SOIL PHYSICAL STATUS IN A LONG-TERM LAND MANAGEMENT TRIAL AND ADJACENT NEW TRIAL AT HALBURY, SOUTH AUSTRALIA

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Abstract

Data from a long-term tillage and crop rotation trial and a new trial adjacent to it were compared. The new trial has been established to address subsoil constraints in order to lift yield to its potential. This has not been achieved in the old trial. Soil compaction resulted in high bulk density for conventional cultivation continuous cropping (C+) for both sites. The bulk density ranged from 1.2 to 1.6 t/m^3 for no-till pasture-wheat (R-) and C+ for 0-15 cm at the old site. The new site had a high bulk density of between 1.7 and 2.0 (0-15 cm). This reduced steady state infiltration to less than half of that for the long-term trial (12 and 30 cm^3/minute respectively - means of all tillage treatments for the long-term trial). There was >2 times increase in macroporosity (>0.5 mm equivalent diameter) in the long-term trial for R- compared with C+ and? >3 times compared with the new site. The higher macroporosity is attributed to higher earthworm numbers. An examination of clean broken core faces, at 5 and 10 cm, of R- soil cores showed that 60-70 % of the surface was visible old and new casts compared with only 5 % in the C+ of the old site and 0 % in the C+ of the new site. Penetrometer measurements at a mean water content of 14 % w/w at the old site (means of all treatments) ranged from 5 to 7 MPa at 5-10 cm while at the new site they ranged from 7 to 8 MPa at the same depth at a mean water content of 15 %. Penetration resistance between crop row was significantly greater in conventional cultivation (CC) plots than no-till (NT) and tillage rotation (TR) plots. The big differences in soil physical status between the old and the new trials leaves a big scope for improvement in the new trial.

Key words: Soil structure, tillage, rotation, water use efficiency, bulk density, infiltration rate, earthworms, pore size distribution.

Shallow red-brown earths comprise the largest percentage of soil on which cereals, pulses and pastures are grown in SA. Because of their shallowness and the effects of tillage, they retain little water relative to well structured soils. A long-term trial has been run on a red-brown earth at Halbury, SA for the last 18 years to test the effects of different tillage and crop rotations on soil properties and crop production. Despite consider-able improvement in soil physical properties in the conservation treatments, where total water use efficien-cy based on differences in available water content at anthesis was greater with No-till pasture-wheat (R-) than with conventional cultivation continuous cropping (C+), yield for all treatments remained lower than the potential yield for the area (1). We believe that we can raise the yield if we understand the causes and nature of the subsoil conditions that have developed under contrasting tillage regimes. Therefore a new trial was established in 1996 adjacent to the old site to study subsoil constraints which restrict infiltration and root growth and water use efficiency. The treatments include three tillage regimes: conventional cultivation (CC) wide shares; no-till (NT) narrow points; and tillage rotation (TR). TR is a treatment in which depth of tillage and choice of tillage tool can be varied from year to year, depending on the crop sown and the seasonal conditions.

Materials and methods

Both sites are located at latitude 34^{o}04' S, longitude 138^{o}38' E, with average annual rainfall of 450 mm and soil texture (0-10 cm layer) at the old site: clay, 22 %;? silt, 17 %; sand, 61 %. On the new site the farmer had cropped continuously using traditional systems for about 10 years and before this time he had a wheat-pasture-long fallow rotation. The number of machinery passes in 1996 was 6.

Infiltration rate at different soil depths was determin-ed simultaneously using a newly developed method based on the falling-head well permeameter principle (2). The three depths chosen (5, 10 and 15 cm) were based on the results of past research work on the long-term trial at Halbury, which indicated that degraded layers had developed within these depths.

Penetration measurements were obtained with an electrically operated cone penetrometer with a cone of 10mm diameter and 33^{o}angle. The data were logged into a computer in the field and loaded into the office computer later. Bulk density was determined on clods of approximately 125 cm^3 each from 5, 10 and 15 cm depths.

Pore size distribution was determined from the bottom end of cores (80 mm diameter) using a magnify-ing glass calibrated for a 1 mm size object and then counting pores of particular sizes. Some of the pores <0.5 mm were hard to discern and the pore numbers of this size are good estimates only.

Results

Different degrees of change in soil structure were recorded at the two sites. Soil was compacted at and below the plough depth (6?1 cm) and the A/B horizon interface at the long-term site for C+. A minimal compacted layer was observed in R- and no-till continuous cropping (C-) except at the A/B horizon interface in C-. Compaction was quite high down to the B2 horizon at the new site. Infiltration rate changed at the plough depth and at the A/B horizon interface below 12 cm at both sites.

Soil compaction resulted in a high bulk density, increased volume of solids phase and decreased infiltrat-ion rate in C+ at both sites. The bulk density at 0-15 cm ranged from 1.2 to 1.6 t/m^3 for R- and C+ at the old site, while the new site had developed an extremely high bulk density of between 1.7 and 2.2 (Fig. 1). This reduced the infiltration rate and volume and steady state infiltrat-ion to 40 % of that for the long-term trial (*eg.* steady state infiltration was 12 and 30 cm^3/minute for new site and old site, respectively, based on the means of all till- age treatments for the old long-term trial (Fig. 2).

Macroporosity (0.5 mm equivalent diameter) was upto 3 times greater in the long-term trial for R- compared with C+ or C- and the new site (Fig.3). The increase in macroporosity is attributed to an increase in earthworm numbers as an examination of clean broken soil core faces, at 5 and 10 cm, of R- showed that about 60-70 % of the surface was visible old and new casts compared with only 0 and 5% in the C+ of the new and old sites, respectively. The difference in sorptivity at 5, 10 and 15 cm depths (averaged over flux in 1, 2, and 3 minutes) (Fig. 2) was 160 cm^3/minute for R- compared with 80 cm^3/minute for C+ and 55 cm^3/minute at the new site. The high sorptivity in R- is attributed to the increased macroporosity.

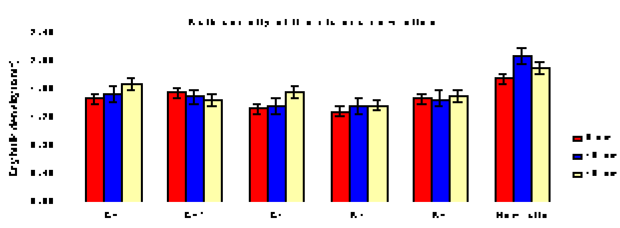

Figure 1

Penetrometer resistance at a mean water content of 14% w/w at the old site (means of all treatments) ranged from 5 to7 MPa at 5 –15 cm while at the new site it ranged from 7 to 8 MPa at 5-15 cm at a water content of 15% (data not given here). After the treatments were established at the new site, penetrometer readings in the crop row (at about 25% moisture content) showed that TR is different from CC and NT (Fig. 4a). This difference is significant ($P<0.05$) on Ln transformed data. NT and TR had similar water contents down to 300 mm depth with CC moisture content reducing below 180mm depth (Fig. 4b). Depths of cultivation/seeding for NT, CC and TR were 7, 5 and 12 cm, respectively.

Discussion

Roots are the means by which plants take up water and nutrients. Cereal roots are not able to penetrate soil with a penetration resistance 3 MPa (3). The resistance will reduce with increasing water content but for much of the growing season the water content of the upper 15 cm is within the 15-20% range. A uniform high bulk density, low infiltration rate and high resistance to penetration at the new site are consistent with other findings (4, 5), and indicate the need for improvement in subsoil physical status in order to increase root exploration and water and nutrient uptake. If the soil physical limitations can be overcome, we believe that the yield for this area can approach the potential.

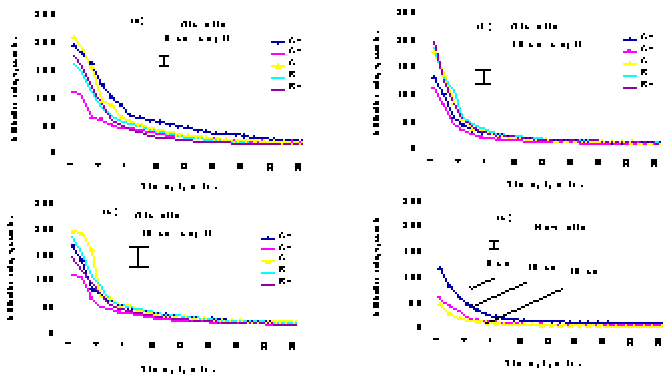

Figure 2

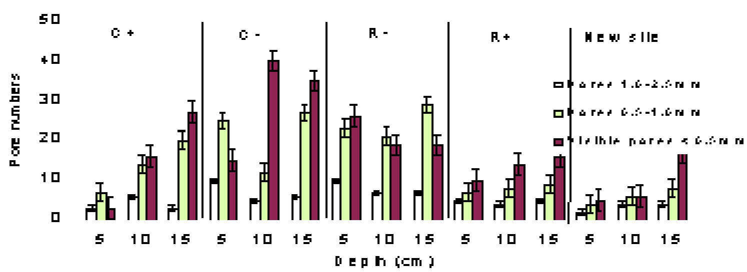

Figure 3

The big difference in soil structure between the old and the new site was due to repeated loosening of the soil (by cultivation) in the new site making it more prone to compaction by machinery, raindrop impact and overburden stress. The old trial had controlled traffic on all plots. Also for no-till plots, the continuity of pores, the abundance of earthworms and greater OC (6) played a major role in the improvement of structure of the surface and near surface soil. Because of the narrow non limiting water range (NLWR) and low water storage capacity of this shallow soil, tillage induced differences in soil water content had no significant effect on yield in the old trial.

To realise an increase in yield to its potential, we must develop and maintain continuous vertical pores to offer pathways for root growth through the compacted layer, we must reduce the soil penetration strength to 3 MPa at a water content of 14-20% (range of water content during most of the growing season) for this red-brown earth, and we must increase and maintain the depth of soil exploitable by roots. Root performance is influenced by availability of water, and therefore we must increase soil water retention by changing some chemistry and physics of the immediate subsoil. Together with disease checks and control of weeds, the new conservation tillage regime ("Tillage rotation") is likely to produce the required results, where root systems, grain and straw yield will be higher.

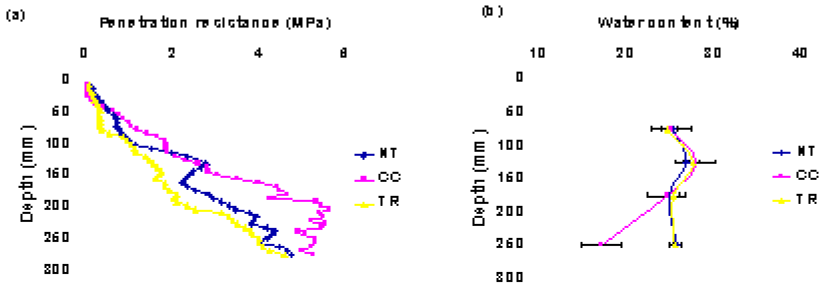

Figure 4

Conclusion

Although we have considerably improved surface and subsurface soil physical and chemical properties in the conservation treatments of the long-term trial, we have not been able to raise yield to its potential. The improvements have been mainly beneficial in terms of improved organic carbon, lower bulk density, reduced runoff, and reduced nutrients entering the waterways as a result of erosion.

The traditional methods of farming have proved to be deleterious to soil structure, thus limiting plants in extracting water and nutrients from the subsoil with adverse effects on crop yield. We believe that it is possible, with further improvement in subsoil physical conditions, and an increase in the NLWR, for yield in this area to approach the potential yield (5 t/ha).

Acknowledgment

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