The Weed Seed Wizard: have we got a solution for you!

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Summary The Weed Seed Wizard is a computer simulation tool that uses farm-specific management inputs and site-specific weather to predict and monitor changes in weed seedbanks and estimate losses in grain yield caused by weed populations. The Wizard helps inform a farmer's choice of weed control practices to manage multiple weed species and possible herbicide resistance on their specific farm.

Decisions on what weed control practices to adopt are based on a combination of past experience, intuition, rules of thumb and available technologies. The Weed Seed Wizard is a scenario-exploring tool that is easy to use and provides farm consultants and farmers with the opportunity to explore the potential impacts of adopting various weed management strategies. It allows the user to test and verify existing rules of thumb and explore new ones, allowing the user to decide on the 'fit' of a new practice within their specific system and location.

Four attributes make the Weed Seed Wizard very valuable to farmers and farm consultants. These attributes are:

1. The generation of season- and location-specific predictions regarding the emergence of weeds from the weed seed bank and the consequences of different management actions, such as seed management at harvest.
2. The capacity to consider multiple weed species simultaneously for the same paddock, which is very important when considering long-term management options that affect different species in different ways.
3. A simple interface that facilitates the entry of individualised and farm specific scenarios and corresponding predictions. This allows users to test and develop their own rules of thumb, adding confidence to their decision-making process.
4. Economic analyses can be generated from the input and outputs to ensure that any management changes will be cost-effective in the longer term.

Keywords Integrated weed management, decision support tool, weed seed bank, planning.

INTRODUCTION

Weeds are a major constraint in Australian cropping systems. Spiralling herbicide resistance together with new and emerging weed species are forcing growers to rethink their weed control tactics. Growers can no longer rely on simple herbicide decisions but must integrate a range of weed control techniques into complicated farming systems where weed control is only one aspect of many interacting factors. For example, growers must choose rotations to manage their soils and their environment, control diseases and insects and also be profitable. It can therefore be difficult for growers to envisage a weed management strategy that will fit with their farms, especially where some integrated weed management tactics are perceived as too costly or just plain too hard.

The cropping industry in Australia needs to integrate new weed management technologies to be able to compete on the world market. The Weed Seed Wizard is a decision support tool designed to help growers understand and manage weed seedbanks specific to their farms (Renton *et al.* 2006). It can be used to explore new weed management strategies and help decide where a new practice fits into a specific system and location, leading to faster adoption.

The Weed Seed Wizard is able to simulate population dynamics of a range of weeds over a variety of integrated weed management strategies (Renton *et al*. 2008) and has been validated against data collected from trials across Australia. This paper will describe the features of the 'Wizard' and how it works. The paper will then discuss how it can be used in extension and be helpful in the decision making process.

THE MODEL

The Weed Seed Wizard is a computer simulation tool which runs as a stand-alone application with a graphical user interface (based on the Eclipse Rich Client Platform and written in Java™). There is an input interface with two 'windows' which allow the user to configure the model, set up the scenario and schedule management events and an output

window which presents the results of the simulated scenario.

Input The Wizard uses farm-specific information. The users input their paddock soil type, their local weather and the weed species specific to their farm into the first of the input windows (Setup Scenario Window). As the model simulates the dormancy and germinability of each weed species against soil moisture and temperature, major inputs that influence the predictions include weather characteristics such as rainfall, daily temperature and evaporation plus soil type (which provides information on soil water-holding capacity). The Wizard comes with a set of weather files (in CSV format) for each state. The user can choose the file for the site closest to their farm or set up their own from their weather stations or from weather providers. There is also a range of soil types (sand to clay) and a choice of weed species. In the southern states, weed species include annual ryegrass (*Lolium rigidum* Gaud.), barley grass (*Hordeum leporinum* Link.), wild radish (*Raphanus raphanistrum* L.), wild oat (*Avena fatua* L.), brome grass (*Bromus* spp.) and silver grass (*Vulpia* spp.). Northern weeds include liverseed grass (*Urochloa panicoides* P. Beauv.), barnyard grass (*Echinchloa colona* L. Link), bladder ketmia (*Hibiscus trionum* L.), fleabane (*Conyza bonariensis* L. Cronq.) and sowthistle (*Sonchus oleraceus* L.).

The users then put in their past management records or future plans into the second input window (Event Management Window). This window shows a sequence of management events for a specific paddock, where each event is expressed as a date and a description of the event. These are shown both as a list of events and pictorially as a type of event with a representative icon (for example, all sowing events are depicted with a red tractor pulling a seeding implement) sorted into a timeline across each year. The choice of events is very flexible to reflect the multitude of options growers have and how they can they integrate them into their crop management (Table 1).

Table 1. The management events within the Weed Seed Wizard and the choices available within each.

Event Type	Choices
Till Event	Tickle event, full inversion or full-cut or new tillage type, distribution of seeds within soil depths.
Sow Event	Type of crop, seeding rate and seeding implement
Spray Event	Specific or new herbicide, control percentage for each species, residual control percentage and half-life
Harvest Event	Numerous harvest seed management options (plus new), choice of percentage of seeds dropped and choice of simulated or to enter specific yield
Graze Event	Number of plants killed and percentage of seeds dropped after stock
Seed Rain	The percentage of seeds produced this season relative to the average season
Incorporation Event	Ability to adjust for stock trampling seed into soil
Plant Observation	Weed and crop counts
Seed Observation	Seed counts
Seed Reset	Reset weed numbers at any time

Output After the scenario has been simulated, there are three main sets of results (or outputs) to be viewed from the Simulation Window; the seedbank, plant numbers, and crop yields. These outputs show how the decision of crop choice, sowing date, seeding rate, tillage and grazing management, herbicide application and harvest option affects the weed seedbank numbers, the weed germination and density and ultimately, the crop yield.

Each weed species has different dormancy and germination characteristics. Some species have no dormancy, others have an after-ripening requirement but can germinate with the opening rains while others require specific environmental (light, temperature, etc.) cues for dormancy to be broken and germination to commence. Different management techniques, for example a tillage operation, can redistribute the seed and place it into an environment which is more (or less) conducive to germination and emergence. The Wizard portrays the number of seeds in the seedbank over time, where numbers increase each year with seed production and seedbank replenishment then decline due to germination and seed decay. The simulated plant numbers are shown to increase with every germination (following a breakdown in dormancy and an adequate rainfall event) and to decrease with each control event (for example an herbicide application or tillage event) until the plants are removed at harvest (Figure 1). By exploring a range of simulated scenarios, the user can easily see how weed and seed numbers can be affected, potentially over several seasons, by the choice of management strategy and the herbicide resistance status of each species.

The Wizard also estimates how much crop yield is reduced by weed competition, based on a hyperbolic

competition function (Firbank and Watkinson 1985) and provides a comparison with the potential harvest yield without weeds (Figure 2). The user can enter either the weed-free or weed-reduced yield, with the Wizard then calculating the other, or the Wizard can estimate both. This is an important tool for growers as they can easily see how weeds can affect crop yields and ultimately profitability by quickly assessing the disparity between the potential and modelled yields.

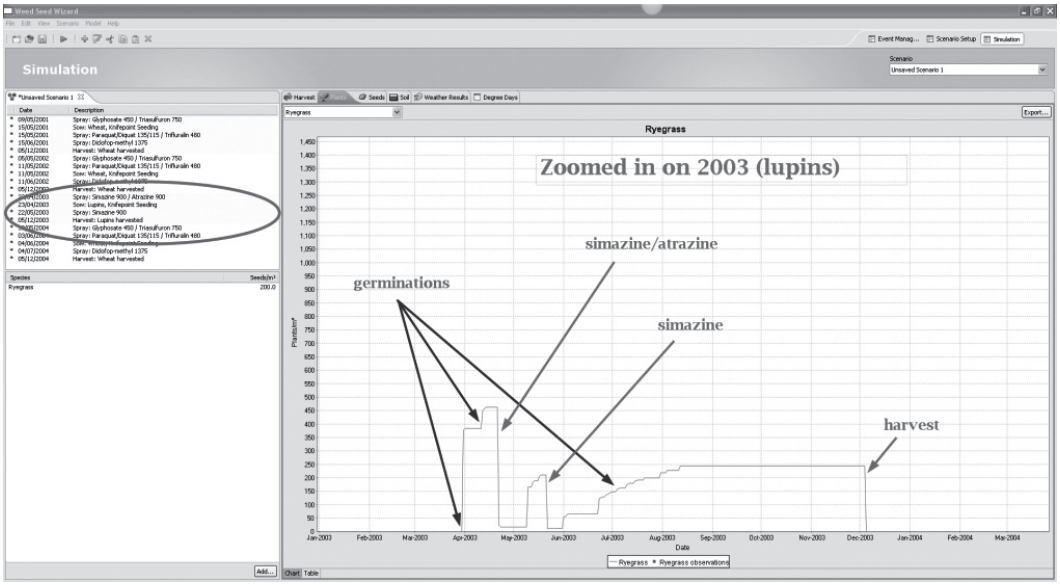

Figure 1. A screen shot (zoomed in) of the plant numbers (annual ryegrass) in Simulation Window where numbers increase with germination and decrease with herbicide application and harvest.

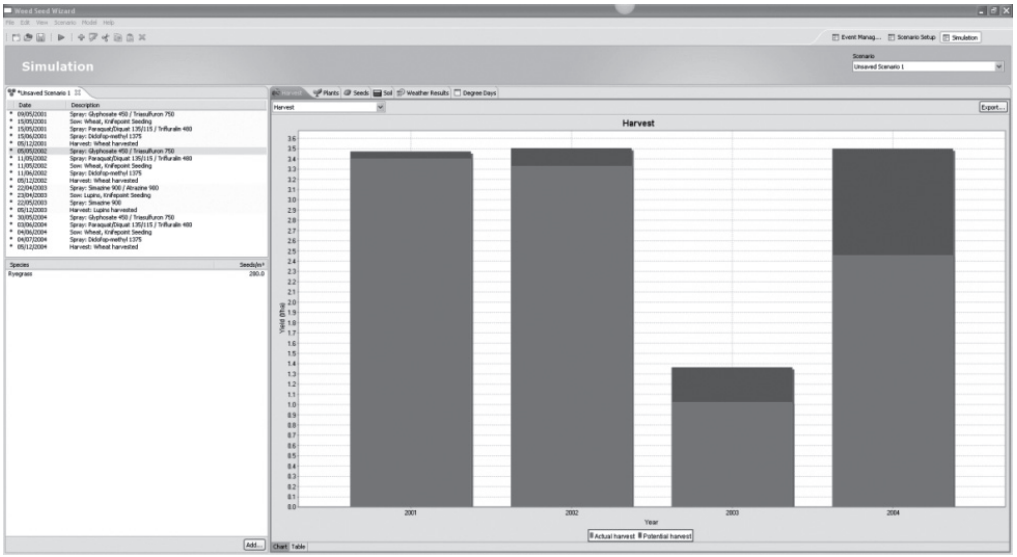

Figure 2. A screen shot of the harvest yields in the Simulation Window where a stacked bar graph depicts the 'actual' yields (grey) and the 'potential' yields (dark grey).

USING THE MODEL IN THE DECISION-MAKING PROCESS

'Long-term sustainable cropping needs a long-term sustainable weed control program' (Doug Smith, pers. comm.). Wise words, but weed control programs will differ between growers, who need to integrate a range of weed control methodologies into their unique systems and individual lifestyles. In order to do this, growers must make decisions on which methodology will fit with them and in some instances, adopt new technologies.

Computer-based tools can successfully support decision making but they must be flexible and relevant to the context of one's own farm (Brennan *et al.* 2007). The Weed Seed Wizard provides the perfect tool for growers to develop their own weed management program. It is location-specific and very flexible. It allows growers to input their own weather, their own weeds and their own management options, weighing alternatives and risks and investigating how new practices might perform on their farm. Its specificity allows growers 'ownership' to test and verify their existing rules of thumb and explore new ones.

According to Abadi Ghadim and Pannell (1999), there are two important aspects of adoption. One is the collection and evaluation of new information while the other is the application of the innovation to fit grower's own situation. The Weed Seed Wizard increases the awareness of a range of new technologies by including them in scenario building exercises. They can then be evaluated using simulations for the grower's own system, location and climate prior to a real on-farm trial.

Computer-based decision support tools, such as the Wizard, are not used extensively by the farming community (Muchow 2011). Social networks such as farmer groups and consultant/client relationships, however, can be effective ways to introduce these technologies and provide support (Brennan *et al.* 2007). The Wizard can be an excellent extension tool for consultants and agronomists to provide examples for their clients and to illustrate and reinforce extension messages. For example, the Wizard could be used to demonstrate how an increase in seeding rate could increase crop competition, what weed numbers are needed to make dry sowing feasible, or how to manage glyphosate resistance. The extension messages could be communicated *via* written material, presentations and video. Case studies based on a specific grower's weed management program can also be validated with the Wizard, using growers' experiences to teach other growers.

In conclusion, the Wizard, with its ease of use and specificity, can increase the rate of adoption of new technologies and ideas by allowing growers to scope out their effectiveness on the user's own farm, for very little investment and no risk. It has the potential to save growers both time and money in weed management decision making and become a standard tool for educators and consultants when considering the dynamics of farming systems.

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