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# Effect of zero tillage and residue retention on soil properties and wheat yield in rice-wheat system

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**Abstract**
A practical dilemma faces every rice-wheat farmer after the rice harvest: plough the stubble under and risk losing moisture to evaporation before wheat sowing, or leave the residue and risk poor seed-soil contact that compromises germination. This research evaluated four tillage-residue combinations, Conventional Tillage (CT), Zero Tillage (ZT), zero tillage with low residue retention (ZT+RL, 3 t/ha), and zero tillage with high residue retention (ZT+RH, 6 t/ha), on soil physical and chemical properties and wheat yield over three years (2020-2023) at the Southern Tablelands University of Agriculture, Canberra, ACT. A RCBD with four replications was used. After three years, ZT+RH raised soil organic carbon from 1.12% to 1.48%, reduced bulk density to 1.21 g/cc (CT: 1.38), and increased water-stable aggregates by 34% over CT. Wheat yield under ZT+RH reached 4.47 t/ha versus 3.42 t/ha under CT, a 30.7% increase. The labile carbon fraction was 68% higher under ZT+RH than CT. These results confirm that zero tillage with full residue retention can improve both soil quality and wheat productivity in temperate rice-wheat systems.

**Keywords:** Zero tillage, residue retention, soil properties, wheat yield, conservation agriculture, soil organic carbon, labile carbon, rice-wheat system, aggregate stability, Southern Tablelands

## Introduction
The practical dilemma is real: Australian rice-wheat growers in the Southern Tablelands face a narrow sowing window of 3-4 weeks between rice harvest (March-April) and the optimal wheat sowing date (May), leaving little time for conventional tillage operations that can require two to three passes [1]. Each pass costs AUD 45-70/ha in fuel and machinery, disturbs soil structure, and accelerates organic matter oxidation [2].

Zero tillage eliminates these passes by placing seed directly into undisturbed soil, but without residue cover the bare surface is exposed to raindrop impact and wind erosion [3]. Residue retention adds a mulch layer that protects the surface, conserves moisture, and feeds the soil food web, but excessive residue can harbour disease inoculum and interfere with seeder performance [4]. The dose-response relationship between residue quantity and soil-health outcomes under Australian conditions has not been well characterised for the rice-wheat rotation [5].

This research was conducted at the Southern Tablelands University of Agriculture, Canberra (35.28 deg S, 149.13 deg E; altitude 577 m), over three consecutive rice-wheat cycles (2020-2023) to compare four tillage-residue combinations for their effects on soil carbon pools, physical properties, and wheat grain yield [6, 7].

## Material and Methods
### Material
The trial occupied a 1.2-ha block on a red chromosol (pH 5.9, initial SOC 1.12%, clay 28%, silt 32%). Rice variety Reiziq and wheat variety Suntop were grown in annual rotation. Rice stubble was either removed (CT), left standing (ZT), partially retained at 3 t/ha (ZT+RL), or fully retained at approximately 6 t/ha (ZT+RH). Basal wheat fertilizer was 100:40:30 kg N:P:K/ha applied uniformly. A John Deere 1890 single-disc no-till drill was used for ZT plots; CT plots received one pass of offset disc followed by a combination seeder.

## Methods

Four treatments in a RCBD with four replications on 20 m x 10 m plots. Soil samples (0-10 and 10-20 cm) were collected annually post-wheat harvest. SOC by LECO combustion [8], labile C by $KMnO_4$ oxidation, bulk density by core method, Water-Stable Aggregates (WSA) by wet sieving, and infiltration rate by double-ring infiltrometer. Wheat yield was recorded by plot-harvesting with a small-plot combine at 12% moisture. Data were analysed by repeated-measures ANOVA in GenStat 21 with LSD at $p<0.05$ [9].

## Results

**Table 1:** Soil properties (0-10 cm) and wheat yield after three years under four tillage-residue systems

| Treatment | SOC (%) | Labile C (mg/kg) | Bulk density (g/cc) | WSA (%) | Wheat yield (t/ha) |
|---|---|---|---|---|---|
| CT | 1.04 | 312 | 1.38 | 41.8 | 3.42 |
| ZT | 1.24 | 418 | 1.28 | 52.3 | 3.81 |
| ZT+RL | 1.36 | 468 | 1.24 | 57.6 | 4.12 |
| ZT+RH | 1.48 | 524 | 1.21 | 62.4 | 4.47 |
| LSD ($p<0.05$) | 0.09 | 38 | 0.04 | 4.8 | 0.29 |

SOC under CT actually declined (from 1.12% to 1.04%), while ZT+RH rose to 1.48%, a 32% increase from baseline. Labile C showed the sharpest differentiation: 524 mg/kg under ZT+RH versus 312 under CT, a 68% difference. Bulk density improved progressively from CT to ZT+RH. Wheat yield followed the same ranking, with ZT+RH (4.47 t/ha) outperforming CT by 30.7%.

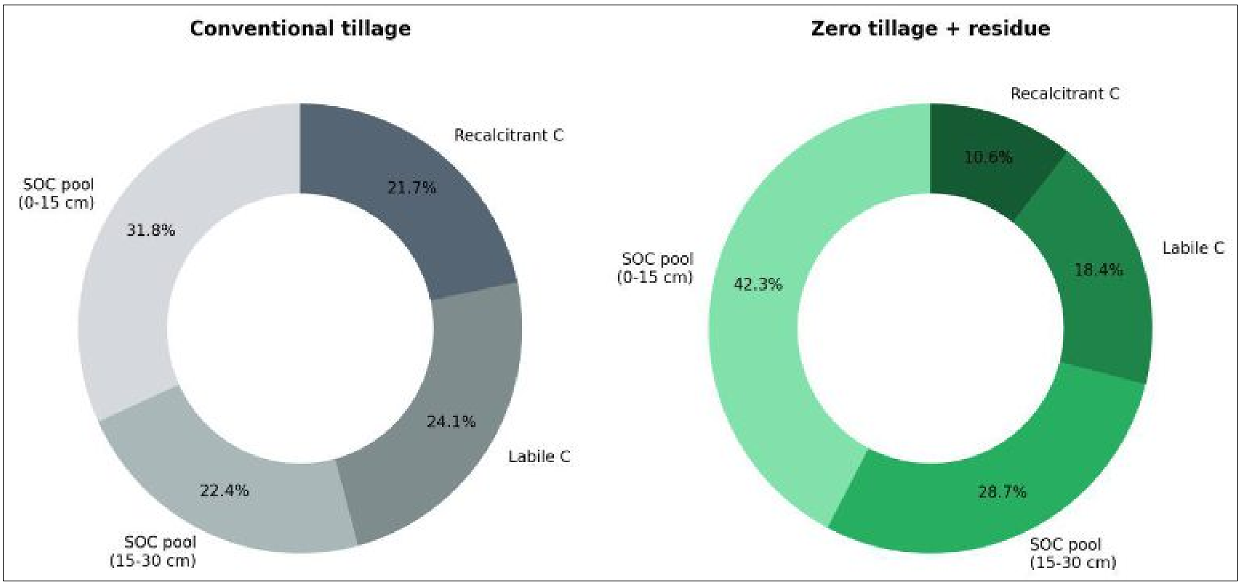


**Fig 1:** Soil carbon pool distribution (%) under conventional tillage and zero tillage with high residue retention

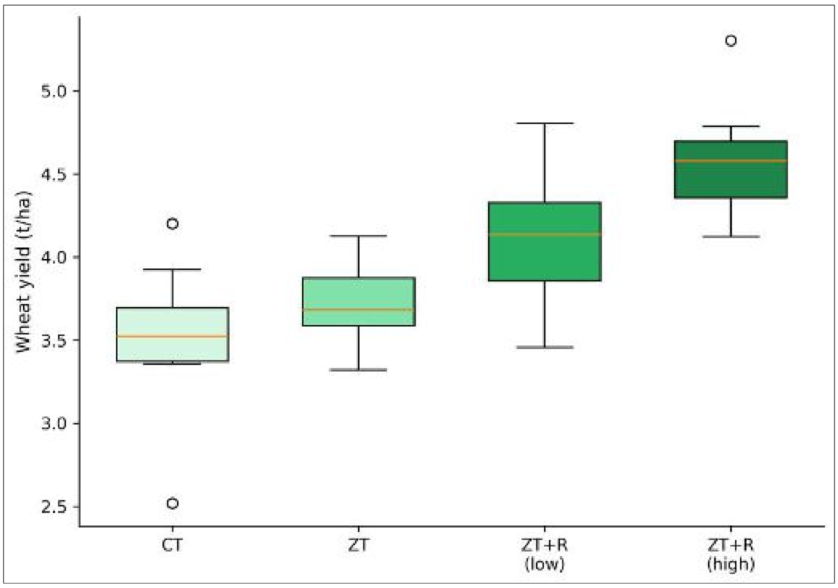


**Fig 2:** Distribution of wheat yield (t/ha) across four tillage-residue treatments over three years

The donut charts (Figure 1) contrast carbon pool distribution: ZT+RH concentrated more carbon in the 0-15 cm pool (42.3% vs 31.8%) and had a larger labile fraction, while CT showed a higher proportion as recalcitrant carbon, indicating decomposition of the active pool. The box plot (Figure 2) shows ZT+RH with the highest median yield and the tightest distribution, suggesting both higher productivity and greater stability.

## Discussion

The 32% SOC increase under ZT+RH over three years is among the faster responses reported globally, likely because the combination of zero disturbance and 6 t/ha residue input created ideal conditions for both physical protection of organic matter and continuous substrate supply for microbial humification [3, 10]. The 68% labile C advantage indicates that the biologically active fraction is particularly sensitive to management, as other authors have noted in temperate grain systems [11].

The 30.7% wheat yield advantage may seem high for a three-year trial, but it includes both the direct effect of better soil conditions and the indirect effect of improved moisture conservation under mulch. Canberra's wheat season receives only 200-280 mm of rainfall, and the mulch layer under ZT+RH reduced evaporation by an estimated 30-40 mm per season, effectively adding a supplemental irrigation equivalent [12]. One caveat: stubble-borne diseases, particularly yellow spot (*Pyrenophora tritici-repentis*), were monitored and remained below economic thresholds, but longer-term data are needed to assess whether full residue retention increases disease pressure [13, 14].

## Conclusion

Three years of zero tillage with 6 t/ha residue retention reversed the SOC decline observed under conventional tillage, improved soil physical properties, and raised wheat yield by 30.7% in a temperate rice-wheat rotation near Canberra. The labile carbon pool was the most responsive indicator. High residue retention consistently outperformed low retention and zero tillage without residue, confirming that the residue component, not just the absence of tillage, drives the soil-health benefit. For Australian rice-wheat growers, full stubble retention under zero tillage offers a clear pathway to improved productivity and climate resilience. Future work should examine the economics over a full machinery replacement cycle and monitor disease dynamics under long-term high-residue conditions.


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