Root Growth of Rotation Crops

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Introduction

Many Australian cotton growers sow rotation crops after irrigated cotton assuming that they will improve soil quality, reduce pest and disease incidence, and maintain profitability of cotton. Commonly used rotation crops include wheat, faba bean and field pea (Cooper, 1999). Research suggests, however, that in cracking clay soils, wheat may be a better rotation crop than legumes such as field pea and faba bean due to several factors; *viz.* wheat results in better soil structure, is more tolerant of moderate salinity and high sodicity, facilitates recycling of leached N and is not an alternative host for black root rot of cotton (Hulugalle *et al.*, 1999, 2001, 2002). Consequently sowing wheat after cotton results in greater long-term profitability than sowing legumes (Hulugalle *et al.*, 1999, 2001, 2002). With respect to soil N, short-term studies suggest that legumes sown after cotton can greatly increase root zone soil N (Rochester *et al.*, 1998). Over a long-term, however, differences in soil N between legumes and wheat are less dramatic due to recycling of leached N by the latter (Hulugalle *et al.*, 1999, 2001).

This paper presents results from an on-farm experiment in northwestern New South Wales, Australia. Elsewhere (Hulugalle *et al.*, 2001) we have reported details of changes in soil organic C, N, and structure; cotton lint yield and fibre quality; and profitability between 1993 and 1999 at this site. In this paper, details of root growth and water extraction by the rotation crops are reported for the same period.

Materials and methods

The experiment was located on at "Glen Arvon", a commercial cotton farm near Wee Waa in north-western New South Wales (30° 13'S, 149° 27'E). The soil at the experimental site is a medium grey clay. Mean annual rainfall is 616 mm. Clay, silt and sand contents in the 0-0.6 m depth are 55%, 18% and 27%, respectively. Soil pH (in 0.01M $CaCl_2$) was 7.4, organic C was 0.98% and $EC_{1:5}$ was 0.10 dS/m in June 1993. The cropping sequences used in were cotton followed by N fertilised wheat (urea at 140 kg N/ha in 1993; 120 kg N/ha thereafter), unfertilised wheat, unfertilised grain legumes (chickpea in 1993; faba bean thereafter) which were either harvested or the grain incorporated during land preparation. Between harvesting the rotation crop in December and sowing cotton in October a chemical fallow was imposed. Insect damage in 1995 and late sowing in 1997 resulted in poor flowering and seed production by faba bean. Consequently, faba bean grain was not harvested and the crops were ploughed in. Both faba bean treatments were, therefore, identical in these years. A randomized complete block experimental design with 4 replications was used. Individual plots consisted of twenty-four cotton rows, each 400-m long, spaced at 1-m intervals. Land preparation after cotton consisted of minimum tillage with an aer-way cultivator and residue incorporation into the ridges. The rotation crops were sown in rows spaced 0.25 m apart, whereas cotton was sown in rows spaced at 1-m intervals. Land preparation for cotton consisted of incorporating rotation crop residues with a disc-plough followed by ridging. Commercial cropping practices (mechanised chemical application, and harvesting; aerial application of pesticides and defoliants etc.) used in local farming systems were followed, with all field operations being performed by the co-operating farmer. All crops in the cropping sequences were irrigated by furrow irrigation at a rate of 1 ML/ha.

Root growth of the rotation crops was measured in November 1993 and 1995 with the trench-profile method (Smit *et al.* 2000) using a 5 cm x 5 cm root grid which was 1-m wide and 1-m deep. After a 1.2 m deep trench was dug with a back-hoe at right angles to plant rows, the grid was placed on the exposed profile face between 2 ex-cotton rows and the root number in each 5 cm x 5 cm square counted and recorded. Data is presented as the total root number in each 5-cm deep x 1-m wide depth increment in the soil profile. Root density was analyzed by fitting the data to a model of the form: $y = ae^{-bx}$ where y is root number in a 5 cm deep x 100 cm wide section and x is depth, and regression analysis used to compare the resulting curves for the individual treatments. Root distribution was analyzed similarly with y being defined as (the root number in a 5 cm deep x 100 cm wide section/the total root number in the 100 cm x 100 cm profile face) x 100. Soil water content in the 0.2-1.2 m depth was measured with a neutron moisture meter and that in the surface 0.2-m was measured gravimetrically.

Results and discussion

Root growth

Root densities of the cereal crops in 1993 were higher than those of the chickpea crops in the subsoil, but were similar or lower in the surface 30-cm. In 1995, root densities in the subsoil was in the order of N fertilized wheat > unfertilized wheat = grain-incorporated faba bean > grain-harvested faba bean. The high subsoil root densities of the N fertilized wheat was probably due to the application of N fertilizer at sowing. There was little difference in soil surface root densities of the rotation crops. In comparison with 1993, root densities of all crops were significantly higher in 1995. This may be due to an increase in soil nitrate-N (Hulugalle *et al.*, 2001) with time in all treatments. Part of the increase in root densities of the legumes may be a species effect due to substitution of faba bean for chickpea. Greatest increases in the 100-cm x 100-cm profile occurred with the cropping systems which had the greater nutrient input, *viz.* N fertilized wheat (by 68%) and grain-incorporated faba (by 79%). As the increase in root density of the latter was greater than that with the seed-harvested legume (36%) it was probably due to the additional nutrients supplied by the chickpea seed incorporated in 1993. The distinct reduction in root density in the 20-30 cm depth of the unfertilized wheat in 1993 suggests the occurrence of a compaction layer, whereas

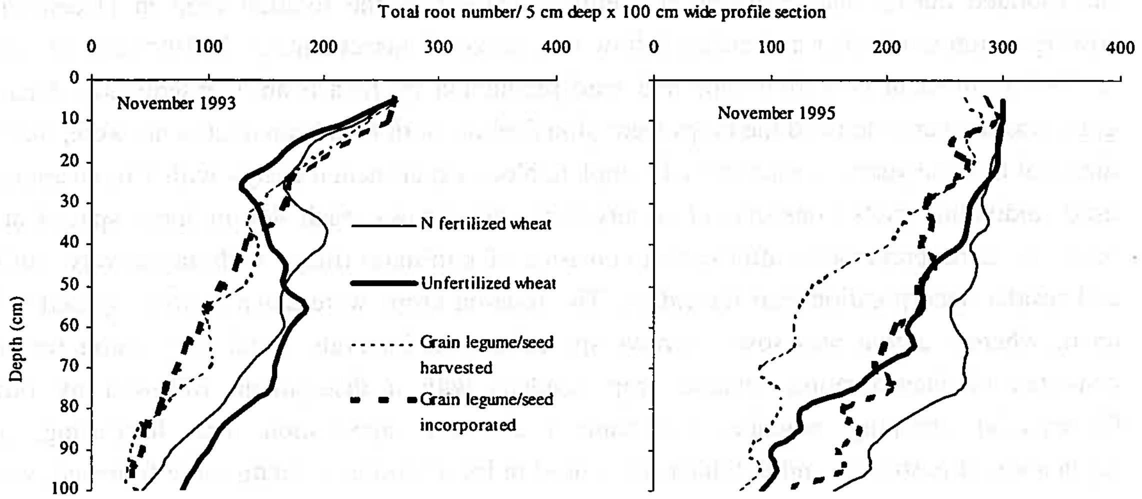

Figure 1. Root densities in a 100 x 100 cm profile face under wheat and grain legume crops, November 1993 and 1995

neither the N fertilized wheat nor the legumes showed a similar reduction. The addition of an external supply of N either as inorganic fertilizer or atmospherically fixed N may have overcome the effects of what was presumably mild soil compaction. The exponential model used gave a good "fit" to the data; r values ranged from 0.6 to 0.9, with the poorest fit occurring with the unfertilized wheat crop in 1993, and may be due to the presumed compaction effect. The legumes had a higher proportion of their root systems in the surface 0.30-m, whereas the reverse was true for the wheat. Root concentration in soil cracks was common under the legumes in both years, whereas this was less frequent under wheat in 1993 and relatively infrequent in 1995.

Profile water content

Profile water depletion to a depth of 1.2-m was faster with the wheat crops until grain filling commenced. Thereafter due to nutrient stress, water depletion by the unfertilized wheat declined sharply such that it was in the order of N fertilized wheat > grain-incorporated faba bean = grain-

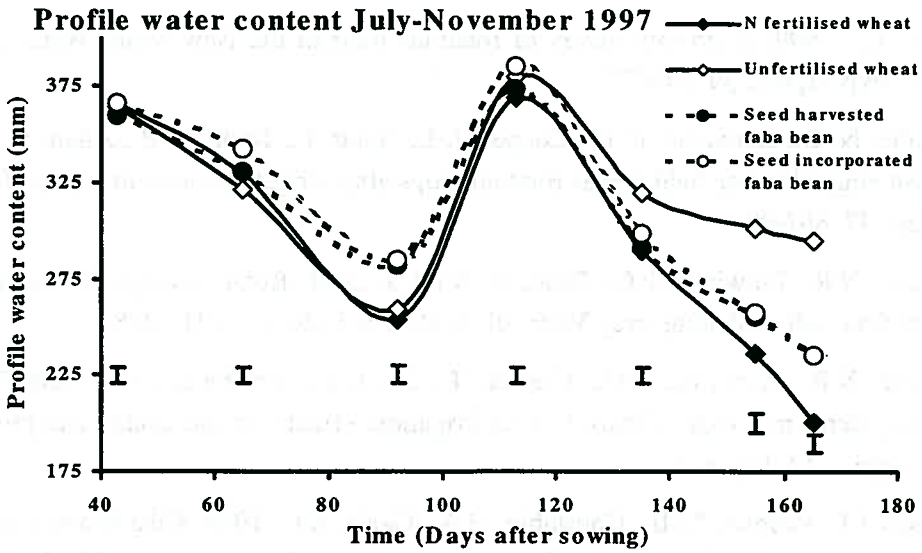

Figure 2. Profile water content under the rotation crops, July-December 1997. Vertical bars are standard errors of the means

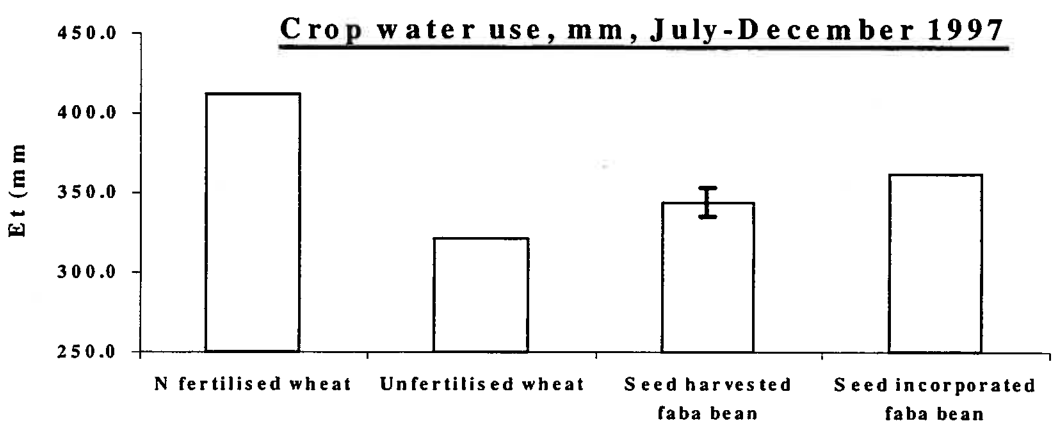

Figure 3. Effect of rotation crop and its management on crop water use. Vertical bar is the standard error of the means

harvested faba bean > unfertilized wheat. Seasonal water extraction was highest with N fertilized wheat.

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Conclusions

Subsoil root densities were highest with N fertilized wheat with grain legumes tending to have lower values. Addition of nutrients (such as incorporation of seeds instead of harvesting) can, however, increase legume root numbers. In comparison to wheat, the legumes had a higher proportion of their roots in the soil surface horizons and they tended to be concentrated in soil cracks. Profile water depletion reflected root densities and water extraction was greatest with N fertilized wheat.

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