Research priorities for weed suppression by crops in Australia

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Summary Crop competition is an important tactic for suppressing weed growth and maintaining crop yield, especially with the increasing levels of herbicide resistance in Australia. In 2015, a team of weed scientists from the western, southern and northern grain production regions conducted a comprehensive review of research on crop competition in Australia, funded by the Grains Research and Development Corporation (GRDC). The aim of the study was to enable a 20% increase in grower adoption of this tactic for weed suppression by 2020. The project team: identified priority weed species; conducted a meta-analysis of pooled data to identify common trends; conducted a knowledge gap analysis based on the literature review and the meta-analysis; defined an approach for improved future crop competition experimentation; and identified and provided recommendations for future Research, Development and Extension (RD&E).

An updated assessment of priority and key weed species was provided. The need for more studies on agronomic means of enhancing weed competition were identified, especially for weakly competitive crops such as pulses. These included crop rotation, fertiliser manipulations and determination of traits conferring competitiveness that can be used in varietal selection and breeding programs. Further, it is necessary to guide farmers on understanding the benefits of growing a competitive crop as a viable alternative to chemical weed control. Plant breeding for crop traits associated with strong competitive ability will provide an alternative and longer-term solution to weed management.

Keywords Crop competition, review, meta analysis, research protocol, recommendations.

INTRODUCTION

Across all Australian grain growing regions, herbicides have been heavily relied upon for in-crop weed management. This reliance has resulted in widespread herbicide resistance in a range of common in-crop weed species. In Australia, there have been 49 weed species identified as having herbicide resistance across 16 sites of action (Heap 2018). Of these, 32 were confirmed as resistant in Australian grain cropping systems. As herbicide-resistant individuals survive herbicide treatments, other non-herbicide weed management tactics are required, including crop competition.

Competitive crops have been shown to have a positive impact on in-crop weed suppression and maintaining crop yield. Several agronomic practices can influence the competitiveness of a crop (Lemerle *et al.* 2001, Borger *et al.* 2015). These include crop species and cultivar, row spacing, density, seeding methods and row orientation. Furthermore, the competitive ability of a crop can be influenced by fertiliser placement, depth and time of sowing, effective control of insects and diseases, and a complex interaction of weather and soil conditions (Palta and Peltzer 2001).

Crop competition was used in Australia to increase the yield and thereby profitability of crops prior to the advent of selective herbicides and in organic crops. However, with the spread of herbicide resistance, there has been a renewed interest in competitive crops for weed management.

There has been much research during the last 20 years on crop competition across all Australian grain growing regions and published in refereed scientific journals, (Lemerle *et al.* 1996, Bajwa *et al.* 2017), while some more recent research has been reported only in GRDC Crop Updates.

GRDC identified a need to review all available literature to identify current knowledge and required future Research, Development and Extension (RD&E) needs.

A team of weed scientists from the western, southern and northern GRDC regions was sponsored by GRDC to:

- identify priority weed species;
- conduct a comprehensive review of literature on crop competition as a cultural weed management tactic;
- conduct a meta-analysis of pooled data from the literature to identify common trends; and
- conduct a knowledge gap analysis based on the literature review and meta-analysis.

Through this process, we identified future RD&E needs and defined a consistent approach for future experimentation.

The review is a basis for prioritising future RD&E investment. It also provides a standard protocol for a nationally consistent approach to experimentation on crop competition, thereby providing more reliable and comparable research results for use in predictive models of the benefits and costs of crop competition for weed control. This knowledge will likely increase adoption of this weed management tactic.

MATERIALS AND METHODS

Priority weed species The project team identified the most important key weed species for each region, and prioritised these based on potential impacts and current and future threats of herbicide resistance. The project team used their knowledge of industry weed issues and research in this process.

Literature review A comprehensive review was undertaken of reported research on crop competition across the wheat belt of Australia from the early 1980's to 2015 for each region (western, southern and northern agro ecological zones). The studies included in the literature reviews examine either individual or multiple crop competition factors across various crops, weeds, rotations, seasons and sites, and research approaches.

Meta analysis The meta-analysis was designed to pool data sourced from the literature and to identify common trends. For individual crop competition factors, like-measurements have been compared to identify trends. In both the southern and northern regions, mimic weeds have commonly been used in place of target weed species.

The meta-analysis consisted of three components:

1. a summary of the number of trials conducted in each region and for each weed species;
2. a total of 64 graphs of data, based on data presented in papers, to explore trends between crop competition factors and measures of weed growth; and
3. a summary of the pooled data across each region showing general trends.

Knowledge gaps In order to determine the knowledge gaps for crop competition, the project team firstly 'brainstormed' an importance rating for each key crop competition factor (crop species, cultivar, crop density, row spacing, row orientation, sowing time, depth of sowing, nutrition, soil characteristics, rainfall) and each key crop (wheat, barley, oats, canola, lupins, field pea, chickpea, faba bean, triticale, maize, soybean, sunflower, mung bean, soybean) on a 1 to 5 scale for each region. The relative importance for each combination of crop competition factor and key crop was calculated by multiplying this product by 4. This meant the relative importance value could range from 0 to 100 (100 = highly important). Priority was taken into account when identifying key knowledge gaps.

Secondly, following the review of literature, an intuitive rating (0% = nothing available, 100% = completely covered) was made as to how completely each crop competition by crop factor had been researched for each region.

Thirdly, to identify the knowledge gaps, the relative importance percentages (0–100%) were subtracted from the intuitive percentages (0–100%). Using these differences, priority levels were assigned. When the relative importance percentage was greater than the intuitive percentage of coverage by the literature, this indicated a potential knowledge gap. The reverse indicated there was sufficient knowledge for that crop competition by crop factor.

Finally, a list of national and regional priorities was developed, taking into account the importance of the crop competition factor and the crop species.

Experimental design protocol One of the key findings of this study is the need for an improved and consistent approach to experimentation on crop competition. The project team developed an experimental protocol to guide future planning and experimentation.

RESULTS

Priority weed species Common weeds across the regions were annual ryegrass (*Lolium rigidum* Gaudin), wild radish (*Raphanus raphanistrum* L.), wild oat (*Avena* spp.) and fleabane (*Conyza* spp.), while windmill grass (*Chloris truncata* R.Br.) and feathertop Rhodes grass (*Chloris virgata* Sw.) were seen as emerging problems.

Weeds specific to regions include brome grass (*Bromus* spp.) and prickly lettuce (*Lactuca serriola* L.) for the western and southern regions, and sweet summer grass (*Brachiaria eruciformis* (Sm.) Griseb.) for the northern region.

There is a more limited range of species in the western region reflecting the simpler farming rotations and limited ecological zones compared with the southern and northern regions.

Literature review A total of 88 references were included in the study. However, only 46 of these were used in the meta-analysis because these papers had data in a form that was accessible.

The most common focus of crop competition research was on crop productivity with a lesser focus on this tactic for weed suppression.

More research was done in the western and southern regions compared with the northern, possibly due to the earlier onset of herbicide resistance in annual ryegrass and wild radish.

Most of the research has been on wheat agronomy by manipulating factors such as crop density, row spacing and cultivar. Work on other crops varied with region, as expected.

Some experiments were confounded by crop rotation and other weed management practices, including herbicide application, therefore making it difficult to extract and interpret main crop competition effects.

Meta analysis Research to date has focused on a small number of key weeds in the western region, mainly annual ryegrass and wild radish. Similarly, research in the southern region was mainly on annual ryegrass. Research in the northern region was even more limited, but most has been on wild oat or other weed species present at the experimental site.

Key findings include that:

- an increase in crop density commonly resulted in a decrease in weed growth. This was consistent across crops and regions and for different weed species;
- cultivars can differ in their competitive ability across crop species with more competitive cultivars resulting in a decrease in weed growth. However, not all studies show a difference between cultivars and the effects of different cultivars can be inconsistent due to seasonal conditions;
- a wheat row orientation of east-west, as opposed to north-south, generally results in a reduction in weed growth, especially in the western region. However, results are inconsistent, with one southern region study having the opposite result;
- a decrease in row spacing generally resulted in a decrease in weed growth. This effect was consistent across crop species and regions. However, in several studies, wider row crops resulted in a reduction in weed growth due to interaction with in-crop control measures such as herbicide application;
- skip row research has only been conducted in the northern region. Generally, solid planting reduces weed growth compared with skip rows; and
- an early sowing time generally reduced weed growth. However, there has been little research on this crop competition factor.

Knowledge gaps The study identified RD&E needs at both national and regional levels. National RD&E needs include:

- breeding for, and evaluation of competitive ability of the most important crops and their cultivars. Also, for understanding of the traits and genetics that influence competitive ability (e.g. allelopathy, early vigour);
- whether gains can be made in the competitive ability of weakly competitive crops (e.g. pulses)? Such crops represent a weak phase in the crop rotation (in terms of crop competition) and therefore gains should be pursued;
- fertiliser rates and more efficient fertiliser placement (horizontally and vertically) to favour the crop over the weed, measuring impact of crop competitive ability on weed control;
- that there are insufficient data across all regions on many priority weed species;
- the effect of the timing of weed emergence on the efficacy of crop competition;
- whether specific crop rotations seem to out compete weeds compared to others?;
- that farmers need more guidance and demonstration/extension as to how to use crop competition and how to best implement it in the farming system;
- if crop and cultivar competitiveness information is available then it should be included in crop production agronomy guides; and that
- it may be feasible to model different crop competition by crop species interactions once there is sufficient data that has been measured with a consistent procedure. This information could be used in the extension of crop competition as a weed management tactic.

Regionally specific RD&E needs include:

For the western region:

- canola across all crop competition factors;
- field pea for cultivar and crop density; and

- chickpea for cultivar, crop density and row spacing.

For the southern region:

- lupins, faba bean, chickpea for cultivar, crop density and row spacing; and,
- canola for row spacing.

For the northern region:

- chickpea, faba bean, mungbean and maize for cultivar, crop density and row spacing; and, wheat and barley, for cultivars.

Experimental design protocol Recommendations for future crop competition research have been made to ensure reliable and useful data for change of practice, including experimental design, establishing the weed population, what to measure, statistical analysis and reporting.

Weed:crop competition is complex. The research needs to be kept relatively 'simple' to tease out the main effects. Much of the existing work combines several crop competition and non-crop competition factors and clear messages are lost.

DISCUSSION

To enable a 20% increase in grower adoption of crop competition by 2020, there is a need for both agronomic research (short-term) and plant breeding research (long-term) to improve the competitive ability of crops. In addition, Development and Extension is required regionally to provide farmers with knowledge as to how best to use crop competition in their farming system.

Future crop competition research requires national funding, coordination and communication for national breeding for competitive ability traits, regional packages for agronomy, and research consistency to improve the quality of research outputs. Bio-economic modelling is required to provide farmers and advisors with cost-effective and reliable predictions of the benefits of crop competition to ensure future adoption of this tactic for weed management where appropriate.

Since crop competition is only one aspect of weed management and crop agronomy, it needs to be investigated as part of an integrated package for weed control. For example: the interaction between crop competition and in-crop herbicides; the effect on weed seed retention for harvest weed seed control; and effect on in-crop disease levels.

We recommend a National Crop Competition Program to improve communication, coordination and quality of RD&E on crop competition for the grains industry of Australia.

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