Increasing plant species diversity in cropping systems

Jane McInnes[1], Terry Rose[2], Shahnaj Parvin[2], Jason Condon[3]

[1] Riverine Plains
[2] Southern Cross University
[3] Charles Sturt University

Key points

- During 2019, nine crop treatments were established using a range of winter crops (including wheat, field peas for grain and brown manure, as well as a brown-manure mix) at Burramine, Victoria, as part of a larger, long-term project looking at increased plant species diversity in cropping systems.
- A number of plots from this trial were sown to summer crop mixes during January 2020 and this impacted on water availability (when canola was sown over the treatment plots during May 2020) and levels of some diseases in the soil. During 2020, canola and peola were sown over the treatments established during 2019.
- The use of a pulse in the rotation, or inclusion of a brown-manure crop, substantially increased mineral nitrogen (N) at sowing of the subsequent canola crop.
- There was no difference in biomass production or yield between the control and the pulse rotation treatments or the control and increased diversity treatments.
- Cover crops sown during 2021 were affected by poor summer rainfall

Background

Cropping systems in Australia can have limited species diversity, exacerbated by declining legume use in cropping systems during the past decade. Increases in plant diversity, either in time or space, are more likely to enhance the species richness of soil biota by providing more diverse litter deposition, exudates, rooting patterns and plant associations. Diversification of crop rotations, compared with monoculture or minimal break crops and/or the integration of green manures (including cover crops), into crop rotations have positive benefits for soil health.

To help address a lack of species diversity across the region, Riverine Plains has established a long-term (five-year) trial site at Burramine, Victoria as part of a national Cooperative Research Centre for High Performance Soils (Soil CRC) project, led by Southern Cross University. The trial is assessing the viability of integrating diverse species into the farming system, as either winter rotation crops (or green/brown manures) or as summer cover crops, within the constraints of soil water and weed pressures. These trials will investigate a range of rotation options for improving soil function and, ultimately, grain yields and farm profitability. Soil function will be assessed in terms of measuring soil microbial communities, structure and their extracellular enzyme activities as well as mineralisation rate of nutrients (carbon [C], nitrogen [N] and phosphorus [P]) through decomposition of litters, root debris and soil organic matter (SOM) over the time.

Further, the Burramine trial evaluates how green manure crops, cover crops (crops grown over summer primarily for the benefit of the soil rather than for yield), intercrops (where multiple species of crop are grown at the same time and are all taken through to harvest) and companion crops (where multiple crops are sown, but only one is taken to harvest) can affect soil functionality through modulating a suite of soil health assays.

Aim

Although the cereal–oilseed crop–legume rotation offers advantages in terms of disease control, microbial abundance and nutrient transformation, there is little incentive for growers in southern cropping systems to increase plant diversity by growing alternative winter crops. This project aims to investigate other options to increase plant diversity, such as summer cover cropping, intercropping or companion cropping, and to examine their impacts on soil function and winter crop yields.

Method

A field trial spanning four growing seasons (winter-summer-winter-summer) was established at Burramine, Victoria, during autumn 2019. A total of nine different rotational treatments were established based around the core wheat–canola rotation growers in the area typically employ (Table 1).

On 13 May, 2020, the entire trial site was sown to either canola (cv Bonito) or 'peola' (a canola (cv Bonito) and field pea (cv Morgan) intercrop), representing the second (canola) phase of the wheat–canola rotation. The canola-only treatments were sown into soil moisture following a significant rainfall event during early May, at a rate of 3kg/ha with 80kg/ha of MAP and 50kg/ha of GranAM below the

TABLE 1 Treatments and crop rotations for the *Increasing crop diversity trial* for four growing seasons (winter 2019, summer 2020, winter 2020 and summer 2021), Burramine, Victoria

	Treatments	2019 winter crop	2020 summer cover crop	2020 winter crop	2021 summer cover crop
1	Control (wheat/ canola/wheat)	Wheat (cv Trojan)	-	Canola (cv Bonito)	-
2	Pulse/canola/ wheat	Field peas (cv Morgan)	-	Canola (cv Bonito)	-
3	Pulse (brown manure)/canola/ wheat	Field pea (cv Morgan)	-	Canola (cv Bonito)	-
4	Brown manure (mix)/canola/ wheat	Field pea (cv Morgan) + tillage radish (cv Tillage Radish)	-	Canola (cv Bonito)	-
5	Intercrop (wheat/ peola/wheat)	Wheat (cv Trojan)	-	Canola (cv Bonito) + Field Pea (cv Morgan) (peola)	-
6	Companion crop (wheat undersown with subclover/ canola/wheat)	Wheat (cv Trojan) + sub-clover (cv Riverina)	-	Canola (cv Bonito)	-
7	Cover crop mix 1	Wheat (cv Trojan)	Medic and buckwheat	Canola (cv Bonito)	Medic and buckwheat
8	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)
9	Maximum diversity	Wheat (cv Trojan)	Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish)	Canola (cv Bonito) + Field Pea (cv Morgan) (peola)	Sorghum (cv Crown), millet (cv Shirohie), forage rape (cv Greenland) and oilseed radish (cv Tillage Radish)

Note: The 2021 cover crops (treatments 7 and 8) and maximum diversity plots (treatment 9) were sown into the same 2020 summer cover crop and maximum diversity treatment plots and have grown two summer and two winter crops to date.

seed. The 'peola' mix was sown using a canola rate of 3kg/ha and a field pea rate of 100kg/ha, with fertiliser applied at the same rate as the canola-only treatments.

A range of measurements, including soil moisture, soil nitrogen and disease status, as well as crop establishment, biomass and yield, were taken during 2020 to determine the effect of the summer and winter crop treatments, established during 2019, on the yield of the canola and 'peola'. Additional soil measurements were also taken to investigate whether summer cover crops provide more benefit if the summer cover crop species are from different plant families than the winter crops grown in the rotation (results were not available in time for publication). Statistical analysis was undertaken separately for the rotation treatments and the increased diversity treatments using $P < 0.1$. Data from the peola treatments was not statistically analysed due to the difficulty comparing treatments.

On 28 January 2021, summer cover crops were sown into the same plots as the 2020 summer cover crops. The same mixes were used during 2021 as during 2020; these

Peola (peas and canola) sown together in the maximum diversity plot (Photo taken 2 September 2020).

included cover crop mix 1 (CC mix 1: medic and buckwheat) and cover crop mix 2 (CC mix 2: sorghum, millet, forage rape and oilseed radish (tillage radish), while the maximum diversity treatment was sown to CC mix 2.

The cover crops emerged well, having received 30mm of rainfall during the 10 days following sowing, however they subsequently struggled due to the lack of rainfall from sowing until late March. The cover crops were terminated with glyphosate on 1 April, 2021 to prepare for the 2021 winter crop.

During winter 2021, the site will revert to the cereal phase of the rotation, with selected plots sown to treatments with greater diversity. Actual species determination for the remaining years of the trial will be subject to crop performance and with consideration to the specific range of weeds, pests or diseases that require active management.

Delays associated with soil analysis means not all soil function results were available in time for publication of this article.

Results and comments

2020 summer cover crop treatments

Summer cover crops emerged following a rainfall event during January 2020 and produced 0.6–0.7t/ha dry matter (DM) biomass before being sprayed out with glyphosate on 18 March 2020 (see report in Research for the Riverine Plains, 2020, p33).

A range of soil measurements, including available soil water, was taken for the plots sown to canola during 2020 by soil coring at a depth of up to 1m when the winter crop (canola) was sown on 13 May, 2020. The peola plots (Treatments 5 and 9) were excluded from statistical analysis due to difficulty in comparing treatments.

Impact of crop rotation on soil function and soil water at sowing

Plots sown to pulse treatments during 2019 (field peas for grain, field peas for brown manure or mixed-species brown manure) were sampled for soil moisture and compared against the control (wheat) during May 2020. There was no difference between soil moisture overall in the (bulked) 0–90cm increment (Table 2), however, there was significantly more moisture available in the control (Treatment 1) for the 0–10cm increment compared with the other pulse rotation treatments (Figure 1). For the 60–90cm depth increment, there was significantly less moisture available in the control (wheat) and field pea for grain treatments compared with the brown-manure treatments and this difference likely reflects late-season water use at depth during 2019 in crops grown for grain compared with those terminated in spring by brown manuring.

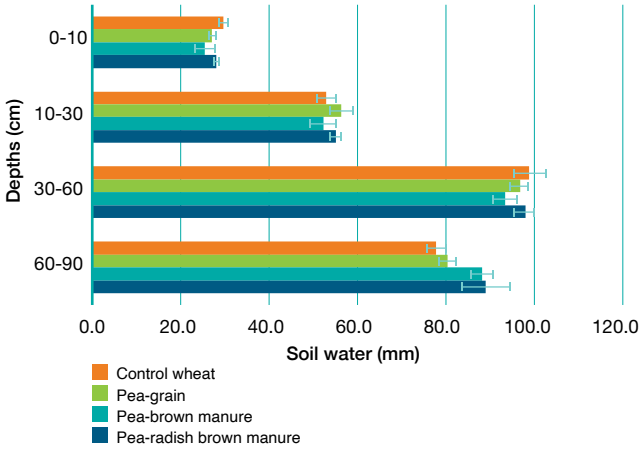

FIGURE 1 Effect of 2019 winter control and pulse treatments (pulse crop – field pea, brown manure – field pea, brown manure mix – field pea plus tillage radish) on available soil water on 13 May, 2020

Cover crop treatments before being sprayed out with glyphosate on 1 April, 2021. a) Cover crop mix 1; b) Cover crop mix 2 at Burramine, Victoria.

When moisture availability was compared between the wheat and increased diversity treatments (Table 3), there was significantly less moisture available overall in the plots sown to wheat plus mixed species cover crop (CC mix 2) at sampling, compared with the control and wheat undersown with sub-clover treatments. This may be related to the increased rooting depth and rooting patterns of the different species in CC mix 2.

For the rotation treatments sown to pulses during 2019, mineral nitrogen at sowing was significantly lower in the control (119kg/ha) and mixed brown-manure treatments (field peas and tillage radish, 128kg/ha) than the field peas for grain (179kg/ha) and field peas for brown-manure treatments (223kg/ha). This likely reflects the higher rate of decomposition and release of nitrogen in the field pea treatments compared with the wheat and mixed-species brown-manure treatments.

There was no statistical difference in mineralised soil nitrogen between the increased diversity (wheat and summer cover crop or undersown treatment plots) when measured during May 2020.

Predicta B testing in the wheat and increased diversity treatments showed that pythium and take-all were significantly higher in the wheat plus summer CC mix 2 treatment compared with the undersown wheat and wheat plus CC mix 2 treatments. The reason for this difference is currently unclear.

2020 winter crop treatments

Emergence and biomass at flowering

Plentiful opening rains during autumn 2020 meant that for plots in the wheat (2019) – canola (2020) rotation canola establishment rates and canola biomass at flowering was not significantly different to the other treatments (Table 2).

TABLE 2 Effect of rotation on water use, soil nitrogen at sowing, emergence, DM and yield for plots sown to canola in 2020 at Burramine, Victoria

	Rotation treatments			
Treatment reference	**1**	**2**	**3**	**4**
Rotation	**Control (2019: wheat, 2020: canola)**	**Pulse for grain (2019: field pea, 2020: canola)**	**Pulse brown manure (2019: field pea, 2020: canola)**	**Brown manure mix (2019 field pea/ tillage radish, 2020 canola)**
Water at sowing (mm)	261[a]	262[a]	260[a]	271[a]
Mineral N at sowing (kg N/ha)	119[a]	179[b]	223[c]	128[a]
Emergence (plants/m^2)	24[a]	30[a]	29[a]	31[a]
Canola biomass at flowering (t/ha)	4.5[a]	5.6[a]	7.7[a]	5.3[a]
Canola yield (t/ha)	1.76[a]	1.86[a]	2.05[a]	2.11[a]

TABLE 3 Effect of integrating plant species within the wheat – canola rotation as summer cover crops or wheat undersown with clover treatments on water use, soil nitrogen at sowing, disease levels, emergence, DM production and yield at Burramine, Victoria, 2020

	Integrated plant species treatments within the wheat/canola rotation			
Treatment reference	**1**	**6**	**7**	**8**
Rotation	**Control (2019: wheat, 2020: canola)**	**Intercrop – undersown wheat (2019: wheat undersown with sub-clover, 2020: canola)**	**Cover crop mix 1 (2019: wheat, 2020 CC mix 1, 2020: canola, 2021 CC mix 1)**	**Cover crop mix 2 (2019: wheat, 2020 CC mix 2, 2020: canola, 2021 CC mix 2)**
Water at sowing (mm) (P = 0.07)	261[b]	257[b]	245[ab]	225[a]
Mineral N at sowing (kg N/ha)	119[a]	137[a]	124[a]	105[a]
Pythium	41[ab]	16[a]	16[a]	77[b]
Take all (0.07)	0[a]	0[a]	0[a]	0.4[b]
Emergence (plants/m^2)	24[a]	27[a]	26[a]	21[a]
Canola biomass at flowering (t/ha)	4.5[a]	4.5[a]	5.7[a]	3.1[a]
Canola yield (t/ha)	1.76[a]	1.74[a]	1.85[a]	1.48[a]

* Pythium and take all disease levels measured by Predicta B testing.

There was also no significant difference in canola emergence for treatments that used summer crops or wheat undersown with sub-clover to increase diversity in the rotation (Table 3). However, the canola sown into the CC mix 1 plots emerged somewhat poorly relative to the other treatments and was affected by high levels of volunteer buckwheat. Similarly, poorer canola emergence was observed in the plots sown to CC mix 2, due to the later-than-ideal chemical termination of summer crops, which resulted in seed set.

Canola biomass accumulation was measured as DM at flowering for all treatments. The highest biomass production was measured in the brown manure treatment (7.7t/ha), however this was not significantly different to the wheat plus CC 2 mix, which produced the lowest biomass at flowering (3.1t/ha)

Yield

There was no difference in canola yield between the control and the pulse rotation treatments (Table 2).

For the increased diversity through summer cropping or undersowing treatments, canola yield was highest in the wheat plus summer CC mix 1 treatment (1.85t/a), however this was not significantly different to any other treatment, including the control, which represented a summer fallow (1.76t/ha) (Table 3). The additional water used by the wheat plus 2020 summer CC mix 2, reduced canola yield by 10 per cent (1.48t/ha), however this was not significantly different to the yield of the other treatments.

The two peola treatments yielded similarly during 2020, with the intercropped peola (2019: wheat, 2020: peola) treatment yielding 1.97t/ha and the maximum diversity (2019: wheat, 2020 CC mix 1, 2020: peola, 2021 CC mix 1) yielding 1.92t/ha. The peola yield represents both the canola and pea yields combined together.

2021 summer cover crop

Dry matter production

Due to a lack of rainfall, the summer cover crop treatments were not sown until late January 2021. The late sowing, combined with poor follow-up summer rainfall received after crop emergence, affected cover crop biomass production. There were approximately eight weeks of growth from the time of cover crop emergence until crop termination on 1 April, 2020, with no significant differences in biomass production observed between the two treatments (Figure 2).

Following the termination of the summer cover crops, soil function samples were taken from the control and cover crop plots. There was a noticeable difference in the ground conditions observed at sampling, with the control plots being much harder and it was more difficult to insert the probe into the ground.

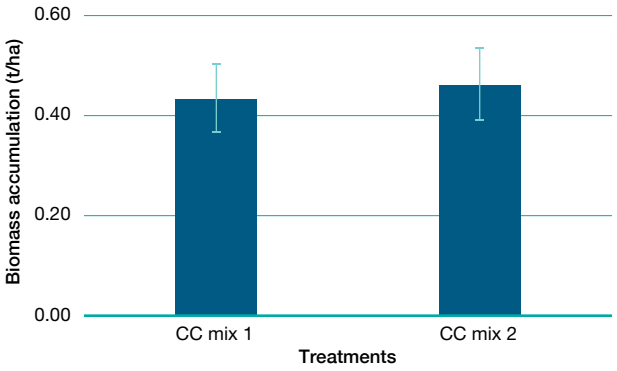

FIGURE 2 Biomass accumulation of summer cover crop treatments (CC mix1: medic and buckwheat and CC mix 2: sorghum, millet, forage rape and oilseed radish (tillage radish)) after eight weeks of growth, before being sprayed out with glyphosate on 1 April 2021 at Burramine, Victoria

Observations and comments

The use of a pulse in the rotation, or inclusion of a brown manure crop, substantially increased mineral nitrogen at the sowing of the subsequent canola crop, but the economic benefits of these alternatives are yet to be explored.

Summer cover crops can be incorporated into the system, but biomass production to date has been low due to low summer rainfall and hot summer conditions. The summer cover crops sown during 2020 impacted on water availability at 2020 winter crop sowing, as well as levels of some diseases in the soil, but no significant impact on canola grain yields was observed.

Soil function and winter grain yields will be monitored during upcoming seasons to determine whether impacts of summer cover crops become apparent over the longer term.

Acknowledgements

This trial is part of the *Plant-based solutions to improve soil performance through rhizosphere modification* project, led by Southern Cross University. The project is supported by the Cooperative Research Centre for High Performance Soils whose activities are funded by the Australian Government's Cooperative Research Centre Program. The project is also supported by the Goulburn Broken Catchment Management Authority's 'From the Ground Up' program through funding from the Australian Government's National Landcare Program.

Contact

Jane McInnes Riverine Plains Inc.
P: (03) 5744 1713
E: jane@riverineplains.org.au