Carbon allocation dynamics in contrasting crop-soil system trials in southern NSW

Dr Bhupinder Pal Singh, **Yunying Fang** and **Jharna R Sarker** NSW DPI, Menangle

Key findings

- Although high below-ground carbon input by plants is important to enhance soil organic matter, only a few studies have quantified carbon allocation dynamics in crop-soil systems in dryland regions under contrasting management practices.
- There seems to be environmental constraints and features of dryland farming systems (such as high aridity and low rainfall, low soil carbon and low moisture) that limit the extent of below-ground carbon allocation as found in this study. It is thus challenging to enhance soil organic matter stocks in the dryland regions through conservation tillage only.
- The majority of newly assimilated carbon remained in above-ground plant material, particularly in the wheat-soil system at Condobolin, which is a relatively drier climate than Wagga Wagga.
- A larger proportion of newly assimilated carbon was translocated to below-ground carbon pools in the canola-soil system at Wagga Wagga (7%–11%) than in the wheat-soil system at Condobolin (2%).
- Tillage practices had no effect on the allocation and storage of newly assimilated carbon in the crop-soil systems. Moreover, the management practices had no significant effect on grain yield, soil carbon stocks or bulk density.
- These results suggest that reduced tillage or no-till can maintain equivalent soil functionality relative to conventional tillage while reducing operational costs associated with energy and machinery inputs.

Introduction

Organic matter (OM) plays a vital role in maintaining soil functions such as carbon (C) storage and nutrient cycling. It is hypothesised that improved crop management practices can increase soil C, for example by increasing plant-derived organic matter input into the soil, and influence nutrient use efficiency and crop yield. This understanding can be enhanced through using in-situ techniques to examine above-ground and below-ground allocation of newly assimilated C and its stabilisation and interaction with nitrogen (N) in soil under contrasting crop management practices. The aim of these experiments is to examine how tillage intensity influences allocation and stabilisation (storage) of newly assimilated C in canola crop-soil and wheat crop-soil systems at Wagga Wagga and Condobolin.

Site details

Two trial sites were selected: one short-term trial at Wagga Wagga and one long-term trial at Condobolin (Table 1).

Table 1. Sites for the carbon isotope labelling studies.

Location	Wagga Wagga	Condobolin
Coordinates	35°07' S and 147°22' E	33°05' S and 147°08' E
History	Established in 2012	Established in 1998
Experiment period	Sep–Nov 2013	Sep–Nov 2014
Total C (0–10 cm)	1.5%	1.2%
Total N (0–10 cm)	0.13%	0.10%–0.12%
pH	5.8	5.8
Bulk density (0–10 cm)	1.3 g/cm^3	1.3 g/cm^3
Soil classification	Red kandosol	Red chromosol
Soil texture	Sandy clay loam	Sandy clay loam
Crop	Canola	Wheat

Location	Wagga Wagga	Condobolin
Management practices	1. Conventional tillage 2. No tillage	1. Conventional tillage 2. Reduced tillage
Fertiliser	100 kg urea-N/ha	Farmer's practice
Annual rainfall (long-term)	~570 mm	~435 mm

Methods and treatments

An in-situ C isotope labelling technique was used that allows the fate of newly assimilated atmospheric carbon to be traced. We exposed crop-soil systems to $^{13}CO_2$ (5 L or 10 L of 99 atom %) for fixation by plants via photosynthesis. The crop-soil system areas used for pulse labelling were 1.5 m wide × 2.0 m long at Wagga Wagga (Figure 1. photos 1a and 1b) and 1.8 m wide × 2.0 m long at Condobolin (Figure 1. photos 1c and 1d). In the Wagga Wagga crop rotation trial (wheat–canola–legume–wheat), canola was grown in 2013 in a factorial combination of four treatments (0 kg N/ha and 100 kg N/ha under conventional tillage, and no till, with three replicates each). In the Condobolin mixed farming system trials (five rotational phases of wheat and pastures), the wheat crop rotation was selected in 2014 across the conventional versus reduced tillage treatments.

Results

At both sites, management practices had no significant effect on grain yield and soil C and N stocks in the years the labelling study was conducted. At Wagga Wagga, soil organic C (0–30 cm) ranged from 30 t/ha in no till to 40 t/ha in conventional tillage. Grain yield for the canola crop was 1.2 t/ha in no till and 1.6 t/ha in conventional tillage. At Condobolin, soil organic C (0–30 cm) ranged from 36 t/ha in conventional tillage to 40 t/ha in reduced tillage. Grain yield for the wheat crop was 2.3 t/ha in conventional tillage and 2.1 t/ha in reduced tillage.

The allocation and storage of newly assimilated C in plant and/or soil components varied at these two sites. At Wagga Wagga, 43%–55% of the added $^{13}CO_2$-C remained in the crop-soil system after 45 days, while 36%–45% of the 'new' C was recovered in the shoot, 1.8%–2.8% in the tap root, and 5.6%–7.8% in the soil plus fine roots at grain harvesting in November 2013 (Figure 2a). At Condobolin, 77%–80% of the added $^{13}CO_2$-C remained in the wheat crop-soil system after 50 days, with 74% of the 'new' C recovered in the shoot, 0.3%–0.5% in the nodal roots, 1.2%–1.3% in the soil plus fine roots, and 2.3%–3.3% was respired CO_2 at grain harvesting in November 2014 (Figure 2b).

Figure 1. In-situ stable carbon and nitrogen isotope labelling of a canola-soil system at Wagga Wagga (a and b) and a wheat-soil system at Condobolin (c and d).

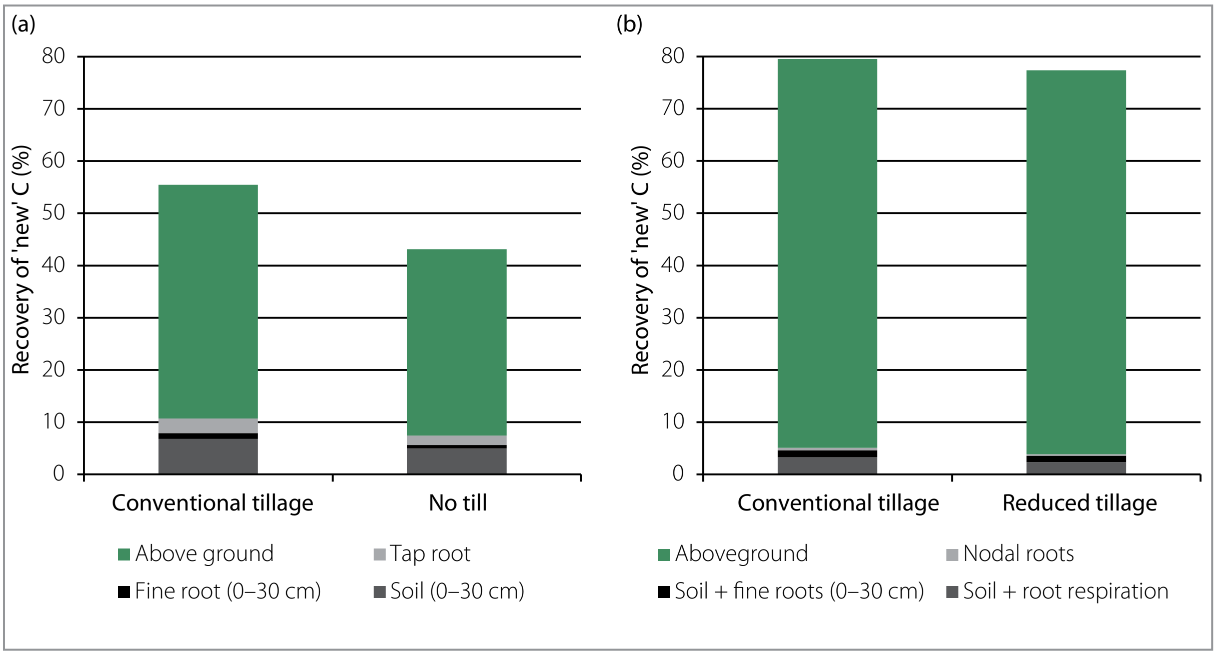

Figure 2. Allocation of isotopically-labelled 'new' carbon in a canola crop-soil system at the grain harvesting stage at Wagga Wagga (a) and Condobolin (b). 'New' carbon means the newly assimilated isotopically labelled-C.

The contrasting tillage practices had no effect on allocation and storage of new C among plant, soil and/or respiration C pools (figures 2a and 2b).

Our results show that the majority of newly assimilated C remained above-ground and only a small amount was translocated to below-ground in both crop-soil systems. This pattern could be attributed to both:

1. smaller below-ground plant C pools (i.e. root biomass) relative to above-ground plant C pools
2. dry conditions hampering C translocation from shoots to roots and root-derived organic matter (exudates).

Less assimilated C was translocated to below-ground in the Condobolin wheat-red chromosol system than in the Wagga Wagga canola-red kandosol system. This was possibly due to the relatively dry environment at Condobolin compared with that of Wagga Wagga, and Condobolin's soil-gravimetric moisture at 4%–8%, which was lower than that recorded at Wagga Wagga (7%–16%) during the C tracing period.

Summary

The results reveal no effect of contrasting tillage practices on the dynamics and magnitude of 'new' C (^{13}C-labelled) allocation and storage in the crop-soil system, soil C stock or crop yield. These results suggest that reduced tillage or no till could maintain the same level of soil functionality as conventional tillage in the low to medium rainfall regions. It seems that the climate and low soil C features of the dryland regions limit the effect of tillage management on below-ground C input and crop productivity.

Acknowledgements

These experiments involved collaborations with Guangdi Li (Wagga Wagga trial), Annette Cowie (Wagga Wagga trial), Warwick Badgery (Condobolin trial) and Xinhua He (both trials). As part of the project 'Building resilient and profitable grain cropping systems through improved knowledge of soil organic carbon fractions and their functionality', DAN00169, the experiment was jointly funded by NSW DPI and GRDC. It also involved Central West Farming Systems and on-farm collaborators. We acknowledge technical input from Khushbu Gandhi, Adam Lowrie, Richard Lowrie, Rebecca Coburn, Michael McLean, Satvinder Bawa, Dougal Pottie, Luke Beange, Nilusha Henaka Arachchi, Kamal Hossain and Mathew Coggan. We also thank Central West Farming Systems for allowing access to the long-term trial.