

CONTENTS

	Page
Acknowledgement	iii
Abstract in Thai	iv
Abstract in English	vii
List of Tables	xv
List of Figures	xx
Statement of Originality	xxii
Chapter 1 Introduction	1
1.1 Historical background	1
1.2 Literature review	3
1.2.1 Grain structure and storage compounds	3
1) Structure of rice grain	3
2) Storage compounds in rice grain	4
1.2.2 Rice grain characteristic definitions and standards	7
1) International markets standard	7
2) Specific markets: Case studies in Thailand	10
3) Standard for Thai Hom Mali Rice	11
1.3 Nutritional quality of rice grain	12
1.3.1 Energy	12
1.3.2 Protein	12
1.3.3 Lipids	13
1.3.4 Vitamins	14
1.3.5 Minerals	14
1.4 Genotype x Environment interactions affecting rice grain quality	14
1.4.1 Effect of genotype x environment on milling quality	15

1.4.2	Effect of genotype x environment on cooking quality	16
1.4.3	Effect of genotype x environment on nutritional quality	18
1.5	Nutrients transport into rice plant	18
1.5.1	Nutrient uptake	18
1.5.2	Nutrients mobilization	20
1.5.3	Fe and Zn distribution in rice grain	22
1.5.4	Increasing Fe and Zn in rice grain	23
1.6	Objectives	24
Chapter 2	Effect of cropping season on rice grain quality	26
2.1	Introduction	26
2.2	Materials and methods	27
2.2.1	Rice varieties and culture	28
2.2.2	Data collection	28
2.3	Results	31
2.3.1	Meteorological environment	35
2.3.2	Yield and yield components	40
2.3.3	Milling quality	43
2.3.4	Nutritional quality	42
1)	Nitrogen in rice grain	47
2)	Phosphorus in rice grain	51
3)	Zinc in rice grain	54
4)	Iron in rice grain	58
2.4	Discussion	
Chapter 3	Effects of iron and zinc foliar application on rice grain quality	63
3.1	Introduction	63
3.2	Materials and Methods	65
3.2.1	Rice varieties and culture	65
3.2.2	Data collection	66
3.3	Results	67

3.3.1 Grain and milling quality	67
3.3.2 Nutritional quality	70
1) Zinc in rice grain	70
2) Iron in rice grain	75
3) Nitrogen in rice grain	80
4) Phosphorus in rice grain	85
3.4 Discussion	90
Chapter 4 Iron and zinc distribution along the grain length of different Thai rice varieties and implications on grain quality	93
4.1 Introduction	93
4.2 Materials and methods	94
4.2.1 Samples and varieties examined	94
4.2.2 Sample preparation	95
4.3 Results	96
4.3.1 Comparison of Fe and Zn concentrations between full and broken grain of commercial rice	96
4.3.2 The proportion of broken fractions	98
4.3.3 Distribution of Fe and Zn between grain fractions	101
4.3.4 Partitioning of Fe in grain fractions of brown and white rice	106
4.3.5 Partitioning of Zn in grain fractions of brown and white rice	108
4.4 Discussion	111
Chapter 5 General discussion	114
5.1 Rice yield and cropping season	114
5.2 Milling quality and cropping season	115
5.3 Nutritional quality and cropping season	116
5.4 Nutritional quality and foliar fertilizer	119
5.5 Genotypic variation of rice grain yield and quality	121
5.6 General conclusion	124
5.7 Future research	125

References	127
List of Publications	143
Curriculum Vitae	144



ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
 Copyright© by Chiang Mai University
 All rights reserved

LIST OF TABLES

	Page
Table 2.1 Grain appearance, disintegration rate and numerical scale for scoring gelatinization temperature	30
Table 2.2 The data of rice cropping in 3 season, rainy season, cool season and summer season from August 2009 to June 2010.	32
Table 2.3 Tiller number of 4 rice varieties grown in rainy, cool and summer seasons.	37
Table 2.4 Panicle number per plant of 4 rice varieties grown in rainy, cool and summer seasons	37
Table 2.5 Filled grain weight of 4 rice varieties grown in rainy, cool and summer	38
Table 2.6 Total grain weight (t/ha) of 4 rice varieties grown in rainy, cool and summer seasons.	38
Table 2.7 Thousand grain weight (g) of 4 rice varieties grown in rainy, cool and summer seasons.	39
Table 2.8 Percentage of head rice yield of 4 rice varieties when grown in rainy, cool and summer seasons	41
Table 2.9 Degree of milling of 4 rice varieties when grown in rainy, cool and summer seasons	41
Table 2.10 Percentage of grain chalkiness of 4 rice varieties grown in rainy, cool and summer seasons	42
Table 2.11 Alkali spread value of 4 rice varieties grown in rainy, cool and summer seasons	42
Table 2.12 The N concentration in brown rice of 4 rice varieties when grown in rainy, cool and summer seasons.	44
Table 2.13 The N concentration in white rice of 4 rice varieties when	44

	grown in rainy, cool and summer seasons	
Table 2.14	The milling loss of N of 4 rice varieties when grown in rainy, cool and summer seasons.	45
Table 2.15	The N content in brown rice of 4 rice varieties when grown in rainy, cool and summer seasons	45
Table 2.16	The N content in white rice of 4 rice varieties when grown in rainy, cool and summer seasons	46
Table 2.17	The P concentration in brown rice of 4 rice varieties when grown in rainy, cool and summer seasons	48
Table 2.18	The P concentration in white rice of 4 rice varieties when grown in rainy, cool and summer seasons	49
Table 2.19	The milling loss of P of 4 rice varieties when grown in rainy, cool and summer seasons	49
Table 2.20	The P content in brown rice of 4 rice varieties when grown in rainy, cool and summer seasons	50
Table 2.21	The P content in white rice of 4 rice varieties when grown in rainy, cool and summer seasons	50
Table 2.22	The Zn concentration in brown rice of 4 rice varieties grown in rainy, cool and summer seasons	52
Table 2.23	The Zn concentration in white rice of 4 rice varieties when grown in rainy, cool and summer season	52
Table 2.24	The milling loss of Zn of 4 rice varieties when grown in rainy, cool and summer seasons	53
Table 2.25	The Zn content in brown rice of 4 rice varieties when grown in rainy, cool and summer season	53
Table 2.26	The Zn content in white rice of 4 rice varieties when grown in rainy, cool and summer season	54
Table 2.27	The Fe concentration in brown rice of 4 rice varieties grown in rainy, cool and summer seasons	55

Table 2.28	The Fe concentration in white rice of 4 rice varieties grown in rainy, cool and summer seasons	56
Table 2.29	The milling loss of Fe of 4 rice varieties when grown in rainy, cool and summer seasons.	56
Table 2.30	The Fe content in brown rice of 4 rice varieties when grown in rainy, cool and summer seasons	57
Table 2.31	The Fe content in brown rice of 4 rice varieties when grown in rainy, cool and summer seasons	57
Table 3.1	Weight of filled grain of 4 rice varieties sprayed with 6 fertilizer treatments	68
Table 3.2	grain weight of 4 rice varieties sprayed with 6 fertilizer treatments	68
Table 3.3	Thousand filled grain weight of 4 rice varieties sprayed with 6 fertilizer treatments	69
Table 3.4	Percent head rice of 4 varieties after sprayed with 6 fertilizer treatments	69
Table 3.5	Zn concentration in brown rice of 4 varieties after sprayed with 6 fertilizer treatments	71
Table 3.6	The Zn concentration in white rice of 4 varieties after sprayed with 6 fertilizer treatments	72
Table 3.7	Zn content in brown rice of 4 varieties after sprayed with 6 fertilizer treatments	73
Table 3.8	The Zn content in white rice of 4 varieties after sprayed with 6 fertilizer treatments	74
Table 3.9	The Fe concentration in brown rice of 4 varieties after sprayed with 6 fertilizer treatments	76
Table 3.10	The Fe concentration in white rice of 4 varieties after sprayed with 6 fertilizer treatments	77
Table 3.11	The Fe content in brown rice of 4 varieties after sprayed with 6	78

	fertilizer treatments	
Table 3.12	The Fe content in white rice of 4 varieties after sprayed with 6 fertilizer treatments	79
Table 3.13	The N concentration in brow rice of 4 varieties after sprayed with 6 fertilizer treatments	81
Table 3.14	The N concentration in white rice of 4 varieties after sprayed with 6 fertilizer treatments	82
Table 3.15	The N content in brown rice of 4 varieties after sprayed with 6 fertilizer treatments	83
Table 3.16	The N content in white rice (mg/grain) of 4 varieties after sprayed with 6 fertilizer treatments	84
Table 3.17	The P concentration in brown rice of 4 varieties after sprayed with 6 fertilizer treatments	86
Table 3.18	The P concentration in white rice of 4 varieties after sprayed with 6 fertilizer treatments	87
Table 3.19	The P content in brown rice of 4 varieties after sprayed with 6 fertilizer treatments	88
Table 3.20	The P content in white rice of 4 varieties after sprayed with 6 fertilizer treatments	89
Table 4.1	The concentration of Fe in full and broken grains of four commercial rice samples from two markets in Chiang Mai, Thailand	97
Table 4.2	The concentration of Zn in full and broken grains of four commercial rice samples from two markets in Chiang Mai, Thailand	97
Table 4.3	Proportion by weight of the basal, middle and distal fractions of 5 commercial and 4 laboratory broken rice samples	99
Table 4.4	Proportion by number of the basal, middle and distal fractions of 5 commercial and 4 laboratory broken rice samples	100
Table 4.5	The Fe concentration in three fractions of brown rice of seven	102

	varieties	
Table 4.6	The Fe concentration in three fractions in white rice of seven varieties	103
Table 4.7	The Zn concentration in three fractions of brown rice of seven varieties	104
Table 4.8	The Zn concentration in three fractions of white rice of seven varieties	105
Table 4.9	Proportion of grain Fe in three grain fractions; basal, middle and distal of brown rice of seven varieties.	107
Table 4.10	Proportion of grain Fe in three grain fractions; basal, middle and distal of white rice of seven varieties	108
Table 4.11	Proportion of grain Zn in three grain fractions; basal, middle and distal of brown rice of seven varieties	109
Table 4.12	Proportion of grain Zn in three grain fractions; basal, middle and distal of white rice of seven varieties	110

LIST OF FIGURES

	Page
Figure 2.1 Daily maximum and minimum air temperature (°C) throughout the experimental period from August 2009 to June 2010	33
Figure 2.2 Daily relative humidity throughout the experimental period from August 2009 to June 2010	33
Figure 2.3 Daily rainfall (mm.) throughout the experimental period from August 2009 to June 2010	34
Figure 2.2 Daily sunshine duration (hrs.) throughout the experimental period from August 2009 to June 2010	34
Figure 2.5 Daily evaporation (mm.) throughout the experimental period from August 2009 to June 2010	35
Figure 2.6 Individual grain weight (mg) of 4 rice varieties grown in rainy, cool and summer seasons	39
Figure 3.1 Relationships between Zn concentrations in brown and white rice among four rice varieties after sprayed with 6 fertilizer treatments	72
Figure 3.2 Relationships between Fe concentrations in brown and white rice among 4 rice varieties after sprayed with 6 fertilizer treatments	77
Figure 5.1 Relative value of (A) total grain yield and (B) 1000 filled grain weight; of rice grown in three seasons (rainy, cool and summer)	118
Figure 5.2 Relative value of grain Fe of rice grown in the cool and summer seasons compared to the rainy season: (A) Fe concentration in brown rice, (B) Fe concentration in white rice, (C) Fe content in brown rice and (D) Fe content in white rice	118

Figure 5.3 Relative value of grain Zn of rice grown in the cool and summer seasons compared to the rainy season: (A) Zn concentration in brown rice, (B) Zn concentration in white rice, (C) Zn content in brown rice and (D) Zn content in white rice



ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

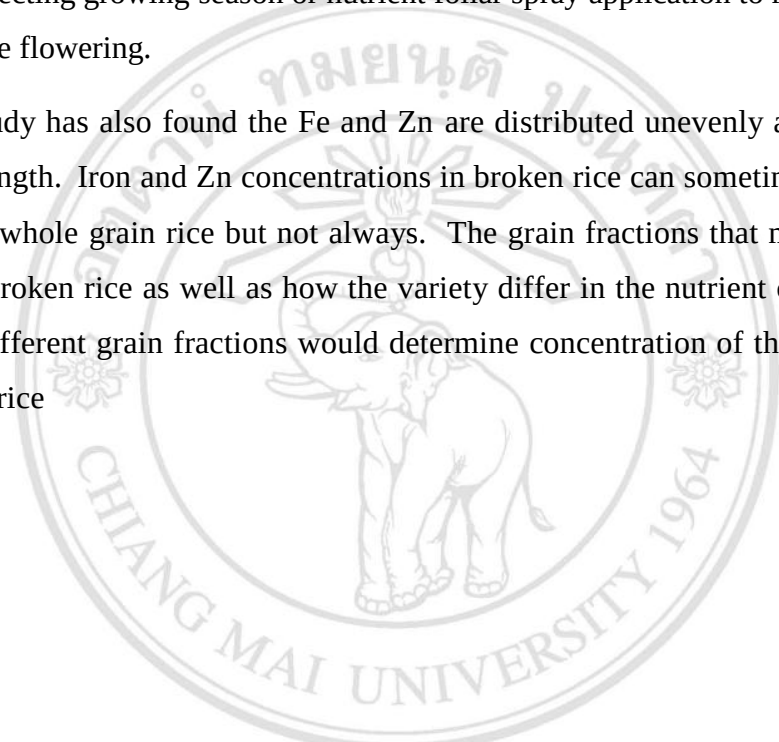
ข้อความแห่งการริเริ่ม

- 1) วิทยานิพนธ์นี้ได้นำเสนอข้อมูลเกี่ยวกับอิทธิของสภาพแวดล้อมและพันธุกรรมที่มีต่อคุณภาพข้าวในด้านคุณภาพการขัดสี และคุณค่าทางโภชนาการ และแนวทางในการเพิ่มปริมาณธาตุเหล็กและสังกะสีในเมล็ดข้าว โดยการเลือกฤดูเพาะปลูกที่เหมาะสม หรือการฉีดพ่นธาตุเหล็กและสังกะสีแก่ข้าวในระยะหลังออกดอก
- 2) ธาตุเหล็กและสังกะสีตามมีการกระจายตัวไม่สม่ำเสมอตามด้านยาวของเมล็ดข้าว โดยความเข้มข้นของธาตุเหล็กและสังกะสีในส่วนหัวเมล็ด (ด้านคัพพะ) และ/หรือบริเวณส่วนท้ายเมล็ดสูงกว่าส่วนกลางเมล็ด ขึ้นอยู่กับพันธุ์ข้าว ดังนั้นข้าวหัก จึงอาจมีความเข้มข้นของธาตุเหล็กและสังกะสีสูงกว่าข้าวเต็มเมล็ด ในกรณีที่ข้าวหักประกอบด้วยส่วนหัวและท้ายเมล็ดสูง

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

STATEMENT OF ORIGINALITY

- 1) This thesis represents the influences of environmental conditions and genotypic variation that affect on rice grain quality; milling quality and nutritional quality. This also represents the process to improve Fe and Zn concentration in rice grain with selecting growing season or nutrient foliar spray application to rice plant after rice flowering.
- 2) This study has also found the Fe and Zn are distributed unevenly along the rice grain length. Iron and Zn concentrations in broken rice can sometimes be higher than in whole grain rice but not always. The grain fractions that make up most of the broken rice as well as how the variety differ in the nutrient concentration in its different grain fractions would determine concentration of the nutrients in broken rice



ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved