UNIVERSITI PUTRA MALAYSIA

EVALUATION AND UTILIZATION OF EGGPLANT GERMPLASM (Solanum melongena L.) IN THE DEVELOPMENT OF HIGH YIELDING AND QUALITY HYBRIDS

DEBI RANI DATTA

IPTSM 2022 6

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By

DEBI RANI DATTA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

February 2022

DEDICATIONS

I dedicate my thesis to my lovely daughter, Nobomita Modak, my respected parents and my beloved husband, Avijit Kumar Modak, for their lot of sacrifice, love and encouragement.

Thank you very much for every sphere of my PhD life.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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February 2022

Chairman : Professor Mohd Rafii Yusop, PhD
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Eggplant ranks the fifth economic important crops among the Solanaceae family after tomato, potato, chilli, and tobacco. In Malaysia eggplant production is relatively low (17 t/ha) compared to other neighbouring countries (i.e. China 46.28 t/ha and Thailand 35.25 t/ha). One of this crop's major production limitations is the lack of high-yielding and high-quality variety. Hence, there is a need to step up the current eggplant production to meet the continuously growing demands. Therefore, the specific objectives of this study were to determine the genetic diversity of eggplant accessions using morphological data and simple sequence repeat (SSR) molecular markers. In addition, to identify superior parents and their hybrids based on general (GCA) and specific combining ability (SCA), and to estimate heterosis values for yield trait and yield components. The study locations were UPM field Ladang 15 and Ladang 10, Serdang, Selangor, Malaysia. This study consisted of four experiments, where the first experiment was done to evaluate 56 accessions in an open research field. All the traits showed high heritability and genetic advance values, indicating that these traits can easily be transferred from parents to their progenies. Dendrogram was constructed based on yield performance, and the genotypes were clustered into seven groups. From this study, the accessions from clusters II, III and IV were selected, which having a high number of fruits per plant. In the second experiment, out of 102 SSR markers, 16 were found polymorphic. The selected markers reveal a high level of polymorphism within the population and low polymorphism level among populations. In the third experiment, 27 accessions selected from previous study were further evaluated on the field to select the best genotype based on quantitative and qualitative traits performance. From this evaluation, a total of 11 accessions (BB1, BT13, BM9, BB26, BB31, BM5, BB23, BT17, BB12, BT6 and BT15) were selected as parents for hybridization through 11×11 half diallel method. The hybrids (55), parental lines (11) and check varieties (3) were evaluated over two locations followed by randomised complete block design (RCBD) with three replications to evaluate the hybrids performance and to estimate gene effects and combining ability of 15 morphological and biochemical traits. The analysis of variance indicated highly significant differences between the environments and interaction of genotype and environment for all the traits, except for fruit length to width ratio. Additive gene effects were significant for the inheritance of these traits and the expression of additive genes were greatly affected by environments. The general combining ability (GCA) was greater than their respective specific combining ability (SCA) for all traits except for fruit yield per plant. High values of GCA and SCA effects for characters of interest were dispersed among genotypes. From this evaluation, it was observed that the best parental line was BT15 based on days to first flowering, number of fruits per plant, total soluble solids (TSS) and total phenol content. Besides, the parent BM5 showed good general combining ability effects for fruit yield per plant, fruit length and fruit length to width ratio, while the parent BB1 performed good general combining ability for fruit diameter, fruit girth and average fruit weight. On the other hand, the hybrid BT6 × BT15 showed bearing early flowering with high total phenol content, while the hybrid BM9 × BB26 had high fruit yield per plant and total soluble solids. In addition, hybrid BM9 × BB1 had a high fruit diameter and average fruit weight. These superior eggplant hybrids are recommended for a large-scale evaluation and then for commercial cultivation by local vegetable farmers.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENILAIAN DAN PENGGUNAAN GERMPLASMA TERUNG (*Solanum melongena* L.) DALAM PEMBANGUNAN HIBRID BERHASIL TINGGI DAN BERKUALITI

Oleh

DEBI RANI DATTA

Februari 2022

Pengerusi : Profesor Mohd Rafii Yusop, PhD
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Terung berada pada kedudukan kelima dalam kepentingan ekonomi di kalangan tanaman Solanacea selepas tomato, kentang, cili, dan tembakau. Di Malaysia, pengeluaran terung agak rendah (17 t/ha) berbanding dengan negara jiran yang lain (contohnya China, 46.28 t/ha dan Thailand, 35.25 t/ha). Salah satu faktor pengeluaran utama tanaman ini adalah kekurangan varieti berhasil tinggi dan berkualiti tinggi. Oleh itu, terdapat keperluan untuk meningkatkan pengeluaran terung semasa untuk memenuhi permintaan yang terus meningkat. Justeru, objektif khusus kajian ini adalah untuk menentukan kepelbagaian genetik aksesi terung menggunakan data morfologi dan penanda molekul ulangan jujukan ringkas (SSR). Selain itu, adalah untuk mengenal pasti pokok induk dan kacukan yang unggul berdasarkan variasi keupayaan bergabung umum (GCA) dan khusus (SCA), dan menggangarkan nilai heterosis untuk ciri hasil dan komponen hasil. Lokasi kajian ini adalah di Ladang 15 and Ladang 10, UPM Serdang, Selangor, Malaysia. Kajian ini terdiri daripada empat eksperimen, di mana eksperimen pertama dilakukan untuk menilai 56 aksesi terung di ladang penyelidikan terbuka. Semua ciri menunjukkan nilai heritabiliti dan kemajuan genetik yang tinggi, menunjukkan bahawa ciri-ciri ini mudah diwariskan daripada pokok induk kepada keturunannya. Dendrogram dibina berdasarkan prestasi hasil, dan genotip-genotip diklusterkan kepada tujuh kumpulan. Daripada kajian ini, kluster II, III dan IV telah dipilih kerana menghasilkan jumlah hasil buah sepokok yang tinggi. Dalam eksperimen kedua, 16 dari 102 penanda SSR telah didapati polimorfik. Penanda yang terpilih menunjukkan tahap polimorfisme yang tinggi di dalam populasi dan tahap polimorfisme yang rendah antara populasi. Dalam eksperimen ketiga, 27 aksesi terung yang terpilih daripada kajian sebelumnya untuk penilian lanjutan di ladang untuk memilih genotip terbaik berdasarkan prestasi ciri kuantitatif dan kualitatif. Dari penilian ini, sebanyak 11 aksesi terung (BB1, BT13, BM9, BB26, BB31, BM5, BB23, BT17, BB12, BT6 dan BT15) dipilih sebagai pokok induk untuk hibridisasi melalui kaedah kacukan 11×11 separuh dialel. Hibrid (55), titisan induk (11) dan varieti ujian (3) dinilai didua lokasi dengan mengikut reka bentuk blok penuh terawak (RCBD)

dengan tiga replikasi untuk menilai prestasi hidrid tersebut dan untuk menganggarkan kesan gen dan keupayaan bergabung 15 ciri-ciri morfologi dan biokimia. Analisis varians menunjukkan perbezaan yang sangat signifikan antara persekitaran, dan interaksi genotip dengan persekitaran bagi kesemua ciri-ciri kecuali untuk nisbah panjang ke lebar buah. Kesan gen aditif adalah signifikan ke atas pewarisan ciri-ciri tersebut dan ekspresi gen ini sangat dipengaruhi oleh persekitaran. Keupayaan bergabungan umum (GCA) lebih besar daripada keupayaan bergabungan spesifik (SCA) untuk semua ciri kecuali hasil buah sepokok. Nilai tinggi kesan GCA dan SCA untuk ciri yang difokuskan tersebar dikalangan genotip. Daripada kajian ini, didapati bahawa titisan induk terbaik adalah BT15 berdasarkan bilangan hari keluar bunga pertama, jumlah buah sepokok, jumlah pepejal larut (TSS) dan jumlah kandungan fenol. Selain itu, induk BM5 menunjukkan kesan keupayaan bergabungan umum yang baik untuk hasil buah sepokok, panjang buah dan nisbah panjang buah ke lebar, manakala induk BB1 menunjukkan keupayaan bergabungan umum yang baik untuk diameter buah, lilitan buah dan berat buah. Sebaliknya, kacukan BT6 × BT15 didapati berbunga lebih awal dengan kandungan jumlah fenol yang tinggi, manakala hibrid BM9 × BB26 pula mempunyai hasil buah sepokok dan TSS yang tinggi. Di samping itu, hibrid BM9 × BB1 menunjukkan diameter buah dan berat buah yang tinggi. Hibrid-hibrid terung unggul ini adalah disyorkan untuk penilaian skala besar dan kemudiannya untuk penanaman komersial oleh petani sayur tempatan.

ACKNOWLEDGEMENTS

All praise to God, who is the most Merciful and Gracious, for his unending blessings, I could complete my Ph.D. program well.

I would like to give my heartfelt appreciation to my supervisor Prof. Dr. Mohd Rafii Yusop for his encouragement, invaluable support and helpful suggestions throughout the whole Ph.D. journey. I also wish to express my heartiest gratitude to my co-supervisor Dr. Azizah Misran and Dr. Mashitah Jusoh for their valuable guidance and encouragement, which ultimately led to my PhD's success.

I also would like to thanks Dr. Oladosu Yusuff for his continuous advice and suggestions. All the members and students of the Laboratory of Climate-Smart Food Crop Production, Institute of Tropical Agriculture and Food Security (ITAFoS), Universiti Putra Malaysia (UPM), are well acknowledged. Specially, Ismaila, Jamilu, swaray, Jalloh, Azad, Amdad, Sharif and all other Bangladeshi Student who are always helped me to do my research; thank you to all.

I would like to express my sincere thanks to Bangabandhu Science and Technology Fellowship, Bangladesh Ministry of Science and Technology, for selecting me as a PhD fellow. I wish to give my special thanks to the Bangladesh Agricultural Research Institute (BARI) management for providing my deputation during this PhD program.

I want to express my special gratitude to my beloved husband Avijit Kumar Modak, for his unalloyed sacrifice and keep my daughter secured & comfortable while I was away during this period.

I also express my deepest gratitude to my lovely parents and other family members for their love, affection, and continuous mental support until the end of this journey.

At last but not the least, I would like to very special thanks to my lovely daughter who sacrifices a lot for me, May God will take you to greatest height. I love you all.

Finally, thank you all to make me, who I am today, hope God will reward you.

This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	Percentage
µg	Microgram
µl	Microliter
µM	Micro molar
^{0}C	Degree celcius
AMOVA	Analysis of molecular variance
ANOVA	Analysis of variance
bp	Base pair
BP	Better parent
cm	Centimetre
CTAB	Cetylmethylammonium bromide
CV	Coefficient variation
DNA	Deoxyrobose nucleic acid
DNase	Deoxribonuclease I
dNTPs	deoxribonucleotide triphosphate
DPPH	Diphenylpicryl hydrazyl
EDTA	Ethylene diamine tetracetate
et al.	*et alia*
F_1	First filial generation
FAOSTAT	Food and agriculture organization (Statistics Division)
g	Gram
GCA	General combining ability
GCV	Genotypic coefficient of variation

h^2B	Broad sense heritability
HCL	Hydrochloric acid
HSD	Honestly significant differences
L	Litre
LSD	Least significant differences
M	Molar
mg	Milligram
mg/ mL	Milligram per millilitre
Min	Minute
ml	Millilitres
MP	Mid parent
NaCl	Sodium chloride
ng	Nanogram
nm	Nanometer
NTYSYS	Neighbour-Joining Numerical Taxonomy And Multivariate Analysis System
PCA	Principal component analysis
PCR	Polymerase chain reaction
PCV	Phenotypic coefficient of variation
pH	Potentiometric hydrogen ion concentration
PVP	Polyvinyl Polypyrrolidone
REML	Restricted maximum likelihood
rpm	Rotation per minute
SAHN	Sequential, agglomerative, hierarchical, and non-overlapping
SAS	Statistical analysis software

SCA	Specific combining ability
SSR	Simple sequence repeat
t/ ha	Tonne/ hectare
TBE	Tris-borate-EDTA
Tm	Melting temperature
TPC	Total phenolic content
UPGMA	Unweighted pair group method using arithmetic mean
UV	Ultraviolet
V	Volt

CHAPTER 1

INTRODUCTION

1.1 Background

Solanum melongena L., also known as eggplant or brinjal, is considered one of the important non-tuberous crops under the Solanaceae family (Nightshade family). It is an economically beneficial crop that provides a significant income source for small-scale farmers worldwide, especially in China, the highest eggplant-producing country (FAOSTAT, 2019). It is used as a popular vegetable, especially in Indian cuisine. It is enriched in vitamins and minerals, although it is popular for its antioxidants like anthocyanins, phenolic acids, and alkaloids that have a favourable effect on human health (Gajewski *et al*., 2009). Eggplant is reported to be domesticated in India, which happens to be the highest diversity is found. There are more significant attempts scope of eggplant improvement through heterosis breeding. The endeavour could improve its productivity and quality without dedicating consumer preference. Although the advancement of eggplant begins in the 1900s, consolidated efforts took a long time on genetic improvement. Exploration is still going on for a better variety because most commercial varieties lack one or other desirable characters (Dubey *et al*., 2014). Hybrid vigour in eggplant was first observed by Nagai and Kada (1926). As the popularity of F_1 hybrids is increasing in eggplant, it is obligatory to get certain hybrids with excellent quality and high yield (Dubey *et al*., 2014). Eggplant occupies among the top five vegetable crops in Asia and the Mediterranean basin (Boyaci *et al*., 2020).

According to the report of FAOSTAT, the world eggplant production areas were 1.84 million hectares, and the total production was 55.20 million metric tonnes (2019) which are 2.03% higher (54.10 million metric tonnes) than an earlier year (2018). Asia has the largest eggplant production, comprising more than 91% of the world production area and 94% of the total world production. In Asia, the eggplant production area was 1.7 million ha, whereas the total production was 52 million metric tonnes (FAOSTAT, 2019). The highest eggplant producing country is China (35.59 million metric tonnes) comprises over 62% of world production, followed by India (12.68 million metric tonnes) and Egypt (1.18 million metric tonnes). But in Malaysia, the production area is only 2,342 ha, whereas the total production was 39,103 metric tonnes (DOA, 2019). The top ten highest eggplant-producing countries in the world are presented in Appendix A1.

1.2 Significance of the study

Eggplant is a very delicious and year-round vegetable in Asian countries. It is a crop of the old world, which is domesticated in Asia. On the contrary, congeneric crops of eggplant are potato and tomato, which are new world (South American) crop representatives of the genus (*Solanum*) (Weese and Bohs, 2010; Chapman, 2019). But the production of eggplant in Malaysia is deficient (16.69 t/ha; DOA, 2019) compared to other countries like France (41.64 t/ha; FAOSTAT, 2019), where F_1 hybrids make up the majority of the economically viable cultivars (Dhaka *et al*., 2017). So, the ultimate goal is to increase productivity in the shortest time for this crop through heterosis breeding (Dhaka *et al*., 2017). Therefore, it is essential to breed for improved varieties with high yield and high quality. One of the major factors responsible for low production is the lack of high-yielding improved variety. It is believed that the use of the diallel breeding technique would lead to high yielding and high-quality variety development, which will lead to an increase in production of eggplant for local demand as well as increase source of more foreign reserves through export.

1.3 Problem Statement

Compared to other countries, the eggplant production in Malaysia is less i.e. 39,103 metric tonnes (DOA, 2019). In this context, it is critical to assess local eggplant germplasm for yield and yield contributing qualities to select better cultivars for appropriate output (Alam *et al*., 2021). Besides, lack of genetic resources was another factor of low production. The demand and production of eggplant are not proportioned in Malaysia. Hence, eggplant deserves profound discussion for advancement (Ramireddy *et al*., 2011). Vegetables are an essential ingredient in the ingestion of Malaysians. The vegetable production area was 40,000 ha reported by (Alam *et al.,* 2021). The demand for vegetable seeds is increasing day by day because of the commercialization of vegetables in the whole country.

Vegetable seed is needed yearly 265 tonnes, but production locally is only 13 tonnes (Mahmood, 2006). The deficiency of this vegetable seed is 252 tonnes per year which are imported from other exporting countries. But, these imported seeds do not produce a high yield in local environments. Hence, using agronomic features to assess yield performance and adaptability to climatic circumstances has been a focus of research in the recent decade. Hence, effort could extend with its high quality and high yielding but without propitiation of consumers preference. So it can be believed that the development of a high-yielding hybrid will lead to increase local vegetable production to fulfil local demand. Ultimately, income will increase for local people and reduce the outflow of foreign exchange. In addition, taste, texture, and appearance are now among the aspects being addressed alongside nutrient contents (Causse *et al.,* 2010) to suit consumer demand. So with limited eggplant production and research, it is incumbent on us to raise awareness of the necessity of utilizing and developing our available varieties for food security in the high-value vegetable market of Malaysia. A superior variety is the only way to get improved yields from any crop (Alam *et al.,* 2021). Hence, this research focuses on the development program of a superior hybrid variety of eggplant under Malaysian environmental conditions.

1.4 Research Objectives

The main objective of this study was to develop superior hybrids that can meet quality requirements and be high yielding through diallel crosses.

The specific objectives were to:

i) To determine morphological divergence among the accessions of eggplant

ii) To quantify molecular genetic diversity among the accessions of eggplant using SSR markers

iii) To select superior parents and hybrids based on GCA (general combining ability) and SCA (specific combining ability) effects

iv) To determine heterosis for fruit yield, other than fruit yield, and fruit-related quality traits

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