# INCREASING PLANT SPECIES DIVERSITY IN CROPPING SYSTEMS

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**KEY POINTS**

**Cover crops produced < 1 t biomass in the 2020/21 summer. Cover crop water use did not significantly affect 2021 wheat yields, likely due to the relatively wet season.**

**Growing vetch as a temporary intercrop with wheat did not significantly ($P < 0.05$) lower grain yield, however, evidence suggests that a greater understanding on impacts to yield be completed. The effect of temporary intercropping on the 2022 canola yields will be assessed this season.**

**Few changes in soil functional properties were observed due to cover cropping, likely due to the small amounts of biomass produced each season.**

**The current summer cover crop (2021/2022) appears larger than previous seasons due to the wet conditions, so any impacts on soil biology may be more detectable this season.**

**Background**

Cropping systems in Australia can have limited plant species diversity, with cropping sequences dominated by cereals and declining use of legumes. Increasing plant diversity can enhance species richness of soil biota by providing more diverse litter, root exudates and rooting patterns. To help address a lack of species diversity in the region, Riverine Plains has established a long-term (five-year) trial site at Burramine as part of a national Cooperative Research Centre for High Performance Soils (Soil CRC) project, led by Southern Cross University. The trial is examining the viability of integrating diverse species into the farming system, as either winter rotation crops (or green/brown manures), winter temporary intercrops (where multiple crops are sown but only one is taken to harvest) or as summer cover crops, within the constraints of soil water and weed pressures. The effect of each of these treatments on soil function and, ultimately, grain yields and farm profitability, will be examined.

**Aim**

Cereal-canola or cereal-canola-legume rotations have advantages in terms of yield stability and profitability in southern Australia, and there is little incentive for grain growers to include other cash crops (a crop that returns a monetary value rather than for use by the grower) in their rotations. This project aims to identify other options for increasing plant diversity in cropping systems without upsetting the use of crops with the highest earning potential. This will be achieved by testing the impact of summer cover cropping, intercropping, or temporary intercropping (sowing multiple species and spraying out all but the cash crop species during the season) on soil water balance and mineral N at sowing, crop performance, and soil function over time.

## Method

A field trial spanning three growing seasons (2019, 2020 and 2021) was established at Burramine, Victoria, during autumn 2019. A total of 9 different rotational treatments were established based around the core wheat–canola rotation growers in the area typically employ (Table 1). The 2019 winter treatments also included a temporary intercropping treatment with wheat under-sown with sub-clover, field peas for grain, a pulse brown manure treatment (field peas) and a brown manure mix (field peas + radish). Mixed species cover crops were grown over the summer period in cover crop treatments in early 2020 following the harvest of the 2019 wheat crop. Details of species sown in 2019, 2020 and 2021 are given in Table 1.

For the 2021 season, all plots were sown on 12 May 2021 using a randomised block design, with plots measuring 8m × 18m. Wheat (cv. Rockstar) was sown at 75 kg/ha using direct drilling by the plot planter. In the temporary intercrop treatment, wheat (cv. Trojan) was sown at 75 kg/ha with an additional 40 kg purple vetch (cv. Popany, Vicia americana) in the same seeding row. Vetch was inoculated with Group F peat-based inoculant (WSM-1455 Rhizobium leguminosarum bv. Viciae). All plots received 80kg/ha MAP and 50kg Urea fertiliser at sowing. Two applications of 100kg Urea were applied on 6th August and 2nd September. Vetch was terminated using XX on 9th September 2021. The timing of key events, as well as rainfall and temperature data, are shown in Figure 1.

A range of measurements including soil moisture and soil mineral N prior to sowing, as well as crop emergence counts, biomass at anthesis and grain yield were taken during the 2021 season. Summer cover crop biomass from the 2020/21 summer was also measured. In January 2022, summer cover crops were sown in the cover crop treatments. While no measurements have been taken on these cover crops yet, photos are shown in Figure 4 to give an indication of their growth this season.

**Table 1:** Treatments and crop rotation from 2019-2022

| Treatments | 2019 Winter Crop | 2020 Summer Cover Crop | 2020 Winter Crop | 2021 Summer Cover Crop | 2021 Winter Crop | 2022 Summer Cover Crop | 2022 Winter Crop |
|---|---|---|---|---|---|---|---|
| Control (wheat–canola) | Wheat (cv Trojan) | | Canola (cv. Bonito) | | Wheat (cv Trojan) | | Canola (cv. Bonito) |
| Pulse–canola–wheat | Field peas (cv Morgan) | | Canola (cv. Bonito) | | Wheat (cv Trojan) | | Canola (cv. Bonito) |
| Brown manure (pulse) | Field peas (cv Morgan) | | Canola (cv. Bonito) | | Wheat (cv Trojan) | | Canola (cv. Bonito) |
| Brown manure (mix) | Field peas (cv Morgan + Oilseed Radish (cv Tillage Radish) | | Canola (cv. Bonito) | | Wheat (cv Trojan) | | Canola (cv. Bonito) |
| Intercrop | Wheat (cv Trojan) | | Canola (cv. Bonito) + pea (cv. Morgan) | | Wheat (cv Trojan) | | Canola (cv. Bonito) |
| Temporary intercrop | Wheat (cv Trojan) + sub-clover (cv Riverina) | | Canola (cv. Bonito) | | Wheat (cv Trojan) + Common vetch | | Canola (cv. Bonito) |
| Cover crop mix 1 | Wheat (cv Trojan) | Medic and buckwheat | Canola (cv. Bonito) | Medic and buckwheat | Wheat (cv Trojan) | Buckwheat and cowpea (cv Red caloona) | Canola (cv. Bonito) |
| Cover crop mix 2 | Wheat (cv Trojan) | Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish | Canola (cv. Bonito) | Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish | Wheat (cv Trojan) | Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish | Canola (cv. Bonito) |
| Maximum diversity | Wheat (cv Trojan) | Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish | Canola (cv. Bonito) | Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish | Wheat (cv Trojan) + Common vetch | Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish | Canola (cv. Bonito) |

Additional soil measurements were taken to investigate whether summer cover crops or temporary intercrops improve soil function. Soil samples were analysed for several indicators that have been proposed as candidates for assessing soil health. These include soil enzyme activities (6 different enzymes involved in organic C, N, P and S-cycling), hot-water extractable carbon (C) (representing biologically-active C), microbial biomass C (the size of the soil microbial community) and autoclavable-citrate-extractable protein (ACE-protein, which is contributes to soil aggregation and mineralisable-N).

Data on water and nitrogen pre-sowing and wheat yields were analysed using a one-way ANOVA. Statistical analysis of soil function measurements involved individual ANOVAs for each sampling time, with treatment and block as main factors. Where significant differences (P<0.1) were detected, treatment means were compared using least-significant difference. All statistical analysis and plotting were conducted in the R statistical framework using the packages 'agricolae', 'lsmeans', 'ggplot2'.

## Results

### *Soil water balances and grain yields*

Summer cover crop biomass was marginally higher in the autumn of 2020, but in both seasons the aboveground biomass was well below 1 t/ha (Table 2). The sorghum/millet/forage rape/radish cover crop that produced 731 kg/ha biomass in 2020 resulted in around 35 mm less water in the soil profile prior to sowing compared to the chemical fallow control (Table 3). The reduction in total soil water at sowing in the sorghum/millet/forage rape/radish cover crop treatment was due to water use in the subsoil (30-60 cm and 60-90 cm depths; Figure 2a). The canola yield following the sorghum/millet/forage rape/radish cover crop of 1.48 t/ha was lower than the 1.76 t/ha in the chemical fallow treatment, but the yield loss was not statistically significant at P < 0.1.

In the 2021 season, the sorghum/millet/forage rape/radish cover crop resulted in around 25 mm of water less in the soil profile in autumn compared to the chemical fallow treatment (Table

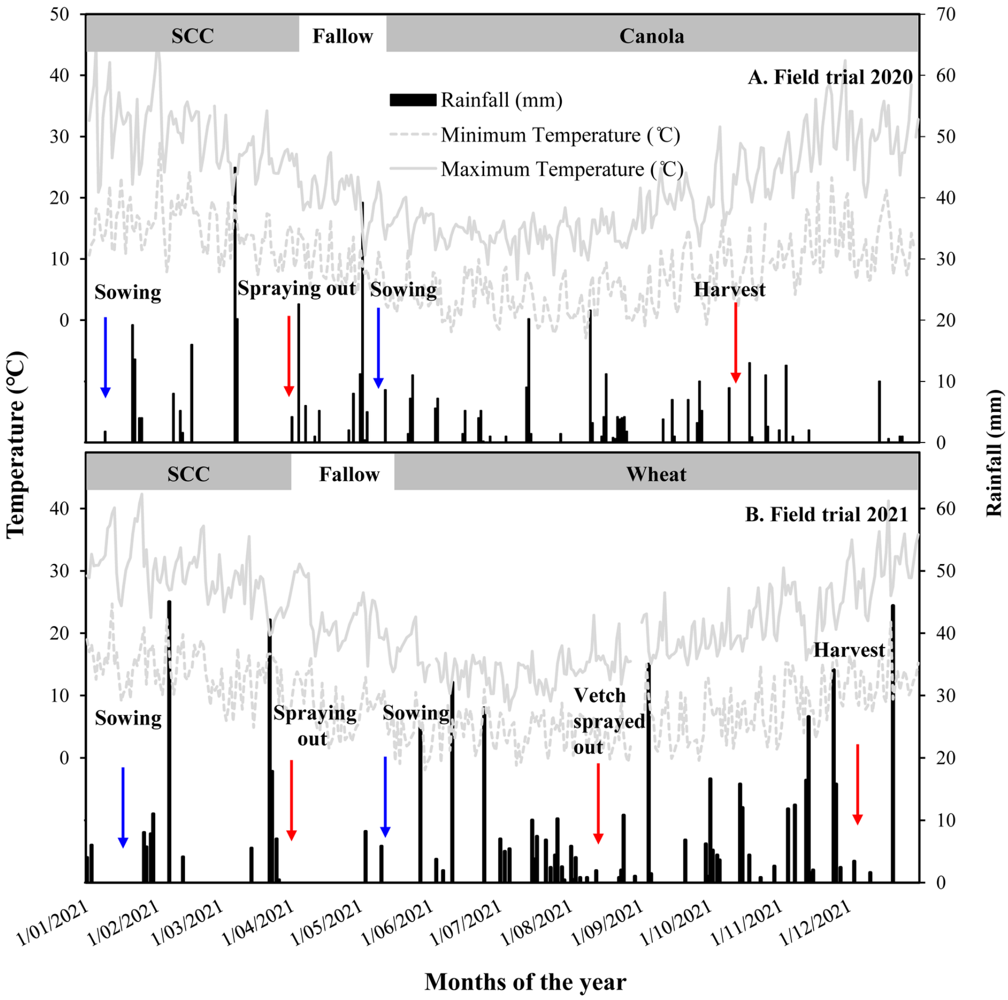


**Figure 1:**

Seasonal rainfall (black bars), maximum (solid lines) and minimum (dotted lines) temperature at the Burramine site during 2020 (A) and 2021 (B). Arrows indicate sowing and termination of summer cover crops (SCC) as well as sowing and harvest of winter crops (canola in 2020 and wheat in 2021). Vetch was sprayed out on 09 September 2021.

3). Once again, the reduction in total soil water at sowing in this cover crop treatment was due to depletion of subsoil water in the 30-60 cm and 60-90 cm layers (Figure 2b). The reason that topsoil moisture contents at sowing were similar between all treatments in both years was because of rain events between termination of the cover crops and soil water measurements prior to sowing (Figure 1), which recharged the 0-10 cm and 10-30 cm layers in all treatments. The soil water use by the summer sorghum/millet/forage rape/radish cover crop had no effect on wheat grain yields (around 4.3 t/ha in both the chemical fallow control and the sorghum/millet/forage rape/radish cover crop treatments), likely due to the wet seasonal conditions (Figure 1).

In contrast to the summer cover crop treatments, the temporary intercropping treatment (wheat/vetch sown together with vetch sprayed out in winter) resulted in a reduction in wheat grain yield (3.6 t/ha vs 4.3 t/ha in the control treatment; Table 3), although the difference was not statistically significant at P < 0.1. This difference may be linked to lower wheat emergence counts in the intercropping treatment (65 plants/m2 compared to 81 plants/m2 in the control treatment; Table 3).

### *Effect of cover crops on soil function*

There was no significant effect of summer cover crops on soil health indicators after the first summer of the experimental trial (2019/20). However, after termination of the summer cover crops in 2020/21, a significant increase in the levels of ACE-protein were detected in the sorghum/millet/forage rape/radish cover crop (SCC-2) treatment (Figure 3). Significantly higher (P < 0.05) concentrations of labile C (water soluble C plus hot-water extractable C) were also detected in this treatment in March 2021, compared with the control and medic/buckwheat cover crop (SCC-1) treatment. Although levels of both ACE-protein and labile-C were also higher the sorghum/millet/forage rape/radish cover crop (SCC-2) plots in April 2022, a month after cover crop termination, the effect was no longer significant at P < 0.05. ACE-protein is a measure of non-specific soil proteins and potentially other organic matter fractions (previously known as 'glomalin') thought to be predominantly formed by soil fungi and are well-correlated to soil aggregation and soil mineralisable N. Although ACE-protein concentrations returned to similar levels as the control plots by sowing in May 2021, it is not known if any associated benefits to soil

**Table 1:** Treatments and crop rotation from 2019-2022

| Season | Cover crop biomass (kg/ha) | |
|---|---|---|
| | medic/buckwheat | Sorghum/millet/forage rape/radish |
| 2020 | 561 ± 54 | 731 ± 119 |
| 2021 | 434 ± 70 | 463 ± 70 |

**Figure 2:** Effect summer cover cropping or temporary intercropping on distribution of soil water to a depth of 90 cm at sowing of winter cash crops in a) 2020 and b) 2021. Error bars depict the standard error of the mean of three replicate plots. Treatment bars not followed by a common letter are significantly different at P < 0.1.

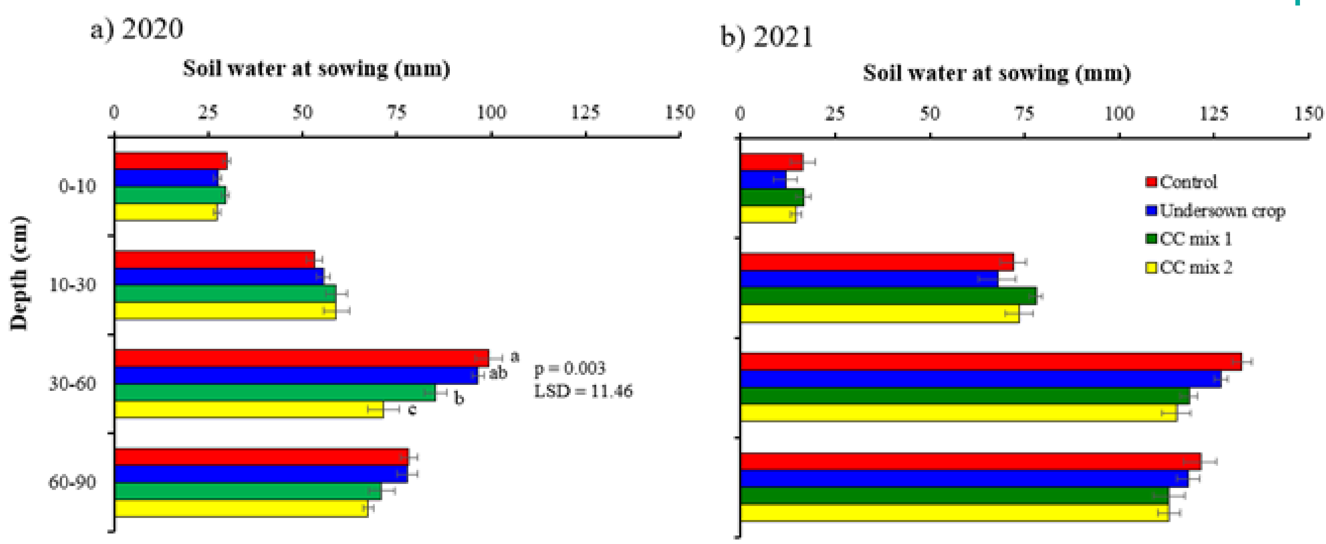

**Figure 2:** Effect of cover crop treatments SCC-1 (medic + buckwheat) and SCC-2 (sorghum, millet, forage rape and tillage radish) on ACE-protein levels in soil over summer 20/21, compared with no summer cover crop control. Different letters above bars indicate a significant difference between treatments (P < 0.05), ns = not significant (P > 0.05). Error bars are standard error of the mean.

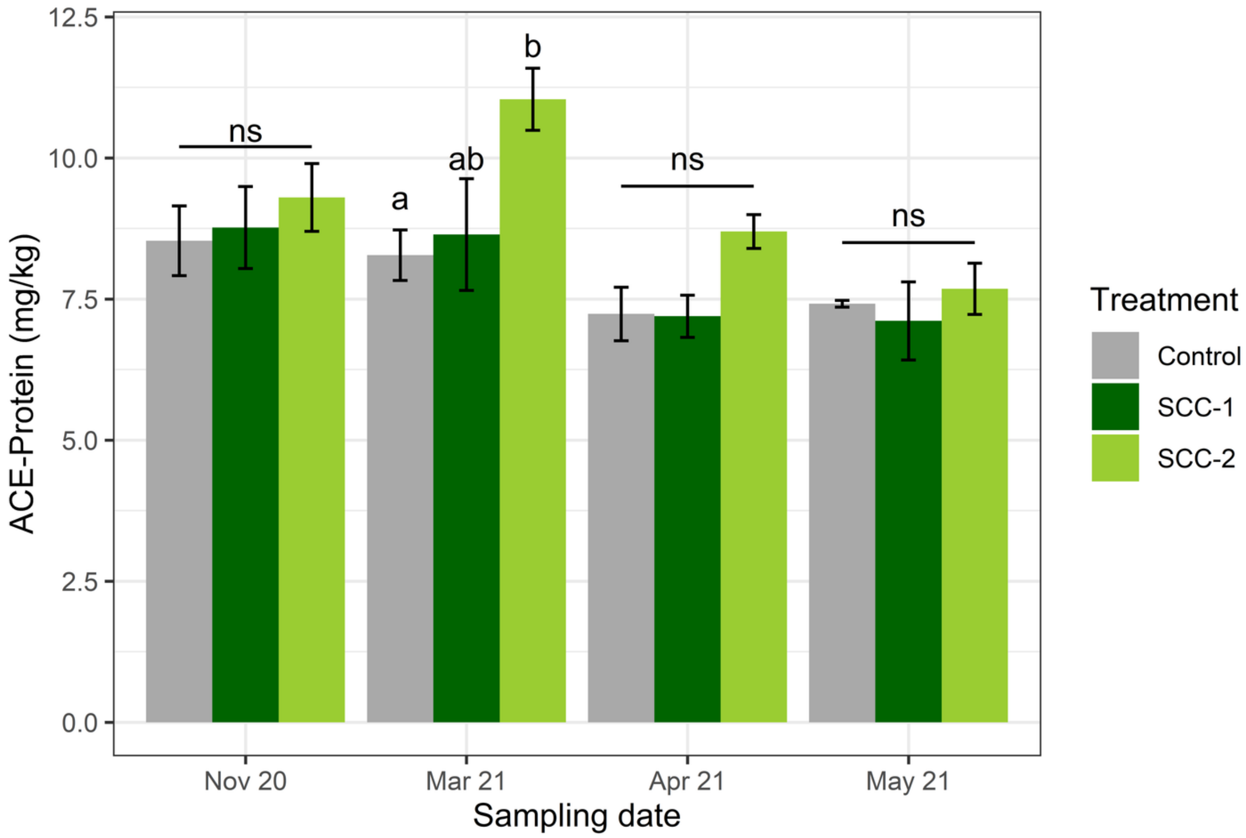


**Figure 2:** Cover crop treatments a) Cover crop Mix 1 (buckwheat with medic; b) Cover crop mix 2 (sorghum, millet, forage rape and oilseed radish (Tillage Radish) at Burramine, Victoria in March 2022.

(a)

(b)

**Table 3:** Effect of integrating plant diverity within the wheat-canola rotation using summer cover crops or temporary intercrops with wheat (vetch) on soil water and mineral N at sowing, and crop emergence, biomass production and grain yields in 2020 and 2021. Means not followed by a common letter are signfiicnatly different at P < 0.1.

| Integrated plant species treatments within the wheat/canola rotation | | | | |
|---|---|---|---|---|
| **Treatment** | **1** | **6** | **7** | **8** |
| **Rotation** | Control (2019: wheat, 2020: canola 2021: wheat) | Intercrop-undersown wheat (2019: wheat undersown with sub-clover 2020: canola, 2021: wheat undersown with vetch) | Cover crop mix 1 (2019: wheat, 2020: CC mix 1, 2020: canola, 2021: CC mix 1, 2021: wheat, 2022: CC mix 1 | Cover crop mix 2 (2019: wheat, 2020: CC mix 2, 2020: canola, 2021: CC mix 2, 2021: wheat, 2022: CC mix 2) |
| **2020 season (canola)** | | | | |
| **Water at sowing (mm) (P = 0.05)** | **261 b** | **257 b** | **245 ab** | **225 a** |
| **Mineral N at sowing (kg N/ha) (P = 0.21)** | 119 a | 137 a | 124 a | 105 a |
| **Emergence (plants/m2) (P= 0.22)** | 24 a | 27 a | 26 a | 21 a |
| **Canola biomass at flowering (t/ha) (P= 0.28)** | 4.5 a | 4.5 a | 5.7 a | 3.1 a |
| **Canola yield (t/ha) 2020 season (P = 0.12)** | 1.76 a | 1.74 a | 1.85 a | 1.48 a |
| **2021 season (wheat)** | | | | |
| **Emergence (plants/m2) (P = 0.06)** | 81a | 65 (wheat) b<br>56 (vetch) | 83 a | 86 a |
| **Water at sowing (mm) (P = 0.41)** | 342 a | 325 a | 326 a | 316 a |
| **Mineral N at sowing (kg N/ha) (P = 0.22)** | 72 a | 65 a | 55 a | 49 a |
| **Wheat biomass at anthesis (t/ha) (P =0.76)** | 6.22 a | 6.69 a | 6.86 a | 6.56 a |
| **Wheat yield (t/ha) 2021 season (P = 0.28)** | 4.28 a | 3.57 a | 4.20 a | 4.33 a |

## Background

Biomass production in the summer cover crop treatments has been < 1t/ha dry matter each season owing to low rainfall over summer and the short (2 month) growing season. Cover crops have been terminated after 2 months to allow time for some soil water to be replenished by rainfall between a late March termination and a May sowing of crops. This has been largely successful with soil water deficit of around 35 mm (2020) and 25 mm (2021) between the sorghum, millet, forage rape and tillage radish cover crops treatment and chemical fallow treatment. In the drier 2020 this water deficit at sowing led to a yield reduction of around 10% in canola that was not significant at P < 0.1, but there was no wheat yield loss in the wetter 2021 season. The temporary intercrop treatment did lead to a wheat yield reduction of around 10% (again, this was not statistically significant at P < 0.1), which was likely associated with lower plant establishment counts compared to control treatments. In subsequent years, we will focus on ensuring adequate plant numbers to give this treatment the best chance of success.

Few changes in soil functional properties were due to cover cropping, likely due to the small amounts of biomass produced each season.

However, some transient increases in water-extractable C and ACE-protein were observed in the 2021 season. This season we will focus on examining whether these soil functional changes after cover crops are linked to any measurable benefits in soil aggregation and water infiltration.

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