Planning horizon, commodity price and weed burden influence the number of break crops in a crop sequence

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Abstract
Crop rotation, where one crop or pasture is grown to provide a break from diseases, weeds and replenish nutrients for a subsequent crop is well known. In modern farming systems the intensity of cropping has increased, where cereals may be grown for many years before a break occurs. Here we test how frequently break crops are grown in response to the planning horizon (3 year, 5 year or 10 year) and the price of wheat ($270 /t, $350 /t). We also determined the size of the weed seed bank necessary to change the crop sequence. This weed seed bank was viewed as a break crop trigger. Economic simulations were conducted for the wheat belt of Western Australia using the crop rotation model LUSO. Under high wheat prices, in 3 years, continuous wheat was the most profitable. When the rotation was extended to 5 years, 1 canola break crop was grown. When the rotation length was extended to 10 years, 2 green manure pasture breaks were used. At low wheat prices, in 3 years 1 canola crop was included. At 5 years, 2 canola crops were grown and in 10 years, 2 canola crops and 2 green manure pastures were included in the crop sequence. More breaks were grown when wheat prices were low and the planning horizon was longer. The size of the weed seedbank required to justify growing a break crop declined as the planning horizon increased and the commodity price of the dominant crop decreased.

Key words
Pastures, oilseeds, cereals, crop rotation, optimisation

Introduction
The decision to grow a break crop or cereal crop is complex. At one level, it is widely acknowledged that break crops enhance the yield of subsequent cereal crops by increasing nutrient supply, interrupting disease life cycles and allowing the farmer to use different weed control options (Angus et al. 2015, Seymour et al. 2012, Lawes et al. 2013). However, in many situations, break crops may not appear profitable. For example, in Western Australia, lupins were recently valued at $200/t, and potentially unviable at that price. Similarly, in drier climates, break crop options like canola and chickpeas have failed during droughts. Therefore, simple gross margins would suggest that break crops may be uneconomic, and farmers can generate superior returns by growing continuous cereals, particularly when they appear to be the obvious choice.

Simple gross margins ignore future returns, and intangible concepts such as future weed control costs, the effect of disease and changes to nutrient supply. Managing these intangibles can often lead to improved cereal yields, and higher economic returns for similar or lower levels of input. As a result there is a dichotomy between a crop choice or rotation that maximises immediate economic returns and another that focuses on the longer term economic payoff. This dichotomy is often influenced by commodity prices and the extent of the biotic stresses present in the paddock. Recently, Kirkegaard and Ryan (2104) coined the term “break crop trigger” for defining the biotic conditions when a particular break crop should be grown. It is conceivable that this trigger point could be influenced by the biotic stress, the planning horizon and commodity price of the dominant rotation crop.

We explore the impact the planning horizon, and commodity price has on the number of break crops grown, and consider how these factors alter the trigger point of weeds that force another break to be included in the crop sequence. The crop sequencing model LUSO is parameterised for the Kojonup region in Western Australia.

Methods

We parameterise the Land Use Systems Optimiser (LUSO), for canola, lupins, managed legume pasture, and wheat for the Kojonup region of Western Australia (table 1). LUSO is a bio-economic state and transition model that integrates the effects of weeds, disease, nitrogen dynamics and crop yields. The model determines the optimal rotation from a given set of crop or pasture choices. Each crop or pasture influences the weed populations, disease populations and nitrogen dynamics. The weeds and diseases influence the yields of subsequent crops, while the nitrogen dynamics and weed population influences the cost of managing the crop. The model can be used to explore strategic and tactical management strategies and explore how risky particular rotation sequences are (Lawes and Renton 2010, Lawes and Renton 2015, Renton et al. 2015).

Table 1. Enterprises and economic parameters defined for the LUSO analysis

Enterprise	Yield (t/ha)	Low Price ($/t)	High Price ($/t)	Cost ($/ha)	N requirement (kg/ha)	Weed survival (0-1)
Wheat	3	270	350	250	160	0.05
Lupins harvested	1.5	270	270	200	0	0.05
Sprayed pasture	3	0	0	80	0	0.03
Canola	1.3	550	550	250	120	0.03
Lupins manured	1.5	0	0	150	0	0.03
Pasture	3	90	90	100	0	0.03

Here, we use LUSO to quantify the costs and benefits of including a break crop in the rotation at Kojonup on a sand over gravel soil, where the input parameters are generated via consultation with local growers and the APSIM crop simulation model. The changes in weed population and disease are simulated.

The optimal rotation is evaluated over 3 years, 5 years and 10 years. These optimisations were conducted to determine whether more break crops are selected when the planning horizon increases from 3 to 5 to 10 years with low and high initial weed pressures. Each scenario was run at a high wheat price ($350/t), that would automatically favour an intensive cereal crop sequence and at a low wheat price ($270/t), where the gross margin for wheat is less favourable.

The starting seedbank was increased from the initial population of 50 seeds/m2 at increments of 1 seed/m2 to determine when the starting seedbank brought about a change in the crop sequence. This was defined as the seedbank trigger point, and we evaluated this trigger under low and high wheat prices for the 3 yr, 5 yr and 10 yr rotation sequences.

Results

For the short (3 yr) simulation with low wheat prices, a wheat canola wheat sequence was selected and it generated a cumulative profit of $405/ha. Under high wheat prices a continuous wheat sequence was selected that generated $915/ha (Figure 1). For this particular crop sequence, wheat yields declined from 2.64 t/ha in year 1 to 2.39 t/ha in year 3, The decline in yield occurred because the disease impact from growing continuous wheat increased from 5% in year 1 to 14% in year 3. The losses due to weeds increased from 7% in year 1 to 8% in year 3, and the continuous wheat system left a residual seedbank that increased from 50 seeds/m2 to 305/m2. The decline in wheat yields resulted in a steady decline in annual returns from $364/ha in year 1 to $250 in the final year of the crop sequence (Figure 1). When cereal prices were low, and canola was grown, the steady decline in annual profit did not occur (Figure 1).

For the mid (5 yr) simulation of crop sequences, with high wheat prices, a wheat, wheat, canola, wheat, wheat sequence was selected. After 5 years, this sequence generated a cumulative profit of $1332. Wheat yields declined from 2.64 t/ha in year 1 to 2.50 t/ha in year 2. The canola crop managed the disease, and wheat yields in year 4 and 5 were equivalent to those of year 1 and 2. The weed population, and yield loss due to weeds had increased from 7% in year 1 to 10% by year 5 and at the conclusion of the crop sequence

972 seeds/m2 were returnded to the seedbank. Annual returns declined from year 1 to year 3, when a canola crop was grown. Profits increased after the canola crop before declining again in the final year of the crop sequence (Figure 1). With low wheat prices the crop sequence changed to wheat canola wheat canola wheat. In this scenario, weeds and disease were managed and wheat yields declined from 2.64 t/ha in year 1 to just 2.62 t/ha in year 5. This crop sequence mimicked the start of the 3 year crop sequence.

With the long (10 yr) crop sequence, wheat crops were grown for 3 years, and then a managed pasture, that controlled weeds, was grown. This was repeated, so over a 10 year period, 2 sprayed pastures were grown and 8 wheat crops were grown. This particular crop sequence managed the weed burden until the 10th year, when the seedbank increased to 1300 seeds/m2. Wheat yields were reduced to 2.46 t/ha in the final year of the sequence. The pasture was expensive to grow, and generated a loss of $230/ha. However, nitrogen from the pasture contributed to substantial profits in years 5 and 9 of the crop sequence (Figure 1). With low wheat prices a complex crop sequence of wheat, canola, wheat, canola, wheat, wheat, pasture, wheat, pasture, wheat, was selected. The first 3 and 5 years of this sequence mimicked the sequence selected by the 3 and 5 year simulations. However, after that time, weeds became a problem and were again managed with a sprayed pasture (Figure 1).

Under high wheat prices the optimal crop sequence changed when the starting conditions for the weed seedbank were increased from 50 to 750 seeds/m2 for the 3 year crop sequence. A sprayed pasture replaced the second wheat crop in this scenario. For the 5 year rotation, the canola crop was replaced by a sprayed pastured in the second year when the initial weed seed bank increased from 50 seeds/m2 to 148 seeds/m2. The long term crop sequence altered when the starting seedbank increased from 50 seeds/m2 to 131 seeds/m2. The number of wheat crops declined by 1, and the number of pastures grown increased from 3 to 4. For the low wheat price scenario, a crop sequence change occured when the weed seedbank increased from 50 to 557 seeds/m2 , where a pasture replaced the canola. This switch occured in the 5 yr sequence when the starting seedbank reached 158 seeds/m2. Pasture again replaced canola in the 10 yr sequence when the starting seedbank was 82 seeds/m2. In general, the trigger point to change the crop sequence from the initial solution was influenced by the commodity price of wheat, and the length of the crop sequence. As crop sequences increased in length, the size of the trigger declined.

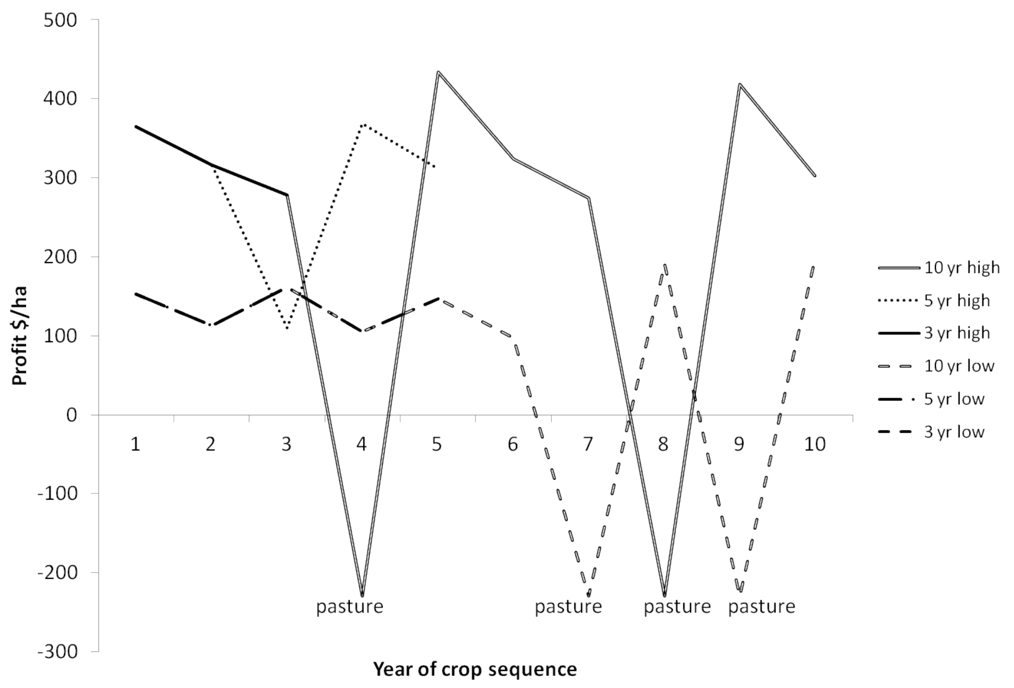

Figure 1. Annual profit in dollars per hectare for the the 3 yr, 5 yr, 10 yr optimal crop sequences with low and high wheat prices. The dominant crop is wheat, and all other crop or pasture choices are labelled.

Discussion and conclusions

The question about whether the optimal crop sequence changes with respect to the length of the planning horizon is dependent on commodity price. Under a low priced regime, the crop sequence for the 3, 5 and 10 year scenarios did not change, until the 10 year scenario moved beyond the 5th year. For this regime, wheat was still the most profitable crop, but the break crop generated profits that were not substantially lower than wheat. The crop sequence did not change until the break crop was unable to control an emerging weed problem. In contrast, under a high priced scenario, each crop sequence differed, where the short term crop sequence was more exploitative than the 5 year scenario, which included a break crop in the 3rd year. The 10 year sequence actually mimicked the 3 year sequence for the first 3 years, before growing a pasture break. Therefore, longer term planning horizons did not necessarily result in a management change. The underlying implication is that if the scale of the biotic stress is understood, short term and long term crop sequences may generate similar economic returns, as the crop sequences selected are initially similar.

The duration of the crop sequence had a far greater impact on the size of the weed seed bank that triggered a change in the crop sequence. In general, a moderate (< 2 fold) increase in the weed seed bank brought about a change in rotation when viewed over a 10 year time horizon. However a massive (> 10 fold) increase in the biotic stress was required to bring about a change in management when viewed over a short time frame. Indeed, the time horizon had a greater impact on this shift in the size of the trigger than the commodity price of wheat. The underlying implication is that to develop the concept of a crop trigger, scientists need to develop reliable estimates about the size of the initial biotic stress, its rate of increase under certain management scenarios and an idea of the time frame the farmer is working too. Long term sequences suggest it is worth keeping biotic stresses low, while short term planning would suggest they can be ignored until they have reached obviously large proportions. These outcomes are dependent on possessing management solutions than can correct large weed seed banks in one year.

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