HGCA

PROJECT REPORT No. 12

DEVELOPMENT OF A PROPTOTYPE EXPERT SYSTEM FOR CEREAL CROP PROTECTION

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FREE

HOME-GROWN CEREALS AUTHORITY

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Development of a Prototype Expert System for Cereal Crop Protection

by

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Final Report of a six month project commencing April 1988 which was carried out at the Silwood Centre for Pest Management. The project was funded with a grant of £14,988 from the Home-Grown Cereals Authority (Project No 0101/1/87).

Report on a Home Grown Cereals Authority funded project to develop a prototype knowledge-based system for cereal crop protection.

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Objectives:

1. To develop a prototype knowledge-based (expert) system for a specific cereal insect pest - wheat bulb fly.
2. To obtain information that will allow an assessment of the feasibility and practical value of an overall knowledge-based system for cereal crop protection.

Project summary.

Knowledge-based systems are tools, usually computer-based, for helping to solve problems and give advice. They are advocated and used in a number of disciplines, including medical diagnosis and treatment, agriculture and pest management. After a period of six months funding a prototype knowledge-based system for cereal crop protection has been constructed. The initial menu leads the user to information and advice on *Septoria*, mildew, rusts, eye-spot, frit fly, yellow cereal fly and cereal aphids as vectors of *BYDV* in the autumn or as direct pests in the summer (Figure 1). These are all based on current ADAS recommendations, as available in leaflets. Within this context there is a wheat bulb fly option which is at a much more detailed level. As well as providing both strategic and tactical advice for wheat bulb fly management, the system also provides to differing degrees of complexity and rigour, comparative costings of the various treatments recommended, ecological and biological information, a guide-line to recognizing the symptoms of various insect pests, information on cultural practices, and general recommendations for the safe use of insecticides.

This report describes the prototype knowledge-based system for wheat bulb fly and considers the feasibility and practical value of further development of this, and other, modules in an overall knowledge-based system for cereal crop protection.

Wheat bulb fly.

The wheat bulb fly is the most serious and regularly occurring insect pest of winter wheat in the eastern counties of Britain. Approximately 33% of the total wheat area in the East Anglian region alone is theoretically at risk from wheat bulb fly attack. Of that total area at risk, Ministry of Agriculture records indicate that, annually, a varying proportion of between 2% (13,000 ha)

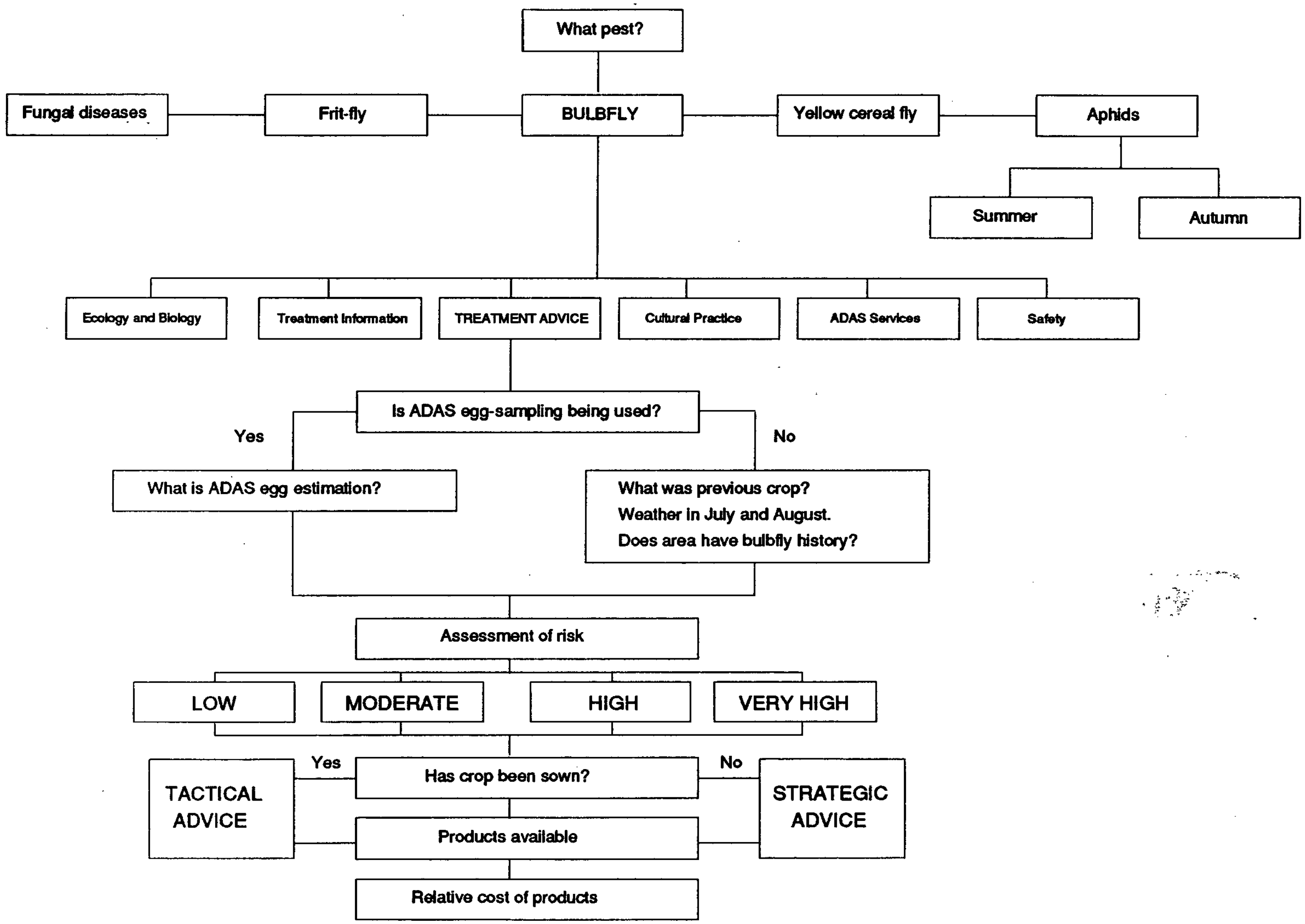

Figure 1. Schematic representation of prototype knowledge-based system for cereal crop protection. The option for wheat bulb fly management is considered at a more detailed level (see text for further details).

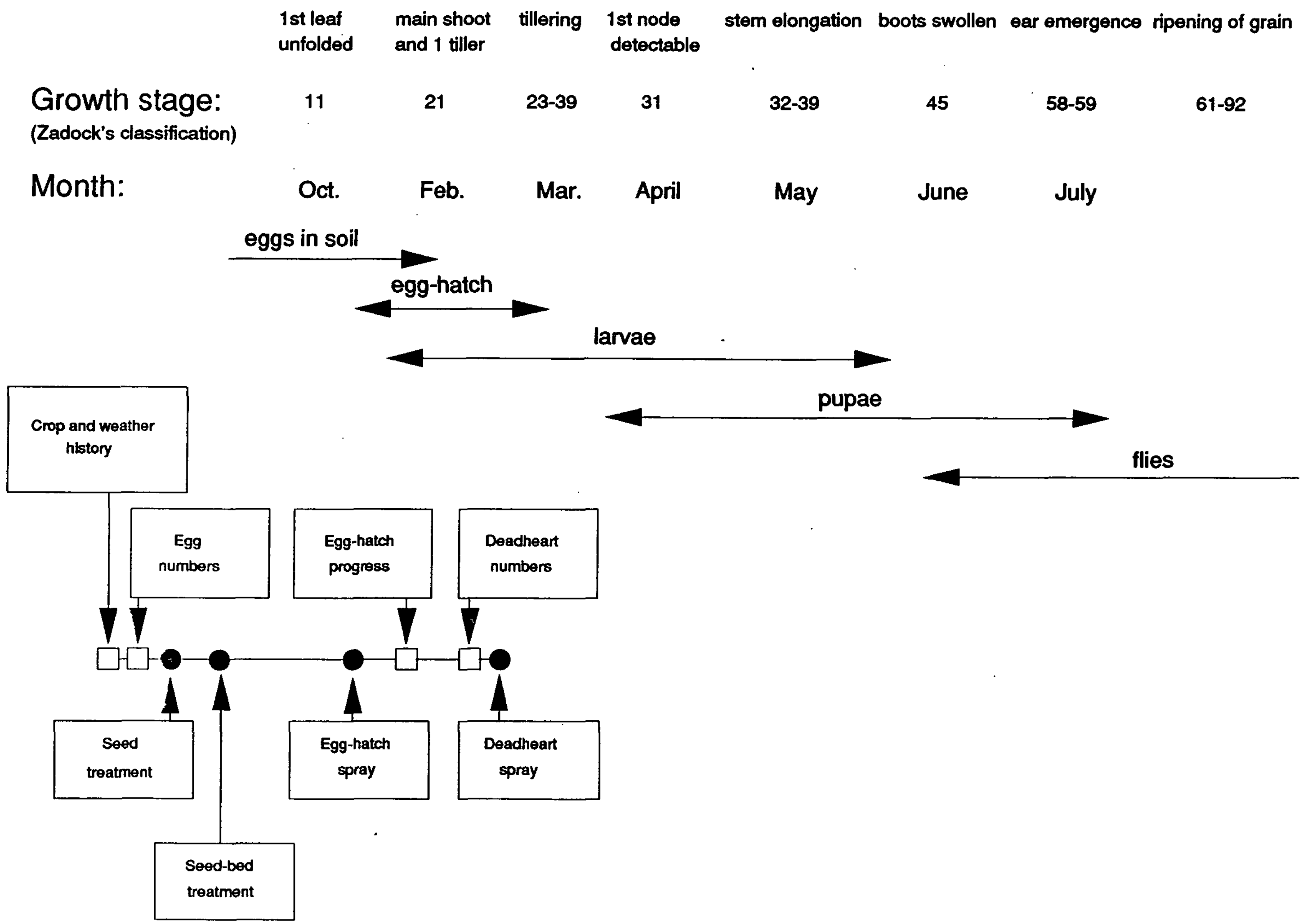

Figure 2. Decision timetable for wheat bulb fly management.

and 17% (127,000 ha) of East Anglian winter wheat is estimated to be potentially subject to economic damage. The insecticides that are currently employed to control this pest can be applied as seed treatments, seed-bed treatments with sprays or granules applied at sowing, and sprays at egg-hatch or at the first signs of plant damage. No single treatment will give full control of wheat bulb fly damage. Combinations of two or more of these treatments are normally applied when there is a risk of attack causing economic damage.

Construction of the knowledge-based system.

The basic steps involved in the construction of any knowledge-based system are:-

i. determining and describing the logical structure of the decision problem,
ii. collating and interpreting the knowledge base, in the form of facts and rules and
iii. encoding this information in computer (knowledge-based system) software.

Structure of the decision problem:

A decision timetable (Figure 1) was constructed to determine what factors are important in arriving at a recommendation. The processes involved in this decision recommendation are given in Figure 2.

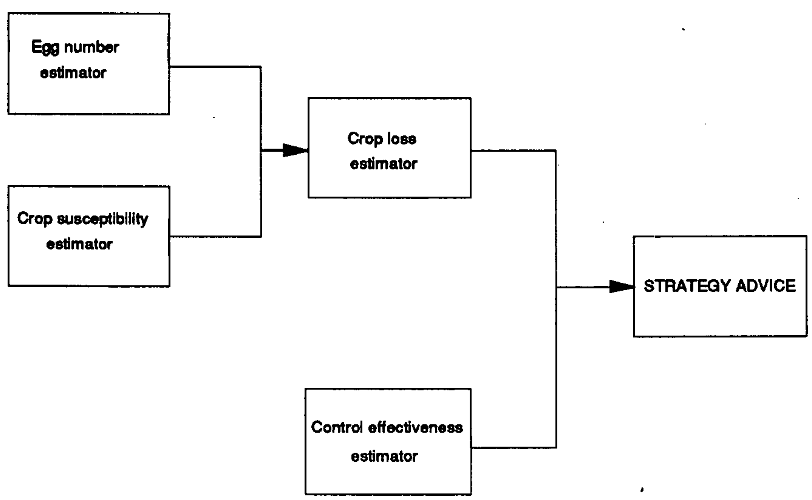

Figure 3. Diagrammatic representation of the processes involved in arriving at a treatment recommendation for the control of wheat bulb fly.

The knowledge base:

The knowledge base for the system, in the form of rules and facts, was obtained from the literature, ADAS trials' reports and the expert opinion and knowledge of ADAS entomologist J.E.B.Young (ADAS, Cambridge).

Crop loss estimator:

The estimator of crop loss involves the assessment of two interacting factors - the level of wheat bulb fly attack and the susceptibility of the crop (Figure 2).

Egg number estimator:

The level of wheat bulb fly attack is best assessed by the number of eggs laid. Egg counts show considerable variation between fields and districts; they are more reliable when applied to individual fields. ADAS offers a sampling service to farmers that provides an egg count for individual fields. This quantitative assessment of risk enables the most appropriate control strategy and level of expenditure on insecticides to be advised for the site in question.

Not all farms have ADAS sampling information, in which case other factors have to be used to determine the likelihood and level of wheat bulb fly attack. Differences in the scale of attack, as measured by oviposition of the wheat bulb fly, can often be linked with previous crop, soil condition and weather conditions during the oviposition period. Damage chiefly occurs in winter wheat following low standing or open canopy crops and in fields where cultivation exposes the soil to oviposition. For example, a cereal crop that follows an onion crop is known to be at a very high risk from wheat bulb fly attack. The weather during oviposition may also affect the number of eggs laid, fewer eggs being laid when the weather is cool and wet. Finally, the geographical location of the crop also has a bearing on the likelihood and severity of attack. Although the wheat bulb fly is a widespread problem in eastern England, the distribution tends to be characterised by widely scattered and localised "hot-spot" areas which harbour large populations of the pest.

Crop susceptibility/tolerance estimator:

The date of sowing has an important effect on the risk to the crop from wheat bulb fly infestation. Crops sown before the end of October can withstand heavy infestations as the plants have normally produced two or more tillers by the time of larval invasion. Shallow sowing also encourages early establishment of the crop prior to attack and improves the efficacy of insecticide seed treatment. Damage to spring-sown wheat can be avoided by sowing from late March onwards, after the egg hatching period.

Control effectiveness estimator:

The effectiveness of various treatments has been considered by numerous workers. Summarised, the effectiveness of the treatments are as follows:

Seed treatment: In certain conditions may be very effective but in high risk situations seed treatments are not the sole means of chemical control and tend to be supplemented by other treatments.

Seed-bed treatment: Very effective. Granular treatments have been tested as seed-bed treatments applied at the time of sowing and incorporated into the top 5cm of soil. Fonofos granules are consistently effective in organic and mineral soils. Because of their relatively high cost, fonofos granules are, however, reserved for use in fields where there is a known high risk of attack. Sprays of chlorfenvinphos, chlorpyrifos and fonofos can also be applied at, or soon after, sowing. Trials have shown these seed-bed sprays to be generally less effective than fonofos granules.

Egg-hatch spray: Applied immediately before or during the early stage of egg-hatch, protective sprays compare favourably with seed treatments. If a cold period is experienced after spraying, the treatment's persistence may be lost and its effectiveness lowered.

Deadheart spray: Timing is of the utmost importance. First instar larvae are the ideal target organisms, second instars move from one shoot to another, third instars are very difficult to kill. In general, deadheart sprays give a 50 - 60% kill rate. Deadheart sprays are often applied as an emergency measure or to supplement earlier treatments which have not given adequate control of a severe attack.

Strategy advice.

Based on the information available the estimated risk to a crop from wheat bulb fly attack may be categorised into one of four levels. When egg number data is available, risk is determined on the basis of four egg number thresholds identified from ADAS literature. In other situations, as already discussed, the interaction of many factors are used to determine the estimated level of crop damage. The estimated risk to crops from wheat bulb fly attack is classified into one of four categories, low, moderate, high and very high. The control strategies currently employed at these varying levels of risk are summarised in Table 1.

By basing control recommendations on egg counts the most appropriate and cost-effective combination of control measures can be recommended. For example, multiple treatments have been shown to be cost effective only in situations where severe bulb fly damage is expected.

Table 1. Control strategies for wheat bulb fly employed at varying levels of risk.

Level	Action
Low	Preventative chemical treatments are not recommended.
Moderate	Some damage likely on late sown crops. Avoid deep drilling and use seed-treatments on crops sown after mid-October.
High	Economic damage is very likely. Use egg-hatch sprays or seed-bed treatments. For late drilling on organic soils use a seed treatment followed by at least one well-timed deadheart spray.
Very High	Some damage is inevitable. Increase seed rate. Multiple chemical treatments recommended; use granules at drilling plus egg-hatch or deadheart sprays.

For all categories it is recommended that an emergency or follow-up deadheart spray treatment may have to be applied at the first signs of plant damage.

Tactical advice.

As well as providing strategic advice the system also provides tactical, present-time advice for wheat bulb fly management. This latter advice may vary with the treatment already applied and on the accurate monitoring of both egg hatch and larval invasion.

The treatment recommendations at egg hatch vary depending on the timing of egg hatch. Chlorfenvinphos and fonofos are the more persistent treatments and can be applied before, or after, egg hatch. Pirimiphos methyl and chlorpyrifos application are less persistent and should be applied later, nearer to peak egg hatch.

As wheat bulb fly larvae start to invade the crop, plant samples are removed and dissected to estimate the level of attack before the deadheart symptoms become visible. An estimate of crop density is also used at this stage. The damage thresholds for deadheart sprays are based upon percentage shoot attack and vary according to growth stage of the crop and density of plant population. By this method a deadheart spray warning is issued, the timing of which is known to be critical.

Poor soil conditions can often delay the application of egg-hatch sprays and in some seasons when egg-hatch is prolonged by cold weather, physical damage can occur well before the completion of egg-hatch. In such difficult situations a tank-mix of an egg-hatch spray such as chlorpyrifos in combination with the systemic dimethoate may be applied. This technique however is a compromise as neither ingredient of the mixture is being applied at the optimal time.

A diagrammatic description of how the system deals with both strategic and tactical advice is shown in Figure 3. For illustrative purposes, a consultation in December in an area at high risk from wheat bulb fly is considered.

Encoding:

CRYSTAL (Copyright 1986 Intelligent Environments Ltd.), a commercial software package, or shell, was used to encode the wheat bulb fly knowledge-based system. The use of a commercial shell allowed the main focus of the project to be on the acquisition of knowledge and the construction of the system, rather than detailed computer programming.

Future Development.

In investigating the feasibility of developing further modules to be included in the system eyespot treatment recommendations were considered. By making a more detailed investigation of a disease problem it was hoped that this would not only illustrate the differences in comparisons to insect pests but would also show how the system would deal with factors such as crop variety and fungicide resistance. Although only explored at a very superficial level similar advantages in approaching decision-making from this angle were found as for the wheat bulb fly.

One of the main advantages of developing a knowledge-based system is that areas of knowledge that require further research effort are identified. This is particularly true during the knowledge acquisition process. For example, a lack of detailed information on the yield effects of the various wheat bulb fly risk categories, and the importance of wheat variety, specifically their tillering capacity, in restricting or compensating for the level of wheat bulb fly attack, has left major information gaps in the decision making process. Thus, developing such systems allows an assessment of research priorities based on their practical contribution to pest management.

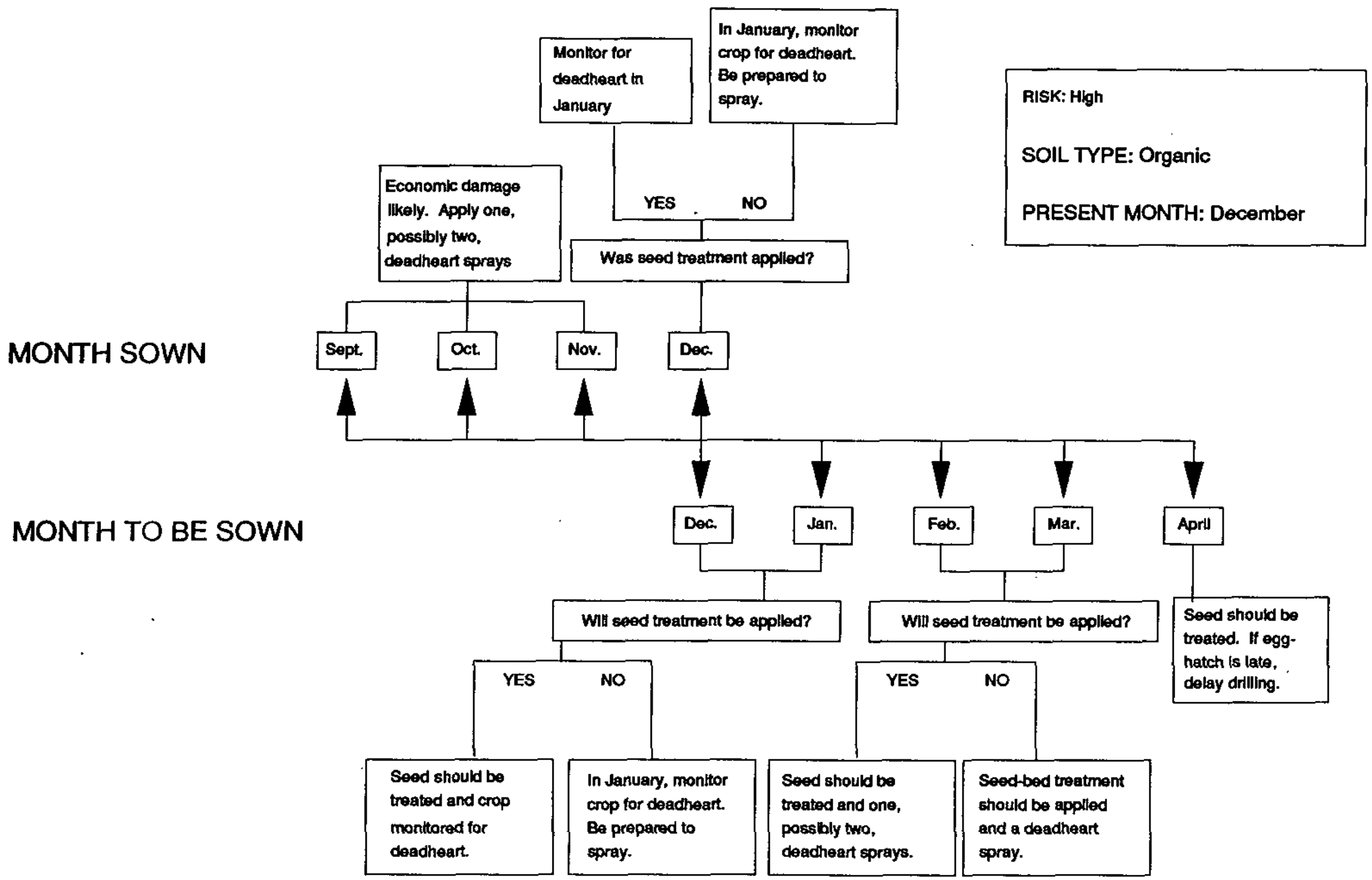

Figure 4. Diagrammatic representation of the decision-making process for a December consultation in an area at high risk from wheat bulb fly attack.

Management strategies for wheat bulb fly control are, at present, available from various advisory services (*e.g.* crop consultants, ADAS entomologists). Advice is consequently concentrated, and frequently expensive, and potential users of the advice must trade-off the costs and the benefits of the advice from that source. Making a knowledge-based system available allows the advice to be more freely available and thus increases the dissemination of the knowledge.

Future development of the wheat bulb fly (and any other module) system requires the thorough testing of the system by its developers and, more importantly, the validation of the system by potential users to ensure that the expertise it provides is both appropriate and acceptable. The ultimate test for any such system is its ability to improve current decision making procedure. It is hoped that the potential usefulness of the system to cereal growers will be investigated, in association with ADAS, in the near future.

Further information regarding the development of this, and other, modules in an overall knowledge-based system for cereal crop protection can be obtained from **Dr G A Norton, Director, Silwood Centre for Pest Management, Imperial College at Silwood Park, Ascot, Berks. SL5 7PY (Tel.: Ascot (0990) 23911).**