An overview of the extent, distribution and impact of subsoil constraints in Western Australia's agricultural soils

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Abstract

Four broad soil groups dominate the 18M hectares of agricultural soils in south-west Western Australia (WA): texture contrast (duplex) soils; deep sands and sandy earths; gravelly soils (at least 20% gravel); and loamy earths. Numerous subsoil constraints can occur in these soils including, hard pans, acidity, poor water and nutrient holding capacity, poor subsoil structure, waterlogging, boron toxicity and salinity. Estimates of the extent and distribution of these constraints were determined using the WA Department of Agriculture and Food's map unit database. Data show that one third of WA's agricultural soils are affected by subsurface acidity and 70% are susceptible to subsurface compaction. Experimental data indicates wheat yields can be reduced by 20-40% by these induced constraints. These constraints often occur as distinct layers between 10 and 40 cm making them are more amenable to amelioration using liming or deep ripping. Low water storage affects nearly two-thirds of WA's soils and poor structure one-third. Waterlogging, subsoil alkalinity and boron toxicity are less common with 15% or less of the agricultural soils being affected. Many of these constraints are inherent and tend to be less amenable to amelioration. In these instances varieties that are tolerant of these constraints should be grown and managed appropriately.

Key Words

Subsoil constraints, acidity, compaction, liming, deep ripping

Introduction

Western Australia's southwest agricultural soils are characteristically highly weathered with low fertility. Coarse textured soils are common, deep sands and sandy earths represent 25% of the 18M hectares of cropping soils with the sandy and loamy duplexes 40% and gravelly soils which contain 20% or more gravel usually in a sandy matrix a further 10% of the agricultural soils. The soils in each of these groups often have one or more subsoil constraints which can restrict crop root growth and yield. The area affected by each of these constraints and their distribution and impact on crop yield in has been assessed for the agricultural soils of south-west Western Australia.

Methods

Extent and distribution of subsoil constraints

Estimates of the extent and distribution of individual subsoil constraints were determined using the Western Australian Department of Agriculture and Food's Map unit database (Schoknecht *et al.* 2004) accessed May 2006. Specific parameters defining each constraint were used to interrogate the database and determine the areas at high risk of the constraint occurring (Table 1; van Gool *et al.* 2005).

Table 1. Description of the parameters used to determine the extent of soils affected by subsoil constraints using the WA Department of Agriculture and Food's map unit database.

Subsurface	Subsoil parameters used to define constraint

constraint	
Hardpan	Moderate to high susceptibility to compaction
Acidity (Al toxicity)	Soils currently acid with $pHCaCl_2$<4.5 at 20 cm and those highly susceptible to becoming acid in <u><</u>10 years as determined by the pH, pH buffering capacity and acidification rate.
Alkalinity	Soils strongly alkaline with $pHCaCl_2$>8.0 at 50-80 cm.
Low water holding capacity	Low soil water storage with <70mm/m available water in top 100 cm or to the depth of a root restricting layer.
Poor subsoil structure	Poor subsoil clay within 30-50 cm.
Waterlogging	Moderate to high waterlogging risk if perched watertable <30cm for a week or more.
Boron toxicity	Risk of high subsoil B if: alkaline $pHCaCl_2$ to >7.5 at 30-80 cm; Exchangeable Sodium Percentage >6; Clay >29% and annual average rainfall <450 mm.

Impact of subsoil constraints

Subsoil constraint impact on crop performance was estimated by reviewing published and unpublished data that show the crop yield response to constraint amelioration or the benefit obtained by tolerant crop lines.

Results

The average decline in wheat grain yield from compacted hardpans, subsurface acidity and waterlogging are substantial ranging from 20-60% as determined by constraint amelioration or the use of tolerant varieties (Table 2). For example, grain yield responses to deep ripping compacted soil can be large, especially in the deep sandy earths where deep ripping can triple the rate of early root growth and allow crop roots to keep up with water and solutes moving down the soil profile (Delroy and Bowden 1986). Similarly grain yield responses to correction of subsurface acidity are also large (Whitten *et al.* 2000) but it can >5 years for surface applied lime to significantly increase the soil pH below 10 cm (Whitten *et al.* 2000). Low water storage and poor subsoil structure are common inherent constraints (Table 2) but their specific impact on yield has not been documented. Generally, subsoil constraints reduce yield. Exceptions do occur, for example, the low permeability of poorly structured subsoil below 50 cm can slow the movement of water and dissolved nutrients through sandy soils making them more available to the crop (Hamblin *et al.* 1988).

Table 2. Estimates of the extent and average impact on wheat grain yield (% decline) of the major subsoil constraints that occur in the agricultural soils of south-west Western Australia and their basic characteristics.

Subsurface	Extent of	Impact on	Basic characteristics of the constraint in WA soils

Constraint	soils at risk (%)	wheat yield (%)	
Hardpan	70	20-30	Induced through compaction or inherent as a result of soil cementation and packing processes
Low water holding capacity	60	Unknown	Inherent in sandy textured soils with low clay and organic matter content. Impact is seasonally dependant.
Acidity (Al toxicity)	30	30-40	Inherent in acid sands but is also induced by agriculture
Poor subsoil structure	30	Unknown	Inherent due to structural instability caused by high sodium (sodicity) or induced through structural decline
Waterlogging	15	35-60	Inherent or induced, common in duplexes because of the low permeability of the clay subsoil. Incidence is seasonal.
Boron toxicity	15	0-15	Inherent, incidence is restricted to sensitive crops on fine-textured alkaline subsoils (usually sodic) in regions where rainfall <450 mm. Incidence can be seasonal.
Subsurface alkalinity	10	Unknown	Inherent, considered strongly alkaline if $pHCaCl_2$ >8
Transient subsoil salinity	Unknown	Unknown	High salt levels inherent in the subsoil that fluctuates with depth and seasonal conditions.

Conclusion

Many of the subsoil constraints found in WA’s agricultural soils are inherent and amelioration is currently not economically feasible. Management of these constraints is restricted to using tolerant species and crop varieties and managing agronomic inputs according to the constraint limited yield potential. Hardpans caused by compaction and subsurface acidity are induced constraints that can often be economically ameliorated using deep ripping and liming.

References

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