and root biomass (grey bars) and (b) nitrogen uptake of Janz a current wheat commercial cultivar and vigour wheat lines, Vigor 18 and B18 at stem elongation.

The visible new roots were also traced on the glass wall in order to identify the new root growth at the subsequent set of measurements. When the vertical roots reached the bottom of the box around stem elongation the plants in each box were harvested. Above-ground and below-ground biomass was measured in each box by separating the shoots from the roots before being dried at 70 ?C and weighed. The soil in each box was separated in 0.1 m sections, sampled and the roots in each section were recovered from the soil following the methodology described by Palta and Fillery (1993). Roots recovered from each section were stained for 30 minutes with 0.1% (w/v) methylene blue, scanned and the images were analysed as below. The root material was then dried and weighed. Root length density was calculated as root length (cm) per cm^3 soil. Total nitrogen in shoot and root was determined using a VG-Micromass Sira 10 (V-G Isogas Ltd, Middlewich, England) connected to a Europa Roboprep C-N Analyzer (Europa Scientific Ltd, Crewe, England). The transparent film for each tracing day was also cut into 0.1 m sections and each section was scanned using a Scan Jet, Hewlett Packard scanner connected to a computer. The images were analysed for the root length in each section and for each tracing day using ROOTEDGE (Rootedge, 1999).

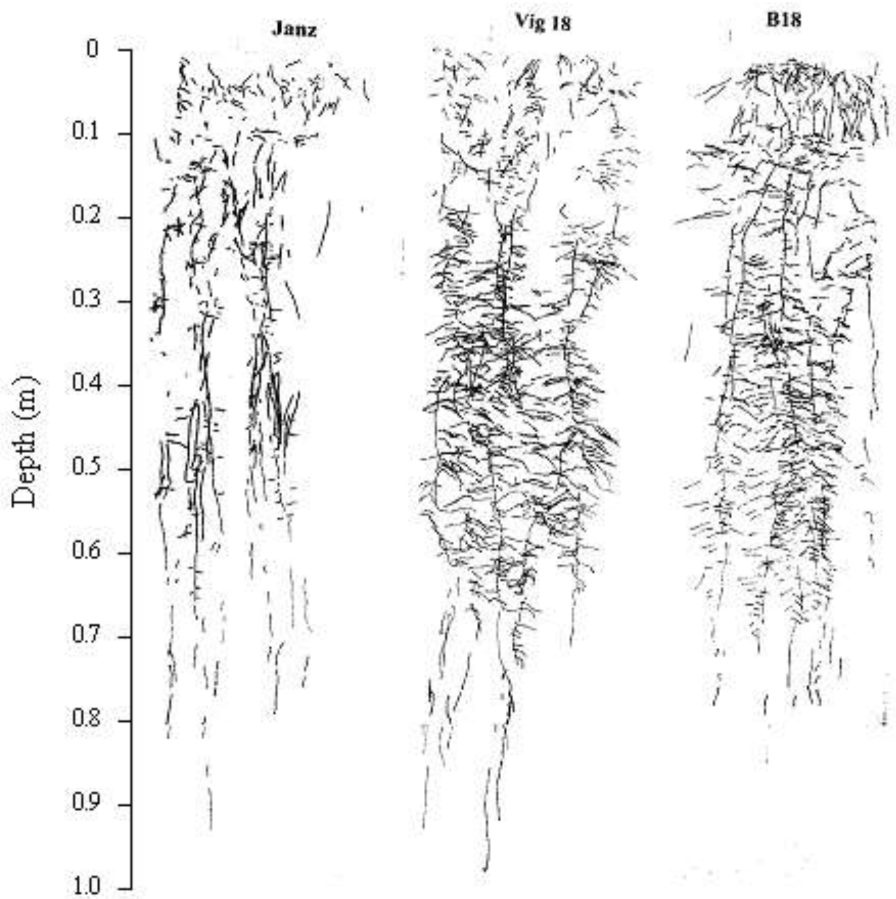

Figure 2. Early rooting patterns in cv. Janz, and the vigour wheat lines Vigor 18 and B18 visible through the wall glass of the growth boxes

Results

Shoot biomass of the vigour wheat lines, Vigor 18 and B18 was 47-67% larger than the shoot biomass of Janz at stem elongation. At the same stage of development root biomass and nitrogen uptake by vigour wheat lines was 50-70% and 42-60%, respectively, higher than in Janz (Fig. 1). There were no differences in the maximum rooting depth between the vigour wheat lines and Janz at stem elongation. However, the roots of the vigour lines branched earlier and considerably more down the soil profile than the roots of Janz. Branching of the vigour lines was more plentiful in the top 0.7 m of the soil profile than in Janz (Fig. 2). This branching increased significantly the number of roots per cm^2 in the vigour wheat lines. The number of roots below 0.7 m of the soil profile was similar in the vigour lines and Janz. Root length density in the vigour wheat lines was significantly higher than in Janz in the top 0.7 m of the soil profile at stem elongation (Fig. 3). Root length density below 0.7 m of the soil profile was similar in the vigour lines and Janz. Cumulative root length from 1-leaf stage to stem elongation was 83% higher in the vigour wheat lines than in Janz.

Conclusions

There is evidence of different rooting patterns between the vigour wheat lines, Vigor 18 and B18 and Janz a current wheat commercial cultivar widely adapted in Western Australia. The much larger root biomass of the vigour wheat lines resulted from an early and prolific root branching in the top 0.7 m of the soil profile rather than from deeper roots.

The early and abundant root branching in the vigour wheat lines, Vigor 18 and B18 increased the number of roots, the root length density and presumably improved the capture of nitrogen before it moved down the soil profile. At any given time from 1-leaf stage and stem elongation the root growth of the vigour wheat lines, Vigor 18 and B18 was larger than in Janz. More work is required to capitalize on this new finding, particularly on the identification of root system characteristics able to intercept most of the nitrogen before it moves below the rooting depth.

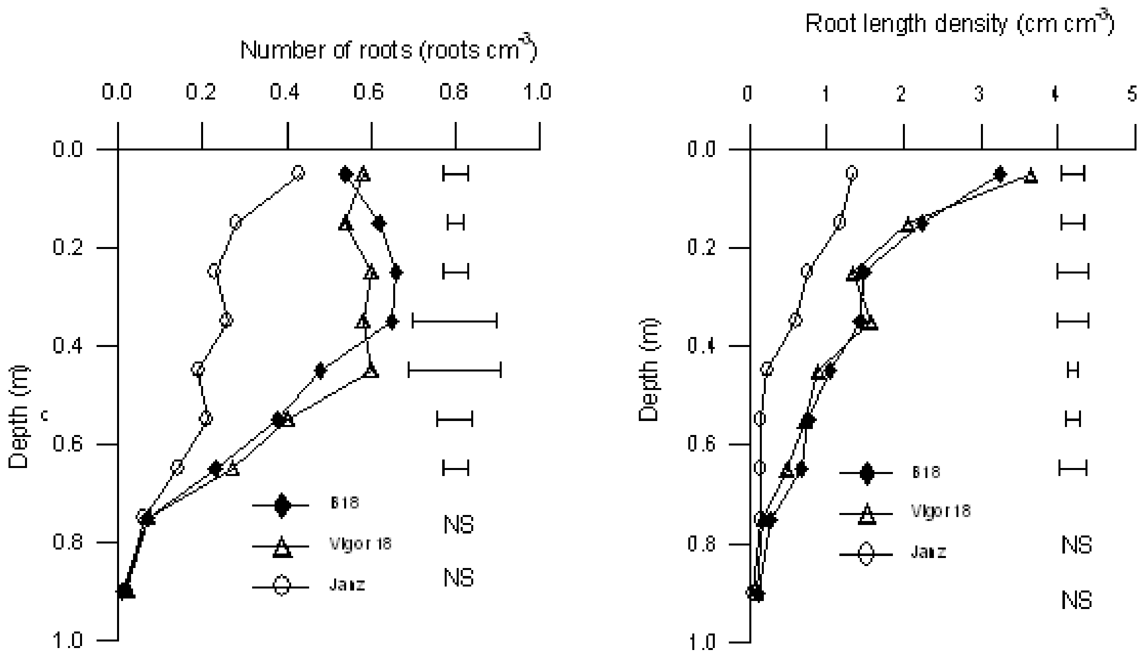

Figure 3. (a) Root number across the soil profile and (b) root length density of cv. Janz, and the vigour wheat lines Vigor 18 and B18 at stem elongation. Horizontal bars represent the l.s.d. (P=0.05)

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