Sequence effects on cropping system productivity and profitability in two environments in Western Australia

Bob French[A], Raj Malik[B], and Mark Seymour[C]

Department of Agriculture and Food Western Australia
[A] Dryland Research Institute, PO Box 432, Merredin WA 6415 bob.french@agric.wa.gov.au
[B] Great Southern Agricultural Research Institute, 10 Dore St, Katanning, WA, 6317 raj.malik@agric.wa.gov.au
[C] Esperance District Office, PMB 50, Melijinup Rd, Esperance, WA 6450 mark.seymour@agric.wa.gov.au

Abstract

Two large experiments compared the productivity and profitability of up to 100 crop sequences at Katanning and Wongan Hills in Western Australia. 10 different crops were grown in 100 m × 10 m strips in year 1, then in strips at right angles in year 2 on year 1 residues. This gives 100 unique sequences in 10 m × 10 m plots. The whole site was cropped to wheat in years 3 and 4.
Crop sequence had significant effects on wheat yield, including second year effects, in both trials. At Katanning highest yields followed lupins but good responses were also observed after field pea, winter fallow, and green manure. The second year at Wongan Hills was very dry and the only significant response was after fallow. Year 3 at Wongan Hills was much wetter but a large fallow response was again observed, along with responses to lupin and serradella pasture. There were no significant responses to canola in either trial. Cereal root disease levels were low in both trials. At Katanning weed populations were low until year 4 when brome grass began to build up in continuous cereals, and sequence effects were driven largely by soil N. At Wongan Hills there were up to 20-fold differences between sequences in annual ryegrass populations and this was an important determinant of wheat productivity in year 3, along with soil N.

Key Words
Crop sequence, rotations, break crops, fallow

Introduction

Cropping systems generally consist of a sequence of components, which may be different crop species or other land-use activities such as fallow, pasture, or green manure, practiced in successive years. It is widely recognised that cropping systems encompassing a diverse range of components are more biologically stable than monocultures (e.g. Kirkegaard *et al.* 2008) and, without a rigidly pre-defined sequence, better able to adapt to changing economic and ecological circumstances (Tanaka *et al.* 2002). This is what Tanaka *et al.* (2002) call a dynamic cropping system.

Cropping systems in WA have evolved over the past decade in response to high cereal and oilseed prices relative to lupins, other pulses, and wool as well as increasing production costs, particularly for weed control in lupins; and perceived riskiness of pulses and oilseeds. As a result there is now less pasture, less lupin and other pulses, more cereal after cereal and, while there is also more canola, cropping systems are less diverse than they were 20 years ago. Despite this farmer surveys consistently reveal the opinion that this heavy dependence on wheat and barley is unsustainable in the long run, and that more diversity is desirable.

Each cropping system component has advantages and disadvantages, and whether it will bring benefits to a cropping system will depend on the state of that system. For instance, legumes can provide organic N to a system but this is of no particular value if N is not deficient. Canola can reduce levels of cereal root diseases such as take-all and crown rot, but this confers no advantage when these pathogens are absent. Similarly, the differential weed control that some components offer has no value in weed free situations.

There are a great many combinations of land use history, weed status, disease status, nutrient status and economic outlook that can arise on WA farms; and a diversity of farm business goals as well. Computer models such as the Land Use Sequence Optimiser, or LUSO, (Lawes and Renton 2010) can help farmers make better decisions about their cropping options by predicting the likely consequences of different decisions. But models must be based on real-world data, and tested against real-world situations before decision makers will adopt them confidently.

There are considerable data on wheat responses in WA to lupin; less on responses to field pea, canola, and oats; and very little on responses to other break crops (Seymour *et al.* 2012). In addition, there are almost no data on comparative responses to different cropping components in the same experiment. To provide such data, to help understand the processes driving the performance of WA cropping systems, and to help validate models such as LUSO, we initiated two Dynamic Crop Sequence trials; one at Katanning in 2008, and the other at Wongan Hills in 2009. These trials looked at how crop performance depends on the previous crops in sequence, taking into account the context at each site. The ultimate objective is to answer the following questions: what factors determine the performance of different crops; how are these affected by cropping history; and how can we use this information to design ecologically and economically robust options for crop sequences.

Method

The trials were based on the design described by Tanaka *et al.* (2002). The one at Katanning, WA, was on a mildly acid shallow duplex soil, and the one at Wongan Hills, WA, was on a mildly acid deep earthy sand over gravelly clay. Both soils are representative of cropping paddocks in their regions. The design consisted of 10 cropping system components applied in10 m × 100 m plots in year 1 (2008 at Katanning, and 2009 at Wongan Hills) in randomized blocks. The treatments at each site are given in Table 1. In year 2 the same treatments (with slight modifications at Wongan Hills, see Table 1) were applied in 10 m × 100 m plots at right angles to the year 1 plots, thus dividing the experiment into 100 10 m × 10 m plots each with a unique sequence. Wheat was grown across the whole site in year 3 and year 4 but year 4 results are not presented in this paper.

Table 1. Crop system component treatments in dynamic crop sequence trials at Katanning and Wongan Hills.

Katanning	Wongan Hills
Wheat	Wheat
Wheat + Jockey seed treatment	Wheat (in year 2 wheat sown after soil inversion by mouldboard ploughing)
Barley	Barley
Oats for grain	Oats cut for hay
Oats cut for hay	TT canola
TT canola	Clearfield juncea canola (in year 2 Roundup Ready canola)
Lupin	Lupin
Field pea	French serradella
Green manure (vetch + oats)	Volunteer pasture
Fallow	Fallow

Fallow in each trial was achieved by spraying with glyphosate in winter after there was sufficient ground cover to protect the soil over the following summer, and keeping plots clean with further sprays if necessary. Green manure at Katanning was sprayed with glyphosate prior to seed set and left to brown naturally over time and then slashed. Serradella and pasture at Wongan Hills were slashed to simulate grazing, and sprayed with glyphosate and paraquat in late spring to prevent ryegrass seed set. Crop growth and yield, weed populations, crop disease levels, soil nutrient status, and soil water extraction in selected treatments were measured.

Results and Discussion

Grain yield responses

Wheat grain yield responses are shown in Figures 1 and 2. In the interests of conciseness year 3 responses to year 1 treatments are averaged over all year 2 treatments, and responses to year 2 treatments are averaged over all year 1 treatments. This hides considerable complexity, but illustrates the main points. For Katanning, responses are presented for the wheat + Jockey treatment since this yielded 21% higher on average than wheat without Jockey in year 2. Wheat yields at Katanning were highest after lupin in both years 2 and 3 (2009 and 2010), but significant responses were also observed to canola, fallow, field pea, green manure, and oaten hay in year 2. The capacity of the crop to respond was probably limited in year 3 by a very dry finish, when less than 7 mm rain fell during grain filling. In year 2 the highest yields of oats and oaten hay were also after lupin, but field pea, canola, and barley were less responsive than wheat to lupin.

At Wongan Hills year 2 (2010) was one of the driest on record (growing season rainfall 132 mm compared to long term average 268 mm) and year 3 (2011) quite wet (growing season rainfall 366 mm). In year 2 wheat only responded to fallow, producing 52% more grain than after wheat. In year 3 wheat again responded to fallow, but also to lupin, serradella, and soil inversion by mouldboard ploughing before wheat in year 2. There were also significant second year responses to fallow, lupin, oaten hay, serradella, and volunteer pasture in year 1. There were no significant responses to canola at Wongan Hills.

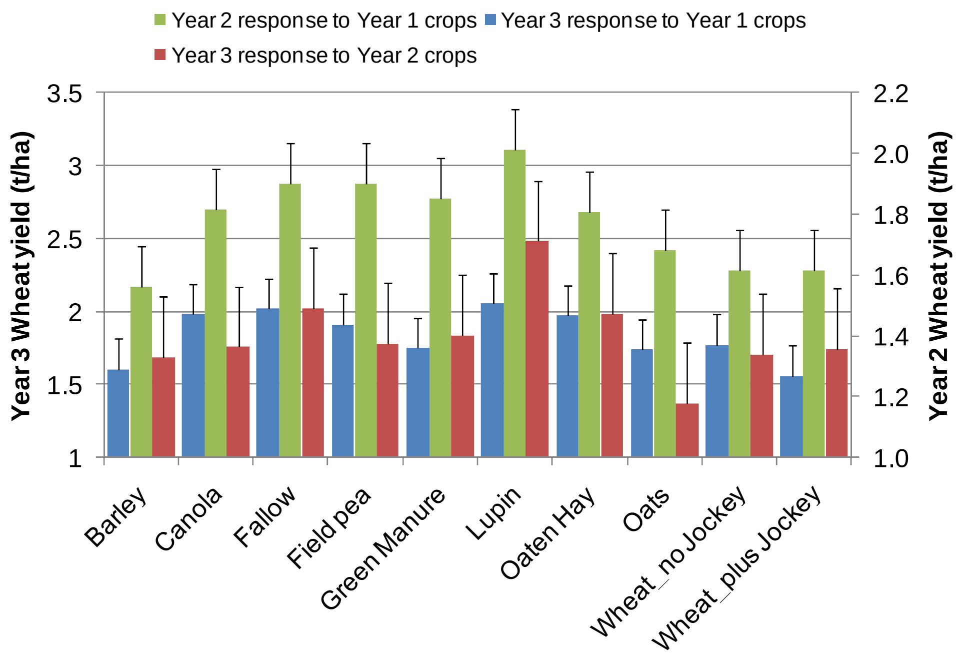

Figure 1. Wheat + Jockey yields at Katanning in Year 2 (2009) after a range of treatments in Year 1 (2008), and in Year 3 (2010) after the same treatments in years 1 and 2. The response to year 1 treatments in year 3 is averaged over all year 2 treatments, and the response to year 2 treatments in year 3 is averaged over all year 1 treatments.

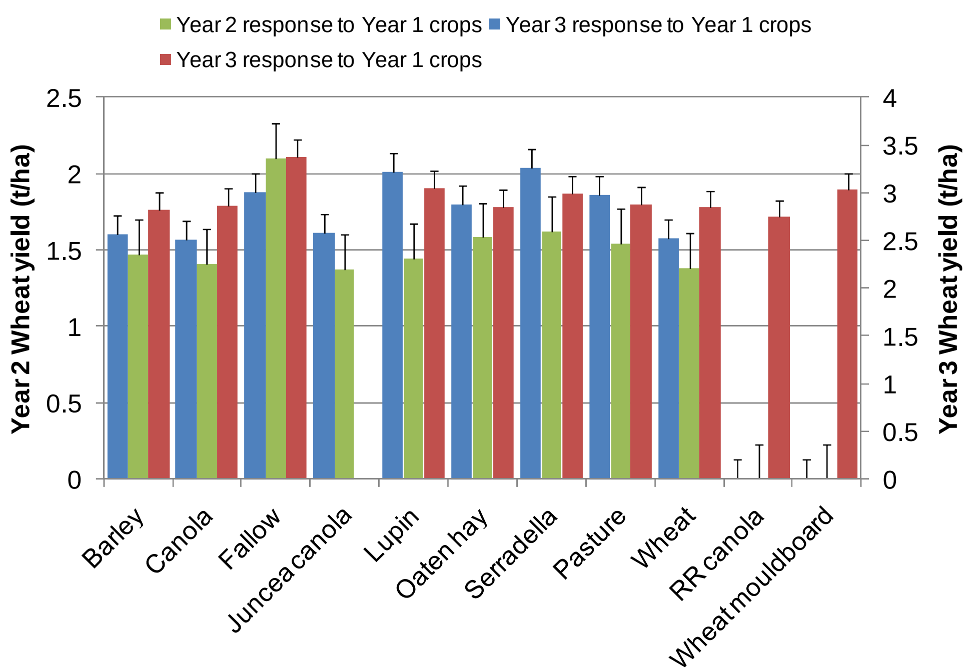

Figure 2. Wheat yield at Wongan Hills in Year 2 (2010) after a range of treatments in Year 1 (2009), and in Year 3 (2011) after the same treatments in year 1, and after year 2 treatments. The response to year 1 treatments in year 3 is averaged over all year 2 treatments, and the response to year 2 treatments in year 3 is averaged over all year 1 treatments.

Mechanisms of responses

Crop sequence can affect cereal yields through effects on soil nutrient (including N) supply, soil water supply, levels of crop disease inocula, and weed populations (Kirkegaard *et al.* 2008). We considered each

of these in relation to the responses we observed. Both sites had very low levels of cereal root diseases, confirmed by Predicta-B testing and disease symptom ratings, so this was not an important factor. Crop water use did not vary between treatments at Katanning, but improved water supply did contribute to the fallow response at Wongan Hills in year 2 (total ET of wheat after fallow was 179 mm, compared to 161 mm for wheat after wheat) but not in (year 3). Soil mineral N at sowing increased after fallow, lupin, and serradella at Wongan Hills, and after fallow, lupin, field pea, and green manure at Katanning, and contributed to the responses to these crops (Figure 2). Soil mineral N was still elevated at Wongan Hills two years after lupin and serradella in year 1, but not after fallow.
Weed levels were low at Katanning throughout the trial, although brome grass numbers were beginning to build up in continuous cereal treatments in year 4. There was a high level of herbicide resistant annual ryegrass at Wongan Hills when the trial began (94 plants/m² in wheat in July 2009), and fallow, oats for hay, lupins, serradella and volunteer pasture in year 1 all reduced ryegrass numbers dramatically, but canola did not. These differences in weed numbers persisted into year 3 and made a large contribution to the second year responses to these crops (Figure 2). Soil inversion by mouldboard ploughing in year 2 also dramatically reduced ryegrass numbers, and this contributed to the yield response to this treatment.

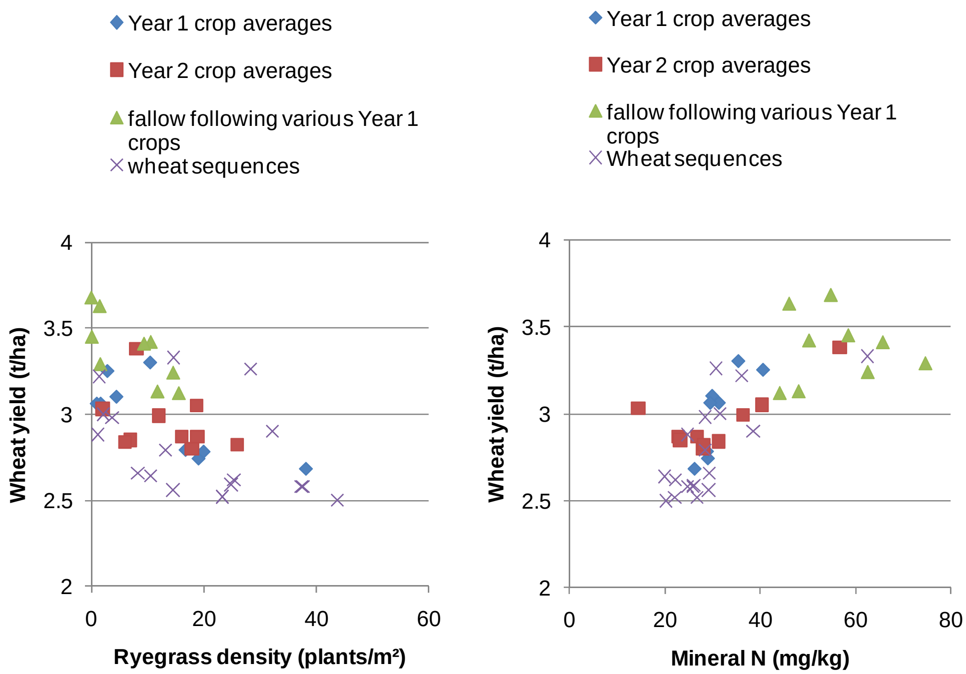

Figure 3. Effects of annual ryegrass density in July 2011 and mineral N at sowing on wheat yield at Wongan Hills in Year 3 (2011). Symbols represent averages for each Year 1 treatment over all Year 2 treatments, averages for each Year 2 treatment over all Year 1 treatments, fallow in Year 2 after each Year 1 treatment, and all treatments that had wheat in either Year 1 or 2.

Conclusions

Crop sequence effects are complex and can be profoundly affected by, among other things, season, weed status, soil nutrient levels, and soil type. All of these factors can influence crop sequence decisions.

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