Soil & Tillage Research 140 (2014) 29–39

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

Changes in soil cone resistance due to cotton picker traffic during harvest on Australian cotton soils

M.V. Braunack *, D.B. Johnston

CSIRO, Plant Industry and the Cotton Catchment Communities CRC, Locked Bag 59, Narrabri, NSW 2390, Australia

ARTICLE INFO

Article history:
Received 14 August 2013
Received in revised form 30 January 2014
Accepted 4 February 2014

Keywords:
Soil compaction
Irrigation
Rainfed
Simulation
OZCOT
Cone penetrometer

ABSTRACT

Australian cotton growers have rapidly adopted new picking technology of round module balers on dual tyres. These machines weigh twice that of previous basket pickers, usually on single tyres, being replaced. This raises some concern about implications for subsoil compaction (>0.4 m depth) from harvest traffic. The objective of this study was to quantify changes in soil strength due to picker traffic during harvest. Measurements of soil strength were undertaken before and after traffic by new round module baler (32 t) and current basket (16 t) pickers during one cotton picking season. Soil cone resistance, water content and plastic limit (PL) were measured in the upper 0.6 m depth at eight sites during normal picking operations. Results showed that soil strength increased after traffic of either picker compared with before traffic and increases were detected to a depth of 0.6 m. Despite differences in soils and profile water content, the change in strength was similar under the round module baler and the basket pickers. A zone of greater soil strength (3 MPa) occurred closer to the soil surface under the round module baler (0.3 m) compared with the basket picker (0.4 m). Zones of increased soil strength were also detected at 0.6 m depth under both pickers indicating possible subsoil compaction. The OZCOT cotton simulation model was used to determine the frequency at which the soil profile was wetter than the PL for both irrigated and dryland systems. Simulations showed that the soil profile could be expected to be wetter than the PL 75% and 14% of the time under irrigated and dryland systems, respectively, at harvest over the period from 1960 to 2012. This indicates that cotton picking in irrigated systems has a high probability of occurring when the soil is susceptible to compaction, with the risk of subsoil compaction greater with the round module baler.

1. Introduction

It is well known that crop yield is reduced by soil compaction (Soane and van Ouwerkerk, 1994) and subsoil compaction (>0.4 m depth) is of concern due to the increase in size and weight of agricultural equipment (Horn et al., 2000). Cone penetrometers are often used to assess soil strength in relation to soil compaction and root growth (Bengough et al., 2001). Resistance to penetration is affected by soil type; soil texture, organic matter content and clay mineralogy (Stitt et al., 1982), while within a soil type it is affected by soil water content, bulk density and structure. Soil resistance greater than 2 MPa is considered to limit root growth (Hamza and Anderson, 2005). However, soils with a resistance less than 2 MPa have been shown to reduce cotton yield (Carter and Tavernetti, 1968) while root growth in repacked soil columns ceased at 2.5 MPa (Rosolem et al., 2008). Recently Kulkarni et al. (2010) indicated that although cotton growth was affected by soil resistance as low as 1.6 MPa (measured range 1.6–2.9) on a loam soil in Arkansas, there was no yield penalty.

The plastic limit is an arbitrary measure of the soil water content where the soil changes from brittle and fracturing to becoming plastic and ductile. The soil plastic limit (PL) has been used to define the point where the soil is susceptible to degradation from tillage operations or harvesting traffic and that damage will be limited when the soil is drier than the PL (Kirby, 1990, 1991). Soil degradation due to picker traffic will be influenced by picker and soil parameters; whether the picker has tyres or tracks, the total load of the picker, the contact area of the tyres or tracks and the speed of travel while soil factors include the soil strength which is a function of water content, texture and structure (Kirby, 1988). As the clay fraction and soil organic matter increase, so will the PL as these parameters affect soil water content. Soil beneath a tyre or track is subject to both compression

* Corresponding author. Tel.: +61 2 6799 1500; fax: +61 2 6793 1186.
E-mail addresses: michael.braunack@csiro.au (M.V. Braunack), david.b.johnston@csiro.au (D.B. Johnston).

http://dx.doi.org/10.1016/j.still.2014.02.007
0167-1987/

and shear force and soil degradation is due to the soil response to these stresses.

A difficulty in assessing the risk of soil degradation is identifying when the soil is susceptible to compaction. By using crop simulation models and simulating the cropping system over a long period it is possible to gain an idea of the frequency that a soil profile may be wetter or drier than the PL at harvest. Augment this with the amount of rainfall in the five days prior to harvest and the data provides information on the risk for compaction on an operational basis (Littleboy et al., 1998).

To reduce the effect of machinery traffic on soil degradation, manufacturers have used dual tyres and tracks to reduce ground pressure. The cotton industry uses both rubber tyres and tracks on tractors for planting and in-crop operations and rubber tyres on pickers. Soil stress beneath two and four wheel drive cotton pickers was similar and much greater than beneath a rubber tracked tractor (Kirby et al., 1991). With respect to dual versus single wheels Kirby and Blunden (1993) have demonstrated that compaction near the soil surface is dependent on ground contact pressure while that at depth is dependent on total axle load. The measurement of stress transmission/distribution through field soil profiles also reflects this (Lamandé and Schjønning, 2011a,b). In reality as the weight of equipment increases, the tyre size should increase to maintain ground contact pressure and minimise surface compaction and the number of axles should increase to share the increased weight to minimise subsoil compaction (Håkansson and Reeder, 1994).

Research was undertaken during the period from 1981 to 2002 in response to planting and harvesting on wet soils and the amelioration of soil degradation (Daniells, 1989; McGarry and Chan, 1984; Stewart et al., 2002). Sullivan and Montgomery (1998) concluded that subsoil compaction in cotton fields was due to in-field traffic and not clay translocation. Although it is claimed that Vertosol soils (Isbell, 1996) are self repairing due to the shrink–swell behaviour, it may take in the order of 11 wet/dry cycles to repair structural degradation as blocks of compressed soil remain between the large cracks in the profile, and especially in subsoil due to overburden (Sarmah et al., 1996). This raises an issue as to whether cotton growers still suffer from subsoil degradation from past years when operations were undertaken on wet soils.

Growers are adopting new harvesting technology of round module balers. These pickers build a round module on the go in an integrated baling mechanism and drop the wrapped module while building another, compared to a basket picker which collects cotton seed in a basket on the go and then transfers this to a module builder on the headland. The new pickers offer several advantages over the basket picker: a reduction of in-field labour, greater picking efficiency (Willcutt et al., 2009) and less equipment to clean down and move between locations – all reducing the cost of production. These pickers are considerably larger and weigh more than current basket pickers and pose a risk in generating subsoil compaction, especially if wet soil conditions occur at harvest or the soil has not dried sufficiently at depth after the last irrigation or significant rainfall. Growers need to be proactive in developing strategies to minimise the risk of subsoil compaction which is difficult to ameliorate and can limit crop performance.

The objective of this work is to quantify changes in soil strength due to cotton picker traffic on Australian cotton soils and identify the potential risk of subsoil compaction using long-term crop simulation modelling.

2. Materials and methods

2.1. Field measurements

Eight typical cotton fields were selected during the 2011 cotton harvest covering a range of soil types and soil moisture conditions at harvest (Table 1). Soil cone resistance was measured, to depth of up to 0.6 m at intervals of 0.02 m, with a recording penetrometer inserted at a constant rate (ASAE, 1986) (12.3 mm dia. cone, 30° included angle) across twelve or eight furrows (round module baler and basket picker, respectively) and crop rows before and after the passage of a fully laden cotton picker operating in the field at the time. It was not possible to insert the cone penetrometer to 0.6 m at all sites due to dry soil or traffic pre-history of the field. The penetrometer was mounted in a metal frame and inserted at a constant rate by a battery driven ram; this eliminated operator fatigue and ensured consistent strength data. Measurement always started and finished in a non-traffic furrow across twelve or eight rows with strength being recorded at 20 mm depth intervals; the

Table 1
Details of sites, soil type and equipment measured.

Site	Soil	Equipment	Weight (t)			Profile (0–0.6 m) soil water (%)			
			Empty	Full	Front Axle	Pre- & post-traffic	PL	WP	DUL
Auscott (1) (Narrabri)	Vertosol[a] (grey cracking clay) Light clay (35% clay, 0–0.1 m) to heavy clay (>50% clay, 0.1–1.2 m)	Round module (dual tyres) + trailer	38	47	21	32	25	22	40
Auscott (2) (Narrabri)	Vertosol (grey cracking clay) As above	Round module (dual tyres) + trailer	38	47	21	24	22	22	40
Hillston (1)	Chromosol (red brown clay) Silty-clay (35% clay, >25% silt, 0–0.1 m) to Clay (45% clay, 0.1–0.9 m)	Round module (dual tyres)	32	34	21	19	17	13	36
Hillston (2)	Chromosol (red brown clay) (As above)	Basket (single tyres)	17	20	14	23	22	13	36
Boggabilla	Vertosol (black cracking clay) Medium clay (45% clay, 0–0.9 m)	Basket (single tyres)	16	18	12	22	19	18	44
Bourke	Kandosol (red earths) Loamy-clay (30% clay, 0–1.0 m)	Basket (single tyres)	15	17	13	20	21	19	35
Myall Vale	Vertosol (grey cracking clay) Medium clay (40% clay, 0–0.1 m) to heavy clay (>50% clay, 0.1–1.0 m)	Basket (dual tyres)	19	20	16	23	21	19	40
St George	Sodosol (solodic soils) Silty-Loam (25%, >25% silt, 0–0.1) to Clay-loam (30%, clay, 0.1–1.2 m)	Basket (single tyres)	15	18	13	17	19	15	26

PL, plastic limit measured (%); WP, wilting point (%, 15 bar); DUL, drained upper limit (%) (WP & DUL from APSoil database).
[a] Australian Soil classification (Isbell, 1996). Field texture & approximate clay or silt content and profile depth are given in parenthesis.