Soil and yield improvements from Controlled Traffic Farming CTF on a Red Chromosol were similar to CTF on a swelling Black Vertosol

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Introduction

There is a significant body of knowledge on the detrimental effects of soil compaction in agriculture, the benefits of Controlled Traffic Farming CTF (Hamza and Anderson, 2005) and its synergy with no-till (direct drilling) practices (Tullberg, 2010). Greater adoption of CTF could be one obvious step towards feeding a growing world population, using less energy and a decreasing soil resource (Cribb, 2010). The benefits of CTF on swelling Black Vertosols in northern New South Wales and Queensland, Australia have been reported consistently for two decades e.g. (Tullberg et al., 2007). These include higher yields, less runoff, less erosion, better direct drilling and more energy efficient field operations. On the sandy soils of Western Australia, deep tillage and subsequent exclusion of traffic has had similar results. The effects of CTF on Vertosols have sometimes been attributed to the natural swelling and cracking characteristics; on the sandy soils, the disruption by deep ripping (deep tilling) of indurated layers has improved root and crop growth e.g. (Hall et al., 2010). Without the swelling characteristics of the Vertosols, nor the indurated layer of the sands, Red Chromosols and other soils in south eastern Australia have been thought unlikely to benefit from CTF (unpublished opinions). Here we revisit a large CTF experiment conducted on a Red Chromosol in South Australia (SA) from 1989 to 1994, which compared the effects of wheel traffic, deep ripping and their interactions (Sedeghatpour et al., 1995). These effects showed remarkable similarity to those on the swelling Black Vertosol i.e. (1) decreased bulk density and penetration resistance, increased aggregate stability, visible porosity, infiltration, worm population, root growth and crop yield; and (2) increased load-bearing capacity of the permanent tracks. (1) was also manifested as better soil friability giving improved tillage and direct drilling efficacy. Most notable on both the Black Vertosol and the Red Chromosol was that greatest improvements occurred when wheel traffic was excluded, without deep ripping. More friable soil, combined with greater traffickability, can also lead to systemic improvements from CTF – some are often not obvious *a priori* e.g. fewer machine hours needed, requiring less powerful tractors; more timely chemical application etc. We suggest greater attention should be paid to the possibility of wider adoption of CTF in SA and south eastern Australia to raise yields, improve soils and lower inputs.

Materials and Methods

Details of the experiment are presented in Ellis (1990) and Sedeghatpour et al. (1995). Field trials were established at the (then) Roseworthy College (28°30’S, 115°7’E; elev. 68 m), now a campus of the University of Adelaide, about 40km NNE of Adelaide, SA. The climate is Mediterranean-like with winter dominated annual average rainfall and potential evaporation of 440 mm and 1750 mm, respectively. The soil was a Red Chromosol (Isbell, 1996). A compact layer (~100 mm thick) existed below the tilled depth (~75 mm), which tended to contort and deflect roots, although not dramatically. The majority of root branching, with thickened and flattened root tips, occurred in horizontal fissures. Deeper seminal and tap roots existed mainly in old root channels and other biopores. Deep tillage (main treatments) and wheel traffic (sub treatments) were arranged in a randomised split-plot design. This produced four replicates of the four treatments: conventional wheel traffic (C); no wheel traffic (CT); conventional wheel traffic, deep ripped (CR) and no wheel traffic, deep ripped (CTR). Deep ripping to 300 mm depth was done once, at trial establishment, using a chisel plough fitted with narrow points. Tillage, seeding and spraying of CT and CTR was undertaken using a self-propelled gantry, which spanned 4 m wide beds and used 400 mm wide tyres; a harvester was modified to match the wheel tracks so that CT and CTR experienced no traffic at all. Conventional tractors and trailed implements were used for all operations on C and CR with wheel tracks covering 40-60% of the area each year. Where possible, in C and CR, tractor-implement combinations were alternated to distribute the traffic as evenly as possible. All four treatments received identical field operations within a 24 hour period. Sheep were grazed on all treatments over the dry summer months. Crops grown from 1989 to 1994 were: barley (*Hordeum vulgare*), bean (*Vicia faba*), wheat (*Triticum aestivum*), bean (*Vicia faba*), wheat (*Triticum aestivum*) and medic pasture (*Medicago trunculata*). Observations included: soil strength (by penetrometer), bulk density (of core samples), visible porosity (resin impregnation), aggregate stability (wet sieving) and surface hydrology (laboratory rainfall simulation), root morphology (whole, washed samples and profile pin boards), root density (washed and scanned core samples), earthworm population ($1m^2$ x 0.1m pits), grain and biomass yields (harvester and quadrats).

Results and Discussion

The previously compacted soil ameliorated under CT i.e. exclusion of wheel traffic without deep ripping (Figure 1). Earthworm densities in C and CT in August 1993 wheat were 12 and 23 worms m^{-2}, respectively ($p<0.03$). Root abundance on inspection was consistently greater in CT compared to C (Figure 1). This “biological tillage” is thought to have helped disrupt the compact layer and form smaller, blocky aggregates (Figure 1). Root straightness and abundance followed the order: C<CT<CR<CTR. Root length density of wheat in 1991 at 300 mm depth was 16 (Sdev 3) and 31 (Sdev 3) mm cm^{-3} in C and CT, respectively. In 1994, medic cumulative root length from 0 to 750 mm deep was 912 (Sdev 61) and 1251 (Sdev 220) mm cm^{-2} in C and CT, respectively. Bulk density (Figure 2) and penetration resistance consistently decreased during the trial and wet aggregate stability (Figure 2), visible porosity (Figure 3) and water infiltration increased (Figure 3) in CT. Deep tillage reduced penetration resistance to 300 mm deep but also reduced wet aggregate stability of surface soil. In five of the six years, CT significantly improved grain yields (by 12 to 17%) of barley, wheat, bean and pasture biomass (22%). This more than compensated for the land area lost to permanent, bare wheel tracks (10%). The exact reasons for yield increases are unknown but the biological tillage effects deserve greater attention to elucidate these, which could include: greater access to soil water, reduced root disease or less gaseous loss of nitrogen. It appears that the amelioration of soil structure once wheel traffic is excluded is not peculiar to swelling clays. In addition, as with the Black Vertosol, biological tillage appears to be more favourable (and less costly) than deep ripping, which did not significantly increase yields. Soil structural changes resulted in: 1) more friable and better-drained topsoil, which produced better tilth and better soil-seed contact and seed coverage in direct drilling; and 2) harder wheel tracks in CT and CTR, which were more trafficable than the cropped zones in C and CR. These soil conditions often produce other opportunities (e.g. fewer rain delays to operations; greater timeliness of tillage, seeding and spraying). These effects are commonly reported by CTF farmers but were not exploited in these trials. It is likely that they would

result in even higher yields from CTF and need to be quantified. In the face of a possible coming world famine (Cribb, 2010), there is ample and longstanding evidence that CTF can improve yields (possibly ~20%) and protect and improve the structure of swelling and non-swelling soils in southern Australia. Future research should also explore other, systemic advantages (e.g. timeliness; earlier seeding etc.), which are mostly unmeasured or unreported.

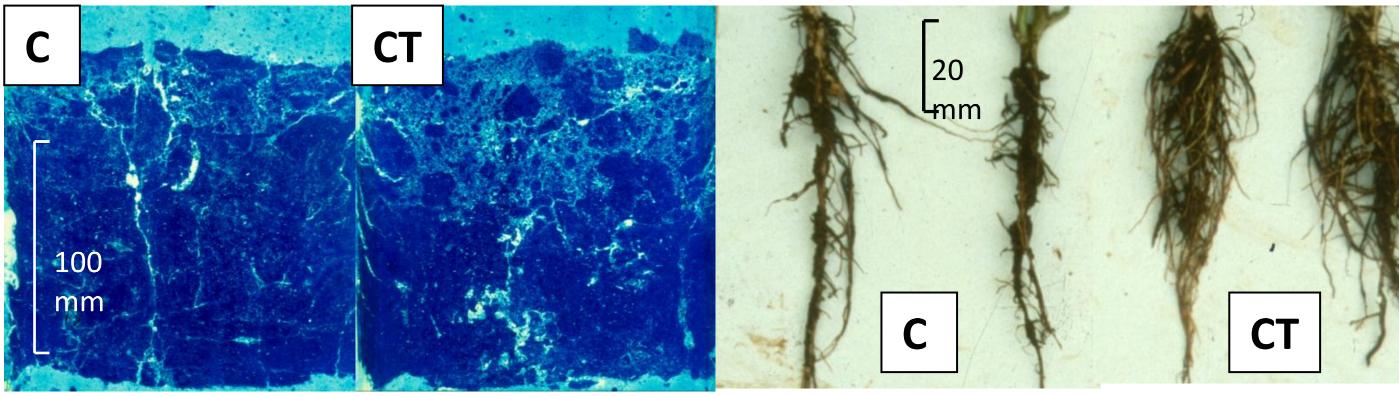

Figure 1 Resin impregnated soil profiles (left) and bean (*Vicia faba*) seedling roots (right)

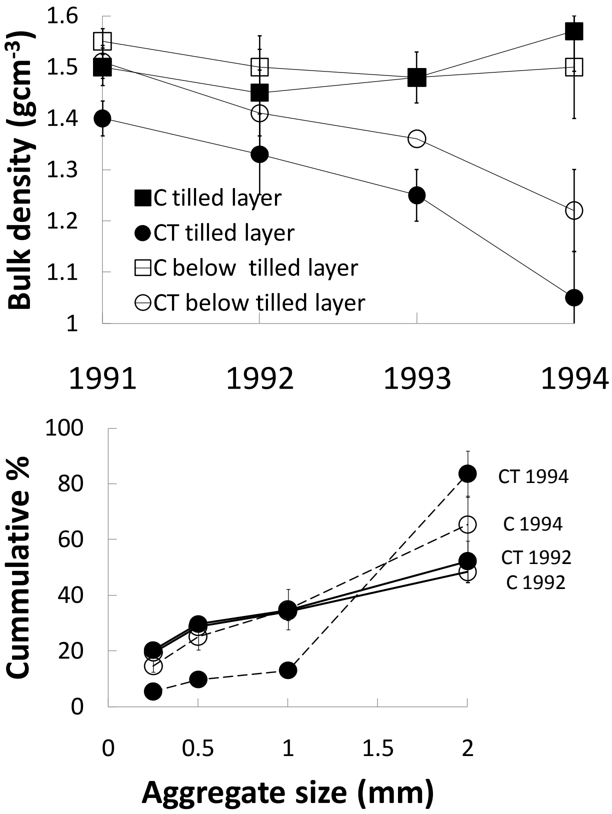

Figure 2: Evolution of soil bulk density with time (left) and evolution of wet aggregate stability (right). Error bars represent one standard deviation.

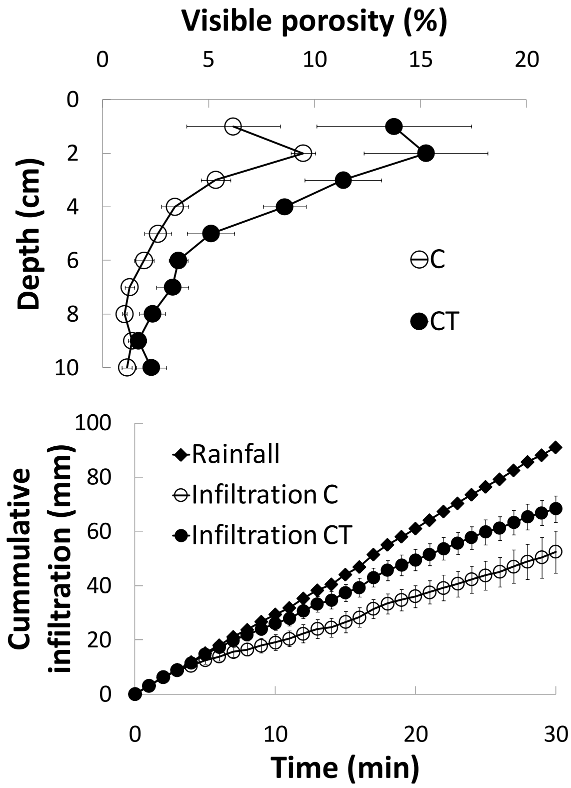

Figure 3: Soil visible porosity after 6 years (left) and surface water infiltration after 6 years (right). Error bars represent one standard deviation.

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