

Dedication

I would like to dedicate this thesis to my parents, Mr. Swapan Acharyya and Mrs. Sherald Phelomena Acharyya, who have made me what I am today.

Declaration

I declare that the thesis entitled “MOLECULAR AND BIOCHEMICAL CHARACTERIZATION OF MERCURY TOLERANT BACTERIA FROM VARIOUS REGIONS IN AND AROUND DARJEELING” has been prepared by me under the supervision of Dr. Malay Bhattacharya, Assistant Professor of the Department of Tea Science, University of North Bengal. No part of the thesis has formed the basis for the award of any degree or fellowship previously.

Sukanya Acharyya

[Sukanya Acharyya]
Department of Tea Science
University of North Bengal
Raja Rammohunpur, Siliguri-
734013

Date *05/02/2024*

UNIVERSITY OF NORTH BENGAL

Accredited by NAAC

DEPARTMENT OF TEA SCIENCE



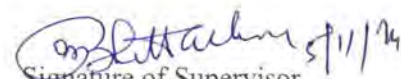
समस्तं मन्त्रं समितिं समानं

P.O. NORTH BENGAL UNIVERSITY
Raja Rammohunpur, Dist. Darjeeling
Siliguri-734013, West Bengal, INDIA
Tel.: +91 353 2776380
Website: www.nbu.ac.in

We develop skills for your cup!

CERTIFICATE OF SUPERVISOR

It is certified that the work contained in the thesis titled "MOLECULAR AND BIOCHEMICAL CHARACTERIZATION OF MERCURY TOLERANT BACTERIA FROM VARIOUS REGIONS IN AND AROUND DARJEELING", by "Sukanya Acharyya," has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.


Signature of Supervisor

Department of Tea Science
North Bengal University
February/2024



The Report is Generated by DrillBit Plagiarism Detection Software

Submission Information

Author Name	Sukanya Acharyya
Title	MOLECULAR AND BIOCHEMICAL CHARACTERIZATION OF MERCURY TOLERANT BACTERIA FROM VARIOUS REGIONS IN AND AROUND DARJEELING
Paper/Submission ID	1385158
Submitted by	nbuplg@nbu.ac.in
Submission Date	2024-02-01 12:52:01
Total Pages	277
Document type	Thesis

Result Information

Similarity **0 %**

Exclude Information

Quotes	Excluded
References/Bibliography	Excluded
Sources: Less than 14 Words %	Excluded
Excluded Source	5 %
Excluded Phrases	Not Excluded

Database Selection

Language	English
Student Papers	Yes
Journals & publishers	Yes
Internet or Web	Yes
Institution Repository	Yes

Sukanya
Acharyya
05/02/2024

Dr. Subrata Acharya
5/1/24



UNIVERSITY OF NORTH BENGAL

Accredited by NAAC with Grade B⁺⁺

DEPARTMENT OF TEA SCIENCE



সম্মান্যে সম্মান্য সম্মান্যে

P.O. NORTH BENGAL UNIVERSITY
Raja Rammohunpur, Dist. Darjeeling
Siliguri-734013, West Bengal, INDIA
Tel.: +91 353 2776380
Website: www.nbu.ac.in


We develop skills for your cup!

DRC CERTIFICATE

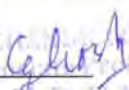
It is certified that the work contained in the thesis titled "MOLECULAR AND BIOCHEMICAL CHARACTERIZATION OF MERCURY TOLERANT BACTERIA FROM VARIOUS REGIONS IN AND AROUND DARJEELING", by "Sukanya Acharyya", has been carried out following University guideline and has been approved by the Departmental research Committee for processing by the Board of Research Studies.

Approved:

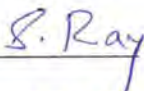
Date:

Dr. Malay Bhattacharya 
Name and Signature of DRC Member Dr. Malay Bhattacharya
Assistant Professor
Department of Tea Science
University of North Bengal

01.02.24

Dr. Chandra Anosh 
Name and Signature of DRC Member Dr. Chandra Anosh
Assistant Professor
(M.Sc., Ph.D., PGAT, FEHT)
Department of Tea Science
University of North Bengal

01.02.2024

Dr. Sonali Ray 
Name and Signature of DRC Member DR. SONALI RAY
ASSISTANT PROFESSOR
DEPARTMENT OF TEA SCIENCE
UNIVERSITY OF NORTH BENGAL
DARJEELING, W.B. INDIA - 734013

1.2.2024

Department: Tea Science
University of North Bengal

Preface

Intellectual curiosity was instilled in me during my formative years in school, which I owe to my biology teacher Dr. Avijit Majumder. He always encouraged me to ask questions and explore beyond the boundaries of assigned books and a set curriculum. This remained with me throughout my academic journey, which culminated in my seeking a Ph.D. The ignited curiosity was further fuelled in my Ph.D. research and this thesis represents several years of rigorous study, reflection, and relentless dedication to my work.

The pursuit of research often feels like a solitary expedition through uncharted territories. As I stand at the threshold of this endeavour, I am filled with a profound sense of gratitude and humility. I was blessed to have landed in the care of a very supportive supervisor, Dr. Malay Bhattacharya, Assistant Professor and Head of the Department of Tea Science, University of North Bengal. He not only nurtured my curiosity but taught me invaluable lessons in the pursuit of science, as well as, life. He has been a teacher and guide to me in the true sense of the words. I express my heartfelt gratitude to him and feel immensely lucky to have traversed this difficult journey under his guidance. I also thank Dr. Chandra Ghosh, Dr. Sonali Ray and Dr. Tanmayee Mishra for their encouragement and support during my years in the Department of Tea Science. I also acknowledge the contributions of Mr. Mainak Mukherjee, the soil analyst of our department, non-teaching staff members and fellow research scholars for making this journey easier for me each day.

This work would not have been possible without the unwavering support of my lab mates, who have become more akin to family in these past few years. The guidance, encouragement, and insightful feedback of Soumya Majumder, Arindam Ghosh, Sourav Chakraborty, and Sahadeb Sarkar have been my saving grace more times than I can count. Research has been an enjoyable experience because of them. I extend my heartfelt appreciation to each one of them for their invaluable contributions. I also thank my juniors Preeti Subba and Sudeshna Nandi, who have brought enthusiasm and fresh perspectives to my final years of work.

A Ph.D. is a deeply personal and transformative experience. It is a journey marked by moments of triumph and frustration, clarity and ambiguity. I was fortunate enough to have undertaken these trails with my dearest friend and confidant, Sumedha Saha, who has always been there for me in my most difficult times. I thank her for her camaraderie and sharing in my experiences. I am also indebted to Mrs. Ranjana Saha and Mr. Uma Sankar Saha, who have been like my parents away from home. I will forever be grateful for their warmth, love and kindness.

I have been privileged in the wealth of people I have made the acquaintance of in my life. I would like to specially mention my friends Steffi Adhikary, Pallavi Addy, Mugdha Bhattacharya and Srijita Kundu who have supported me and whatever I may dream, since my school days. Not only their constant support, but also their own journeys in life have inspired me in mine. The friends I made during my M.Sc. course, Mohit Singh, Baishakhi Ghosh, Priya Bhuiya, Debrupa Sarkar, and Moumita Mukherjee have encouraged me, helped me sustain my mental well-being and stood by me through thick and thin.

Finally, I dedicate this work to my father, Mr. Swapan Acharyya, mother, Mrs. Sherald Phelomena Acharyya, and my sister, Sunayana Acharyya, whose constant love and support have sustained me throughout this endeavour. They have always encouraged me to pursue my dreams and been my guiding light. Their belief in my abilities and faith in my ambition have been my greatest source of motivation, and for that, I am eternally grateful.

In this thesis, I aim to make a meaningful contribution to my field of research. I hope that the insights and conclusions presented here will serve as a foundation upon which future researchers can build, fostering a deeper understanding of the complex issues surrounding this topic. This thesis is a testament to the cumulative efforts of countless researchers who have paved the way for exploration. As so many people have done for me, I hope with this work I can incite curiosity in others as well. Thus, with humility and anticipation, I present this thesis, hoping that it contributes a small yet significant piece to the vast mosaic of human knowledge.

LIST OF FIGURES

Figure	Page No.
Figure 1. Map of soil collection sites	70
Figure 2. Bacterial pure culture isolation	74
Figure 3. MIC determination of bacterial pure culture isolates	76
Figure 4. Various biochemical characterization tests conducted on pure culture isolates	100
Figure 5. UPGMA tree based on biochemical characteristics of the bacterial isolates	102
Figure 6. Carbohydrate fermentation test	108
Figure 7. In vitro Plant growth promotion tests	117
Figure 8. Heavy metal cross-tolerance test	128
Figure 9. UPGMA tree based on heavy metal resistance of the studied bacterial isolates	131
Figure 10. Growth curves under category 1	134
Figure 11. Growth curves under category 2	135
Figure 12. Growth curves under category 3	135
Figure 14. UPGMA tree based on antibiotic susceptibility among the bacterial isolates	176
Figure 15. UPGMA type tree for antibiotic and heavy metal resistance of the bacterial isolates	178
Figure 16. Representative chromatogram (MTK3A) from GC-MS of bacterial isolates	180
Figure 17. Butyric acid synthesis and derived compounds	185
Figure 18. Some detected cyclic dipeptides	188
Figure 19. Some detected heterocyclic compounds	193
Figure 20. Polyaromatic hydrocarbon degradation	195
Figure 21. Important detected bioactive fatty acids	197
Figure 22. Suggested pathway for synthesis of 1,3-diazaadamantane	202
Figure 23. Other detected compounds of interest	204

LIST OF TABLES

Tables	Page No.
Table 1. Soil sample collection sites with corresponding consortium ID	72
Table 2. Bacterial isolate ID with colony morphology	73
Table 3. MIC and MTC of bacterial pure culture isolates	75
Table 4. Gram characteristic and cellular morphology	78
Table 5. Methyl Red (MR) and Voges-Proskauer (VP) test	83
Table 6. Citrate utilization test	85
Table 7. Triple Sugar Iron (TSI) test	87
Table 8. Starch and gelatin hydrolysis tests	91
Table 9. Sulphide-indole-motility (SIM) test	93
Table 10. Nitrate reduction (NR) and urease production	96
Table 11. Catalase and Coagulase test	99
Table 12. Carbohydrate fermentation profile of the bacterial isolates	107
Table 13. <i>In vitro</i> plant growth promoting (PGP) traits of the bacterial isolates	111
Table 14. Heavy metal cross-tolerance profile of the bacterial isolates	129
Table 15. Molecular identification results of selected bacterial isolates	137
Table 16. Resistance profile of the bacterial isolates towards beta-lactam antibiotics	149
Table 17. Resistance profile of bacterial isolates to glycopeptide antibiotics	151
Table 18. Resistance profile of the bacterial isolates to sulphonamide and non-sulphonamide drugs	154
Table 19. Resistance profile of the bacterial isolates to fluoroquinolone and aminocoumarin antibiotics	157
Table 20. Resistance profile of the bacterial isolates to aminoglycoside, macrolide, lincosamide, and streptogramin antibiotics	160
Table 21. Resistance profile of the bacterial isolates to tetracycline and tigecycline antibiotics	164
Table 22. Resistance profile of the bacterial isolates to chloramphenicol and oxazolidone antibiotics	167
Table 23. Resistance profile of the bacterial isolates to fosfomycin, nitrofurantoin, fusidic acid, aminocyclitol, polymyxin, polypeptide and antimycobacterial antibiotics	169
Table 24. Some major bioactive metabolites of the bacterial isolates	181