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***, a decision support system that can 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: 1) a simple method that growers can use to assess the CHO status of their crops' root systems, 2) knowledge about how to interpret the information and use it to help make management decisions, and 3) a system on the Internet to deliver the knowledge interactively. Other features of ***AspireNZ*** include a database that retains information about each crop registered with it. The information can be retrieved at any time so 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.

Additional key words: Asparagus officinalis *L., storage roots, carbohydrate, Brix, annual growth cycle, database, Internet*

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 rarely known the CHO status of the root system during the annual cycle or how to interpret such information. Therefore the traditional 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 that 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; and
- 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 (Fig. 1). Stored CHO is usually at a 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 (Fig. 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 that is vital for potential spear yield the following season. Lower recharge than normal could result from poor fern growth

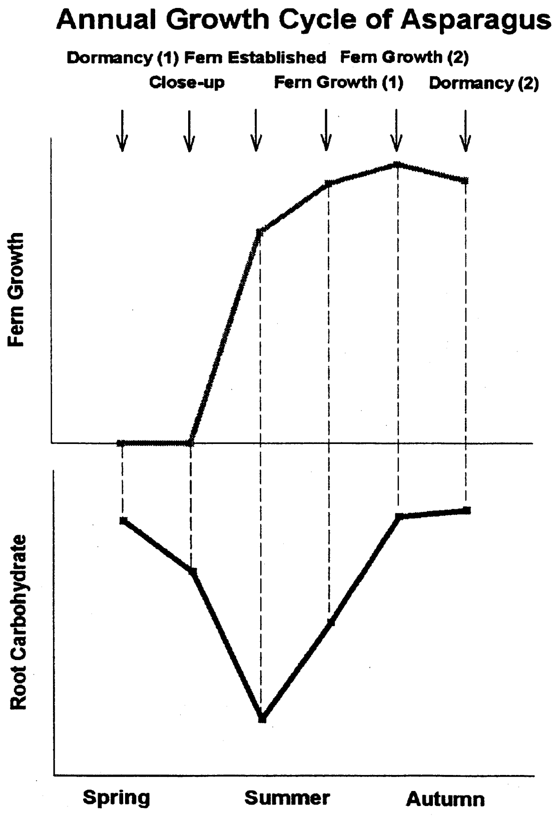

Figure 1. Typical patterns of above-ground growth and carbohydrate content in the root system of asparagus during an annual growth cycle. The six arrows indicate key stages when root sampling is recommended. See text for details.

caused by factors such as water deficit or a foliar disease such as *Stemphylium*, and may requireadditional 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) 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 (Quarmby and 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% could be used with confidence as a surrogate for analytical measurement of CHO content.

There is considerable variation in Brix% 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 via the Internet

AspireNZ is on the Crop & Food Research website (www.crop.cri.nz/psp/aspirenz/index.htm). The home-page has an index of general information that can be viewed in the public section of the system (Fig. 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 with the system as they wish, 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

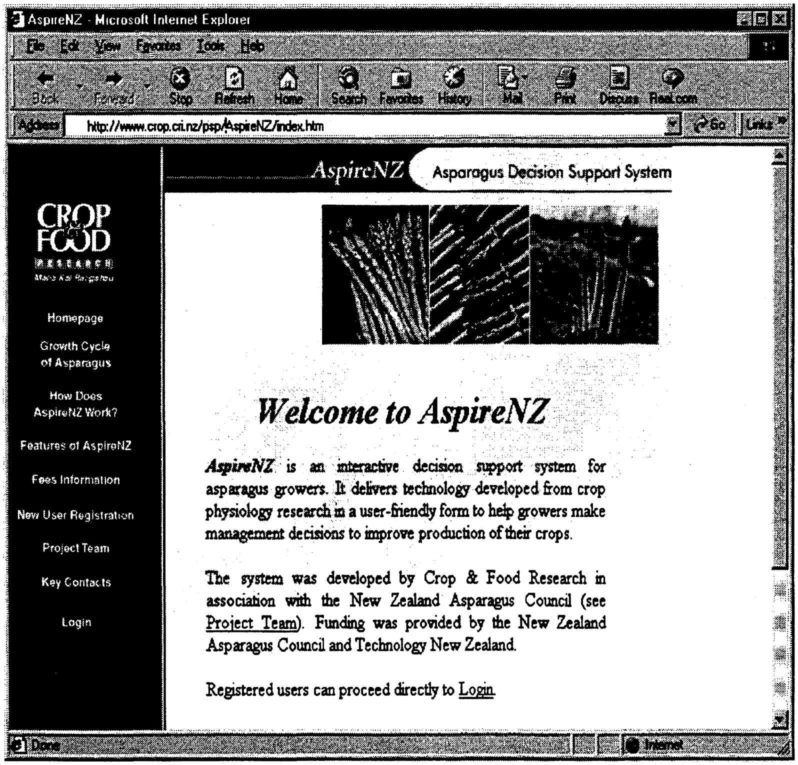

Figure 2. ***AspireNZ*** **homepage.**

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 that more root samples should be obtained and measured for Brix%.

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 Fig. 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 *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 to websites with information about products such as agri-chemicals used in asparagus production.

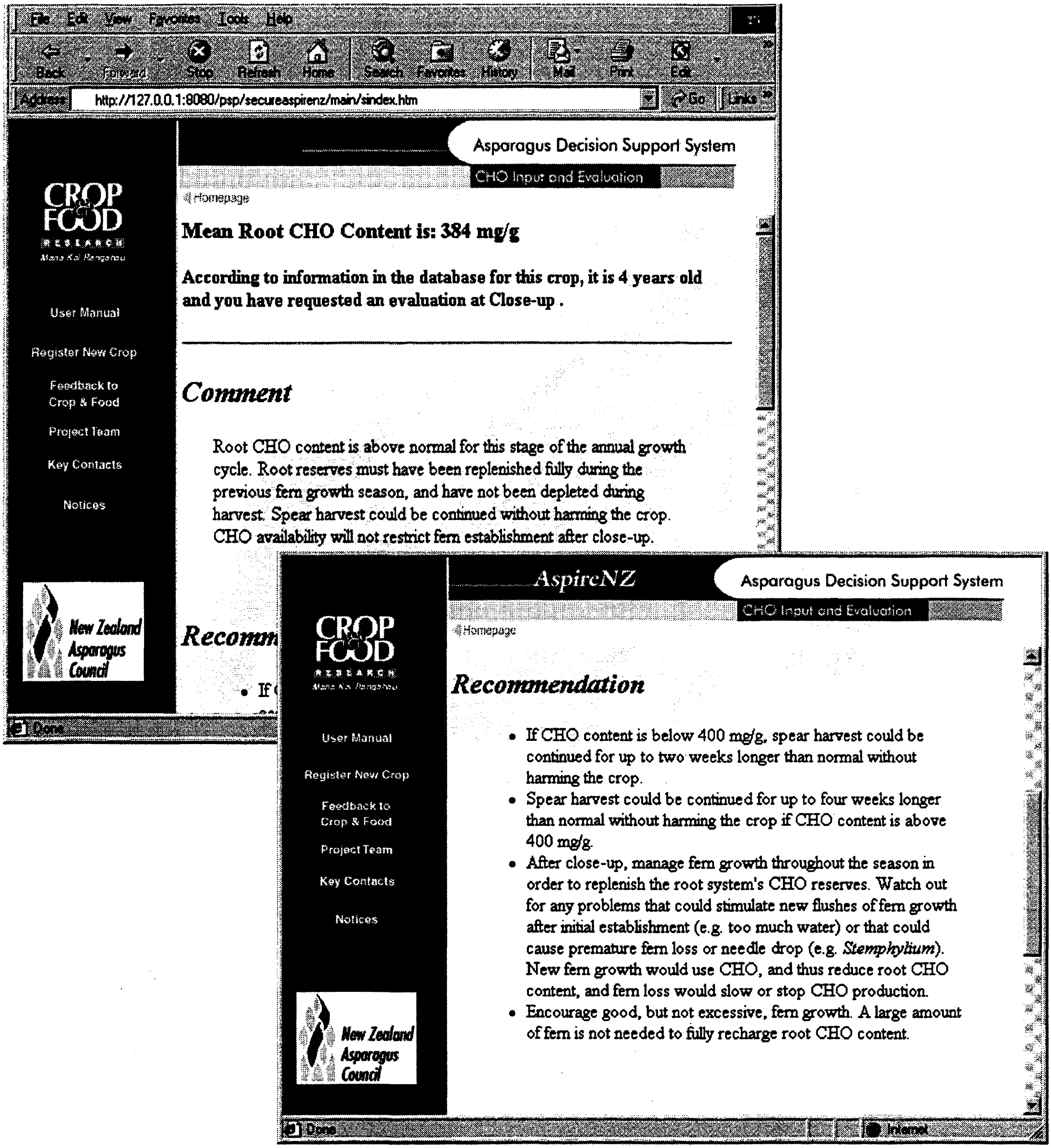

Figure 3. Example output page from *AspireNZ* showing the estimated root CHO content, confirmation of information entered by the user, and resulting comments and recommendations.

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 the 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., 2000) 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 "guinea 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). The NZAC and Technology New Zealand provided funding. 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 to Dr Dan Drost of Utah State University, USA, for valuable discussions and to the ten growers in New Zealand's asparagus production regions that participated in the crop monitoring programme.

References

Cloughley, C.G., Wilson, D.R., Jamieson, P.D. and Sinton, S.M. 1999. Model of the growth physiology of asparagus (*Asparagus officinalis* L.). Proceedings of the International Symposium, Modelling Cropping Systems, European Society for Agronomy - Division of Agroclimatology and Modelling, Llieda, Spain, pp. 159-160.

Drost, D.T. 1997. Asparagus. *In* The Physiology of Vegetable Crops (ed., H.C. Wien.), pp. 621-649. CAB International, Wantage.

Haynes, R.J. 1987. Accumulation of dry matter and changes in storage carbohydrate and amino acid content in the first two years of asparagus growth. *Scientia Horticulturae* ***32***, 17-23.

Pressman, E., Schaffer, A.A., Compton, D. and Zamski, E. 1993. Seasonal changes in the carbohydrate content in two cultivars of asparagus. *Scientia Horticulturae* ***53***, 149-155.

Quarmby, C. and Allen, S.E. 1989. Organic Constituents. *In* Chemical Analysis of Ecological Materials (ed., S.E. Allen), pp.164-166. Blackwell, Oxford.

Robb, A.R. 1984. Physiology of asparagus (*Asparagus officinalis*) as related to the production of the crop. *New Zealand Journal of Experimental Agriculture* ***12***, 251-260.

Shelton, D.R. and Lacy, M.L. 1980. Effect of harvest duration on yield and on depletion of storage carbohydrates in asparagus roots. *Journal of the American Society of Horticultural Science* ***105***, 332-335.

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.