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EFFECTS OF TEMPERATURE ON SEASONAL CHANGES IN GROWTH AND CARBOHYDRATE PHYSIOLOGY OF ASPARAGUS

(Asparagus officinalis L.)

A thesis presented in partial fulfilment of the requirements for the degree of Doctorate of Philosophy in Plant Science at Massey University

Avis Rosalie Hughes
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ABSTRACT

In a temperate climate, most of the visible, seasonal changes in asparagus growth are induced by or dependent on changing temperature regimes. Senescence of ferns in autumn occurred below 13C, but was prevented by 20C. Crowns required chilling at temperatures below 12.5C to release the internal dormancy which occurred during winter. Although budbreak was never completely suppressed, the minimum temperature at which budbreak could occur changed during winter dormancy. Budbreak did not occur at 12.5C in some cultivars at maximum dormancy. The optimum temperature for the growth of young plants was between 25C and 30C.

A model was developed which simulated seasonal changes in carbohydrate accumulation and utilisation, and the changing source-sink relationships within male and female plants. The model used temperature, indirectly, to determine the times at which seasonal changes in plant growth occurred.

The basic unit for carbohydrate production and allocation in cultivars with well defined rhizomes, e.g., ‘Rutger’s Beacon’, was a rhizome and it’s attached developing axillaries. An axillary rhizome became independent very soon after it had developed fern. The basic unit may differ in cultivars such as ‘UC157’ which have less well defined rhizomes. The strength of correlative inhibition within a cultivar appears to affect both rhizome morphology and budbreak patterns during spear harvest.

In summer, young fern had a higher mobilising ability for assimilate than older fern or roots in male plants. In late summer-early autumn, roots became a stronger sink than the fern. On female plants, reproductive sinks (i.e, berries) had the highest competitive and mobilising ability.

Crown carbohydrate concentration appeared to reach a physiological maximum of 65% in late summer. Most of the carbohydrate pool was long chain fructans, i.e, with degree of polymerisation above eight. The size of the crown carbohydrate pool increased during autumn and senescence as crown dry weight increased. The concentration of disaccharide increased during senescence indicating that it may have a role in cold tolerance. There was little change in crown dry weight or carbohydrate concentration of chilled plants until after the plants had been chilled for five weeks and the minimum temperature for budbreak had decreased. Respiration then increased as internal dormancy was further released.
Changes in the composition of carbohydrate reserves are associated with the chilling process, and may affect the release of internal dormancy. Dormant plants required exposure to temperatures below 12.5°C to increase the monosaccharide concentration above 4.5% dry weight and to depolymerise long chain fructans. Both these factors would decrease the substrate for some energy requiring process which must occur before budbreak can occur.

‘Rutger’s Beacon’ required approximately 500 chilling units (calculated using the Utah model) to release 50% of the basal buds from internal dormancy and permit growth at 12.5°C. The chilling response curve for asparagus appears to be flatter than the Utah model.

This thesis confirmed earlier work which indicated that improved agronomic performance may be related to increased partitioning into carbohydrate storage tissue i.e., the crown. Genotypic differences in depth of internal dormancy and spear growth rate will also affect yield.

Differences in carbohydrate metabolism are not the reason for agronomic differences between male and female plants. The strong sink effect of berries on female plants reduces crown dry weight and thus the crown carbohydrate pool.
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TABLE OF CONTENTS

Abstract ii
Acknowledgements iv
Table of contents v
List of figures x
List of tables ixx

Chapter 1 Introduction
  1.1 Introduction 1
  1.2 Botany 1
    1.2.1 Botanical background 1
    1.2.2 Morphology 2
  1.3 Physiology 2
    1.3.1 Root growth 2
    1.3.2 Shoot growth 4
    1.3.3 Rhizome growth 4
    1.3.4 Dormancy 5
    1.3.5 Vegetative growth 5
    1.3.6 Seasonal changes in carbohydrates 8
    1.3.7 Male-female differences 8

Chapter 2 The effects of temperature and genotype on the development of young asparagus
  2.1 Introduction 9
  2.2 Materials and methods 11
    2.2.1 Treatments 11
    2.2.2 Experimental design 13
    2.2.3 Propagation and growing conditions 13
    2.2.4 Plant measurements 13
    2.2.5 Analysis of data 13
2.3 Results

2.3.1 Effect of temperature and genotype on relative growth rate 15
2.3.2 Effect of temperature and genotype on partitioning 17

2.4 Discussion

2.4.1 Effect of temperature on relative growth rate 22
2.4.2 Effect of temperature and genotype on partitioning 23

2.5 Conclusions

Chapter 3 Source-sink relationships

3.1 Introduction

3.1.1 Definitions and general principles 27
3.1.2 Factors determining partitioning 28
3.1.3 Objectives of experiment 31

3.2 Materials and methods

3.2.1 Plant material 32
3.2.2 Application of 14CO₂ 33
3.2.3 Treatments 35
3.2.4 Sampling 36
3.2.5 Analysis of total 14C 37
3.2.6 Data analysis 38

3.3 Results

3.3.1 Distribution of 14C between rhizomes 38
3.3.2 Source-sink relationships: approach used to analyse data 43
3.3.3 Source-sink relationships in male asparagus plants during summer and autumn 47
3.3.4 Detailed analysis of source sink relationships in male plants during summer and autumn. 62
3.3.5 The effect of berry production on the source-sink relationships of asparagus plants 66
3.3.6 Growth and source-sink relationships between growing seasons 74

3.4 Discussion

3.4.1 Distribution of 14C between rhizomes 75
3.4.2 Seasonal changes in respiratory requirements 79
3.4.3 Changes in sink priorities for current assimilate: summer-autumn

3.4.4 Translocation of stored assimilate: summer-autumn

3.4.5 Growth and source-sink relationships from senescence to spear emergence

3.4.6 Growth and source-sink relationships from spear emergence to fern establishment

3.4.7 Effect of plant sex on dry matter production

3.4.8 Methodology used in this experiment

3.5 Conclusions

Chapter 4 Factors affecting initiation of spear growth in spring and autumn

4.1 Introduction

4.1.1 The induction and release of dormancy

4.1.2 Chill unit models

4.1.3 Features of asparagus spear growth

4.2 Materials and methods

4.2.1 Introduction

4.2.2 Plant material

4.2.3 Environmental regimes

4.2.4 Data collection

4.2.5 Data analysis

4.3 Results

4.3.1 Senescence of fern: experiment A

4.3.2 Spear growth by Rutger's Beacon: experiments A & B

4.3.3 Spear growth by Rutger's Beacon following natural chilling: experiment C

4.3.4 Some genotypic effects: experiment D

4.4. Discussion

4.4.1 A model of dormancy in asparagus

4.4.2 Estimation of chill units required to remove internal dormancy

4.4.3 Budbreak patterns and the effects of correlative inhibition

4.5 Conclusions
Chapter 5 Carbohydrate metabolism in asparagus

5.1 Introduction

5.1.1 Seasonal changes in carbohydrate reserves of asparagus
5.1.2 Fructan metabolism
5.1.3 Physiological changes associated with fructan metabolism

5.2 Materials and methods
5.2.1 Plant material and environmental conditions
5.2.2 Fructan analysis

5.3 Results
5.3.1 Changes during autumn
5.3.2 Changes during chilling
5.3.3 Changes during spear harvest
5.3.4 Fructan metabolism
5.3.5 Some effects of plant sex

5.4 Discussion
5.4.1 Changes in the carbohydrate pool
5.4.2 Fructan metabolism within asparagus
5.4.3 Other aspects of fructan metabolism in asparagus
5.4.4 Some effects of plant sex

5.5 Conclusions

Chapter 6 A model of seasonal changes in growth and carbohydrate metabolism

6.1. Defining the basic unit for carbohydrate movement and allocation.
6.2 A model for carbohydrate production and utilisation in harvested asparagus plants
6.2.1 The model
6.2.2 Evaluating the model
6.2.3 Incorporating male-female differences

6.3 Advantages and limitations of the model
### Chapter 7 General conclusions

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1 Effects of temperature on growth of asparagus</td>
<td>204</td>
</tr>
<tr>
<td>7.2 Agronomic implications</td>
<td>205</td>
</tr>
<tr>
<td>7.3 Methods</td>
<td>206</td>
</tr>
</tbody>
</table>

### References

207
LIST OF FIGURES

Figure 1.01: Stylised diagram showing the parts of a mature asparagus plant and the terminology used to describe the plant parts.

Figure 1.02: Stylised diagram to show the relationship between rhizome and sympodial branching pattern.

Figure 1.03: Stylised diagram to show the development of axillary rhizomes as a result of sympodial branching.

Figure 2.01: Effect of temperature regimes on Relative Growth Rate (RGR) of whole plant. Plant growth is exponential (A, B). Temperatures were constant (A), or alternating (12 hour day/night)(B). Bars represent twice standard error of mean.

Figure 2.02: Allometric relationship between crown and fern dry weight. Temperatures were constant (A), or alternating (12 hour day/night)(B). Allometric constant, $K_{dw}$, is slope of line. Data from first two weeks after transfer to treatment conditions omitted.

Figure 2.03: Effect of temperature regimes on $K_{dw}$, allometric constant for partitioning dry weight. $K_{dw}$ was calculated from the following equation:

\[
\log_e \text{crown dry weight} = \log_e a + (K_{dw} \times \log_e \text{shoot number})
\]

Temperatures were constant, or alternating (12 hour day/night). Bars represent twice standard error of mean.

Figure 2.04: $K_{dw}$ of four asparagus genotypes in constant (A) and alternating (B) temperature regimes. Bars represent twice standard error of mean.

Figure 2.05: Effect of temperature regimes on $K_{wo}$, allometric constant for root and shoot number. $K_{wo}$ was calculated from the following equation:

\[
\log_e \text{root number} = \log_e a + (K_{wo} \times \log_e \text{fern dry weight})
\]

Temperatures were constant, or alternating (12 hour day/night). Bars represent twice standard error of mean.

Figure 3.01: Arrangement of $^{14}$CO$_2$ labelling apparatus and direction of gas flow.
Figure 3.02: Diagrammatic view of an asparagus rhizome, and the nomenclature used to describe the carbohydrate sinks within the crown.

Figure 3.03: Photographs of a dissected asparagus plant, and the nomenclature used to describe the carbohydrate sinks within the crown.

Figure 3.04: Schematic view of biological oxidiser used to combust samples to determine total $^{14}$C content.

Figure 3.05: Classification of rhizome arrangements in plants sampled from February to May, 1987. Active rhizomes (those supporting fern) coloured black; dormant rhizomes white.

Figure 3.06: Effect of rhizome weight on mobilising ability ($\%$ of plants $^{14}$C) as secondary and axillary rhizomes. 
A: dry weight as a percentage of plant dry weight 
B: actual dry weight.

Figure 3.07: Mobilising ability ($^{14}$C content, dpm x $10^3$), with respect to the labelled fern, of sinks within male asparagus plants labelled with a pulse of $^{14}$CO$_2$ at 3 stages during fern growth and sampled 4 to 12 weeks later. See Table 3.01 for labelling and sampling dates. Standard error of mean is in italics.

Figure 3.08: Competitive ability ($^{14}$C concentration, dpm x $10^3$/mg) of sinks, with respect to the labelled fern, within male asparagus plants labelled with a pulse of $^{14}$CO$_2$ at 3 stages during fern growth and sampled 4 to 12 weeks later. See Table 3.01 for labelling and sampling dates. Standard error of mean is in italics.

Figure 3.09: Dry weight of sinks within male asparagus plants labelled with a pulse of $^{14}$CO$_2$ at 3 stages during fern growth and sampled 4 to 12 weeks later. See Table 3.01 for labelling and sampling dates. Standard error of mean is in italics.

Figure 3.10: Mobilising ability with respect to the labelled fern ($^{14}$C content, dpm x $10^3$) of sinks within male plants, female plants with berries and female plants without berries labelled with a pulse of $^{14}$CO$_2$ in mid-late
January and sampled four and twelve weeks later in mid February and mid April. Standard error of mean is in italics.

Figure 3.11: Competitive ability ($^{14}$C concentration, dpm x $10^3$/g dry weight) of sinks within male plants, female plants with berries and female plants without berries labelled with a pulse of $^{14}$CO$_2$ in mid-late January and sampled four and twelve weeks later in mid February and mid April. Standard error of mean is in italics.

Figure 3.12: Dry weight (g) of sinks within male plants, female plants with berries and female plants without berries labelled with a pulse of $^{14}$CO$_2$ in mid-late January and sampled four and twelve weeks later in mid February and mid April. Standard error of mean is in italics.

Figure 3.13: Distribution of $^{14}$C in male asparagus plants following labelling with $190 \times 10^3$ dpm in January. Plants in first 3 samplings were labelled 2 weeks earlier than remaining samples. Bars represent twice standard error of mean.

Figure 3.14: Distribution of dry weight in male asparagus plants following labelling with $190 \times 10^3$ dpm in January. Bars represent twice standard error of mean.

Figure 3.15: Number of roots in main rhizome of male asparagus plants following labelling with $190 \times 10^3$ dpm in January. Bars represent twice standard error of mean.

Figure 4.01: Position of buds at the apex of a dormant rhizome.
   a. Photograph of dormant rhizome.
   b. Schematic drawing - numbers denote position of bud. Position 1 is the oldest bud i.e., the basal bud

Figure 4.02: Effect of temperature and daylength on fern of ‘Rutger’s Beacon’ in ‘autumn’: plants after 5 weeks at
   a - 20.0C - 16 hour photoperiod
   b - 20.0C - 8 hour photoperiod
c - 12.5C - 16 hour photoperiod

d - 12.5C - 8 hour photoperiod

e - natural conditions.

Figure 4.03: Effect of temperature and daylength on chlorophyll content of 'Rutger's Beacon' in simulated autumn: chlorophyll content (mg/g FW) 19 days after the experiment began on 22 March. Plants transferred to natural conditions or to 12.5C senesced; plants transferred to 20C produced a growth flush. Bars represent twice standard error of mean.

Figure 4.04: Mean number of days to budbreak by first spear to grow on each rhizome of 'Rutger's Beacon' at 20C (A) or 12.5C (B). Plants transferred to growing temperature on 22 March and 26 May were from a heated glasshouse (minimum temperature 13C); plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks. Bars represent twice standard error of mean.

Figure 4.05: Effect of chilling on the position of the first bud to grow on 'Rutger's Beacon' at 20C (A) or 12.5C (B). Plants transferred to growing conditions on 22 March and 26 May were from a heated glasshouse (minimum temperature 13C) and produced very few or no spears at 12.5C: plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks.

Figure 4.06: Mean relative spear growth rate (RSGR) of first and subsequent spears to grow on 'Rutger's Beacon' at 20C (A) or 12.5C (B). Plants transferred to growing conditions on 22 March and 26 May were from a heated glasshouse (minimum temperature 13C) and produced very few or no spears at 12.5C: plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks. Bars represent twice standard error of mean.

Figure 4.07: Effect of chilling on cumulative percentage of rhizomes following each budbreak pattern on 'Rutger's Beacon' at 20C (A) or 12.5C (B). Data restricted to rhizomes which produced at least three spears. Buds numbered from the base of the dormant rhizome towards the apex, thus 1=basal bud. Plants transferred to growing conditions on 22 March and 26 May were from a heated glasshouse (minimum temperature 13C) and
produced very few or no spears at 12.5C: plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks.

Figure 4.08a: Budbreak patterns in ‘Rutger’s Beacon’ plant with one active bud cluster.
A: rhizome map showing positions of buds which produced spears.
B: measurements of spear height and the regression line fitted to calculate relative spear growth rate (slope of line) of each spear.

Figure 4.08b: Budbreak patterns in ‘Rutger’s Beacon’ plant with two active bud clusters.
A: rhizome map showing positions of buds which produced spears.
B: measurements of spear height and the regression line fitted to calculate relative spear growth rate (slope of line) of each spear in rhizome A.
C: measurements of spear height and the regression line fitted to calculate relative spear growth rate (slope of line) of each spear in rhizome B.

Figure 4.09: Mean number of days to budbreak by first spear to grow on each rhizome of ‘Rutger’s Beacon’ transferred to 12.5C after chilling in natural conditions. Bars represent twice standard error of mean.

Figure 4.10: Mean relative spear growth rate (RSGR) of first and subsequent spears to grow on each rhizome of ‘Rutger’s Beacon’ transferred to 12.5C after chilling in natural conditions. Bars represent twice standard error of mean.

Figure 4.11: Effect of chilling in natural conditions on percentage of rhizomes following each budbreak pattern ‘Rutger’s Beacon’ transferred to 12.5C after chilling in natural conditions. Data restricted to rhizomes which produced at least three spears. Buds numbered from the base of the dormant bud, thus 1=basal bud.

Figure 4.12a: Mean number of days to budbreak by first spear to grow on each rhizome of ‘Jersey Giant’ at 20C (A) or 12.5C (B). Plants transferred to growing temperature on 26 May were from a heated glasshouse (minimum temperature 13C); plants transferred on 2 July had been...
chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks. Bars represent twice standard error of mean.

Figure 4.12b: Mean number of days to budbreak by first spear to grow on each rhizome of 'UC157' at 20°C (A) or 12.5°C (B). Plants transferred to growing temperature on 26 May were from a heated glasshouse (minimum temperature 13°C); plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks. Bars represent twice standard error of mean.

Figure 4.13a: Mean relative spear growth rate (RSGR) of first and subsequent spears to grow on 'Jersey Giant' at 20°C (A) or 12.5°C (B). Plants transferred to growing conditions on 26 May were from a heated glasshouse (minimum temperature 13°C) and produced very few or no spears at 12.5°C: plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks. Bars represent twice standard error of mean.

Figure 4.13b: Mean relative spear growth rate (RSGR) of first and subsequent spears to grow on 'UC157' at 20°C (A) or 12.5°C (B). Plants transferred to growing conditions on 26 May were from a heated glasshouse (minimum temperature 13°C) and produced very few or no spears at 12.5°C: plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks. Bars represent twice standard error of mean.

Figure 4.14a: Budbreak patterns in 'Jersey Giant' plant with one clearly defined bud cluster.
A: rhizome map showing positions of buds which produced spears.
B: measurements of spear height and the regression line fitted to calculate relative spear growth rate (slope of line) of each spear.

Figure 4.14b: Budbreak patterns in 'Jersey Giant' plant with two clearly defined bud clusters.
A: rhizome map showing positions of buds which produced spears.
B: measurements of spear height and the regression line fitted to calculate relative spear growth rate (slope of line) of each spear.
Figure 4.14c: Budbreak patterns in 'UC157' plant with several active bud clusters but no clearly defined rhizomes.
A: rhizome map showing positions of buds which produced spears.
B: measurements of spear height and the regression line fitted to calculate relative spear growth rate (slope of line) of each spear.

Figure 4.14d: Budbreak patterns in 'UC157' plant with several active bud clusters but no clearly defined rhizomes.
A: rhizome map showing positions of buds which produced spears.
B: measurements of spear height and the regression line fitted to calculate relative spear growth rate (slope of line) of each spear.

Figure 4.15: Effect of chilling on the position of the first bud to grow on 'Jersey Giant' at 20C (A) or 12.5C (B). Plants transferred to growing conditions on 26 May were from a heated glasshouse (minimum temperature 13C); plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks.

Figure 4.16: Modification of Vegis’s model of internal dormancy to show a change in the optimum temperature for budbreak of asparagus, caused by changes in the minimum and maximum temperatures for budbreak being offset.

Figure 4.17: Effect of chilling units (Richardson et al. 1974) on percentage of first spears produced by the basal bud on a rhizome.
A: In 'Rutger's Beacon'
B: In 'Jersey Giant'

Figure 5.01: Chromatogram of a) hydrolysed sample and b) standard containing fructose and sucrose
Chromatographic conditions: column, 'Dextropac' (radially packed, reversed phase column with C18 bonded silica), with C18 guard column; eluent: water (reverse osmosis purified and degassed) at a flow rate of 2ml/min; detection by differential refractometer (Waters Model R401) set at 8x attenuation.

Figure 5.02: Chromatograms of non-hydrolysed extract from storage roots of asparagus. Numbers indicate degree of polymerisation of fructan.
a. Plant chilled at 10\textdegree{}C for 10 weeks.

b. Plant chilled at 2\textdegree{}C for 10 weeks.

Chromatographic conditions: column, ‘Dextropac’ (radially packed, reversed phase column with C18 bonded silica), with C18 guard column; eluent: water (reverse osmosis purified and degassed) at a flow rate of 2ml/min; detection by differential refractometer (Waters Model R401) set at 4x attenuation.

Figure 5.03: Plant dry weight and size of crown carbohydrate pool (g/plant) before and after simulated autumn. Plants were transferred from a heated glasshouse (minimum temperature 13\textdegree{}C) on 22 March and sampled 7 weeks later. Plants transferred to natural conditions senesced faster than those at 12.5\textdegree{}C. Plants transferred to 20\textdegree{}C underwent a growth flush. Data from 8 and 16 hour photoperiods at 12.5\textdegree{}C and 20\textdegree{}C combined. Bars represent twice standard error of mean.

A: Dry weight of new roots, old roots and fern.
B: Dry weight of crown and carbohydrate pool.

Figure 5.04: Composition of carbohydrates in storage roots before and after simulated autumn. Plants were transferred from a heated glasshouse (minimum temperature 13\textdegree{}C) on 22 March and sampled 7 weeks later. Plants transferred to natural conditions senesced faster than those at 12.5\textdegree{}C. Plants transferred to 20\textdegree{}C underwent a growth flush. Data from 8 and 16 hour photoperiods at 12.5\textdegree{}C and 20\textdegree{}C combined. Bars represent twice standard error of mean.

Figure 5.05: Crown and spear dry weight and size of carbohydrate pool (g/plant) during simulated winter and spear harvest at 12.5\textdegree{}C or 20\textdegree{}C. Plants were chilled at 2, 5, or 10\textdegree{}C for 5 or 10 weeks during ‘winter’. Plants transferred to growing temperature on 22 March and 26 May were from a heated glasshouse (minimum temperature 13\textdegree{}C); plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks. Bars represent twice standard error of mean.

A: Before spear harvest
B: After spear harvest at 12.5\textdegree{}C
C: After spear harvest at 20\textdegree{}C
Figure 5.06: Effect of chilling on concentration of carbohydrates (% DW) during simulated winter and spear harvest at 12.5C or 20C. Plants were chilled at 2, 5, or 10C for 5 or 10 weeks during 'winter'. Plants transferred to growing temperature on 22 March and 26 May were from a heated glasshouse (minimum temperature 13C); plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks. Bars represent twice standard error of mean.

Figure 5.07: Effect of spear harvest at 12.5C or 20C on composition of carbohydrates in roots. Plants transferred to growing temperature on 22 March and 26 May were from a heated glasshouse (minimum temperature 13C); plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks. Data from chilling temperatures of 2, 5 or 10C combined. Bars represent twice standard error of mean.
A: Concentration of carbohydrates before spear harvest
B: Concentration of carbohydrates after spear harvest at 12.5C
C: Concentration of carbohydrates after spear harvest at 20C.
LIST OF TABLES

Table 2.01: Conditions in DSIR Climate Laboratory controlled environment rooms for plants at each temperature regime 12

Table 3.01: The labelling and sampling dates for all treatments in the source-sink experiment. 35

Table 3.02: Frequency of rhizome types in plants sampled from February to May. 44

Table 3.03: Correlation (r) between mobilising ability (\(^{14}\)C content), (with respect to the labelled fern), of axillary or secondary rhizomes and other plant attributes at sampling, and it’s significance (P). Plants were labelled by exposing the youngest fern to \(^{14}\)CO\(_2\) in January, February or March, and sampled 4 to 12 weeks later, before the end of April. 46

Table 3.04b: Concentration of \(^{14}\)C (dpm x 10\(^3\)/g) recovered from sinks within male asparagus plants labelled with a pulse of \(^{14}\)C during fern growth: effect of labelling date on competitive ability for current assimilate, i.e. 4 weeks after labelling. Standard error of mean is in brackets. 54

Table 3.04c: Dry weight (g) recovered from sinks within male asparagus plants during vegetative growth: sink dry weight 4 weeks after labelling with a pulse of \(^{14}\)C. Standard error of mean is in brackets 55

Table 3.05a: Total \(^{14}\)C (dpm x 10\(^3\)) recovered from sinks within male asparagus plants labelled with a pulse of \(^{14}\)C during fern growth: changes in ‘mobilising ability with respect to the labelled fern’ over time. Standard error of mean is in brackets. 56

Table 3.05b: Concentration of \(^{14}\)C (dpm x 10\(^3\)/mg) recovered from sinks within male asparagus plants labelled with a pulse of \(^{14}\)C during fern growth: changes in competitive ability over time. Standard error of mean is in brackets. 57
Table 3.05c: Dry weight (g) recovered from sinks within male asparagus plants during vegetative growth: changes in sink dry weight over time. Standard error of mean is in brackets.

Table 3.06a: Total \(^{14}\)C (dpm x \(10^3\)) recovered from sinks within male asparagus plants labelled with a pulse of \(^{14}\)C during fern growth: effect of labelling date on plants sampled in April. Standard error of mean is in brackets.

Table 3.06b: Concentration of \(^{14}\)C (dpm x \(10^3/g\)) recovered from sinks within male asparagus plants labelled with a pulse of \(^{14}\)C during fern growth: effect of labelling date on plants sampled in April. Standard error of mean is in brackets.

Table 3.06c: Dry weight (g) recovered from sinks within male asparagus plants during vegetative growth: effect of labelling date on plants sampled in April. Standard error of mean is in brackets.

Table 3.07a: Male plants labelled with a pulse of \(^{14}\)C in mid January and sampled 4 weeks later: mobilising ability with respect to the labelled fern expressed as a percentage of the \(^{14}\)C recovered.

Table 3.07b: Male plants labelled in mid January with a pulse of \(^{14}\)C and sampled 4 weeks later: competitive ability expressed as percentage \(^{14}\)C recovered/percentage dry weight.

Table 3.07c: Male plants labelled with a pulse of \(^{14}\)C in mid January and sampled 4 weeks later: total weight, and dry weight as a percentage of total weight.

Table 3.08a: Male plants labelled with a pulse of \(^{14}\)C in mid February and sampled 4 weeks later: mobilising ability with respect to the labelled fern expressed as a percentage of \(^{14}\)C recovered.

Table 3.08b: Male plants labelled with a pulse of \(^{14}\)C in mid February and sampled 4 weeks later: competitive ability expressed as a percentage of the \(^{14}\)C recovered/percentage dry weight.
Table 3.08c: Male plants labelled with a pulse of $^{14}$C in mid February and sampled 4 weeks later: total dry weight and dry weight expressed as a percentage of total.

Table 3.09a: Total $^{14}$C (dpm x 10$^3$) recovered from sinks within male asparagus plants, females with berries and females without berries labelled with a pulse of $^{14}$C in mid January: differences in mobilising ability with respect to the labelled fern within and between plants. Standard error of mean is in brackets.

Table 3.09b: Concentration of $^{14}$C (dpm x 10$^3$/mg) recovered from sinks within male asparagus plants, females with berries and females without berries labelled with a pulse of $^{14}$C in mid January: differences in competitive ability within and between plants. Standard error of mean is in brackets.

Table 3.09c: Dry weight (g) recovered from sinks within male asparagus plants, females with berries and females without berries labelled with a pulse of $^{14}$C in mid January: differences within and between plant. Standard error of mean is in brackets.

Table 4.01: The effect of temperature on chill unit accumulation on fruit trees with a range of chilling requirements (from Saure 1985). The trees were located at the sites the models are named after.

Table 4.02: Mean air and soil temperatures (30 year normals) during spring and autumn harvest at the Palmerston North DSIR meteorological station.

Table 4.03: Temperature regimes applied to plants in Experiment A: fern senescence and spear growth in autumn.

Table 4.04: Temperature regimes applied to plants in Experiments B and D: Effect of simulated winter temperatures on subsequent spear growth.

Table 4.05: Temperature regimes applied to plants in Experiment C: Plants exposed to natural conditions before transfer to 12.5C.
Table 4.06: Chi-squared analysis on the effects of various factors on the position of the first bud to grow following transfer to 12.5C or 20C.  

Table 4.07: Chi-squared analysis on the effects of various factors on budbreak pattern within the first three spears to grow following transfer to 12.5C or 20C.  

Table 4.08: Mean relative spear growth rates (RSGR) of first two spears to grow on rhizomes of ‘Rutger’s Beacon’ with budbreak pattern of ‘1 2 3’ or ‘2 1 3’. Standard errors of means in brackets.  

Table 4.09: Time at which a spear commences exponential growth (T0), and subsequently reaches 200mm in length (T200) at 12.5C for the first two spears per rhizome when the second bud commences growth before the basal bud. Plants transferred to growing conditions on 22 March and 26 May were from the heated glasshouse (minimum temperature 13C); plants transferred on 2 July had been chilled for 5 weeks; plants transferred on 10 August had been chilled for 10 weeks.  

Table 4.10: Effect of photoperiod on time to budbreak (days) and relative spear growth rate (RSGR, mm/mm/day) of plants at 20C in a simulated autumn harvest. Effect of photoperiod not significant at P=0.05 in analysis of variance. Standard error of mean in brackets.  

Table 4.11: Effect of plant sex on time to budbreak (days) and relative spear growth rate (RSGR, mm/mm/day) of plants at 12.5C or 20C in a simulated autumn and spring harvests. Standard error of mean is in brackets.  

Table 4.12: Genotypic differences in mean number of active rhizomes per plant, 3 weeks after transfer to 20C or 5 weeks after transfer to 12.5C. Standard errors of means in brackets. Note that plants chilled for zero weeks do not have a chilling temperature.  

Table 5.01 Summary of literature on asparagus carbohydrate reserves.  

Table 5.02: Effect of chilling on dry weight and number of old and new roots on crowns of asparagus plants chilled at 2, 5 or 10C, starting on 26 May.
Data for 5 and 10 weeks chilling combined. Standard error of means in brackets

Table 5.03a: Carbohydrate budget for plants harvested at 12.5C. Data from plants chilled at 2, 5 and 10C pooled. Standard errors of means in brackets.

Table 5.03b: Carbohydrate budget for plants harvested at 20C. Data from plants chilled at 2, 5 and 10C pooled. Standard errors of means in brackets.

Table 5.04: Composition of crown fructans, crown dry weight and percentage dry matter in asparagus plants in simulated autumn, winter and spring. Standard errors of means in brackets. Plants sampled on 10 May had senesced in natural conditions; plants sampled on 26 May were from a heated glasshouse (minimum temperature 13C); plants sampled on 10 August had been chilled for 10 weeks; plants sampled on 25 September had been transferred to ‘spring’ temperatures on 10 August, after 10 weeks chilling. Data from chilling temperatures of 2, 5, and 10C combined.

Table 5.05: Correlations between carbohydrate oligomers comprising the storage carbohydrate in asparagus roots and other measures of the size of the carbohydrate pool. (All correlations listed statistically significant at P=0.0001)

Table 5.06: Effect of plant sex on crown dry weight, crown carbohydrate pool (g/plant) and concentration of carbohydrate (% DW) during a simulated winter and subsequent spring harvest. Standard errors of means in brackets. Plants were sampled before transfer to ‘spring’ temperature on 26 May, 2 July and 10 August, and after 5 weeks of harvesting at 12.5C or 20C. Data from 12.5C and 20C combined.

Table 5.07: Effect of plant sex on weight (g/plant) and number of old and new roots following winter and subsequent spring harvest. Standard errors of means in brackets. Plants were sampled before transfer to ‘spring’ temperature on 26 May, 2 July and 10 August, and after 5 weeks of harvesting at 12.5C or 20C. Data from 12.5C and 20C combined.
Table 6.01: Temperate climate in which asparagus growth was modelled: temperature normals and daylength. Data from DSIR, Palmerston North, latitude 40 23S, longitude 175 37E (meteorological station E05363).

Table 6.02: A model of asparagus growth in a temperature climate: summary of phenology, agronomic practices and status of carbohydrate reserves associated with spring harvest of a mature crop.

Table 6.03: Carbohydrate status at end of each phase of growth of a male plant with a 100g rhizome. The plant was harvested for 4 weeks in spring.

Table 6.04: Carbohydrate status at end of each phase of growth of a male plant with a 200g rhizome. The plant was harvested for 10 weeks in spring.

Table 6.05: Carbohydrate status at end of each phase of growth of a female plant with a 200g rhizome. The plant was harvested for 10 weeks in spring.