Managing sodic duplex soils for furrow irrigation

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Summary. Sodic duplex soils occupy some 35% of the gazetted area of the Burdekin River Irrigation Area (BRIA) in north Queensland. Land suitability assessments suggest substantial areas of these soils are marginal for production of furrow irrigated crops, such as sugar cane, maize and soybean. For sustained agricultural production on these soils, the recognition of yield limiting factors is essential if appropriate furrow irrigation management strategies are to be developed. This paper reviews results of research on furrow irrigation management of a strongly sodic duplex soil from the BRIA. Agronomic trials identified irrigation management, crop establishment, sodicity management and nutrition as major factors limiting yield. Ameliorative options (e.g., gypsum) and irrigation design criteria (e.g., slope, irrigation inflow rate, furrow length) are discussed and their extrapolation to other sodic duplex soils considered.

Introduction

The BRIA, situated 100 km south of Townsville, is an expanding irrigation area which is expected to provide an additional 400 new farms when completed. Soil surveys have identified four broad soil groups *viz* cracking clays, sodic duplex soils, non-sodic duplex soils, and gradational and uniform non-cracking soils that represent 43%, 35%, 12% and 10% of the gazetted area, respectively (3). High intensity surveys (1:25,000) with parallel land suitability assessments suggest substantial areas of sodic duplex soil are marginal for production of sugar cane, maize and soybean under furrow irrigation.

This paper describes salient features of sodic duplex soils from the BRIA and reviews the results of studies on the strongly sodic Gaynor soil. Some irrigation management and ameliorative options are examined and these findings are extrapolated to other less sodic soils.

Classification of sodic duplex soils and their suitability for furrow irrigation

In four high intensity soil surveys within the BRIA (Table 1), 12,400 ha or 38% of the total surveyed area of some 32,000 ha are sodic duplex soils. In all, 50 sodic duplex soil variants have been recognised. These fall within three broad subgroups (3):

Subgroup A

Soils are moderately to strongly alkaline (pH 7-9; 1:5 soil/water suspension, Method 4A1 (6)) and strongly sodic (ESP >15) by 0.3 m (cations and CEC after Method 15C1, and ESP after Method 15N1 (6)). Surface horizons are usually hardsetting and thin (<0.15 m) with ESP levels ranging from non-sodic (ESP <6) to sodic (ESP 6-14). Maximum mean ESP values reach 40 by 0.6 m and persist to 1.5 m. Variations in mean salinity (EC of 1:5 soil/water suspension, Method 3A1 (6)) and ESP levels with depth are shown in Figure 1.

Subgroup B

Soils are moderately to strongly alkaline (pH 8-9) and strongly sodic by 0.6 m. The A horizon is of intermediate depth (0.15-0.30 m) and is usually non-sodic. These soils become strongly sodic below 0.3 m, with maximum ESP levels of about 30 between 0.6 and 0.9 m. Variations in mean EC and ESP levels with depth are shown in Figure 1.

Subgroup C

Soils are sodic below 0.9 m and have deep A horizons. These soils are considered suitable for furrow irrigation and will not be considered in this paper.

Table 1. Areas (ha) of sodic duplex soil within the three subgroups on the basis of 1:25000

	Area (ha)	Area (ha) within subgroups			Reference
		A	B	C	
Mulgrave	8580	1075	2070	425	(5)
Northcote	7820	25	2140	1150	J. McClurg (pers. comm., 1991)
Jardine	5810	45	1465	330	N. Christianos (pers. comm., 1991)
Leichhardt Downs	9650	1365	1715	605	(2)

Within the land suitability classification framework developed for the BRIA (1), the factors likely to limit crop productivity on sodic duplex soils are effective soil depth and depth to slowly permeable subsoil, the nature of the surface soil, salinity, sodicity and topography (2). Using these criteria, soils from subgroup A are generally assessed as marginal for all furrow irrigated crops, whereas those from subgroup B are suitable for sugar cane and row crops. In the design of new farms, soils from subgroup B are usually included within farms as irrigable soils whereas those from subgroup A tend to be excluded where possible, or farms are designed larger to compensate for their inclusion.

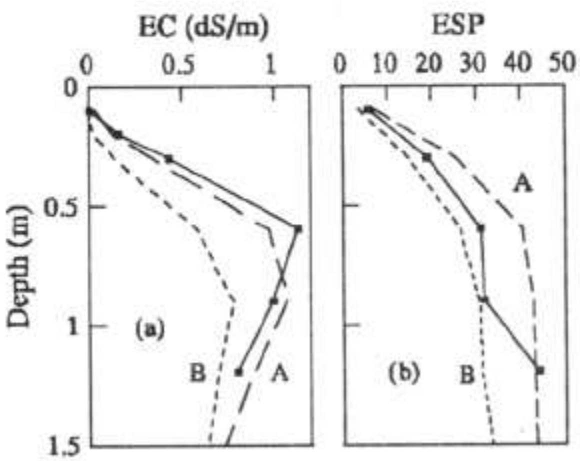

Figure 1. Variations in (a) mean salinity (EC, dS/m) and (b) mean sodicity (ESP) levels with depth for Gaynor soils (11) and also sodic duplex soils from subgroups A and B.

Gaynor test site

To further qualify these limitations to crop production on sodic duplex soils, and to examine the effect of some ameliorative treatments and alternate irrigation strategies, a 10 ha test site was established on a Gaynor soil within the BRIA. The Gaynor soil is a strongly sodic duplex soil type and covers some 500 ha within the Leichhardt Downs survey area. The map unit containing the test site has been assessed *as* only suitable for the furrow irrigation of sugar cane (2). Profile ESP and EC trends with depth are shown in Figure 1, and mean profiles for soils from subgroups A and B are included for comparison. The similarity between Gaynor soils and those from subgroup B, in terms of ESP, suggests these soils will need to be managed similarly. Salinity levels in the Gaynor soils, however, are among the highest recorded from subgroup A.

Irrigation management and ameliorative options

Trials (4) (Elliot, unpublished data) at the Gaynor site identified irrigation management, crop establishment, sodicity management and crop nutrition as major factors limiting yield. Within the soil profile, high levels of salinity and sodicity acted to restrict rooting depths to <0.6 m and to lessen the soil's effective water holding capacity.

Irrigation management

The major limiting factors were those that influenced infiltration and plant available water (PAW), namely slope and irrigation frequency. When crops were irrigated at the same cumulative net pan evaporation (60-65 mm), increasing slopes from 0.1-0.5% lessened the opportunity for infiltration. Incomplete recharge occurred and the soil's PAW content decreased. As the growing plant's requirements for water were not met, yield declined. When steeper slopes were more frequently irrigated, however, yield improved. Crop type also influenced yield response with maize better able to tolerate water stress than soybean. Water inflow rates into furrows were also limited by slope to about 20 L/m in due to scouring in the furrow and soil loss near the head ditch at higher flow rates.

For the Gaynor soil, water extraction by plants occurred to 0.6 m regardless of slope which corresponds to PAW contents of 40-50 mm and 70-80 mm for subgroups A and B, respectively. Yield data, for slopes of 0.1% and 0.5%, suggest that if sodic duplex soils from subgroup B are to be successfully irrigated, then slopes of near 0.1% are required to optimise irrigation frequency, infiltration and, hence, the soil's PAW content.

Crop establishment

Careful land levelling prior to initial cropping is required to minimise incorporation of sodic subsoils in the seedbed. Where surface horizons are very shallow, double cutting with soil replacement may be necessary. Subsequent tillage with tyned implements rather than discs may further minimise the incorporation of subsoils.

Poor emergence was associated with soil water content at tillage and the resultant clod size distribution within the seedbed. At sowing, the presence of large clods resulted in non-uniform placement of seed. Seeds failed to imbibe, became waterlogged or were invaded by pathogens upon irrigation, depending upon location within the seedbed. Poor emergence and seedling establishment were also associated with the stability of these clods upon wetting. Once wet, clods tended to slake and slump rapidly, especially when sodic subsoils were incorporated into the seedbed during tillage. Slumping caused blocked furrows, overtopping of ridges, and waterlogging. Slaking led to crusting. On steeper slopes, poor crop establishment was often due to a failure of the ridges to adequately wet upon irrigation.

The incorporation of previous crop residues also influenced establishment of the following crop because of benificial effects on water infiltration and soil stability. For example, a previous maize crop (4 t/ha of residue) improved establishment of a following crop better than soybean (1.5 t/ha of residue) because of the amount and type of residue. Since soils from subgroups A and B may be suitable for rice, a pioneer rice crop may increase soil organic matter levels and improve the seedbed for a following grain crop. In addition, short season horticultural crops with shallow roots (e.g., cucumber) have been successfully grown under furrow irrigation by mounding surface soils. Once roots enter the sodic subsoil, however, these crops fail.

Sodicity management and use of gypsum

An application of by-product grade gypsum was shown to improve yield (4). Yield increases were associated with increased water entry, greater infiltration and improved crop establishment. Leaching of soluble salts also increased. Further, in furrows without gypsum, a uniform depth of water application resulted along the furrow, infiltration often did not meet the soil water deficit (SWD), deep drainage losses were minimal and plants did not extract water from below 0.5 m. However, following a gypsum application of 20 t/ha, water entry and infiltration in excess of the SWD increased, the total amount of water applied increased and significant deep drainage losses occurred.

For soils from subgroup B, amelioration with gypsum at a rate above 11 t/ha will be necessary to achieve infiltration sufficient to met the SWD. Further, ratoon sugar cane yields decreased rapidly from plant cane levels suggesting that annual applications of gypsum may be required if gypsum is applied at rates of <10 t/ha. With gypsum, however, irrigation design (e.g. furrow length, slope, inflow rate) may need to be modified to minimise deep drainage losses.

Nutrition

Soils in subgroups A and B are very low in P (<3 ppm Colwell P) and are strongly P sorbing. Phosphorus nutrition will be a major limiting factor. However, unless limitations associated with PAW and infiltration are overcome, the addition of high amounts of P is not warranted. Other limiting nutrients were K and Zn.

Management recommendations

Where individual landholders are looking to develop extensive areas of sodic duplex soil, they must identify their soils, recognise any limitations and adopt suitable management strategies. Certain soils may, in fact, be excluded from a farm layout as being unsuitable for irrigation. This will require access to soil maps and associated soil survey data, and consultation with local extension and soil survey staff. For irrigable sodic duplex soils, landholders should adopt a farm layout which will (i) limit subsoil exposure during landforming, but provide a suitable slope of say 0.1-0.3% for irrigation and drainage, (ii) limit furrow length to say 600 m, (iii) provide consistent slopes of close to 0.1% for uniform management of irrigation water, and allow a manageable irrigation frequency (say five to eight days with net evapotranspiration interval of 60-70 mm). They should deep rip, taking care not to bring sodic subsoil into the cultivated layer and apply gypsum (initial rate >11 t/ha) to (i) improve surface soil structure, and (ii) improve infiltration and increase leaching of soluble salts. They should also select an initial crop that is easily established and will add organic matter to the soil.

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