## Table of contents

Acknowledgen	nent	iii
บทคัดย่อ		v
Abstract		viii
Table of conte	nt S	хi
List of table		xv
List of illustra	tions	xxi
Chapter 1	Introduction	1
Chapter 2	Review of Literature	4
1. Effe	ect of mango rootstocks on scions	4
	1.1 Effect on growth, yield and fruit quality of scions	4
	1.2 Effect on nutrient uptake of scions	6
	1.3 Effect on tolerance of scions	6
	1.4 Effect of everbearing mango rootstock on off-season flowering of scions	s 6
2. Env	vironment influence on growth and reproductive development	7
	2.1 Temperature	7
	2.2 Water relations	10
	2.3 Photoperiod	13
3. Hor	rmonal influence on flowering	13
<b>2.</b> 2.20.	3.1 Cytokinins	13
	3.2 Gibberellins	15
4 Pho	otoassimilate influence on flowering	17
	2 assimilation and stomatal behavior	18
		20
•	pacts of climatic variability	
Chapter 3	Material and Methods	29 29
1. Ma		29 29
	1.1 Experimental plants	29 29
	1.2 Other apparatus	رے

2	2.	Experimental Design		30
. 3	3.	Methods		31
Chapter	4	Results		37
1	۱.	Effect of scion-rootstock combinations on growth and develop	ment of mangoes	37
		1.1 Effect of scion-rootstock combinations on stem height		37
		1.2 Effect of scion-rootstock combinations on canopy width		44
		1.3 Effect of scion-rootstock combinations on stem diameter		51
2	2.	Effect of scion-rootstock combinations on terminal shoots		58
		2.1 Effect of scion-rootstock combinations on percentag	e of shooting	58
		2.2 Effect of scion-rootstock combinations on the number	er of new shoots	65
		2.3 Effect of scion-rootstock combinations on the number	er of shooting	70
		2.4 Effect of scion-rootstock combinations on the percent	ntage of flowering	74
		2.5 Effect of scion-rootstock combinations on the numb	er of flowering	78
		2.6 Effect of scion-rootstock combinations on the new s	hoots	83
3	3.	Effect of scion-rootstock combinations on yields		85
		3.1 Effect of scion-rootstock combinations on the ratio of r	nale to perfect flower	85
		3.2 Effect of scion-rootstock combinations on the percent	ntage of fruit setting	86
		3.3 Effect of scion-rootstock combinations on the average n	umber of fruit per tree	88
4	4.	Effect of scion-rootstock combinations on fruits qualities		89
		4.1 Effect of scion-rootstock combinations on fresh frui	t weight	89
		4.2 Effect of scion-rootstock combinations on fruit size		90
		4.3 Effect of scion-rootstock combinations on total solu	ble solids (TSS)	92
		4.4 Effect of scion-rootstock combinations on titratable	acid (TA)	93
;	5.	Effect of scion-rootstock combinations on net photosynthetic	rate	93
(	6.	Effect of scion-rootstock combinations on chlorophyll a and b con	tent of leaves	94
	7.	Effect of scion-rootstock combinations on the stomatal behav	vior .	95
		7.1 Effect of scion-rootstock combinations on the stoma	atal width	95
		7.2 Effect of scion-rootstock combinations on the stoma	atal density	101
		7.3 Effect of scion-rootstock combinations on the infilt	ration rate of leaves	103
	8.	Effect of scion-rootstock combinations on dry weight of mar	igo tree	107

8.1 Effect of scion-rootstock combinations on dry weight of roots, stems and leaves	107
8.2 Effect of scion-rootstock combinations on dry weight of whole plants	108
9. Effect of scion-rootstock combinations on total-nonstructural carbohydrate (TNC),	109
reducing sugar (RS) and nutrient content of leaves and new terminal shoots	
9.1 Effect of scion-rootstock combinations on total nonstructural carbohydrate:	109
(TNC) of leaves	
9.2 Effect of scion-rootstock combinations on reducing sugar: (RS) of leaves	111
9.3 Effect of scion-rootstock combinations on total nonstructural	113
carbohydrate:(TNC) of terminal shoots	
9.4 Effect of scion-rootstock combinations on reducing sugar:	115
(RS) of terminal shoots	
9.5 Effect of scion-rootstock combinations on total nitrogen; TN of leaves	117
9.6 Effect of scion-rootstock combinations on total nitrogen (TN) of terminal shoot	s 119
9.7 Effect of scion-rootstock combinations on carbohydrate/nitrogen	121
(C/N) ratio of leaves	
9.8 Effect of scion-rootstock combinations on C/N ratio of terminal shoots	123
9.9 Effect of scion-rootstock combinations on phosphorous of leaves	125
9.10 Effect of scion-rootstock combinations on potassium of leaves	127
9.11 Effect of scion-rootstock combinations on calcium of leaves	129
9.12 Effect of scion-rootstock combinations on magnesium of leaves	131
10. Effect of rootstock and scion-rootstock combinations on endogenous hormones	135
10.1 Effect of rootstock on cytokinins content in xylem exudate	135
10.2 Effect of scion-rootstock combinations on gibberellin-like substances	137
of terminal shoots during flowering	
Chapter 5 Discussion	140
1. Comparison of vegetative growth and development and flowering of mango between	140
El Niño and La Niña conditions.	
2. Effect of scion-rootstock combinations on growth and development of scions.	153
3. Effect of scion-rootstock combinations on flowering and fruit-setting.	154
4. Effect of scion-rootstock combinations on fruit qualities.	155

5. Effec	ct of scion-rootstock combinations on the amount of chlorophyll a and b of the leaves.	155
6. Effe	ct of scion-rootstock combinations on net photosynthetic rate	156
7. Effe	ct of scion-rootstock combinations on the stomatal behavior	157
	7.1 Effect of scion-rootstock combinations on the stomatal width	157
	7.2 Effect of scion-rootstock combinations on the stomatal density	161
8. Effe	ct of scion-rootstock combinations on dry weight of the scions	163
9. Effec	et of scion-rootstock combinations on carbohydrate of leaves and terminal shoots	163
	9.1 Effect of scion-rootstock combinations on amount of	163
	total non-structural carbohydrate (TNC) and reducing	
	sugar (RS)content of leaves during flowering	
	9.2 Effect of scion-rootstock combinations on amount of total non-structural	164
	carbohydrate (TNC) and reducing sugar (RS)	
	of the terminal shoot during flowering	
	9.3 Effect of scion-rootstock combinations on total nitrogen (TN) of leaves	167
	9.4 Effect of scion-rootstock combinations on total nitrogen (TN) of terminal shoots	167
	9.5 Effect of scion-rootstock combinations on carbohydrate/nitrogen ratio of leaves	167
	9.6 Effect of scion-rootstock combinations on C/N ratio of the terminal shoots	167
10. Effe	ect of scion-rootstock combinations on nutrients level of scions	168
11. Eff	ect of scion-rootstock combinations on endogenous hormones	169
11	1.1 Effect of scion-rootstock combinations on cytokinins content in xylem exudate	180
	.2 Effect of scion-rootstock combinations on gibberellin-like substances of	169
	terminal shoots during flowering	
Chapter 6	Conclusions	173
References		179
Curriculum vit	tae	195

## List of tables

		Page
Table		
4.1	Effect of scion-rootstock combinations on the percentage of stem height growth rate	37
	during June 1998 to November 1999	
4.2	Effect of scion-rootstock combinations on the cumulative percentage of stem height	42
	growth rate during June 1998 to November 1999	
4.3	Impact of El Niño and La Niña on the cumulative percentage of stem	43
	height growth rate. (El Niño = during June to September	
	1998; La Niña = during June to September 1999.)	
4.4	Effect of scion-rootstock combinations on the percentage of canopy width growth	44
	rate during June 1998 to November 1999	
4.5	Effect of scion-rootstock combinations on the cumulative of canopy width growth	49
	rate during June 1998 to November 1999.	
4.6	Impact of El Niño and La Niña on the cumulative percentage of canopy	50
	width growth rate. (El Niño = during June to September	
	1998; La Niña = during June to September 1999.)	
4.7	Effect of scion-rootstock combinations on the percentage of stem diameter growth	51
	rate during June 1998 to November 1999	
4.8	Effect of scion-rootstock combinations on cumulative percentage of stem diameter	r 56
	growth rate during June 1998 to November 1999	
4.9	Impact of El Niño and La Niña on the cumulative percentage of stem diameter	57
	growth rate. (El Niño = during June to September 1998;	
	La Niña = during June to September 1999.)	
4.10	Effect of scion-rootstock combinations on the percentage of shooting	58
	during May 1998 to March 2000	
4.11	Impact of El Niño and La Niña on the cumulative percentage of shooting.	64
	(El Niño = during May to September 1998; La Niña = during May	
	to September 1999)	

		Page
Table		
4.12	Effect of scion-rootstock combinations on the average numbers of new shoots	65
	during May 1998 to March 2000	
4.13	Effect of scion-rootstock combinations on the numbers of shooting	70
	during May 1998 to March 2000	
4.14	Effect of scion-rootstock combinations on the total numbers of shooting	74
	during May 1998 to March 2000	
4.15	Effect of scion-rootstock combinations on the percentage of flowering during	76
	May 1998 to March 2000	
4.16	Effect of scion-rootstock combinations on the numbers of flowering	79
	during May 1998 to March 2000	
4.17	Effect of scion-rootstock combinations on the total numbers of flowering	82
	during May 1998 to March 2000	
4.18	Effect of scion-rootstock combinations on number of leaves per new shoot	83
	during May 1998 to May 1999	
4.19	Effect of scion-rootstock combinations on the length of new shoot (cm) during	83
	May 1998 to May 1999	
4.20	Effect of scion-rootstock combinations on the diameter of new shoots (cm)	84
	during May 1998 to May 1999	
4.21	Effect of scion-rootstock combinations on the length of new leaves (cm)	84
	during May 1998 to May 1999	
4.22	Effect of scion-rootstock combinations on the width of new leaves (cm)	85
	during May 1998 to May 1999	
4.23	Effect of scion-rootstock combinations on the ratio of male to perfect flower	85
	during May to November 1998 (off-season)	
4.24	Effect of scion-rootstock combinations on the ratio of male to perfect flower	86
	during December 1998 to March 1999 (normal season)	
4.25	Effect of scion-rootstock combinations on percentage of fruit setting	86
	(fruit size of match' head) during May to November 1998 (off-season)	

	L. L	age
Table		
4.26	Effect of scion-rootstock combinations on percentage of fruit setting (fruit size of	87
	match's head) during December 1998 to March 1999. (normal-season)	
4.27	Effect of scion-rootstock combinations on percentage of fruit setting (fruit size of 1.5 cm)	87
	during May to November 1998. (off-season)	
4.28	Effect of scion-rootstock combinations on percentage of fruit setting (fruit size	88
	of 1.5 cm) during December 1998 to March 1999. (normal-season)	
4.29	Effect of scion-rootstock combinations on the average numbers of fruit per tree	88
	during May to November 1998. (off-season)	
4.30	Effect of scion-rootstock combinations on the average numbers of fruit per tree	89
	during December 1998 to May 1999. (normal-season)	
4.31	Effect of scion-rootstock combinations on fresh fruit weight (g) harvested during	89
	May to June 1999	
4.32	Effect of scion-rootstock combinations on fruit width (cm) harvested during	90
	May to June 1999	
4.33	Effect of scion-rootstock combinations on fruit length (cm) harvested during	91
	May to June 1999	
4.34	Effect of scion-rootstock combinations on fruit thickness (cm) harvested during	92
	May to June 1999	
4.35	Effect of scion-rootstock combinations on total soluble solids ( <sup>o</sup> Brix); TSS of fruits	92
	harvested during May to June 1999	
4.36	Effect of scion-rootstock combinations on titratable acids (%); TA of fruits	93
	harvested during May to June 1999	
4.37	Effect of scion-rootstock combinations on net photosynthetic rate (μmol CO <sub>2</sub> m <sup>-2</sup> s <sup>-1</sup> )	94
	of scions measured during 3-18 February, 2000 (08.30 to 10.30 a.m.)	

		Page
Table		
4.38	Effect of scion-rootstock combinations on chlorophyll a and b content (mg/g FW)	94
	of leaves	
4.39	Effect of scion-rootstock combinations on the stomatal width (μm) from	96
	the time 06.30 a.m. to 18.30 p.m.	
4.40	Effect of scion-rootstock combinations on the average stomatal width(μm) from	99
	06.30 a.m. to 18.30. p.m.	
4.41	Effect of scion-rootstock combinations on the stomatal density (number/mm <sup>2</sup> ) of leaves	101
4.42	Effect of scion-rootstock combinations on the infiltration rate (second) of leave	103
4.43	Effect of scion-rootstock combinations on dry weight (g) of roots	107
4.44	Effect of scion-rootstock combinations on dry weight (g) of stems	108
4.45	Effect of scion-rootstock combinations on dry weight (g) of leaves	109
4.46	Effect of scion-rootstock combinations on dry weight (g) of whole plants	111
4.47	Effect of scion-rootstock combinations on total-nonstructural carbohydrate (TNC)	113
	content (mg/g DW) of terminal shoots during inflorescence development	
4.48	Effect of scion-rootstock combinations on reducing sugar (RS) content (mg/g DW)	115
	of terminal shoots during inflorescence development	
4.49	Effect of scion-rootstock combinations on total-nitrogen (TN) content (% DW) of leaves	117
	during inflorescence development	
4.50	Effect of scion-rootstock combinations on total-nitrogen (TN) content (% DW)	119
	of terminal shoots during inflorescence development	

		Page
Table		
4.51	Effect of scion-rootstock combinations on carbohydrate/nitrogen (C/N) ratio	121
	of leaves during inflorescence development	
4.52	Effect of scion-rootstock combinations on carbohydrate/nitrogen (C/N) ratio	123
	of terminal shoots during inflorescence development	
4.53	Effect of scion-rootstock combinations on the level of phosphorous (% DW)	125
	of the terminal shoots' development during the flowering	
4.54	Effect of scion-rootstock combinations on the level of potassium (% DW)	127
	of the terminal shoots' development during the flowering	
4.55	Effect of scion-rootstock combinations on the level of calcium (% DW)	129
	of the terminal shoots' development during the flowering	
4.56	Effect of scion-rootstock combinations on the level of magnesium (%DW)	131
	of the terminal shoots' development during the flowering	9
4.57	Effect of scion-rootstock combinations on the mineral content (%DW)	133
	for all four stages	
4.58	Effect of rootstocks on zeatin/zeatin riboside (Z/ZR) level in xylem exudate	135
4.59	Effect of rootstocks on N <sup>6</sup> -( $\delta^2$ -Isopentenyl) adenine/N <sup>6</sup> -( $\delta^2$ -Isopentenyl) adenosine	136
	(iP/iPA) level in xylem exudate comparing between Choke Anan and Kaew	
4.60	Effect of scion-rootstock combinations on changes in the gibberellins-like	137
	substance (unit: x 10 <sup>-3</sup> μg/g FW) of shoot during Inflorescence development.	
4.61	Effect of scion-rootstock combinations on changes in the average gibberellins-like	139
	substance (unit : x $10^{-3} \mu\text{g/g}\text{FW}$ ) of shoot during Inflorescence development.	

		Page
Table	e	
5.1	Sea surface temperature anomaly (°C) in the Pacific Ocean (NOAA, 1999)	144
5.2	Climatological data for 1961-1996 with 1997 and 1998	144
5.3	The average stomatal width (µm) from 06.30 a.m. to 11.30 a.m.	158
	(the low temperature period: 21.1 to 28.7 °C) and from 13.30 p.m. to	
	17.30 p.m.(the high temperature period: 31.6 to 32.5°C)	
6.1	Effect of everbearing mango rootstocks on growth and development	175
	Physiology and flowering of scions	

## List of illustrations

		Page
Figure		
2.1	(a) Equatorial thermocline during the occurrence of (upper) La Niña	23
	conditions (middle) Normal conditions (lower) El Niño conditions	
	(cpc. NCEP/NOAA, 1999). (b) Sea surface temperature anomaly of	
	the Pacific Ocean surface during the occurrence of (upper) La Niña	
	conditions (middle) Normal conditions (lower) El Niño conditions	
	(U.S. Department of Commerce/NOAA/PMEL/TAO; 1999)	
3.1	The 4 stages of inflorescence development which collected from each	34
	of the experimental tree	
4.1	Effect of scion-rootstock combinations on the percentage of stem height growth	41
	rate during June 1998 to November 1999	
4.2	Effect of scion-rootstock combinations on the cumulative percentage of stem height	42
	growth rate during June 1998 to November 1999	
4.3	Impact of El Niño and La Niña on the cumulative percentage of stem	44
	height growth rate. (El Niño = during June to September 1998;	
	La Niña = during June to September 1999)	
4.4	Effect of scion-rootstock combinations on the percentage of canopy width growth rate	: 48
	during June 1998 to November 1999	
4.5	Effect of scion-rootstock combinations on the cumulative of canopy width growth	h 49
	rate for during June 1998 to November 1999	
4.6	Impact of El Niño and La Niña on the cumulative percentage of canopy	51
	width growth rate. (El Niño = during June to September 1998;	
	La Niña = during June to September 1999)	
4.7	Effect of scion-rootstock combinations on the percentage of stem diameter growth	. 55
	rate during June 1998 to November 1999	

		Page
Figur	re	
4.8	Effect of scion-rootstock combinations on cumulative percentage of stem	56
	diameter growth rate during June 1998 to November 1999	
4.9	Impact of El Niño and La Niña on the cumulative percentage of stem	58
	diameter growth rate. (El Niño = during June to September	
	1998; La Niña = during June to September 1999)	
4.10	Effect of scion-rootstock combinations on the percentage of shooting during	63
	May 1998 to March 2000	
4.11	Impact of El Niño and La Niña on the cumulative percentage of shooting	65
	(El Niño = during May to September 1998; La Niña = during May to September 1999	
4.12	Effect of scion-rootstock combinations on the average numbers of new shoots	69
	during May 1998 to March 2000	
4.13	Effect of scion-rootstock combinations on the percentage of flowering during	75
	May 1998 to March 2000	
4.14	Effect of scion-rootstock combinations on the total number of flowering during	82
	May to March 2000	
4.15	Effect of scion-rootstock combinations on fresh fruit weight harvested	90
	During May to June 1999)	
4.16	Effect of scion-rootstock combinations on fruit size (cm) harvested during	91
	May to June 1999	
4.17	Effect of scion-rootstock combinations on total soluble solids (OBrix)	92
	; TSS of fruit harvested during May to June 1999	
4.18	Effect of scion-rootstock combinations on titratable acid (%); TA of fruits harvested	98
-	during May to June 1999) unit : percent	
4.19	Effect of scion-rootstock combinations on the net photosynthetic rate (µmol CO <sub>2</sub> m <sup>-2</sup> s <sup>-1</sup> )	93
	of scions measured during 3-18 February, 2000 (08.30 to 10.30 a.m.)	
4.20	Effect of scion-rootstock combinations on the stomatal width (µm) from 06.30	98
	a.m. to 18.30 p.m.(upper), and the temperature dry bulb ( °C) and relative	
	humidity (%) in the experimental date (February 17, 2000) (lower)	
4.21	Effect of scion-rootstock combinations on the average stomatal width ( $\mu m$ )	99
	from 06.30 a.m. to 18.30. p.m.	

		Page
Figur	re	
4.21	Stomata of mango leaf cv. Khiew Sawoey on Choke Anan rootstocks at 12.30 p.m.,	100
	narrowest opening was 0.53 μm (upper) and cv. Pim Sen Mun on Choke Anan	
	rootstock at 10.30 a.m., widest opening was 3.01 µm (lower)	
4.23	Effect of scion-rootstock combinations on the stomatal density (number/mm²)	101
	of leaves	
4.24	Stomatal density of mango leaf cv. Khiew Sawoey on Kaew rootstock	102
	(upper), and cv. Nam Dok Mai on Choke Anan rootstock (lower)	
4.25	Effect of scion-rootstock combinations on the infiltration rate (second) of leaves	106
	(upper) and the temperature dry bulb ( °C) and relative humidity (%)	
	in the experimental date (April 1, 2000)(lower)	
4.26	Effect of scion-rootstock combinations on dry weight (g) of roots, stems and leaves	108
4.27	Effect of scion-rootstock combinations on dry weight (g) of whole plants	108
4.28	Effect of scion-rootstock combinations on the changes in the total nonstructural	110
	Carbohydrate (TNC) content (mg/g DW) of leaves during	
	inflorescence development	
4.29	Effect of scion-rootstock combinations on the changes in the reducing sugar	112
	(RS) content (mg/g DW) of leaves during inflorescence development.	
4.30	Effect of scion-rootstock combinations on the changes in the total nonstructural	114
	carbohydrate (TNC) content (mg/g DW) of the terminal shoots during	
	inflorescence development	116
4.31	Effect of scion-rootstock combinations on the changes in the reducing sugars	116
	(RS) content (mg/g DW) of terminal shoots during inflorescence development	118
4.32	Effect of scion-rootstock combinations on the changes in the total nitrogen (TN)	110
	content (%DW) of leaves during inflorescence development.	
4.33	Effect of scion-rootstocks combinations on the changes in the total nitrogen (TN)	120
	content (%DW) of terminal shoots during inflorescence development	
4.34	Effect of scion-rootstock combinations on the changes in the C/N ratio of leaves	122
	during inflorescence development	
4.35	Effect of scion-rootstock combinations on the changes in the in C/N ratio	124
	of terminal shoots during inflorescence development	

		Page
Figu	re	
4.36	Effect of scion-rootstock combinations on changes in the level of phosphorous	126
	(%DW) of leaves during inflorescence development	
4.37	•	128
	(% DW) of leaves during inflorescence development.	
4.38	Effect of scion-rootstock combinations on the level of calcium (% DW)	130
	of leaves during inflorescence development	
4.39	Effect of scion-rootstock combinations on the level of magnesium (% DW)	132
	of leaves during inflorescence development.	
4.40	Effect of scion-rootstock combinations on the average mineral content of	134
	leaves (%DW) for all four stages.	
4.41	Effect of rootstocks on zeatin/zeatin riboside (Z/ZR) level (ng/ml) in xylem exudate.	135
4.42	Effect of rootstocks on $N^6$ -( $\delta^2$ -Isopentenyl) adenine/ $N^6$ -( $\delta^2$ -Isopentenyl)	136
	adenosine(iP/iPA) level (ng/ml) in xylem exudate.	
4.43	Effect of scion-rootstock combinations on the changes in the gibberellin-like	138
	substances of terminal shoot during inflorescence development	
4.44	Effect of scion-rootstock combinations on changes in the average gibberellin-like	139
	substances (x $10^{-3}$ $\mu$ g/g FW) of shoot during inflorescence development	
5.1	Monthly rainfall during 1961-1996, 1997 and 1998	143
5.2	Numbers of Rainy day during 1961-1996 and 1997	143
5.3	Relatively Humidity during 1961-1996 and 1998	147
5.4	Maximum temperatures during 1961 to 1966, 1997 and 1998	147
5.5	Minimum temperatures during 1961 to 1996, 1997 and 1998	148
5.6	Mean temperatures during 1961 to 1996, 1997 and 1998	148
5.7	Off-season inflorescence of the mango cv. 'Nam Dok Mai' grafted on	150
	'Choke Anan' rootstock occurred during 'El Niño' condition (Photograped. at 1998,	
	July 27 at the experimental plot Department of Horticulture Chiang Mai	
	University)	

		Page
Figur	re .	
5.8	Off-season flowering which fruit-setting have fruit's size of match's head of the	150
	mango cv. 'Nam Dok Mai' grafted on 'Kaew' rootstock occurred during	
	'El Niño' condition (Photograped at 1998, July 27 at the experimental plot	
	Department of Horticulture Chiang Mai University)	
5.9	Off-season flowering which fruit-setting have fruit's size larger than 1.5 cm long	151
	of the mango cv. 'Nam Dok Mai' grafted on 'Choke Anan' rootstock	
	occurred during 'El Niño' condition (Photograped at 1998, July 27 at the	
	experimental plot Department of Horticulture Chiang Mai University)	
5.10	Off-season inflorescence of the mango cv. 'Pim Sen Mun' grafted on 'Choke Anan'	151
	rootstock occurred during 'El Niño' condition (Photograped at 1998, July	
	27 at the experimental plot Department of Horticulture Chiang Mai	
	University)	