Dual-purpose cropping: changes in pasture availability and composition from incorporating dual-purpose crops into a Tablelands pasture system

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Abstract
Pastures in a grazing systems experiment near Canberra were measured for pasture mass over four years and for composition in the final year to identify the effect of sowing 33% of the available land to dual-purpose crops (wheat and canola) each year. The system that included dual-purpose crops had significantly less feed on offer in February (when ewes were joined) and May (when grazing of crops commenced) compared to the pasture only system. In the final year of the experiment the proportion of weed species in the pastures of the dual-purpose cropping system was significantly higher compared to the pasture-only treatment.

Keywords
Canola, wheat, forage, feedbase, sheep, weeds.

Introduction
In southern Australia, dual-purpose cereal and canola crops are typically sown early with the intention of providing extra forage for grazing livestock during the crops' vegetative growth stage, as well as harvesting grain at the end of the season. Livestock are removed prior to the crop commencing reproductive growth (i.e. stem elongation in cereals). The key advantages of including dual-purpose crops in a grazing system include livestock and grain production from the same paddock in a given year, and large amounts of high quality feed for livestock during late-autumn and winter when feed is scarce due to low pasture growth rates. Over the past 20 years there has been increased interest in dual-purpose crops in high rainfall areas of southern Australia which have traditionally supported pasture-only grazing enterprises.

A grazing systems experiment was used to examine the potential to intensify production in a Tablelands environment by including dual-purpose crops in a grazing enterprise. A component of this experiment was to assess the impact on the remaining pasture area of replacing part of the permanent pasture area of the farm with a dual-purpose cropping program based on a four-year rotation. This paper reports differences in amount of pasture available to livestock at different times of the year during the systems experiment and the proportions of desirable and weed species in the pastures during the final year of the experiment.

Methods
Experimental design
The experiment was conducted at the Ginninderra Experiment Station near Hall, ACT (35° 11' S, 149° 3' E, 600 m elevation, average annual rainfall 665 mm) from 2013 to 2016; the site was run under a similar regimen in 2012 to set up the systems experiment. The experiment was established in relatively flat terrain on a Yellow Chromosol (average Colwell P 33 mg/kg, organic C 27 g/kg and pH ($CaCl_2$) of 4.9 in the surface 100 mm).

The experiment and its design have been described previously by Pinares-Patiño et al. (2015). Briefly, the experiment included three treatments: a treatment which included dual-purpose crops that were grazed preferentially by weaners, a treatment that included dual-purpose crops grazed preferentially by ewes and a control treatment with sheep grazing permanent pasture only. Each grazing system treatment was replicated 3 times. Each experimental unit (farmlet) comprised 6 x 0.23 hectare sub-paddocks. Within the cropping farmlets, two sub-paddocks had been sown to permanent pastures of phalaris (cv. Holdfast), cocksfoot (cv. Currie) and subterranean clover (cv. Campeda). The other four sub-paddocks formed a 4-year cropping sequence: pasture-pasture-canola-wheat (i.e. in any one year there was a wheat crop, a canola crop, two sub-paddocks of pasture ley and two permanent pasture sub-paddocks). Ley pastures were sown to cocksfoot (cv. Porto) and subterranean clovers (cultivars Rosabrook, Bindoon and Leura). The ley pastures were not grazed for the first 8 months following sowing, and were generally grazed by weaners on the first grazing event. The 3 control farmlets were sown to the same pasture species as the permanent pastures in the cropping farmlets (phalaris, cocksfoot and subterranean clover). In 2013 this treatment had the same area of land available as the area sown to pasture in the crop grazing treatments, (i.e. 4 x 0.23 hectare plots). In 2014 the area of land in the control treatment was increased to 6 x 0.23 plots so that the area available to graze was the same as in the cropping farmlets. The change in design followed very high supplementary feeding in the control treatment during 2013, and reduced the winter stocking rate on control experimental units from 19 to 13 DSE/ha. Each replicate was grazed by 6 Merino ewes and their progeny, with the ewes replaced by a younger cohort at the mid-point of the experiment. Ewes were joined to Merino rams in February/March (Table 1) to lamb in July/August. During joining, ewes were removed from the experimental plots and replaced by wethers to maintain equivalent grazing pressure. Weaning was in October or early November. Six weaners were retained in each experimental unit for sale as yearlings in the following winter (Table 1); excess weaners were sold in December-January.

Table 1. Key dates for ewes and weaners during the systems experiment related to feed on offer measurements

Year	Joining	Weaning	Yearling sheep sold
2013	14 Feb-27 Mar	15 Oct	2 Aug
2014	13 Feb-1 Apr	5 Nov	30 Jul
2015	9 Feb-19 Mar	13 Oct	8 Jul (crop); 18 Aug (control)
2016	15 Feb-22 Mar	12 Oct	29 Jul (crop); 8 Sep (control)

Grazing management was conducted flexibly on the basis of forage availability and the nutritional requirements of the animals. Animals were fed grain in response to low forage availability or quality deficiencies. Crop grazing commenced in the relevant treatment when withholding periods from crop chemical applications had finished and sufficient biomass was available for grazing. Grazing of crops finished in late-winter/early spring (Table 2) to protect grain yield, and always prior to stem elongation. In 2015 wheat crops were sacrificially grazed prior to harvest due to a poor prognosis for grain yield and low forage availability in pasture plots in the crop treatments. Sheep in cropping treatments were able to graze stubble for a short period following each harvest (Table 2).

Table 2. Crop sowing, grazing and stubble grazing dates, and order of crop grazing in ewe crop grazing treatment

Year	Sowing dates	Crop grazing dates	Crop grazing sequence	Stubble grazing dates
2013	7 Mar	10 May- 4 Sep	canola-wheat	9 Jan-12 Feb
2014	24-27 Feb	19 May-16 Aug	canola-wheat	24 Dec-21 Jan
2015	4-11 Feb	30 Apr- 2 Sep	wheat-canola	17 Nov-16 Dec[a]
2016	12-15 Feb	12 May- 24 Aug	canola-wheat	end of experiment

[a] sacrificial grazing of wheat crops.

Pasture measurements

Forage dry mass was measured close to the times that grazing mobs (ewes, ewes and lambs, or weaners) entered the sub-paddocks. In pasture sub-paddocks, forage within six 0.245 m^2 randomly placed quadrats were cut with electric shears. Cut forage was weighed fresh and sub-samples oven-dried (65°C, 72 h) for determination of dry matter (DM) content. Pasture samples were manually separated for botanical composition in 2016 at periods associated with the end of joining (March), start of crop grazing (May), end of crop grazing (August), and spring peak/weaning (October). Components for botanical composition were green forage (perennial grass and legume species), senescent material (grass and legume species), and green weeds.

Statistical analysis

For the purposes of this paper, pasture mass from both dual-purpose crop treatments (i.e. ewe crop grazing and weaner crop grazing) was defined as treatment “crop” and compared to pasture from the control system (“pasture”). A linear mixed model (Genstat, 18th Edition) was used to compare pasture mass or proportions of each pasture component at defined event (end of joining, start of crop grazing, end of crop grazing and spring peak), with the fixed terms including treatment (crop v. pasture), year and their interactions (when significant) and replicates as a random term. The botanical components of pasture mass measured during 2016 were analysed using linear mixed models with fixed terms including treatment and collection period and replicates as a random term.

Results and Discussion

The systems experiment was notable for between-year variation in weather conditions. 2013 was marked by good rainfall in late-February, a dry and warm March-May period and favourable spring conditions. A dry hot summer in 2013-14 was followed by good rain in mid-February and good plant growth conditions in autumn, winter and spring 2014. The 2015 growing season was less favourable than 2014 and the canola did not germinate until April, resulting in canola being grazed after wheat in this year (Table 2). There was limited rainfall at important times in spring 2015, resulting in crop failure in the wheat crop. There was good rainfall in late January/early February in 2016; after a dry February-April period, 2016 was marked by exceptionally wet and relatively warm conditions from May to November.

Inclusion of dual-purpose crops in the system changed the availability of feed to livestock through the year. The early sowing dates during the period 2013 to 2016 in the current experiment provided the opportunity to graze crops early, with grazing commencing in the period from late April to mid-May. This was an important occurrence given the lower pasture availability in the crop grazing treatments in autumn. Pasture availability was significantly higher in control treatments at the start of joining (3.3 v. 2.0 t DM/ha; $P<0.001$) and the commencement of crop grazing (2.3 v. 1.4 t DM/ha; $P<0.001$) and was also significantly higher in the control treatment during March (the end of joining) in 2015 and 2016 (Table 3). The decision to replace permanent pasture with an annual crop such as dual-purpose wheat or canola comes at a cost or "cropping penalty" (Dove 2002), with reduced grazing area during the period of crop establishment increasing grazing pressure on the rest of the farm while the crop is established (Dann et al. 1974; Dove 2002). These results suggest that the period of lowest feed availability in a system that includes dual-purpose crops is during the late-summer and autumn period, and highlights the importance of taking early sowing opportunities for crop establishment to allow early grazing of crops.

Crop grazing provided a long rest period for pastures during the late autumn and winter. Previous experiments have reported that one of the key benefits of grazing crops can be the "pasture spelling" effect, where pastures can accumulate biomass during the crop grazing period, resulting in additional biomass available for grazing in spring compared to systems where livestock continually graze pastures (Virgona et al. 2008; Dove et al. 2015). This effect was apparent in 2013, but not in any other season at the end of winter (Table 3). In the 2013 season, the lower availability in the control treatment likely was associated with the higher stocking rate per hectare of pasture used in that year as well as the poor seasonal conditions. The results do indicate that crop grazing did allow accumulation of pasture over winter, given pasture availability was lower in the crop grazing treatment at the commencement of crop grazing (above) but was either not different or higher by the end of the crop grazing period in late-winter/spring (Table 3).

Table 3. Comparison of feed on offer (t DM/ha) presented to livestock in pasture plots associated with systems with pasture only ("pasture") or that included dual-purpose crops ("crop").

Year	2013		2014		2015		2016		average	
treatment	pasture	crop	pasture	crop	pasture	crop	pasture	crop	s.e.d.	P-value
start joining	3.2	2.2	2.3	1.3	5.1	2.5	2.5	2.2	0.70	<0.001^
end joining	3.8	4.0	2.3	1.9	5.6a	1.2b	4.6a	1.1b	0.57	<0.001#
start crop grazing	1.6	0.9	3.6	2.4	2.7	1.4	1.8	1.0	0.68	<0.001^
end crop grazing	2.0a	4.2b	4.8	4.2	4.4	3.6	2.6	2.6	0.49	<0.001#
spring peak	2.9	3.2	8.7	7.3	5.8	7.0	3.7	5.2	0.72	0.018#

^ P-value is for treatment. Interaction of treatment*year was not significant.

P-value is for treatment*year interaction. Different letters on the same line indicate significant differences between treatments in that year ($P<0.05$).

Senescent material in control pastures during spring was higher than pastures in crop treatments in 2016 (Table 4). This may suggest under-utilisation of pasture in the control plots resulting in senescence and subsequent deterioration in pasture quality by early spring. The stocking rate in the control treatment in 2016 may therefore have been sub-optimal in the very good growing conditions experienced in winter and spring of that year. An important observation in this experiment was the effect of cropping on pasture composition. The proportion of green legume (as a proportion of green material) in the pastures did not differ significantly between treatments in 2016, suggesting no impact of inclusion of dual-purpose crops on legume content of pastures (Table 4). A barley grass (*Hordeum vulgare*) infestation in one permanent pasture plot in one of the crop grazing treatment in 2015 resulted in the plot being removed from the experiment and replaced by a different plot. The proportion of weed as a component of the pasture was significantly higher in crop treatments during early autumn and spring in 2016; annual grasses (Lolium *spp*., Hordeum *spp.* and Vulipa *spp*.) were the main weeds in pastures in early spring while other species (mainly Chenopodium *spp.* and Rumex *spp.*) were the main weeds observed in pastures in autumn (Table 4). The higher stocking rates per hectare of pasture at times of the year may have allowed greater weed infestation in the cropping treatments.

Table 4. Proportion of green material in the total biomass samples, and the proportion of perennial grass, legume, annual grasses and weed material within the green component collected during different periods in 2016. Treatment means with different letters on the same line are significantly different (P<0.05) on that measurement date.

	March		May		August		October		average	
	pasture	crop	pasture	crop	pasture	crop	pasture	crop	s.e.d.	P-value
Green:total	0.32	0.31	0.23	0.24	0.35a	0.88b	0.77a	0.88b	0.05	<0.001
Proportion of Green:										
perennial grass	0.82a	0.32b	0.89	0.80	0.82a	0.34b	0.40	0.32	0.12	0.017
legume	0.01	0.16	0.01	0.06	0.13	0.12	0.42	0.38	0.10	n.s.
annual grasses	0.14	0.14			0.04a	0.52b	0.17	0.19	0.09	0.002
other weeds	0.03a	0.38b	0.10	0.12	0.01	0.02	0.01	0.13	0.07	0.003
total weeds	0.18a	0.52b	0.10	0.12	0.05a	0.54b	0.18	0.32	0.09	0.003

Conclusion

Inclusion of dual-purpose wheat and canola crops in a Merino-based system can provide a substantial period of the year when sheep are not grazing pastures. The availability of feed is changed by inclusion of these crops in the system, with the lowest pasture availability – and hence the main feed gap – shifting to late summer and autumn. Replacing a large portion of the permanent pasture on a farm with dual-purpose crop without reducing livestock numbers may increase the proportion of annual weeds in the pasture component of the farm over time. If nothing were done to address this, the productivity and longevity of the pasture may be compromised in a crop-pasture system. Alternatively, these results probably indicate that there will be an optimum area to be used for cropping that is less than the 33% of total land area used in this experiment. Further investigation is required to confirm if high autumn stocking densities on pasture increases weed invasion in perennial pastures. Modelling work will be used to investigate the optimal proportion of land to dedicate to dual-purpose crops in a grazing enterprise and the alternative, a change in the farm stocking rate, to accommodate use of dual-purpose crops in a pasture-based grazing system.

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