Weed suppressive potential of winter cover crops established as monocultures and mixtures in Southern Australia

Saliya Gurusinghe[1], Shamsul Haque[1,2], Michael Widderick[3], Annemieke Ruttledge[3], Asad Shabbir[4], Michael J. Walsh [4] and Leslie A. Weston [1,2]

[1] Graham Centre for Agricultural Innovation, Charles Sturt University, Boorooma Street, Wagga Wagga NSW 2650, Email: sgurusinghe@csu.edu.au

[2] School of Agriculture and Wine Sciences, Charles Sturt University, Boorooma Street, Wagga Wagga NSW 2650

[3] Queensland Department of Agriculture and Fisheries, Leslie Research Facility, 13 Holberton Street, Rockville QLD 4350 [4] Centre for Carbon Water and Food, School of Life and Environmental Sciences, The University of Sydney, 380 Werombi Rd, Camden NSW 2570

Abstract
Leguminous and other cover crops provide rotational diversity resulting in reduced erosion, improved soil tilth, moisture retention, weed control and nitrogen fixation in mixed farming and cropping systems. Cover crops suppress weeds through competition for resources or through the production and release of phytotoxic metabolites exuded by living roots or decomposing plant residues. Field experiments were established in winter growing season in Wagga Wagga and Narrabri NSW, and Kingaroy QLD, to evaluate the establishment of various cover crop species and assess their competitive traits for winter weed suppression in 2018, 2019 and 2020; however, only results from the experiments established in the 2020 growing season are presented. Crop and weed competitive traits were estimated by assessment of canopy light interception (LI), and crop and weed biomass, in both monocultures and binary species mixtures of cover crops. Overall, grazing oats and tillage radish as winter covers accumulated the greatest biomass and strongly reduced weed number and biomass in winter annual weeds. Interestingly, binary mixtures of suppressive cover crops performed similarly to individual monocultures with respect to ground cover and accumulation of weed biomass. Experimentation to optimise the economical use of productive monocultures and mixtures in eastern Australia is underway.

Keywords
Weed suppression, legume cover crops, multi-species mixtures, cover crop residues, phytotoxicity

Introduction
Cover crops provide important agro-ecological functions by improving soil tilth and moisture availability for subsequent crops. Nitrogen fixing legumes enhance the plant available nitrogen content in the rhizosphere (Komatsuzaki and Wagger, 2015), while providing fodder rich in nutrients for livestock in mixed farming systems (Dear and Ewing, 2008). They also suppress the emergence and establishment of annual weeds (Schipanski et al., 2014). Integrated weed management strategies incorporating cover crops have resulted in reduced herbicide use and incidence of herbicide resistance, both of which are important considerations for Australian grain producers (Peterson et al., 2018; Wallace et al., 2018). The weed suppressive potential of cover crops typically manifests either through competition for resources (Lawley et al., 2012) or through the release of phytotoxic secondary metabolites from crop residues and root exudates, resulting in inhibition of weed seed germination or reduction in weed seedling growth (Bhadoria, 2011).

Graminacious crop species such as wheat, rye and maize are known to suppress weeds through competition for resources as well through production of numerous phytotoxic metabolites (Wu et al., 2000; Pérez and Ormenoñuñez, 1991). It has also been shown that legume cover crops and their residues can sometimes suppress weeds very effectively depending on crop vigour and canopy (Gurusinghe et al., 2018; Latif et al., 2019). From the perspective of enhanced competition for resources, low growing clovers and other densely established legume mixtures frequently provide adequate ground cover to suppress weed germination and establishment. Legumes cover crops associated with the tropical or sub-tropical members of the Fabaceae family can also inhibit both germination and emergence of annual grass and broadleaf weeds effectively (Adler and Chase, 2007).

A series of field, glasshouse and laboratory experiments were thus designed to assess the performance of a diverse collection of winter and summer cover crops in the northern grain growing region, with respect to establishment, canopy formation, biomass accumulation and weed suppression over time. Studies were performed in three locations across NSW and QLD and addressed the following objectives: 1) evaluation of cover crop establishment 2) determination of the competitive ability of diverse cover crops/ ground covers contributing to early season weed suppression and 3) the selection of multispecies mixtures for optimal biomass production and weed suppression.

Methods

Cover crop establishment

Field experiments were established in 2020 at the Graham Centre field site, Wagga Wagga NSW, the University of Sydney research site in Narrabri, NSW and the Department of Agriculture and Fisheries field site, Kingaroy, QLD. Experiments were designed as randomised complete blocks with four replications per treatment. Multispecies binary mixtures were also sown at various ratios within the recommended sowing rate ranges. Residual weed infestations were removed using glyphosate, applied at a rate of 1.6 L ha^{-1} in late April before sowing in all plots across all locations. Winter cover crops were sown on 23rd April 2020 in Narrabri, and 13th May 2020 and 19th May 2020 in Wagga Wagga, respectively, and 22nd June 2020 in Kingaroy. Cover crops were seeded using a precision cone planter with plot dimensions of 10 m × 1.6 m. Due to the near complete absence of a natural weed infestation in Kingaroy, Italian ryegrass (*Festuca perennis)* was over-sown as a weed mimic to reach a target population of 50 plants/m^2. Crops were subsequently terminated using glyphosate at a rate of 2L/ha at 150 days after planting at maturity.

Crop assessments

Crop emergence was recorded in 2 × 0.25 m^2 quadrats per treatment, at 25 days after sowing. Two aboveground biomass samples were collected at 60, 90 and 110 days after sowing within each plot by cutting at the soil surface in two 0.25 m^2 quadrants and total biomass of both the crop and weed species was determined. Plant material was collected and sorted immediately after harvest before drying at 70 °C for 120 h, and dry weights of crop and weeds were determined. Aboveground crop competition was also assessed within each treatment sub-plot at ~30, 50, 70 and 90 days after sowing. Canopy cover was assessed by determination of percent interception (LI) of photosynthetically active radiation at the base of the crop using a light ceptometer (AccuPAR LP-80 Ceptometer, Decagon Devices®), typically performed on a cloudless day.

Statistical analysis

Trial randomization, design and data analysis were performed using Agricultural Research Manager (ARM) version 9.0, a statistical software package by GDM (Gylling Data Management Inc., 2014). Statistical analysis of data was performed by one-way or two-way analysis of variance for randomised experiments with four replicates using the statistical software, R (R Core Team, 2017). Significant differences were separated using Tukey's HSD test for multiple comparisons, with significance declared at $P<0.05$.

Results

Climatic conditions

From May to October 2020, 340 mm, 203 mm and 157 mm of precipitation was recorded in Wagga Wagga, Narrabri, and Kingaroy, respectively, indicative of drought conditions in northern NSW and southern QLD. However, above-average precipitation was received at Wagga Wagga for this period.

Performance of winter cover crops established as monocultures

All winter cover crop species established successfully in the three experimental field sites, except for lupins which failed to establish in Wagga Wagga due to herbivory by animal pests (cockatoo; *Cacatuidae* spp.). Collectively, the accumulation of crop biomass was similar in Wagga Wagga and Kingaroy field sites, while biomass in Narrabri was significantly lower ($P<0.05$). Maximal biomass was observed in grazing oats (13.4 t/ ha; Figure 1A), followed by tillage radish (11.1 t/ ha), field pea (8.9 t/ ha) and vetch (7.6 t/ ha), at the Wagga Wagga location. Crop biomass accumulation in Narrabri was greatest in tillage radish (8.2 t/ ha), followed by grazing oats (6.5 t/ ha) and field pea (5.5 t/ ha).

Tillage radish also performed well in Kingaroy, accumulating 10 t/ha of crop biomass, followed by grazing oats (7.9 t/ ha) and field pea (8.2 t/ ha).

Weed biomass was reduced in all cover crop treatments with the exception of lupins, when compared to the unsown control in Wagga Wagga (Figure 1B). No weed infestation was noted in grazing oats and tillage radish treatments, and biomass was reduced by 98% in the vetch treatment when compared to the unsown control. Arrowleaf clover, field pea and vetch provided only moderate weed suppression (58 – 65% reduction) when compared to the unsown control. Overall, covers which generated large quantities of biomass rapidly were more strongly weed suppressive.

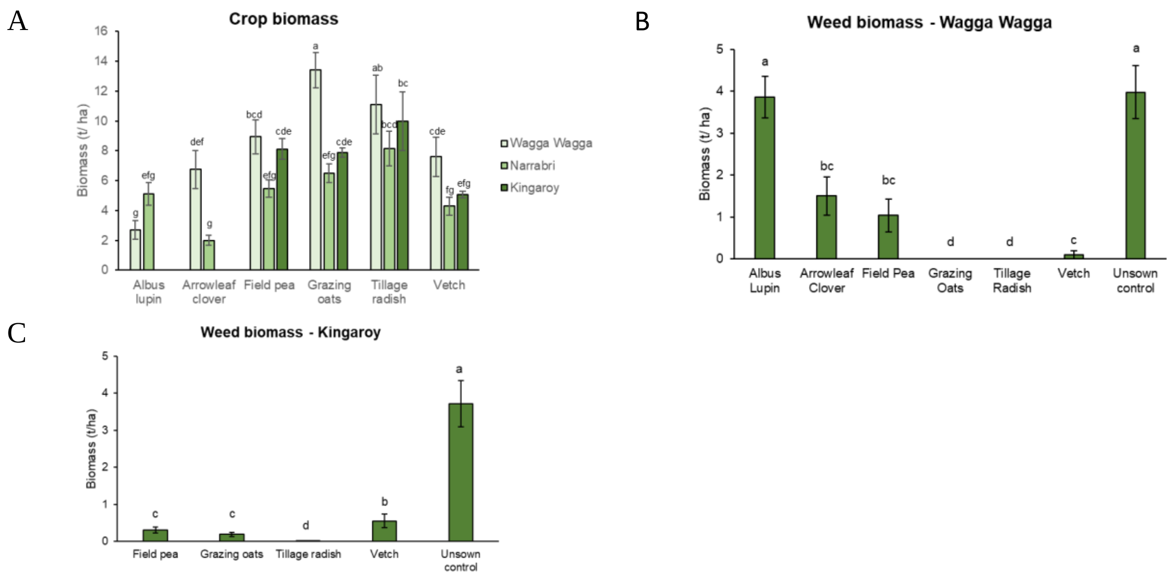
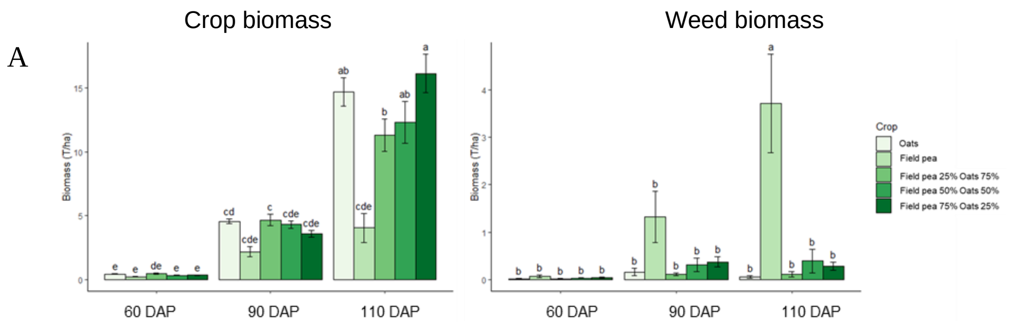


Figure 1. Accumulated biomass of (A) winter cover crop monocultures, (B) weeds emerging from the natural weed seedbank at maturity and (C) weed mimic Italian ryegrass (110 days after sowing) in each cover crop treatment. Error bars indicate the standard error of means. Means sharing the same letters are not significantly different. Albus lupin and arrowleaf clover not sown in Kingaroy.

Performance of winter cover crops established as multispecies mixtures

Crop biomass accumulation in multispecies mixtures was typically dominated by the more vigorous member of the mixture, for example, grazing oats or tillage radish (Figure 2). In Wagga Wagga, a higher ratio of grazing oats in the mixture provided greater biomass than the less competitive companion species as a monoculture, both at 90 and 110 days after planting (DAP; $P < 0.05$). Multispecies mixtures reduced weed biomass accumulation more significantly ($P < 0.05$) when compared to a field pea monoculture, in Wagga Wagga.



B

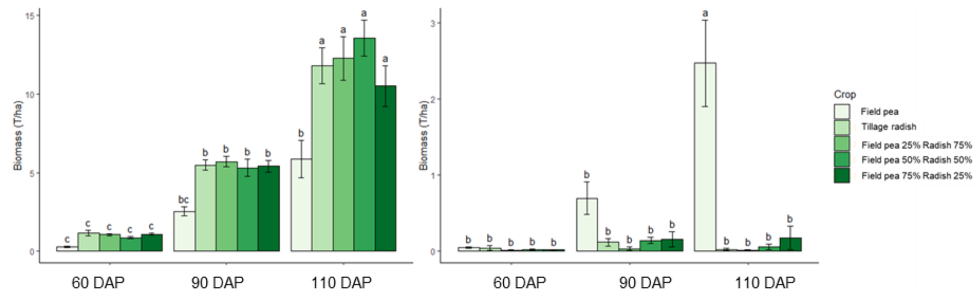


Figure 2. Crop and weed biomass for multispecies binary mixtures of winter cover crops (A) grazing oats/ vetch; and (B) field pea/ tillage radish, established in Wagga Wagga. DAP; Days after planting. Error bars indicate the standard error of means. Means sharing the same letters are not significantly different.

Conclusions

Field experimentation performed over the winter growing season in central and southern NSW and southern QLD evaluated cover crop species appropriate for establishment in the low to medium rainfall zones in diverse soil types and climatic conditions, while further investigating their impact on annual weeds by characterizing their growth habits over time. Those cover crops and binary mixtures that established rapidly and generated considerable biomass generally formed canopies that effectively suppressed annual weeds. Data generated from this study will better inform growers on the suitability of cover crop choice and the use of multispecies mixtures for the eastern grain belt.

Acknowledgements

The authors acknowledge the funding support from GRDC (project: US000084) and technical assistance at from field teams at CSU, USYD and QDAFF.

References

Adler MJ and Chase CA (2007). Comparison of the allelopathic potential of leguminous summer cover crops: Cowpea, sunn hemp, and velvet bean. HortScience 42, 289–293.

Bhadoria PBS (2011). Allelopathy: a natural way towards weed management. Am. J. Exp. Agric. 1, 7.

Dear BS and Ewing MA (2008). The search for new pasture plants to achieve more sustainable production systems in southern Australia. Aust. J. Exp. Agric. 48, 387–396.

Gurusinghe S, Latif S, Brown WB, Weston PA and Weston LA (2018). A useful in vitro bioassay for evaluation of weed suppression by legume cover crop residues, in: Proceedings of the 21st Australasian Weeds Society.

Komatsuzaki M, Wagger MG (2015). Nitrogen recovery by cover crops in relation to time of planting and growth termination. J. Soil Water Conserv. 70, 385–398.

Latif S, Gurusinghe S, Weston PA, Brown B, Quinn JC, Piltz JW and Weston LA (2019). Performance and weed suppressive potential of selected pasture legumes against annual weeds in southeastern Australia. Crop Pasture Sci. (https://doi.org/10.1071/CP18458)

Lawley YE, Teasdale JR and Weil RR (2012). The mechanism for weed suppression by a forage radish cover crop. Agron. J. 104, 205–214.

Peterson MA, Collavo A, Ovejero R, Shivrain V, and Walsh MJ (2018). The challenge of herbicide resistance around the world: A current summary. Pest Manag. Sci. 0. (https://doi.org/10.1002/ps.4821).

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Schipanski ME, Barbercheck M, Douglas MR, Finney DM, Haider K, Kaye JP, Kemanian AR, Mortensen DA, Ryan MR, Tooker J and White C (2014). A framework for evaluating ecosystem services provided by cover crops in agroecosystems. Agric. Syst. 125, 12–22.

Wallace JM, Keene CL, Curran W, Mirsky S, Ryan MR and VanGessel MJ (2018). Integrated Weed Management Strategies in Cover Crop–based, Organic Rotational No-Till Corn and Soybean in the Mid-Atlantic Region. Weed Sci. 66, 94–108. (https://doi.org/10.1017/wsc.2017.53)