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Foreword

Dual-purpose cropping – capitalising on potential grain crop grazing to enhance mixed-farming profitability

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Introduction

Mixed farming enterprises throughout the world balance and integrate crop and livestock enterprises to spread economic risk and capture synergies in terms of forage supply, but in many areas of the world these have become increasingly separated and specialised (Wilkins 2008). Despite an intensification of cropping during the last 25 years, most farms in Australia's cropping zone operate a mix of cropping and livestock enterprises (Kirkegaard *et al.* 2011). Livestock in these farming systems are regularly exposed to periods of forage deficit (feed gaps) that can reduce both animal performance, but also lower the 'safe' carrying capacity of the farm (Moore *et al*. 2009). These feed gaps occur regularly during autumn and winter in much of southern Australia. One option to address this feed gap is to utilise grain crops as a forage source during their vegetative stage, which are then later allowed to regrow to be harvested for grain at maturity – defined herein as dual-purpose crops (Harrison *et al.* 2011*a*). Dual-purpose crops provide a highly digestible forage source during periods when growth rates of pasture forage is low, and the crops can recover to achieve similar grain yields to ungrazed crops (Kirkegaard *et al.* 2008; Dove and McMullen 2009). Together this can increase the net economic gains from these crops by 25–75% (Bell *et al.* 2014).

Dual-purpose crops have been used in this way in several regions of the world for decades. Early reports of horse grazing in Kansas and cattle grazing in New Jersey on winter wheat was shown to increase crop grain yields (Swanson 1935; Sprague 1954). In Australia, breeding of grain crops has predominantly focussed on short-season spring varieties that do not require vernalisation to initiate reproductive development, and are intended for use as grain-only production (Virgona *et al.* 2006). However, with the release of several long-season and high grain protein cereal varieties during the later 1990s, farmers in the higher rainfall mixed farming regions could make use of dual-purpose crops to increase net returns from crops and provide greater market flexibility. Recent analysis conducted by GRDC suggested the area of dual-purpose crops has grown rapidly in Australia in the past 10 years with at least 300 000 ha of long-season dual-purpose crops are grown in Australia currently (Radcliffe *et al.* 2012), though accurate data is difficult to attain.

More recently, Kirkegaard *et al*. (2008) have demonstrated the potential for dual-purpose use of canola which provides concurrent advantages associated with both disease control of break crops as well as enhanced animal production (Dove and Kirkegaard 2014; Sprague *et al.* 2014). While successful dual-purpose grazing can be achieved with spring canola varieties, most commonly used in Australian grain systems, the introduction of long-season winter-type canola have been shown to provide large grazing opportunities and wider sowing windows similar to long-season winter wheats (Kirkegaard *et al.* 2008, 2012; McCormick *et al.* 2012; Sprague *et al.* 2014).

In addition to increased forage supply, dual-purpose crops have generated a range of other benefits to the mixed farming system. First, grazing reduces crop height and hence the risk of crop lodging in cereals, improves the ease of harvest in canola, and reduces post-harvest stubble load to facilitate sowing in the following season (Baumhardt *et al.* 2009; Nuske *et al.* 2009; Harrison *et al.* 2011*a*). In addition, the flexibility in sowing date and delayed phenological development after grazing can reduce risk of frost damage during flowering from early sown crops. Finally, grazing crops are generally thought to reduce grazing pressure on pastures on other parts of the farm (pasture-spelling) which enables increased growth and grazing value for livestock later in the season once crops cannot be grazed.

The previous success with dual-purpose crops in higher rainfall regions of south-eastern Australia has increased interest in the potential of dual-purpose crops in new regions of Australia, and the world, including exploration of winter wheat for grazing in north-west China (Tian *et al*. 2012). Capitalising on dual-purpose crops in existing areas and expanding their use in new areas requires underpinning research to understand crop responses to grazing, crop agronomic and grazing management to maximise the benefits and whole-farm integration to optimise the synergies at the farm level. This special issue documents recent research conducted across a range of environments in Australia which deals with these key research areas.

Physiological and mechanistic understanding of grazing effects in dual-purpose crops

In dual-purpose crops, the removal of biomass during vegetative growth can either boost or penalise grain yield. Harrison *et al.* (2011*a*) surveyed more than 270 experiments and found that the overall effect of crop defoliation on grain yield was moderately negative (–7%), but ranged from –35% to 75%. Typically the large yield reductions are often attributed to grazing crops after stem elongation (Harrison *et al.* 2011*a*), but even when crops are defoliated during the vegetative stage, large seasonal and environmental effects on grain yield recovery are documented. For example under stressful conditions such as heat stress or soil moisture deficit, increased yields have been attributed to reduced transpiration and conservation of soil water allowing more effective grain filling in defoliated crops (Harrison *et al.* 2010, 2011*b*). However, the diverse range of effects of grazing on grain yield underscores significant knowledge gaps in the physiological understanding of crop defoliation and feedback effects between continuous green tissue removal, crop soil water use and regrowth dynamics of crops after defoliation (Harrison *et al.* 2011*b*, 2012*a*).

This Special Issue documents some new physiological work on the effects of defoliation on root growth and on crown temperature and hence phenological development of dual-purpose crops after grazing. Previous research has shown that root growth of canola ceases immediately after defoliation, and taproot starch reserves are remobilised to support new leaf area, leading to gradual loss of fine roots (McCormick *et al.* 2012, 2013). In testing whether similar effects occur in cereal crops, Kirkegaard *et al*. (2015) conducted extensive field experiments and found little evidence that grazing influences root penetration or final rooting depth, except when defoliation occurs regularly and in early plant development. Their work supports earlier conclusions of Harrison *et al*. (2011*c*, 2012*b*) that yield reductions of grazed winter wheat crops are primarily due to green tissue removal, reduced light interception and photosynthesis, rather than to a reduction in water or nutrient acquisition by roots. Harrison *et al*. (2015) also investigate the effects of grazing on the soil and crown temperature of crops, a key factor underpinning early crop ontogeny and subsequent crop phenological development. Harrison *et al*. (2015) showed that grazing treatments with greater intensity or longer duration significantly elevated maximum daily crown temperatures, with differences of 6−7°C regularly measured in the month following grazing. They concluded that although initial phenological delays caused by defoliation were large, greater diurnal crown temperature fluctuation in grazed crops led to a greater rate of growing degree-day accumulation between the end of grazing and anthesis, and this was likely prominent factor driving enhanced post-grazing development rates of grazed crops.

Exploring the wider potential of dual-purpose crops in new regions and with new options

The success of dual-purpose crops in the high rainfall mixed farming areas of south-eastern Australia, where purpose-bred dual-purpose cereal varieties have been available for decades (Bell *et al.* 2014; Dove and Kirkegaard 2014) has prompted recent investigations of their potential in other mixed farming zones. An obvious first target was the estimated 6M ha of arable land in other high rainfall zones of Australia (Zhang *et al.* 2006), where livestock enterprises comprise a significant portion of the farm enterprise, and where cropping has recently expanded (Riffkin *et al.* 2012). Significant areas of the south-eastern and north-eastern Tablelands and slopes, and the southern and western high rainfall zones have suitable soils and climates for cropping, well suited to longer-season cereal and canola varieties, and predominately mixed farming enterprises that could capitalise on dual-purpose crops.

Recently released, well adapted slow-maturing winter canola cultivars (Sprague *et al.* 2014), along with winter-spring crosses and later-maturing spring canola (Christy *et al.* 2013) will expand the existing cereal options available for dual-purpose use in high rainfall areas. The simulation studies reported herein for both dual-purpose wheat (Bell *et al.* 2015*a*) and dual-purpose canola (Lilley *et al.* 2015) present for the first time a systematic and comprehensive assessment of the potential for dual-purpose crops across Australia's HRZ, accounting for the variations in soil type and climate which influence sowing opportunities, and the forage and grain production potential. Supported by related experimental data (e.g. Sprague *et al*. 2015*a*), the simulation studies predict significant potential for dual-purpose use of winter wheat and canola in all regions, with the simulated mean wheat and canola yields of 6.0 and 4.0 t/ha, following 1500 to 3000 sheep grazing days. The studies emphasise the importance of agronomic decisions such as sowing date and variety choice, sowing density and nitrogen management to maximise grazing potential.

In some high-rainfall areas, entirely new options have also emerged, including the potential to sow the new European winter canola varieties in spring, rather than early autumn, and to utilise them as biennial dual-purpose crops (Paridaen and Kirkegaard 2015). Suited to areas where early-autumn sowing opportunities are more limited, this option provides an extended grazing period from early summer to early winter generating 3–5 t/ha of potential forage while maintaining the same high grain yield potential of autumn-sown crops. Though limited in area and requiring further refinement, the concept emphasises the diversity and flexibility of dual-purpose crops in mixed farming systems.

Interest in the potential for dual purpose crops is also growing in the lower and medium rainfall zones. In most of these areas, the season length and temperatures limit the use of purpose-bred, later-maturing dual-purpose crops, but interest has focussed more on the opportunities to graze the traditional 'grain-only' spring cereal and canola crops. The studies reported here investigated the grazing spring cereals in the Mallee (Frischke *et al.* 2015), Western Australia (Seymour *et al.* 2015) and the Eyre Peninsula (Latta 2015) and grazing canola in western Australia (Seymour *et al*. 2015) and southern NSW (McCormick *et al*. 2015). In general, and in common with the HRZ simulation studies mentioned above, economically useful grazing (200–800 sheep grazing days) is feasible from spring crops with early sowing and careful grazing management. In Western Australia, the recommendation for 'clip grazing' which commences earlier, extends past the accepted 'safe' phenological stage of Z30, but is careful to avoid damage to developing reproductive organs by leaving higher residual biomass (Seymour *et al.* 2015), preserved grain yield while providing significant amounts of biomass for grazing. The studies demonstrate how adjustments to traditional management rules based on a physiological understanding of crop recovery, can provide strategies to successfully graze spring crops in traditional grain-only areas (e.g. McCormick *et al*. 2015).

Understanding the whole-farm implications of dual-purpose crops

Ultimately, in mixed farming systems, much of the additional revenue from dual-purpose crops is realised within the livestock enterprise – by filling feed gaps and maintaining or increasing the winter carrying capacity. Recent reviews (Harrison *et al*. 2011*a*; Dove and Kirkegaard 2014) have provided excellent summaries describing the recommended livestock management on dual-purpose crops (timing and intensity of grazing, use of mineral supplements, animal health issues) to maximise the benefits to animal production while avoiding significant crop yield penalties. In this issue, we focus less on the specific livestock management related to grazed dual-purpose crop, but more on how the availability of dual-purpose fodder sources interacts with whole-farm fodder supply to increase overall livestock enterprise productivity and profitability.

A case study in south-eastern Australia presents an experimental series which provides an analysis of the crop (Sprague *et al.* 2015*b*), and livestock (Dove *et al.* 2015) productivity, and the integrated whole-farm impacts (Bell *et al*. 2015*b*) of dual-purpose wheat and canola crops on a typical high rainfall livestock enterprise farm. The inclusion of measured benefits from both crop grazing and pasture spelling afforded by the dual-purpose crops is a novel aspect of the work. Compared with grazing pasture over winter, allowing grazing of wheat or canola alone provided an extra 1000–2000 sheep grazing days per ha and 2600–3500 sheep grazing days per ha when the two crops were grazed in combination. Extra pasture growth over this crop grazing period could then provide more grazing from pastures after crop grazing had ceased. When these data were extrapolated to the whole-farm (Bell *et al.* 2015*b*), the higher stocking rates that can be supported by grazing crops allow 2–3 times the area of pasture to be spelled thus increasing potential winter stocking rate. Thus, converting up to 20% of the farm area to dual-purpose crops was able to maintain or increase farm livestock production while also adding grain production which together could increase farm profitability by up to $150/farm ha or $1000–1500 per ha of dual-purpose crop.

Whole-farm simulation studies explore these issues in lower rainfall Mediterranean environments in Western Australia (Thomas *et al*. 2015; Kingwell and Squibb 2015). Thomas *et al*. (2015) found little benefit to total annual pasture production but the accumulation of pasture during crop grazing increased animal production and lamb weights at weaning. This benefit is also in addition to reduced supplementary feeding during winter, particularly in lower rainfall environments and seasons (Thomas *et al*. 2012). The addition of grazing of wheat and canola crops to mixed farming enterprise in south-west Western Australia was found to increase farm profit by 88% compared with the baseline, with the proportions of crop and pasture remaining constant (Kingwell and Squibb 2015). This benefit arose from increased farm stocking rate and hence higher wool and sheep sales (260%); interestingly summer feed supply was increased by a higher proportion of lucerne to compliment the higher winter feed supply provided by the dual-purpose crops.

It would appear that our greater understanding of crop responses to grazing opens the way for further studies on what changes to livestock enterprises are required to best capitalise on the timing, quality and quantity of the new feed source on-farm, an area actively pursued by new research commissioned by Meat and Livestock Australia.

Conclusion

Together the research documented in this special issue presents a compelling case for the wider potential of dual-purpose crops to increase farm profitability and productivity across Australia's mixed farming zone. Experimental and simulation studies find significant opportunities for strategic use of long-season winter cereal and canola varieties for grazing and grain production across the high rainfall zone. Similarly, in environments with shorter growing seasons, faster developing cultivars can be used opportunistically for grazing, though greater understanding of the grazing management required to avoid risks of grain yield loss is required. Complimenting the existing cultivars with shorter season winter cultivars that provide flexibility for sowing windows in these environments would greatly enhance this potential. We now also have improved understanding of the indirect benefits of winter grazing of dual-purpose crops on the whole-farm feed-base and how this can increase potential winter stocking rates and substantially increase overall farm profitability. By increasing the productivity of food from the same land area with minimal impacts on the environment and lower farm risk, dual-purpose crops represent the type of technology that will be required to achieve the global food security targets confronting humanity.

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