Performance and Weed Suppressive Potential of Winter Cover Crops Established as Monocultures and Multispecies Mixtures in Southern Australia

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Summary Cover crops provide rotational diversity that frequently results in reduced erosion and improved soil health, weed control, and moisture retention in mixed farming and cropping systems. They have also been shown to suppress weeds due to their physical abilities and/or chemical properties. Field experiments were established in winter 2021 in Wagga Wagga and Narrabri NSW to evaluate the establishment of selected cover crop species potentially well adapted to each region and assess their ability to provide winter annual weed suppression through weed interference. Cover crop species evaluated in these experiments included conventional grass, legume and non-legume broadleaf established either as monocultures or multi-species binary mixtures. Crop and weed competitive traits were estimated by assessment of crop competitive traits including canopy light interception (LI), leaf area index (LAI) and crop and weed biomass. Grazing oats and tillage radish strongly reduced weed biomass accumulation at both Wagga Wagga and Narrabri sites. Multispecies binary mixtures of cover crops performed similarly to monocultures with respect to formation of suppressive ground covers by shading the soil surface and thereby reducing weed biomass. Total biomass accumulation in winter cover crop treatments was generally similar between sites.

Keywords Weed suppression, interference, competition, legumes, multi-species mixtures

INTRODUCTION

Cover crops provide important agro-ecological functions by improving soil tilth and moisture availability for subsequent crops while suppressing annual weeds and reducing soil erosion (Schipanski et al., 2014). Cover crops incorporated into integrated weed management strategies have resulted in reduced herbicide use and the incidence of herbicide resistance, both of which are important considerations for Australian grain producers (Peterson 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 (Bhadoria 2011). However, the latter has not always been well demonstrated under field conditions. In addition, residues remaining on the soil surface over time can create a mulch-like effect, forming a physical barrier to weed seedling establishment and seed germination (Galloway and Weston, 1996).

In southern grains region farming systems, the decision to incorporate cover crops in rotations is driven by factors including cost of establishment as well as water use requirements of cover crops during vegetative growth, and their ability to conserve soil moisture post-termination and before establishment of the subsequent grain crops (Bell et al., 2012). The net water benefit associated with establishment of common cover crop species on subsequent winter crops was previously evaluated (Erbacher et al., 2019). However, performance when established as monocultures or multispecies mixtures, in various soil types, requires further investigation.

Therefore, a series of field, glasshouse and laboratory experiments were designed to assess the performance of a diverse collection of summer and winter cover crops with respect to weed suppression, biomass accumulation and water usage over time. Studies were performed in both northern and southern NSW and addressed the following objectives: 1) evaluation of cover crop establishment at each field site 2) comparison of the competitive ability of diverse covers established as monocultures or multispecies mixtures contributing to early season weed suppression and 4) impact of cover crops on plant-available soil water over time.

MATERIALS AND METHODS

Cover crop establishment Field experiments were established in 2021 at the Graham Centre field site, Wagga Wagga NSW and the University of Sydney research site in Narrabri. All experiments were arranged in a randomised complete block design with four replications per treatment. Soil types were characterised as a fine red kandosol at Wagga Wagga with pH of 5.9 and grey vertosol with a pH of 8.7 at Narrabri. Monocultures were established in separate split blocks from the multispecies mixtures to reduce the influence of spatial variation on soil type, tilth and cover crop establishment. Monocultures were sown at commercially recommended sowing rates for New South Wales. Multispecies binary mixtures were also sown at various ratios within the recommended sowing rate ranges (ie. 1:0, 0.75:0.25; 0.5:0.5, 0.25, 0.75, and 0:1).

Crops were sown on 23rd April 2021 in Narrabri, and 13th May 2021 and 19th May 2021 for multispecies mixtures and monocultures in Wagga Wagga, respectively. Cover crops were seeded using a precision cone planter with plot dimensions of 10 m × 1.6 m, at 20 cm row spacing at Wagga Wagga. At Narrabri, the row spacing was 25 cm. Row spacings utilised reflect the preferred recommendations at each location based on resource availability. Plots were established in a randomised complete block design at each location, with 4 replications. Experiments were fertilised with 100 kg ha–1 of Croplift 12 (NPS 12: 18: 6; Incitec Pivot, Melbourne, VIC) at the time of sowing at Wagga Wagga and with 65 kg ha–1 Cotton Sustain (NPS 6:12:22; Incitec Pivot, Melbourne, VIC) in Narrabri. To facilitate soil moisture assessment over time in various treatments, two 50 mm diameter soil cores were removed to a depth of 20 cm and 70 cm from the centre of monoculture treatments and multispecies treatments containing equal (50/50) ratios of crop mixtures in Narrabri. Polyvinyl chloride (PVC) pipes (50 mm diameter) were installed where soil cores were removed, and later capped. Fortnightly, soil moisture measurements were obtained using a moisture sensor (MP406; ICT International Ltd, VIC) and reported as volumetric water content. Crops were subsequently terminated using glyphosate at a rate of 2 L ha^{-1} at 120 days after planting at late vegetative growth stage, or at maturity at 150 days after planting.

Crop assessments Crop emergence was recorded in 2 × 0.25 m^2 quadrats per treatment, at 25 days after sowing. Aboveground biomass samples were collected at 80 days after sowing (DAS) for the crop and at 80, and 120 DAS for weeds 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 40 °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 randomized 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

Performance of winter cover crop monocultures

All winter crops established successfully at Wagga Wagga and Narrabri. Maximal crop biomass in Wagga Wagga was recorded in tillage radish at ~ 8 t ha^{-1} and was higher than grazing oats at~ 6.5 t ha^{-1} ($P<0.05$) (Figure 1A). Maximum biomass accumulation at Narrabri was observed in field pea and grazing oats treatments at ~ 8 t ha^{-1} and was significantly higher than that of other cover crop species assessed (Figure 1B) (P<0.05).

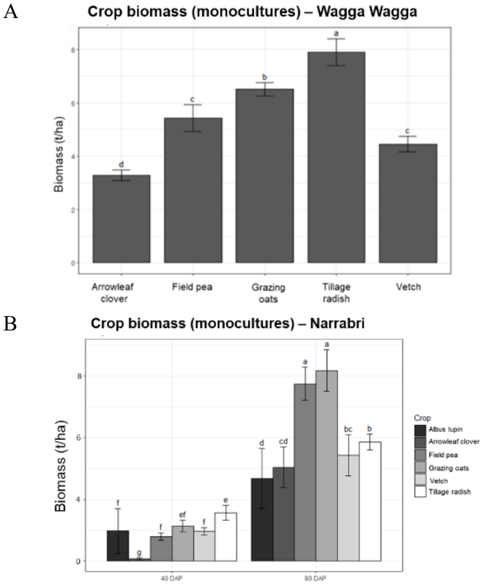

Figure 1. Accumulated biomass of winter cover crop monocultures at (A) Wagga Wagga at maturity and (B) Narrabri at 40 and 80 days after planting. DAP; days after planting. Error bars indicate the standard error of means. Means

sharing the same letters are not significantly different.

The weed suppressive potential of winter cover crop monocultures The key winter annual weed species present in the natural weed seedbank at Wagga Wagga included annual ryegrass (*Lolium rigidum* Gaudin), barley grass (*Hordeum* spp.), sowthistle (*Sonchus* spp.), poppy (*Papaver* spp.) and fumitory (*Fumaria* spp.). At Narrabri, the natural weed seedbank consisted mainly of annual ryegrass, brome grass (*Bromus* spp.) and sowthistle. The accumulated weed biomass was recorded at maturity (80 DAS) and following cover crop desiccation at 120 DAS at Wagga Wagga, and at 40 and 80 days after sowing at Narrabri, as crops matured early at this site.

Weed biomass accumulation was significantly reduced by all treatments at maturity, when compared to the untreated control (Figure 2) (P<0.05), except for Albus lupin and arrowleaf clover at Narrabri due to late emergence and slow growth of these crops at that location. At crop maturity, all other cover crop treatments reduced the accumulated weed biomass similarly, with reductions in weed biomass ranging from 30% - 92% when compared to the untreated control (P<0.05).

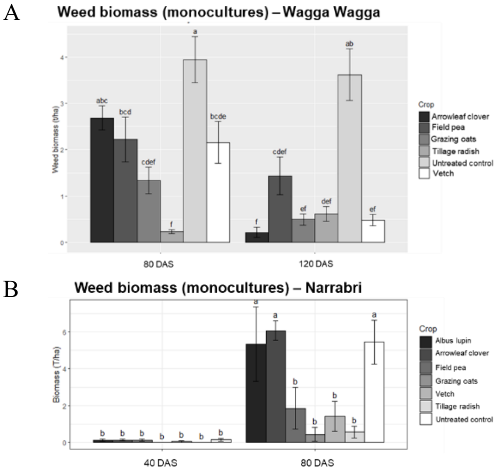

Figure 2. Accumulated biomass of winter annual weeds emerging from the natural weed seedbank (A) Wagga Wagga (B) Narrabri. DAS; days after sowing. Error bars indicate the standard error of means. Means sharing the same letters are not significantly different.

Performance of multispecies mixtures Crop biomass accumulation in the multispecies mixtures vetch/ oats and field pea/ oats was similar among the companion species (data not shown). However, in the tillage radish/ field pea mixture, all sowing ratios containing the radish treatment accumulated more crop biomass when compared to a monoculture of field pea at Wagga Wagga (P<0.05) (Figure 3A). At Wagga Wagga, all ratios of cover crop mixtures suppressed weed biomass accumulation by approximately 50% (P<0.05) when compared to the untreated control, except for the monoculture treatment of the tillage radish/ field pea mixture, which impacted the weed biomass accumulation less than the other sowing ratios in the mixture (P<0.05) (Figure 3B).

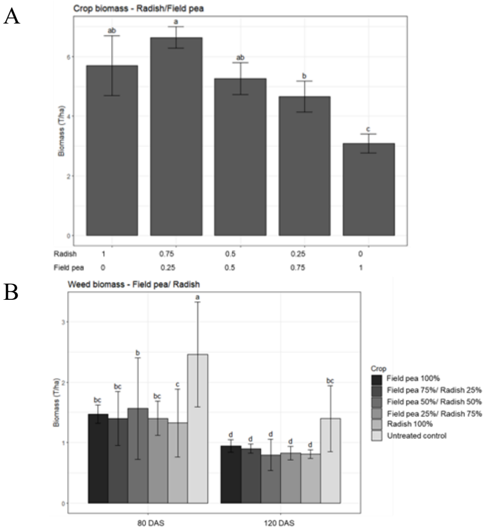

Figure 3. (A) Crop and (B) weed biomass accumulation in the multispecies binary mixture field pea/ tillage radish, established at Wagga Wagga. DAS; Days after sowing. Error bars indicate the standard error of means. Means sharing the same letters are not significantly different.

Multispecies mixtures established at Narrabri also performed similarly with no difference in crop biomass and weed biomass accumulation observed between treatments (data not shown).

Soil moisture usage Moisture measurements were performed fortnightly at soil depths of 20 cm and 70 cm in all monocultures established at Narrabri. Soil moisture content at the initiation of sampling 20 days after sowing ranged between approximately 26-32% across the site at both 20 and 70cm below the soil surface (data from 20cm depth shown; Figure 4). Differences in soil moisture among monocultures were more pronounced between 120 and 150 days after sowing at both depths, with the early terminated treatments, except for arrowleaf clover conserving between 10- 17.5% volumetric soil water compared to the late termination time (P<0.05).

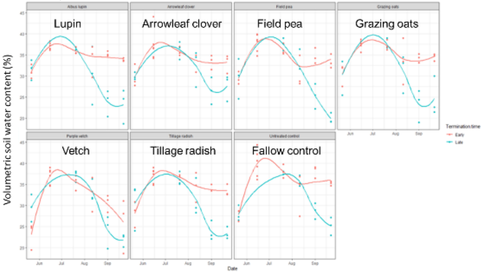

Figure 4. Volumetric soil water content measured in monocultures established at Narrabri NSW, 20 cm below the soil surface. Red: early termination; Blue: late termination.

DISCUSSION

Field experimentation performed over the winter growing season in northern and southern NSW identified cover crop species appropriate for establishment in the low to medium rainfall zones in diverse soil types and climatic conditions. Favourable environments experienced at both field locations also enabled the evaluation of the weed suppressive potential of both monocultures and binary mixtures of those cover crop accessions. Strongly competitive crops were those which exhibited early vigour and biomass accumulation, which included grazing oats and tillage radish in the winter growing season These treatments provided excellent suppression of weed growth and establishment. Most binary multispecies mixtures of winter cover crops reduced the accumulation of weed biomass similarly to that in their respective monocultures. This suggests that multispecies mixtures could provide ample biomass and crop biodiversity in the cover cropping phase of crop rotations, while reducing annual weeds in broadacre cropping systems.

The selection of the appropriate cover crop termination time is critical, particularly in the case of grazing oats, a species that conserved soil water when terminated early, but showed significant soil water depletion when terminated at crop maturity. Results from this experiment describing suppressive, biodiverse cover crops as useful rotational crops will better inform farmers interested in regimes for enhancement of crop biomass, soil moisture conservation and productivity on-farm and reducing weed seedbank density over time.

ACKNOWLEDGMENTS

The authors acknowledge investment from GRDC (US000084) and technical assistance at from field research teams at Charles Sturt University, University of Sydney and Queensland Department of Agriculture and Fisheries.

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