Predicting profitability of summer weed control timing and impact on crop yield potential: $ummer

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Summary
Summer fallow weed control has been shown to be an integral component of modern crop production systems in a changing Australian climate. At the same time suboptimal control of summer weeds have been shown to have high continuing cost to yield and profitability. Field trial results are used to show the importance of the soil water and nitrogen drivers of the impact of summer weed control timing options under different soil and weed scenarios. A predictive tool ($ummer) designed to inform summer weed control investment decisions including the impact of timing options is presented.

Keywords Summer Weed control, Yield benefits, APSIM

INTRODUCTION

Summer fallow weed control is an increasingly important component of modern cropping systems and has played an important role in how Australian grain growers have profitably adapted to climate challenges (Hunt and Kirkegaard 2011). Although usually shown to increase average profitability, there are many situations where summer weed management and timing decisions are not always clear-cut, and returns from fallow can vary greatly by region, soil type and season (Oliver *et al*. 2010). The cost of control and impact of summer weeds on crop yield is high, with estimates of annual revenue loss due to summer weeds in southern and western Australian cropping regions estimated at $350 M (Llewellyn *et al.* 2016). Sub-optimal summer fallow weed control has been identified as one of the major reasons for Australian wheat yields not reaching yield potential (Hochman and Horan 2018).

To inform summer weed decisions which typically take place under uncertainty of the coming summer and winter crop season conditions, we have applied APSIM-based modelling to produce a tool designed to be applied at the time of specific summer weed control decisions. The $ummer tool produces probabilistic estimates of the two important elements of summer weed impact; soil water, soil nitrogen (Hunt *et al*. 2013) and subsequent crop yield impacts from summer weed populations and timing options.

To support development of the tool we have also conducted field trials to expand the relatively limited range of summer weed control timing field experiments that have measured both soil water and nitrogen impacts in conjunction with simulation modelling on characterized soils.

MATERIALS AND METHODS

Trials

In addition to preliminary field validation trials conducted in Western Australia in 2020-21 (data not presented), trials have been conducted in the southern region in 2021.

Trial 1 - Wharminda South Australia: dune location, sand, increasing clay from approximately 0.3 m. Summer rainfall (November-March) 2021/2022 was 205 mm which is significantly higher than the long-term average of 86 mm. There was a 71 mm and 16 mm of rainfall on the 22nd and 24th January respectively.

Trial 2 - Bute South Australia: a) dune site, shallow sand with clay and calcrete increasing with depth and b) flat site, a loamy sand over clay. The 2021/2022 summer rainfall (November-March) was 127 mm, which slightly higher than the 101 mm long-term average. There were large rainfall events of 54.4 mm on 12th November 2021 and 33 mm on 21st January 2022.

Treatments:

1. Full control with follow-up as required (10th -17th February and 4th -17th March),
2. Initial control with no follow-up (10th -17th February)
3. Delayed control (4th -17th March)
4. No control

All treatments were treated with knock-down herbicide in April in preparation for crop seeding. Soil water and nitrogen measurements are presented here, with crop yields to be measured from harvested crops in November-December 2022.

APSIM simulations are being conducted on the trials to validate the modelling and show the range of probable yields with different soil water measured in April from the weed control treatments in the trials with 100 years of season conditions.

$ummer weed app

The $ummer tool is currently populated with APSIM modelling output based on:

1) Different locations (7 sites across Western Australia, South Australia, Victoria)
2) Contrasting soils of sand, loam or clay at each site
3) A range of periods in which the target population of weeds can germinate based on rainfall (December, January, February, March) where there are no weeds at other times.
4) Different weed types (deep and shallow rooted)
5) Difference in weed density (from 1 to 50 plants m^{-2})
6) Differences in maturity of the weed population at the time of assessment (days since typical emergence).
7) A range of spray timing options from time of assessment through to various delayed options, compared to no weed control prior to pre-seeding time control.

The modelling is focused on wheat impacts, and the crop was assumed to be sown between 25th April and 30th June when 15 mm rain has fallen over 5 days, with 100 plants m^{-2} of Mace wheat, sown with 50 kg ha^{-1} nitrate and a further 50 kg ha^{-1} 40 days after sowing. The high level of fertiliser was to ensure that only water stored, and rainfall were limiting the yield potential, rather than any difference in N due to weeds. The impact of the weed populations on available soil N is reported separately.

The app is designed for the scenario that the user is standing in a paddock with summer weeds and inputs the location, date, basic soil type and general weed population characteristics (i.e. density and age of deep or shallow rooted weeds) (Fig. 1). The app then asked the user to compare ‘control now’ and ‘control in X days’ and/or ‘do nothing’ scenarios.

From this input the app chooses the set of simulations to determine the expected yield benefit from the control options, determined by the soil water conditions. The gain in starting N available to the subsequent crop is also estimated. The app uses an adjustable wheat price to determine expected returns from control and presents results as the likelihood of achieving an outcome (e.g. probability of a $20 ha^{-1} yield gain) as well as expected value (average).

To demonstrate the $ummer weed app outputs (Fig 4) the Minnipa South Australia site was chosen as the closest site to Wharminda, with inputs of 50 deep rooted summer weeds m^{-2} on the 10th February that had emerged 10 days ago. The $ummer weed app compared scenarios where these could be killed in that week or in the next 30 days compared to no summer weed control prior to pre-seeding control. Both Sand and Loam soil results are shown for comparison.

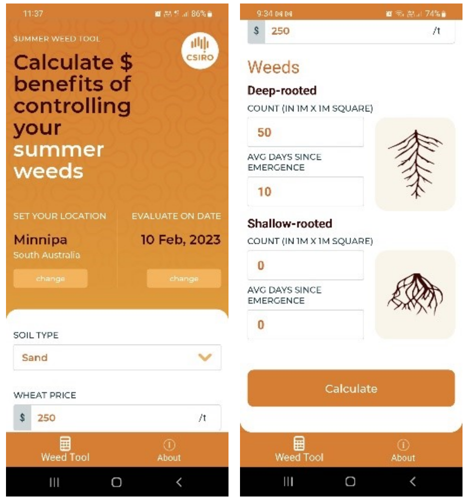

Figure 1. Two screen shots of the $ummer weed app input pages

RESULTS

Trial results

The high summer rainfall in November and January caused high weed density and different species at the sites. At Wharminda the average weed density was 206 plants m^{-2} with blanket weed (79 plants m^{-2}), volunteer wheat, (79 plants m^{-2}), Lovegrass (21 plants m^{-2}), capeweed (17 plants m^{-2}), medic (13 plants m^{-2}), and heliotrope (10 plants m^{-2}). At Bute Dune and Flat sites the weed density was 79 and 65 plants m^{-2} with the dominant weed volunteer wheat (78, 49 plants m^{-2}) as well as a mixture of large and small heliotrope (1,8 plants m^{-2}).

Table 1. Additional water (mm) in profile (to 60 cm) compared to no weed control

Treatment	Wharminda	Bute Dune	Bute Flat
Full ongoing control	22.2	22.6	16.9
Initial control with no follow up	15.9	14.2	9.5
Control delayed 30 days	9.3	8.8	3.7

Between February and early April, the uncontrolled weeds used an additional 17-23 mm of stored soil water compared to when the weeds were fully controlled (Table 1). Even when the weed control was delayed by 30 days, the additional water was 4-10mm. At Wharminda, there was additional soil nitrate to 0.9 m of 30, 13 and 4 kg ha^{-1} for the full controlled, initial control with no follow up and delayed control treatments respectively.

However, in April the GSR is unknown, so these April soil water levels were used with APSIM and climate data from 100 seasons to estimate the range of likely yield increases from this stored soil water for 2022 season.

At Wharminda, there was a 50% chance of achieving a 0.31 t ha^{-1} yield increase from managing weeds completely, 0.22 t ha^{-1} for only for the early weed control or 0.19 t ha^{-1} for delaying weed control by a month. In this case, the average and 50th percentile values were similar (Fig 2). There was about 20% of years where there was no yield increase from these differences in soil water, which is likely in years with high growing season rainfall e.g. 13% of the years had greater than 280 mm (Fig 3).

At Bute, the soil water differences resulted in less chance of achieving yield increases, with up to 50% of years having no difference in yield (Fig 2). This lower chance of a yield benefit at Bute may be caused by the higher GSR where 33% of years have growing season rainfall greater than 280 mm (Fig 3). However, due to the abnormal distribution the average yield increase for full weed control was 0.19 at Dune and 0.26 t ha^{-1} at Flat sites and for delayed weed control was 0.12 t ha^{-1} at Dune and 0.08 t ha^{-1} at Flat sites.

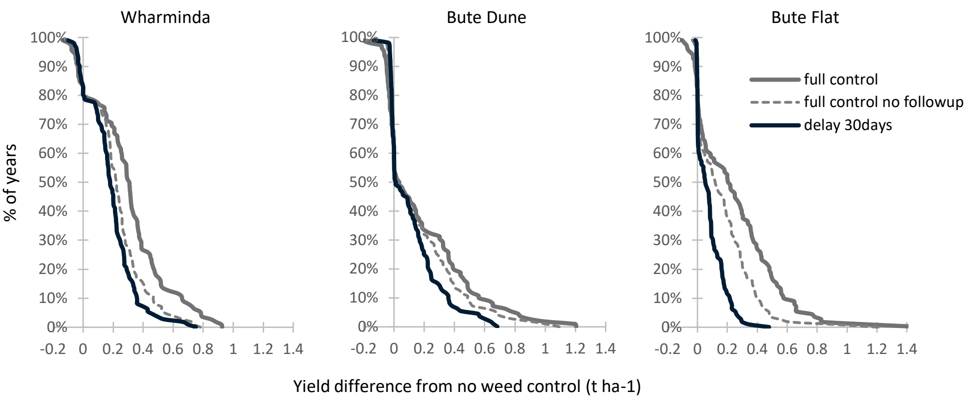

Figure 2. The yield increase (kg ha^{-1}) estimated using APSIM with the different starting soil water measurements for the treatments and 100 years of climate at Wharminda and Bute.

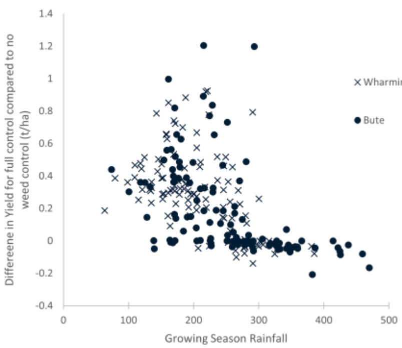

Figure 3. The growing season rainfall compared to the APSIM predicted yield increase (kg ha^{-1}) using the water content on 4th April 2022 from full weed control and no weed control with 100 season finishes at Wharminda and Bute.

APSIM modelling forms the basis for the $ummer weeds app. However in the simulations the weeds are grown to create the soil water difference, rather than using measured values (Fig 2) and only the years where weeds germinated are used to estimate the yield differences. An example of the output from the app is shown in Figure 4.

At Minnipa, with 50 deep rooted weeds that were controlled now or in 30 days, the main findings are: there are lower yield benefits in sandy compared to loam, which is due to the lower ability to store water in sands (Table 2). Delaying the weed control by 30 days reduced the yield benefit. When you use threshold values of 0.2 t ha-1 (similar to a break-even yield) this was achieved in 78-90% of years even if the weed control was delayed by 30 days.

The Nitrogen in the soil was similar for the two soils at Minnipa with an average 17-21 kg ha^{-1} left in the soil if weeds were managed now, which reduced to 9-10 kg ha^{-1} if weeds were managed in 30 days. A difference of at least 10 kg N ha^{-1}, assumed to be an amount potentially influential in nutrient management decisions, occurs less often when weed control is delayed (Table 2).

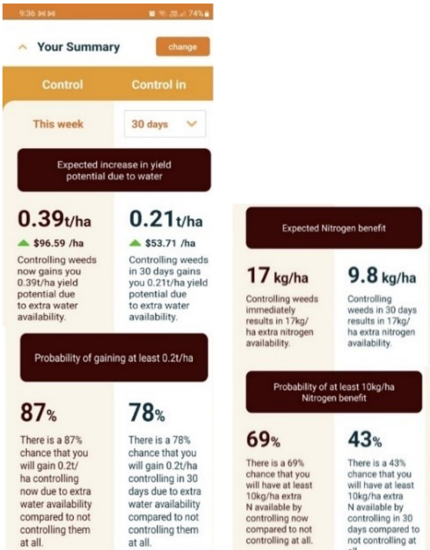

Figure 4. $ummer weed app output at Minnipa using a Sand for the Yield and nitrogen benefits

Table 2. Yield (t ha^{-1}) and Nitrogen (kg ha^{-1}) increases compared to no weed control and the probability of achieving yield and nitrogen targets.

	Weeds controlled	
	This week	30 days
Sand		
Yield increase (t ha^{-1})	0.39	0.21
Probability of gaining > 0.2 t ha^{-1}	87%	78%
Nitrogen increase (kg ha^{-1})	17	9.8
Probability of achieving > 10 kg ha^{-1} Nitrogen benefit	69%	43%
Loam		
Yield increase (t ha^{-1})	0.52	0.26
Probability of gaining > 0.2 t ha^{-1}	96%	90%
Nitrogen increase (kg ha^{-1})	21	8.6
Probability of achieving > 10 kg ha^{-1} Nitrogen benefit		

DISCUSSION

With the high summer rainfall at the Wharminda and Bute sites, there were large densities of weeds which if left uncontrolled used 17-20 mm of stored soil water. Whether this additional water also increased yield depended on the following GSR. GSR greater than 280 mm led to little yield benefit to stored soil water. There was a large range of likely yield increases, which highlights the risk of weed management when the GSR is unknown, and early season indicators may play a role in summer weed management.

The $ummer weed app can be used with other sites, weed types and densities in addition to those shown here and is designed to be readily applicable at the time of summer weed control decisions to inform expectations of yield benefits and likelihood of profitable yield benefit for different spray timings.

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