# Biomass production, water use and root growth of a range of summer cover crop species in a semi-arid cropping environment

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## Abstract

Cover crops can improve ground cover and increase soil water storage in Australia's northern cropping zone during long fallows, but in southern Australia, water use by cover crops over the summer allow period may impact on subsequent winter crop growth. Soil water use by cover crops is likely to be influenced by biomass production, but whether the rooting depth and root architecture of specific cover crop species affect water use is not known. Field and glasshouse experiments were conducted to investigate biomass production, root growth and water use of a range of cereal, legume and non-legume broadleaf cover crops terminated at 8 weeks of growth. The field trial design was a randomised complete block design with four replicates. Above ground biomass, root length (RL), root density (RD; the number of roots counted cm$^{-2}$ of area) and soil water retention were measured after the termination of cover crops. Biomass accumulation was in the order of balansa clover > barrel medic > lablab > sunnhemp > mungbean > buckwheat > cowpea > millet > radish. The soil water content after termination had the reverse trends. RL and RD of balansa clover, buckwheat, barrel medic and sunnhemp were greater at the surface soil (0-20 cm depth). In contrast, both RD and RL were the highest for millet and cowpea at the deeper profile (40-80 cm), and this contributed to less soil water storage under these species after termination. These complementary root architectures of different summer cover crops suggested that shallow rooted species having greater RD and RL at the surface soil might get less access to deeper soil profile which could maximise cover crop benefits at termination to improve soil water retention for cash crops.

## Keywords

Summer cover crops, above ground biomass, root density, root length and soil water retention

## Introduction

The integration of cover crops into cropping systems can improve ground cover and increase water infiltration and storage, which may benefit the yield of the following cash crop (Blanco-Canqui et al., 2012). In the Australian northern high rainfall cropping zone, summer cover crops (SCC) can increase cash crop yields by 50% or more as a result of increased stored water (Erbacher A et al. 2019). However, in the lower rainfall zone of Australia, SCC may affect the growth and yield of winter crops depending on soil water use over summer and rainfall patterns during the winter crop phase.

The depth of roots of SCC could affect soil water extraction and hence the soil water balance in early autumn. Different species of SCC may differ in their water use depending on their roots distribution within soil profiles. Therefore, it is of great interest in the dry land environment to identify the rooting patterns of SSC species (i.e. legumes, cereals or broadleaves) in order to predict the soil water preservations for the following cash crops after the termination of SCC.

Although many studies on cover crops have assessed soil water use and biomass yields in the northern hemisphere, we are unaware of any studies that have examined biomass accumulation, roots distribution and soil water use in the Mediterranean dryland environment. The aim of the study was to investigate shoot biomass, roots attributes (density, length etc.) of a range of different cover crop species, and assess their impact on soil water use. A glasshouse experiment was carried out to assess individual plant attributes, water use and their root length and a field experiment were also conducted to test these attributes under field conditions.

## Materials and methods

### *Field experiment*

A field experiment was conducted from January-March 2020 (summer) at Charles Sturt University research farm, Wagga Wagga, on clay loam soil (Red Kandosol; Isbell 1997). The experiment assessed shoot growth and root distribution of 9 cover crop species, i.e. cereal (millet), legume (balansa clover, barrel medic, sunnhemp, lablab, mungbean, cowpea) and broadleaf (buckwheat and tillage radish) and was laid out as a randomised complete block design with four replicate plots per plant species. Plots were 9 $m^2$ (1.5 m width × 6 m length). Seeds of SCC were sown on 29 January 2020 using a Kimseed Disc Cone Seeder with a 24 cm row spacing. Before sowing, legumes were inoculated with appropriate peat based inoculum (groups C, I, I, I, J and AM) (Nodule NTM, New Edge Microbials PTY Ltd., Albury, NSW, Australia). Total rainfall during the SSC growing season (Jan-March 2020) was 96 mm, and supplemental irrigation (50 mm) was applied immediately after sowing.

Biomass was collected on 24 March 2020 using a 1 $m^2$ quadrat and oven dried at 65℃ for 72 hrs. On 25 March 2020 (about 8 weeks growth), SCC were terminated using glyphosate (a.i. 2 L/ha) and wetter surfactant TX. After 3 weeks of termination, 1 m deep soil cores (45 mm diameter) were collected for assessing soil moisture and root density at different sections of cores, i.e. 0-10, 10-20, 20-30, 30-40, 40-60, 60-80 cm depths. Gravimetric soil moisture was measured at each depth and was converted to soil water content (mm) with a site-specific bulk density and soil volume for each soil depth. Finally, the total soil water content of the profile was calculated as the sum of soil water to 80 cm soil profile.

### *Glasshouse experiment*

A glasshouse experiment was conducted at Charles Sturt University glasshouse facilities, Wagga Wagga, from August-September 2020 and consisted of the same treatments to field experiment. The temperature and humidity of the glasshouse were set up according to the field conditions from the preceding summer (February to March 2020) as based on weather data acquired from the Bureau of Meteorology (BOM), Wagga Wagga weather station.

Topsoil (0-10 cm) was collected from the field site described above and sieved through 5 mm mesh. Twenty seven 60-cm-high, 15-cm diameter pots, comprising 9 cover crop treatments × 3 replicate pots per treatment, were filled with 15 kg air-dried soil and wet up to field capacity. Five seeds of the appropriate species were sown per pot, thinned to two plants per pot after emergence. Pots were then maintained at 70% field capacity throughout the growing season before a 2 week dry down period prior to termination (harvest) at 8 weeks. At harvest, shoots were cut at ground level and oven dried at 65℃ for 72 hrs. Pots were opened vertically, and soil was sectioned at different depths (i.e. 0-10, 10-20, 20-30, 30-40 and 40-60 cm) for measuring soil water and root length using WinRhizo within the soil column.

### *Statistical analysis*

All data were analysed using R version 3.4.1 (R Core Team, 2020). Analysis of variance was performed by the linear mixed-effect model fit by REML using the R package "nlme" (Pinheiro et al., 2017), considering treatments as fixed effect and replications as a random effect. When the treatments effects were significant, the least significant difference (LSD) test was performed to assess significant differences among treatments mean ($P < 0.05$) using the R package "predictmeans" (Luo et al., 2014).

## Results

### *Biomass*

In both field and glasshouse experiments, significant differences in shoot biomass were observed between cover crop species ($p<0.001$) (Table 1). Millet and cowpea had the highest biomass, while balansa clover and barrel medic had the lowest biomass in both experiments. Mung bean, lablab and sunn hemp produced moderate amounts of biomass.

### *Soil water*

Balansa clover and barrel medic had significantly higher residual soil water than all other cover crops in the field experiment, while cowpea and millet had the lowest residual soil water (Table 1). Similar trends were seen in the glasshouse experiment.

**Table 1: Biomass and soil water remaining after termination of summer cover crop species at the field and glasshouse trials, Wagga Wagga.**

| Crops | Field experiment | | Glasshouse experiment | |
|---|---|---|---|---|
| | Biomass (t ha$^{-1}$) | Soil water retention to 80 cm depth (mm) | Biomass (g plant$^{-1}$) | Soil water retention to 60 cm depth (mm)* |
| Balansa clover | $0.24^{C}$ | $226^{A}$ | $0.43^{G}$ | $194^{A}$ |
| Barrel medic | $1.02^{C}$ | $218^{A}$ | $2.98^{F}$ | $162^{B}$ |
| Lablab | $1.19^{C}$ | $138^{B}$ | $7.59^{DE}$ | $137^{CD}$ |
| Sunnhemp | $1.95^{BC}$ | $160^{B}$ | $6.88^{E}$ | $149^{BC}$ |
| Mungbean | $2.01^{BC}$ | $152^{B}$ | $7.68^{CDE}$ | $119^{D}$ |
| Buckwheat | $3.29^{AB}$ | $168^{BC}$ | $8.53^{CD}$ | $126^{D}$ |
| Cowpea | $3.93^{A}$ | $106^{C}$ | $8.66^{B}$ | $77^{E}$ |
| Millet | $4.57^{A}$ | $107^{C}$ | $9.85^{C}$ | $81^{E}$ |
| Tillage radish | | | $11.40^{A}$ | $75^{E}$ |
| P-value | <0.001 | <0.001 | <0.001 | <0.001 |
| LSD | 1.59 | 29.76 | 0.978 | 18.92 |

Note: Means of n = 4 replicates for field trial and n = 3 replicates for glasshouse trial. Means that do not share a common letter are significantly different from each other at P<0.05.

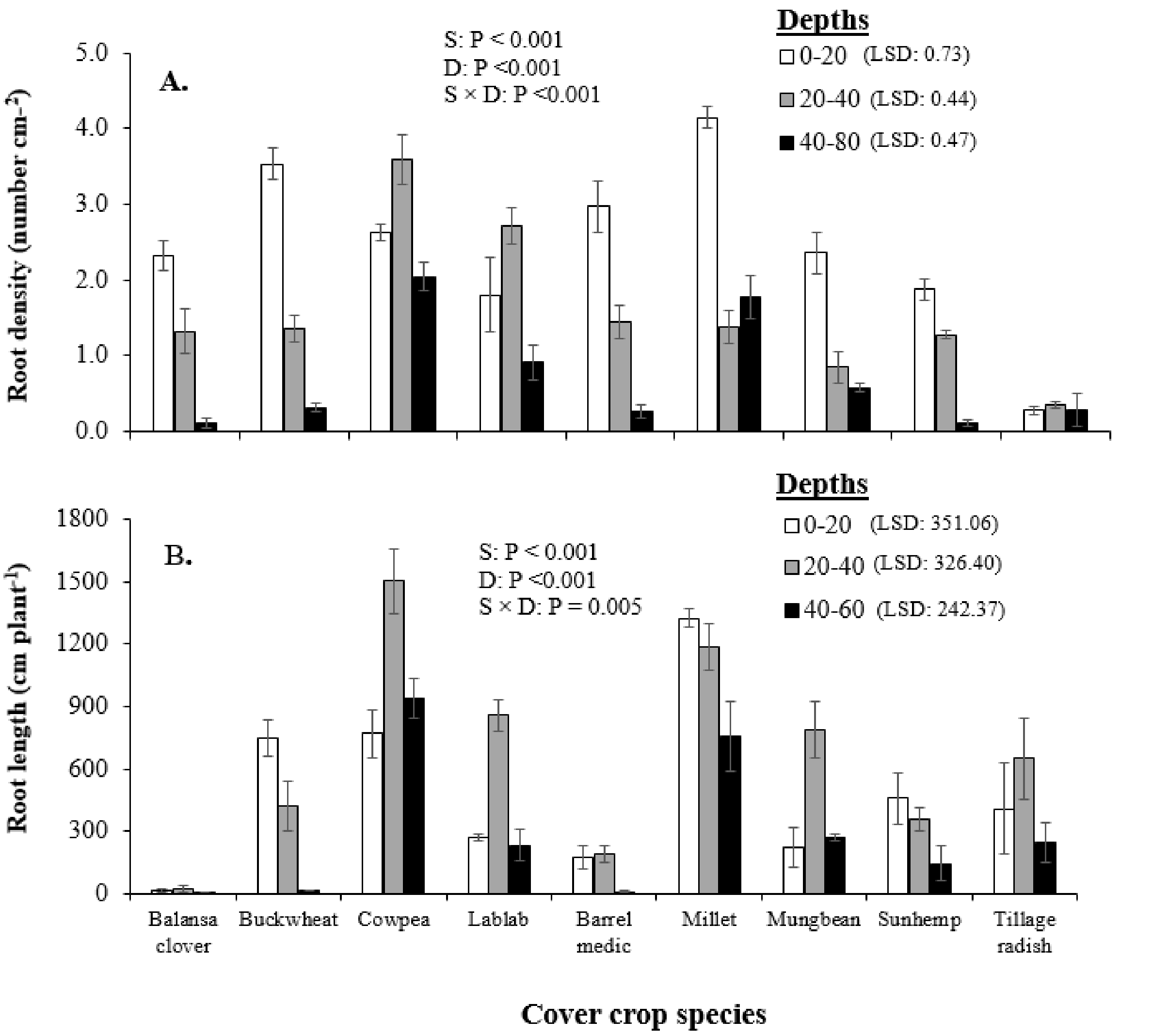


**Fig.1 A. Root density (average no. of roots per cm$^{-2}$ area of soil profiles up to 80 cm depth) in the field and B. total root length up to 60 cm in the glasshouse trial. Cover crop species (S), depth (D) and their interaction effects are shown in the graph along with the least significant difference (LSD) value.**

***Root density and root length***

In the field experiment (Fig. 1A), root density of balansa clover, buckwheat, medic, mungbean and sunnhemp was greater at the top (0-20 cm) and sub-surface (20-40 cm) soil while cowpea and lablab had greater amount of roots at the sub-surface to deeper soil depth (40-80 cm). Root length data showed similar trends in the glasshouse experiment (Fig. 1B). Among all SCC, the higher root length of cowpea and millet were found in the deeper (40-60 cm) soil column.

## Discussion

In our study, soil water retention differed among SSC species and was inversely related to biomass production. Millet and tillage radish produced the greatest amount of biomass which led to lower soil water retention after termination. In contrast, clover had the lowest biomass accumulation and had the greatest amount of soil water remained at termination. Our findings are consistent with other studies on cover crops (St Aime et al. 2020; Nielsen et al. 2015; Mitchell et al. 2015), which showed biomass accumulation was linked with soil water use because increases in transpiring leaf area of the greater biomass lead to greater soil water use during growth (Sanders et al. 2018).

The large increase in root density/length observed at the surface (0-20 cm depth) for some species (clover, buckwheat, medic and sunnhemp). This suggests that those shallow rooted SCC had less access to the deeper soil profile beyond 40 cm depth that might lead to less use of deeper soil water and lower yield penalty for the cash crop as the surface water usually lost by evaporation from the bare or fallow lands. Rooting depth at the deeper profile (40-80 cm) of cowpea and millet was significantly higher than that of others SCC, supporting the potential of these species for capturing water in deeper soil layers which may compromise soil water retention at termination.

## Conclusion

Our results highlighted that soil water use of SCC is related to biomass accumulation as well as roots distribution. Roots distribution varied among tested SCC species (shallow-rooted vs deep-rooted). Shallow rooted species had lower access to deeper soil profiles which might be advantageous to retain soil water for cash crop at termination.

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