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Assessing the carbohydrate status of storage roots in asparagus crops

—a management tool for growers

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New Zealand Asparagus Council

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1 EXECUTIVE SUMMARY

The aim in asparagus production is to maximise spear yield and quality. These attributes both depend on the availability of resources in the crop's storage root system. A key indicator of the level of resources is the soluble carbohydrate (CHO) content in the roots. In this report we describe a simple, inexpensive technique that could be used by growers or their advisers to obtain quick, reliable measurements of CHO content in the root systems of their crops at any time of the year. We also provide guidelines for interpreting the measurements gathered when using this technique to aid decision making about the management of root CHO content during the season in order to optimise crop performance.

The technique was developed using 80 root samples with a wide range of CHO contents that had been collected previously during two years of experiments. Their CHO contents were measured using an accurate, reliable analytical procedure. These results were compared with Brix % readings made with a refractometer, and a close relationship was found between the two sets of results. This means that Brix % readings can be used with confidence to assess the CHO status of asparagus roots. Statistical analyses showed that readings should be done on ***at least*** seven different root samples to obtain a reliable estimate of CHO content for a crop.

A procedure is described that growers could use to measure the Brix % values in root samples they have collected in order to obtain a representative measure of root CHO content in an asparagus field. We conclude with guidelines for interpreting the measurements to aid crop management.

2 INTRODUCTION

The aim in asparagus production is to maximise spear yield and quality. These attributes both depend on the availability of resources in the crop's storage root system during harvest.

A key indicator of the level of resources is the soluble carbohydrate (CHO) content in the roots. We suggest that this indicator could be used to help growers make more informed crop management decisions. Currently, most management practices emphasise control of above-ground growth, aiming to ensure healthy, vigorous fern growth and, therefore, high spear yield and quality. However, we believe that it is just as important for both short- and long-term performance to manage the storage root system of the crop. Information on the root CHO content could be used to help answer questions such as:

- **How long should spear harvest be continued?** Stopping too early could sacrifice potential yield unnecessarily. Stopping too late could deplete CHO too much and reduce the crop's ability to produce fern and restore the CHO content of the roots before winter,

- **How much fern growth should be stimulated?** Too much is not desirable. Fern production is a heavy drain on CHO reserves, and a large amount of fern is not needed to recharge root CHO content, and

- **When is the root system full of CHO?** A full system is needed to ensure good performance the following season. Ferns can be removed towards the end of autumn once this point is reached, but not if there is still the risk of a late flush of growth which could reduce CHO in the roots.

To gather this information a procedure for measuring the CHO content of the roots easily at any time and then interpreting the results is needed. In this report we describe a project in which the objectives were to provide growers with:

- a method using a refractometer, a portable instrument, to obtain quick, reliable measurements of root CHO contents in their own crops, and

- guidelines for interpreting the measurements to help make decisions for managing root CHO content during the season, thereby optimising crop performance.

3 METHODS

The method was developed by comparing refractometer readings with CHO contents measured using a reliable analytical procedure. Data were obtained for 80 root samples selected from more than 300 samples that had been collected in the course of our previous research on asparagus root systems. The samples were chosen to cover a wide range of CHO contents, from depleted to fully charged root systems.

The samples were obtained from root systems that were excavated at various times during two years of experiments. Fresh samples weighing about 200 g and consisting of up to 40 short lengths of individual storage roots were cut from a zone about 15-30 cm from the crown. They were washed, air-dried on absorbent paper, and stored in a deep-freeze.

A sub-sample of about 50 g of frozen roots was prepared for CHO content measurements. Roots were cut into short lengths and freeze-dried for 48 hours before being ground to a powder with a grain grinder. Roots that were not ground immediately after freeze-drying either had to be kept in an oven at between 30 and 40°C or re-dried for at least 12 hours to avoid clogging the grinder. Ground samples were stored in plastic specimen jars at room temperature. After CHO content was measured samples were dried at 70°C and their moisture contents determined. All CHO content results were expressed on an oven-dry weight basis.

The CHO contents were measured by the anthrone method, a reliable analytical procedure for determining total soluble CHO levels (Allen 1989). Approximately 0.1 g of finely-ground, freeze-dried root sample was weighed in duplicate into centrifuge tubes and 30 ml of distilled water were added. The tubes were heated in a glycol bath at 95°C for five minutes, then they were screw-capped, tumbled in an end-over-end shaker for five minutes, and centrifuged at 4000 rpm for five minutes. A 0.1 ml aliquot of the clear supernatant was added to a boiling tube with 1.9 ml of distilled water, and soluble CHO content was determined using anthrone reagent with fructose standards and distilled water blanks. Results were expressed on a root dry weight basis by correcting for variable moisture content after drying a 1 g sample of freeze-dried roots overnight in a forced-air oven at 70°C.

About 20 g of each sample selected for refractometer measurements was thawed by microwaving on a high setting for 20 seconds. The roots were then cut into 1 cm lengths and juice was extracted using a garlic crusher. Brix % readings were then made on the juice sample with two refractometers: a digital, electronic model (Atago 0-32%, cost about $1350) and a hand-held, manual model (Atago ATC-1E, cost about $500). The entire procedure took about three minutes for each sample.

Data were analysed to:

- determine the distribution of CHO contents in the 80 samples using the results from the analytical procedure,

- compare the results from the two refractometers, and

- determine the relationship between analytical CHO content and refractometer results.

We used information gained from this project and our research on asparagus root systems during the last few years to formulate guidelines that growers could use to make refractometer measurements on root samples from their own crops and to interpret the measurements to help make decisions that would optimise crop performance.

4 RESULTS

The CHO contents of the 80 samples ranged from about 150-700 mg/g on a dry weight basis (Fig. 1). The number of samples was not consistent across the range of contents. Most were in the 400-600 mg/g range, reflecting the distribution in the total number of samples collected.

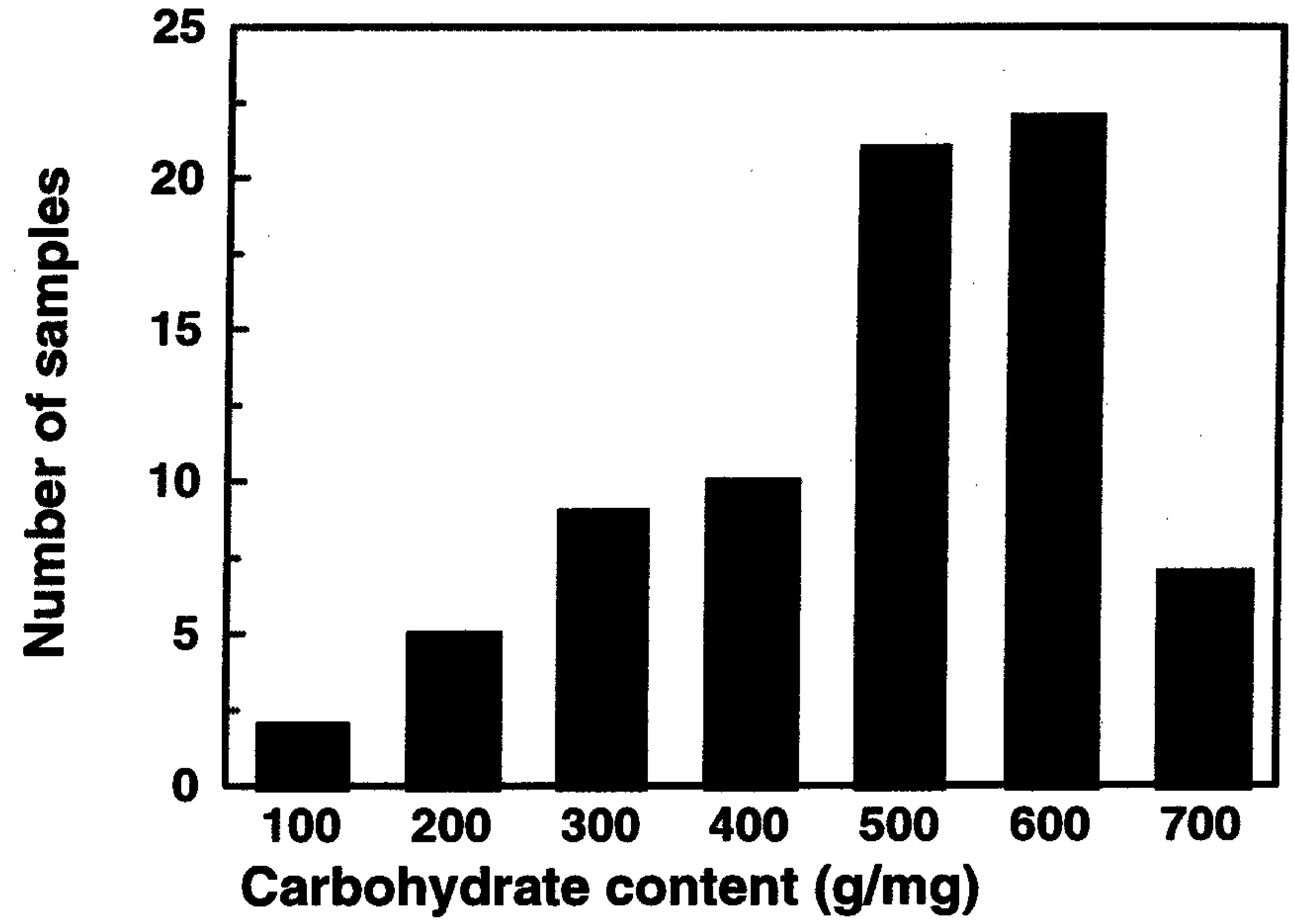

Figure 1: Frequency distribution of the carbohydrate contents of the 80 samples selected for the analysis.

There was excellent agreement between the Brix % measurements made with the two refractometers (Fig. 2). The linear regression was not significantly different from the 1:1 line, and the R value was 0.99. This means that there was no advantage of using the more expensive electronic model over the cheaper manual instrument. The latter is a more realistic option for growers.

There was a close relationship between the CHO contents measured with the analytical procedure and the refractometer results (Fig. 3). Thus, Brix % readings can be used with confidence to assess the CHO status of asparagus roots. Although a linear regression was fitted to the data, the relationship deviates from a straight line at both ends so is less reliable at high and low Brix % values. The scatter of data about the regression suggests that there is uncertainty about the extent to which each refractometer measurement accurately estimates the corresponding CHO content. A statistical analysis of this uncertainty showed that refractometer readings should be done on ***at least*** seven samples to obtain a reliable estimate of the average root CHO content. With seven samples, the confidence limits of each estimate are about ±2% of the mean value. Ideally, more than seven samples should be measured; the accuracy of the average CHO content estimate increases as the number of readings increases.

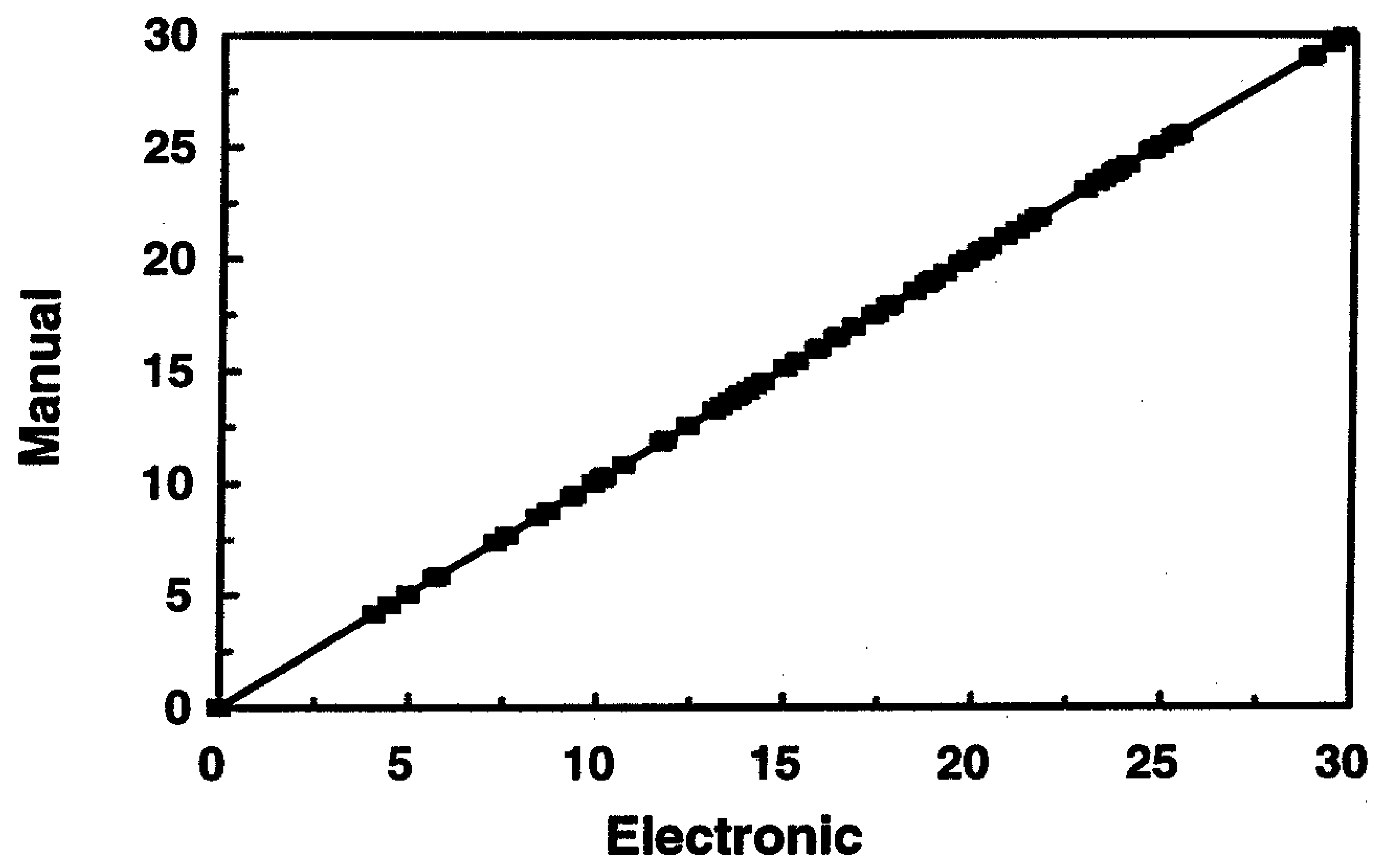

Figure 2: Comparison between Brix % measurements made with the electronic and manual refractometers (regression equation: Y = 0.05 + 1.01X, R = 0.99).

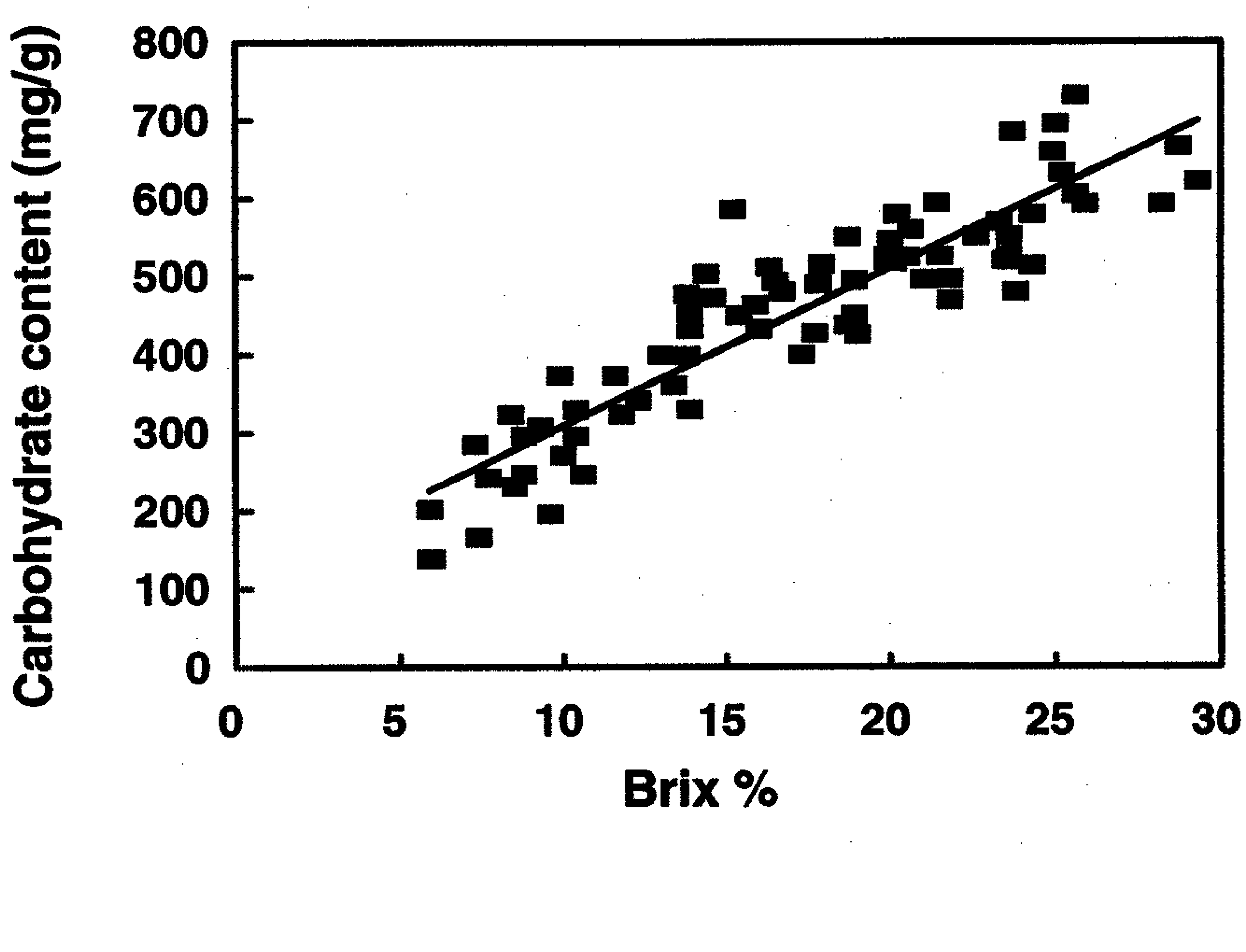

Figure 3: Relationship between Brix % measurements made with the manual refractometer and carbohydrate content measured with the analytical procedure (regression equation: Y = 106 + 20.3X, R = 0.91).

5 DISCUSSION

We have demonstrated that a refractometer can be used to obtain quick, reliable measurements of soluble CHO content in the roots of asparagus crops. CHO content is a key indicator of the amount of resources available for spear and fern growth. It represents the non-structural component of root biomass, and fluctuates during the crop's annual growth cycle—it increases and decreases in association with sequences of fern and spear growth during the year. In contrast, the structural component of root biomass changes relatively slowly, increasing steadily as the size of the root system increases during the establishment years of a crop and then remaining quite stable in established crops.

It is feasible for growers or their advisers to use the method. A manual refractometer costs about $500 and is easy to use. We recommend the following procedure to collect root samples and measure their Brix % values in order to obtain a representative measure of root CHO content in an asparagus crop:

- take 15-20 samples to about 30 cm depth with a soil corer (3 cm diameter) at random positions diagonally across the field. Each core should be about 10 cm away from a crown. Try to select a range of plant sizes—not all large or small ones,

- separate the roots from the soil in each sample and aim to gather about enough to fill an eggcup from each plant. This may require two or three cores to be taken from around the same plant,

- it takes about one hour to obtain 15 or 20 samples in the field,

- thoroughly wash the samples, dry them, and then either extract their juice immediately (as described in Section 3) or store them in a deep-freeze until later,

- follow the directions in the manual to obtain a refractometer reading for each sample,

- use the regression equation from Figure 3 to convert Brix % to CHO content for each sample. In the equation, Y is the estimate of CHO content and X is the Brix % reading. Therefore, for example, a Brix % reading of 15 is converted to CHO content as follows:

$$Y = \text{CHO content} = 106 + 20.3\,X = 106 + (20.3 \times 15) = 410\text{mg/g}$$

- calculate the average CHO content of the 15-20 samples. Any values that are unusually high or low for an identifiable reason (e.g. a very low value from an obviously unhealthy plant) should be excluded from the calculation.

We suggest guidelines below for managing root system CHO content to optimise crop performance that are based on the results of our asparagus growth physiology research over several years. Our results have shown that fluctuations in CHO content are large, predictable and very responsive to above-ground management of the crop. They have also shown the importance of balancing the accumulation and depletion of root resources, both within a season and between seasons. The guidelines are:

- a crop should start the season with a full root system (>600 mg/g CHO content). Anything less will reduce performance below optimum during the season. A low CHO content at the beginning of a season is the result of problems during the previous season,

- spear harvest can continue until the CHO content drops to about 250-300 mg/g. CHO content drops slowly during harvest, and the time taken to reach this point may vary from year-to-year. Stopping spear harvest too early sacrifices potential yield unnecessarily. Stopping too late reduces the crop's ability to produce fern and restore the CHO content of the roots before winter,

- too much fern growth is not desirable. Initial fern production is a heavy drain on root reserves, and the CHO content usually drops sharply to a minimum in the 100-200 mg/g range before recovering once fern is established. A large amount of fern is not needed to fully recharge root CHO content,

- more than one flush of fern growth during a season is very undesirable because of their adverse effect on root CHO content, and

- the root system CHO content should reach >600 mg/g CHO content again by the end of autumn to ensure good performance the following season. Ferns can be removed once this point is reached but not if there is still the risk of a late flush of growth.

6 REFERENCE

Allen, S.E. 1989: Chemical analysis of ecological materials. Allen, S.E. *ed*. Blackwell, Oxford, pp. 164-166.

7 ACKNOWLEDGEMENTS

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