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**The kinetics of spear growth and
asparagus productivity: control by
environmental and internal factors**



Ku, Yang Gyu

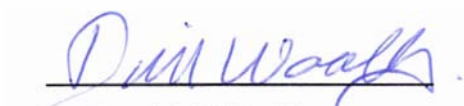
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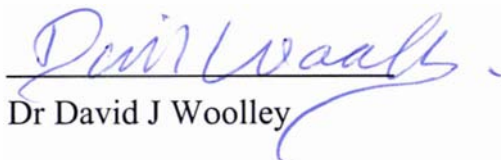
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Dr David J Woolley

10-08-06
Date

**The kinetics of spear growth and
asparagus productivity: control by
environmental and internal factors**

**A thesis presented in partial fulfilment
of the requirements for the degree of**

DOCTOR OF PHILOSOPHY

in

Plant Science

**at Massey University, Palmerston North,
New Zealand**

Ku, Yang Gyu

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ABSTRACT

Studies on asparagus growth in relation to yield were undertaken in environmentally controlled growth cabinets and in greenhouses. Bud production during the annual growth cycle was also investigated in the field. Growth cabinet experiments showed that increasing the temperature had a significant effect on bud break and relative spear growth rate (RSGR), but although prior chilling had a significant effect on the length of time to bud break at 10°C and 15°C, the effect on RSGR was not so clear. The cytokinin-active compound, *N*-(2-chloro-4-pyridyl)-*N'*-phenylurea (CPPU), and the naturally occurring cytokinin, zeatin riboside (ZR) significantly stimulated spear elongation. However, spear leaf scale removal reduced spear elongation in the absence and presence of CPPU. CPPU only stimulated spear growth when spear leaf scales were present, indicating that other plant hormones may interact with cytokinins in promoting elongation. The importance of spear growth rate to yield was discussed.

In greenhouse experiments, CPPU applied as a foliar spray at 10 or 20 mg L⁻¹ was effective in producing longer and thicker cladodes that might be associated with increased photosynthetic rate. However, photosynthetic rate was unaffected by 10 mg L⁻¹ CPPU treatment. Repeated CPPU applications to foliage reduced net assimilation rate (NAR) compared to untreated controls as determined by growth analysis studies. In asparagus plants, it was difficult to collect xylem sap and further experiments were undertaken with *Capsicum annuum*. The root exudate of CPPU-treated plants significantly decreased hypocotyl length in the lettuce gibberellin bioassay, suggesting that CPPU blocks gibberellin biosynthesis in roots. However, the application of GA₃ to shoots did not reverse growth suppression caused by CPPU-treated roots.

Bud production, both in growth cabinets and in open field plantings, started to occur during the spear harvest period in contrast to previously accepted views. During harvest three to four additional buds per cluster were produced in cabinet-grown plants and an average of 51 buds per m² in field plantings. These results confirm that new bud initiation and development starts to occur during spear harvest, as well as during fern growth and establishment.

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EXTENDED SUMMARY

Studies on asparagus growth were undertaken both in environmentally controlled growth cabinets and in greenhouses. A field experiment was also carried out to investigate bud production during the annual growth cycle. Two main experiments were carried out in the growth cabinets; one studied the effects of length of chilling and growing temperature on dormancy of crown buds and subsequent rates of spear growth, the other studied the effects of plant hormones and spear leaf scales on spear growth.

In growth cabinet experiments, one main experiment was the effect of different chilling periods at several different growing temperatures on bud break, and relative spear growth rate (RSGR) of asparagus. In the first experiment, twenty-two-month asparagus non-chilled plants of 'Apollo' and 'Desto' were placed into controlled growth cabinets at one of five temperatures (15°C, 20°C, 25°C, 30°C, and 35°C) for two months. In the second and third experiment, two and half year plants of 'Dariana' and five-year-old plants of 'Apollo' were placed in a coolstore at 5°C for 0, 3 and 6 weeks. After the specified chilling time, the pots were placed into controlled growth cabinets at one of five temperatures (10°C, 15°C, 20°C, 25°C, and 30°C) for 'Apollo' and three temperatures (20°C, 25°C, and 30°C) for 'Dariana' in dark conditions. The results showed that increasing the temperature had a significant effect on the time to bud break, but at 15°C and below chilling had a significant effect on the timing of bud break. Chilling facilitated commercial production by hastening bud break at lower temperatures. The RSGR increased with increasing temperature from 10°C to 30°C, but the effect of prior chilling on RSGR was not clear, possibly because control plants received some chilling due to insufficient heating in the glasshouse. The growth of spears was mainly exponential (constant RSGR) from 20°C to 30°C. At 15°C, 56.9% of the spears showed exponential growth and 8.1% linear growth. At 10°C and 35°C less than 50% showed exponential growth. These results confirm that at 10°C and 35°C spear growth tended to be linear while between 15°C and 30°C spears grew exponentially. Thus growing temperatures are important factors for affecting RSGR and time to bud break, but the effect on bud break and RSGR may be modified by the amount of prior chilling.

The other main experiment investigated the effect of plant growth regulators and spear leaf scales on spear elongation in asparagus. Spears of uniform size were immersed completely in indole-3-acetic acid (IAA), abscisic acid (ABA), gibberellic acid (GA_3) or *N*-(2-chloro-4-pyridyl)-*N'*-phenylurea (CPPU) in test tubes. IAA and GA_3 slightly stimulated, and ABA inhibited, elongation of specific regions of the shoot, but overall the effects on total spear elongation were small. In contrast CPPU and ZR significantly stimulated spear elongation. Increasing CPPU concentration from 0 to 10 mg L⁻¹ increased the elongation rate of spears. CPPU may influence spear length by stimulating the biosynthesis of native cytokinins or other plant growth promoter hormones as the naturally occurring cytokinin, ZR, was also found to stimulate spear elongation. However, spear leaf scale removal reduced spear elongation in the absence and presence of CPPU. CPPU only stimulated spear growth when spear leaf scales were present, indicating that other plant hormones may interact with cytokinins in promoting elongation.

In greenhouse experiments, the effect of CPPU application to foliage (foliar spray and foliar dip), soil drench and roots (crown soaking) on fern numbers, cladophyll length and diameter, root number and bud production was investigated. CPPU applied as a foliar spray, foliar dip and root soak decreased fern numbers, but drenching asparagus crowns with CPPU at 10 mg L⁻¹ was effective in stimulating fern numbers, which may increase canopy size and photosynthetic surface area. The increase in fern might be expected to improve crown activity (root dry weight, bud number, root number, and total bud numbers). However, CPPU-treated plants did not show increased crown activity. CPPU applied as a foliar spray was effective in producing longer and thicker cladodes, features often associated with increased photosynthetic rates. However, photosynthetic rates were unaffected by CPPU foliar spray.

It was observed that the cladodes of new ferns were of normal size, and that therefore repeat foliar sprays of CPPU were required to increase the diameter and length of cladodes of subsequent ferns. Repeated CPPU foliar sprays significantly increased cladophyll surface area and cladophyll dry weight, but decreased root dry matter and the number of buds. Despite the higher cladophyll surface area, CPPU did not increase photosynthetic efficiency as measured by relative growth rate (RGR) and net assimilation rate (NAR).

Soaking asparagus crowns in 10 mg L^{-1} CPPU decreased fern height, root dry weight and crown buds of asparagus, suggesting that CPPU applied as a crown soak may affect plant hormones in roots such as gibberellins. Because of difficulty in collecting xylem sap from asparagus plants, further experiments were undertaken with pepper plants. Root applied CPPU at 10 mg L^{-1} significantly decreased plant height, probably by inhibiting the activity of the sup-apical region of shoot, reduced internode number and length at 2 and 4 weeks after treatment, and suppressed root growth. Leaf water potential of the 10 mg L^{-1} CPPU-treated plants was lower than untreated controls, suggesting the smaller root systems of CPPU-treated plants may limit water uptake. Xylem sap collected from the roots of CPPU-treated *Capsicum* plants had less detectable gibberellin, possibly associated with blocking of gibberellin biosynthesis. However, GA_3 foliar spray at 100 mg L^{-1} did not reverse growth suppression caused by the CPPU treatments of pepper roots.

Bud production both in growth cabinets and in open field plantings occurred during the spear harvest period. Under the growth cabinet conditions, during spear harvest new buds were produced but new buds per cluster were not influenced by temperatures between 15°C to 30°C , while at 10°C bud production decreased. Three to four additional new buds were produced per cluster during the spear harvest period. Thus, as well as slowing spear growth, temperatures below 15°C may limit the production of new buds, and thus subsequent yield. In field plantings an average 51 buds per m^2 were produced during the spear harvest period. These results confirm that bud initiation and development occurs during harvest season as well as during the summer.

TABLE OF CONTENTS

ABSTRACT	II
ACKNOWLEDGEMENTS.....	III
EXTENDED SUMMARY.....	V
TABLE OF CONTENTS.....	VIII
LIST OF TABLES.....	XIV
LIST OF FIGURES.....	XVII
LIST OF ABBREVIATIONS	XXIII

CHAPTER 1

GENERAL INTRODUCTION

1.1 Introduction	1
1.2 Botany and morphology of Asparagus	2
1.3 Physiology of asparagus in relation to phenology and yield	5
1.3.1 Phenology	5
1.3.1.1 Dormancy	5
1.3.1.1.1 The induction and maintenance of dormancy.....	5
1.3.1.1.2 The release of dormancy.....	7
1.3.1.1.3 Hormonal control of innate winter dormancy	8
1.3.1.1.4 Chill units of perennial fruit and vegetables.....	9
1.3.1.2 Correlative inhibition (CI).....	11
1.3.2 Yield	13
1.3.2.1 CH ₂ O level.....	13
1.3.2.2 Bud number and size	16
1.3.2.3 Spear elongation rates.....	17
1.3.2.3.1 Temperature.....	17
1.3.2.3.2 Spear growth in relation to hormones.....	19
1.3.2.3.3 Cell division and elongation	19
1.3.2.3.4 Apical region and sub-apical meristem	20
1.3.2.4 Root growth	21

1.3.2.5 Photosynthetic rate and Net assimilation rate	21
1.3.2.6 Growth analysis	23
1.3.2.7 Root-shoot relationships	25
1.3.2.7.1 Root-shoot communication.....	25
1.3.2.7.2 Root-shoot allometric relationship	25
1.4 Rationale for thesis and use of CPPU.....	27

CHAPTER 2

EFFECT OF PLANT GROWTH REGULATORS AND SPEAR BUD SCALES ON GROWTH OF *ASPARAGUS OFFICINALIS* SPEARS

2.1 Introduction	30
2.2 Materials and methods.....	31
2.2.1 Experiment 1	31
2.2.2 Experiment 2	32
2.2.3 Experiment 3	32
2.2.4 Experiment 4	32
2.2.5 Data analysis.....	33
2.3 Results	34
2.3.1 Experiment 1	34
2.3.2 Experiment 2	36
2.3.3 Experiment 3	38
2.3.4 Experiment 4	39
2.4 Discussion.....	40
2.5 Summary.....	42

CHAPTER 3
THE EFFECT OF CHILLING DURATION AND TEMPERATURE ON
ASPARAGUS SPEAR GROWTH

3.1 Introduction	44
3.2 Materials and methods.....	45
3.2.1 Experiment 1	46
3.2.1.1 Plant materials and temperatures.....	46
3.2.1.2 Measurements of spear height.....	46
3.2.1.3 Relative spear growth rate (RSGR).....	46
3.2.1.4 Data analysis.....	47
3.2.2 Experiment 2	47
3.2.3 Experiment 3	47
3.2.4 Experiment 4	48
3.2.4.1 Plant material and experimental conditions.....	48
3.2.4.2 Measurements of spear height, bud break and bud numbers.....	48
3.2.4.3 Data analysis.....	49
3.2.5 Experiment 5	49
3.3 Results	50
3.3.1 Experiment 1	50
3.3.2 Experiment 2	52
3.3.3 Experiment 3	53
3.3.4 Experiment 4	55
3.3.5 Experiment 5	61
3.4 Discussion.....	62
3.5 Summary.....	66

CHAPTER 4
EFFECT OF CPPU TREATMENTS ON ASPARAGUS GROWTH AND DEVELOPMENT

4.1 Introduction	68
4.2 Materials and methods.....	69
4.2.1 Experiment 1	69
4.2.2 Experiment 2	70
4.2.3 Experiment 3	70
4.2.4 Measurements of plant growth	71
4.2.5 Measurements of cladophyll length and width.....	72
4.2.6 Data analysis.....	72
4.3 Results	73
4.3.1 Experiment 1	73
4.3.2 Experiment 2	80
4.3.3 Experiment 3	83
4.4 Discussion.....	88
4.5 Summary.....	90

CHAPTER 5
EFFECT OF CPPU TREATMENT ON FERN NUMBER, BUD NUMBER, AND PHOTOSYNTHETIC RATE

5.1 Introduction	92
5.2 Materials and methods.....	93
5.2.1 Experiment 1	93
5.2.2 Experiment 2	94
5.3 Results	95
5.3.1 Experiment 1	95
5.3.2 Experiment 2	98
5.4 Discussion.....	99
5.5 Summary.....	100

CHAPTER 6
EFFECTS OF REPEATED CPPU APPLICATION ON PLANT GROWTH AND DEVELOPMENT

6.1 Introduction	102
6.2 Materials and methods.....	102
6.2.1 Plant materials and experimental conditions.....	102
6.2.2 Measurements of plant growth	103
6.2.3 Relative growth rate (RGR), Leaf area ratio (LAR), Net assimilation rate (NAR), Specific leaf area (SLA), and Leaf weight ratio (LWR).	103
6.2.4 The root-total dry weight allometric ratio	104
6.2.5 Data analysis.....	105
6.3. Results	106
6.4 Discussion.....	120
6.5 Summary.....	121

CHAPTER 7
EFFECT OF CPPU TREATMENT OF *CAPSICUM ANNUUM* L. cv. ‘Ancho St Luis’ ROOTS ON PLANT GROWTH CHARACTERISTICS

7.1 Introduction	123
7.2 Materials and Methods	124
7.2.1 Experiment 1	124
7.2.1.1 Experimental conditions and treatments.....	124
7.2.1.2 Measurements of plant height, internode number and length, flower number and dry weights	124
7.2.1.3 Measurements of stomatal conductance (gs) and photosynthesis	125
7.2.1.4 Data analysis.....	125
7.2.2 Experiment 2	125
7.2.2.1 CPPU concentration and GA ₃ treatments.....	125
7.2.2.2 Data analysis.....	126
7.3 Results	127
7.3.1 Experiment 1	127
7.3.2 Experiment 2	132
7.4 Discussion.....	137
7.5 Summary.....	139

CHAPTER 8

PLANT GROWTH, CHLOROPHYLL CONTENT, LEAF WATER POTENTIAL, PHOTOSYNTHETIC RATES AND GIBBERELLIN ASSAY OF ROOT EXUDATE OF *CAPSICUM* PLANTS TREATED WITH CPPU

8.1 Introduction	140
8.2 Materials and methods.....	141
8.2.1 Experimental conditions and treatments.....	141
8.2.2 Measurement of plant height, leaf area and leaf length & width	141
8.2.3 Chlorophyll content	142
8.2.4 Measurement of leaf water potential and photosynthesis.....	142
8.2.5 Xylem sap collection and lettuce bioassay method.....	142
8.2.6 Data analysis.....	143
8.3 Results	144
8.4 Discussion.....	154
8.5 Summary.....	156

CHAPTER 9

GENERAL DISCUSSION

9.1 Physiological factors affecting productivity in temperate climates.....	157
9.2 Bud break, spear growth rates and bud numbers.....	159
9.2.1 Bud break.....	159
9.2.2 Spear elongation	160
9.2.2.1 Correlative inhibition.....	161
9.2.3 New bud numbers (buds produced during the harvest period).....	164
9.2.4 Yield	165
9.3 Bud break and spear growth rates in relation to hormones	166
9.4 Yield and partitioning of dry matter in relation to CPPU treatments.....	168
9.4.1 Fern numbers	169
9.4.2 Root: shoot ratio	169
9.4.3 Photosynthesis	169
9.4.4 Bud numbers.....	170
9.5 Effect of CPPU treatments on pepper plant growth and development.....	170
9.6 Suggestions for further investigations	172
REFERENCES	174

LIST OF TABLES

Chapter 2

Table 2.1 Effects of CPPU on spear growth, fresh weight and stem diameter of 'Jersey Giant' over 96 hours.....36

Table 2.2 The effect of CPPU and the removal of spear leaf scales on spear length of 'UC-157' over 96 hours.....38

Chapter 3

Table 3.1 The number and percentage of spear growth patterns of two asparagus cultivars at four temperatures.51

Table 3.2 Growth pattern of 'Apollo' spears grown at five temperatures and three chilling treatments.57

Table 3.3 The number of new buds (cv. 'Apollo') per cluster produced at five growing temperature regimes and three chilling treatments.....60

Table 3.4 Comparison bud counts before and after spear harvest period of 'Jersey Giant' in the field. Old buds represent buds from previous season, new buds formed during the spear harvest.....61

Chapter 4

Table 4.1 Effect of CPPU foliar sprays and drench on fern production of 'Jersey Giant' plants.....73

Table 4.2 Effect of CPPU sprays on stem diameter of 'Jersey Giant' plants at week 12.76

Table 4.3 Effect of CPPU application to young asparagus on growth parameters emergence of asparagus seedlings at week 12.....79

Table 4.4 Effect of CPPU soaking of asparagus crowns on fern numbers of 'Jersey Giant' plants.80

Table 4.5 Effect of CPPU soaking of asparagus crowns on length of the longest fern of ‘Jersey Giant’ plants.....	80
Table 4.6 Effect of CPPU soaking of asparagus crowns on stem diameter, bud number, fern+bud number, cluster number and root number.....	82
Table 4.7 Effect of CPPU soaking of asparagus crown on fresh mass, dry mass, total dry weight and root to shoot ratio over a 2 month growth period.....	82
Table 4.8 Effect of CPPU foliar spray, foliar dip and crown soak on fern numbers of ‘Jersey Giant’ plants.....	83
Table 4.9 Effect of CPPU foliar spray, foliar dip and crown soak on the height of initial ferns of ‘Jersey Giant’ plants.....	83
Table 4.10 Effect of CPPU foliar spray, foliar dip and crown soak on the height of the subsequent ferns of ‘Jersey Giant’ plants.....	84
Table 4.11 Effect of CPPU foliar spray, foliar dip and crown soak on axillary shoot numbers of the initial fern.	85
Table 4.12 Effect of CPPU foliar spray, foliar dip and crown soak on axillary shoot length of the initial fern.	85
Table 4.13 Effect of three CPPU treatments on length, diameter, leaf area, fresh and dry weight of cladodes, and specific leaf weight (SLW mg cm ⁻²) of initial fern. Measurements were determined eight weeks after the three CPPU applications.....	86
Table 4.14 Effect of three CPPU treatments on stem diameter, number of primary branches of subsequent, and crown buds, total buds, clusters and storage roots of the crown 70 days after treatment.	86
Table 4.15 Effect of CPPU foliar spray, dip and treatment of crowns on fresh weight, dry weight, total dry weight, and shoot to root ratio of ‘Jersey Giant’ plants 70 days after treatment.....	87

Chapter 5

Table 5.1 Effect of foliar applied and root applied CPPU at 10 mg L ⁻¹ on length, diameter, fresh weight, and dry weight of cladodes 2 weeks after CPPU treatment.....	96
Table 5.2 Effect of CPPU foliar spray on photosynthetic rate, cladode dry weight and root dry weight of two cultivars twenty four days after treatment.	98

Chapter 7

Table 7.1 Effect of 10 mg L⁻¹ CPPU treatment of roots on plant height, internode number and length at week 2, 4, and 12 weeks after application.129

Table 7.2 Effect of CPPU-treated roots on photosynthetic rate, stomatal conductance, intercellular CO₂ concentration and stomatal resistance at week 5 after treatment.130

Table 7.3 Effect of root-applied CPPU on dry weight and total dry weight of plants, and root:shoot ratio at week 12.130

Table 7.4 Effect of GA₃ foliar sprays following root applied CPPU on plant characteristics of 'Ancho St Luis' pepper plants after 11 weeks.136

Chapter 8

Table 8.1 Effect of CPPU-treated roots on chlorophyll content (mg/g fresh weight) of 'California Wonder' leaves at 1, 3, 6, or 9 weeks after CPPU treatment.....148

Table 8.2 Effect of CPPU-treated roots on photosynthetic rate, stomatal conductance, intercellular CO₂ concentration and stomatal resistance by five weeks after treatment.150

Table 8.3 Effect of CPPU-treated roots on plant characteristics of 'California Wonder' at each harvest, 1, 3, 6, and 9 weeks after application.....151

Table 8.4 Effect of CPPU-treated roots on root exudate (g hour⁻¹) of 'California Wonder' at 1, 3, 6, or 9 week after CPPU treatment.....152

Chapter 9

Table 9.1 Difference between actual and estimated spear numbers grown at 10 and 15°C.....163

Table 9.2 Average monthly mean, maximum and minimum air temperatures (1971-2000 year) at National Climate Centre (<http://www.niwasience.co.nz/ncc>).166

LIST OF FIGURES

Chapter 1

Figure 1.1 The structure of asparagus: underground and above ground (After Nichols, 1996).....	4
Figure 1.2 Diagram of signals and four seasons response to the different types of dormancy (cited in Horvath et al., 2003).....	7
Figure 1.3 Fern growth and root carbohydrate during asparagus annual growth cycle in temperate regions (cited in Daningsih, 2005).....	14
Figure 1.4 Typical patterns of spear growth over time, linear (A), exponential (B, C) or two phases of exponential (D).....	18
Figure 1.5 Diagram of spear showing the position of spear tip, elongation zone and rest of the spear.	20
Figure 1.6 Structure and outline of this thesis.	28

Chapter 2

Figure 2.1 Effect of plant growth regulators on spear length of ‘Jersey Giant’ over time. Each point is the mean of five spears per treatment. Vertical bars represent the LSD at $P \leq 0.05$	34
Figure 2.2 The effect of plant growth regulators on mean segment length of ‘Jersey Giant’ spears over 102 hours (initial length of each segment = 20 mm). Vertical bars represent the standard error of mean (n = 5). The LSD for each segment is shown above (right corner).....	35
Figure 2.3 The effect of CPPU concentration on mean segment length of ‘Jersey Giant’ spears over 96 hours (initial length of each segment = 20 mm). Vertical bars represent the standard error of means (n = 15). The LSD for each segment is shown above (right corner) (Experiment 2).....	37

Figure 2.4 The effect of sucrose and zeatin riboside on spear length of ‘Rutgers Beacon’ spears over 100 hours grown at 25°C. Each point is the mean of eight spears per treatment. Vertical bars represent the LSD at $P \leq 0.05$ (Experiment 4).39

Chapter 3

Figure 3.1 The effect of temperature on relative spear growth rate (RSGR) of ‘Apollo’ and ‘Desto’ cultivars. Bars represent the standard error of the mean.....50

Figure 3.2 The effect of chilling on subsequent spear growth rates of ‘Apollo’ plants at 15°C. Plants were chilled in a coolstore at 5°C for two weeks and transferred to 15°C under dark conditions. Control plants remained at 15°C without chilling under dark condition.52

Figure 3.3 Relationship between growing temperature and chilling on mean days to bud break of 1st bud per cluster for ‘Dariana’ grown at 20°C, 25°C, and 30°C. Control: no chilling. Treated plants were chilled for either 3 or 6 weeks at 5°C. Bars represent the standard error of the mean.53

Figure 3.4 Effect of three temperatures and three chilling treatments on RSGR of ‘Dariana’ cultivar grown under dark condition. Control: no chilling, or plant chilled for 3 or 6 weeks at 5°C. Bars represent the standard error of the mean.....54

Figure 3.5 Effect of temperature and chilling on bud break of ‘Apollo’ plants. Each point is the mean of three plants. Bars represent the standard error of the mean.....55

Figure 3.6 Effect of temperature and chilling pre-treatment at 5°C (3 and 6 week combined) on RSGR of ‘Apollo’ plants in the dark. Bars represent the standard error of the mean (within symbol).56

Figure 3.7 Asparagus plants cv. ‘Apollo’ incubated at 20°C after a 3 week chilling pre-treatment. Dark brown buds were developed in the previous season and white buds developed during the harvest period.....58

Figure 3.8 “New” bud (cv. ‘Apollo’) producing a marketable spear. Large buds behind the spear, small buds in front.....59

Chapter 4

- Figure 4.1 Effect of foliar spray and drench of CPPU on height of initial ferns that were initially CPPU-treated at week 12. Vertical bar represents the LSD at $P \leq 0.05$ 74
- Figure 4.2 Effect of foliar spray and drench of CPPU on the longest height of subsequent ferns at week 12. Vertical bar represents the LSD at $P \leq 0.05$ 75
- Figure 4.3 Effect of CPPU foliar spray and CPPU drench on lateral bud breaking of 'Jersey Giant' plants 2 weeks after treatments. Bar represents the standard error of mean. 77
- Figure 4.4 Effect of CPPU spray on basal axillary bud break of 'Jersey Giant' plants. 78
- Figure 4.5 Effect of CPPU soaking of asparagus crowns on number of axillary buds growing (A) and axillary shoot lengths (B) at week 3. Vertical bars represent the standard error of means ($n = 7$). 81

Chapter 5

- Figure 5.1 Effect of foliar applied and root applied CPPU at 10 mg L^{-1} on fern numbers over 12 weeks. Each point is means of six plants. Vertical bars represent the LSD at $P \leq 0.05$ 95
- Figure 5.2 Effect of foliar applied and root applied CPPU at 10 mg L^{-1} on total buds (ferns + spear + crown buds) and buds on the crown 12 weeks after CPPU treatments (Treatments: A control + 0 mg L^{-1} foliar spray, B control + 5 mg L^{-1} foliar spray, C control + 10 mg L^{-1} foliar spray, D root application + 0 mg L^{-1} foliar spray, E root application + 5 mg L^{-1} foliar spray, F root application + 10 mg L^{-1} foliar spray). Bars with different letter are significant different by Duncan's multiple range test at $P \leq 0.05$ 97

Chapter 6

Figure 6.1 Log_e dry weights of total (A), roots (B), ferns (C), and rhizomes (D) of asparagus treated with or without CPPU foliar sprays. CPPU application was repeated after 4, 8, and 12 weeks. Each point is the means of eight plots. Vertical bars represent the LSD at $P \leq 0.05$ 107

Figure 6.2 Number of ferns (A), roots (B), crown buds (C), and total buds (fern + spear + bud) (D) of asparagus treated with CPPU foliar sprays. CPPU application was repeated after 4, 8, and 12 weeks. Each point is the means of eight plots. Vertical bars represent the LSD at $P \leq 0.05$ 109

Figure 6.3 Log_e cladode area and cladode dry weight of asparagus with CPPU foliar spray. CPPU application was repeated after 4, 8, and 12 weeks. Each point is the means of eight plots. Vertical bars represent the LSD at $P \leq 0.05$ 110

Figure 6.4 Relative growth rate (RGR) of two cultivars of asparagus seedlings treated with foliar sprays of CPPU. 111

Figure 6.5 Leaf area ratio (LAR) of two cultivars of asparagus seedlings treated with foliar sprays of CPPU. Vertical bars represent the LSD at $P \leq 0.05$ 112

Figure 6.6 Net assimilation rate (NAR) of two cultivars of asparagus seedlings treated with foliar sprays of CPPU. Vertical bars represent the LSD at $P \leq 0.05$ 113

Figure 6.7 Specific leaf area (SLA) of two cultivars of asparagus seedlings treated with foliar sprays of CPPU. Vertical bars represent the LSD at $P \leq 0.05$ 114

Figure 6.8 Leaf weight ratio (LWR) of two cultivars of asparagus seedlings treated with foliar sprays of CPPU. Vertical bars represent the LSD at $P \leq 0.05$ 115

Figure 6.9 Relationship between total and root dry weight for CPPU-treated and control plants. The regression of relationship between log_e total weight and log_e root weight for CPPU-treated plants and control plants are Log_e total dry weight = Log_e 1.20 + 0.78 x (Log_e root weight) and Log_e total dry weight = Log_e 1.03 + 0.82 x (Log_e root weight) respectively. 116

Figure 6.10 Log_e total dry weight (A), root (B), fern (C), and rhizome (D) of 'UC 157' and 'Jersey Giant' asparagus seedlings during 16 weeks growth after CPPU treatment. CPPU application was repeated after 4, 8, and 12 weeks. Each point is the means of eight plots. Vertical bars represent the LSD at $P \leq 0.05$ 117

Figure 6.11 Number of ferns (A), roots (B), crown buds (C), and total buds (fern + spear + bud) of 'UC 157' and 'Jersey Giant' asparagus seedlings during 16 weeks growth after CPPU treatment. CPPU application was repeated after 4, 8, and 12 weeks. Each point is the means of eight plots. Vertical bars represent the LSD at $P \leq 0.05$. 118

Figure 6.12 Relationship between total and crown dry weight with two cultivars. The regression of relationship between \log_e total dry weight and \log_e root weight for UC 157 and Jersey Giant are $\text{Log}_e \text{ total dry weight} = \text{Log}_e 1.25 + 0.79 \times (\text{Log}_e \text{ root weight})$ and $\text{Log}_e \text{ total dry weight} = \text{Log}_e 1.07 + 0.82 \times (\text{Log}_e \text{ root weight})$ respectively. 119

Chapter 7

Figure 7.1 Effect of 10 mg L^{-1} CPPU treatment of roots on chilli (*Capsicum annuum* L. cv. 'Ancho St Luis') plant height. Each point is the mean of five plants. Vertical bars represent the standard error of the mean. Upward arrows indicate the week after CPPU treatment when the first flower opened. 127

Figure 7.2 Pepper plants (*Capsicum annuum* L. cv. 'Ancho St Luis') treated with CPPU at 0 (control, left) and 10 mg L^{-1} (right) 5 weeks after CPPU treatment. Note the shorter internodes and increased lateral shoot number of the treated plants. 128

Figure 7.3 Pepper roots treated with CPPU at 10 mg L^{-1} (left) and 0 (control, right).. 131

Figure 7.4 Effect of root applied CPPU concentrations on plant height of chilli pepper plants. Each point is the mean of ten plants. Vertical bars represent the LSD at $P \leq 0.05$. L*** represents a significant linear trend to response to CPPU concentration at $P \leq 0.001$ 132

Figure 7.5 Effect of 100 mg L^{-1} GA₃ foliar sprays on plant height of CPPU-treated chilli pepper plants. Each point is the mean of twenty plants. ns, * and ** represents nonsignificant, significant at the $P \leq 0.05$ and significant at $P \leq 0.01$ 133

Figure 7.6 Effect of GA₃ foliar sprays following root applied CPPU on plant height of chilli pepper plants. Each point is the mean of five plants. Vertical bars at week 11 represent the standard error of the mean. 134

Figure 7.7 Effect of GA₃ foliar spray following CPPU soaked roots on flower number 11 weeks after treatment. Bars are the standard error of the mean. 135

Chapter 8

Figure 8.1 Effect of CPPU-treated roots on plant height of ‘California Wonder’ pepper. Each point is the mean of six plants per treatment. Vertical bars represent the LSD at $P \leq 0.05$ 144

Figure 8.2 Effect of CPPU-treated roots on leaf mid rib length and maximum width of ‘California Wonder’ pepper. Each point is the mean of eighteen leaves per treatment. Vertical bars represent the LSD at $P \leq 0.05$ 145

Figure 8.3 Effect of CPPU-treated roots on total leaf area of ‘California Wonder’ pepper. Each point is the mean of six plants per treatment. Vertical bars represent the LSD at $P \leq 0.05$ 146

Figure 8.4 Effect of CPPU-treated roots on average leaf area and mean leaf number of ‘California Wonder’ pepper. Each point is the mean of six plants per treatment. Vertical bars represent the LSD at $P \leq 0.05$ 147

Figure 8.5 Effect of CPPU-treated roots on leaf water potential of ‘California Wonder’ pepper. Each point is the mean of twelve leaves per treatment. Vertical bars represent the LSD at $P \leq 0.05$ 149

Figure 8.6 Lettuce hypocotyl assay of root exudates of CPPU plants (right graph) and corresponding standard curve for GA₃ response (left graph). Values followed by different letters are significantly different by LSD test at $P \leq 0.05$ (left graph). Vertical bars represent the LSD at $P \leq 0.05$ (right graph). 153

Chapter 9

Figure 9.1 Relationship between main physiological factors affecting asparagus yield as discussed in this thesis. 158

Figure 9.2 Three phases of correlative inhibition in asparagus bud clusters. 1. Inhibition period – time between growth of one spear and rapid growth of the subsequent spear. 2. Lag period – time between harvest of the previous spear and growth of the following spear. 3. Overlap period – period when both spears are growing simultaneously but the growth rate of one spear is reduced by the other (from Daningsih, 2005). 162

LIST OF ABBREVIATIONS

ABA	Abscisic acid
AD	Apical dominance
ANOVA	Analysis of variance
ATA	Auxin transport autoinhibition
BA	Benzyladenine
CCC	Chlormequat chloride
CI	Correlative inhibition
CP	Chilling period
CPPU	<i>N</i> -(2-chloro-4-pyridyl)- <i>N'</i> -phenylurea
CRD	Completely randomized design
CV	Cultivar
CVs	Cultivars
EC	Electrical conductivity
GA _n	Gibberellic acid _n - n denotes the acid number
GAs	Gibberellic acids
GS	Stomatal conductance
IAA	Indole-3-acetic acid
iRGR	Instantaneous relative growth rate
LAI	Leaf area index
LAR	Leaf area ratio
LSD	Least significant difference
LWR	Leaf weight ratio
NAA	α -naphthaleneacetic acid
NAR	Net assimilation rate
P _n	Net photosynthetic rate
\bar{R}	Mean relative growth rate
RGR	Relative growth rate
RSGR	Relative spear growth rate
SAS	SAS system for statistical analysis
SLA	Specific leaf area
SLW	Specific leaf weight
ZR	Zeatin riboside