STUDY OF GRAIN DIVERSITY AMONG THREE TRADITIONAL AROMATIC RICE (*Oryza sativa*) GENOTYPES FROM SABAH

SHAMINI A/P TANGAYA

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS

CROP PRODUCTION PROGRAMME
SCHOOL OF SUSTAINABLE AGRICULTURE
UNIVERSITI MALAYSIA SABAH
2014

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN TESIS

JUDUL: STUDY OF GRAIN DIVERSITY AMONG THREE TRADITIONAL AROMATIC RICE (*Oryza sativa*) GENOTYPES FROM SABAH

IJAZAH: SARJANA MUDA SAINS PERTANIAN DENGAN KEPUJIAN

SAYA: SHANAINI MP TANGAYA **SESI PENGAJIAN:** SEMESTER 1 SESI 2013/2014

(HURUF BESAR)

Mengaku membenarkan tesis *~~(LPSM~~/Sarjana/~~Doktor Falsafah)~~ ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:-

1. Tesis adalah hak milik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (/)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di AKTA RAHSIA RASMI 1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☑	TIDAK TERHAD	

Disahkan oleh:
NURULAIN BINTI ISMAIL
LIBRARIAN
UNIVERSITI MALAYSIA SABAH

(TANDATANGAN PENULIS)

Alamat Tetap: NO. 25, Lorong 16, Taman Sejahtera, 14000 Bukit Mertajam, Pulau Pinang

(TANDATANGAN PUSTAKAWAN)

PROF. DATIN DR. MARIAM

(NAMA PENYELIA)

TARIKH: _____

TARIKH: _____

Catatan:
*Potong yang tidak berkenaan.
*Jika tesis ini SULIT dan TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.
*Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana Secara Penyelidikan atau disertai bagi pengajian secara kerja kursus dan Laporan Projek Sarjana Muda (LPSM).

DECLARATION

I hereby declare that this dissertation is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that no part of this dissertation has been previously or concurrently submitted for a degree at this or any other university.

Shamini A/P Tangaya
BR10110070
18th December 2013

VERIFIED BY

1. Prof. Datin Dr. Mariam Abd. Latif
   SUPERVISOR

2. Asso. Prof. Haji Mohd. Dandan @ Ame Bin Haji Alidin
   CO-SUPERVISOR

Profesor Madya Hj. Mohd. Dandan Hj. Alidin
(B.S.K., A.D.K., A.S.D.K.)
Felo Kanan Kepada
Sekolah Pertanian Lestari,
Universiti Malaysia Sabah, Sandakan

3. Asso. Prof. Dr. Harpal Singh Saini
   EXAMINER

PROF. MADYA. DR. HARPAL SINGH SAINI
PROFESOR MADYA/PENASIHAT AKADEMIK
SEKOLAH PERTANIAN LESTARI
UNIVERSITI MALAYSIA SABAH

4. Asso. Prof. Dr. Siti Raehanah binti Muhamad Shaleh
   DEAN
   SCHOOL OF SUSTAINABLE AGRICULTURE

ACKNOWLEDGMENT

First of all, I am very grateful to GOD ALMITHY; without His graces and blessings, this would not have been possible. I would like to take an opportunity to express my sincere thanks to my supervisor, Prof. Datin Dr. Mariam Abd. Latip, who suggested me a good research study to be studied and worked on. Supports from her provide a good pathway for my success.

Besides, I would to thank my co-supervisor, Prof Madya Tuan Haji Mohd. Dandan @ Ame Bin Haji Alidin, who was tremendously helped me to achieve my desired project journey. The organizational work and time keeping sense made me to produce research a good paper. In addition, examiners are also nevertheless in providing a good comments and ideas to produce a quality research study. Farm management staffs are also supportive in teaching us a skilful works and very kind in supplying any knowledge regarding to the projects.

Futhermore, I would like to thank my parents, Mr. and Mrs. Tangaya Parameswary, who stood up by my side as supportive person that initiates my studies from beginning. The moral support and values that have been taught by parents has brought me to the success path. Besides, I would also like to thank my siblings (Sutharsan and Deshanthen), for their love and concern.

Friends played major part in giving support and knowledge. Thank you, my friends. Their kindness and patience helped me a lot to accomplish my project study. Finally, I would like to thank everyone who was involved in this research study.

ABSTRACT

This study was carried out to study the diversity among three traditional aromatic rice genotypes from Sabah. The objectives of this study were to determine morphological and chemical characteristics of traditional aromatic rice genotypes. Study was conducted at green house and experimental laboratory in School of Sustainable Agriculture (latitude 5° 55′ N, longitude 118° 02′ E). There were five types of varieties used for research. Hijau manis, Samarinda and Kendinga were traditional rice, whereas, TQR 1 (positive control) and TQR 2 (negative control). The parameters of study for morphological characters were grain length, grain breadth, grain length/breadth ratio, kernel length, kernel breadth, kernel length/breadth ratio and kernel elongation ratio which were measured in millimetre. The chemical parameters were leaf and grain aroma scoring and scored based on strong aroma, moderate aroma, less aroma and absent aroma. Experimental design that used in this study was Completely Randomize Design (CRD). The data was analyzed using SPSS version 21 software. The morphological characteristics were tested with one-way Analysis of Variance (ANOVA) for the mean comparison at 5 % significant difference. Leaf and grain aromatic scores were analyzed with descriptive statistics on mode. Correlation coefficients analysis was tested on all parameters that present in received and harvested samples. Finally, the presence of aroma in both received and harvested samples was compared with relatedness Chi-square test. All morphological characters were statistically significant except kernel elongation ratio for harvested samples at $p<0.05$. Hijau manis and Kendinga are present with strong aroma (1). Samarinda was present with moderate aroma (2) for both leaves and grains characters. Positive correlation was shown for grain aroma with grain breadth ($r = 0.526$) and kernel breadth ($r = 0.554$) for received samples. However, these associations were not significant for harvested samples except for leaf aroma ($r = 0.869$). The grain aroma in harvested samples was stronger than received samples. Finally, variation of rice in terms of grain morphology and chemical characteristics proved that traditional aromatic rice differed from each other.

KAJIAN MENGENAI KEPELBAGAIAN DALAM KALANGAN TIGA JENIS GENOTIP PADI WANGI TRADISIONAL DARI SABAH

ABSTRAK

Satu kajian telah dijalankan untuk mengkaji tentang kepelbagaian terhadap genotip tiga jenis varieti padi wangi tradisional dari Sabah. Objektif kajian ini adalah untuk menentukan ciri-ciri morfologi dan kimia bagi genotip padi wangi tradisional. Kajian ini telah dijalankan di rumah hijau dan makmal kampus Sekolah Pertanian Lestari (latitude 5° 55' N, longitude 118° 02' E). Kajian ini dianalisasi dengan menggunakan lima jenis varieti padi iaitu Hijau manis, Samarinda, Kendinga, TQR 1 (kawalan positif) dan TQR 2 (kawalan negatif). Parameter kajian bagi ciri-ciri morfologi ialah panjang butiran padi, lebar butiran padi, nisbah panjang/lebar butiran padi, panjang kernel, lebar kernel, nisbah panjang/lebar kernel dan nisbah pemanjangan kernel yang diukur menggunakan unit milimeter. Parameter kimia ialah aroma daun dan aroma padi yang diukur menggunakan tahap bau wang padi. Semua data telah dianalisis dengan menggunakan SPSS versi 21. Morforlogi padi telah dianalisis menggunakan ujian ANAVA sehala pada aras keertian 5%. Aroma daun dan padi ini telah dianalisis dengan menggunakan mod statistik diskriptif. Analisis korelasi telah diuji ke atas semua parameter dalam sampel dapatan dan sampel tuai. Akhirnya, kehadiran aroma dalam kedua-dua sampel dapatan dan tuai dibandingkan dengan kesesuaian ujian "Chi-Square". Semua sifat morfologi bagi ujian ANAVA adalah signifikan kecuali nisbah pemanjangan kernel untuk sampel tuaian pada aras keertian 5%. Hijau Manis dan Kendinga telah dikategorikan kepada skala bau aroma yang kuat (1). Samarinda pula kepada skala bau aroma yang sederhana (2) bagi kedua-dua daun dan sifat-sifat kernel. Korelasi positif didapati melalui ujian korelasi untuk aroma padi bersama dengan lebar bijiran padi (r = 0.526), lebar kernel (r= 0.554) untuk sampel sumber dapatan). Manakala, ujian korelasi untuk sampel sumber tuai menunjukkan kolerasi negatif selain nisbah pemanjangan kernel (r = 0.869). Aroma padi dalam sampel tuai adalah lebih kuat berbanding dengan aroma sampel dapatan. Akhir sekali, kepelbagaian dalam ciri-ciri morfologi dan kimia membuktikan bahawa varieti antara padi wangi tradisional wujud.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

°C	Degree Celsius
µl	Microlitre
ARC	Agriculture Research Centre
ASV	Alkali Spreading Value
CIMMYT	International Maize and Wheat Improvement Center
cm	Centimetre
DAS	Days After Sowing
g	Gram
GAT	Grain Aromatic Test
GB	Grain Breadth
GL	Grain Length
IBPGR	International Board for Plant Genetic Resources
IRRI	International Rice Research Institute
K2O	Potassium Oxide
KB	Kernel Breadth
KER	Kernel Elongation Ratio
kg	Kilogram
KL	Kernel Length
LAT	Leaf Aromatic Test
Lf	Length of grain after cooking
Lo	Length of grain before cooking
m	Metre
ml	Mililitre
mm	Milimetre
N	Nitrogen
P2O5	Phosphorus Oxide
SPSS	Static Package for Social Science
SSA	School of Sustainable Agriculture
UMS	Universiti Malaysia Sabah

LIST OF FORMULAE

Formula		Page
3.1	Kernel Elongation Ratio $= \frac{\text{Length of cooked rice (Lf)}}{\text{Length of raw rice (Lo)}}$	27

CHAPTER 1

INTRODUCTION

1.1 Rice

Rice or scientifically known as *Oryza sativa* is a major crop that is consume by most of world population. Diversification of rice is huge in the world from tropical to subtropical countries. Rice diversity has originated from its species differentiation as *Oryza sativa*, *Oryza rufipogon*, *Oryza glaberrima*, *Oryza minuta*, *Oryza nivara* and *Oryza officinalis* (Morishima, 2001).

Rice species genomic expression across the worldwide promotes for character diversification (Khush and Brar, 2000). Diversity is the state of being diverse and contains many different characteristics which are good for evolution. Diversity arises by various genes in alleles which may encode for particular trait. Rice diversity increases rice production and creates more choice to people for farming and diet.

Rice aromatic trait is encoded by particular gene that present in allele. The gene is betaine aldehyde dehydrogenase enzyme (badh2). Badh2 gene is present in exon 7 of chromosome 8 (8-base pair deletion). The badh2 gene compound is being shortened during 8-base pair deletion in exon 7. Condense $badh_2$ gene promotes the accumulation 2-acetyl 1-pyrroline (2AP), an aromatic compound (Saktivel *et al.*, 2009). Essential chemical accumulation produces aromatic rice. Aromatic rice is a rice that emits sweet aroma when cooked or during its growth (Kovach *et al.*, 2009).

Aromatic rice is important due to its special quality. Market demand of aromatic rice is much higher than normal rice. Special traits of aromatic rice highly induce the consumers' interest to consume it (Tomlins *et al.*, 2005). Physical condition of cooked aromatic rice, matches all type of rice based cuisine (Shobha Rani, 2012). Basmati and Jasmine are being commercial and popular. However, there is much aromatic rice that not has been cultivated for commercial purpose.

Traditional aromatic rice genotypes are rich in varietal gene expression. India and China have geographical variation of traditional aromatic rice which shows huge character diversification among traditional and domestic aromatic rice (Shobha Rani, 2012; Zeng *et al.*, 2003). Indigenous aromatic rice had been tabulated around world such as Bay Kyar, Kamar Kyi Saw, Mee Don Yin and Nga Cheik (Myint et al., 2012), Juwari, Gorkhali, Gola, Tunde and Masino (Rijal et al., 1998), Najkuri, Kanika, Kalajeera, Basuabhog, Ramachandrabhog, Tulsibas, Laxmibhog, Krishnabhog, Katrani, Sugandha, Tilak Chandan, Bindli Pusa Basmati and Jeeringa Samba (Subudhi et al., 2012; Joshi and Behera, 2007).

Traditional aromatic rice in Sabah is present but not commercialize. The establishments of traditional aromatic rice still remain undetermined and haven't confirmed. Researchers are unable to conduct their research with traditional aromatic rice in Sabah without an establishment of its aromatic traits. So, this study can be a part to help establish the traditional aromatic rice in Sabah. The study is to determine the aromatic quality of traditional aromatic rice. The quality may achieve the quality of commercial aromatic rice such as Basmati and Jasmine. Furthermore, the findings from this study can be used for future plant breeding research. Those varieties are known as aromatic rice among local residents in Sabah. There are about eighteen varieties of traditional aromatic rice cultivated in several districts of Sabah (Agriculture Research Centre, 2013). Several locally produced varieties are only used in this study such as Hijau manis, Samarinda and Kendinga using its grain and leaf aroma test.

1.2 Justification

Unexplored traditional aromatic rice in Sabah develops an interest to study about their diversify characters. The demand of aromatic rice worldwide creates a curiosity to explore well on traditional rice. Study reveals their characters that can be commercialized and increase market demand. Thus, aromatic rice production in Sabah can be an important commodity for Malaysia. Traditional rice that contains huge

genotypes can be preserve well from its extinction. The aromatic gene might be used for new rice hybrid production. Knowledge on existence of aromatic rice may diminish from time to time due to unexplored study. Besides, populations of Sabah are showing more interest on commercial aromatic rice such as Basmati and Jasmine on their diet rather than its traditional variety. Now, farmers are only cultivate traditional aromatic rice for their own purposes such as traditional rituals, cooking and further activity. Besides, status of traditional aromatic rice will be updated with rise up demands in future. Demands of rice can be promoted to consumers by establishment and proper marketing strategy.

1.3 Objectives

1. To determine morphological characteristics of aromatic rice grain
2. To determine chemical characteristics of aromatic rice

1.4 Hypothesis

Null hypothesis

Ho: There is no diversity among traditional aromatic rice

Alternative hypothesis

Ha: There is diversity among traditional aromatic rice

CHAPTER 2

LITERATURE REVIEW

2.1 Botanical Description of Rice

Kingdom : Plantae

Division : Magnoliophyta

Class : Liliopsida

Order : Cyperales

Family : Poaceae

Genus : Oryza

Species : *Oryza sativa*

Rice, *Oryza sativa* L. is a diploid species with haploid number, n=12 chromosomes. The life span of rice is annual and perennial (depends on environmental factors). Rice originated from grass family as its characteristics similar to grass group. Rice plant is normally consists of leaves, tillers, culm, nodes, leaf sheath, panicle, spikelet, flag leaf, lemma hair and palea hair, collar sheath, awns and grains. Root network system of rice is consists of short tap root and large fibrous root system. Fibrous root system is consists of rootlets or root hairs (Panda, 2010), which can be identified as crown roots (Maclean *et al.*, 2002). Structure of rice leaf is flat with parallel veins, round and hollow leaf sheath. Auricles of rice are present on leaf sheath. Leaf sheath contains collar where auricles appear. Leaf lanceolate has long length with shorter diameter of leaf lamina. Rice inflorescence consists of panicle at lower region and raceme at upper region. Panicle and raceme formation in inflorescence determine its size and shape. Panicle of rice consists of rice spikelets than produces rice grains. Spikelet formation in rice industry is an important formation stage to determine yield of rice plants (Gurinder *et al.*, 2006).

2.2 Origin and Evolution of rice

Rice is the one of major staple food in Asia. Era of rice cultivation begins from human civilization era. There are about two species of rice which is commonly edible by human beings such as *Oryza sativa* and *Oryza glaberrima.* Wild rice such as *Oryza rufipogon* and *Oryza nivara* also has been found in Asia but has not been domesticated commercially (Sharma, 2010). Four species complexes had been divided from Oryza genus such as *O. sativa*, *O. officialis*, *O. ridelyi* and *O. granulate*. Haploid chromosomes number of genus Oryza species are 12 (Sweeney and McCough, 2007).

Asian cultivated rice is originated from *Oryza sativa* species. It is only grown in Asia and in some region of European countries (Panda, 2010). Asian rice has been cultivated commercially in many regions. However, both Asian and African rice shares some similar morphological characteristics. Besides, cross breeding among two species to produce F_1 progeny are not relevant as their genetic materials are not easily exchangeable. Cross breeding process may end-up in sterile offspring as product (Sharma, 2010).

Ancestors or parental plant for *Oryza sativa* are *O. rufipogon* and *O. nivara*. *O. rufipogon* is a wild perennial crop and *O. nivara* is a wild annual crop (as shown in Figure 2.1). Whereas, *O. longistaminata* and *O. braviligulata* are ancestors for *O. glaberrima*. *O. longistaminata* is a wild perennial plant and *O. braviligulata* is wild annual rice (Khush, 1997).

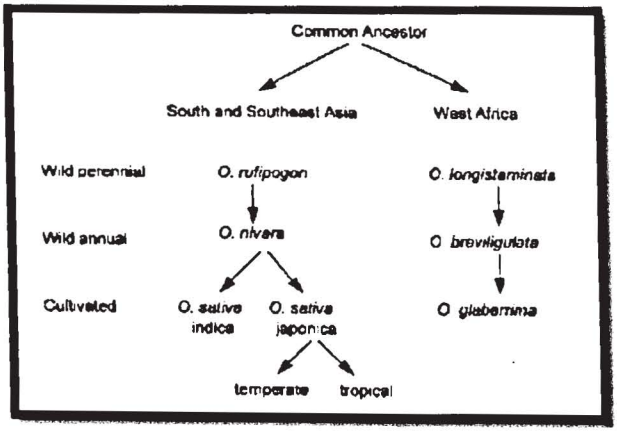

Figure 2.1: Evolutionary Pathway of Two Cultivated Species of Rice.
Source: Khush, 1997

Genome composition differentiates rice species into diverse characters. Wild species and domesticated rice shares the similar genome as AA genome (Khush *et al.*, 2001). Genome is genetic material content in an organism (Klug *et al.*, 2007). Rice

species that shares AA genome shows common meiosis in chromosome pairing between hybrids (Khush *et al.*, 2001).

2.3 Classification of rice

There are about three types of Asian rice sub-species that have been grown popularly such as japonica rice, indica rice and javanica rice. Sub-species do not exist for African rice, *O. glabberima* (Oka, 1991). Consumption of indica rice is higher compared to those other rice. Indica rice grain is long and grown in hot and rainy season. Japonica rice grain is short that contain high amylopectin compound. This compound produces rice sticky. Normally, japonica rice is cultivated in the temperate climate. Whereas, javanica rice grain is broad and favours to grow in tropical climate. Tropical japonica sub-population is the name for javanica (Sweeney and McCough, 2007). Morphological comparisons between three sub-species are shown in Table 2.1 below.

Table 2.1: Differences Between The Three Sub-species of *Oryza sativa*

	Indica	Japonica	Javanica
Leaves	Bread, light green leaves	Narrow, dark green leaves	Broad, stiff, light green leaves
Tillering	Profuse tillering	Medium tillering	Low tillering
Height	Tall plant stature	Short plant stature	Tall plant stature
Hair on Lemma and Palea	Thin and short hairs on lemma	Dense and long hairs on lemma and palea	Long hairs on lemma and palea
Awns	Mostly awnless	Awnless to long awned	Awnless or long awned
Grains	Slender, somewhat flat grains	Short, roundish grains	Broad, thick grains
Grains shattering	First shattering	Low shattering	Low shattering
Tissues	Soft plant tissue	Hard plant tissues	Hard plant tissue
Photosensivity	Varying sensitivity to photoperiod	Varying sensitivity to photoperiod	Low sensitivity to photoperiod

Source: Panda, 2010

2.3.1 Asian Rice, *Oryza sativa*

Variations of Asian rice are arising from three sub-species of rice and cross breeding. Genetic variations can be obtained by create desirable recombinants in the breeding lines (Sharma, 2010). Indica and japonica cultivars crosses are major to produce indica traits in cold climates. Japonica able to grow in such climate as it is resistance and tolerant. Wild progenitor of japonica is originated from weedy rice (Oka, 1991). According to Moon *et al.*, (2003), rice breeding from different cultivars conducted by anther culture and single-seed descent method. These methods able to trigger cross breeding very well. In a study by Sweeney and McCough (2007) shows that hybrids of indica and japonica is a combination of huge gene pool then single genetic pool. Hybrids also contain some genetic material from rice ancestor such as *O. rufipogon*.

2.4 Aromatic rice

Rice types exposed with high marketable demand and prices internationally (Sakthivel *et al.*, 2009). Aromatic rice releases its fragrance as special traits. Aromatic rice varieties produce its sensory criteria from all parts of rice except from roots. This is because roots have low potential of odour level and present in low concentration. During vegetative growth, production aroma is essential and released to surrounding by leaves. The production of aroma is by certain aromatic gene that present in rice genotype (Panda, 2010). Aromatic gene help in accumulation of some chemical compound that produce aroma in young and healthy foliar (Chen *et al.*, 2008).

Aroma smell of rice is a sort of 'pandan' leaves and pop corn smell. Evolution of rice varies in quality and strength of 'pop corn' aroma in cooked rice (Singh, 2000). The chemical compound which emits its characteristics can be well determined after cooked. Water absorption by heating process secretes chemical compound with present of starch. Starch is a carbohydrate molecule (sugar) that able to contribute sweet odour more rapidly. Aromatic rice that being commercializes less is known as traditional rice or indigenous rice. Indigenous aromatic rice are vast in quality traits, high genomic variation pattern and tolerant to many microbes and situation. Indigenous rice is also rich in nutrient source

Nutritional rich rice able to deplicit its germplasm due to competition, less conservation and popular. Eco-geographical location of rice cultivation affects the rice aroma. Aromatic traits are essential in cooler region than tropical region (Das *et al*, 2012). Fragrance of rice and its quality determine by some chemical compounds that present in rice. The chemical compound consists of volatile and non-volatile compound. Besides, gene strongly holds the criteria of aroma very well. Genetic material activities such as mutation, biochemical cycle also have a role in production of aromatic compound in rice. Betaine aldehyde dehydrogenase (Badh2) allele of *fgr* gene stands for the aromatic traits in rice. Whereas, 2-acetyl 1-pyrroline (2AP) is a volatile aromatic compound that emits very pleasant aroma of rice (Bourgis *et al.*, 2008).

2.4.1 Aromatic Volatile Compounds

There are about more than 100 volatile compounds in rice that produce aromatic trait of rice. However, 2-acetyl 1-pryrroline (2AP) compound is most significant and well determined in producing rice fragrance (Kovach *et al.*, 2009). According to Sakthivel et *al.* (2009), badh2 allele that encoded by *fgr* (single recessive gene) in chromosome 8 for rice aroma independently helps in accumulation of 2AP. During 2AP synthesis pathway, $_{L}$- proline acts as precursor. Synthesis process of 2AP with the presence of BADH2 enzyme can be obtained in two ways by polyamine pathway.

First pathway in the presence of non-functional BADH2 enzyme, 4–aminobutyraldehyde (AB-ald) was changed immediate precursor of 2AP to 1-pyrroline (1P). AB-ald is an immediate precursor of 4-aminobutyric acid (GABA) and obtained by oxidation process of Badh2 allele. This help in accumulation of 2AP in aromatic variety. Besides, accumulation of 2AP can be triggered by substrate y-aminobutyraldehyde (GABald) to form pyrroline molecule (Sakthivel *et al.*, 2008; Chen *et al.*, 2008).

Second pathway was undergone with presence of functional BADH2 enzyme, AB-ald changed to GABA. This process ends up with restriction of 2AP accumulation in non-aromatic rice (Chen *et al.*, 2008). The process pathways differentiate rice into aromatic and non-aromatic group. Badh2 allele is act as independent in some process of 2AP accumulation. Intermediate precursor, 1-pyrroline-5-carboxylate from glutamate able to form 2AP after react with methylglyoxal. Volatile compounds of organic acids such as alkanals and phenylathanol involves in production rice aroma (Sakthivel *et al.*, 2009). Figure 2.2 shows pathway of 2AP biosynthesis in rice.

2.4.2 Aromatic Non-Volatile Compound

Rice is also emits its fragrance in the absence of such volatile compounds. Genotype of rice encodes same protein as in presence of aromatic compound by mutation process (Sakthivel *et al.*, 2009). Mutation processes of Badh2 gene in exon 7 end up in encode stop codon at premature stage. Protein encoded by nucleotide strand restricts complete function of BADH2 enzyme (Sakthivel *et al.*, 2009). Process of 2AP accumulation is carried out without badh2 allele.

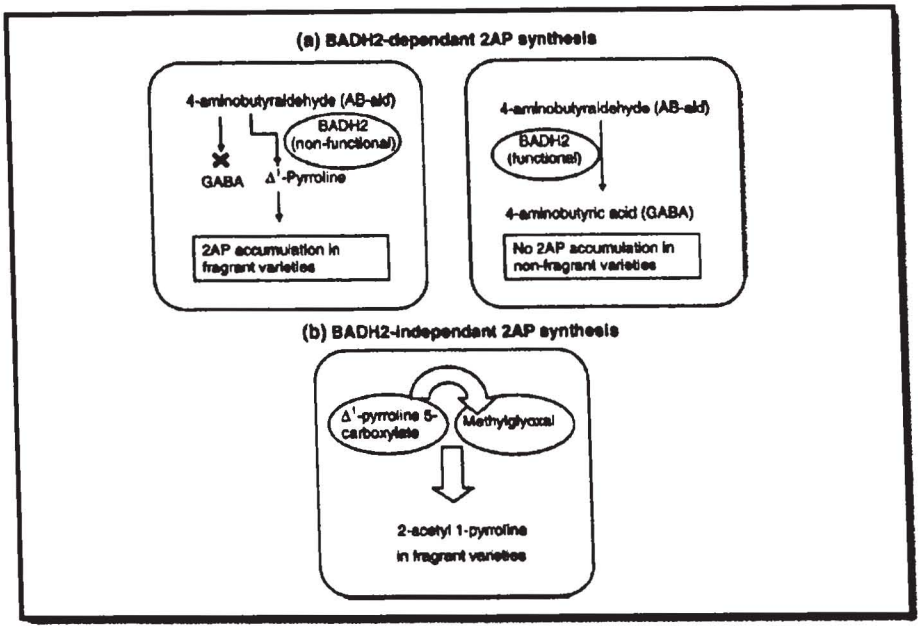

Figure 2.2: Pathway of 2AP Biosynthesis in Rice
Source: Sakthivel *et al.*, 2009

2.4.3 Distribution of Aromatic Rice

Distributions of aromatic germplasm are high throughout whole countries in tropical, semi-tropical, temperate and cooler region (Sakthivel *et al.*, 2009). Badh2 is a heterozygous allele which almost absent in most of wild varieties (Kovach *et al.*, 2009). Asian rice can be divided into main six groups. Source of aromatic rice is group I, V and IV out of six groups (Napasintuwong, 2012). Studies that conducted by Kovach *et al.*, (2009) clearly denotes aroma tabulation in subpopulation of rice. Subpopulation of rice that classified into indica ('Jasmine' varieties), tropical japonica and Group V ('Basmati' and 'Sadri' varieties) are closely related with rice aromatic with high bootstrap value. Bootstrap value (Figure 2.3) shows the richness of aroma in rice varieties out of 100 range value using unrooted neighbor-joining tree with haplotype chloroplast branch colour. Rice variations with aromatic quality are highly observed in most Asian countries such as India, China, Indonesia, Bangladesh, Vietnam, Myanmar

and Thailand. Table 2.2 shows aromatic rice distribution in groups with country of origin. Basmati and Jasmine rice shows high acceptance by most consumers (Napasintuwong, 2012).

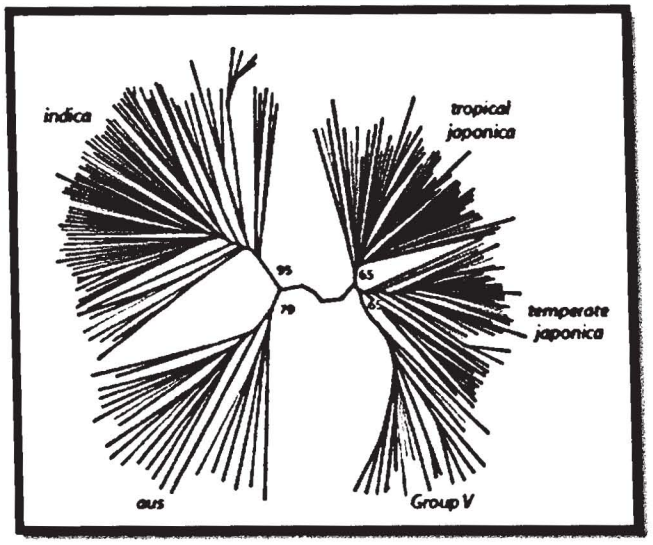

Figure 2.3: Bootstrap Values of Subpopulation *O. sativa*
Source: Kovach *et al.*, 2009

Table 2.2: Aromatic Rice Distribution by Country of Origin Based on Rice Groups

Country	I	II	V	VI	*	Total
India	11	7	62	21	32	133
Pakistan	-	1	60	-	4	65
Indonesia	19	-	1	24	4	48
Thailand	29	-	-	4	1	34
Bangladesh	3	3	17	7	3	33
Malaysia	9	-	1	9	2	21
Iran	-	-	17	-	1	18
Nepal	1	2	6	1	6	16
Vietnam	6	-	-	2	7	15
Philippines	1	-	-	11	-	12
China	3	-	-	8	-	11
Myanmar	4	-	4	-	-	8
Laos	-	-	1	2	-	3
Sri Lanka	-	2	1	-	-	3
Korea	-	-	-	2	-	2
U. S. A.	-	-	-	1	-	1
Japan	-	-	-	1	-	1
Afghanistan	-	-	1	-	-	1
Total	86	15	171	93	60	425

* Does not belong to any groups
Source: Napasintuwong, 2012

References

Africa Rice Center (AfricaRice). 2010 Participatory Varietal Selection of Rice - Technician's Manual. Cotonou, Benin: Print Right

Agriculture Research Centre (ARC). 2013. Traditional Aromatic Rice Seeds Variety in Sabah. Tuaran, Sabah.

Angelita, P. L., Buang, A., Ahmad, J. and Hajrial, A. 2011. Performance of Grain Quality and Aroma of Aromatic New Plant Type Promising Rice Lines. *Indonesian Journal of Agricultural Science* **12(2)**: 84-93

Anonymous. 2009. Rice Growth Stages. International Rice Research Institute. http://www.knowledgebank.irri.org/extension/growth-stages-0-9.html Access on 21 March 2013. Verified on 22 March 2013

ARC Tuaran. 2001. Agriculture Reseach Centre Tuaran

Arwind, K. R., Ranjay, K. S. and Rakesh, B. 2011. Upland Rice in Arunachal Pradesh. In: Singh, R. K., Mandal, N. P., Singh, C. V. and Anantha, M. S. (Eds.). *Upland Rice in India*. India: Scientific Publisher

Bioversity International. IRRI. and WARDA. 2007. Descriptors for Wild and Cultivated Rice (Oryza sativa spp.). In: Bioversity International. Rome, Italy; International Rice Research Institute. Los Banos, Philippines; Africa Rice Centre (WARDA). Cotonou, Benin. Bioversity International: 22-38

Bourgis, F., Guyot, R., Gherbi, H., Tailliez, E., Amabile, I., Salse, J., Lorieux, M., Delseny, M. and Ghesquiere, A. 2008. Characterization of the Major Fragrance Gene from Aromatic Japonica Rice and Analysis of its Diversity in Asian Cultivated Rice. *Theory Application Genetics* **117**: 353-368

Chen, S., Yang, Y., Shi, W., Ji, Q., He, F., Zhang, Z., Cheng, Z., Liu, X. and Xu, M. 2008. Badh2, Encoding Betaine Aldehyde Dehydrogenase, Inhibits the Biosynthesis of 2-Acetyl-1-Pyrroline, a Major Component in Rice Fragrance. *Plant Cell* **(20)**: 1850-1861

Das, B., Sengupta, S., Ghosh, M. and Ghose, T. K. 2012. Assessment of Diversity Amongst A Set of Aromatic Rice Genotypes from India. *International Journal of Biodiversity Conservation* **4(5)**: 206-218

Dela Cruz, N. and Khush, G. S. 2000. Rice Grain Quality Evaluation Procedures. In Singh, R. K., Singh, U. S. and Khush, G. S. (Eds.). *Aromatic Rices*. New Delhi, Calcutta: Oxford and IBH Publishing Co. Pvt. Ltd.

Faruq, G., Hui Yin, Y., Masitah, A., Afnierna, N., Nazia, A. M., Norzulaani, K. and Mohamad Osman. 2011. Analysis of Aroma and Yield Components of Aromatic Rice in Malaysian Tropical Climate. *Australian Journal of Crop Science* **5(11)**: 1318-1325

Gurinder, J. R., Shashi, B., Celia, V. C., Vandana, T., Desh, D. V. and Manoranjan, H. 2006. Document on Biology of Rice (*Oryza sativa* L.) in India. New Delhi: Alpha Lithographics Inc

IBPGR. and IRRI. 1980. Descriptors for Rice (Oryza sativa L.). In: International Board for Plant Genetic Resources - International Rice Research Institute. P. O. Box 933/ IRRI, Manila (Philippines). IRRI: 11-16

IRRI. 1965. The Morphology and Varietal Characteristics of the Rice Plant. In: Technical Bulletin (4). International Rice Research Institute, Philippines

IRRI. 2000. Rainfed Rice: A Sourcebook of Best Practices and Strategies in Eastern India. International Rice Research Institute. Los Banos, Philippines

IRRI. and CIMMYT. 2009. Rice Growth Stages. International Rice Research Institute and International Maize and Wheat Improvement Center: Rice Knowledge Bank.

Jing, Q., Spiertz, J. H. J., Hengsdijk, H., van Keulen, H., Cao, W. and Dai, T. 2010. Adaptation and Performance of Rice Genotypes in Tropical and Subtropical Environments. *Wageningen Journal of Life Sciences* **57(2)**: 149-157

Joshi, R. K. and Behera, L. 2007. Identification and Differentiation of Indigenous Non-Basmati Aromatic Rice Genotypes of India Using Microsatellite Markers. *African Journal Of Biotechnology* **6(4)**

Kavi Kishor, P. B., Sangam, S., Amrutha, R. N., Sri Laxmi, P., Naidu, K. R., Rao, K. R. S. S., Sreenath, R., Reddy, K. J., Theriappan, P. and Sreenivasulu, N. 2005. Regulation of Proline Biosynthesis, Degradation, Uptake and Transport in Higher Plants: Its Implications in Plant Growth and Abiotic Stress Tolerance. *Current Science* **88(3)**: 424-438

Khush, G. S. 1997. Origin, Dispersal, cultivation and Variation of Rice. *Plant Molecular Biology* **35**: 25-34

Khush, G. S. and Brar, D. S. 2001. Rice Genetics IV: Rice genetics from Mandel to functional genomics. United Straits of America: Science publisher

Kovach, M. J., Calingacion, M. N., Fitzgerald, M. A. and McCouch, S. R. 2009. The Origin and Evolution of Fragrance in Rice (*Oryza sativa* L.). *Proceedings of the National Academy of Sciences (PNAS)* **106 (34)**: 14444 – 14449

Maclean, J. L., Dawe, D. C., Hardy, B. and Hettel, G. P. 2002. Rice Almanac, Source Book for Most Important Economic Activity on Earth. 3rd edition. In International Rice Research Institute (IRRI). Metro Manila, Philippines; West Africa Rice Development Association (WARDA). Bouaké 01, Côte d'Ivoire; International Center for Tropical Agriculture (CIAT). Cali, Colombia; Food and Agriculture Organization of the United Nations (FAO). Rome, Italy. United Kingdom: CABI Publishing

Moon, H. P., Kang, K. H., Choi, I. S., Jeong, O. Y., Hong, H. C., Choi, S. H. and Choi, H. C. 2003. Comparing Agronomic Performance of Breeding Populations Derived from Anther Culture and Single-Seed Descent in Rice. In: Khush, G. S. Brar, D. S. and Hardy, B (Eds). Advanced Rice Genetics. *Proceedings of the Fourth International Rice Genetics Symposium.* 22-27 October 2000. Los Baños, Philippines. Los Baños (Philippines): International Rice Research Institute. 642

Morishima, H. 2001. Rice Genetics IV: Evaluation and Domestication of Rice. United Straits of America: Science publisher

Myint, K. M., Courtois, B., Risterucci, A-M., Frouin, J., Soe, K., Thet, K. M., Vanavichit, A. and Glaszmann, J-C. 2012. Specific Patterns of Genetic Diversity among Aromatic Rice Varieties in Myanmar. *Rice Journal* **5(20)**

Napasintuwong, O. 2012. Survey of Recent Innovations in Aromatic Rice. *Proceedings of 131st EAAE Seminar 'Innovation for Agricultural Competitiveness and Sustainability of Rural Areas'.* 18-19 September 2012. Prague, Czech Republic

Oka, H. I. 1991. Genetic Diversity of Wild and Cultivated Rice. In: Khush, G. S. and Toenniessen. (Eds.). Rice Biotechnology. *Biotechnology in Agriculture 6.* United Kingdom: C. A. B. International

Panda, S. C. 2008. Dryland Agriculture (Dryland Agriculture and its Characteristics). Jodhpur: Hinglaj Offset Printers

Panda, S. C. 2010. *Rice Crop Science (Farming Systems).* Jodhpur: Hinglaj Offset Printers

Panda, S. C. 2010. *Rice Crop Science (Origin and Distribution).* Jodhpur: Hinglaj Offset Printers

Panda, S. C. 2010. *Rice Crop Science (Rice Botany).* Jodhpur: Hinglaj Offset Printers

Randhawa, G. J., Bhalla, S., Celia Chalam, V., Tyagi, V., Verma, D. D. and Hota, M. 2006. Document on Biology of Rice (*Oryza sativa* L.) in India. New Delhi, India: Alpha Lithographics Inc.

Rautaray, S. K. 2011. Upland Rice (Ahu) in Assam. In: Singh, R. K. Mandal, N. P. Singh, C. V. and Anantha, M. S. (Eds.). *Upland Rice in India*. India: Scientific Publisher

Ray, A., Debal, D., Ray, R. and Chattopadhayay, B. 2013. Phenotypic Characters of Rice Landraces Reveal Independent Lineages of Shortgrain Aromatic Indica Rice. *Annals of Botany* **5**: 1-24

Rijal, D. K., Kadayat, K. B., Kadayat, Joshi, K. D. and Sthapit, B. R. 1998. Inventory of Indigenous Rainfed and Aromatic Rice Landraces in Seti River Valley Pokhara, Nepal. In: LI-BIRD Technical Paper No. 2. *Proceedings of Local Initiatives for Biodiversity, Research and Development (LI-BIRD)*. December 1998. Pokhara, Nepal

Sakthivel, K., Sundaram, R. M., Shobha Rani, N., Balachandran, S. M. and Neeraja, C. N. 2009. Genetic and Molecular Basis of Fragrance in Rice. *Biotechnology Advances* **27**: 468-473

Sareepuang, K., Siriamornpun, S., Wiset, L. and Meeso, N. 2008. Effect of Soaking Temperature on Physical, Chemical and Cooking Properties of Parboiled Fragrant Rice. *World Journal of Agricultural Sciences* **4 (4)**: 409-415

Sharma, S. D. 2010. *Rice Origin, Antiquity and History*. United Straits of America: CRC Press

Shobha Rani, N. 2012. Present Status of Basmati Research In India: Prospects for Enhancement of its Export. Rice Knowledge Management Portal.

Singh, R. K., Singh, U. S., Khush, G. S. and Rohilla, R. 2000. Genetics and Biotechnology of Quality Traits in Aromatic Rices. In Singh, R. K., Singh, U. S. and Khush, G. S. (Eds.) *Aromatic Rices*. New Delhi, Calcutta: Oxford and IBH Publishing Co. Pvt. Ltd.

Singh, V. P. 2000. The Basmati Rice of India. In Singh, R. K., Singh, U. S. and Khush, G. S. (Eds.) *Aromatic Rices*. New Delhi, Calcutta: Oxford and IBH Publishing Co. Pvt. Ltd.

Subudhi, H. N., Samantaray, S., Swain, D. and Singh, O. N. 2012. Collection and Agro-Morphological Characterization of Aromatic Short Grain Rice In Eastern India. *African Journal of Agricultural Research* **7(36)**: 5060-5068

Sudharani, M., Prasanna Rajesh, A., Jayalakshmi, V. and Rajyalakshmi, K. 2012. A Brief Review on Genetic Divergence in Rice for Yield Contributing Traits and Quality Parameters. *International Journal of Applied Biology and Pharmaceutical Technology* **3(4)**: 44-48

Sweeney, M. and McCouch, S. The Complexe History of the Domestification of Rice. *Annals of Botany* **100**: 951-957

Tomlins, K. I., Manful, J. T., Larwer, P. and Hammond, L. 2005. Urban Consumer Preferences and Sensory Evaluation of Locally Produced and Imported Rice in West Africa. *Food Quality and Preference* **16**: 79-89

Venkata Subbaiah, P., Reddi Sekhar, M., Reddy, K. H. P. and Eswara Reddy, N. P. 2011. Variability and Genetic Parameters for Grain Yield and Its Components and Kernel Quality Attributes in CMS Based Rice Hybrids (*Oryza sativa* L.). *International Journal of Applied Biology and Pharmaceutical Technology* **2(3)**: 603-609

Wilkie, K. and Wootton, M. 2004. Flavour Qualities of New Australian Fragrant Rice Cultivars. In: Rural Industries Research and Development Corporation, No. 40/160/ RIRDC, Kingston Act (Australia). Project No: UNS-12A

Wopereis, M. C. S., Defoer, T., Idinoba, P., Diack, S. and Dugue, M. J. 2009. Curriculum for Participatory Learning and Action Research (PLAR) for Integrated Rice Management (IRM) in Inland Valleys of Sub-Saharan Africa: Technical Manual. WARDA Training Series. Cotonou, Benin: Africa Rice Center

Yoshida, S. 1981. Fundamentals of Rice Crops: Tillering. Philippines (Los Banos): International Rice Research Institute (IRRI)

Zhout, Z., Robarts, K., Helliwell, S. and Blanchard, C. 2001. Ageing of Stored Rice: Changes in Chemical and Physical Attributes. *Journal of Cereal Science* **33**: 1-15

Zhu, Y., Chang, L., Tang, L., Jiang, H., Zhang, W. and Cao, W. 2009. Modelling Leaf Shape of Dynamics in Rice. *Wageningen Journal of Life Sciences (NJAS)* **57(1)**: 73-81