New Zealand Institute for Crop & Food Research Limited
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CROP & FOOD RESEARCH
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Crop & Food Research Confidential Report No. 306

A crop management decision support system for asparagus growers—final report TBG project APG801

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November 2000

A report prepared for the
New Zealand Asparagus Council

Copy 2 of 11

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Contents

1 Executive summary

A project was conducted between October 1998 and September 2000 to develop a decision support system (DSS) that asparagus growers could use to help make management decisions that would improve the performance of their crops. All objectives described in the original proposal were achieved successfully, and the project has concluded with the implementation of an interactive DSS, named ***AspireNZ***, which is available to growers via the Internet (www.crop.cri.nz/psp/aspirenz/index.htm). Development of the DSS was accompanied by a crop monitoring programme that involved growers in each of the main asparagus production regions in New Zealand. Information from the monitoring programme was incorporated in the DSS, and the direct involvement of growers helped to establish the system's credibility when it was completed. As a result, about 20% of New Zealand's 150 asparagus growers have subscribed to the system and have been using it since the harvest season started in September 2000. The number of users is increasing steadily, and the level of uptake is expected to be much higher next year. Access to ***AspireNZ*** is restricted to New Zealand growers for the first three years. However, the system has good potential for international application, and opportunities to develop it further for use in asparagus production regions that do not compete with the New Zealand industry are being explored. A paper describing ***AspireNZ*** is appended to this report. It was presented at the 2000 conference of the Agronomy Society of New Zealand where it received the best paper award. It has been accepted for publication in the next volume of *Agronomy New Zealand*.

2 Introduction

This TBG project was proposed in 1998 to capitalise on the outputs from crop physiology research on asparagus funded by the Public Good Science Fund and the New Zealand Asparagus Council (NZAC) by packaging and facilitating the transfer of the new technology. The objective was to develop and implement a DSS that asparagus growers could use to help make management decisions that would improve the production of their crops.

The project was based on the proposition that better management of the crop's storage root system is the key to increasing asparagus production substantially. Traditional practices have emphasised management of above-ground growth, aiming to ensure healthy, vigorous fern growth and, therefore, high spear yield. However, recent research had demonstrated clearly the importance of managing the root system to enhance the short and long term performance of the asparagus crop. Spear yield and quality both depend on

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the availability of resources, especially soluble carbohydrate (CHO) in the storage roots during harvest.

Although better root system management promised improved crop performance, the problems for growers were that there was (a) no suitable method for measuring CHO content in roots of crops and (b) no information about how to interpret CHO content results for making crop management decisions to improve yield. This project used the results from recent research to solve both problems. A protocol was developed that growers can use to sample their crops and obtain quick, reliable measurements of the CHO content in the root system at any time of the year. Also, an interactive, user-friendly DSS was developed that they can use with the CHO results to obtain management recommendations that will help to optimise crop performance. The system was tested and validated using results from monitoring of commercial asparagus crops that was done with the help of collaborating growers.

3 Project team

The project was operated by Crop & Food Research (CFR) and managed by a team consisting of CFR and NZAC representatives:

CFR: Derek Wilson (Project Leader); Chris Cloughley (DSS Development); Sarah Sinton (Crop Monitoring and DSS Administration); Alistair Clough (Business Manager).

NZAC: Lesley McKeown (Project Manager); Philip Schofield (Technical Advice); Peter Falloon (Technical Advice); Executive Officer (Administration); 12 Asparagus Growers (Crop Monitoring).

4 Achievement of objectives

The project consisted of three objectives which were achieved as follows.

4.1 Objective 1: Develop and test the DSS

Milestone 1: A draft version of the DSS was developed during the first four months of the project. This consisted of two parts which together constitute the intellectual property of the system. In the first part we used knowledge derived from previous research to produce a set of rules and logic based on the principles that fluctuations in root CHO content are large, predictable and very responsive to above-ground management of the crop, and that it is necessary to balance the accumulation and depletion of root resources, both within a season and between seasons. In the second part we put considerable effort into beginning to develop innovative software for the new system, including capability to make it available to growers through an

Internet website and a database to store information about growers' crops. This work continued throughout the project.

Milestone 2: The draft DSS and preliminary results from the crop monitoring part of the project (see Objective 2 below) were presented to a group of asparagus industry representatives at a workshop held at the Vegfed offices in Wellington in March 1999. The industry group consisted of the three NZAC members of the project team, the NZAC Executive Officer, and four leading growers who were invited to participate. The project was received very positively by the industry representatives. They approved the content and principles of the system, provided valuable feedback to the CFR project team, and endorsed future plans for the project.

Milestone 3: Following the workshop, considerable effort went into refining the DSS through further logic and software development, in preparation for launching it to the industry at the NZAC Research Seminar.

Milestone 4: The preliminary version of the DSS was launched to the industry at the NZAC Research Seminar in May 1999. It was given the name ***AspireNZ***. It was received enthusiastically by about 70 participants and attracted substantial publicity. Even though it was still incomplete, there was strong interest in implementing the system as soon as possible. At that stage enquiries about access to the system had already been received from asparagus growers in other countries.

Milestone 5: Results from the crop monitoring part of the project (see Objective 2 below) were used to test and, where necessary, improve the system. Little change was needed, because the data confirmed that the information obtained previously from experimental crops, especially regarding the patterns of root CHO content and their relationship with above-ground growth, also applied to the commercial crops. Each grower was given detailed feedback on the results from his crop and a summary of the information was included in the presentation at the NZAC Research Seminar in May 1999.

Milestone 6: Development and testing of the system's rules and logic were largely completed on time by September 1999, although minor improvements continued until the end of the project. Development of the software continued until the end of the project. The system was sufficiently advanced that it was ready for testing with a group of leading growers during the 1999-2000 season (see Objective 3).

4.2 *Objective 2: Develop protocol and monitor crops to validate DSS forecasts and recommendations*

Milestones 1 and 2: These were completed in the first month of the project. Procedures were developed for monitoring key features of the above- and below-ground growth of commercial crops during the season. Three crops were located in each of the four regions (Waikato, Hawke's Bay, Manawatu and Canterbury), the growers were contacted, and all agreed to be involved in the project.

Milestone 3: The protocol was used to monitor the 12 crops from October 1998 to June 1999. Each crop was visited six times to collect root and fern samples for CHO and biomass measurements. All crops were sampled by members of the CFR project team on the first occasion, and the collaborating growers were briefed fully about the project and what was required of them. During harvest, spear yields were measured daily by the growers and data were provided to CFR. The growers assisted regional CFR staff who visited the crops for subsequent measurements.

Milestone 4: During the period from June to September 1999, the results obtained from the crop monitoring were used to check and refine the rules and logic in the DSS (Objective 1, Milestone 5).

4.3 *Objective 3: Implement the DSS and link to growers through website*

Milestone 1: Five leading growers were approached and accepted invitations to trial the DSS interactively during the 1999-2000 season. We interacted with them throughout the season, from October 1999 to May 2000, to show them how to collect data from their crops, and teach them how to use ***AspireNZ*** and take advantage of it. The growers monitored crop performance during harvest and returned the data for analysis. Each crop was visited regularly to collect root samples for CHO content measurements and to measure fern growth. Throughout the season the growers responded to regular contact so that the performance of their crops could be assessed, and the performance of the DSS checked and refined. All the growers were visited in February, and the results from their crops were reviewed in relation to the DSS. All were enthusiastic about the system and indicated that they intend to use it on a commercial basis when the TBG project has finished. The continual interaction with growers during its development helped to establish the system's credibility with growers when it was completed.

Milestone 2: Plans for this milestone ("Display the completed DSS and demonstrate its performance at the NZAC Research Seminar in May 2000") were revised because a research seminar was not held in 2000. Instead we described the performance of ***AspireNZ*** in presentations at the AGMs of the Growers' Associations in the five main asparagus production regions of the country in May. Also, we demonstrated the system to the project team at a meeting at Palmerston North in March. At that meeting, progress on the project was reviewed in detail, and plans for commercialising ***AspireNZ*** were discussed. In all cases the system was well received.

Milestone 3: Development of ***AspireNZ*** was complete by September 2000. By that time the system had been operating successfully on our computers at CFR for several months. However, software problems occurred with New Zealand's getting it to operate reliably on the Internet, and these still have not been resolved completely. Despite the problems, about 20% of NZ's 150 asparagus growers have subscribed to the system and have been using it since the harvest season started in September. Completion of this final report was delayed while (a) the software problems were investigated and (b) until the Project Leader returned from an overseas trip.

5 Project outputs

There were two main tangible outputs from the project. One is ***AspireNZ*** which is available to growers as an interactive application via the Internet (www.crop.cri.nz/psp/aspirenz/index.htm). It includes substantial documentation about the system and its capability which is not reproduced in this report. The other output is a paper describing the system which was presented at the 2000 conference of the Agronomy Society of New Zealand where it received the best paper award. It has been accepted for publication in the next volume of *Agronomy New Zealand*, and is appended to this report.

6 Commercial development

As agreed at the start of the project, ***AspireNZ*** is owned jointly by CFR and the NZAC, and is operated by CFR. Terms of the operating agreement are:

- Only registered subscribers can gain access to ***AspireNZ***.
- For the first three years, registration is restricted to New Zealand growers who are members of the NZAC. The three-year moratorium applies to results of all research funded by the NZAC.
- There is a one-off registration charge of $100 per user. This covers set-up costs.
- Registered subscribers may register as many crops as they wish with ***AspireNZ***. There is a charge of $50 per registered crop per season. This fee entitles unlimited access to the system for that crop during the season, and covers the costs of operating and maintaining the system.
- CFR retains the first $10k of revenue per annum to cover system operating costs.
- Revenue above $10k is shared equally between CFR and NZAC with an agreement that each partner will invest it in research that will benefit the asparagus industry.
- The fees were set to encourage maximum participation by New Zealand growers.

Marketing of the system started in May 2000, even though it was still not completed at that stage, and growers started registering for its first season of operation. So far about 30 growers (20% of New Zealand's growers) have subscribed, and the number is increasing steadily. This figure is good considering the problems we have had getting the system going reliably on the Internet, and we expect the level of uptake to be much higher next year when all the software problems have been resolved. The NZAC has indicated that it is very satisfied with ***AspireNZ***, and is encouraging New Zealand growers to use it. The system will be used as a tool in further research projects supported by the NZAC.

The system has good potential for international application. Publicity during the project attracted interest from asparagus producers in other countries. Development is restricted by the NZAC policy of applying a moratorium to the results of all research funded by the Council for three years. However, AspireNZ could generate significant revenue for the NZAC and CFR. Higher subscription charges could be set for overseas users who have not contributed to the system's development costs. Therefore, in the meantime, opportunities to develop the system for use in asparagus production regions that do not compete with the New Zealand industry are being explored.

Appendix

Paper presented at the 2000 conference of the Agronomy Society of New Zealand

AspireNZ: A Crop Management Decision Support System for Asparagus Growers

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Abstract

Asparagus is a perennial vegetable crop with a large storage root system. Above-ground growth during the crop's annual cycle is associated with cycles of accumulation and depletion of soluble carbohydrate (CHO) in the roots. This paper describes *AspireNZ* which is a decision support system that has been developed to help asparagus growers achieve high yields through better management of root CHO. *AspireNZ* does not make decisions for growers - it interprets information about their crops and suggests options to help them reach the best decisions. This paper describes the three main elements of the system: (a) a simple method that growers can use to assess the CHO status of their crops' root systems, (b) knowledge about how to interpret the information and use it to help make management decisions, and (c) a system on the Internet to deliver the knowledge interactively. Other features of *AspireNZ* include a database which retains information about each crop registered with it. The information can be retrieved at any time so that growers can retrospectively evaluate the effects on crop performance of previous management decisions. In the future, similar systems could be developed for other crops, and they could become primary sources of information for growers about each crop.

Introduction

Asparagus (*Asparagus officinalis* L.) is a perennial vegetable crop with an annual growth cycle that includes a sequence of depletion and accumulation of soluble carbohydrate (CHO) in a large storage root system (Shelton and Lacy, 1980; Robb, 1984; Haynes, 1987; Pressman et al., 1993; Drost, 1997). The general features of this cycle are well known. However, asparagus growers have seldom known the CHO status of the root system during the annual cycle or, if they did, how to interpret such information. Therefore, traditionally the focus of crop management practices has been on above-ground growth, assuming that production of healthy, vigorous fern will lead to high spear yield and quality in the following season.

Our studies of the growth cycle of asparagus (Cloughley et al., 1999; Wilson et al., 1999) have highlighted the crucial role of the root system in determining crop performance, both in the current year and in the long term. To achieve sustainable high production from a crop, management of the root system, and of the balance between above-ground and root growth, needs to ensure that there is a high level of CHO in the roots to drive spear production each spring.

In this paper we describe *AspireNZ*. It is a new interactive decision support system which we have developed to help asparagus growers achieve high yields through better management of root CHO during the annual growth cycle. After outlining the key features of the annual cycle, we describe the three elements resulting from our research that have made the system feasible:

- a simple, reliable method that growers can use to assess the CHO status of their crops' root systems,
- knowledge about how to interpret the information and use it to help make management decisions,
- a system on the Internet to deliver the knowledge interactively.

Asparagus Growth Cycle

The order and timing of events in the annual growth cycle depend on the climate and crop management system. In temperate climates like ours, there are usually three phases in each cycle:

- a dormant phase during winter when the soil temperature is low,
- a spring-summer spear harvest period during which spear growth starts and increases as soil temperature increases, and
- a summer-autumn phase when the spears are allowed to grow and form a fern canopy which senesces when the crop enters dormancy again.

This sequence includes characteristic patterns of above-ground growth and of depletion and accumulation of CHO in the root system (Figure 1). Stored CHO is usually at maximum during dormancy, it is depleted during spear growth and fern establishment, and it is then replenished before winter by assimilate production by the established fern canopy. Crops are most likely to produce high yields if they follow these patterns consistently. *AspireNZ* operates on the principle that knowledge of these patterns during each season, and especially deviations from them, can be used to help make crop management decisions. The status of a crop can be evaluated at any time, but there are six key times when evaluations are highly recommended (Figure 1):

- *Dormancy (1).* At the end of winter, before spear growth starts. This assesses how full of CHO the root system is and indicates whether the potential size and duration of the spear harvest are likely to be more or less than normal.
- *Close-up.* In late spring-early summer, at the end of spear harvest when the crop is closed up to allow fern growth to start. This assesses the extent of CHO depletion during harvest, and whether fern establishment could be restricted. The latter would indicate a need for extra agronomic inputs to stimulate fern establishment. Additional CHO evaluations before close-up can be used to help decide whether harvest duration should be reduced or could be extended if root CHO is lower or higher than normal respectively.
- *Fern established.* In mid-summer, about a month after close-up, when the fern canopy is fully established. This assesses the maximum depletion of root CHO content, before recharge starts.
- *Fern growth (1)* and *Fern growth (2).* In late summer and autumn, at successive intervals of about a month after full fern establishment. These assess the level of CHO recharge which is vital for potential spear yield the following season. Lower recharge than normal could result from poor fern growth caused by factors such as water deficit or stemphylium (a foliar disease), and may require additional agronomic inputs. Low recharge could also be caused by excessive fern growth.
- *Dormancy (2).* At the end of autumn, when ferns have senesced. This assesses whether the CHO content of the root system is fully replenished, and indicates the potential for spear production in the following spring.

Measuring Root CHO Status

There have been many studies of the CHO changes that occur in asparagus during the annual cycle, and the CHO physiology of the crop was reviewed recently by Drost (1997). Most CHO in the root system consists of fructans. These storage CHOs are synthesised from simple sugars (sucrose, glucose and fructose) that are produced from photosynthesis in the ferns and translocated to the roots. They accumulate in the roots, and then are hydrolysed when they are required for spear growth or fern establishment.

Measurement of root CHO content by growers for use in *AspireNZ* is based on results from our research (Wilson et al., 1999). We have used the anthrone method (Allen, 1989; see description in Wilson et al., 1999) to measure total root CHO content in commercial and experimental crops over

several seasons in the main asparagus production regions of New Zealand. About 400 samples have been analysed, with CHO contents ranging from about 150 to 600 mg/g (i.e. 15 to 60%). It would not be feasible to use the anthrone method for large numbers of routine CHO analyses, so we tested a simpler, more practicable method. The Brix% of solution extracted from the same 400 root samples was measured with a refractometer. Statistical analyses showed that there was a strong correlation between the two sets of data (R = 0.91). Therefore, we concluded that Brix% can be used with confidence as a surrogate for analytical measurement of CHO content.

There is considerable variation among plants within an asparagus crop. We determined statistically that Brix% values are needed from a minimum of 20 root samples collected randomly from a crop to obtain a reliable estimate of its mean CHO content. Therefore, *AspireNZ* requires users to provide at least 20 values from a crop on each assessment occasion.

Interpreting CHO Information

Knowledge about how to interpret root CHO content was developed from the large number of measurements we have made in experimental and commercial crops, and associated measurements of crop performance (spear yield, fern growth and root biomass). Root CHO content values are evaluated taking account of the age of a crop and the stage of its annual cycle. The system identifies and quantifies deviations from the ideal crop condition by comparing the data with built-in performance benchmarks. Deviations usually indicate or foreshadow a potential problem. It then provides comments about the condition of the crop, suggests possible causes of deviations, and recommends management options to optimise crop performance. *AspireNZ* contains a library of responses and uses logic to extract the one that is appropriate for each set of circumstances. The responses do not make decisions for growers - they provide information and suggest options to help them reach decisions.

Interactive Knowledge Delivery via the Internet

AspireNZ is on the Crop & Food Research website (www.crop.cri.nz/psp/aspirenz/index.htm). The homepage has an index of general information that can be viewed in the public section of the system (Figure 2). However, the interactive section is only available to those who have registered as users and have been provided with a Username and Password to gain access. These ensure that each user=s information is secure, and not accessible to anyone else. At this stage, registration is restricted to members of the New Zealand Asparagus Council. New subscribers may register on-line or by mail. Registered subscribers may register as many crops as they wish with the system, and they may add new crops at any time. The system provides detailed instructions about how to sample root systems and measure Brix% correctly.

When a user has logged in to an interactive session, *AspireNZ* requires a sequence of responses. These include a crop identifier, age of the crop, stage of the annual cycle and the corresponding Brix% values. A minimum of 20 values is required, and it will accept a maximum of 40. These data are evaluated statistically to determine whether a reliable estimate of mean root CHO content can be obtained. If variability is high, measurements that are more than two standard deviations from the mean are omitted and the data are re-evaluated. If variability is still high, a warning message appears advising that a reliable estimate of root CHO content cannot be made and recommends that more root samples should be obtained and Brix% measurements made.

The system then estimates the mean root CHO content and displays the result along with the associated comments and recommendations. An example output page is shown in Figure 3. The CHO content value is stored automatically in the database for the crop (see below).

Other Features of *AspireNZ*

Apart from its CHO evaluation capability, the other main feature of the system is its database of all registered users and of the crops registered by each user. This retains all information for future reference, including historical information provided when the crop was registered. In this way a progressive record is accumulated of the performance of a crop, and it can be used retrospectively to evaluate the consequences of past management decisions. An optional feature of the database is a crop diary facility which subscribers can use to record any information about each registered crop. Information can be retrieved from the database at any time in text, graph or table form.

We envisage that, in the future, *AspireNZ* could become a central source of information about asparagus for growers. For example, the New Zealand Asparagus Manual could be available on-line through the system. This would allow easy and rapid updating as new information becomes available. Links could be provided to other sources of information about asparagus, perhaps including to websites with information about products such as agrichemicals used in asparagus production.

There is also scope for technical improvements to improve the value of the system. Currently, the evaluation of crop condition is restricted to root CHO content. Root mass is not considered, although mass is the other main determinant of the total amount of stored CHO, and it would be a better indicator of crop performance (Haynes, 1987; Drost; 1997). The two main components of root mass per unit area are plant population and mean root mass per plant. We have already identified loss of plants as a primary cause of declining crop performance. A new core sampling technique is showing promise for estimating root mass per plant (Drost, pers. comm.) and, in the future, could be used together with CHO content data to assess crop condition.

Conclusions

This paper is not primarily about asparagus agronomy. It is mainly about a novel system to achieve effective technology transfer by putting interpreted knowledge derived from agronomic research into the hands of end-users in a form that they can use readily. Asparagus happens to be the Aguinea pig@ crop for which we chose to develop the first system. We intend that it will be the forerunner of similar systems for other crops. In the future, these systems could be the primary sources of knowledge about each crop. In addition to their unique interactive, interpretative and database capabilities, they could contain libraries of information and have links to other relevant information sources on the Internet. The latter could include links to commercial product databases, so that growers could readily access information about products needed to manage each crop.

Acknowledgements

AspireNZ was developed by Crop & Food Research in association with the New Zealand Asparagus Council (NZAC). Funding was provided by the NZAC and Technology New Zealand. We thank other members of the project team: Justine Lee and Dean Patfield (Internet development); Justine Polkinghorne (Website design); Charles Wright (CHO chemistry); Lesley McKeown, Peter Falloon and Phillip Schofield (NZAC representatives). Thanks also Dr Dan Drost of Utah State University, USA for valuable discussions and to the ten growers in NZ=s asparagus production regions who participated in the crop monitoring programme.

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Wilson, D.R., Sinton, S.M. and Wright, C.E. 1999. Influence of time of spear harvest on root system resources during the annual growth cycle of asparagus. *Acta Horticulturae 479,* 313-319.

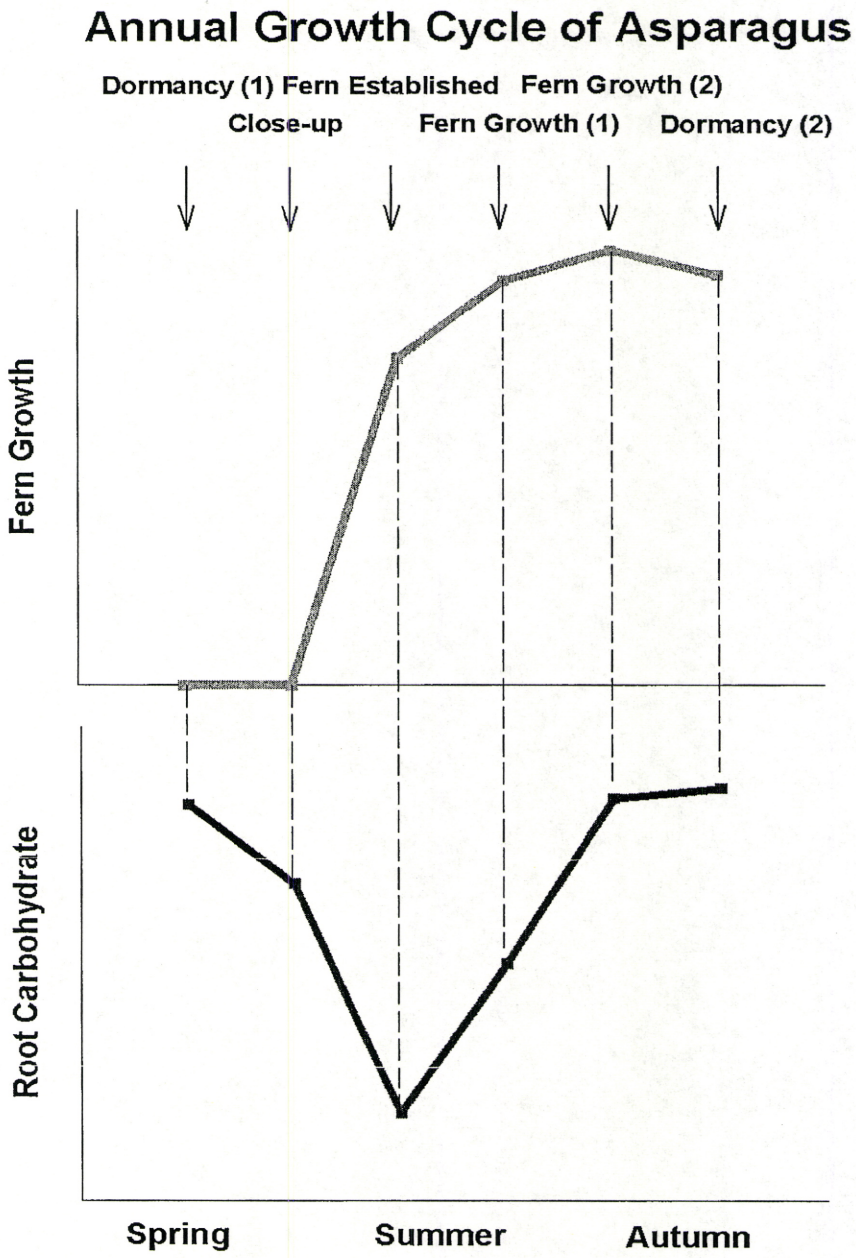


Figure 1: Typical patterns of above-ground growth and carbohydrate content in the root system of asparagus during an annual growth cycle. The six arrows indicate key stages when root sampling is recommended. See text for details.

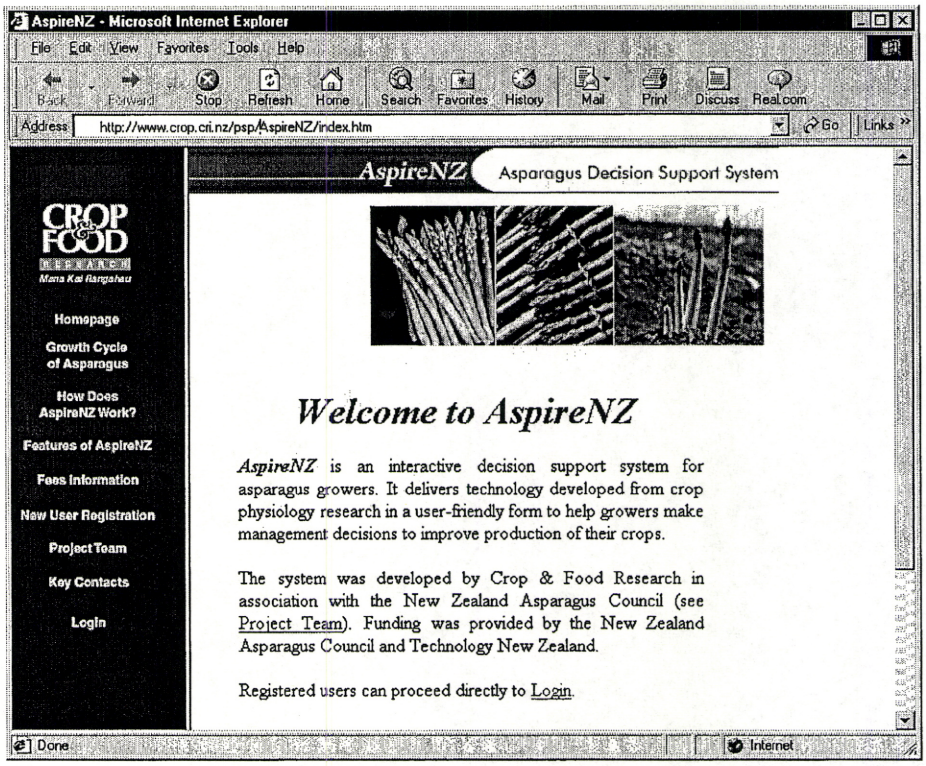
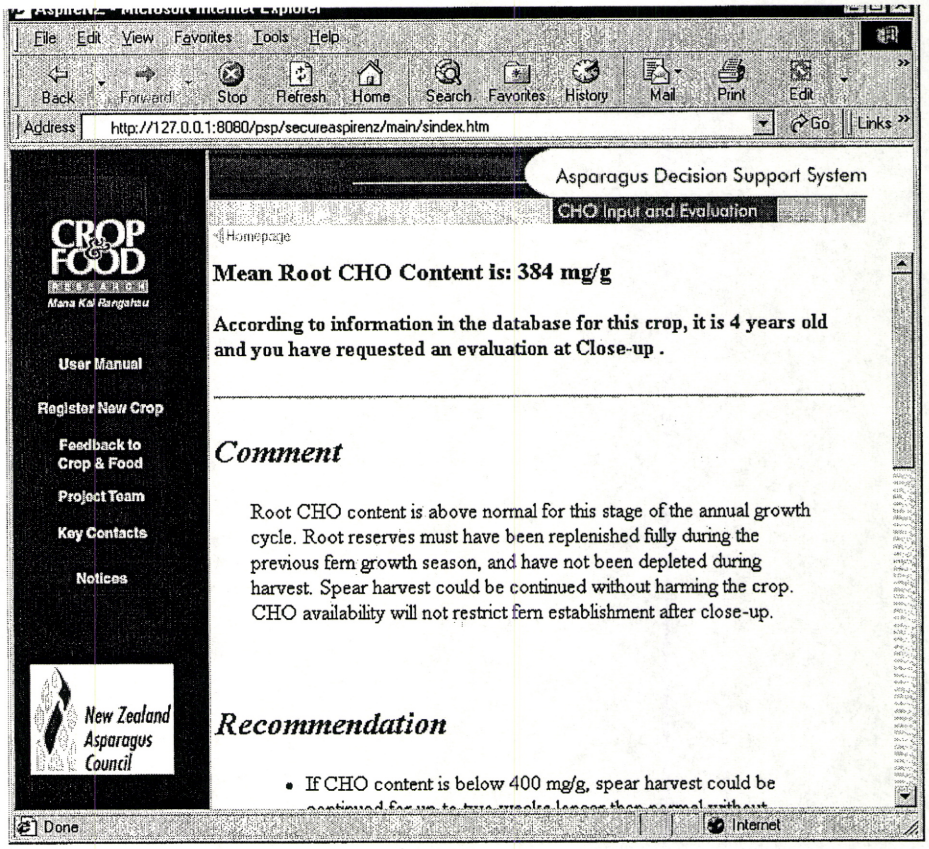


Figure 2: **AspireNZ** *homepage.*



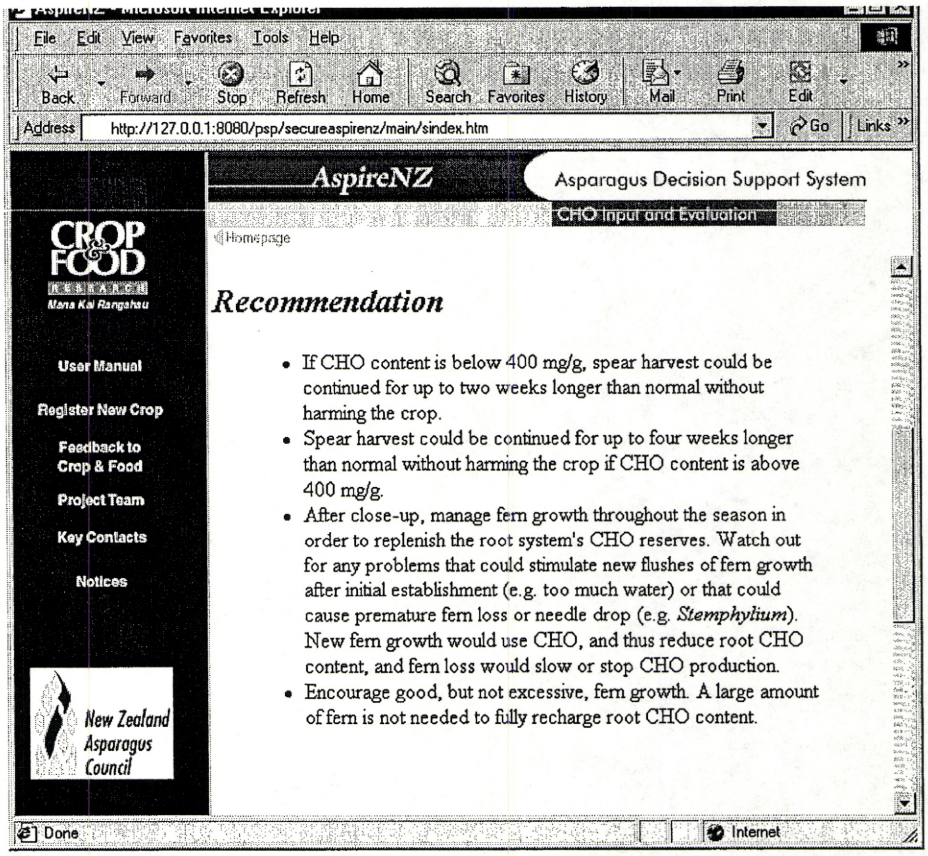


Figure 3: Example output page from **AspireNZ** *showing the estimated root CHO content, confirmation of information entered by the user, and resulting comments and recommendations.*