

**AN EXPLORATION OF THE ROLE OF MICROBES AND
BIOSTIMULANTS IN THE PHYTOREMEDIATION OF
NITRATED POLYCYCLIC AROMATIC
HYDROCARBONS (nitro-PAHs)**

THESIS SUBMITTED TO THE BODOLAND UNIVERSITY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY IN BOTANY
UNDER THE FACULTY OF SCIENCE AND TECHNOLOGY



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CERTIFICATE

I have the pleasure in forwarding the thesis entitled: "*An Exploration of the Role of Microbes and Biostimulants in the Phytoremediation of Nitrated Polycyclic Aromatic Hydrocarbons (nitro-PAHs)*" submitted by **Mr. Bhoirob Gogoi** to Bodoland University for the award of the Ph.D. degree.

The thesis is the outcome of his original research work, which he performed under my guidance, putting in his best efforts. The thesis presented is worthy of being considered for the award of the Ph.D. degree.

Mr. Gogoi has fulfilled all the requirements under the regulations of the Ph.D. degree. The candidate has duly acknowledged the help received by him.

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DECLARATION

I, Bhoirob Gogoi, do hereby declare that the subject matter of my thesis entitled “An exploration of the role of microbes and biostimulants in the phytoremediation of nitrated polycyclic aromatic hydrocarbons (nitro-PAHs)” is the research work done by me under the supervision of Dr. Hemen Sarma, Associate Professor & Head, Department of Botany, Bodoland University. No part of the thesis has been submitted for any research degree or diploma to any other University / Institute.

This is being submitted to Bodoland University for the award of the degree of Doctor of Philosophy in Botany under the Faculty of Science and Technology.

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List of Figures

Figure No.	Figure Caption	Page No
Fig. 1.1.	Nitro-PAH pollution negatively impacts various environmental and health-related Sustainable Development Goals (SDGs).	3
Fig. 1.2.	Oil spills in a paddy field at the study site– a common issue in Assam’s oil fields.	5
Fig. 2.1.	Chemical structure of some specific nitro-PAHs.	11-12
Fig. 2.2.	Mechanism of phytoremediation.	31
Fig. 2.3.	Microbial remediation of nitro-PAHs.	34
Fig. 2.4.	Role of biostimulants in physiological modulation, anatomical modulation, and biochemical modulation.	39
Fig. 3.1.	Study site – ONGC GGS Borholla, Assam, India (26°45' N latitude and 94°37' E longitude), where plants and soil samples were collected.	44
Fig. 3.2.	Greenhouse experimental setup for evaluating the effects of isolated bacterial strains and their co-inoculum (BGC01) on the growth of (a) <i>Cyperus rotundus</i> , (b) <i>Cyperus esculentus</i> , (c) <i>Axonopus compressus</i> , and (d) <i>Imperata cylindrica</i> .	57
Fig. 3.3.	Schematic illustration of the steps for biostimulant preparation.	58
Fig. 3.4.	Greenhouse experimental setup for evaluating the effects of the biostimulants on the growth of (a) <i>Cyperus rotundus</i> , (b) <i>Cyperus esculentus</i> , (c) <i>Axonopus compressus</i> , and (d) <i>Imperata cylindrica</i> .	59
Fig. 3.5.	Experimental microcosms for phytoremediation studies before inoculation of plant-bacterial co-inoculum.	61
Fig. 4.1.	The screened-out plant species from the sampling site.	69
Fig. 4.2.	Standard calibration curve for 1-nitropyrene (a) and 2-nitrofluorene (b).	72
Fig. 4.3.	Standard HPLC chromatogram of 1-nitropyrene at varying concentrations: (a) 5 µg/mL, (b) 10 µg/mL, and (c) 20 µg/mL.	73

Fig. 4.4.	Standard HPLC chromatogram of 2-nitrofluorene at varying concentrations: (a) 5 µg/mL, (b) 10 µg/mL, and (c) 20 µg/mL.	74
Fig. 4.5.	Representative HPLC chromatogram of 1-nitropyrene in root samples collected on day 30 from pots treated with different plant species: (a) <i>Cyperus rotundus</i> , (b) <i>Cyperus esculentus</i> , (c) <i>Axonopus compressus</i> , and (d) <i>Imperata cylindrica</i> .	75
Fig. 4.6.	Representative HPLC chromatogram of 1-nitropyrene in root samples collected on day 60 from pots treated with different plant species: (a) <i>Cyperus rotundus</i> , (b) <i>Cyperus esculentus</i> , (c) <i>Axonopus compressus</i> , and (d) <i>Imperata cylindrica</i> .	76
Fig. 4.7.	Representative HPLC chromatogram of 2-nitrofluorene in root samples collected on day 30 from pots treated with different plant species: (a) <i>Cyperus rotundus</i> , (b) <i>Cyperus esculentus</i> , (c) <i>Axonopus compressus</i> , and (d) <i>Imperata cylindrica</i> .	77
Fig. 4.8.	Representative HPLC chromatogram of 2-nitrofluorene in root samples collected on day 60 from pots treated with different plant species: (a) <i>Cyperus rotundus</i> , (b) <i>Cyperus esculentus</i> , (c) <i>Axonopus compressus</i> , and (d) <i>Imperata cylindrica</i> .	78
Fig. 4.9.	Accumulation of 1-nitropyrene (a) and 2-nitrofluorene (b) in the root tissues of <i>Cyperus esculentus</i> , <i>Cyperus rotundus</i> , <i>Imperata cylindrica</i> , and <i>Axonopus compressus</i> over 30-day and 60-day intervals.	80
Fig. 4.10.	Average count ($\times 10^6$ cfu/g soil) of total rhizosphere bacteria in the rhizosphere soil samples of screened plant species was recorded.	81
Fig. 4.11.	Bacterial biomass (g/L) at different concentrations of 1-nitropyrene (a) and 2-nitrofluorene (b) after 7 days of incubation.	83
Fig. 4.12.	Gram staining of isolated nitro-PAHs tolerant rhizobacterial strains BG034 (strain 1) (a) and strain BG05 (strain 2) (b).	83
Fig. 4.13.	Various biochemical tests of the isolated strains—Citrate test (a), Methyl red test (b), Voges-Proskauer test (c), Urease test (d), Catalase test (e), Gelatin test (f), and Oxidase Test (g).	87

Fig. 4.14.	Amplicon photographs of (a) <i>Bacillus cereus</i> BG034 and (b) <i>Bacillus altitudinis</i> BG05.	88
Fig. 4.15.	Electropherogram of <i>Bacillus cereus</i> BG034 16S rDNA.	89
Fig. 4.16.	Electropherogram of <i>Bacillus altitudinis</i> BG05 16S rDNA.	90
Fig. 4.17.	The submitted gene sequence of <i>Bacillus cereus</i> BG034 in GenBank.	91
Fig. 4.18.	The submitted gene sequence of <i>Bacillus altitudinis</i> BG05 in GenBank.	92
Fig. 4.19.	The neighbor-joining phylogenetic tree is based on 16S rDNA sequences, illustrating the taxonomic position of nitro-PAHs tolerance isolated bacteria (yellow highlighted) and NCBI bacteria references.	94
Fig. 4.20.	Compatibility test of the bacterial strains <i>Bacillus cereus</i> BG034, and against <i>Bacillus altitudinis</i> BG05 (a) and <i>Bacillus altitudinis</i> BG05 against <i>Bacillus cereus</i> BG034 (b).	95
Fig. 4.21.	Schematic representation of the degradation study conducted under shaker flask conditions.	96
Fig. 4.22.	Representative HPLC chromatogram illustrating the abiotic degradation of 1-nitropyrene in 1-nitropyrene-spiked PBYS medium at different time intervals: (a) 0 hours, (b) 24 hours, (c) 48 hours, and (d) 72 hours.	98
Fig. 4.23.	Representative HPLC chromatogram illustrating the degradation of 1-nitropyrene by <i>Bacillus cereus</i> BG034 in 1-nitropyrene-spiked PBYS medium at different time intervals: (a) 0 hours, (b) 24 hours, (c) 48 hours, and (d) 72 hours.	99
Fig. 4.24.	Representative HPLC chromatogram illustrating the degradation of 1-nitropyrene by <i>Bacillus altitudinis</i> BG05 in 1-nitropyrene-spiked PBYS medium at different time intervals: (a) 0 hours, (b) 24 hours, (c) 48 hours, and (d) 72 hours.	100

Fig. 4.25.	Representative HPLC chromatogram illustrating the degradation of 1-nitropyrene by Co-inoculum BGC01 in 1-nitropyrene-spiked PBYS medium at different time intervals: (a) 0 hours, (b) 24 hours, (c) 48 hours, and (d) 72 hours.	101
Fig. 4.26.	Representative HPLC chromatogram illustrating the abiotic degradation of 2-nitrofluorene in 2-nitrofluorene-spiked PBYS medium at different time intervals: (a) 0 hours, (b) 24 hours, (c) 48 hours, and (d) 72 hours.	102
Fig. 4.27.	Representative HPLC chromatogram illustrating the degradation of 2-nitrofluorene by <i>Bacillus cereus</i> BG034 in 2-nitrofluorene-spiked PBYS medium at different time intervals: (a) 0 hours, (b) 24 hours, (c) 48 hours, and (d) 72 hours.	103
Fig. 4.28.	Representative HPLC chromatogram illustrating the degradation of 2-nitrofluorene by <i>Bacillus altitudinis</i> BG05 in 2-nitrofluorene-spiked PBYS medium at different time intervals: (a) 0 hours, (b) 24 hours, (c) 48 hours, and (d) 72 hours.	104
Fig. 4.29.	Representative HPLC chromatogram illustrating the degradation of 2-nitrofluorene by Co-inoculum BGC01 in 2-nitrofluorene-spiked PBYS medium at different time intervals: (a) 0 hours, (b) 24 hours, (c) 48 hours, and (d) 72 hours.	105
Fig. 4.30. (a)	Degradation of 1-nitropyrene by the formulated bacterial co-inoculum and individual strains in a shaker flask over a 72-hour incubation period.	107
Fig. 4.30. (b)	Degradation of 2-nitrofluorene by the formulated bacterial co-inoculum and individual strains in a shaker flask over a 72-hour incubation period.	107
Fig. 4.31.	The kinetic regression equation for 1-nitropyrene (Strain BG034 (a), BG05 (b), and BGC01(c)).	110
Fig. 4.32.	The kinetic regression equation for 2-nitrofluorene (Strain BG034 (a), BG05 (b), and BGC01 (c)).	111

Fig. 4.33.	The <i>in vitro</i> PGP test of the isolated bacterial strains. Phosphate solubilization test (a), Siderophore production test (b), Ammonia Production test (c), IAA test (d), HCN production test (e), Triple Sugar Iron (TSI) test (f).	118
Fig. 4.34.	Standard calibration curve of soluble phosphate (a), ammonium (b), IAA (c), and HCN (d).	119
Fig. 4.35.	<i>In vivo</i> experiment setup for plant growth-promoting by isolated bacterial strains and formulated co-inoculum. <i>Cyperus rotundus</i> (a), <i>Cyperus esculentus</i> (b), <i>Imperata cylindrica</i> (c), and <i>Axonopus compressus</i> (d).	121
Fig. 4.36.	Effects of bacterial inoculation on the root length (a-d) of <i>Cyperus rotundus</i> (a), <i>Cyperus esculentus</i> (b), <i>Imperata cylindrica</i> (c), and <i>Axonopus compressus</i> (d)— throughout 21 days.	122
Fig. 4.37.	Effects of bacterial inoculation on the shoot length (a-d) of <i>Cyperus rotundus</i> (a) <i>Cyperus esculentus</i> (b), <i>Imperata cylindrica</i> (c), and <i>Axonopus compressus</i> (d)— throughout 21 days.	124
Fig. 4.38.	<i>In vivo</i> experimental setup for plant growth-promoting test by formulated biostimulant. <i>Cyperus rotundus</i> (a), <i>Cyperus esculentus</i> (b), <i>Imperata cylindrica</i> (c), and <i>Axonopus compressus</i> (d).	128
Fig. 4.39.	Effects of biostimulant on the shoot length (a-d) of <i>Cyperus rotundus</i> (a), <i>Cyperus esculentus</i> (b), <i>Imperata cylindrica</i> (c), and <i>Axonopus compressus</i> (d)— throughout 21 days.	129
Fig. 4.40.	Effects of biostimulant on the root length (a-d) of <i>Cyperus rotundus</i> (a), <i>Cyperus esculentus</i> (b), <i>Imperata cylindrica</i> (c), and <i>Axonopus compressus</i> (d) throughout 21 days.	131
Fig. 4.41.	TIC of 1-nitropyrene metabolites via GC-MS under the plant-bacterial co-inoculum and biostimulant treatment at baseline conditions (0 days).	135

Fig. 4.42.	TIC of 1-nitropyrene metabolites via GC-MS throughout the plant-bacterial co-inoculum and biostimulant treatment following 30 days of incubation.	135
Fig. 4.43.	TIC of 1-nitropyrene metabolites via GC-MS throughout the plant-bacterial co-inoculum and biostimulant treatment following 60 days of incubation.	136
Fig. 4.44.	TIC of 2-nitrofluorene metabolites via GC-MS under the plant-bacterial co-inoculum and biostimulant treatment at baseline conditions (0 days).	138
Fig. 4.45.	TIC of 2-nitrofluorene metabolites via GC-MS throughout the plant-bacterial co-inoculum and biostimulant treatment following 30 days of incubation.	138
Fig. 4.46.	TIC of 2-nitrofluorene metabolites via GC-MS throughout the plant-bacterial co-inoculum and biostimulant treatment following 60 days of incubation.	139
Fig. 4.47.	Proposed nitro-PAH degradation pathways by plant-bacterial co-inoculum in microcosms.	141
Fig. 4.48.	Graphical representation of the study.	155

List of Tables

Table No.	Table Caption	Page No
Table 2.1.	Concentration of nitro-PAHs in the environmental matrix.	10
Table 2.2.	Physicochemical properties of nitro-PAHs.	16
Table 2.3.	The human health impact of specific nitro-PAHs.	26
Table 4.1.	Detailed floristic diversity of the sampling site showing relative density, relative frequency, and importance value index.	70
Table 4.2.	Standard calibration for 1-nitropyrene.	72
Table 4.3.	Standard calibration for 2-nitrofluorene.	72
Table 4.4.	The biochemical characterization of the isolated strains.	86
Table 4.5.	Percentage degradation of 1-nitropyrene and 2-nitrofluorene by bacterial strains and co-inoculum over an incubation period of 0 to 72 hours.	106
Table 4.6.	Degradation rate ($\text{mg L}^{-1} \text{ h}^{-1}$) of 1-nitropyrene and 2-nitrofluorene by bacterial strains and co-inoculum over a 0-72 hour incubation period.	109
Table 4.7.	Kinetic parameters and regression equations for the degradation of 1-nitropyrene and 2-nitrofluorene by isolated bacterial strains and their co-inoculum over a 0–72 hour incubation period.	111
Table 4.8.	PGP traits of isolated bacteria.	119
Table 4.9.	Statistical results on root length among the species upon application of bacterial strains and their co-inoculum (from 7 days to 21 days experiment periods).	122
Table 4.10.	Statistical results on shoot length among the species upon application of bacterial strains and their co-inoculum (from 7 days to 21 days experiment periods).	123

Table 4.11.	The composition of amino acids (mg/L) in mustard cake and prepared biostimulant.	126
Table 4.12.	Statistical results on shoot length among the species upon biostimulant treatment (from 7 days to 21 days experiment periods).	127
Table 4.13.	Statistical results on root length among the species upon treatment of biostimulant (from 7 days to 21 days experiment periods).	130
Table 4.14.	Identified metabolites of 1-nitropyrene in spiked microcosms at baseline (0 days) and after 30 and 60 days of treatment with plant-bacterial co-inoculum and biostimulant.	133-134
Table 4.15.	Identified metabolites of 2-nitrofluorene in spiked microcosms at baseline (0 days) and after 30 and 60 days of treatment with plant-bacterial co-inoculum and biostimulant.	142-143
Table 4.16.	Soil Physicochemical properties of microcosm at 0, 30, and 60 days of treatment.	147
Table 4.17.	Statistical test of soil physicochemical properties in the microcosms at the treatment periods.	148
Table 4.18.	Antioxidant enzyme activities of the plant species in the experimental microcosm at 0, 30, and 60 days of treatment by plant-bacterial co-inoculum and biostimulant.	150-151
Table 4.19.	Statistical results of antioxidant enzymes of the plant species in the experimental microcosm at 0, 30, and 60 days of treatment by plant-bacterial co-inoculum and biostimulant.	152-154

Abbreviation used

nitro-PAHs: Nitrated Polycyclic Aromatic Hydrocarbons

PAHs: Polycyclic Aromatic Hydrocarbons

ROS: Reactive Oxygen Species

SDGs: Sustainable Development Goals

U.S. EPA: United States Environmental Protection Agency

OSHA: Occupational Safety and Health Administration

WHO: World Health Organization

OIL: Oil India Limited

ONGC: Oil and Natural Gas Corporation Limited,

IOCL: Indian Oil Corporation Limited

BPCL: Bharat Petroleum Corporation Ltd

AHECL: Assam Hydrocarbon and Energy Company Limited

GGs: Group Gathering Stations

PUF: Polyurethane Foam

LLE: Liquid-liquid Extraction

SPE: Solid-phase Extraction

UAE: Ultrasound-assisted extraction

LPME: Liquid-phase microextraction

DLLME: Dispersive Liquid-Liquid Microextraction

SDME: Single-Drop Microextraction

SFO-DLLME: Solidification of Floating organic Drop-Dispersive Liquid-Liquid
Microextraction

HS-LPME: Headspace Liquid-Phase Microextraction

QuEChERS: Quick, Easy, Cheap, Effective, Rugged, and Safe

PDMS/DVB: Polydimethylsiloxane/Divinylbenzene

GC-MS: Gas Chromatography coupled with Mass Spectrometry

HPLC: High-Performance Liquid Chromatography

iNOS: Inducible Nitric Oxide Synthase

COX-2: Cyclooxygenase-2

NF- κ B: Nuclear factor-kappa B

IL-1 β : Interleukin-1 beta

IL-6: Interleukin-6

TNF- α : Tumor Necrosis Factor Alpha

IARC: International Agency for Research on Cancer

NADPH: Nicotinamide Adenine Dinucleotide Phosphate

TNT: 2,4,6-trinitrotoluene

RHO: Ring-Hydroxylating Oxygenase

CYP450: Cytochrome P450 Monooxygenases

TCA: Tricarboxylic Acid

ATP: Adenosine Triphosphate

IVI: Importance Value Index

cfu: Colony forming Unit

PBYS: Peptone Beef Yeast Extract

R^2 : Coefficient of Determination

k : Rate constant

$T_{1/2}$: Half-life

CAS: Chrome Azurol S

HDTMA: Hexadecyltrimethylammonium bromide

NCBI: National Center for Biotechnology Information

BLASTn: Basic Local Alignment Search Tool for Nucleotide sequences

MEGA: Molecular Evolutionary Genetics Analysis

PGP: Plant Growth Promoting

PGPR: Plant Growth Promoting Rhizobacteria

BGCP01: A plant-bacterial co-inoculum

BGC01: Bacterial co-inoculum

MSD: Mass Selective Detector

NIST: National Institute of Standards and Technology

TIC: Total Ion Chromatogram

dS/m: DeciSiemens per meter