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Application note

# A web-based expert system for advising on herbicide use in Great Britain

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**Abstract**

A web-based system was developed to advise on the relative efficacy of different herbicides for mixes of weed and crop species at different times of the year in a forestry or farm forestry setting. The system assumes that weed identification and impact assessment or prediction have already been accomplished and that there are no cost-effective non-chemical alternatives. The expert system produces a relative suitability index for each herbicide, as well as an English language discussion of the case.


*Keywords:* Expert system; Knowledge base; Decision support system; Herbicide

## 1. Introduction

Control of competing vegetation around young trees is essential for successful tree establishment on the majority of plantations in Great Britain, with plantations on ex-agricultural lands facing distinctive problems. Weeds are categorized into grasses and/or herbaceous weeds, and woody weeds, with bracken, heather, gorse, broom and rhododendron being special cases. In most situations, several different methods of achieving effective weed control exist, including mulching, cultivation, and hoeing/screefing and herbicides. Good working practice, as reflected in the UK Woodland Assurance Certification Standard (UKWAS, 2000), calls upon managers to consider the practicality of using non-chemical alternatives. However, in some instances no practical non-chemical alternative is currently available,

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and even when one does exist, it is usually considerably more expensive than the chemical option. Hence, the use of herbicides remains the most common method of weed control in forestry in the UK. Canada has fewer herbicides registered for forestry use, so more emphasis is placed on comparing herbicides with other options (Campbell, 1991).

Once a decision is made to use herbicides, managers must also give careful thought to selecting the most appropriate herbicide formulation and application technology. In addition to maximising the potential benefit of reducing weed competition with planted or regenerated trees, the optimal choice helps reduce the total quantity of herbicide applied and, hence, reduces the risk of adverse environmental impacts. In the UK, Forestry Commission manuals (Willoughby and Clay, 1996, 1999; Willoughby and Dewar, 1995; Willoughby and Palmer, 1997) can be used to assist in the decision-making process. A decision on whether a herbicide is appropriate in a particular case requires cross-checking a number of elements. As each site in a management area might represent a unique case, with different combinations of weeds and crop species, this could entail considerable effort. When used in conjunction with the printed publications, which remain the official basis of all decisions, expert systems can help to shorten and refine the decision-making process by guiding users more quickly to the most appropriate options. A preferred option is one that can control all weeds, or at least the principal weed, at the desired time, while harming none of the crop trees, or causing only a negligible amount of damage.

A herbicide use decision includes assessing an existing problem or predicting a potential problem (for pre-emergence treatments); diagnosing and identifying causal agents; examining attributes of possible non-chemical and chemical control methods; determining the appropriate control method based upon efficacy, cost and potential risks to operators and the environment; determining the appropriate formulation; identifying the most suitable method for applying the method; and assessing treatment results. When weeds have been identified and requirement for a herbicide is determined, Thomson and Williamson (1992) demonstrated the technical feasibility of developing an expert system for advising on herbicide use, based upon the earlier Forestry Commission publication by Williamson and Lane (1989). The system ranked potential herbicides, based upon their efficacy, for use in a particular case defined by a combination of weed and crop species as well as time of year of application.

The original system was based on floppy disk technology. The rationale and user knowledge requirements for the system have not changed. However, it is now possible to deliver and maintain expert systems operationally over the World Wide Web (Thomson et al., 1998). In addition, changes in herbicide availability and pesticides regulation have required substantially altered and updated written guidance on herbicide use to be issued (Willoughby and Dewar, 1995). Changes include specific herbicides for farm forestry (new woodland creation on fertile former agricultural land) situations, use of tank mixes of herbicides, and specific recommendations for herbaceous weeds, which were previously treated as a group. In the present study, we describe extension of the earlier expert system for compliance with current herbicide guidelines, and deployment of the system on the World Wide Web (http://www.pfc.cfs.nrcan.gc.ca/management/herbicide/index_e.html).

## 2. The knowledge base

Herbicide properties include name, crop tolerance, timing, and valid uses (forestry, farm forestry, pre-emergence, post-emergence), and are listed in a prolog (Amzi! prolog, Lebanon, OH 45036) knowledge base, processed by a prolog-based inference engine (Thomson and Williamson, 1992).

Weed susceptibility (ease of control by a particular herbicide) is more complex now than in the previous system, requiring separate consideration of pre-emergence and post-emergence susceptibility in both forestry and farm forestry settings. In the earlier system, only susceptibility of grasses was specified. The original herbicide manual treated all herbaceous weeds as equally susceptible. Now susceptibility data is available for each herbaceous weed.

## 3. The rule base

The rule base is similar to that described in Thomson and Williamson (1992), with two significant additions: advice on tank mixes and herbicide rankings. At the time the earlier system was developed, regulations did not permit tank mixes of herbicides in forestry settings. However, in farm forestry settings, only weeds of the Grass–Herbaceous category are significant, as other weed types are rarely present in the first 5 years of plantation establishment represented by this situation, and tank mixes of herbicides are permitted and are often necessary where a single herbicide is not effective against all weeds present. If a herbicide can control the principal weed, but not all the other weeds present, advice is now provided on availability of other herbicides that could be used to control the missed weeds. Rules for ranking herbicides evaluate the suitability of each herbicide with respect to degree of weed control and appropriate timing.

## 4. The web-based user interface

On the opening screen, the user selects either the forestry or farm forestry setting, then, if in the forestry setting, selects the category of the principal weed and its stage of development (Fig. 1). For example, if the category selected is ‘Grass–Herbaceous’ or ‘Other Woody Weeds’, a list of candidate species is presented. Subsequent screens depend on user entries. For example, if the principal weed is in the Grass–Herbaceous category, the next screen would be ‘Other Grass–Herbaceous weeds’ followed by ‘Woody weed species’. After specifying the weed complex, the user then specifies the crop. First the category (conifer or broadleaf) of the principal crop is identified, and then a select-list is used to indicate the species. Finally, the presence of other conifer or broadleaf species and the timing of the herbicide application are specified by the user. When the case definition is complete, the expert system then advises on herbicide suitability for that case (Fig. 2, Table 1).

In migrating the system to the World Wide Web, we ensured that changes in the knowledge base were automatically included in the user interface by writing the user interface

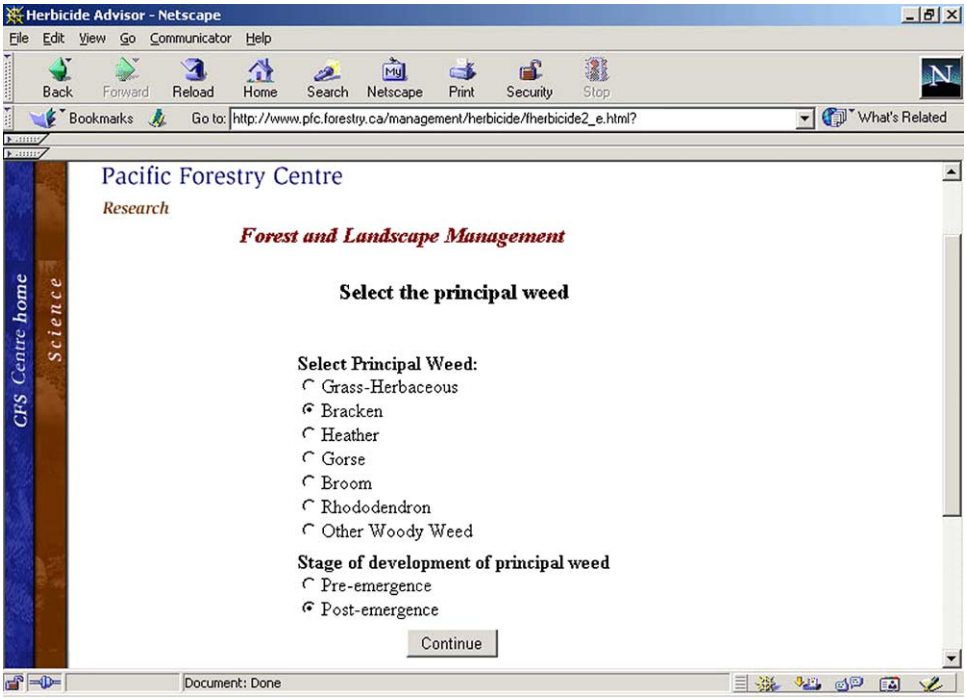


Fig. 1. Category selection (by radio button) for the principal weed, and specification of its stage of development.

in PERL. The PERL program can read the knowledge base files, which are simple ASCII files. For example, the knowledge base includes a code (grass/herbaceous or woody weed), scientific name and common name of each weed species:

common_name(gh12, 'Festuca rubra', 'Red fescue').
common_name(gh13, 'Holcus lanatus', 'Yorkshire fog').
common_name(ww2, 'Alnus glutinosa', 'Alder').

To construct an HTML select-list of grass/herbicide species, PERL code reads each record of the knowledge base dropping each record that does not have a gh code, and then wraps the common name in the appropriate HTML tags before printing it out:

< optionvalue = Red%20fescue > Redfescue < /option >

The main feature of this design is that a common file is used as the basis of both the interface and the reasoning system. The file format is dictated by the prolog format for facts and rules, while the text-processing power of PERL facilitates the parsing of this file into entities that can be embedded in the HTML code written by the PERL script. As new information is added, or if information is changed, the interface adapts automatically.

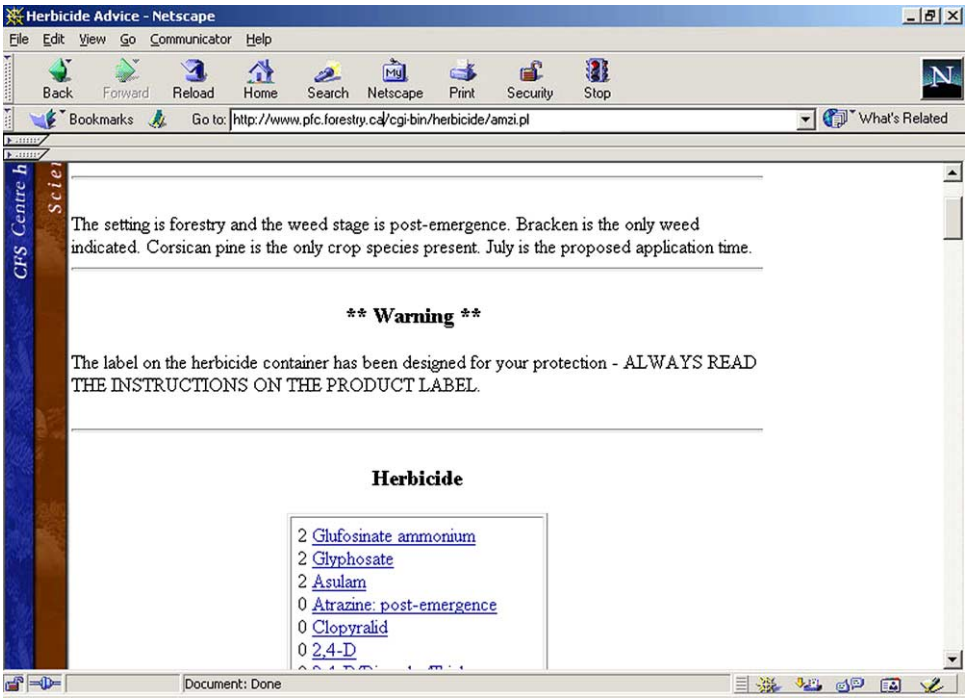


Fig. 2. The results of a hypothetical case. By scrolling down the page, the explanation of the rating system, and the results for each herbicide, can be viewed.

Table 1
System output for Asulam in the hypothetical situation illustrated in Fig. 2

Asulam: suitability=2

*Reference*
Field Book 8 page 98
Crop tree tolerance is dependant on rate applied. Growth stage of target weed species and rate used affect weed susceptibility—refer to manuals and product labels for essential additional information.

*Weed control*
Asulam can control all the weeds specified.

*Timing of application*
The proposed month is optimal for control of these weeds by this herbicide. Herbicide applied at this time may be too late to lessen adverse effects of weed competition in the current year.

*Crop tolerance*
All crop trees are tolerant of application of Asulam at the proposed time.

*Constraints*
Use of Asulam requires the bracken to be left at least 14 days after treatment before cutting or ploughing, and is less effective if the weeds are under frost or drought stress, or if senescence has commenced. Heavy rainfall within 24 h of application may reduce the effectiveness. Do not apply within 10 m of watercourses or 20 m of lakes or reservoirs. Do not contaminate ponds, watercourses or ditches with the chemical or the used container. *Always read and comply with the conditions of use on the product label.*

## 5. Discussion

Web pages created by an expert system provide a very powerful tool, particularly for inexperienced practitioners and those unfamiliar with the subject of the system. When used in conjunction with official manuals, they can help refine the search for solutions and reduce the amount of time needed when referring to the text.

There are some potential disadvantages to web-based expert systems. While potentially producing quicker results than conventional text manuals, there is a danger that expert systems, in producing automated results, could possibly take away an element of self-learning and cognition. Manuals provide a reference source which enables users to come to reasoned professional judgments on the suitability of pesticides in specific local situations or conditions that it may not be practical to anticipate in an expert system. Therefore, expert systems may be of most utility when viewed as a powerful aid to decision-making, rather than as a complete replacement for text manuals and product labels. In addition, given current technology, text manuals are probably easier to use in the field, and skilled practitioners will find information quicker with the manuals than if they relied on expert systems back at the office. However, recent trials using Personal Digital Assistants linked remotely to the Internet indicate that expert systems may soon be readily accessible in the field.

Programming expertise and resources need to be available to support the updating of information in the expert system in the light of new data and recommendations from researchers, lest it become rapidly out of date (although printed manuals suffer from similar problems, and are more difficult to update). Institutional issues can be significant, such as when the domain expert and knowledge engineer reside in different institutions, as in the present circumstances. In this case, a formal agreement regarding server, maintenance, and other issues was required before the system could be deployed.

The system described in this paper has so far only addressed the choice of a herbicide based upon crop tolerance for overall sprays and weed susceptibility in the month chosen for application. Other aspects of an integrated approach to vegetation management, for example, assessing and predicting impact of the perceived weed problem, considering non-chemical alternatives, determining suitable herbicides based upon cost and environmental risk, crop tolerance for directed applications, most suitable time for operations, most appropriate method and level of application, and assessment of results, are all amenable to expert system delivery in the future (Thomson, 1992).

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