Yield benefits of fallow to high value crops

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Abstract

Recently, there has been renewed interest in long (18-month) fallowing as a means of managing risk in Australian dryland cropping systems. Traditionally, wheat was grown after long fallows, however, given the high commodity value and rotational benefits of crops such as canola and pulses, the contribution of long fallow to additional yield potential warrants exploration. We used a crop simulation modelling approach to assess the yield benefits of growing canola (*Brassica napus*), lentil (*Lens culinaris*) and wheat (*Triticum aestivum*) after either an 18-month fallow or wheat crop (i.e. 6-month fallow) using initialisation data from a long-term rotation experiment (Sustainable Crop Rotations In Mediterranean Environments; SCRIME) in the Wimmera region of Victoria. Secondly, we simulated a three-phase rotation to see whether the benefits of fallow would persist beyond the first season. Long fallowing provided large yield benefits to wheat (17%) and canola (14%) and to a lesser extent in lentils. Additional soil water was observed (31 mm) after fallow/lentil. The soil water and nitrogen benefits of the fallow/lentil rotation persisted to third phase wheat crop and increased yield. On average, however, continuous cropping including a pulse crop (i.e. wheat/lentil/wheat) yielded more but was subject to greater risk of crop failure. Consequently, given the high value of canola and lentil, it is worth considering the benefit of using a long fallow ahead of these crops to maximise yield potential and stability. Next steps include assessing the net economic benefit of these proposed rotations, where long fallow equates to lost income in that year.

Key Words

long fallowing, continuous cropping, high value crops, oilseed, pulse

Introduction

Fallowing was traditionally regarded as an important management strategy to reduce production risk/variability in the low and medium rainfall regions of southern (and northern) Australia. The key benefits of fallowing were increased soil water and mineral N for the subsequent crop, which is generally wheat (Hunt 2017). Other benefits of long fallow include reduced disease and weed issues. The downside, however, is the opportunity cost of a 'missed crop'. The use of fallowing in southern Australia declined during the late 1990's with the development of better herbicides, alternative high value break crops to cereals such as lentils and canola, and declining wool prices. Currently, many growers consider that the benefits of long fallows do not offset yield lost when crops are not sown.

There is evidence that the seasonal rainfall patterns experienced during the 'Millennium Drought' (later autumn breaks, reduced winter and spring rainfall combined with more episodic summer events) represents a long-term shift in weather patterns (O'Leary et al. 2018). Since fallowing provides greatest benefits in seasons with low and variable rainfall (Angus et al. 2015; Hunt 2017) these new rainfall patterns may make fallowing an increasingly attractive option for risk management. A key driver for the decline in the use of fallowing was the development of high value non-cereal crop options such as lentils, chickpeas and canola and a greater use of management options such as green and brown manures. These high-value non-cereal crops, however, are considered sensitive to seasonal conditions and carry more risk than a cereal crop. Implementing a fallow prior to the high value crop, may provide one management tool to reduce the risk of crop failure and increase yield stability. A simulation study was undertaken to assess the performance of different crop species (wheat, lentils and canola) under fallow and continuous cropping systems, using 100 years of historic weather data from the Wimmera region of Victoria.

Methods

The Agricultural Production Systems sIMulator (APSIM) was used to simulate crop growth, water and nitrogen dynamics of wheat, canola and lentil after either a long (18-month) or short (6-month) fallow within various crop sequences. Data collected from the long-term rotation experiment, SCRIME (Sustainable Crop Rotations In Mediterranean Environments) was used to initiate and validate the model. SCRIME has been running for over 20 years (Armstrong et al. 2018) and is located at Longerenong in the Victorian Wimmera (36.84□S, 142.82□E, average annual rainfall: 1860-2016 = 415 mm) on an alkaline self-mulching Grey Vertosol (Isbell 1996).

The lentil module was validated using data from several rotations in SCRIME in 2013 and 2014. The crop lower limits for lentil were set to prevent the crop accessing water deeper than 60 cm (Fan et al. 2016) and soil water availability in the topsoil was reduced by 10% compared to wheat, as this was the magnitude of difference observed at harvest in previous field experimentation. The RSME for lentil yield was 397 kg/ha and the slope of the fitted line between observed and simulated data was 0.95.

In the first phase of crop modelling the effect of long or short fallows was determined for the three-crop species (wheat, canola and lentil). The crop sequences examined were wheat/wheat, fallow/wheat, wheat/canola, fallow/canola, wheat/lentil and fallow/lentil. To initialise the model, soil water was set at the lower limit of extraction and initial soil mineral N was set to the average values measured from harvest data. Crop residue was set to 1 t/ha of wheat stubble, with a C:N ratio of 73. Sowing windows were set to accumulated rainfall of 10 mm over a 5-day period. Sowing windows were: wheat (15 May to 30 July); canola (1 April to 1 June) and lentil (15 May to 30 July). If the accumulated rainfall was not achieved by the last day of the window the crop was sown. The wheat cultivar (*cv.* Goldmark) grown in SCRIME was not available in APSIM, so the cultivar Gregory was used due to its similar phenology. Lentil cultivar grown in SCRIME (PBA Hurricane) was not available in APSIM, so the cultivar PBA Bolt was used (J. Brand, Pers. Comm.). The canola cultivar was set to Beacon. Wheat and canola crops were fertilised with 11.5 kg N/ha at sowing. Wheat was top-dressed with 46 kg N/ha, between GS 29 and 32, if the soil N was below 30 kg N/ha in the top 2 layers (0-20 cm) and there was 150 mm of water in profile. Canola received the same fertiliser rates as wheat but was fertilised on a fixed date (30 June). Canola only received additional in-season nitrogen when the wheat was top dressed. Lentil crops received 2.5 kg N/ha of urea at sowing to account for the small amount of N in MAP fertiliser.

In the second phase of the crop modelling, three phase simulations were developed to examine the carryover benefits of fallowing to the following crop (i.e. a common third phase wheat crop). The four rotations tested were wheat/wheat/wheat (continuous wheat), fallow/lentil/wheat, fallow/wheat/wheat and wheat/lentil/wheat.

Historical meteorological data from Longerenong (station no. 079028) were obtained from SILO and was used to run the 100-year simulations. Soil water, nitrogen and organic matter content were reset either after every second year (i.e. fallow/wheat) or after three years (i.e. fallow/wheat/wheat) to reflect the observed rotational differences.

Results and Discussion

The RMSE for the grain yield of wheat was 777 kg/ha and the slope of the fitted line between simulated and measured yield (forced through 0) was 1.01 (data not presented). Sowing soil mineral N was higher after the long fallow (73 kg N/ha) compared to continuous cropping (after wheat, 59 kg N/ha). Fallowing increased the amount of available water in the soil profile at sowing (120 cm), by an average of 22% and there was more water present at sowing for the lentil and wheat (227 mm) compared to canola (209 mm), which is a reflection differences in the sowing window. Wheat and lentil were sown later and hence more soil water was accumulated. Average simulated grain yields were highest for wheat (3473 kg/ha), followed by lentil (2608 kg/ha) and canola (1955 kg/ha). Fallowing increased the average grain yield of wheat and canola by 17 and 14% respectively (Figure 1). For lentil, however, there was no yield advantage due to long fallowing. In 90% of the simulations, the yield of the fallow/wheat rotation exceeded that of wheat/wheat. This effect was stronger in the canola, where the fallow/canola treatment out-yielded wheat/canola in 93% of years (Y-axis intercept in Figure 1). For lentil, fallow only increased yield, above the wheat/lentil rotation in 28% of years. Inclusion of a fallow, however did boost the minimum yields simulated for lentil as well as wheat and canola. Hence including a fallow reduced the risk of crop failure.

Profile mineral N at harvest declined in order of wheat (55kg N/ha), lentil (45 kg N/ha) then canola (39 kg N/ha) and there was little difference between the fallow and continuous cropping in these rotations. Soil water at harvest remained slightly higher after the fallow treatment (190 vs 180 mm) and there was more water present after lentil (197 mm), followed by canola (189 mm) and then wheat (170 mm), reflecting differences in soil water extraction. This is attributed to the shallow rooting characteristics of lentil. While lentils may leave behind some residual water at depth, which may be useful to a following crop, they can also dewater the upper levels of the soil profile, therefore adequate recharge of the soil profile is required before any additional subsoil water can be utilised by the next crop.

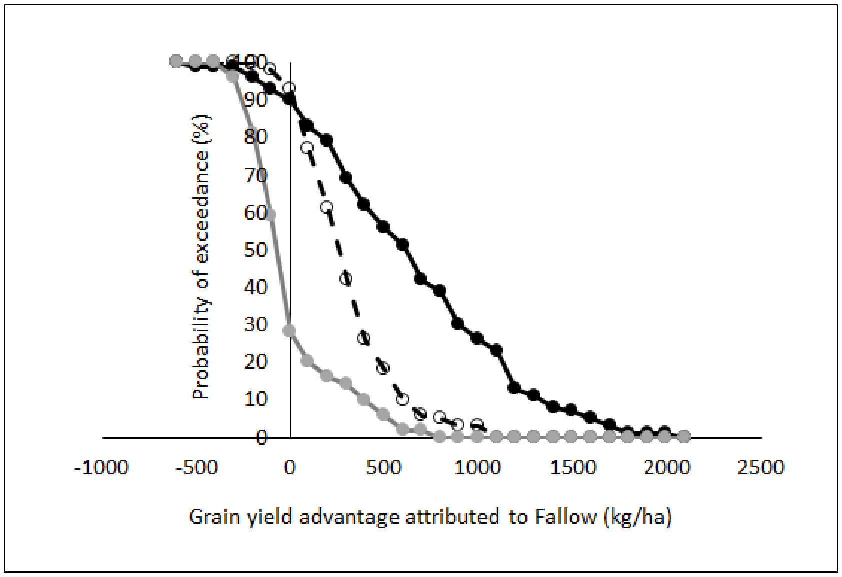

Figure 1. Probability of exceedance for grain yield advantage from long fallow of wheat (●), canola (○) and lentil (●) compared to continuous cropping with wheat instead of fallow over 100 years (1917-2017).

In the three phase simulations (Figure 2), soil mineral N was assessed at sowing of the third phase crop. Average profile mineral N was similar in the wheat/lentil/wheat (81 kg N/ha) to the wheat/wheat/wheat rotation (80 kg N/ha), but least in the fallow/wheat/wheat rotation at sowing (69 kg N/ha). The presence of higher levels of mineral N at sowing in the continuous cropping may have been due to residual fertiliser from previous phases in the rotation. The fallow/lentil/wheat rotation contained the most soil water at sowing (244 mm), with little difference in sowing soil water between the fallow/wheat/wheat (233 mm) and wheat/lentil/wheat (230 mm). The wheat/wheat/wheat rotation contained the least quantity of soil water at sowing (219 mm).

On average the fallow/wheat/wheat rotation yielded the least (2804 kg/ha) compared to the other rotations and did not show a consistent advantage over the wheat/wheat/wheat rotation. On average, the fallow/wheat/wheat rotation yielded 430 kg/ha less than the wheat/wheat/wheat rotation over the 100 years. The grain yield of the fallow/wheat/wheat treatment yielded more than the wheat/wheat/wheat rotation in only 15% of the simulations. The fallow/lentil/wheat rotation showed strong advantages over the fallow/wheat/wheat (754 kg/ha) and wheat/wheat/wheat rotations (324 kg/ha); out-yielding these rotations in 89% and 74% of seasons, respectively. The fallow/lentil/wheat rotation, however, did not consistently show yield benefits over the wheat/lentil/wheat rotation and on average there was a yield penalty of 158 kg/ha compared to continuous cropping or a 4.4% yield increase from the wheat/lentil/wheat rotation. Fallow/lentil/wheat out yielded wheat/lentil/wheat in only 29% of years with an average loss of 158 kg/ha. The minimum yield of the fallow/lentil/wheat rotation, however, was higher; 921 kg/ha for fallow/lentil/wheat compared to 546 kg/ha for wheat/lentil/wheat, suggesting a reduced risk of crop failure in dry years. A recent study by Cann and Hunt (2017) found that fallow/wheat could be more profitable than a chickpea/wheat rotation when chickpea prices were less than $800/t. Hence, when the economics of production are factored in this system may show greater benefits.

The causes for the higher yield in continuous wheat and wheat/lentil/wheat rotation may reflect the initial conditions reset every 3 years in these scenarios and further exploration of the effects of continuous simulation over the 100 years is warranted with a full economic analysis of the costs and benefits of the various crop choices is our next step to bring this to a conclusion. In local cropping systems, canola is commonly being grown after pulse phase and before a cereal crop, because of its requirement for N and lower risk of haying off. Any carryover benefits of canola to wheat were not examined in this study but may warrant further investigation.

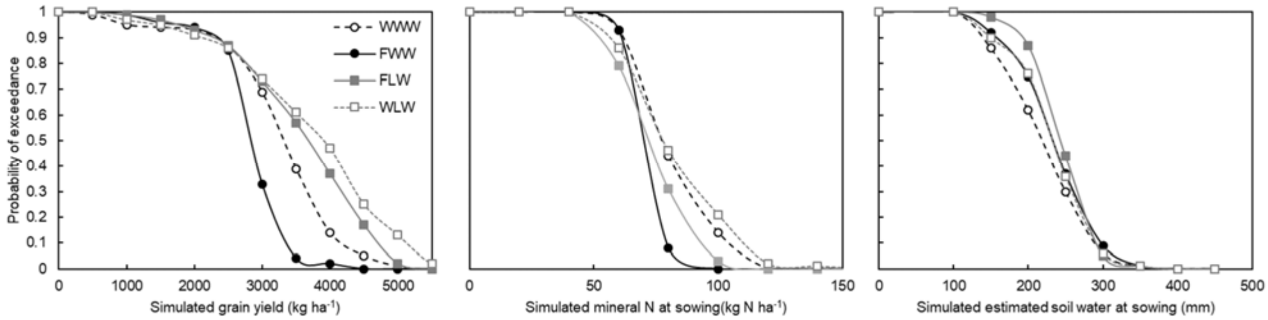

Figure 2. Probability of exceedance for grain yield of a common 3rd phase wheat crop simulated of wheat/wheat/wheat, fallow/wheat/wheat, fallow/lentil/wheat and wheat/lentil/wheat rotations over 100 years (1917-2017).

At harvest, however, on average there was more water remaining after fallow/wheat/wheat (207 mm, range 93 – 314 mm), followed by wheat/wheat/wheat (182 mm, range 90 – 303 mm). The fallow/lentil/wheat and wheat/lentil/wheat contained the least water at maturity, 178 mm (range 97 – 288 mm) and 171 mm (89 – 293 mm), respectively. Soil mineral N at harvest following the third phase wheat crop was for the fallow/lentil/wheat (81 kg N ha^{-1}) and wheat/lentil/wheat (80 kg N ha^{-1}) rotations, compared to the fallow/wheat/wheat (73 kg N ha^{-1}) and wheat/wheat/wheat rotation (73 kg N ha^{-1}).

Conclusion

Wheat and canola appear more responsive to the effects of fallow than lentil, although fallow prior to growing the lentil crop reduced the risk of crop failure. The benefits of additional soil water and N remaining after the fallow/lentil rotation persisted through the third phase wheat crop, and increased grain yield above the wheat/wheat/wheat and fallow/wheat/wheat rotation. While the wheat/lentil/wheat rotation produced the highest average grain yield, differences in the minimum values suggested that inclusion of the fallow may be an important strategy to reduce the risk of crop failure. The results presented are from simulations were carried out over 100 years. Given the change in weather patterns associated with the millennium drought, A comparison of results from the last 20 years against the previous 80 years, may provide a valuable insight into the change in weather patterns associated with the millennium drought and may highlight the value of fallowing.

Acknowledgements

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