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Dual-purpose cereals offer increased productivity across diverse regions of Australia's high rainfall zone

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ABSTRACT

Dual-purpose (DP) cereals provide an opportunity to graze vegetative crops in autumn and winter when pasture forage levels are low, and then harvested for grain after the exclusion of stock. The dual use provides significant increases in mixed farm returns and the area of DP crops is expanding from traditional areas in south-eastern Australia. DP crops have particular potential in the 9 M ha high rainfall zones (HRZ, > 500–600 mm annual rainfall) where the crop growing season is longer, increasing the potential grazing period and the capacity to recover high grain yield. To capitalise on this potential, management packages that combine the most suitable varieties and sowing times to maximise forage and grain production are required. We conducted six experiments across the south-eastern, north-eastern and south-western regions of Australia's HRZ to assess potential forage and grain production of DP cereal species (wheat, barley and triticale) and phenology types. In the south-eastern HRZ, slow winter cultivars out-performed spring types due the increased forage production in the 'safe' grazing period (stem elongation, DC30) providing up to 2600 DSE.days/ha and 7.5 t/ha grain yield from a mid-March sowing. Early-sown spring cultivars provided a shorter period of 'safe' grazing as the lack of vernalisation requirement hastened development and reduced grain yield potential. In the south-western HRZ, early sowing opportunities (March) are rare and the season much shorter. The best results were achieved with mid-April sowing of barley and longer season spring and facultative wheat, providing 640 DSE.days/ha and grain yields of 3.0 t/ha and 3.4 t/ha, respectively. In the north-eastern HRZ, grain recovery was more sensitive to grazing, however 2000 DSE.days/ha and 6.5 t/ha grain yield were achieved with winter cereals sown in early April. Grazing in the safe phenological window had no effect on grain yield in the south-west region, but reduced yield of some cultivars in the eastern regions. The reduction in grain yield of early-sown winter wheat cultivars due to grazing (17–28%) was greatest when yield potential was high (> 6.8 t/ha). Overall, the experiments confirm the predicted potential for dual-purpose production of cereals across the Australian HRZ region provided appropriate cultivar and sowing dates are combined with careful grazing management. Further work is required to refine grazing management to reduce reductions in grain yield in well-managed DP crops grazed prior to stem elongation.

1. Introduction

Crops that provide forage for livestock production during vegetative growth and are subsequently harvested for grain after removal of livestock are termed "dual-purpose" (DP) or "grain and graze". DP crops are widely grown across the Australian wheat-belt and in the Great Plains of the United States in 'mixed' farming enterprises that combine both grain and livestock production. In south-eastern Australia, dual-purpose cereals have been a mainstay in mixed farming enterprises for decades whilst dual-purpose canola, as the most important break crop for cereal production in Australia, has been rapidly integrated into these systems following research to refine crop and livestock management (Kirkegaard et al., 1997; Kirkegaard and Dove, 2014).

Dual-purpose crops have wide ranging benefits at the whole farm level in south-eastern Australia (Bell et al., 2013). Research repeatedly demonstrates little or no impact on grain yield when livestock are removed prior to initiation and stem elongation (Harrison et al., 2011a,b). Bell et al. (2013) found use of dual-purpose crops could improve whole farm profitability and productivity by 25–75% compared with grain only crops. Dual-purpose crops provide feed during the late

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autumn and winter periods with cereal growth rates almost double those of pasture (Sprague et al., 2015; Dove et al., 2015). Spelling of pastures whilst animals graze crops leads to additional pasture growth which can account for up to 40% of the total extra grazing in a pasture-DP crop grazing system (Dove et al., 2015). Use of DP crops provides a range of systems benefits, many of which are difficult to value. These include weed control in crops provided by grazing livestock, reduced risk as forage grazing recoups part or all of the crop costs and wider sowing windows with longer-season varieties which reduce labour demands during peak periods.

Historically, grain production in southern Australia has occurred in the low- and medium rainfall zones which receive < 450–500 mm mean annual rainfall. The high-rainfall zone (HRZ), with mean annual rainfall > 500–600 mm, is generally characterised by an extended growing season of 7–10 months and less severe occurrences of water limitations and high temperatures (Robertson et al., 2016). The HRZ can be divided into three regions with differing climates; the south-eastern HRZ has cold winters and long seasons, the south-western HRZ has mild winters with a relatively shorter season and the north-eastern HRZ is variable due to elevation changes with winter conditions ranging from cold to mild and highly variable rainfall. Agricultural production in these regions has historically been dominated by pasture-based grazing enterprises. Although annual crop production has increased, the majority of grain produced is usually retained on-farm for animal feed. Potential to achieve high grain yields with milder climatic conditions and an extended growing season combined with an economic interest to diversify production has led to an increased focus on the expansion of cropping into these regions. Zhang et al. (2006) estimated that up to 9 M ha of arable land could be available for crop production across the HRZ areas. Robertson et al. (2016) reported un-grazed (grain only) wheat yields achieved by growers of between 1.5 and 4.3 t/ha with experimental yields well above those of growers across all regions, indicating a significant yield gap. In a simulation study, the grain yield and grazing days from winter wheats across the HRZ was between 8–10 t/ha and 1700–3700 DSE.days/ha, respectively (Bell et al., 2015a,b).

The potential benefits of expansion of dual-purpose crops into the HRZ provides an obvious fit with existing grazing enterprises. Given the reported potential for dual-purpose cereal production across the Australian HRZ, the investigation of varietal choice and sowing time is critical to assess suitability of currently available cultivars in each of the regions. In this paper, we report the forage and grain production of different cereal grain crops with differing maturity types in the south-eastern, south-western and north-eastern HRZ regions which differ in their environmental characteristics. The aim of this paper was to identify existing cereal cultivars and management for DP cereal production beyond the south-eastern medium rainfall zone where DP crops have traditionally been grown, and to compare the grain yield with un-grazed (grain-only) crops sown in the traditional window.

2. Methods & materials

A series of six experiments was conducted during 2010 and 2011 across the south-eastern (Experiments 1–3), south-western (Experiment 4) and north-eastern (Experiments 5 and 6) HRZ regions of Australia (> 500–600 mm annual rainfall) (Table 1, Fig. 1). A set of cereal cultivars chosen to represent a range of maturity types were sown at different times to determine the potential of different cereal crop types for use as dual-purpose and grain-only crops in each region. At each experimental site, the recommended local rates of pre- and post-emergent herbicides were used for weed control to ensure that all withholding periods were met before grazing. Insecticides and fungicides were used according to recommended rates to protect the yield potential of the crop. Starter fertiliser was applied to the crops at sowing [Granulok 15 or MAP to supply 13 −20 kg P/ha] and post-grazing applications of nitrogen (N) as urea, based on soil N levels at sowing and the seasonal outlook so that yield was not N-limited. The seeding rate in all experiments was adjusted for different cultivars based on germination and seed size to establish a target population of 150–200 plants/m^2. In each experiment, an un-grazed control was compared to a grazed or mechanically defoliated treatment. Defoliation, either mechanical or by livestock, was targeted to occur at a suitable growth stage prior to DC30, to avoid impacts on yield. This was not always possible to achieve due to the different maturity types and sowing dates. Further details on the plant growth stage at defoliation are provided where appropriate. Specific management details at each site are provided below and are summarised in Table 1.

The grazing value in dry sheep equivalent grazing days/ha (DSE.grazing days/ha) was recorded or calculated for each period of grazing or defoliation treatment in all experiments (Table 1). For grazed experiments, the grazing value was calculated by multiplying the stocking rate in dry sheep equivalent (DSE)/ha for the class of animal used and the duration of grazing (McLaren, 1997). This was over the whole grazed experimental area which included all varieties. Where crops were defoliated mechanically, the grazing value was determined by using the average biomass removed by mowing in each cultivar and assuming that 1 kg DM per ha/day is the equivalent of 1 DSE.grazing day/ha.

2.1. Experimental sites and design

2.1.1. South-eastern region

2.1.1.1. Young 2010 (Experiment 1). The experiment at Young in southern NSW (34°22′ 59″ S, 148°18′ 26″ E) was conducted on a typical acidic red Kandosol (Isbell, 2002) used for cropping in southern NSW. The experimental design included a winter wheat (Wedgetail) and a triticale (Endeavour) sown on four dates (10 March, 22 March, 6 April, 15 April) in a split-split-plot design with sowing date as main plots, cultivars as sub-plots (20 m × 2.2 m) and three replicates arranged in blocks. Each treatment was grazed by sheep (rams, ewes or lambs) and/or mechanically defoliated (Table 1) at the recommended phenological stage. Crops at each sowing date recovered sufficient biomass from the first defoliation period to allow a second grazing opportunity. Multiple grazing opportunities can be achieved in the south-eastern HRZ where temperate conditions are favourable for crop recovery. The whole experiment was fenced after establishment so that animals could graze half of the plot (10 m × 2.2 m) for each sowing date for the required period of grazing. Defoliation by mowing or grazing occurred when sufficient biomass was present in each time of sowing and for each cultivar. Grain yield data from Wedgetail sown on 10 March was not measured due to bird damage prior to maturity.

2.1.1.2. Goulburn 2010 (Experiment 2). The experiment at Goulburn on the southern Tablelands of NSW (34°50′ 53″ S, 149°40′ 24″ E) was conducted on a brown sodosol (Isbell, 2002). The experiment was designed as a split-split-plot with two sowing dates (11 March, 9 April) as main plots, with 10 cereal cultivars including wheat and barley randomised within sowing dates as sub-plots (20 m × 2 m) and 3 replicates arranged in blocks (Table 1). These plots were later split so that half was crash-grazed (10 m × 2 m) by sheep (merino wethers) using exclusion fences.

2.1.1.3. Delegate 2010 (Experiment 3). The experiment at Delegate at the southern end of the Monaro Tablelands close to the Victorian border (S 37°03′ 25″S, 148°56′ 43″ E) was conducted on a brown Chromosol soil (Isbell, 2002). The experiment was designed as a split-split-plot with two sowing dates (11 March, 14 April) as main plots, 8 cultivars including a range of maturity types randomised within sowing dates as sub-plots (20 m × 2 m) and 3 replicates arranged as blocks (Table 1). Establishment of the 14 April sowing time was badly affected by birds reducing establishment to < 100 plants/m^2 with unevenness and was abandoned. The plots were split for grazing by sheep (merino wethers)