

## Using the Weed Seed Wizard to Understand and Manage the Weed Seedbank

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### Abstract

The “Weed Seed Wizard” is a simulation model being developed to help co-ordinate weed management by focussing on the seedbank. The wizard uses paddock management records, weather records and simulation of important aspects of seed biology. It tracks and predicts the number, ages, soil depth, dormancy levels, viability and germination of seeds in the soil, and it predicts the number of weeds that will appear each year. Two versions of the model are being created; a relatively simple and user-friendly version for providing decision and management support via the web; and a ‘research’ version, incorporating more detailed representations of soil, seeds and biological processes, for integrating current understanding of the underlying seedbank dynamics and exploring these dynamics in more detail. In this paper, we explain the structure of the model and discuss how it can be used to simulate the effect of decisions regarding choice of crop, sowing date, seeding rate, tillage and grazing management and herbicide application on weed germination, weed density, crop yield and the long-term sustainability of the system.

### Key Words

weed control, seed ecology, simulation model, individual-based

### Introduction

If you think weeds are a problem, think again! The real problem is the weed seedbank hidden beneath your feet! Weeds are the symptom. They compete with crops and pastures to reduce yield, contaminate grain and maybe poison stock. But the seedbank is the disease. If you kill every last weed, your crop will look clean but the weeds will be back next year all the same. We need to take a long-term strategy for managing the seedbank: starving it of new recruits; exposing seeds to their natural enemies; burying them where they will eventually rot and die; and exploiting their dormancy mechanisms to trigger germination in conditions where weeds can be easily killed or will have little effect. Thus we slowly but surely strangle the seedbank to death.

To help move towards this long-term view of weed management, the “Weed Seed Wizard” project aims to construct computer simulations of weed seedbank dynamics for a variety of species. As a national project, with participants in Western Australia, South Australia, New South Wales and Queensland, it will target major in-crop annual weeds from each state. For the southern states, target weeds 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 sweet summer grass (*Brachiaria eruciformis* Sm. Griseb), liverseed grass (*Urochloa panicoides* P. Beauv.), barnyard grass (*Echinochloa colona* L. Link), native jute (*Corchorus trilocularis* L.), bladder ketmia (*Hibiscus trionum* L.), african turnip weed (*Rapistrum rugosum* L. All.) and sowthistle (*Sonchus oleraceus* L.). Different weed species persist in the soil (or seedbank) for different periods. Some species have little or no dormancy and germinate with the opening rains, completely depleting the seed bank. Other species with dormancy require specific environmental (light, moisture, temperature, accumulated degree days, etc) cues for dormancy to be broken and germination to commence. These species can persist for several years. The Wizard will be based on the vast collection of existing documented knowledge about each species, and will then be validated against further data collected from a number of trials in each of the participating states.

As seedbank dynamics and weed seed persistence is complicated and often hard to predict, one objective is to construct a practical decision-aid tool, incorporating current scientific knowledge, that can help farmers and consultants manage weed populations in real agricultural contexts. Eventually this tool will be self-calibrating (have the capacity to adjust its parameters in response to ongoing observation records to better predict weed populations in a particular paddock). Another objective is to build a modelling framework that can be used for more theoretical investigation of the complex mix of factors affecting the weed seedbank, and thus contribute to our understanding of seedbank dynamics. As part of the Sustainable Cropping Systems program within the CRC for Australian Weed Management, the “Weed Seed Wizard” project will contribute to developing crop and pasture systems for sustained productivity and profitability through these objectives.

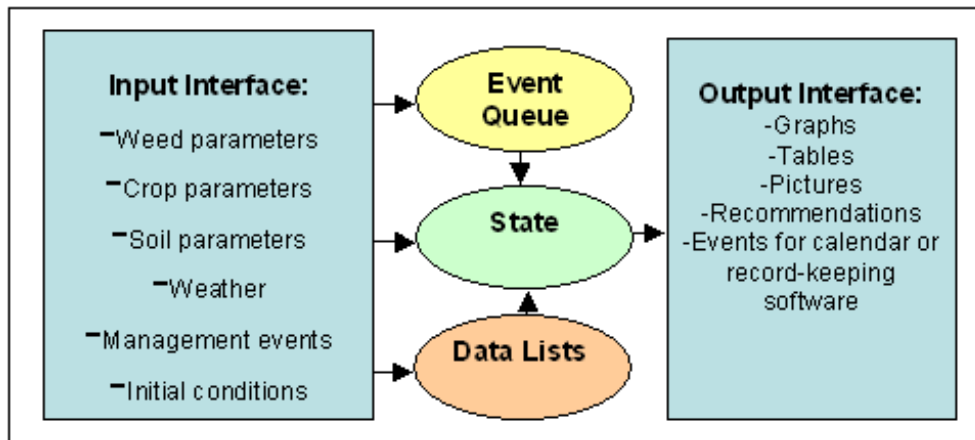
## The Model

The Weed Seed Wizard will take into account conservation tillage systems (including No-Till and Zero-Till) combined with strategic use of a range of other techniques, such as soil inversion, autumn tickle, crop competition, selective and nonselective herbicides, crop topping, swathing, seed catching, and burning or grazing for stubble management. It will also incorporate recent advances in understanding of the factors that affect germination and death of weed seeds, in order to predict the amount of weeds appearing each year. We envisage that the Wizard will operate as an adjunct to paddock record-keeping software, using farmer records concerning paddock management decisions, the site, and other observations. Such records might include crop sown, sowing date, seeding rate, tillage and grazing management, herbicide application, crop yield, weed density, rainfall etc. Eventually the Wizard might be part of a farm management system that integrates farmer record keeping with simulations of biological and physical processes including weed populations, soil water and nutrition, insect pests and diseases.

A prototype of “The Wizard” has been designed and implemented in the Java programming language. The model includes representations of the soil, the daily weather, the plant population, and the individual seeds within the soil. It simulates the moisture and temperature within the soil; the dormancy, after-ripening and germination of the seeds; the effects of competition between different plant species on seed set; and the effects of management actions on plants and seeds. A prototype graphical user interface (GUI) has been designed for the tool, which can run as a stand-alone application, or within a browser window. The GUI includes windows where the user can adjust the initial conditions of the simulated field; add, delete or edit scheduled management actions; and view the simulated output regarding the states of the soil seedbank, plant populations, crop yield etc. Standard data formats have been designed for required data on herbicides, plant species, types of cultivation and management scheduling. Routines have been implemented to read this data into the model.

## Model Structure and Capabilities

The “Weed Seed Wizard” is being built in an ‘object-oriented’ web-friendly programming language (Java) that enables different objects within the natural system to be described clearly as separate ‘objects’ or modules within the program. This facilitates adaptation of the model for different purposes and users. The primary objects in the model (Figure 1) are an **input interface** allowing the user to configure the model, set up the initial state of the system and schedule management events; an **event queue** including all events that affect the system; **data lists** including all required model parameters; a representation of the changing **state** of the system; and an **output interface** for presenting the output of the model.



**Figure 1. The overall modular structure of the Weed Seed Wizard.**

### *Input Interface*

The input interface consists of graphical user interfaces (GUIs) containing buttons, editable text fields, sliders and drop-down lists (Figure 2). If the Wizard is being used as an applet within a browser, the primary input GUI appears as an applet within a webpage and secondary GUIs appear as ‘pop-up’ windows that can be opened or closed as required. Using these GUIs, the user can configure the model, set up the initial state of the system and schedule management events. In configuring the model, the user will have options such as changing the time step used by the model, or deciding whether to download historical weather data, to simulate typical weather data, or to enter their own recorded data. They will also be able to decide whether to simply use existing data files specifying model parameters regarding weed and crop species, herbicides, soil types and cultivation events, or to modify these data files to match their own conditions and observations. Setting up the initial state of the system will involve making estimates of the type, number, and depth of weed seeds in the seedbank at some initial time. This estimation of initial conditions can be made more accurate by simulating several historical years using recorded weather data and management schedules. The user also specifies a schedule of management events before running the model, either by adapting an existing default schedule, by constructing their own, or (eventually) by downloading a record of historical and planned management actions from paddock record-keeping software. The user can explore possibilities by entering a range of different management strategies and comparing their predicted results. It is envisaged that eventually the Wizard will also be able to suggest ‘optimal’ strategies for controlling weeds for a given initial state of the weed seedbank.

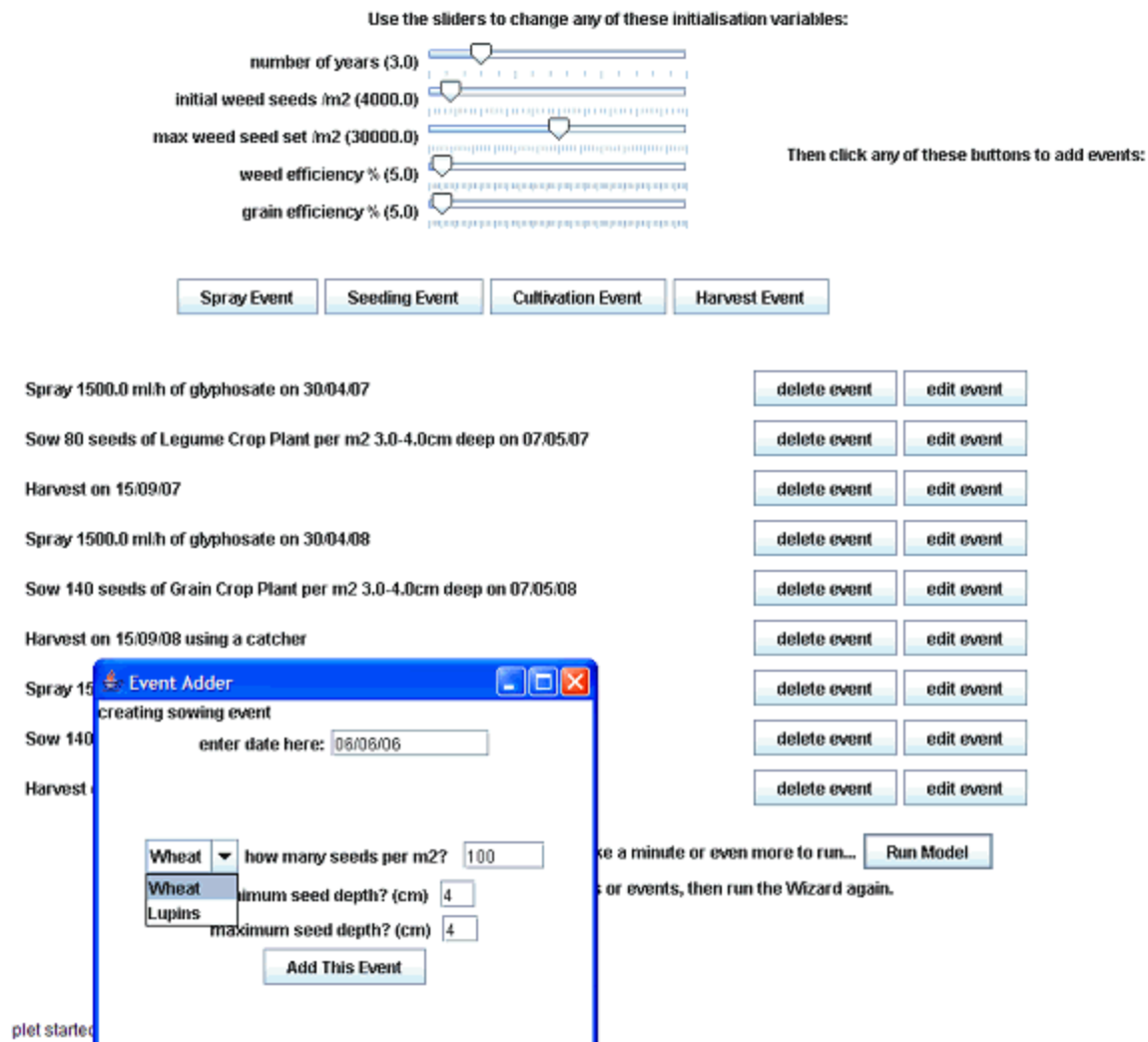


Figure 2. Screen shot of the primary input interface GUI applet with sliders to configure the model and specify its initial state; a list of scheduled events; and buttons to add, edit and delete events and run the simulation (background) and another GUI pop-up window for adding a sowing event to the schedule (foreground).

### Event Queue

The simulation runs by using an event queue. This is a list of events ordered according to their scheduled date and time. This structure allows new events to be easily inserted into the queue as required, by the user or automatically by the program itself, in response to the results of previous events and the evolving state of the system. The queue includes ‘occasional events’ entered by the user, such as herbicide application, cultivation etc; simulated occasional events, such as rainfall events, plant germination and death, and seed rain; as well as regular state updates and record keeping.

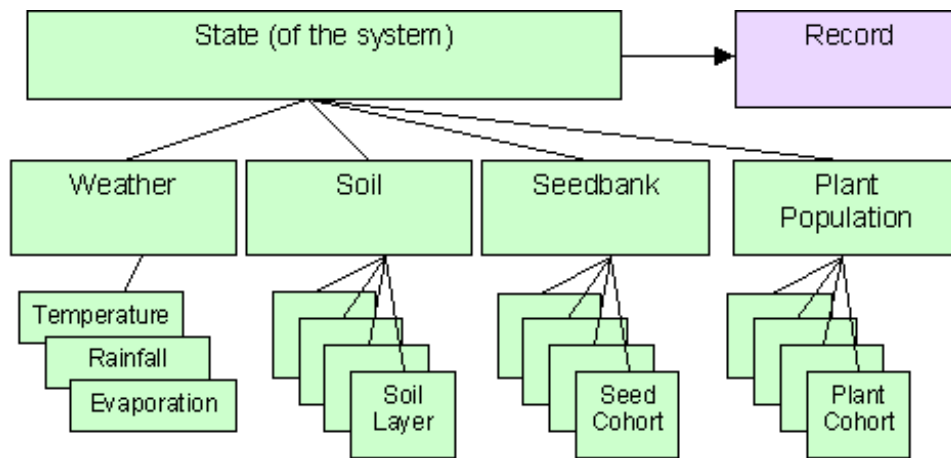
### Data Lists

The simulation depends on a large number of parameters. These parameter values are read from standardised *xml files* by *parsers* in the initiation phase of running the program to create equivalent data list structures that can be used by the program. These include a herbicide list, a plant species list, a cultivation and seeding options list, and soil layer list. There is also a default list of management events.

The user can modify characteristics of an item in a data list, or add new items (such as new weed species, or new herbicides). The standardised structure of the xml files facilitates communication with other software and databases. The parameter values are being drawn from literature, laboratory experiments and ongoing field trials across the country.

### State

The state object is the heart of the Wizard (Figure 3). After the user has used the input interface to set up the initial state, the event queue and the data lists, the events in the event queue are applied to the state one after the other using the parameters specified in the data lists to simulate the dynamics of the system. The state object includes sub-objects representing the **environment** (conditions such as rainfall and temperature), the **soil** (consisting of a number of **layers**), the **seedbank** (consisting of individual **seed cohorts**), the **plant population** (consisting of individual **plant cohorts**), and a **record** of important aspects of the evolving state of the system. After the user has used the input interface to set up the initial state, the event queue and the data lists, the state is iteratively modified by the events in the event queue according to the parameters specified in the data lists. Each object within the system 'knows' certain data (a seed cohort knows its species, age, dormancy, germination status, moisture content, accumulated degree days, and position within the soil) and communicates at least some of that data with other objects (seed germination depends on temperature and moisture level in the relevant soil layer).



**Figure 3. The Weed Seed Wizard's modular representation of the dynamic state of the agronomic system. The record is used to produce the output for the user.**

### Output Interface

The model outputs a series of graphs displaying the information stored in the record, including seedbank levels, weed populations and crop yields over time. In future, we will add the capacity to output results in tabular form, and possibly also as pictures indicating the predicted weed densities, or as a list of recommended actions for the user.

### Conclusion

The Weed Seed Wizard will integrate current knowledge of weed biology and the effects of management techniques to simulate and predict annual weed populations. It will allow us to explore how the dormancy, germination requirements, competitiveness, and herbicide resistance of different weed species or populations can affect the dynamics of the system, and thus the choice of an appropriate management strategy. Through incorporating the effects of herbicides and a range of other strategic options, the Wizard will help us design a truly integrated weed management system. By giving deeper insight into the how different factors interact to determine weed seedbank levels and helping farmers manage weeds

within their paddocks, the Wizard will contribute to building the sustainability of Australian crop and pasture systems.

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