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RESEARCH ARTICLE

SOIL ISSUES AND MANAGEMENT SUGGESTIONS FOR A RED KANDOSOL IN LOXTON, SOUTH AUSTRALIA

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ABSTRACT

Aiming to provide an indication of soil issues and on how to manage them for high productivity, data of chemical and physical properties of a Red Kandosol were evaluated. Values of soil analysis were evaluated and compared to the recent literature. They suggest some problems that need to be addressed before an agricultural activity can take place in the area. In general, the soil has a low level of organic carbon and a good status of exchangeable cations. However, the soil pH indicated a problem with alkalinity. This issue may have leaded to others also present, such as sodicity and phosphorus and micronutrient deficiency. In addition, this soil is also saline, and has a risk of boron toxicity. To solve these problems, alkaline and salt tolerant plants are indicated to overcome alkalinity and salinity. Sodicity can be solved by applying gypsum to decrease the exchangeable sodium percentage. This chemical use can be improved by incorporation of organic matter to the soil, which will also enhance the use of chemical fertilizers and the activity of soil microbes on the amelioration of nutrient status and cation exchange capacity.

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INTRODUCTION

This work evaluates a soil located in Loxton, which is situated at a distance of 246 km east from Adelaide, South Australia, with a mean temperature of 23.9°C and an average rainfall of 273.0 mm, with its majority concentrated during the winter (Bureau of Meteorology, 2015). The soil in this area is classified by Hall *et al.* (2009) as a Mottled-Sodic, Calcic, Red Kandosol (DEWNR, 2014).This is the second most common type of soil found in Australia, being frequently used for extensive agriculture with cereal growing and sheep or cattle grazing on native pastures. However, it commonly suffers from fertility problems and susceptibility to surface soil degradation, for example crusting and hardsetting (McKenzie *et al.*, 2004). Each one of these problems has many potential management strategies. Therefore, the aim of this work was to interpret soil profile information to provide an indication of soil issues and on how to manage them for high productivity, considering the land use capacity.

SOIL PROPERTIES

This soil has a good structure condition, as suggested by its description (DEWNR, 2014). It is moderately well drained and can be easily worked for agricultural purposes, as there are no restrictions such as stones. The water holding capacity in root zone is approximately 75 mm, and the clayey subsoil inhibits root growth to a minor extent. However, some other issues may have negative effects on root growth at subsurface. According to Hazelton and Murphy (2007), the organic carbon level of this soil is low to very low in the top 10 cm (0.40-1.0%). On the other hand, in general the laboratory data (Table 1) shows a good status of exchangeable cations. In Table 2, we observe that the Ca concentration varies from low (2-5 cmol(+)/kg) to moderate (5-10 cmol(+)/kg). Mg oscillates from moderate (1-3 cmol(+)/kg) to high (3-8 cmol(+)/kg). Na starts with a low concentration (0.1-0.3 cmol(+)/kg), and then it varies from high to very high at a depth of 21cm (Na>0.7 cmol(+)/kg). Moreover, K is high throughout all the profile (0.7-2.0 cmol(+)/kg). According to Peveril *et al.* (1999), this soil has available K in a concentration that is satisfactory for any type of crop (K>350mg/kg).

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Table 1. Laboratory data of a Red Kandosol in Loxton, South Australia (DEWNR, 2014)

Depth cm	pH H_2O	EC 1:5 dS/m	ECe dS/m	Avail. P mg/kg	Avail. K mg/kg	Boron mg/kg	Trace Elements mg/kg (DTPA)				CEC cmol (+)/kg	Exchangeable Cations cmol(+)/kg				ESP
							Cu	Fe	Mn	Zn		Ca	Mg	Na	K	
*	7.6	0.07	0.37	16	426	1.0	0.2	0.1	<0.1	0.1	6.6	3.91	1.06	0.12	0.94	1.8
0-10	7.9	0.09	0.45	18	546	1.2	0.3	2.9	4.9	0.5	8.0	4.94	1.36	0.12	1.20	1.5
10-21	8.3	0.05	0.20	5	422	1.0	0.7	2.7	3.3	0.1	11.4	6.40	2.63	0.40	1.19	3.5
21-34	9.0	0.18	0.49	<5	378	1.6	0.9	2.1	1.9	0.2	17.8	8.17	4.67	1.70	1.08	9.6
34-65	9.8	0.82	5.21	<5	355	6.9	0.9	1.9	1.4	0.1	14.9	3.05	4.71	6.41	1.15	43.0
65-100	9.7	1.19	8.00	<5	413	13.9	0.6	2.4	0.8	0.2	12.9	2.29	4.29	5.79	1.16	44.9
100-140	9.6	1.41	6.56	<5	445	15.5	0.2	0.1	<0.1	0.1	16.2	2.15	5.30	7.25	1.25	44.8
140-150	9.6	1.30	6.42	<5	474	18.4	0.5	3.2	1.0	0.2	18.1	2.00	5.85	8.76	1.33	48.4
150-170	8.1	1.41	6.26	<5	504	21.5	0.4	2.1	0.1	0.2	21.0	1.75	5.80	9.21	1.26	44.0

*Paddock sample composed of 20 cores (0-10 cm) collected around the pit.

SOIL ISSUES

The first issue here identified, and maybe the most important, is the soil pH. Based on the criteria of Hazelton and Murphy (2007), this soil has a pH mildly alkaline in the top 10 cm (pH 7.4-7.8), changing to moderately alkaline in the first 21 cm (pH 7.9-8.4) and very strongly alkaline from 34 cm (pH>9.0). Usually, soils with pH greater than 7 are unsuitable for the majority of fruit, field crops and pastures. This is because at alkaline pH, the solubility and availability of phosphorus and micronutrients are severely affected. Alkaline soils are also more susceptible to other soil issues, such as sodicity (Peveril *et al*., 1999).

Problems related to alkaline pH are proven by the laboratory data. From 21cm of depth, analysing the ESP (>6%), it is clear that another issue with this soil is sodicity (Hazelton and Murphy, 2007). The soil is marginally sodic to strongly sodic at this depth. A high concentration of exchangeable sodium can cause dispersion of the clay particles when in the presence of water. This leads to problems such as surface crusting, dense subsoil and susceptibility to erosion processes. In addition, sodicity decreases water infiltration in the soil, leading to the occurrence of water logging. Analysing the nutrient status, it is evident that there is also a problem with the soil fertility. Four out of five micronutrients analysed are below their critical levels (Table 3), and there is a low phosphorus content in the top 10 cm(16mg/kg).This value is below the requirement cited by Peveril *et al*. (1999) for many crops such as vegetables (>50mg/kg), grains (>30mg/kg) and dryland pastures (>20mg/kg). There is also a low CEC in the top 21 cm (6-12 cmol(+)/kg), which means a soil with small capacity to store and release major nutrients (Hazelton and Murphy, 2007).The ECe from 34 cm (4-8 dS/m) suggests that this soil is moderately saline (Hazelton and Murphy, 2007).

Salinity is a problem characterized by high concentration of salts in the soil, which can cause damage to plants in two ways. The first one is reducing the availability of water due to osmotic effects. During this problem, plants are not able to extract water from the soil and consequently they do not absorb nutrients. The second way salinity affects plants is by causing toxicity. However, toxicity can also be caused by an excess in the concentration of micronutrients, such as boron. We can conclude that this soil is at risk of boron toxicity from 34 cm (B>3mg/kg), as mentioned by Peveril *et al*. (1999).

Management Strategies

There is not a common and effective treatment to decrease the soil pH to a desirable extent. Several authors have studied the use of microbiological, biological and chemical treatments aiming to reduce soil pH, but neither of them with immediate results. On the other hand, Xu *et al*. (2002) studied the long-term effect of crop rotation, nitrogenous fertilizer and stubble management on the acidification of agricultural soils in South Australia. In their study, all of the treatments tested contributed to acidify the soil with a significant result, especially when there was nitrogen fertilization. Regarding sodicity, this soil is considered as potentially dispersive from 10-34 cm of depth (Hazelton and Murphy, 2007).Consequently, it is necessary to decrease the ESP to avoid future problems. A simple and efficient method used in Australia to decrease ESP and improve soil structure is applying gypsum. However, deep ripping and incorporation of organic matter can also be used, enhancing the chemical use (Peveril *et al*., 1999). If combined with irrigation, the use of gypsum could solve two problems simultaneously, sodicity and salinity, as described by Filho *et al*. (2012) studying saline-sodic soils.

Table 2. Exchangeable cation status at different depths of a Red Kandosol in Loxton, South Australia, according to Hazelton and Murphy (2007)

Cation	Status (soil depth)
Ca	Low (0-10 cm) / Moderate (10-34 cm)
Mg	Moderate (0-21 cm) / High (21-170 cm)
Na	Low (0-10 cm) / High (21-170 cm)
K	High (0-170 cm)

Table 3. Micronutrient critical levels (mg/kg) in the top 10 cm of a Red Kandosol in Loxton, South Australia, according to Peveril *et al.* (1999)

Micronutrient	Critical level
Cu	0.3 (mg/kg)
Fe	4.5 (mg/kg)
Mn	1.0 (mg/kg)
Zn	0.7 (mg/kg)

Leaching irrigation is the most effective method to control salinity. However, it would be unfeasible for the area (with an annual rainfall of 273.0 mm) as it requires a large volume of water, especially if the water used to irrigate is already saline. In addition, this irrigation technique has a complex process and it is not always completely effective, as describe by Biwas *et al.* (2009). Therefore, using salt tolerant crops might be the most viable way to overcome this problem. Roy *et al.* (2014) describe many Australian relevant crops, such as wheat, barley, cotton and vegetables that have been improved to carry salinity tolerance traits. A fertility management for this soil would be necessary to overcome nutrient deficiency. This fertility management would optimize productivity and assure a sustainable long-term use of the land. It can be achieved basically with the use of chemical fertilizers, but there is also the possibility of using soil microbes (arbuscular mycorrhizal fungi, *Rhizobium* etc.) and organic methods of fertilization with economic and environmental benefits (Miransari, 2011). The last one, specifically, can help by adding organic matter to the soil, improving the cation exchange capacity.

To overcome phosphorus deficiency, it is necessary the use fertilizers rich in phosphorus, such as triple superphosphate (20%) or diammonium phosphate (23%). The last one can also bevery useful as a nitrogen source (Stockdale *et al*., 2013). Moreover, there are dozens of micronutrient fertilizers that can be applied via soil, foliar or fertigation. However, it is necessary to pay attention to possible toxicity problems. If already existent, boron toxicity in this soil can be overcome by leaching irrigation, with the use of gypsum or with the use of tolerant plants (Nable *et al*., 1997).

Recommendations

The following suggestions on how to deal with the issues discussed in this paper are based on information gathered from several studies. Moreover, all of them aim to improve soil management for high productivity. However, these guidelines may not always be the best options, which will depend on a variety of aspects, such as the availability of economic resources and the cost-benefit ratio. Alkalinity: a good strategy could be initially the cultivation of alkaline tolerant crops or other crops that include alkaline pH on their optimum pH range, such as barley, apples and lucerne. Over time, the use of nitrogen fertilizers and crop rotations will naturally decrease the soil pH to a desirable extent. Sodicity: the easiest way to overcome this issue is by applying gypsum to decrease the ESP. Moreover, the incorporation of organic matter will enhance the chemical effect, improving chemical proprieties of the soil. Salinity: salt tolerant crops are probably the best way to deal with this issue. Many improved varieties of wheat, barley, cotton and vegetables show high productivity under salt stress. Soil fertility: chemical fertilizers, inoculation with soil microbes (e.g. mycorrhizae), growing legumes for nitrogen fixation and incorporation of organic matter will be able to improve the nutrient status and cation exchange capacity. Boron toxicity: if already existent in the area, the use of gypsum might solve this problem. Otherwise, it may be necessary the cultivation of plants that are tolerant to this toxicity.

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