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Waterlogging limits crop growth on duplex soils

By Bob Belford, Miles Dracup and David Tennant, Research Officers, Crop Science Branch, South Perth

 Duplex soils - soils with a sandy topsoil overlying a clayey subsoil - are widespread in Western Australia's agricultural areas (see map). These soils are potentially highly productive, but crop growth is variable and the soils can become waterlogged.

Work on a duplex soil site near Beverley has shown that the soil waterlogs where the permeability of the clay is low, and that this permeability varies widely over the site. Waterlogging accounts for an average of half of the variation in wheat yields on this site; surprisingly, lupins have so far appeared less sensitive to waterlogging.

The Department of Agriculture and CSIRO dryland crops and soils group are studying the causes of reduced crop growth on duplex soils to devise management strategies to overcome the problems.

About the trial site

In 1988 and 1989, the occurrence of waterlogging and its effect on crop growth on a duplex soil (sand over yellow clay) at a site east of Beverley was measured.

Mean annual and growing season (May to October) rainfalls at the site are 380 and 300 mm respectively.

Depth of sand over clay varies from 20 to 50 cm.

Aroona wheat was sown in 1988. In 1989, half the experimental site was sown to Gungurru lupins and the remainder to Spear wheat. In both seasons, crop growth was measured at 20 m intervals along two transects which were 220 m long and 100 m apart. Depths of the perched watertable in a network of 72 wells across the site were also measured.

Rainfall, depth of sand over clay, and watertables

In both years, growing season rainfall was below average: 270 mm in 1988 and 210 mm in 1989. Rain in July and August 1988 and June 1989 raised watertables close to the soil surface. At the wettest parts of the site the watertable remained above 30 cm for about 60 days in both years. In the driest parts, watertables reached 30 cm only once each year (for example, Figure 1).

Watertables were expected to rise closest to the surface where there was shallow sand over clay, but there was no relationship between depth of sand and depth of the watertable. This suggests that the permeability of the underlying clay varies considerably, and that this soil property probably accounts for much of the variation in watertable height after rain. (See 'The causes of waterlogging' on p 58).

This was confirmed by measurements of soil water content, which showed that where watertables were high and drainage was poor, water penetration, root growth and subsequent water extraction was limited to about 50 cm. However, where there was little waterlogging and drainage was good, water penetrated to at least 150 cm, and roots grew to, and extracted water from, this depth.

Crop growth and yield

In both years, it was clear soon after emergence that growth of the wheat crops varied widely across the site. These differences were apparent before the watertables rose above the clay, and therefore before roots reached saturated or impermeable layers in the profile.

Root growth was also variable. In some areas, roots in the sand were thickened and distorted, symptoms typical of restricted root growth in compacted soils.

The aerial photos on page 64 give some impression of the variation in growth of wheat at about anthesis (or flowering); in both years the most productive area was in the south-west.
(bottom left) corner of the site where there was also little waterlogging. Grain yields at the measurement points varied from 0.7 to 4.2 t/ha in 1988 with a mean site yield of 2.2 t/ha; and from 0.9 to 2.9 t/ha in 1989, mean 1.8 t/ha.

In contrast, the lupin crop yielded well (mean 2.0 t/ha) and showed less variation in early growth and yield than either of the wheat crops.

Lupins growing in areas previously associated with 'poor' or 'good' wheat growth were studied intensively. In the 'poor' area, lupin roots were severely restricted by the sand layer and reached the clay (at 30 cm depth) 100 days after sowing. In the 'good' area roots grew with little restriction through the sand and into the clay, reaching a depth of 75 cm in the same time.

![Soil profiles](image)

Soil profiles taken from areas showing good growth (the profile on the left), and poor growth of wheat.

The main difference between the profiles is in the structure of the subsoil, that from the good area having many sand-filled cracks and fissures which help water movement and root growth to depth.

![Growing season rainfall](image)

Figure 1. Growing season rainfall, and maximum and minimum watertable heights at the site at Beverley in 1989.

Map of the south-west of the State showing the area occupied by duplex soils, and annual rainfall isolyets. The area between the 350 and 500 mm isolyets is classified as 'medium rainfall.'
An aerial photo (above) of the experimental site near Beverley, taken in September 1989. An area of wheat is shown between lupin crops.

In 1988 and 1989, the most productive area was in the southwest (bottom left) corner of the site where there was also little waterlogging.

Unlike the previous wheat crop, however, lupin shoot growth and yield did not differ between these two areas, which was unexpected. The lupin crop on the 'poor' area adapted better than wheat to the stress imposed by the sand, and obtained more water from the surface soil than the crop on the 'good' area.

Soil characteristics

There are clear differences between soil profiles associated with 'good' and 'poor' wheat growth in both the sand and clay horizons (see photo of soil profiles on page 63):

- The sand horizon is medium to coarse textured with a low (less than 3 per cent) clay content at the 'poor' area, but fine to medium textured with a slightly higher clay content at the 'good' area.
- The clay horizon is sodic (high sodium content) and the clay is dispersed (poorly aggregated) in both profiles; however, the structure is massive (appears solid and devoid of pores) and contains few cracks at the 'poor' area, but contains sand filled cracks and fissures at the 'good' area.
- There are differences in quantity, position and type of gravel, which may have implications for nutrient supply to the crop.

All these characteristics will influence crop growth, particularly the better structure in the clay which promotes good drainage and root growth.

Further work, funded by the Wheat Research Committee of Western Australia, has been started to improve our understanding of how these chemical and physical characteristics affect crop growth on this and other duplex soils.
Limitations to crop growth

Crop growth and final yield can be affected by:

- Disease.
- Crop nutrition.
- Depth of sand over the clay.
- Texture or strength of the sand layer.
- Rooting depth and availability of water.
- Waterlogging above the clay, which is greatly affected by the permeability of the clay.

The incidence of disease, particularly take-all root rot in wheat, and pleiochaeta root rot and brown leaf spot in lupins, was low and fairly uniform across the site, and is unlikely to have reduced yields. However, detailed studies of the incidence of pathogens on the site have not yet been made.

Likewise, although the crops suffered from low nitrogen and copper availability in 1988, and low potassium status in 1989, these deficiencies were widespread over the whole site.

Preliminary analysis of the measured factors against yield showed that the combination of height of the watertable, soil strength, depth of sand and water extraction accounted for about two-thirds of the variation in yield of wheat, but less than 20 per cent of the variation in lupin yield.

Depth of sand over clay, and the effect of soil strength on early root growth, appeared to have little effect on grain yield.

Watertable depth alone, however, accounted for 42 per cent of the variation in grain yield of the wheat in 1988 and 72 per cent in 1989, but hardly any of the variation in lupin grain yield in 1989. Figure 2 shows the relationship between yield and mean watertable height for wheat in 1989. There must also be other causes of this variability in yield.

For the wheat crops, the more severe effect of waterlogging in 1989 than in 1988 is probably related to the earlier occurrence of watertables close to the soil surface in 1989 (Figure 1). Wheat is generally more sensitive to waterlogging when plants are small and have less ability to adapt to supply adequate oxygen to the root system.

By comparison, the lupins appeared insensitive to waterlogging in 1989, which is surprising given their sensitivity to low levels of oxygen when grown in the glasshouse (see 'Waterlogging: How it reduces plant growth and how plants can overcome its effects' on page 51).

This requires further study. In a year of above average rainfall, the severity of waterlogging and its effect on crop growth may be greater than in years of average rainfall.

The future

Further research on duplex soils in the medium rainfall area (350 to 500 mm) will:

- Continue the programme of soil measurements and crop performance at the Beverley site to confirm the relative importance of soil characteristics on crop growth.
- Start 'manipulative' work at the Beverley site, specifically to overcome problems of poor nutrition and restricted root growth in the sand, and to see if the permeability of the clay can be increased.
- Develop a 'best management' package for this site. This would include earlier sowing to help plants grow rapidly before waterlogging is likely, and higher rates of nitrogen fertilizer to minimize the adverse effects of waterlogging (see 'Waterlogging: How it reduces plant growth and how plants can overcome its effects' on page 51).
- Extend the work at Beverley to other duplex soil sites to see if crop growth and yield are influenced by the same factors.

Reference


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