

Exploring opportunities for dual-purpose canola in south-eastern Australia using crop simulation models.

Jeffrey I. McCormick¹, Jim Virgona¹ and John A. Kirkegaard²

¹EH Graham Centre for Agricultural Innovation (an alliance between NSW Department of Primary Industries and Charles Sturt University), Wagga Wagga, NSW 2650, Australia.

²CSIRO Plant Industry, PO Box 1600, Canberra, ACT 2601, Australia.

Email: jeff.mccormick@industry.nsw.gov.au

ABSTRACT

The Agricultural Production SIMulation canola model (APSIM-canola) was calibrated using observations from grazed and un-grazed treatments in order to explore various scenarios for dual-purpose canola in medium rainfall cropping areas such as Wagga Wagga NSW. The existing parameters for APSIM-canola failed to accurately predict the observed growth and grain yield of current cultivars, but adjustments made to the model parameters for new cultivars improved the simulations. For grazed crops, APSIM-canola accurately simulated biomass at flowering. A target biomass at flowering (~5000 kg/ha) has previously been proposed to avoid potential yield loss in grazed crops. The target biomass was confirmed by simulations relating yield to flowering biomass derived using a combination of sowing dates and plant densities. Using rule-based sowing and grazing management strategies our simulations predicted that sowing was possible prior to the 15th May in 54% of years at Wagga Wagga, while grazing was possible in 53% of years with 50% of those years providing grazing opportunities prior to June 7. Depending on stocking rate, crops could be grazed until early to mid July providing 400-1000 DSE-days/ha without compromising the target flowering biomass (5000 kg/ha) thus maintaining grain yield potential for the site. We conclude grazing canola is a viable option for mixed farms in the Wagga Wagga region.

Keywords: *Brassica napus* – graze – APSIM – yield potential

INTRODUCTION

Dual-purpose canola has been successfully demonstrated under seasonal conditions which were adequate for regrowth (Kirkegaard et al., 2008; McCormick, Kirkegaard, & Virgona, 2009). Dual-purpose canola is defined here as crops which can provide useful winter stock grazing without reducing grain yield. The success of dual-purpose canola clearly depends on factors influencing regrowth including post-grazing biomass, length of the recovery period prior to flowering and available resources for regrowth, particularly soil moisture. Dual-purpose cropping is season dependant and will rely on opportunities to sow early combined with favourable conditions for regrowth. The probability of success of dual-purpose canola at specific sites can be investigated using long-term climate data and simulation models validated to local conditions. Simulation models are sensitive to soil, climatic and management factors that will dictate sowing opportunities, early forage production, crop phenology and yield development. The specific impacts of grazing on canola growth and yield have not been explicitly simulated previously. This work investigates the use of the Agricultural Production SIMulation (APSIM) model to identify opportunities for grazing canola in an environment that is somewhat drier than those previously reported (Kirkegaard et al. 2008). APSIM-canola has previously been validated for grain-only canola crops in a range of Australian environments including south west NSW (Robertson & Kirkegaard, 2005), semi-arid subtropics (Robertson & Holland, 2004) and Mediterranean environments in Western Australia (Farre, Robertson, Walton, & Asseng, 2002).

MATERIALS AND METHODS

Data from a field experiment conducted at Wagga Wagga in 2008 was used in the model calibration (McCormick et al., 2009). In that experiment, three different canola cultivars differing in vigour (46Y78 (Hybrid), AV-Garnet (Conventional) and ATR-Marlin (TT)) were sown at three plant densities (28, 50, 68 plants/m²) and were either grazed or un-grazed. The experiment was irrigated to provide the equivalent of average growing season rainfall (350 mm). Validating APSIM for dual-purpose canola was a two-stage process in which un-grazed crops were validated first, and secondly, a grazing routine was incorporated to simulate regrowth following grazing. Phenology parameters were adjusted to reflect the observed flowering date for the respective cultivars in the simulated data. The simulation commenced on the 1st January 2008 with low soil moisture and high nitrogen. A grazing routine was installed into APSIM from GRAZPLAN using the CSIRO Common Modelling Protocol. In the simulation, stock were bought and sold at specified times so that grazing was simulated to match the experimental grazing period. Simulated grain yield was poorly predicted by the model and was therefore not considered a reliable model output. To determine if grain yield was affected by grazing in subsequent scenario testing, a rule was introduced that specified that if flowering biomass exceeded the hypothesised target biomass (~5000 kg/ha) there would be no reduction in potential yield due to grazing. This rule assumed that flowering occurred during the optimal window for Wagga Wagga, nominated here in the model as September 1. Multiple simulations using an un-grazed crop for the calibrated site at Wagga Wagga were used to test the hypothesis of a target biomass at flowering over 109 years of climate data with AV-Garnet sown at multiple sowing dates (1st May, 1st June and 1st July). All sowing dates had a plant density of 30 plants/m², while the 1st May also included plant densities of 60 and 90 plants/m². A range of scenarios were conducted using climate data from 1900-2008 for Wagga Wagga over multiple seasons using flexible sowing and grazing rules. The rules were used to determine (1) the number of sowing opportunities based on receiving 25 mm of rainfall over three consecutive days to facilitate sowing, (2) the effect of management on dry matter accumulation on July 1 and (3) grazing opportunity and duration with stock introduced when biomass exceeded 1000 kg/ha and removed at pre-determined dates.

RESULTS

Model validation

Simulations using the standard parameters in APSIM underestimated the observed biomass (Figure 1a). The simulations were re-run using higher initial water and nitrogen conditions but this did not improve the growth to match the observed data (not shown). Increasing maximum leaf size improved the agreement between actual and modelled prediction of biomass accumulation generally (Figure 1a). Only at the final harvest do the original parameters predict observed biomass with acceptable accuracy. Grain yield was estimated very poorly by the model with RMSD of 1530 kg/ha when all three cultivars were combined. The model accurately simulated flowering biomass following grazing (Figure 1b) with a RMSD of 874 kg/ha. Simulated grain yield for the grazed plots was poorly predicted by the model and was therefore not considered a reliable model output.

Hypothesis testing

All flowering biomass data derived from the multiple sowing dates and multiple plant density simulations, were plotted as a proportion of maximum yield (Figure 2). Two distinct boundaries were observed on the graph; 1) at lower flowering biomass levels, maximum potential yield increased with increased flowering biomass and 2) at higher flowering biomass levels, no further yield response was apparent to increased biomass at flowering. The intersection of these two lines revealed a target biomass at flowering of 4900 kg/ha above which maximum potential yield will not increase with further increases in biomass at flowering. As the model inadequately predicted the grain yield, a critical target biomass of 5000 kg/ha at flowering was chosen. We assumed that if this level of biomass at flowering could be achieved under specific agronomy and grazing scenarios, then potential yield of grazed crops was assumed to be unaffected compared to an un-grazed crop.

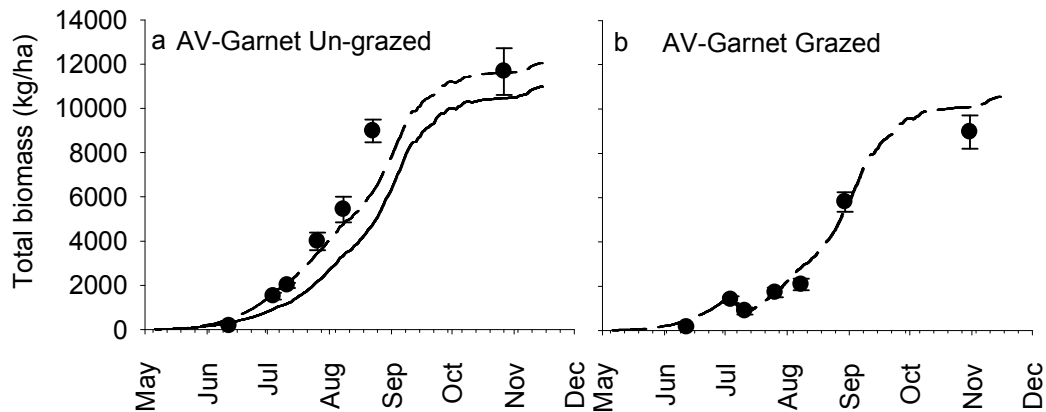


Figure 1. a) Observed (●) and simulated (lines) biomass for AV-Garnet using the original (—) and adjusted parameters (----) at mid sowing rate. b) Observed (●) and simulated (----) biomass for grazed AV-Garnet at mid sowing rate. Error bars are the standard error of the mean and where not evident are smaller than the data symbol.

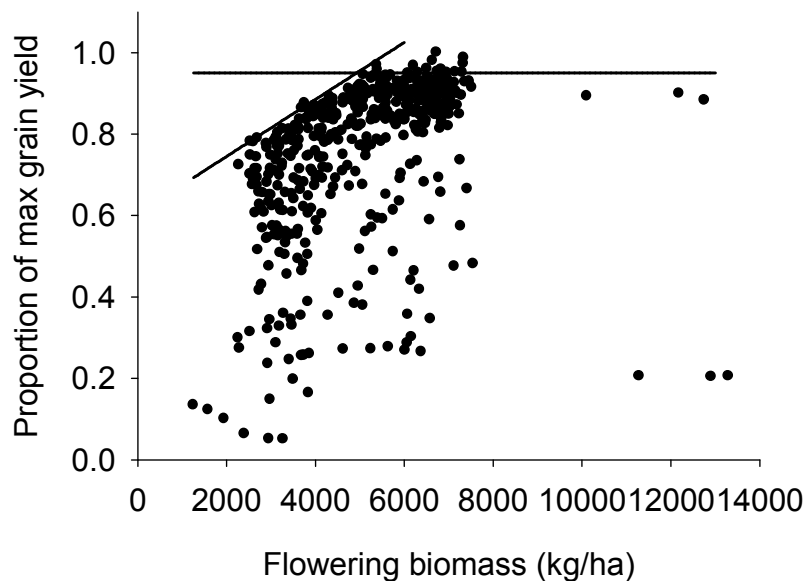


Figure 2. APSIM-canola simulated relationship between flowering biomass and proportion of maximum yield for the Wagga Wagga site for 109 years for multiple sowing dates and plant populations. Lines fitted to 95% of maximum yield. $y = 0.95$, frontier slope fitted by eye, $y = 0.00007x + 0.605$

Scenario analysis

Applying the flexible sowing rule revealed that sowing was possible in 54% of years prior to 15th May, and prior to the 1st May in 40% of years. Agronomic management that increased pre-grazing biomass included early sowing, vigorous cultivars and high sowing rates (60-80 plants/m²). Sowing on or after the 15th May greatly reduced any opportunity for stock grazing if the 1st July is considered near the end of the likely grazing window. Canola crops could be grazed in 42% and 53% of all years if the grazing ceased on the 1st July and 5th August

respectively. Grazing commenced prior to the 7th June in 50% of years that were grazed. Low stocking rate for short durations led to higher biomass levels on the 1st September when compared to high stocking rates and/or long grazing periods (Figure 3). At 10 DSE for the longest grazing period, biomass accumulated by the 1st September was greater than 5000 kg/ha in 50% of years. If stock are removed on the 8th July for the 20 DSE/ha stocking rate, 55% of years will exceed 5000 kg/ha on the 1st September. Similarly, 54% of years will exceed 5000 kg/ha on the 1st September when grazed for the shortest duration at 30 DSE/ha. If stock are not removed prior to the 15th July when stocked at 30 DSE/ha, less than 5% of years will exceed 5000kg/ha by the 1st September. Undertaking conservative grazing to ensure maximum grain recovery of cultivar 46-Y-78 at a stocking rate of 20 DSE allowed an effective stocking rate of 400-1000 DSE·days/ha in the top 75% of years when stock are removed on the 1st July. Under these management conditions it was predicted that in 70% of years dry matter at flowering would exceed 5000 kg/ha

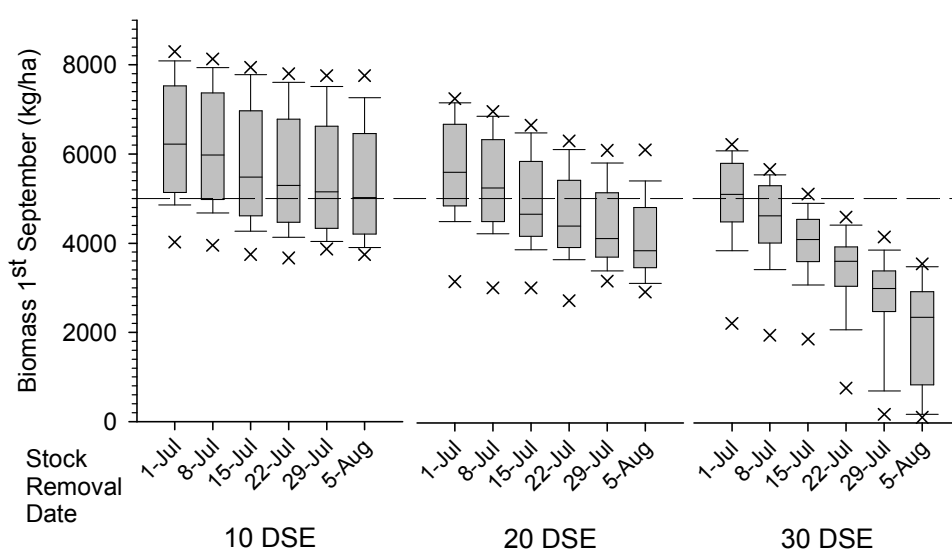


Figure 3. Predicted biomass at flowering for cv 46Y78 following grazing at three different stocking rates with six different lock-up times. Horizontal dashed line at the targeted biomass level (5000 kg/ha). Box plots range from 25th-75th centile of the data with a median line marked. Whiskers extend to 10th-90th centile of simulations with outliers marking 5th and 95th centiles (X).

DISCUSSION

The current APSIM-canola model was unable to accurately simulate the growth rates observed for the set of cultivars at Wagga Wagga in 2008. Soil nitrogen and moisture manipulation in the model failed to improve the simulation. Australian data that has been used to calibrate the model was derived either from experiments conducted in the 1990s or utilised cultivars developed in that decade (Farre et al., 2002; Robertson & Holland, 2004; Robertson, Holland, Kirkegaard, & Smith, 1999; Robertson & Kirkegaard, 2005). In previous calibrations, biomass at flowering and harvest have been key variables, whereas little attention has been paid to early biomass accumulation. The inability of the model to accurately predict grain yield was presumably due to extreme temperatures and moisture stress during the flowering period which occurred in 2008. Previously there have been problems with APSIM-canola accurately predicting grain yields in years characterised by hot and dry conditions during flowering and seed filling (Kirkegaard, Robertson, Hamblin, & Sprague, 2006). The target biomass value of ~5000 kg/ha at flowering was validated by APSIM and demonstrated that yield potential does not continue to increase once crops exceed the target biomass. Crops failing to achieve the target biomass due to grazing may have a reduction in grain yield when compared to un-grazed crops. Optimising dual-purpose canola benefits include maximising forage intake while

maintaining grain yield potential. Early sowing with vigorous cultivars led to maximum available biomass with sowing ideally conducted in April to achieve adequate grazing. Sowing later than the 1st May significantly reduced the opportunity to graze the crop with no grazing opportunities when sown after the 15th May. Grazing could occur in 40-50% of years with increased forage utilisation occurring under high stocking rates for long durations but resulted in reduced post-grazing biomass and biomass accumulation at flowering. Management strategies should be applied to optimise forage consumption while maintaining grain yield with the lowest risk of failure. The grazing window for dual-purpose canola at Wagga Wagga appears to be from June to mid-July and is dependent on stocking rate.

CONCLUSION

Simulation modelling (APSIM-canola) demonstrated that dual-purpose canola is a feasible option for drier inland regions such as Wagga Wagga with currently available vigorous cultivars. Opportunities to sow prior to the 1st May to maximise pre-grazing biomass and a grazing window in June and early July to allow yield recovery was possible in approximately 40% of years. Canola recovery from such management can achieve the target flowering biomass (5000 kg/ha) within the established flowering window for canola (1st September) but will depend on stocking rate and duration of grazing. Stocking rates of 20 DSE/ha for 20-50 days were feasible within these scenarios, representing a significant contribution to feed availability at a time when growth of pastures is usually slow. In reality, the seasonal conditions in any specific year will determine the combinations of sowing time, stocking rate and duration as well as regrowth potential. Managing appropriate grazing timing and pressure for the particular season according to plant growth stage and biomass will be paramount to the success of dual-purpose canola at Wagga Wagga.

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