ANNEXURE QnM 3.7.1/3

3.7.1 Number of functional MoUs /linkage with institutions/ industries in India and abroad for internship, on-the-job training, project work, student / faculty exchange and collaborative research during the last five years

3.7.1.1: Number of functional MoUs with institutions/ industries in India and abroad for internship, on-the-job training, project work, student / faculty exchange and collaborative research during the last five years

SL. NO.	Year of signing MoU	Name of the organization with whom MOU/Collaboration being signed	Duration	Purpose of MOU/Collaboration	List the actual activities under each MOU year-wise	Date of the activity conducted
1	2009	Professor P Kumbhakar, Physics Department, NIT-Durgapur	13 Years	Research on Nonlinear optical devices	Research paper	13 Years
2	2011	ONGC	Still Ongoing	To provide scholarship First Ranking, MSc 1st Year, Physics & Chemistry. (continuing)		Still Ongoing
3	2014	Botanical Survey of India, Salt Lake, Kolkata 700 064	Still Ongoing	To develop the existing herbarium and enrich with digital images of plants specimens. (continuing)	To protect the fragile microcosm of unique biodiversity glorifying the Golapbag campus of The University of Burdwan; adding value to the existing knowledge base, teaching and research activities involving Department of Botany, The University of Burdwan in the process	Still Ongoing
4	2015 Renewed on 2018 for 3 years	Space Application Centre, Indian Space Research Organization, Department of Space, Government of India, Ahmedabad – 380 015	5 Years	IRNSS/NAVIC Navigation Receiver Field Trial and Data Collection. (continuing)	One sponsored project, study reports, publications, trained manpower, software and hardware development	5 Years
5	2015	ICAR-Central Potato Research Institute, Shimla 171 001	03 years, Extendable	To undertake the responsibility and to promote and coordinate agricultural and animal husbandary education and research and in practice. (continuing)	Foundation seed production and distributions, interactive programmes between farmers and growers	03 years, Extendable
6	2015	RIKEN Institute, Japan, Bose Institute, Kolkata, BSI, Kolkata, Department of Chemistry, B.U, Department of Zoology, B.U.	08 Years	Collaborative research activity / Linkage	Research	08 Years
7	2015	Department of Zoology, Calcutta University and B. U, VisvaBharati, Santiniketan,Bhagalpur University, Bihar	08 Years	Collaborative research activity / Linkage	Research	08 Years
8	2015	Department of Marine Science, Calcutta University	08 Years	Collaborative research activity / Linkage	Research	08 Years
9	2015	ICAR-CIFA, Institute funded project	06 Years	Artificial propagation and nursery rearing of Indian Shad, Tenualosa ilisha in freshwater culture system	Ph.D. Program	06 Years
10	2016	BSIP, Lukhnow, National Metallurgical LaboratoryJamshedpur, ZSI, Rohtak	07 Years	Collaborative research activity / Linkage	Research	07 Years
11	2016	IISER Tirupati, IISER Bhopal, Department of Chemistry, B.U	08 Years	Collaborative research activity / Linkage	Research	08 Years
12	2016	Prof. Houria Triki, Radiation Physics Laboratory, Department of Physics, Faculty of Sciences, Badji Mokhtar University, P.O. Box 12, 23000 Annaba, Algeria	08 Years	Collaborative research activity / Linkage	Research Paper	08 Years
13	2017	Dr. Sachindranath Das, Dept. of Instrumentation Science, Jadavpur University	4 Years	Collaborative research activity, Electrochemical characterization / Linkage	CV, GCD and EIS Characterization	4 Years
14	2017	ICAR-CIFA, Institute funded project	3 Years	Development of larval diet for Ompok bimaculatus, a high-valued fish of regional importance	Research	3 Years
15	2018	ICAR-Central Institute of Freshwater Aquaculture (CIFA), Kausalyaganga, Bhubaneswar 751002	3 Years, extendable upto 5 years	Long-term collaboration for promotion of students' training and quality post-graduate research in fresh water aqaculture (continuing)	Completed a collaborative project on the ontogeny and larval diet of butter catfish, Ompok bimaculatus Two students are carrying out research for their Ph.D. degree under joint supervision of the scientists from CIFA and faculty members from BU	3 Years, extendable upto 5 years
16	2018	Department of Biotechnology, Ministry of Science & Technology, GoI	3 Years	One sponsored project	One sponsored project, study reports, publications, trained manpower, software and hardware development	3 Years
17	2018	Visva Bharati, Santiniketan	5 Years	Collaborative research activity / Linkage	Research	5 Years

18	2018	International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India, State Agricultural Biotechnology Centre, Centre for Crop and Food Innovation, Murdoch University, Murdoch, Australia, Department of Earth Resources & Environmental Engineering, Hanyang University, Seoul, Republic of Korea, Chemistry Department, BU, Microbiology Department, BU, BIT, Mersa, Ranchi ; CCSU, Meerut; University of Maule, Talca, Chile, BSI, Kolkata, NABI, Chandigarh	5 Years	Collaborative research activity / Linkage	Research	5 Years
19	2018	BSI,Kolkata	5 Years	Collaborative research activity / Linkage	Research	5 Years
20	2018	Department of Science & Technology, Govt. of West Bengal	3 Years	Diversity, biosystematics and management of mites infesting tea plantations of Himalayan and sub-Himalayan regions of West Bengal, India	Ph.D. Program	3 Years
21	2018	NATIONAL INSTITUTE OF BIOMEDIC AL GENOMICS P.O.: N.S.S., Kalyani 741251, West Bengal, INDIA	1 Year	Agreement to collaborative work (ATC) on "Next Generation Sequencing Service	Research	1 Year
22	2018	Dr. Lars Leichert, Institute for Biochemistry and Pathobiochemistry Microbial Biochemistry Ruhr University Bochum	1 Year 2 Monrhs	DAAD Sandwich Programme	Research	1 Year 2 Monrhs
23	2019	Prof. Ajit Meicap, NIT Durgapur	3 Years	Collaborative research activity, Electrical Characterisation / Linkage	Electrical Characterisation	3 Years
24	2019	Dr. Uma Pada Pal, USA	3 Years	Collaborative research activity,Thermoelectric Measurement / Linkage	Thermoelectric Measurement	3 Years
25	2019	BSI,Kolkata	5 Years	Collaborative research activity / Linkage	Research	5 Years
26	2019	Department of Biotechnology, Ministry of Science and technology, GoI	4 Years	One sponsored project	One sponsored project, study reports, publications, trained manpower, software and hardware development	4 Years
27	2019	Central Cooperative Bank, Burdwan and different other local industrial organizations in Burdwan and Kolkata	2 Months	Summer Internship of MBA Students	Summer Internship of MBA Students	2 Months
28	2019	Prof. Krishnendu Sengupta, SPS, IACS, Kolkata	3 Years	Collaborative research activity / Linkage	Research Paper	3 Years
29	2019	CSIR, Govt. of India	2 Years	Identification of susceptible genetic variants associated with food allergy within population of West Bengal, India	Ph.D. Program	2 Years
30	2020	Tripura University, Agartala, Tripura 799022 And Tezpur University, Tezpur, Assam 784 028	3 Years	Joint Proposaloint proposal under STRIDE-III scheme of the University Grants Commission	Joint proposal under STRIDE-III scheme of the University Grants Commission has been submitted	3 Years
31	2020	NTLabs, Lithuania		Technical Collaboration in the field of NavIC	Testing of NTLabs NavIC enabled modules and Research	
32	2020	Prof. Qin Zhou, School of Electronics and Information Engineering, Wuhan Donghu University, Wuhan 430212, People's Republic of China	3 Years	Collaborative research activity / Linkage	Research Paper	3 Years
33	2021	Shivaji University, Kolhapur 416 004, Maharashtra, India	3 Years	Joint Research on GNSS and NavIC	One publication, data exchange, joint research	3 Years
34	2021	The University Grants Commission	05 years, extendable	Faculty Recharge Program	Dr. Suvro Chatterjee has joined in the Department of Biotechnology, The University of Burdwan as Associate Professor. he has been selected by the UGC under its "Faculty Recharge Programme (FRP)"; the salary would be provided by the UGC for the tenure of the programme	05 years, extendable
35	2021	TU Wein, Germany		Collaborative research activity / Linkage	Joint research on GNSS	
36	2021	Sister Nibedita University	3 Years	Collaborative research activity / Linkage	Fluoride Hydrogeochemistry and defluoridation	3 Years
37	2021	Central Ground Water Board, ER	3 Years	Collaborative research activity / Linkage	Uranium Hydro geochemistry effect on health	3 Years
38	2021	Dr. Sachindranath Das, Dept. of Instrumentation Science, Jadavpur University	1 Year	Collaborative Research, Photocurrent Measurement / Linkage	Photocurrent measurement, EIS spectra	1 Year
39	2023	Dr. Sachindranath Das, Dept. of Instrumentation Science, Jadavpur University	1 Year	Collaborative Research, Electrical Characterisation / Linkage	Electrical characterisation	1 Year

40	2021	Gopal Chakrabarti, Calcutta University	1 Year	Collaborative research activity / Linkage	Research	1 Year
41	2021	Dr. Takashi Mori, RIKEN, Tokyo, Japan	2 Years	Collaborative research activity / Linkage	Research Paper	2 Years
42	2021	Dr. Akitada Sakurai,National Institute of Informatics, Japan	2 Years	Collaborative research activity / Linkage	Research Paper	2 Years
43	2021	RKM Sikshana Mandira, Belur Math, Howrah, West Bengal	5 Years	Collaborative research activity / Linkage	1. Helping students in research activity (Anirban Bhattacharya of RKM Sikshana Mandira and Arunima Ghosh of the University of Burdwan); 2. Using the library of RKM Sikshana Mandira by the students of the University of Burdwan; 3. Preparation and correction of tools of Chandan kumar Sahana of RKM Sikshana Mandira	5 Years
44	2022	**Professor A K Chaudhary, University of Hyderabad**	1 Year	Research on Nonlinear optical devices	Research Paper	1 Year
45	2022	Amity University	3 Years	Collaborative research activity / Linkage	Uranium Hydro geochemistry effect on health	3 Years
46	2023	CSIR-NPL, New Delhi	3 Years	Joint work on GNSS	Joint work on GNSS timing, data sharing	3 Years
47	2023	AGH University of Science and Technology, Mickiewicza, Krakow, Poland	4 Years	Development of a smart scaffold for assisting efficient bone repair	Bilateral research activities to investigate a smart and efficient scaffold for assisting bone repair	4 Years
48	2015	Stesalit system ltd. Kolkata	3 Years	to form technical colaboration	Global satelite system information exchange	3 years
49	2014	University of Dhaka	3 Yerars	Collaborative research activity / Linkage	Exchange faculties, cooperation research endevors	3 years
50	2023	Zoological survey of india	5 years	Scientific cooperation	Taxonomt research purpose	5 years
51	2024	ICMR	1 YEAR	Research project with icmr	Research on hepatic cell trancriptional factor activation	1 year
52	2020	institute od evolution , Haifa, Iarael		Collaborative research activity / Linkage	research program colaboration	
53	2023	Botanical Survey of India		Collaborative research activity / Linkage	Research	
54	2022	institute of fisica, Mexico		Collaborative research activity / Linkage	Research	
55	2023	NIT Durgapur		Collaborative research activity / Linkage	Research	
56	2021	M/S NT LAB Belarus		Collaborative research activity / Linkage	Research	

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Efficient second-harmonic and terahertz generation from single BiB_3O_6 crystal using nanosecond and femtosecond lasers

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The paper reports the efficient UV and terahertz generation from a 1.29 mm thick and Type I, $\theta = 28.9°$ cut BiB_3O_6 (bismuth triborate, BIBO) crystal using femtosecond and nanoseconds laser pulses. We have employed 800 nm wavelength pulses of 50 and 140 fs obtained from a Ti:sapphire laser amplifier and oscillators at 1 kHz and 80 MHz repetition rates, respectively. The conversion efficiency of second-harmonic generation (SHG) was ~ 50% while that obtained for terahertz (THz) generations was of the order of 1.85×10^{-5}%. In addition, LDS-698 dye laser radiation tunable between 650–700 nm was also used as a source for SHG between the 325–350 nm range. The dye laser was pumped by SHG (532 nm) radiation from an electro-optically *Q*-switched Nd:YAG laser having a pulse repetition rate of 10 Hz and a pulse width of 10 ns. A conversion efficiency of 4.01% was obtained for generation of UV at 343.5 nm. Finally, we have measured the transmission, refractive index, absorbance, and conductivity properties of BIBO crystal in the THz domain. We also ascertained the coherence length, relative permittivity and reflectivity of the crystal.

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1. INTRODUCTION

There is a continuous need for growing new nonlinear optical materials with improvised linear and nonlinear optical properties which can cover a wide range of transmission between the deep-UV to far-infrared range. It is possible to generate efficient deep-UV to mid-IR radiation by employing different types of nonlinear frequency conversion processes such as second-harmonic generation (SHG), sum-frequency mixing and difference-frequency mixing (DFM), etc. Some of the well-known nonlinear crystals such as KH_2PO_4 (KDP), KD * P, β-BaB_2O_4 (β-BBO), LiB_3O_5 (LBO), LAP, $KTiOPO_4$(KTP), BNA, DAST, etc., are widely used for making efficient nonlinear devices. In addition, some of the selected inorganic and organic crystals such as BBO, KTP, DAST, BNA, etc., can also be used for the generation of powerful terahertz (THz) radiation using DFM, plasma generated from filamentation of femtosecond laser, and optical rectification techniques [1–6]. Among all the BBOs is the first very promising borate group crystal which has found potential applications in the generation of deep-UV to terahertz radiation due to its excellent optical and nonlinear properties. Bhar *et al*. have reported the best use of the phase-matching condition for efficient deep-UV–vis radiation using frequency mixing techniques. They have used *Q*-switched nanosecond pulse in their study and employed sum frequency generaton (SFG) and SHG techniques [7–9]. There are many more groups who have used femtosecond pulse for powerful UV generation from BBO crystal using the 800 nm wavelength [10,11]. The same femtosecond laser is also used for THz generation and measurement of refractive indices in the THz domain [12,13].

The BiB_3O_6 (bismuth triborate, BIBO) crystal was introduced by Hellwig *et al*. in 1998 [14–17]. It is a highly promising negative biaxial nonlinear optical crystal that belongs to monoclinic group C_2 and apart from having a large nonlinear optical coefficient and laser high damage threshold, it is nonhygroscopic as well. It offers an optical transparency between the 160 nm to 2.7 μm region. The UV transmission cutoff of BIBO is at much deeper wavelength than BBO and it offers large effective nonlinearity ($d_{\text{eff}} = 3.2$ pm/V). Its nonlinear coefficient is 3.5–4 times higher than that of LBO and 1.5–2 times higher than that of BBO. These attractive properties have recently been explored to demonstrate the potential of BIBO for efficient SHG using continuous wave [18,19], long pulse, nanosecond, picosecond [20,21], and femtosecond pulsed lasers [22–26]. For example, conversion efficiencies of SHG at 532 nm in the

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Full Length Article

Tunable and low-threshold random lasing emission in waveguide aided Rhodamine-6G dye incorporated silica embedded thin films

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ARTICLE INFO

Keywords:
Random lasing
Scattering in silica nanosphere
Tunable visible light emission

ABSTRACT

A simple and low-cost approach for producing tunable and low threshold RL emission in the visible region is reported by using a fluorescent laser dye as gain medium and light scattering is achieved in silica nanospheres (SNS) under the pump light of 532 nm, obtained by second harmonic generation of a Q-switched Nd: YAG laser fundamental radiation of 1064 nm wavelength. Depending upon the size (a) of the scatterer particles in comparison to the wavelength (λ) of the pump light, the scattering mechanism can be classified into different categories. However, to demonstrate various RL parameters for scatterer particles residing in Rayleigh scattering ($a < \lambda$) and Geometrical optics regime ($a >> \lambda$) in Rh6G dye doped PVA film, we have deliberately synthesized two different sized SNS (notably, 400 nm and 1000 nm). Also, to demonstrate the tuning in the RL emission by enhancement in pump photon density the gain medium has been enclosed within two glass slides. The performances of developed three RL systems, one made with bare film (S1), one cover with one glass slide (S2) and another one in which the gain medium is enclosed between two glass slides (S3) have been compared. It has been demonstrated experimentally that in the developed RL system with 400 nm SNS particles, RL emission in the incoherent regime is obtained. On the other hand, in the case of 1000 nm SNS particles, RL emission in the coherent regime is demonstrated. The tunable random lasing emission covering 585–592 nm wavelength regions with the lowest emission line-width of 4.2 nm and the lowest RL threshold of 1.59 mJ/cm^2 is obtained from the developed RL systems. The demonstrated low cost and simple strategy for the development of tunable RL devices provided here will find novel applications in laser-based imaging, RL based sensing, and other optoelectronic devices.

1. Introduction

Thanks to the recent progress in the industrial applications of CW and pulsed laser sources. Although conventional laser sources are proved to be very effective for their various applications in fundamental and applied research fields, but still there exist a lot of challenges [1–6]. Therefore, there is a recent surge in the development of laser sources and particularly a lot of impetus has been given in the development of random lasers (RLs) by employing various luminescent materials as gain media [1–4]. However, unlike conventional laser sources, which include (i) a pump source, (ii) a gain medium, and (iii) optical resonators, RLs use a different approach for its operation. Random scattering of light provided by jumbled nano/microstructures present inside a gain medium offers a substitution of optical cavity to achieve lasing [2–6]. The generation of light in RLs mainly relies on several factors, like geometrical configurations, optical properties of gain/scattering media, structural distinctions of the scattering particles etc. However, enclosing the whole random medium into a waveguide feedback configuration gives additional degrees of freedom to simultaneously tune the emission regimes along with decreasing the lasing threshold through various approaches, such as through pump volume amplification techniques, increasing the pump photon density via wave guiding, changing the cavity length (l_c), or by changing scattering strength [3–8]. Further, the optical feedback mainly depends on the scattering mean free path (l_{sc}) and transport mean free path (l_t) of a randomized system. Any change in l_{sc} may also cause the transition of RL emission from incoherent to coherent regime and vice versa [5–9]. However, three distinct scattering regimes can be defined [7], as given below, depending upon the size of the nanoparticles/microparticles used as scatterer particles in RL systems.

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Journal of the Optical Society of America B

OPTICAL PHYSICS

Emission peak shifted incoherent random laser through the combined effects of coupling of surface plasmons in a triangular shaped silver nanostructure, microbubbles, and the waveguiding mechanism

sl.no. 01

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The random laser (RL) is now becoming an essential tool for various photonics applications, and a plethora of research advancements in RL coupled with developments in the field of techniques of syntheses of various nanostructured materials is taking place. But the realization of tuning the peak emission wavelength of RL is still very challenging. However, in this report we have demonstrated an emission peak shifted tunable low threshold incoherent RL in the visible region in a gain medium of a commercially available dye laser material and by employing the rarely used scatterer materials of triangular silver nanoparticles (TSN), microbubbles, and the waveguiding mechanism. The scattering properties of trapped microbubbles, along with the localized surface plasmon resonance property of TSN of appropriate concentration within waveguided thin films composed of glass substrates, have been methodically investigated to demonstrate the reduction in lasing threshold and tunability in the peak emission wavelength. A two-fold reduction in RL threshold by addition of TSN in the disordered system, along with a considerable narrowing down of the emission spectra to a few nanometers, are obtained. Furthermore, the peak emission wavelength shift of 6 nm is reported by suitably changing the system configuration by the addition of an optimum concentration of TSN along with trapped microbubbles. The as-developed system shows high-quality laser performance with the maximum value of $\eta = 0.64$, a quantity describing the ratio of the number of stimulated radiative photons within RL and the total number of emissive photons. We propose that the total internal reflections from the microbubble surface, along with plasmonic enhancement and scattering from the TSN, mediate the waveguided RL to achieve the low threshold. Therefore, this report is an early step towards demonstrating efficient RL in a ternary scattering system. Many more avenues for investigating this developing research issue may be helpful for the future development of affordable and robust optoelectronic devices.

https://doi.org/10.1364/JOSAB.481499

1. INTRODUCTION

The fascinating realm of random lasers (RLs), also designated as "mirror-less lasers," has inspired remarkable curiosity in the scientific community, leading to deep dives into the novel territory of the interaction of light with matter having randomness [1,2]. Since the first theoretical prediction given by Letokhov [3], random lasing action has been investigated in varieties of physical arrangements, gain media, and scatterer particles. Lasing action in a random medium is generally achieved by significantly expanding the trajectory of the light inside a volume, and amplification occurs due to multiple scattering, raising the gain length l_g (l_g is defined as the length over which the intensity of light is amplified by a factor e), owing to which the gain surpasses the overall loss in the system [4]. In contrary to conventional lasers, in RLs, strong light scattering by random scatterers present within the gain medium could improve the confinement of light that may result in the development of closed optical loops within the gain medium that are inherent to coherent RLs [5]. On the other hand, while light gets scattered multiple times by the scatterers placed within the gain medium, some selected modes may obtain a higher dwell time within the medium. Consequently, they can sustain over longer scattering

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Research Article

Employment of nonlinear optical properties of GO/Ag nanocomposite scatterer materials for achieving random lasing in the visible region in the gain medium of a commercially available dye

sl.no. 01

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ARTICLE INFO

Keywords:
Graphene oxide
Surface plasmon resonance
Nonlinear optical properties
Random lasing

ABSTRACT

Graphene oxide (GO) and silver nanoparticles (AgNPs) are recently been widely employed in various sectors including in photonics applications due to their fascinating properties. On the other hand, huge interests are shown by the researchers for development of scatterer materials for achieving random laser (RL) with improved performances. In this work, the GO/Ag nanocomposite material comprising of GO nanosheets and AgNPs have been prepared and its remarkable nonlinear optical (NLO) properties are employed for the first time to demonstrate RL in the visible region by the introduction of disorder and multiple scattering within the amplifying medium of Rhodamine-B dye. Interestingly by changing the cuvette path lengths, here we have shown that the gain volume within the amplifying media can be varied effectively, which directly influence the lasing threshold. The larger value of NLO coefficients in GO/Ag scatterer induced greater refractive index contrast (Δn) between the scatterer and surrounding medium and thus enhances the light-matter interactions in the GO/Ag nanocomposite and consequently the lasing threshold for RL generation is reduced significantly by 50 % than that of bare GO as scattering center. This report opens an exciting prospect of using NLO properties of GO/Ag nanocomposite for achieving enhanced scattering in different gain media for demonstration of low threshold RL, which may revolutionize the future development of RLs.

1. Introduction

In recent decades, the field of photonics has witnessed a remarkable advancement, with a growing emphasis on the development of novel light sources and laser technologies. Among these developments, the phenomenon of random lasing has emerged as a captivating and promising area of research [1]. In random lasers (RLs), amplification of light is provided from multiple scattering events within the disordered configuration of dye and scattering medium [2]. Since, the theoretical prediction by Letokhov in 1967 [3], RLs have gained considerable attention in the scientific community. After the first experimental demonstration of coherent RL in ZnO [4], rigorous theoretical and experimental investigations on RLs have been carried out in different gain media [5–9]. The intrinsic properties of RL, such as low threshold, robustness against external perturbations, and potential for compact and versatile designs for chip-scale optoelectronic devices, have picked up the interest of researchers of inter-disciplines. Most importantly, the efficacy of RL depends on various nanostructures present within the disordered media. In this regard, scattering centers present within an active media is significant in determining its RL characteristics such as the lasing threshold, modal characteristics etc. Particularly, the size, geometrical shape, concentration of scatterers within the gain medium greatly impacts its emission characteristics. In recent years, there has been a growing demand of employing discrete categories of nano/micro-structures in gain media. Particularly, these scattering media including metal [10], semiconductor [11], metal organic framework [12], biological structures [13,14], liquid crystals [15], external feedbacks [16,17], micro-bubbles [18] etc., which have been extensively employed for generation of coherent [19] or white [20] RL emission, however with some drawbacks. Interestingly, the intrinsic nonlinearity in two-dimensional (2D) materials enables the manipulation of gain and absorption profiles, which plays a pivotal role in controlling the threshold for RLs. These 2D materials can be tailored to exhibit tunable and highly efficient nonlinear responses, affecting the

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SL NO. 02

MEMORANDUM OF UNDERSTANDING

This Memorandum of Understanding is made on this the ....17th.... day of .....March..... 2011 between **Oil and Natural Gas Corporation Limited (ONGC)**, a company registered under the Companies Act 1956, having its registered office at Jeevan Bharti Building, Tower-II, 124 Indira Chowk, New Delhi-110001 and one of its offices at Dehradun (herein after referred to as ONGC which expression shall unless repugnant to the context include its representatives, successors and permitted assignees) of the **FIRST PART** and

Burdwan University Burdwan established under / registered under West Bengal, 1959 Act, having its office at Burdwan, West Bengal (hereinafter referred to as Burdwan University which expression shall unless repugnant to the context include its representatives and successors and permitted assignees) of the **SECOND PART.**

Whereas the Burdwan University has been established for the purposes, among others, for imparting education in Science, Arts, and the learned professions and of furthering advancement of learning and original research.

And Whereas ONGC is engaged in the business of hydrocarbons exploration and exploitation and has decided to institute ONGC Scholarships in Burdwan University.

Now Therefore in consideration of the mutual covenants set out in this MoU, the parties hereby agree on the terms and conditions details hereunder:

1. OBJECTIVE:

To strengthen industry–academia linkage by instituting ONGC Scholarships in Burdwan University for rewarding, encouraging and assisting meritorious students for higher studies in the petroleum upstream related education.

2. RESPONSIBILITIES AND COMMITMENTS:

In the spirit and context of the purpose of this MOU the parties agree to assist each other, to be committed to professional excellence, to communicate on a regular basis and to encourage open dialogue and cooperation between ONGC and Burdwan University.

3. SCHOLARSHIP

i) There will be two scholarships in Burdwan University.

ii) These scholarships will be called "ONGC Scholarships" and the scholarship holders will be called as "ONGC Scholars".

iii) The department / course and degree for which ONGC Scholarships will be instituted are presented in following table:

Sl. No.	Department / Course	Degree
1	Chemistry	M.Sc
2	Physics	M.Sc.

iv) The criteria for selection of student for award of ONGC Scholarship, the scholarship amount and scholarship duration will be as follows:

Sl. No.	Degree	Year in which scholarship will be given	Qualifying criteria	Scholarship Amount (Rs per month)	Scholarship Duration
1	M.Sc.	Second Year	First rank in M.Sc. First Year	5000	1Year

4. OBLIGATION OF BURDWAN UNIVERSITY BURDWAN:

i) The Burdwan University will select the student for award of ONGC Scholarship as per the criteria detailed in 3.iv) above.

ii) The Burdwan University after the selection of student for ONGC Scholarship will intimate Head ONGC Academy, Kaulagarh Road, Dehradun through a written report giving detail of the student selected. Biodata and photograph of the selected student will also be enclosed with the report.

iii) The Burdwan University will send a written demand note to Head, ONGC Academy, Kaulagarh Road, Dehradun for release of the fund for two ONGC Scholarships in an academic year for disbursement to the ONGC Scholars.

iv) The Burdwan University will receive the fund for ONGC Scholarships from ONGC and will disburse the same to the ONGC Scholars regularly.

v) The Burdwan University will submit the ONGC Scholarship fund utilization report in respect of an academic year to Head, ONGC Academy, 9, Kaulagarh Road, Dehradun confirming that the ONGC Scholar has received the entire ONGC Scholarship amount due to him, before requesting for release of fund for the next academic year.

5. OBLIGATION OF ONGC:

i). ONGC will award two ONGC Scholarships in the Burdwan University as detailed below:

Sl. No.	Department / Course	Degree
1	Chemistry	M.Sc
2	Physics	M.Sc.

ii) ONGC will release the total fund for two ONGC Scholarships (scholarship at a rate of Rs. 5000 per month) in respect of an academic year after receiving the ONGC Scholar selection report and a written demand note from the Registrar of Burdwan University to Head, ONGC Academy, 9, Kaulagarh Road, Dehradun for release of the total fund for ONGC Scholarships.

6. VALIDITY OF MOU:

This MOU is effective from the academic year 2011-12. The ONGC reserves the right to terminate this MOU at any point of time.

7. DISPUTE RESOLUTION:

In the event of any dispute or difference between the parties hereto, such dispute or difference shall be resolved amicably by mutual consultation or through the good offices of Head ONGC Academy. In case such resolution is not possible, then the unresolved dispute or difference shall be referred to a committee consisting or two members each from ONGC and the Burdwan University with Director (HR) of ONGC as it's head, the decision of the committee shall be binding upon both the parties. Provided, however, any party aggrieved by such decision may make a further reference for setting aside or revision of the decision to the CMD of ONGC whose decision shall bind the parties finally and conclusively.

8. APPLICABLE LAW AND JURISDICTION:

All question disputes or differences arising under out of or in connection with the MOU shall be governed by Indian Laws, both procedural and substantive and shall be subject to exclusive jurisdiction of Courts at Dehradun.

9. AMENDMENT:

This MOU may be amended in writing with the mutual consent of both parties.

10. OPERATION, CONDUCT AND IMPLEMENTATION:

Burdwan University and ONGC agree to nominate specific personnel for operational, conduct and implementation of this MOU.

a. Head ONGC Academy, ONGC shall be the sole operator on behalf of ONGC.
Address :Head ONGC Academy,
KDMIPE Campus, 9, Kaulagarh Road, Dehradun-248195
Phone No. : 0135-2754283
Fax No. : 0135-2758832

b. Registrar, Burdwan University shall be the sole operator on behalf of the Burdwan University.
Address :Registrar,
Burdwan University, Burdwan, West Bengal
Phone No. :
Fax No. :

The document signed by both the parties constitutes the entire understanding between ONGC and the Burdwan University, Burdwan.

In witness whereof, the parties to this MOU through their authorized representatives have affixed their signatures on this MOU on the day and year first hereinabove mentioned.

Signed: _____

On behalf of Burdwan University Burdwan

Name: SHOROSIMOHAN DAN

Registrar Burdwan University Burdwan

REGISTRAR (Addl. Charge)
UNIVERSITY OF BURDWAN
BURDWAN-713104

Date: 17.3.2011

Place: Burdwan

Witness: Sowrangshu Mukhopadhyay
17.03.2011

THE UNIVERSITY OF BURDWAN RAJBATI BURDWAN 713104

Head of
The Department of Physic
UNIVERSITY OF BURDWAN

Signed: _____ 17/03/2011

On behalf of ONGC

Name: DR. TARUN CHAKRABORTI

Head ONGC Academy, Dehradun

Date: 17.03.2011

Place: BURDWAN

Witness: _____ 17-3-2011.

(PROF. MANAS BANERJEE)

[9434252709]

(PABITRA CHATTOPADHYAY)
HOD, Chemistry
The University of Burdwan

SL NO. 03

भारतीय वनस्पति सर्वेक्षण
BOTANICAL SURVEY OF INDIA

सत्यमेव जयते

भारत सरकार
GOVERNMENT OF INDIA
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE

भारतीय वनस्पति सर्वेक्षण / BOTANICAL SURVEY OF INDIA
सी.जी.ओ. कॉम्प्लेक्स / CGO COMPLEX
तृतीय एम. एस. ओ. भवन / 3RD MSO BUILDING
पाँचवाँ और छठा तल/ 5TH & 6TH FLOOR
डी एफ ब्लॉक, सेक्टर१/ DF BLOCK, SECTOR I
साल्टलेक , कोलकाता-६४/ SALT LAKE, KOLKATA – 700064
Tel.: (033) 2321 4050 [Tech. Section] ; E-mail: tech@bsi.gov.in

फ़ाइलसंख्या /File No.:BSI- 295/1 (Misc.)/2025-Tech. /1209 **Date:** 25th **June, 2025**

TO WHOM IT MAY CONCERN

This is to certify that Botanical Survey of India, Ministry of Environment, Forest and Climate Change, Govt. of India, is having a Memorandum of Understanding (MoU) with the Department of Botany, The University of Burdwan, since 2014 toward scientific and Academic collaboration. As per the term and condition of the MoU, currently both the Organizations are in the process of renewing the MoU with renewed objectives. It is also to certify that, during the period of 2019 to till date, both BSI and The Department of Botany pursued activities which establishes strong linkages and collaboration between the two institutes

1. Scientists of BSI registered their research students for Ph. D in Botany under the University of Burdwan.
2. Conducted several collaborative research works and produced Ph.Ds
3. Shared research facilities for research.
4. Shared Herbarium facilities.
5. Faculty of University of Burdwan worked as expert member for recruitment of research personnel.
6. Organized jointly Botanical Science Congress in March 2024.

The faculty members from the University of Burdwan who have made a strong linkages and collaboration with BSI are Prof. Soumen Bhattacharjee (Coordinator, UGC Center for Advanced Study), Dr. Asok Ghosh etc.

The Scientists of BSI, who have made a strong linkages and collaboration with the Department of Botany, The university of Burdwan are Dr S.S. Dash (Scientist F & Additional Director, BSI), Dr. Tapan Sil (Scientist E), Late Dr. B. K. Sinha (Scientist F), Dr Avishek Bhattacharjee (Scientist E) etc.

Hope in future we will carry forward our close association for academic and research.

25/6/2025

(एस. एस. दाश / S. S. Dash)
वैज्ञानिक एफ / Scientist 'F'
(प्रभारी, तकनीकी अनुभाग / In-charge, Tech. Section)

SL NO. 03

MEMORANDUM OF UNDERSTANDING (MOU) BETWEEN THE UNIVERSITY OF BURDWAN, WEST BENGAL AND BOTANICAL SURVEY OF INDIA (BSI) [A NATIONAL BODY SETUP IN 1890 TO SURVEY THE COUNTRY FOR ITS BOTANICAL RESOURCES WITH HEADQUARTER AT CGO COMPLEX, 3RD MSO BUILDING, BLOCK-F, SECTOR-I, SALT LAKE CITY, KOLKATA-64]

Botanical Survey of India, the nodal research organization supported by Ministry of Environment and Forests, always plays a significant role in fulfilling nation's commitment to various International conventions like Convention on Biological Diversity (CBD), Convention on International trade in International Endangered species of wild Flora and Fauna (CITES), etc. It has ample expertise in exploring, identifying, creating inventories and documenting the rich diversity of plant resources of the country with particular reference to protected areas and fragile ecosystems. Its activities also include identification of endemic, endangered and threatened species, conservation of threatened taxa, collection and identification of ethnobotanically important plant resources, etc.

The University of Burdwan sincerely sought the collaboration of BSI so that both the organizations can enter into an understanding in protecting the fragile microcosm of unique biodiversity glorifying the Golapbag campus of the University and adding value to the existing knowledge base, teaching and research activities involving the Department of Botany in the process.

The Department of Botany of the University of Burdwan, established in 1964 under the leadership of the eminent teacher and

scientist, Prof. P. N. Bhaduri, Ph. D (London), is one of the pioneer institutes of Plant Science with apt reputation in both teaching and research. Since then the department has successfully completed DSA phase I, II, III and COSIST. In fact, it is the first Department of this University which was considered as a Centre for Advanced Study (CAS) by the UGC in the year 2007 and presently department is in the second year of phase II of CAS scheme. As a mark of record of excellent research, members of the faculty of this Department have published more than 1600 research papers in various peer reviewed journals of national and international repute. More than 200 research students have been admitted to PhD degree under the guidance of faculty members of this department. Apart from teaching, the department is trying to strengthen R & D linkage with different Scientific Institutions with the objective to enhance collaborative research work and develop knowledge base with non commercial application.

So, for fulfilling the objective as stated the authorities of both the organizations decided to collaborate in the following issues for mutual benevolence in matters of phytodiversity conservation and development of research and academic activities based thereupon.

1. Acharya Jagadish Chandra Bose Indian Botanic Garden, BSI will help in preparing a proposal by the Botany Department, University of Burdwan for inclusion of the Golapbag campus of the University as 'Protected Site' by the state government for conservation of its plant diversity in the

greater interest of the society since this area together with Ramnabagan Wildlife Sanctuary which constitutes a green patch in the periurban area to sustain a wide diversity of fauna and abate pollution to optimize the environment of Bardhaman city has been experiencing threats of biodiversity impoverishment especially of the rare species. Moreover aesthetic attributes of the campus emanating from variation in microhabitats (terrestrial, semiaquatic and aquatic), occupancy by both indigenous and exotic species of trees, herbs, shrubs and vines, ornamentals and the faunal diversity especially of birds (migratory waterfowls sustained by the wide variety of aquatic plants) is highly praiseworthy deserving periodic surveillance for protection.

2. BSI will help the Department of Botany, University of Burdwan to develop its existing herbarium and enrich with digital images of plant specimens especially from Type section of Central National Herbarium (CAL), and provide other related infrastructural facilities. For developing the existing departmental Herbarium, its integration with the activities of BSI is deemed essential.
3. BSI will help the Department of Botany, University of Burdwan for developing a Botanic garden in Golapbag campus of the University, where BSI will take active role in sharing its expertise to develop the garden.
4. BSI shall train the technical staff and research scholars of the University for Taxonomic Documentation.

5. BSI will organize trainings, workshops on collection, processing of specimens, their preservation etc.
6. Both BSI and the Department of Botany, University of Burdwan, West Bengal can exchange plant specimens, especially of the Flora of West Bengal.
7. Both the BSI and Department of Botany, University of Burdwan, West Bengal can be involved in faculty exchange programme.
8. BSI will facilitate and sponsor research in some common thrust areas where faculties and scientists from both the Institutes can work in collaborative projects.

In its turn, the University of Burdwan will contribute through its Botany Department in the following issues:

1. University will recognize the BSI scientist as research guide and will recognize BSI as a research organization for Ph. D. programme as per the existing statutory norms of the University of Burdwan.
2. Department of Botany will collect medicinal plants from the district and the adjoining areas where the local healers use them for therapeutic purpose and share the same along with the data-base of ethnomedicinal plants (which are not the part of any codified, classical traditional Indian medicinal system) with BSI.
3. Department will also submit the proposals to DST, Govt. of West Bengal and other Central agencies for getting appropriate funding in order to carry out the assigned responsibilities to be undertaken by the organization.
4. Department shall donate the duplicate herbarium specimens for preservation in CAL and other herbaria of BSI.
5. Department will assist in carrying out advanced biochemical and molecular characterization of plant specimens.

6. University will give priority access to BSI scientists for availing University Science Instrumentation Centre (USIC) facilities
7. University and Department in particular shall simultaneously identify its own Taxonomists and the Taxonomists of its affiliated Colleges for identifying plants and submitting authenticated samples.
8. Any other academic responsibility which may be assigned to the Department based on its expertise, available resources and feasibility for mutual benefit shall be discharged as far as practicable.

02/08/2014	02.8.14.
DIRECTOR **BOTANICAL SURVEY OF INDIA**	**VICE-CHANCELLOR** **UNIVERSITY OF BURDWAN**
Witness: 02/08/2014 02/08/14 2/8/2014	**Witness:** 02.08.14 02.08.14. 2/8/14

Sl. NO. 04

Memorandum of Understanding

For

IRNSS Navigation Receiver Field Trial and Data Collection

Between

Space Applications Centre
Indian Space Research Organization
Department of Space, Government of India
Ahmedabad - 380015

And

THE UNIVERSITY OF BURDWAN
RAJBATI, BURDWAN, WEST BENGAL, 713104

This MOU is entered into on 7th day of December 2015

BETWEEN

Space Applications Centre, Jodhpur Tekra, Ambawadi Vistar P.O., Ahmedabad, 380015, a centre of Indian Space Research Organization, Department of Space, Government Of India (hereinafter called "SAC" which expression shall where the context so admits include its successors and permitted assignees) of the one part,

AND

THE UNIVERSITY OF BURDWAN, RAJBATI, BURDWAN ,WEST BENGAL,713104

1.0 Preamble:

Whereas, Space Applications Centre (hereinafter referred to as "SAC" which expression shall where the context so admits include its successors and permitted assignees) of the one part and "THE UNIVERSITY OF BURDWAN" (hereinafter referred to as "BU" which expression shall where the context so admits include its successors and permitted assignees) of the one part BU, both are parties to this MoU;

Whereas, SAC is involved in design and development of space-borne instruments for ISRO missions and development and operationalization of applications of space technology for national development. The applications cover communication, broadcasting, navigation, disaster monitoring, meteorology, oceanography, environment monitoring and natural resources survey. SAC designs and develops all the transponders for the INSAT and GSAT series of communication satellites and the optical and microwave sensors for IRS series of remote sensing satellites, Navigation payloads for IRNSS and GAGAN programme. Further, SAC develops the ground transmit/receive systems (earth stations/ ground terminals) and data/image processing systems;

Whereas, The University of Burdwan is a leading University in West Bengal engaged in teaching and research in different fields of knowledge and learning. One of the fields of training and research of the University is use of space based technologies and satellite based navigation systems (GNSS, hereinafter). The University has a GNSS laboratory used for training and research purposes and is willing to extend the activities using IRNSS and GAGAN.

2.0 Effective Date and Duration of MoU: This MoU is effective from the date of its signing and is valid for a duration 2 (Two) years from the date of signing. It may be extended further in writing based on mutual consent.

3.0 Scope of MoU:

Scope of the MoU involves Site identification, site preparation, and Installation of the IRNSS receiver. IRNSS Navigation Data collection and analysis to be carried out on regular basis for verification and for other mutually agreed topics of research for both parties. Depending upon the requirement certain scientific experiments can be planned and executed within overall MoU umbrella. With mutual consent, both the Parties can extend the period of data collection and observation locations (sites).

4.0 Methodology:

4.1 Suitable Site Selection

4.2 Installation and commissioning of IRNSS Receiver

4.3 Continuous IRNSS and GPS data logging, analysis of the data

4.4 Transmission of IRNSS and GPS data to SAC as and when demanded by SAC Data transmission mechanism can be mutually worked out.

5.0 Deliverables:

5.1 SAC deliverables { i, ii & iii through ACCORD Software & Systems Pvt. Ltd }

i. IRNSS receiver and data processing systems as detailed in Annexure-1. (Delivery @ site)

ii. Number of receiver units allocated as per SAC receiver Allocation committee's recommendation in view of your response to EOI for IRNSS Receiver deployment

iii. User and operations manual (Delivery @ site)

iv. Format for Quarterly (Every Three months) status report

5.2 BU deliverables

i. All necessary logistics so that IRNSS Receiver shall be established to collect positional data in raw and RINEX format received from IRNSS, GPS constellation with 1 sec update rate

ii. Send a Quarterly status Report on usage/performance of receiver to SAC in a prescribed format.

iii. Send the Receiver data to SAC as and when asked for

6.0 Guidelines on Receiver / Data Usage:

The data is to be used strictly for internal research purpose only. The Receiver is for experimentation and field trial only and should not be used for any operational purpose. IRNSS constellation is evolving and has not been declared operational for Position Navigation and Time. So the results/performance of IRNSS should be viewed in that context.

7.0 Responsibility of Each Party:

SAC and BU shall jointly work towards IRNSS system verification using data collected from IRNSS receivers. In addition, following are the specific responsibilities.

7.1 BU:

7.1.1 All the logistics support, site identification, site preparation, required for setting up of IRNSS Receiver will be provided by BU.

7.1.2 Installation of the IRNSS Receiver at the site will be carried out by ACCORD SYSTEMS

7.1.3 Utmost care to be taken in handling the IRNSS Receiver.

7.1.4 Send the Receiver Data to SAC when asked for

7.1.5 Safety and security of the IRNSS Receiver

7.1.6 IRNSS data reception, processing, archival to be done by '.

7.2 SAC:

7.2.1 SAC will provide IRNSS Receiver Unit(s) and Receiver operation manual(s) on returnable basis (As detailed in Annexure-1)

7.2.2 SAC will provide technical assistance to BU in working out modalities of Data collection, data sharing, etc.

7.2.3 SAC will provide technical assistance to BU in proper operation and maintenance of IRNSS Receiver

7.2.4 SAC will provide technical assistance to BU in identifying appropriate research areas considering capabilities of this Receiver

8.0 Project schedule:

8.1 Selection of Suitable Site(s) within 10 days from the date of signing MoU by BU

8.2 Installation and Commissioning of IRNSS Receiver by M/S ACCORD.

8.3 Regular data collection and analysis will be carried out for the duration of the MoU from the date of Installation and Commissioning of IRNSS Receiver

9.0 Training:

M/S ACCORD will provide necessary training and guidelines for site identification, receiver operations. SAC will provide guidelines for data collection, processing and data transfer

10.0 Project Monitoring:

10.1 SAC and BU shall identify focal person(s) who shall be responsible for organizational matters and interfacing for day to day operation, such as functioning of IRNSS Receiver, security etc. Each party shall pursue its independent research using data from these IRNSS Receiver, with mutual consultation.

10.2 A periodic Quarterly status report should be generated by BU regarding Receiver operations. A User meet to share results, experience will be held at SAC every six months.

11.0 Functionaries

1. Dr Anindya BOSE, Scientific Officer (Selection Grade), **(BU Focal Persons)**
   Department of Physics, The University of Burdwan, Golapbag, Burdwan 713 104

2. Dr Joydeep Chakravorty, Scientific Officer (Sr Scale)
   Department of Physics, The University of Burdwan, Golapbag, Burdwan 713 104

1. ATUL P. SHUKLA, Group Head, DCTG/SNAA, **(SAC Focal persons)**

2. YAGNESH R. PATEL, Sci/Engr-SF, SNTD/DCTG

12.0 Confidentiality:

12.1 During the tenure of MoU and thereafter both parties undertake on their behalf and on behalf of their employees/representatives to maintain strict confidentiality and prevent disclosure thereof of all the information and data exchanged/generated pertaining to this agreement. However, the data may be published and shared jointly for scientific publication after mutual consent in writing.

12.2 BU will not disclose any research result and Foreground information, generated out of or involving the data, its derivative or information thereof from the IRNSS

Receiver established (at given site) as per terms of this MoU to any third party without seeking prior written permission.

13.0 Intellectual Property Rights :

All the research results and foreground information as well as foreground Intellectual Property Rights, generated out of or involving the data, its derivative or information thereof, from IRNSS Receiver and sites established as per terms of this MoU whether or not legally protected, shall be owned by SAC. BU will be free to use such data for their internal R&D purposes with intimation to SAC.

Notwithstanding any provisions mentioned above or any future licensing agreements, SAC shall be deemed to have all rights including non-exclusive, irrecoverable and royalty-free license for the unlimited development and use of any and all Foreground Information and Foreground Intellectual Property Rights, generated out of or involving the data, its derivative or information thereof, from the IRNSS Receiver established (at given site) as per terms of this MoU, whether or not legally protected, for the purposes of its own applications.

14.0 Change In Scope of Work:

Any change in scope of work would be with mutual consent of both the parties in writing.

15.0 Modifications to MoU:

15.1 Any amendment or modifications of this MOU shall be in writing by both parties.

15.2 The modifications/changes shall be effective from the date on which they are made/ executed, unless otherwise agreed to.

16.0 Force Majeure:

Neither party shall be held responsible for non-fulfillment of their respective obligation under this MoU due to circumstances beyond their control but not limited to war, flood, cyclones, riots, strikes etc. If such condition continues beyond six months, the parties shall then mutually decide about the future course of action. Either party shall intimate each other of any such event.

17.0 Indemnity:

BU shall exercise reasonable skill, care and diligence in the performance of this MoU activity and indemnify and keep indemnified SAC in respect of any loss, damage or claim howsoever arising out of related to breach of MoU, statuary duty or negligence by BU or

its employees, agents or subcontractors in relation to the performance or otherwise of the services to be provided under this MoU.

18.0 Termination of MoU:

18.1 During the validity of the MoU, if it is found that if the IRNSS system is not in use, misuse or due care is not taken, SAC has right to dismantle/uninstall the IRNSS Receiver established as per terms of this MoU with intimation to BU.

18.2 Similarly if BU considers it necessary to dismantle the IRNSS Receiver established as per terms of this MoU for unavoidable reason at a given site, BU will try to provide an alternate site for the IRNSS observations and facilitate SAC to relocate IRNSS Receiver. If however, BU fails in providing such alternate, SAC will be free to dismantle/uninstall and remove the IRNSS Receiver established as per terms of this MoU along with accessories.

19.0 Arbitration:
In the event of any dispute or difference between the parties hereto, such disputes or differences shall be resolved amicably jointly by Director, SAC and Registrar, BU

20.0 Jurisdiction: Ahmedabad shall be the jurisdiction.

In witness whereof, the parties hereto have signed this MOU on the

Tapan Misra
7/12/15

(Shri TAPAN MISRA)
Director,
Space Applications Centre (SAC),
Ahmedabad

तपन मिश्रा/ TAPAN MISRA
निदेशक / Director
अंतरिक्ष उपयोग केंद्र (इसरो)
Space Applications Centre (ISRO)
भारत सरकार / Government of India
अहमदाबाद / Ahmedabad-380 016.

(Dr D K Panja)
Registrar,
The University of Burdwan
Burdwan

REGISTRAR
THE UNIVERSITY OF BURDWAN
BURDWAN-713104

THE UNIVERSITY OF BURDWAN * RAJBATI BURDWAN 713104

Anindya Bose
(DR ANINDYA BOSE)

Annexure-1

List of deliverables for (1 set of) IRNSS/GPS/SBAS Receiver

Sl. No.	Item Description	Qty
1.	IRNSS/GPS/SBAS Receiver	1
2.	AC-DC Adapter	1
3.	DC-DC Adapter	1
4.	Antenna	1
5.	Antenna base plate	1
6.	Antenna mounting rod	1
7.	Battery	1
8.	Charger for battery	1
9.	TNC (M) to TNC (M), 15 m low-loss RF cable	1
10.	TNC (M) to TNC (M), 2 m low-loss RF cable	1
11.	SMA (M) to SMA (M), 2 m RF cable	2
12.	Cat5E Ethernet cable	1
13.	RS232-USB converter cable	1
14.	DC-DC adapter input cable	1
15.	DC-DC adapter output cable	1
16.	Battery to receiver power cable	1
17.	Car Cigarette connector to receiver power cable	1
18.	3 Pin AC power cable for charger	1
19.	User Guide	1
20.	CD containing GUI & other drivers	1
21.	M4 Allen key	1
22.	Adjustable Spanner	1
23.	M4 Allen screws with nuts for receiver	4
24.	M4 Allen screws with nuts for DC-DC adapter	4
25.	M4 Allen screws with nuts for antenna	4
26.	Carry Case	1

भा.कृ.अनु.प.–केन्द्रीय आलू अनुसंधान संस्थान
शिमला–171001 (हि.प्र.)
ICAR - CENTRAL POTATO RESEARCH INSTITUTE
Shimla-171 001, HP (India)

No.F.ST/18-1/2015

Dated: 22nd February, 2016

Speed Post

To

Dr. Jai Prakash Keshri,
Professor & Incharge, CRSFM,
Coordinator, DBT, HRD Programme,
Centre of Advanced Studies in Botany,
The University of Burdwan,
Burdwan 713 104 (WB)

SL.NO.-05

FAX: 91-0342-2556260/64452, e.mail keshrijp@gmail.com, keshri_jp@yahoo.com

Subject: Allotment of breeder seed- regarding.

Sir,

This has reference to your letter dated 01 February, 2016 addressed to Director, ICAR-CPRI Shimla. In this regard please find enclosed herewith Xerox copy of MoU for your record. It is to inform you that the Director, CPRI, Shimla has allotted 15 qtls of breeder seed of Kufri Jyoti from CPRS, Jalandhar. You may contact Head, CPRS, Jalandhar (Mob no.- 9465820837) for further necessary information.

Yours faithfully,

22/2/16

(Sanjeev Sharma)
Acting Head, Division of Seed Technology

Encl.: As above.

Copy to: The Head, CPRS, Post Bag No.1, Model Town, Jalandhar, (Punjab) (Mob no.- 9465820837) for information please.

Telephones: EPABX: 2624830, 2625182, 2625074, 2625073, 2621480, 2625181, 2624575, 2624501; Fax: 0177-2624460, e-mail: headseedcpri@gmail.com Website: http://cpri.eret.in

भारतीय गैर न्यायिक

एक सौ रुपये

Rs. 100

रु. 100

ONE HUNDRED RUPEES

सत्यमेव जयते

भारत INDIA

INDIA NON JUDICIAL

पश्चिमबङ्गा पश्चिम बंगाल WEST BENGAL

U 455344

Jai Prakash Kashyap
In-Charge
CROP RESEARCH AND SEED
MULTIPLICATION FARM
BIDHAN UNIVERSITY
FARIDABAD :: HARYANA

MEMORANDUM OF AGREEMENT
BETWEEN
THE INDIAN COUNCIL OF AGRICULTURAL RESEARCH
AND
PRIVATE SEED PRODUCERS
FOR
ENHANCEMENT OF SEED PRODUCTION CHAIN OF POTATO IN THE COUNTRY

1. This MOU signed on 24/9/2015 2015 between the Indian Council of Agricultural Research (ICAR), Krishi Bhawan, New Delhi, a society registered under the Societies Registration Act, 1860 and to be implement at Central Potato Research Institute, Shimla (through its Director) hereinafter referred to as 'CPRI' which is an institute of ICAR in the first instance and M/s Crop Research & seed Multiplication Farm here in after referred as CRSMF a firm engaged in potato seed production.

2. Whereas the ICAR is charged with the responsibility to undertake, aid, promote and coordinate Agricultural and Animal Husbandry education and research and its application in practice, and to do things as it may consider necessary incidental and conductive to the attainment of these objectives while the CPRI, Shimla is an apex level national institution charged with the responsibility to undertake research and development in all aspects of potato cultivation including production of nucleus and breeder seed of potato through conventional and high-tech system at five various regional stations/centres situated in different states in India.

3. And whereas M/s (**CRSMF, The University of Burdwan, PO-Rajbati, Burdwan-713104, West Bengal**) owns minimum of 15 acre land and is engaged in production of potato seed for the past three years and maintains farms in good condition with all necessary infrastructure where large scale multiplication of breeder seed in subsequent two/three stages ie. Foundation Seed-I (FS-I), Foundation Seed-II (FS-II) and Certified Seed (CS) is to be undertaken.

4. And whereas in the case of cooperatives (societies), it should have a minimum core strength of 25 members. In case of NGOs it should be a registered NGO, having clear cut mandated activities related to Agriculture Sector. Besides it should own a minimum of 15 acre land for undertaking seed production in three clonal cycles.

5. And whereas the CPRI and Private Seed Organization/Progressive Potato Growers/NGOs/Cooperative Society inspired by their common objectives of promoting alternate seed production chain for potato to maximize the availability of certified/quality seed in the country have decided to enter into this agreement.

6. And whereas M/s **CRSMF** is desirous of collaborating with CPRI in potato seed multiplication in three clonal cycles viz. foundation seed-I (FS-I), foundation seed-II (FS-II) and certified seed (CS) with a view to enhance availability of potato quality seed to the potato cultivators of the country.

7. And whereas M/s **CRSMF** will undertake all activities/steps that are required for production of FS-1, FS-2 and certified seed as per seed certification standard. CPRI will not be responsible for any lapse on their part leading to rejection by the seed certification agency.

8. And whereas M/s **CRSMF** will ascertain quality of the seed at CPRI premises at the time of its lifting. Any complaints regarding seed quality, thereafter will not be entertained at all.

9. And whereas M/s **CRSMF** is bound to multiply the breeder seed supplied by CPRI in three clonal generations (FS-1, FS-2 and certified seed). He will dispose-off only the certified seed and not of earlier clonal generation viz. FS-1 and FS-2.

10. And whereas M/s **CRSMF** will keep record of seed production at each stage i.e FS-1, FS-2 and certified. The seed inspection report/certificate from the seed certifying agency will be submitted to CPRI that will include area certified and seed produced annually.

11. And whereas M/s **CRSMF** will be solely responsible for dispose-off the certified seed and CPRI in no way will be held responsible in case of non-disposal of the seed stocks.

12. And whereas M/s **CRSMF** will [illegible] the national seed production programme of CPRI.

13. And whereas the interested parties/firms/farmers/NGO will apply for allotment of breeder seed to CPRI by furnishing the details about their establishment viz. land holding, farm infrastructure, investment capacity, technical knowhow in the area of

potato seed production (with supporting document). The NGOs and cooperatives will submit details of their establishment as above including Registration No. & certificate, validity and number of farmer members.

14. And whereas the CPRI will select the growers/firms/NGO/Society based on merit and subject to availability of seed stocks.

15. A maximum of 40 quintal breeder seed will be allotted to each allottee subject to availability of seed stocks and capacity of the organization/firm.

16. And Whereas the CPRI is willing to provide the necessary technical knowhow, advice and training on usual payment basis if required by them.

17. Activities undertaken under the MOU shall be in accordance with the rules and norms governing consultancies, contract research, contract service and transfer intellectual property involving Institutes of the ICAR. The parties of this agreement may, by mutual consent, add, modify, amend or delete any work, phrases, or article of the agreement.

18. The agreement shall be effective for a minimum period of three years. The MOU can be terminated by either party by serving notice to the other party by giving 3 months notice.

19. In the event of non-compliance of any of the articles enshrined in the MoU, CPRI reserves the right to terminate the MoU and black list the firm for future.

20. In case of any dispute between the two parties arising out of or in connection with this agreement, the same shall be referred to the sole arbitrator appointed by the Secretary, Department of Agricultural Research and Education (DARE) & Director General, ICAR and the decision of Arbitrator would be final

IN WHEREAS WHEREOF, the parties hereunto have signed this on 24/9/2015 date of September 2015 at Shimla.

For first party

(Dr. B. Pal Singh)

Director, CPRI, Shimla or

Indian Council of Agricultural Research

For second Party

M/s Owner/proprietor of the Agency

Jai Prakash Keshri

(Dr. Jai Prakash Keshri)

In charge, CRSMF

Professor

Centre of Advanced Studies in Botany

The University of Burdwan

Burdwan 713104

West Bengal, India

In-Charge
CROP RESEARCH AND SEED MULTIPLICATION FARM
BURDWAN UNIVERSITY
TARABAG :: BURDWAN

Witness : 24/9/2015

1. (Dr. K.K.Pandey)
   Head
   Division of Seed Technology
   CPRI, Shimla

2. Head of Station

Witness: Sabyasachi Patra

1. (Dr. Sabyasachi Patra)
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   CRSMF, The University of Burdwan

Dipendra Nath De

2. (Dr. Dipendra Nath De)
   Estate Officer,
   The University of Burdwan.

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Deoxyelephantopin—a novel PPARγ agonist regresses pressure overload-induced cardiac fibrosis *via* IL-6/STAT-3 pathway in crosstalk with PKCδ

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ARTICLE INFO

Keywords:
Deoxyelephantopin
PPARγ agonist
Cardiac hypertrophy
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ABSTRACT

Pathological cardiac hypertrophy is associated with ventricular fibrosis leading to heart failure. The use of thiazolidinediones as Peroxisome Proliferator-Activated Receptor-gamma (PPARγ)-modulating anti-hypertrophic therapeutics has been restricted due to major side-effects. The present study aims to evaluate the anti-fibrotic potential of a novel PPARγ agonist, deoxyelephantopin (DEP) in cardiac hypertrophy. AngiotensinII treatment *in vitro* and renal artery ligation *in vivo* were performed to mimic pressure overload-induced cardiac hypertrophy. Myocardial fibrosis was evaluated by Masson's trichrome staining and hydroxyproline assay. Our results showed that DEP treatment significantly improves the echocardiographic parameters by ameliorating ventricular fibrosis without any bystander damage to other major organs. Following molecular docking, all-atomistic molecular dynamics simulation, reverse transcription-polymerase chain reaction and immunoblot analyses, we established DEP as a PPARγ agonist stably interacting with the ligand-binding domain of PPARγ. DEP specifically downregulated the Signal Transducer and Activator of Transcription (STAT)-3-mediated collagen gene expression in a PPARγ-dependent manner, as confirmed by PPARγ silencing and site-directed mutagenesis of DEP-interacting PPARγ residues. Although DEP impaired STAT-3 activation, it did not have any effect on the upstream Interleukin (IL)-6 level implying possible crosstalk of the IL-6/STAT-3 axis with other signaling mediators. Mechanistically, DEP increased the binding of PPARγ with Protein Kinase C-delta (PKCδ) which impeded the membrane translocation and activation of PKCδ, downregulating STAT-3 phosphorylation and resultant fibrosis. This study, therefore, for the first time demonstrates DEP as a novel cardioprotective PPARγ agonist. The therapeutic potential of DEP as an anti-fibrotic remedy can be exploited against hypertrophic heart failure in the future.

1. Introduction

In the last few decades, pressure overload-induced pathological cardiac hypertrophy leading to heart failure has become a major health concern. There has been substantial progress in understanding the molecular drivers of hypertrophic pathogenesis. The outcome of such studies has primarily been the identification of potential therapeutic targets to manage clinical manifestations such as ventricular fibrosis. One such class of anti-hypertrophic therapeutics is the thiazolidinedione (TZD) group of Peroxisome Proliferator-Activated Receptor-gamma (PPARγ) ligands (Yamamoto et al., 2001; Asakawa et al., 2002) the use of which has often been restricted due to numerous off-target effects (Chigurupati et al., 2015). Therefore, there is an unmet need for alternative PPARγ-modulating cardioprotective remedies. The present study was intended to explore the therapeutic potential of deoxyelephantopin (DEP) as a novel PPARγ agonist that can act as an anti-fibrotic agent against hypertrophic heart failure.

PPARγ, a member of the nuclear receptor superfamily, is transcriptionally upregulated in hypertrophied hearts where it mediates downstream pro-hypertrophic signals, notably in the absence of exogenous agonists (Krishnan et al., 2009; Banerjee et al., 2020). Interestingly, agonist binding to PPARγ acts as a functional switch regulating the

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opposing effects of liganded *vs.* unliganded PPARγ in renal inflammation (Wen et al., 2010). Nonetheless, whether or not the effects of augmenting cardiac PPARγ during hypertrophy are dependent upon agonist binding remains largely unknown. Although the PPARγ-independent role of DEP has been studied in cancer cells (Zou et al., 2008), the PPARγ-dependent function of DEP and its implication in pathological cardiac hypertrophy have not been explored till now.

Earlier studies have documented the increased membrane translocation and activation of Protein Kinase C-delta (PKC δ) in the pathologically hypertrophied heart (Naskar et al., 2014; Chatterjee et al., 2019). Agonist-dependent induction of PPARγ reduces membrane translocation of PKCα due to increased association between PPARγ and PKCα (Von Knethen et al., 2007); however, whether similar interaction between the induced PPARγ and PKCδ modulates cardiac pathophysiology is still unknown. On the other hand, PKCδ is known to interact with Signal Transducer and Activator of Transcription (STAT)-3 upon stress and phosphorylate it to induce its transcriptional activity (Novotny-Diermayr et al., 2002; Garrobeio et al., 2006). Induction of IL-6/STAT-3 axis is already well-reported to augment myocardial fibrosis during pressure overload hypertrophy (Mir et al., 2012). Taking cues from all these reports, we hypothesized that the anti-fibrotic potential of DEP in the hypertrophied heart might be dependent upon a possible PPARγ/PKCδ/STAT-3-mediated pathway. Taken together, the present study is the first which explores the cardioprotective efficacy and the mechanism of action of DEP as a PPARγ agonist. This is also the first report that determines the relative effects of PPARγ augmentation in the ligand-bound *vs.* unbound conformation as a possible therapeutic approach against cardiac fibrosis.

of Health (NIH Publication No. 85-23, revised 1996) and approved by the Institutional Animal Ethics Committee, University of Calcutta (Registration No. 885/GO/RE/S/05/CPCSEA), registered under "Committee for Control and Supervision of Experiments on Animals" (CCSEA), Ministry of Environment, Forest and Climate Change, Government of India.

2.3. Isolation and maintenance of adult cardiac fibroblast

Adult cardiac fibroblasts were harvested from heart tissues of 24 weeks old male rats by collagenase dispersion method (Mir et al., 2012). Briefly, the animals were euthanized in a pre-filled carbon dioxide (CO_2) chamber with 100% concentration of CO_2. The harvested heart tissue was thoroughly minced and digested with collagenase type 2 (80 units/mL DMEM). The digested cell suspension was centrifuged and the obtained cell pellet was resuspended in freshly prepared complete media supplemented with 10% fetal bovine serum (FBS). Isolated fibroblasts were confirmed by staining with anti-vimentin antibody (Cell Signaling Technology, Cat. No. 5741) (Fu et al., 2020). The cells were maintained at 37 °C and 5% CO_2 in cell culture flasks and subsequently passaged.

2.4. Generation of hypertrophy in vitro

75–80% confluent serum-starved adult cardiac fibroblasts were treated with 10^{-8} mol/L (Sar1) angiotensinII (AngII). The AngII was replenished to the cells at every 6 h for the 24 h of total incubation period (Mir et al., 2012).

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The role of arsenic resistant *Bacillus aryabhattai* MCC3374 in promotion of rice seedlings growth and alleviation of arsenic phytotoxicity

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HIGHLIGHTS

- As resistant *Bacillus aryabhattai* AS6 strain isolated from contaminated rhizosphere.
- AS6 strain could tolerate As (v) and As (III) upto 100 mM and 20 mM respectively.
- It exhibited IAA and siderophore production, P-solubilization and ACCD activity.
- High As removal and bioaccumulation of AS6 confirmed from various *in vitro* studies.
- It improved rice seedling growth under As(V)-spiked soil by reducing phytotoxicity.

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Plant growth promotion
Ethylene production

ABSTRACT

The biological agents have been utilized as an affordable alternative to conventional costly metal remediation technologies for last few years. The present investigation introduces arsenic (As) resistant plant growth promoting rhizobacteria (PGPR) isolated from the As-contaminated agricultural field of West Bengal, India that alleviates arsenic-induced toxicity and exhibited many plant growth promoting traits (PGP). The isolated strain designated as AS6 has identified as *Bacillus aryabhattai* based on phenotypic characteristics, physio-biochemical tests, MALDI-TOFMS bio-typing, FAME analysis and 16S rDNA sequence homology. The strain found to exhibit five times more resistance to arsenate than arsenite with minimum inhibitory concentrations (MIC) being 100 mM and 20 mM respectively. The result showed that accumulation of As was evidenced by SEM- EDAX, TEM-EDAX studies. The intracellular accumulation of arsenic was also confirmed as in bacterial biomass by AAS, FTIR, XRD and XRF analyses. The increased rate of As (V) reduction by this strain found to be exploited for the remediation of arsenic in the contaminated agricultural field. The strain also found to exhibit important PGP traits viz., ACC deaminase activity (2022 nmol α-ketobutyrate/mg protein/h), IAA production (166 μg/ml), N_2 fixation (0.32 μgN fixed/h/mg proteins) and siderophore production (72%) etc. Positive influenced of AS6 strain on rice seedlings growth promotion under As stress was observed considering the several morphological, biochemical parameters including antioxidants activities as compared with an uninoculated set. Thus this strain might be exploited for stress amelioration and plant growth enhancement of rice cultivar under arsenic spiked agricultural soil.

1. Introduction

Arsenic is a toxic metalloid caused serious health problems were described as "the greatest mass poisoning in human history" by World Health Organization (WHO, 2001) and recognized as "Class-1 human carcinogen" by the USEPA (United States Environmental Protection Agency) as a global concern (Ng et al., 2003). In the periodic table, Arsenic (As) belongs to a group 15, period 4, P block

Abbreviations: MALDI-TOFMS, Matrix assisted laser desorption ionization-time of flight mass spectrometry; FAME, Fatty acid methyl ester; SEM, Scanning electron microscopy; TEM, Transmission electron microscopy; EDAX, Energy dispersive X-ray spectroscopy; FTIR, Fourier transform infrared spectroscopy; XRF, X-ray fluorescence.

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Chapter 3
Role of ACC Deaminase as a Stress Ameliorating Enzyme of Plant Growth-Promoting Rhizobacteria Useful in Stress Agriculture: A Review

Pallab Kumar Ghosh, Tarun Kumar De, and Tushar Kanti Maiti

Abstract The crop production is inhibited by a large number of both biotic and abiotic stresses. These stresses include presence of toxic heavy metals, high salt, flood, drought, temperature, wounding, various pathogens, etc. The agricultural production was intensified by management of these stresses with increased use of chemicals, and it needs more attention for incoming population explosion. These chemical inputs caused several harmful effects on the environment and sustainable agriculture. It is ne3cessary to decrease dependence of chemical input for sustainable agriculture with a holistic approach and also essential for environmental protection. One such possible approach is the use of 1-aminocyclopropane-1-carboxylate (ACC) deaminase-producing plant growth-promoting rhizobacteria (PGPR) to protect the crop plants from the harmful effects of both biotic and abiotic stresses. The enzyme ACC deaminase (EC 4.1.99.4) regulates stress ethylene production by catalysing ACC into α-ketobutyrate and ammonia. Various research works have documented the application of ACC deaminase-producing PGPR under both normal and stressed conditions responsible for the increased growth, health and productivity of crop plant. These beneficial rhizobacteria may decrease the dependence on agrochemicals (fertilizer and pesticides) to stabilize the agroecosystems and maintained sustainable agriculture. Different biochemical and biophysical properties of this enzyme and its regulation have been briefly described. This review also describes the role of ACC deaminase enzyme in plant growth and production by ameliorating different stress conditions including heavy metal, salinity, drought, flood, temperature, etc. Finally, the latest paradigms for useful application of ACC deaminase-containing plant growth-promoting rhizobacteria in different agroecosystems have been discussed comprehensively under stress conditions to highlight the recent scenario with the aim to develop future insights.

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ORIGINAL ARTICLE

WILEY Aquaculture Research

Larval rearing of hilsa shad, *Tenualosa ilisha* (Hamilton 1822)

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Abstract

Hilsa, *Tenualosa ilisha* has received much attention for culture due to decline of the natural population. Lack of knowledge on larval rearing is the bottleneck for its culture. This study was aimed at developing larval rearing protocols for hilsa shad. Hilsa larvae (4 days old, 4.76 ± 0.06 mm/0.49 ± 0.01 mg) were stocked in fibreglass-reinforced plastic tanks (1.7 m^3 water volume) at 300, 600 and 1,200 nos/m^3 in triplicates in three experimental systems viz., E-I (circular, 0.567 m water depth), E-II (circular, 0.962 m water depth) and E-III (rectangular, 0.567 m water depth) and reared for 46 days. The larvae were supplied with *Chlorella vulgaris*, *Brachionus calyciflorus*, mixed phytoplankton and mixed zooplankton during 4–50, 6–25, 8–50 and 26–50 days of their age respectively. In each system, higher ($p < 0.05$) fry survival at 300 nos/m^3 than in higher densities indicates density dependent stress. Circular tanks showed higher survival (13.3%–61.31%) than in rectangular tanks (6.88%–27.26%) in each stocking density, indicating the importance of tank shape for rearing. Water depth affected fry survival in circular tanks (E-I and E-II) at 300 nos/m^3; at 0.962 m depth, survival was higher (61.31%, $p < 0.05$) than that of 0.567 m depth (49.93%). Good fry survival was achieved through feeding the larvae initially with *Chlorella* followed by co-feeding with *Brachionus*, mixed phytoplankton and zooplankton and rearing in circular tanks at 300 nos/m^3 densities at 1 m depth. This first-ever larval rearing protocol is useful for mass production of fry to support hilsa aquaculture in future.

KEYWORDS
fry survival, stocking density, tank design, zooplankton culture

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Short Communication

Protein Requirement of *Ompok bimaculatus* (Bloch, 1794) Larvae

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ABSTRACT

Paul, B.N., Das, A., Mandal, R.N., Singh, P., Adhikari, S., Ghosh, K., Chowdhury, D., Chakrabarti, P.P. and Giri, S.S. 2020. Protein requirement of Ompok bimaculatus *(Bloch, 1794) larvae. Animal Nutrition and Feed Technology, 20: 525-533.*

A 22 d experiment was carried out to study the protein requirement of *Ompok bimaculatus* larvae (weight 0.11±0.01 g; length 20.49±0.70 mm). Three different formulated feeds were prepared with graded levels of crude protein i.e., with low (35% CP; LP), medium (40% CP; MP) and high (45% CP; HP) crude protein levels. The water quality parameters were optimum during the whole experimental duration. The survival rate was more than 70%. The fish grew to 0.34±0.06, 0.91±0.15 and 0.36±0.07 g, respectively in LP, MP and HP groups. The final weight was significantly ($P<0.01$) higher in MP having 40% CP in the diet. Both the net weight gain and specific growth rate were significantly ($P<0.05$) higher in MP having 40% CP in the diet as compared to LP and HP. The FCR was also significantly ($P<0.05$) lower in MP having 40% protein in the diet when compared with LP and HP. However, the protein efficiency ratio was similar ($P>0.05$) among the three treatment groups. Further, it was also revealed that the activities of enzymes in the digestive tract namely, α-amylase, lipase and pepsin were significantly ($P<0.05$) higher in MP diet having 40% crude protein. The present experiment, thus, revealed that 40% CP was sufficient for the optimum growth and survival of *O. bimaculatus* larvae.

Keywords: Amylase, Growth, Lipase, *Ompok*, Pepsin

INTRODUCTION

Ompok bimaculatus (Bloch, 1794) popularly known as the 'butter catfish' are found in lakes, rivers, canals, beels, swamps, floodplains and ponds, etc. and are distributed in India, Bangladesh, Borneo, Java, Sri Lanka, Myanmar, Pakistan, Thailand, Cambodia and Vietnam, etc. (Jayaram, 1977). It is a non-air breathing fish belonging

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PENSOFT.

ACTA ICHTHYOLOGICA ET PISCATORIA

Effect of dietary lipid levels on growth, body composition, and enzyme activities of larvae of butter catfish, *Ompok bimaculatus* (Actinopterygii: Siluriformes: Siluridae)

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sl.no 09

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http://zoobank.org/1881259A-9866-43D2-8793-201B9B8F00CA

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Abstract

The Indian butter catfish, *Ompok bimaculatus* (Bloch, 1794), is a high-value catfish that has gained immense consumer preference in South-East Asia. However, information on the nutritional requirements of this species is scanty. Hence, an experiment was conducted to evaluate the effects of varying dietary lipid levels on growth, body composition, and activities of digestive and metabolic enzymes in larvae. Three isonitrogenous (40% crude protein) diets were formulated by supplementing fish and vegetable oil (1:1) at 4.5% (D1), 7% (D2), and 9.5% (D3) levels (containing crude lipid 5.7%, 8.0%, and 10.45%, respectively in diets D1–D3) to a fish meal- and oilcake-based formulated diet. Experimental diets were fed to butter catfish larvae (0.15 ± 0.01 g) in triplicate groups for a period of 42 days. Proximate compositions of the experimental diets, as well as fish carcass, were analyzed using standard procedures (AOAC 2005). Digestive and metabolic enzyme activities were analyzed at the completion of the experiment by standard methodology. Butter catfish larvae fed the diet D2 (8% crude lipid) resulted in the best performance in terms of weight gain (final weight 1.40 ± 0.07 g), net weight gain (1.31 ± 0.06 g), specific growth rate (5.50 ± 0.05% · day^{-1}), and protein efficiency ratio (2.39 ± 0.17). The highest lipid deposition (2.90 ± 0.12%) in the carcass was also recorded in fish reared on diet D2. The final weight, net weight

sl. no. 09

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No.R-Ph.D./Regn. / SC/Zoo/172 Dated: 04.08 , 2017

To:
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C/o Late DebKumar Chakraborty
385, Merry Park P.O. L.D.T. - Hooghly.
Pin - 712103

Sub: Grant of Registration as a candidate for Ph.D.degree in Zoology
with effect from 18.08.2015.

Sir/Madam,

I am to inform you that the Vice-Chancellor's in his orders dated 19.07.2017 permitted you to get yourself registered as a candidate for Ph.D. degree, mentioned above, the title of your thesis being, "ARTIFICIAL PROPAGATION AND NURSERY REARING OF INDIAN SHAD, TENUALOSA ILISHA IN FRESHWATER CULTURE SYSTEM"

Subject to fulfillment of the requirements set forth in the University Ordinances relating to Doctoral Degrees and such terms and conditions as may be laid down by the appropriate authorities of the University from time to time.

You will now be required to deposit the Ph.D. Registration fee of Rs. 2000/- along with part-time research fee of Rs. 4000/- (Total Rs. 6000/-) for enrolment of your name in the Register of candidates for Ph.D. degree, positively within a month from the date of issue of this letter, failing which your case will not be considered for Registration as a Ph.D. candidate.

In this connection you are requested to note that ---

a) You will be required to get yourself registered as a student of this University on migration after completing all the necessary formalities prescribed in this behalf, unless you are already a registered student of this University.

b) On enrolment, you will be required to deliver one seminar talk before submission of the thesis pertaining to the project of your research you have undertaken within the period of your research work and before submission of the thesis.

c) You will have to published at least one research paper related to your research work in a referred journal / peer reviewed journal / journal having ISSN or in a book having ISBN number before submission of the thesis and produce evidence for the same in the form of acceptance letter or the reprint at the time of submission of your thesis.

d) You have been permitted to do research work under Dr. Koushik Ghosh, Dept. of Zoology, B.U. & Dr. D.N. Chattopadhyay, Principal Scientist, ICAR A-5 (Phase-III), Santalpara, Kalyani-741235 as your Supervisor / Joint Supervisors.

e) You will have to submit your thesis within six years from the date of your registration for Ph.D. degree mentioned above, but not earlier than 18.08.2017 in the prescribed manner along with the fee of Rs. 4000/- or as may be fixed by the Executive Council from time to time towards submission of thesis.

f) You will be required to undergo a preliminary test within one year of your enrolment, to be taken by the Supervisor(s) on subject(s) connected with the area of your research as well as on your linguistic equipment as may be prescribed by the Supervisor(s) . Further continuance of your research work will depend on satisfactory result at the test. In the event of unsatisfactory result, the appropriate authority of the University may allow you to appear at a second test within six months of such decision, but not before six months from the date of the first test. If the result of the second test is also found not to be satisfactory, the registration may be cancelled.

After satisfactory result at the test, you will have to get yourself in touch with your Supervisor(s) at least once in every two months in course of research work (applicable in the case of part-time researcher(s) and produce a certificate from the Supervisor(s) about your continuous research and satisfactory progress, from time to time.

g) All the requisite fees should be deposited in case at the University Cash Counter and the relevant copy of the Cash Receipt should be submitted to the *Ph.D. Unit* of the Registrar's Department.

h) In your case , *four/five copies* of the thesis along with a C*.D. in PDF format* (containing the Synopsis and the Thesis) be submitted and one copy be retained by you as a reference copy.

i) At the time of submission of thesis, a certificate in the prescribed form furnished by your Supervisor(s) will have to be pasted on all the copies of the thesis.

j) **The registration granted under this letter will remain valid for six years from the date of registration.** In the event of failure of submission of the thesis within the stipulated period, re-registration may be sought for and the same may be granted after observing all the formalities required in this behalf and on the receipt of the prescribed fee(s).

k) The registration granted herein may be cancelled by the concerned authority/ body of the University in the event of failure of the candidate to fulfill any of the prescribed requirements at any stage.

l) Residential requirements should be fulfilled and maintained (applicable in the case of part-time researchers).

m) Progress, Attendance and Good Conduct Reports of the Supervisor(s) in respect of the candidate should be submitted regularly every three months during the research.

n) Application forms for University Registration/Restoration of University Registration Number and Inward Migration are available at the University Sales Counter.

o) You will be required to submit six typed copies of Synopsis/Abstract of the thesis (not exceeding ten pages) along with the certificate mentioned in Clause(l) above and a certificate of delivering Seminar talk(s) and the Clearance Certificate from the Librarian of the Central Library, Burdwan University at the time of submission of thesis.

Yours faithfully,

Sd/-

Jt.Registrar

No. R/Ph.D./Regn. /sc/zoo/172/11(4) Dated: 04.08.2017

Copy forwarded for information to:

1) The Head of the Department of Zoology B.U.

2) Supervisor(s) of the candidate: i) Dr. Koushik Ghosh, Dept. of Zoology B.U.

ii) Dr. D.N. Chattopadhyay, PI Scientist, ICAR Kalyani

3) The Secretary, Faculty Council for P.G. Studies in Science B.U.

4) The Finance Officer, B.U.

Jt. Registrar

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DOI: 10.1111/are.13934

ORIGINAL ARTICLE

sl.no. 09

WILEY Aquaculture Research

Larval rearing of hilsa shad, *Tenualosa ilisha* (Hamilton 1822)

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Funding information
National Agricultural Science Fund, ICAR, Grant/Award Number: NFBSFARA/WQ-3021

Abstract

Hilsa, *Tenualosa ilisha* has received much attention for culture due to decline of the natural population. Lack of knowledge on larval rearing is the bottleneck for its culture. This study was aimed at developing larval rearing protocols for hilsa shad. Hilsa larvae (4 days old, 4.76 ± 0.06 mm/0.49 ± 0.01 mg) were stocked in fibreglass-reinforced plastic tanks (1.7 m^3 water volume) at 300, 600 and 1,200 nos/m^3 in triplicates in three experimental systems viz., E-I (circular, 0.567 m water depth), E-II (circular, 0.962 m water depth) and E-III (rectangular, 0.567 m water depth) and reared for 46 days. The larvae were supplied with *Chlorella vulgaris*, *Brachionus calyciflorus*, mixed phytoplankton and mixed zooplankton during 4–50, 6–25, 8–50 and 26–50 days of their age respectively. In each system, higher ($p < 0.05$) fry survival at 300 nos/m^3 than in higher densities indicates density dependent stress. Circular tanks showed higher survival (13.3%–61.31%) than in rectangular tanks (6.88%–27.26%) in each stocking density, indicating the importance of tank shape for rearing. Water depth affected fry survival in circular tanks (E-I and E-II) at 300 nos/m^3; at 0.962 m depth, survival was higher (61.31%, $p < 0.05$) than that of 0.567 m depth (49.93%). Good fry survival was achieved through feeding the larvae initially with *Chlorella* followed by co-feeding with *Brachionus*, mixed phytoplankton and zooplankton and rearing in circular tanks at 300 nos/m^3 densities at 1 m depth. This first-ever larval rearing protocol is useful for mass production of fry to support hilsa aquaculture in future.

KEYWORDS
fry survival, stocking density, tank design, zooplankton culture

1 | INTRODUCTION

Hilsa shad, *Tenualosa ilisha* is a high value food fish with rich in *n*-3 polyunsaturated fatty acids, eicosapentaenoic acid and docosahexaenoic acid (Mohanty et al., 2012). The species is widely distributed in Bay of Bengal, Indian Ocean, Persian Gulf and Arabian Sea and is also found in coastal areas, estuaries and freshwater rivers of India, Bangladesh, Pakistan, Indonesia, Sumatra, Myanmar, Malaysia, Kuwait, Qatar, Oman, Thailand, Saudi Arabia, United Arab Emirates, Iraq, Iran, Sri Lanka and Vietnam, where it contributes to the most important commercial fishery (Freyhof, 2014). In India, the fish migrate from Bay of Bengal to the Hooghly river for breeding (Jones & Menon, 1951). Recently, the availability of hilsa has been drastically declining with a consequent increase in demand and price, which often reaches $ 22 per kg (US) depending on the size and freshness. Therefore, the urgent need is culture of the species in confined water systems. The main bottlenecks for hilsa culture are insufficient fry for stocking, lack of knowledge on larval rearing and fry production and lack of ability to consistently produce a steady

sl.no. 09

Institute Project of ICAR-CIFA-reg

2 messages

Baidya Paul <bnpaulcifa@gmail.com> 13 July 2017 at 07:02
To: Koushik Ghosh <kghoshbu@gmail.com>

To
Dr. Koushik Ghosh
Assistant Professor (Stage –III)
Aquaculture Laboratory, Department of Zoology

(DST-FIST & UGC-SAP-DRS Sponsored)

The University of Burdwan

Golapbag, Burdwan – 713 104, West Ben

Dear Sir,

Your name has been proposed and accepted as a Co-PI in the Annual Institute Research Council Meeting held during 3-5th May, 2017 meeting at ICAR-CIFA, Bhubaneswar to execute the Institute funded project entitled " **Development of Larval diet for *Ompok bimaculatus*, a high- valued fish of regional importance".** I may therefore, request you to act as a Co-PI in the said project. Your consent in this collaborative effort and participation in the project will be highly appreciated.

Regards

Dr.Baidya Nath Paul
PI of the Project
Principal Scientist
Regional Research Centre
ICAR-Central Institute of Freshwater Aquaculture (www.cifa.in)
P.O.Rahara. Kolkata-700118
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3 attachments

RPP of larval feed project.docx
47K

RPP signature pages.pdf
559K

proceedings of the 31st Annual IRC meeting of ICAR-CIFA (1).pdf
3445K

Koushik Ghosh <kghoshbu@gmail.com> 13 July 2017 at 08:35
To: Baidya Paul <bnpaulcifa@gmail.com>

Received.
Thanks & best regards,

sl.no. 10

J. Botan. Soc. Bengal 75(2) : 1-16 (2021), ISSN 0971-2976

University of Calcutta, Kolkata 700 019, India

FULL LENGTH ARTICLE

Megaspores of heterosporous lycopsid affinity from the late Permian of Chhattisgarh, Central India and their evolutionary significance

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Received : Accepted : Published :

Dispersed fossil megaspores of heterosporous lycopsids have been recorded for the first time from the late Permian (Raniganj Formation) sediments exposed along the left bank of Banki River, near the village Chaki in Chhattisgarh, India. The outcrop has been palynologically dated based on miospore assemblage of typical late Permian affinity. The assemblage is represented by 7 species of trilete megaspores belonging to the genera *Noniasporites, Maiturisporites, Pantiella, Bokarosporites, Biharisporites, Hughesisporites* and a newly instituted genus of monolete megaspore i.e., *Monoletosporites* gen. nov. For the first time, the genera *Maiturisporites, Pantiella* and *Hughesisporites* have been recorded from the late Permian sediments; which were known earlier only from the Triassic sediments of Peninsular India. This indicates that the opportunistic species which successfully radiated during the Mesozoic had started colonizing themselves in the late Permian. A comparative study reveals that the megaspores possess affinity with the modern day lycopsids.

Key-words: Fossil megaspores, affinity, Raniganj Formation, late Permian, Peninsular India.

INTRODUCTION

The sexual life cycle of plants was a progressive evolutionary innovation that is vividly documented in the fossil records (Chaloner, 1967, 1970; Stewart, 1983). The evolutionary innovations (Niklas *et al*., 1980) in the reproductive biology of vascular plants have been thoroughly characterized by several workers namely Chaloner (1967), Stewart and Rothwell (1993) and Bateman and DiMichele (1994). In early land plants, these innovations in sexual life cycle can be categorized into homospory, incipient heterospory and advanced heterospory i.e., reduction in the number of functional megaspores to one, including gymnospermous reproduction. These newly induced innovations impart significant selective advantages over the less specialized grades (Chaloner, 1967; Niklas *et al*., 1980; Chaloner and Pettitt, 1987). The conjectural selective advantages are widely believed to play a major role in heterosporous plants that became dominant over homosporous pteridophytes and thereby the widespread dominance of flowering plants over the rest of the plant groups (Niklas *et al*., 1983; Stewart, 1983; Chaloner and

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sl.no. 10

Burdigalian to Early Serravallian Diatom Biostratigraphy from Havelock Island, Northern Indian Ocean

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Received May 13, 2020; revised June 18, 2020; accepted July 8, 2020

Abstract—In the Ritchie's Archipelago of the Andaman group of islands (Northern Indian Ocean), Havelock Island is the largest one. The present study on diatoms has been carried out on three outcrops of Havelock Island situated in Kalapathar, South Point and Laccam Point localities. Samples collected from the three Neogene outcrops yielded poor to moderately preserved diatom valves. Two lithological units are exposed in this island, i.e., Inglis and Long formations. The diatoms have been recovered from the Inglis Formation and the diatom assemblages are represented by the marker diatom species, viz., *Actinocyclus ingens, Annellus californicus*, *Araniscus lewisianus*, *Cestodiscus peplum*, *Craspedodiscus coscinodiscus*, *Denticulopsis simonsenii*, and *Rossiella paleacea* that indicate the age as Burdigalian to early Serravallian.

Keywords: biostratigraphy, diatoms, late early to middle Miocene, Ritchie's Archipelago, Andaman and Nicobar Islands

DOI: 10.1134/S0869593821020064

INTRODUCTION

The Ritchie's Archipelago in the Andaman group consists of several islands, namely, Havelock, Neil, Henry Lawrence, John Lawrence, Peel, Wilson, Outram, Hugh Rose, Northern Button etc. including some islets. Sporadic works on fossil diatoms from Neogene sediments have been carried out from some of these islands though Neogene deposits are widely distributed in the Ritchie's Archipelago (Sharma and Srinivasan, 2007). Pioneering work from the Ritchie's Archipelago was done by Jacob and Shrivastava (1952). From the Miocene of Colebrook and other islands of the Ritchie's Archipelago, they reported the occurrence of diatoms along with radiolarians and silicoflagellates. Fifteen diatom taxa were reported by Mathur (1973) from the early Miocene of Havelock Island. Subsequently, seven diatom taxa were listed from the early Pliocene of Neil Island (Singh and Vimal, 1973). Thirty taxa of fossil diatoms belonging to 13 genera were recorded from the same sequence of Neil Island (Singh et al., 1978). Later on, Singh (1979) reported some additional diatom taxa. From the Outram Island, Mathur (1981) described 10 species of diatoms and correlated them to the middle Miocene *Craspedodiscus coscinodiscus* Zone of Bukry and Foster (1973). Further, Mathur (1985) identified 18 genera of diatoms with one new species *Liostephania ovalis* from the middle Miocene of Nicholson Island. After a decade, Singh and Sharma (1996) worked on the diatoms of Neil East Coast Section of Neil Island and recognised ten diatom zones. Chakraborty and Ghosh (2016) studied the late Miocene sediments (Tortonian) of the Neil Island and reported 82 planktonic and benthic diatoms. Recently, Chakraborty et al. (2019) have identified 22 taxa belonging to 17 genera of diatoms from Havelock Island. They are assigned to the late early to early middle Miocene based on multiple microfossils.

It may be mentioned here that planktonic diatoms are useful tool for biostratigraphic interpretation, dating and correlation of Neogene marine sediments (Barron, 1985a) and consequently the planktonic diatoms are frequently used in biostratigraphic studies (Barron, 1992). In view of this, the present study has been undertaken to make more precise age determination based on the study of diatoms from three outcrops exposed at Havelock Island, to identify the palaeoecological zones based on diatoms, and to decipher the diversity patterns of diatom taxa recovered from three different outcrops of Havelock Island.

MATERIALS AND METHODS

Andaman and Nicobar group of islands consists of two major groups, i.e., Andaman group and Nicobar group (Fig. 1a). Amongst these, the Andaman group

Item no: 8

Dr. Debidas Mondal

Joint Registrar

The University of Burdwan

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No.R-Ph.D./Regn. /Sc/Botany/ Dated:

To:
Shri/Sm...Ruma Bhadra
Central National Herbarium , AJC Bose Indian Garden,
Shibpur, Howrah-711103

Sub: Granting Registration under the supervision of Dr. P.V. Prasanna, Scientist-F(BSI),Deccan Regional Centre ,Hyderabad as **Supervisor** and Dr. Saikat Naskar, Dept. of Botany, B.U. as **Co-Supervisor**.

Sir/Madam,

This has a reference to our earlier letter no. R-Ph.D./Regn./Sc/Bot/598 Dated 16.01.2020.

I am to inform you that the Joint Meeting (2022-2023)of the Faculty Councils for P.G. studies in Science &Arts, Commerce, Law etc . at its meeting held on 09.06.2022,resolved that you have been permitted to do research work under Dr. P.V. Prasanna, Scientist-F(BSI), Deccan Regional Centre ,Hyderabad as **Supervisor** and Dr. Saikat Naskar, Dept. of Botany, B.U. as **Co-Supervisor**.

Other terms and Conditions will remain same.

Yours faithfully,

Sd/-

Joint Registrar

No.R-Ph.D./Regn. /Sc/Botany/ 86/1C4) Dated: 08-07-2022

Copy forwarded for information & necessary action to:

1) The Head, Dept. of Botany B.U.
2) Prof./Dr. P. V. Prasanna, Scientist-F(BSI), Deccan Regional Centre, Hyderabad
3)Prof./Dr. Saikat Naskar, Deptt. of Botany, B.U.
4)The Secretary,F.C.(Sc/Arts.), Burdwan University, Burdwan

Joint Registrar

SL NO. 11

PCP
PLANT & CELL PHYSIOLOGY

Exposure to Low UV-B Dose Induces DNA Double-Strand Breaks Mediated Onset of Endoreduplication in *Vigna radiata* (L.) R. Wilczek Seedlings

Sayanti De [1], Jismon Jose [2], Amita Pal [3], Swarup Roy Choudhury [2,*] and Sujit Roy [1,*]

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(Received 13 March 2021; Accepted 28 January 2022)

Multiple lines of evidence indicate that solar UV-B light acts as an important environmental signal in plants, regulating various cellular and metabolic activities, gene expression, growth and development. Here, we show that low levels of UV-B (4.0 kJ m^{-2}) significantly influence plant response during early seedling development in the tropical legume crop *Vigna radiata* (L.) R. Wilczek. Exposure to low doses of UV-B showed relatively less growth inhibition yet remarkably enhanced lateral root formation in seedlings. Both low and high (8.0 kJ m^{-2}) doses of UV-B treatment induced DNA double-strand breaks and activated the SOG1-related ATM-ATR-mediated DNA damage response pathway. These effects led to G2-M-phase arrest with a compromised expression of the key cell cycle regulators, including CDKB1;1, CDKB2;1 and CYCB1;1, respectively. However, along with these effects, imbibitional exposure of seeds to a low UV-B dose resulted in enhanced accumulation of FZR1/CCS52A, E2Fa and WEE1 kinase and prominent induction of endoreduplication in 7-day-old seedlings. Low dose of UV-B mediated phenotypical responses, while the onset of endoreduplication appeared to be regulated at least in part via UV-B induced reactive oxygen species accumulation. Transcriptome analyses further revealed a network of co-regulated genes associated with DNA repair, cell cycle regulation and oxidative stress response pathways that are activated upon exposure to low doses of UV-B.

Keywords: DNA double-strand breaks • DPI • Endoreduplication • ROS • UV-B • *Vigna radiata*

Regular Paper

Introduction

Plants, being sessile in nature and with their obligatory dependence on sunlight for photosynthesis, cannot escape the damaging effects of solar UV-B light. Therefore, they have developed a sophisticated and highly regulated balance between optimal light capture and UV-B protection. Some plant species escape UV-B exposure by limiting their life span to the season or places where they perceive only low levels of UV-B, while others, including crops, grow during the summer months and experience a high incidence of solar UV-B light (Ulm and Jenkins 2015). In tropical climates, plants receive sunlight for longer duration, and the effects of UV-B radiation are greater under such conditions. Early studies in tropical crops, including *Oryza sativa* (Teramura and Sullivan 1994), *Vigna mungo* (Fukumoto and Mazza 2000), *Vigna radiata* (Amudha et al. 2005), *Glycine max* (Guruprasad et al. 2008) and *Triticum aestivum* (Kataria and Guruprasad 2014) have shown compromised growth and yield in response to exposure to ambient UV-B light. More recent studies in cucumber (*Cucumis sativus* L. cv. 'Hi Jack') have correlated the growth retardation effect with the regulatory mechanism associated with the acclimation processes of UV radiation (Qian et al. 2021). Other studies mainly in *Arabidopsis* and some other species indicated that two major mechanisms of UV-B mediated responses, including the accumulation of UV-B absorbing compounds and the DNA damage response, actually vary among various plant species. These factors eventually generate variations in UV-B response in plants (Hidema et al. 2007, Xu and Sullivan 2010). However, the variations in UV-B response in nonmodel crops and other field plant communities remain largely unexplored.

UV-B represents an energy-rich intrinsic component of solar radiation. It affects plant growth and development through diverse physiological and metabolic processes (Jenkins 2009). At high fluence rate, UV-B causes damage to the photosynthetic components (Correia et al. 1998), DNA (Schmitz-Hoerner and Weissenböck 2003), proteins and membranes (Bornman and Teramura 1993). The UV-B-induced photodimers (Taylor 2006), primarily cyclobutane pyrimidine dimers (CPDs) and pyrimidine-6,4-pyrimidinone dimers (6,4PPs) (Gill et al. 2015), create distortions in the DNA double-helical structure and eventually block transcription and replication (Britt 2004, Manova and Gruszka 2015). Furthermore, the inefficient repair

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SL. NO. 11

Plant, Cell & Environment

WILEY

Plant, Cell & Environment

ORIGINAL ARTICLE

The Negative Impact of Prolonged Desiccation on the Recovery of *Selaginella bryopteris*: Insights Into Autophagy and Cellular Protection Strategies

Jismon Jose[1] | Lakhani Amiben[1] | B. P. Girish[2] | Kakali Sen[3] | T. N. V. K. V. Prasad[2] | Sujit Roy[4] | Swarup Roy Choudhury[1]

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Received: 19 March 2024 | **Revised:** 1 August 2024 | **Accepted:** 13 September 2024

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Keywords: autophagy | cell death | cellular protection | desiccation tolerance | metabolomics | protein homeostasis | ROS | *Selaginella bryopteris* | transcriptome | WGCNA

ABSTRACT

Desiccation tolerance is a complex biological phenomenon that allows certain plants to survive extreme dehydration and revive upon rehydration. Although significant progress has been made in understanding the physiological and molecular mechanisms involved in desiccation tolerance, recovery mechanisms after prolonged desiccation periods are enigmatic. Combining physiological, biochemical, transcriptomic and metabolomic approaches, we investigated the role of prolonged desiccation on recovery of *Selaginella bryopteris*. Prolonged desiccation causes a decline in the antioxidant system, leading to accumulation of ROS that hinder recovery by inducing cellular damage. Transcriptome and WGCNA analysis revealed the significance of protective proteins, alternative respiration and protein homeostasis in cellular protection and recovery after short and long-term desiccation. Metabolomic analysis exhibited an increased accumulation of antioxidant compounds, which can be substituted for antioxidant enzymes to maintain cellular protection during prolonged desiccation. The significant role of autophagy and autophagic components was evaluated by H_2O_2 treatment and phylogenetic analysis of ATG4 and ATG8, which unveiled their substantial role in desiccation tolerance and remarkable conservation of the autophagy-related genes across plant species. Our data demonstrated that prolonged desiccation leads to ROS-induced cell death by extensive autophagy due to enormous loss of protective proteins, antioxidant enzymes and energy resources during desiccation.

1 | Introduction

Drought, a major threat to global food security, is considered a central environmental challenge for crop growth and productivity (Zhu 2002; Lobell, Schlenker, and Costa-Roberts 2011). Extreme drought damages plants by desiccating cells. Seeds and spores of most plants can withstand desiccation (Bewley 1979), while the vegetative tissues of most plants lack this feature (Dinakar and Bartels 2013). However, a limited group of plants, termed desiccation tolerant plants (hereafter DT plants), possess exceptional survival potential in the vegetative tissues against desiccation. DT plants are also known as 'resurrection plants' because of their ability to revive from a complete water loss or an air-dry state, upon re-watering. DT plants can survive dehydration by

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Applied Mathematics and Computation 371 (2020) 124951

Contents lists available at ScienceDirect

Applied Mathematics and Computation

journal homepage: www.elsevier.com/locate/amc

Nonautonomous matter wave bright solitons in a quasi-1D Bose-Einstein condensate system with contact repulsion and dipole-dipole attraction

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Matter wave
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Bright solitons

ABSTRACT

We investigate the existence and propagation properties of envelope solitons of an extended nonlinear Schr ödinger equation with the time-modulated dispersion, quadratic-cubic nonlinearities and linear gain or loss, which govern the nonlinear wave propagation in a nonautonomous quasi-1D Bose-Einstein condensate system with contact repulsion and dipole-dipole attraction. A novel class of nonautonomous bright soliton solutions on continuous-wave background is identified for the first time. It is shown that these localized structures possess interesting features that differ from the usual bright solitons. A rich variety of evolution behaviors, which include snakelike and periodic oscillating bright soliton dynamics, is revealed. The constraints of the system parameters to form these nonlinear localized structures are also suggested.

10

1. Introduction

The study of nonautonomous soliton propagation through nonlinear optical media has been one of the considerable recent interests [1–5]. This should not be surprising because the existence of these nonlinear waves have been demonstrated experimentally in a variety of settings, including nonlinear optics, fluid dynamics, condensed matter physics and plasma physics [5]. In general, the wave dynamics in some of the above mentioned areas and many other nonlinear mathematical-physics fields is governed by the well known nonlinear Schrödinger equation [6]. In the setting of Bose-Einstein condensates (BECs), such NLS equation is usually called the Gross-Pitaevskii (GP) equation [7].

To describe the wave propagation behaviors in realistic systems, one uses the variable-coefficient NLS equation and its variants. Noting that most of dynamical models are inhomogeneous in reality because of fluctuations in environmental environment and nonuniform medium, then the governing envelope wave equation should be included the spatially and/or

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0096-3003/

SL. NO. 13

Journal of Alloys and Compounds 821 (2020) 153503

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Advanced asymmetric supercapacitor with $NiCo_2O_4$ nanoparticles and nanowires electrodes: A comparative morphological hierarchy

Mahasweta Chatterjee [a], Samik Saha [b], Sachindranath Das [b], Swapan Kumar Pradhan [a, *]

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Porous structure
Asymmetric supercapacitor device
Energy storage

ABSTRACT

In the present work, hydrothermal and wet chemical methods are adopted to fabricate $NiCo_2O_4$ nanowires (NiCo-NW) and $NiCo_2O_4$ nanoparticles (NiCo-NP) respectively. Owing to the mesoporous nature of these subunits, fast and convenient electron-ion transport and redox reaction, NiCo-NW achieves excellent electrochemical performance. Structure and microstructural characterizations of these samples are carried out by analyzing X-ray diffraction data employing the Rietveld method of structure refinement method and analyzing HRTEM, FESEM images and FTIR spectra. The low dimensional NiCo-NP is found to provide superior electrochemical performance than the NiCo-NW (~13 nm) due to its smaller particle size (~9 nm). This porous structure effectively helps in better transport of ions in the electrolyte. It manifests high specific capacitance 1066.03 F g^{-1} and enormous areal capacitance up to 5.96 F cm^{-2} whereas NiCo-NW exhibits specific capacitance up to 880.72 F g^{-1} and high areal capacitance of 4.93 F cm^{-2}. An asymmetric supercapacitor (ASC) has been fabricated with NiCo-NP and activated carbon as positive and negative electrodes respectively in 1 M Na_2SO_4 electrolyte medium. This device offers maximum specific energy 59.56 Wh Kg^{-1} and maximum power density 3403 W kg^{-1} with a high energy density of 4.197 Wh Kg^{-1} and shows excellent cyclic stability.

1. Introduction

In recent years, enormous attention has been drawn to develop novel materials and devices for the new renewable and sustainable energy sources with high efficiency, high reliability and high energy density. The supercapacitor has been used massively in last few decades as a green energy storage device combining the features of the conventional capacitor (high power density, long cycling life) and rechargeable batteries (high energy density) [1–8]. Based on the charge storage mechanism supercapacitors are of two types: (i) electric double-layer capacitor(EDLC), and (ii) pseudocapacitors. For EDLCs electric energy is stored by separation of charge in Helmholtz double-layer and for pseudocapacitor storage of electric energy is achieved by a faradaic redox reaction with charge transfer [8–10]. Various carbonaceous materials like activated carbon, CNT, graphene are being used as electrode materials for EDLCs for their higher surface area with a porous surface and electrically intercalated networks. EDLCs show high power density, better cycle life than pseudocapacitor but possess very low specific capacitance. However, due to fast multi electro-redox reaction, pseudocapacitors possess higher specific capacitance, higher energy density than observed in EDLCs [11,12], but it leads to deficient cycle stability because of redox reaction like a battery.

The primary focus of the present work is to improve cell voltage and energy density by developing an ASC device in which (EDLC) electrode has been used as the negative electrode and redox-active transition metal oxides as a positive electrode. The maximum operating voltage in the cell system can be reached by using different potential windows of the two-electrode system. Primarily, activated carbon has been used as the negative electrode and transition metal oxides as a positive electrode. So, the main focus of ASC is to develop better metal oxides for advanced positive electrode [3,13].

Various metal oxides and hydroxides with their variable valence states had been widely used for electrode materials in pseudocapacitors [14,15]. Attempts had been made to prepare inexpensive metal oxides like Co_3O_4 [16,17], NiO [10,18], MnO_2 [19], V_2O_5 [20], Fe_2O_3 [21] for high theoretical capacitance and low toxicity. Both Ni and Co-based materials were considered to be the most admirable

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Enhanced electrochemical properties of Co_3O_4 with morphological hierarchy for energy storage application: A comparative study with different electrolytes

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ABSTRACT

A facile hydrothermal route synthesizes Co_3O_4 nanocrystals with urchin spine-like morphology. Structure and microstructural characterizations of the sample are carried out. Electrochemical properties have been explored in the presence of different electrolytes. In order to find out the best electrolyte, three electrolytes (Na_2SO_4, NaOH and Na_2SO_4 with Hq) of fixed concentration (1 M) are used to record the cyclic voltammetry data. In the presence of Na_2SO_4 as an electrolyte, specific capacitance becomes 218 F g^{-1}, possibly because of low ionic conductivity of SO_4^{2-}, higher charge transfer resistance. When NaOH and Na_2SO_4 (with Hq) are used as electrolytes, high specific capacitances of 1720 F g^{-1} and 2433 F g^{-1} respectively are obtained due to extra pseudocapacitive effect of redox reaction. It is worth noting that the semicircle diameter in the EIS plot is highest for Na_2SO_4 and lowest for Na_2SO_4 (with Hq) electrolyte. The R_{ct} value depends on the type of electrode and the interaction between electrolyte ions with the electrode.

1. Introduction

Nowadays, one of the primary focuses of the scientific community is to harvest new sustainable energy materials to cope up with the continuous changes in the global climate. The demand for energy, however, is increasing day by day. It becomes very urgent for a scientist to develop new renewable energy sources with high power and better efficiency. It is now well known that supercapacitors have emerged as an alternative energy storage device with better efficiency than a rechargeable battery [1,2]. Supercapacitors exhibit higher energy efficiency, excellent reversibility, higher energy density than a conventional capacitor. Generally, supercapacitors can be classified into three types based on the charge storage mechanism: (i) electrical double-layer capacitor (EDLC), (ii) pseudocapacitors, and (iii) hybrid system. The energy storage mechanism in the electrochemical capacitor is of two types: faradaic and non-faradaic. The non-faradaic reaction arises in the EDLC due to ion adsorption at the electrode/electrolyte [3]. Various carbonaceous materials such as activated carbon, carbon nanotube (CNT), graphene oxide belong to the EDLCs. Such carbonaceous materials possess a large surface area with a porous surface with the interlaced network [4]. However, EDLCs cannot fulfill the requirement for the peak power assistance in the vehicle since EDLC offers low energy density. Instead, the faradaic pseudocapacitors are based on the fast reversible redox reaction within electroactive materials on the electrode, and its energy density is at least one order of magnitude higher than EDLCs [3,4].

In contrast, various inexpensive transition metal oxides such as Co_3O_4 [1,5–8], NiO [4,9], MnO_2 [10], and Fe_3O_4 [11], $NiCo_2O_4$ [12] are mainly used as electrode materials for pseudocapacitors. They provide enhanced electrochemical performance over EDLCs because of their higher specific capacitance generating from rapid and productive redox reaction. Finding cheap material with superior pseudocapacitive performance has thus attracted enormous attention. Among all these transition metal oxides, Co_3O_4 has been studied extensively for its supercapacitor application due to its high surface area, easily tunable surface area, multiple oxidation states and tunable structural properties. The Co_3O_4 is a p-type direct optical bandgap semiconductor that shows the high theoretical capacity, excellent corrosion stability and can act as

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Ultrastable Asymmetric Supercapacitor Device with Chemically Derived and Mechanically Activated $NiCo_2O_4$

Mahasweta Chatterjee, Adwaita Kundu, Sachindranath Das, and Swapan Kumar Pradhan*

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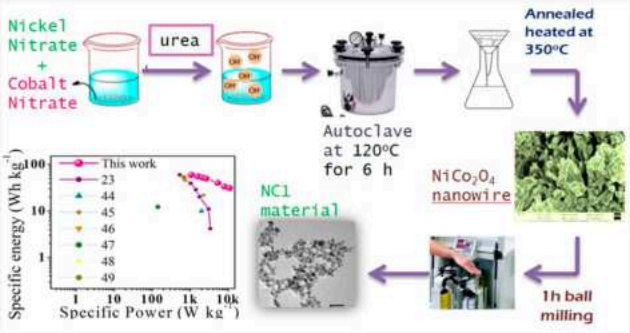
ABSTRACT: We report the effect of mechanical alloying on the chemically synthesized $NiCo_2O_4$ nanowire for better electrochemical performance. The nickel cobaltite nanowires (NC) were successfully synthesized via the hydrothermal method without any surfactant. Then they were milled for 1 h (NC1) and 2 h (NC2) to boost the electrochemical performance. The structural and microstructural parameters, shape, size, and morphology of these samples are revealed by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and transmission electron microscopy (TEM) techniques. The Brunauer–Emmett–Teller (BET) characterization and Barrett–Joyner–Halenda (BJH) model reveal that the NC1 sample offers the highest specific surface area among all three samples with its one-dimensional mesoporous structure (pore diameter, ~7 nm). The NC1 sample displays an excellent specific capacitance and rate capability (1234 F g^{-1} at a scan rate of 2 mV s^{-1}). However, upon further milling (2 h) the electrochemical performance of the sample decays rapidly due to an increase in particle size and reduction in specific surface area. A remarkable specific capacity of 1196 F g^{-1} is achieved in the 1 h milled sample at the lowest current density of 12 A g^{-1}, and at 40 A g^{-1} and 129.2 F g^{-1} specific capacitance can be retained. We further demonstrate an asymmetric device based on the NC1 sample as a positive electrode, which produces an excellent energy density of 59.221 Wh kg^{-1} at a power density of 1065.4 W kg^{-1}. The assembled device can attain an outstanding power density of 10.992 kW kg^{-1} at an enormous high current density of 13.33 A g^{-1} and demonstrates an excellent cyclic performance of 91.7% retention after 5000 cycles.



INTRODUCTION

Due to the rapid growth of portable energy storage systems, mobile systems, and other electronic gadgets, the main interest of scientists in these fields is to develop advanced new generation high energy and power density devices.[1−3] Various transparent energy storage systems are used in commercial and industrial areas. A supercapacitor can be recognized as an efficient, clean energy storage candidate due to its excellent cycle life, high power density, and better cycle stability. Typically, the charge storage mechanism of a supercapacitor is of two types: one is the capacitive type and the other is the pseudocapacitive type. Generally, the charge storage process of the capacitive type is an electric double-layer capacitor that relies on electrostatic charge storage separation of ions at the electron electrolyte interface.[4,5]

In contrast, in a pseudocapacitor, capacitance is produced by a fast multielectron faradaic surface redox reaction. The capacitance performance is much better than the electric double-layer capacitor (EDLC), especially in energy density. Several transition metal oxides (NiO, $NiCo_2O_4$, $CoFe_2O_4$, MnO_2, and Co_3O_4) and sulfides are vastly used and studied as positive electrodes for their different pseudocapacitive nature.[6−10] The binary oxides manifest extraordinary electrochemical performance than a single metal oxide because of their redox reaction between valence states, large electrode–electrolyte contact surfaces, and many defects, which improves pseudocapacitance as well as the energy density of the material.[11−13] The crucial parameters which regulate the electrochemical performance are the porosity, particle size, specific surface area, oxygen vacancy, and surface defects. Scientists these days try to incorporate an optimized amount of oxygen vacancy and surface defects to balance the electrochemical performance of the material in a well-mannered way.[14−16] Since metal oxide with a higher oxygen vacancy ensures a higher CV current and higher positive potential, forming an oxygen vacancy becomes one of the main choices for getting higher electrochemical performance by an easy and economical technique. In metal oxides or ceramics with

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Superior photocatalytic performance and photo disinfection of bacteria of solvothermally synthesized mesoporous La-doped CeO_2 under simulated visible light irradiation for wastewater treatment

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ABSTRACT

A simple, cost-effective, and facile solvothermal approach has been adopted to synthesize mesoporous CeO_2 nanostructures with varying La-doping (2, 4, and 6 mol%) concentrations. Photocatalytic and antibacterial performances are investigated against the inactivation of *Escherichia coli* and *Bacillus licheniformis* bacteria cells. Structural and microstructural characterizations of La-doped CeO_2 nanostructures are performed by analyzing X-ray diffraction (XRD) data employing the Rietveld refinement method, scanning electron (SEM) and transmission electron microscopy (TEM) images, Brunauer–Emmett–Teller (BET), energy-dispersive X-ray (EDX), and X-ray photoelectron spectroscopy (XPS) spectra. Among three doped samples, the 4 mol% La-doped CeO_2 (LCe4) has exhibited high oxygen and Ce^{3+} concentrations, high microstrain, small crystallite size, and lowest band gap energy, as are revealed by the analysis of XPS, UV–VIS absorption spectra, photoluminescence (PL) spectra, and Rietveld refinement result. The LCe4 sample with the highest number of oxygen vacancies and high surface area shows superior photocatalytic activity (~95% Rhodamin B (RhB) degradation in 130 min, ~70% Methylene Blue (MB) degradation within 30 min, and ~95% phenol degradation in 180 min under solar radiation). It shows a striking photo-disinfection effect and enhanced antibacterial activity (almost identical to a pure drug) against gram-positive and gram-negative bacteria under visible light irradiation. This novel disinfection and catalytic property of the LCe4 sample is attributed to the mesoporous structure of materials and surface activity, which lowers the electron-hole recombination rate and transports more photogenerated electrons and holes. The nanostructured mesoporous LCe4 material has been used as an effective visible light-activated photocatalyst and photo disinfection for treating wastewater containing organic dyes and gram-negative and gram-positive bacteria.

1. Introduction

Water pollution from mixing hazardous materials and heavy metals has become a serious global issue. Because of water pollution, various water-born diseases become vulnerable to humanity in most developing countries due to the lack of adequate purifier systems like UV radiation and chlorofication, particularly in rural areas. Thus, the availability of purified drinking water becomes a critical issue for the increasing population. Photocatalytic degradation of pollutants is a facile green chemical, sustainable and cost-effective method to remove contaminants from wastewater containing organic dyes [1–3].

CeO_2 is considered one of the most abundant rare earth oxides frequently used in electrochemical cells, energy storage and optical devices, photocatalysis, and as a biomaterial. CeO_2 is an n-type semiconductor material with various chemical and physical properties, like pollutant elimination with non-toxicity [5–7]. The main feature of CeO_2 is the transformation of the Ce^{4+} to Ce^{3+} valence state, which causes oxygen vacancies and a high stoichiometry deviation, consequentially increasing visible light absorbance [4–8]. Various reports on CeO_2 as a photocatalyst with different morphologies, like nanocube, nanowire, and nanodisc, using different templates are available. The present study intends to develop CeO_2 nanomaterials with an optimum mesoporous structure and

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Research Paper

Mn-doped $NiWO_4$ quantum dots with superior electrochemical and conductivity performance for energy storage application

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Keywords:
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ABSTRACT

Monoclinic amorphous $Ni_{1-x}Mn_xWO_4$ (x = 0.00, 0.02) compounds have been successfully synthesized by hydrothermal technique for achieving better capacitive and conductive performances. Different characterization techniques like X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), ultraviolet-visible (UV–Vis) and photoluminescence (PL) spectroscopy have been employed to investigate their structural, microstructural, and optical properties. Mn-ion incorporation in the $NiWO_4$ lattice reduces the particle size of the sample to ~4.5 nm, compared to the pure undoped $NiWO_4$ sample (~18 nm), confirmed from the transmission electron microscopy image and Brunauer–Emmett–Teller analyses (BET). Tauc plot of $Ni_{0.98}Mn_{0.02}WO_4$ sample exhibits a significant increase in bandgap energy, compared to pure undoped $NiWO_4$ sample due to the quantum confinement effect. The electrochemical performance of electrodes made with these materials has been revealed by cyclic voltammetry (CV), galvanostatic charge-discharge (GCD) properties and electrochemical impedance spectroscopy (EIS). Moreover, the addition of 2 % Mn in $NiWO_4$ causes an increase in specific surface area (117.390 m^2/g) due to the reduced particle size of the material, resulting in excellent specific capacitance of 463 F g^{-1} at 0.5 A g^{-1} current density. The detailed charge storage mechanism for the improvement of conductivity and electrochemical performance of the Mn-doped $NiWO_4$ has been revealed in different studies. An asymmetric supercapacitor device (ASC) has been fabricated using Mn-doped $NiWO_4$ electrode material as positive electrode. The device shows superior cyclic stability upto 5000 cycles, can retain 88.4 % of its initial value.

1. Introduction

Electrochemical storage devices such as supercapacitors, fuel cells, and Li-ion batteries are more sustainable clean energies to deal with the global warming issues [1–3]. Among all three renewable energy sources, a supercapacitor is more promising than Li-ion batteries due to its fast charging, longer recyclability, better power density, and easy maintenance. Supercapacitors are classified into two categories, (i) electric double-layer capacitors (EDLC) and (ii) pseudocapacitors [2–5]. Researchers are continuously trying to improve the energy density of supercapacitors without hampering their power density and cycle life. Pseudocapacitor materials store more energy than an electric double-layer capacitor.

For this reason, various binary and ternary metal hybrid oxides with different morphologies were synthesized for supercapacitor applications [6,7]. However, some drawbacks of using metal oxides in electrochemical applications include poor conductivity, low energy density, and poor cycle stability [8,9]. It has been revealed from recent works that the electrochemical properties of some complex oxides (such as $NiCo_2O_4$ and $MnCo_2O_4$) are superior to single oxides like NiO, MnO_2, and Co_3O_4 because of multiple oxidation states of different metal cations [10–12]. The $NiWO_4$ compound is an attractive material in the electrochemical field because of its high electrical conductivity of $\sim 10^{-7}$–10^{-3} S cm^{-1} [13–15], which is higher than NiO (10^{-13} S cm^{-1}), and $CoWO_4$ compounds [16]. It was reported that the incorporated W atoms had improved the electrical conductivity and electrochemical activity of the compound [17]. Recent reports on core-shell heterostructures with multi-component, such as $MnCo_2O_4/NiWO_4$, Ni.Co.Zn oxide/$NiWO_4$, and $NiWO_4/NiCO_2O_4$ grown on nickel foam showed enormous high electrochemical performance than the $NiWO_4$ lattice

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SL. NO. 14

Gmail

Koushik Ghosh <kghoshbu@gmail.com>

Institute Project of ICAR-CIFA-reg

2 messages

Baidya Paul <bnpaulcifa@gmail.com> 13 July 2017 at 07:02
To: Koushik Ghosh <kghoshbu@gmail.com>

To
Dr. Koushik Ghosh
Assistant Professor (Stage –III)
Aquaculture Laboratory, Department of Zoology

(DST-FIST & UGC-SAP-DRS Sponsored)

The University of Burdwan

Golapbag, Burdwan – 713 104, West Ben

Dear Sir,

Your name has been proposed and accepted as a Co-PI in the Annual Institute Research Council Meeting held during 3-5th May, 2017 meeting at ICAR-CIFA, Bhubaneswar to execute the Institute funded project entitled " **Development of Larval diet for *Ompok bimaculatus*, a high- valued fish of regional importance".** I may therefore, request you to act as a Co-PI in the said project. Your consent in this collaborative effort and participation in the project will be highly appreciated.

Regards

Dr.Baidya Nath Paul
PI of the Project
Principal Scientist
Regional Research Centre
ICAR-Central Institute of Freshwater Aquaculture (www.cifa.in)
P.O.Rahara. Kolkata-700118
+91 33 25683023(Work)
Mob:+91 9432334390

3 attachments

RPP of larval feed project.docx
47K

RPP signature pages.pdf
559K

proceedings of the 31st Annual IRC meeting of ICAR-CIFA (1).pdf
3445K

Koushik Ghosh <kghoshbu@gmail.com> 13 July 2017 at 08:35
To: Baidya Paul <bnpaulcifa@gmail.com>

Received.
Thanks & best regards,

K. Ghosh
[Quoted text hidden]

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Short Communication

Protein Requirement of *Ompok bimaculatus* (Bloch, 1794) Larvae

B.N. Paul*, A. Das, R.N. Mandal, P. Singh, S. Adhikari, K. Ghosh[1], D. Chowdhury[1], P.P. Chakrabarti and S.S. Giri[2]

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ABSTRACT

Paul, B.N., Das, A., Mandal, R.N., Singh, P., Adhikari, S., Ghosh, K., Chowdhury, D., Chakrabarti, P.P. and Giri, S.S. 2020. Protein requirement of Ompok bimaculatus *(Bloch, 1794) larvae. Animal Nutrition and Feed Technology, 20: 525-533.*

A 22 d experiment was carried out to study the protein requirement of *Ompok bimaculatus* larvae (weight 0.11±0.01 g; length 20.49±0.70 mm). Three different formulated feeds were prepared with graded levels of crude protein i.e., with low (35% CP; LP), medium (40% CP; MP) and high (45% CP; HP) crude protein levels. The water quality parameters were optimum during the whole experimental duration. The survival rate was more than 70%. The fish grew to 0.34±0.06, 0.91±0.15 and 0.36±0.07 g, respectively in LP, MP and HP groups. The final weight was significantly ($P<0.01$) higher in MP having 40% CP in the diet. Both the net weight gain and specific growth rate were significantly ($P<0.05$) higher in MP having 40% CP in the diet as compared to LP and HP. The FCR was also significantly ($P<0.05$) lower in MP having 40% protein in the diet when compared with LP and HP. However, the protein efficiency ratio was similar ($P>0.05$) among the three treatment groups. Further, it was also revealed that the activities of enzymes in the digestive tract namely, α-amylase, lipase and pepsin were significantly ($P<0.05$) higher in MP diet having 40% crude protein. The present experiment, thus. revealed that 40% CP was sufficient for the optimum growth and survival of *O. bimaculatus* larvae.

Keywords: Amylase, Growth, Lipase, *Ompok*, Pepsin

INTRODUCTION

Ompok bimaculatus (Bloch, 1794) popularly known as the 'butter catfish' are found in lakes, rivers, canals, beels, swamps, floodplains and ponds, etc. and are distributed in India, Bangladesh, Borneo, Java, Sri Lanka, Myanmar, Pakistan, Thailand, Cambodia and Vietnam, etc. (Jayaram, 1977). It is a non-air breathing fish belonging

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to the family of *Siluridae* with the highest growth amongst the three species under the genus Ompok namely *O. paba, O. Pabo* and *O. bimaculatus*. These fish are commonly known as 'pabda'. Recently, the fish is gaining importance as a promising aquaculture candidate owing to its good taste, balanced nutrient profile, soft bony structure and high market value especially in the entire East and North East India (Banik *et al.,* 2012). Banik *et al.* (2011) reported that the butter catfish is considered as an important candidate for the diversification of freshwater Indian aquaculture. The wild population of *O. bimaculatus* has sharply declined due to anthropogenic activities, ecological changes and indiscriminate fishing. Thus, the species has been categorized under near-threatened category by the International Union for the Conservation of Nature and Natural Resources (IUCN) Red List and faces a risk of extinction in nature (Chakrabarti *et al.*, 2009; Lakra *et al.,* 2010; IUCN Red List, 2014). Considering high demand, price and IUCN status, the species has been prioritized for diversification of aquaculture as well as for conservation and restocking programs (Debnath *et al.*, 2016). This fish has a high commercial value and preferred in Eastern and North-Eastern India. *O. bimaculatus* was also declared as the State Fish of Tripura in the year 2007. The fish is endowed with all essential nutrients and rich in vitamin A and PUFA (Paul *et al.,* 2018). Hence, it is of utmost importance to save the fish from extinction through the development of suitable cultural technique.

Nutritional quality of starter diets and first feeding regimes greatly influenced the success of larval rearing. Santiago *et al.* (1991) reported that fry production and survival can be enhanced by feeding the broodstock with supplemental diets. The ability of fish to metabolize a diet depends on the availability of appropriate digestive enzymes, which mediate specific degradation pathways modulating both the physical and chemical nature of foods (Deng *et al.*, 2010). Fish digestive enzymes emphasizing the mechanisms and best use of nutrients are of unquestionable importance as a background for the optimization of fish feeding procedures (Suarez *et al.*, 1995). The analysis of digestive enzymes provides information on fish nutritional physiology and on their ability to take advantage of the different nutritional fractions of the feed (Odedeyi and Fagbenro, 2010). Thus knowledge of digestive enzymes of fish has important practical implications for their nutrition. The present work was aimed at the development of larval feed with appropriate protein content for *O. bimaculatus* so that the mortality will be reduced and more stocking material would be available for successful grow out of *O. bimaculatus*.

MATERIALS AND METHODS

Experimental diets

Fish meal, groundnut cake, soybean meal, wheat flour, vitamin-mineral mix and oil were used as feed ingredients in different proportions for preparation of three experimental feeds (Table 1). The finely powdered ingredients were weighed separately and after thorough mixing with water, fortified with vitamin and mineral mixtures. Three different formulated feeds were prepared to have different levels of protein

viz., low protein (LP; 35% CP), medium protein (MP; 40% CP) and high protein (HP; 45% CP). The powdered ingredients including vitamin and mineral mixture were thoroughly mixed and stored in –20°C.

Table 1. Ingredients and proximate composition of experimental diets

Particulars	Diets†		
	LP	MP	HP
Ingredient composition (%)			
Fish meal	44	53	65
Groundnut cake	15	15	15
Soyabean meal	10	10	5
Wheat flour	19	10	03
Carboxy methyl cellulose	2	2	2
Vitamin-mineral mixture#	5	5	5
Veg oil	5	5	5
Proximate composition (% DM basis)			
Dry Matter	93.02±0.93	92.39±0.22	92.34±1.33
Crude Protein	35.33±2.25	40.69±0.55	45.23±0.17
Crude lipid	9.11±0.47	9.49±0.31	9.61±0.31
Total ash	15.40±0.39	16.35±0.09	16.37±0.39

†Diets with low (35% CP; LP), medium (40% CP; MP) and high (45% CP; HP) protein levels.

‡Vitamin-mineral premix contains: Vitamin A (as acetate) 5000 IU, cholecalciferol 1000 IU, thiamine monocitrate 10 mg, riboflavin 10 mg, pyridoxine hydrochloride 5 mg, cyanocobalamine 15 μg, nicotinamide 75 mg, calcium pantothenate 10 mg, ascorbic acid 150 mg, a-tocopheryl acetate 25 mg, biotin 5 mg, folic acid 5 mg, menadione 100 mg, choline chloride 50 mg, PABA 5 mg, myoinositol 10 mg, calcium lactate 0.125 mg, magnesium oxide 60 mg, dried ferrous sulphate 30 mg, manganese sulphate 2 mg, copper sulphate 2 mg, zinc sulphate 2 mg, sodium molybdate 0.25 mg, sodium borate 0.80 mg, potassium iodate 20 mg, dicalcium phosphate 0.10g, cobalt chloride 20 mg (Paul *et al.*, 1997)

Fish maintenance and feeding

The growth experiment was carried out in ICAR-Central Institute of Freshwater Aquaculture. The duration of the study was 22 d. The larvae of *O. bimaculatus* (weight 0.11±0.01 g; length 20.49±0.70 mm) were stocked in glass jar tanks of 30 m^3 capacity with 30 larvae in each tank. Each dietary treatment consisted of three replicates of uniform-sized glass tanks.

Water quality parameters such as temperature, pH and dissolved oxygen were recorded at fortnightly intervals as per the method of APHA (2005). The feed was offered *ad libitum* during the morning (9.00 am.) and evening (4.00 pm). After the experiment, individual BW of fish was recorded. The net weight gain (NWG), protein efficiency ratio (PER), feed conversion ratio (FCR), specific growth rate (SGR) and per cent survivability was measured as per Castell and Tiews (1980). The proximate composition of feed was analyzed as per AOAC (1990).

Enzyme analysis

The fish were starved for 24 h before dissection to clean the digestive tract. A 10% homogenate of the digestive tract was prepared with chilled phosphate buffer saline (PBS, pH 7.4). The homogenates were centrifuged at 12,500 $\times g$ for 30 min at 4°C and supernatants were used as enzyme extracts. Metabolic enzymes were prepared by 10% homogenates fish tissue in 0.25 M ice-cold sucrose solution (pH 7.4). The α-amylase activity was estimated as per Bernfeld (1955). The total protease activity was measured as per Walter (1984). The activity of lipase was measured as per Bier (1955). Pepsin activity was measured as per Anson (1938). The activities of trypsin and chymotrypsin were measured as per Erlanger (1961).

The activities of alanine transaminase (ALT) and aspartate transaminase (AST) were assayed as per Reitman and Frankel (1957). Total protein of enzyme supernatant was assayed as per Lowry *et al.* (1951).

Quantification of DNA-RNA in fish tissue

Larval tissues (100 mg) were extracted in 1% sarcosine (sodium N-lauroylsarcosine) in Tris-EDTA buffer (pH 8.0). After centrifugation, the supernatant of homogenate samples was washed with phenol-chloroform-isoamyl alcohol (49.5:49.5:1; v/v) followed by further washing with isoamyl alcohol-chloroform (1:24; v/v) for purification. Purified supernatants were treated with nucleases. The DNA and RNA contents of the tissues were estimated according to the procedures of Burton (1956) and Marham (1955), respectively.

Statistical analysis

All the data generated from the experiment were statistically assayed by one-way analysis of variance (ANOVA) as per Snedecor and Cochran (1994). The differences between the means of treatments were examined using the least significance difference (LSD).

RESULTS

The feed formulations and proximate composition of different feeds are shown in Table 1. The protein content of the three feeds was 35.33 ± 2.55, 40.69 ± 0.55 and 45.23 ± 0.17 per cent, respectively, in the LP, MP and HP groups. Because of the graded increase in protein levels, the total ash contents of diets increased linearly from 15.40 ± 0.39 to 16.37 ± 0.39, which could be attributed to the presence of higher levels of fish meal as the major feed ingredient. Water quality parameters during the study were: temperature, 28-30°C, pH 7.4-7.8, dissolved oxygen 5.0-5.8 mg/L and total alkalinity 235-240 mg $CaCO_3$/L. All the water quality parameters were also within the acceptable range as reported earlier (Paul *et al.,* 2000). Dissolved oxygen plays a vital role in the rearing of larvae because larvae require an optimum level of oxygen for sustaining their physiological condition. Paul and Giri (2016) reported that suitable temperature required for optimum growth of catfish is 30°C.

Table 2 represents the growth performance data of *Ompok* larvae fed with different levels of protein. The feed was offered twice in a day as per the findings of Paul *et al.* (2014) who studied that a feeding frequency of up to two times is optimum for catfish *O. pabda*. Initially, the larvae were fed with natural food which was followed by feeding of the formulated feed. The data on the initial BW, net weight gain, specific growth rate, feed conversion ratio, protein efficiency ratio and survivability are shown in Table 2. Butter catfish larvae fed diet MP containing 40% CP had the highest weight gain, which was significantly ($P<0.01$) different from the other two dietary protein levels. The net weight gain was significantly ($P<0.01$) higher in MP. The SGR was significantly ($P<0.01$) higher in MP in comparison to LP and HP groups. The values of final weight, NWG and SGR were significantly ($P<0.05$) higher in MP compared to those of LP and HP groups. The FCR value was significantly ($P>0.05$) lower for fish fed diet MP vis-a-vis other groups. Lowest FCR in MP indicated that a lower amount of feed was needed to produce one unit of fish biomass; lower the FCR, better is the efficiency of the feed utilization. The PER, RNA, DNA, RNA/DNA ratio and survival (%) did not differ significantly among the dietary treatments.

Amylase activity of fish fed the LP differed significantly ($P<0.05$) from those on the MP and HP diet (Table 3). Lipase and pepsin activities were significantly ($P<0.05$) higher on MP diet which was also accompanied by significantly ($P<0.05$) lower trypsin and chymotrypsin activities. The ALT activity changed positively according to the increase in CP content of the diets and, therefore, was significantly ($P<0.05$) higher on HP diet. The AST activity, on the other hand, was significantly ($P<0.05$) lower in MP.

Table 2. Growth of *O. bimaulatus* larvae fed with different levels of dietary protein.

Particulars	Dietary groups[†]		
	LP	MP	HP
Initial weight (g)	0.11±0.004	0.106 ±0.008	0.106±0.008
Final weight (g)	0.34[a]±0.06	0.91[b]±0.15	0.36[a]±0.07
NWG (g/22d)	0.23[a]±0.05	0.81[b]±0.15	0.26[a]±0.06
SGR (%/d)	4.54[a]±0.60	7.97[b]±0.76	5.30[a]±0.53
FCR	3.62[b]±0.51	1.93[a]±0.43	3.68[b]±0.35
PER	0.82±0.13	1.42±0.33	0.62±0.05
Survivability	73.50±2.02	71.00±1.00	59.00±4.70
DNA (μg/mg)	30.59±0.30	34.31±0.43	31.04±0.54
RNA (μg/mg)	34.86±0.41	45.16±0.36	35.65±0.31
RNA/DNA	1.14±0.07	1.32±0.04	1.15±0.04

[†]Diets with low (35% CP; LP), medium (40% CP; MP) and high (45% CP; HP) protein levels.

[ab]Means with different superscripts in a row differ significantly ($P<0.01$).

Table 3. Enzyme contents of digestive tract of *O. bimaculatus* larvae fed with different levels of dietary protein

Particulars	Initial	Dietary groups[†]		
		LP	MP	HP
Amylase[‡]	17.4[a]±0.33	23.87[b]±0.17	25.36[c]±0.34	25.46[c]±0.47
Total protease[§]	1.76[d]±0.03	0.67[a]±0.02	0.81[b]±0.01	0.73[c]±0.01
Lipase[#]	0.40[a]±0.01	0.57[b]±0.02	0.69[d]±0.03	0.61[c]±0.02
Pepsin[¥]	0.38[a] ±0.01	2.53[b]±0.02	2.67[c]±0.01	2.49[b]±0.01
Trypsin[¶]	0.89[c]±0.02	0.20[a]±0.01	0.18[a]±0.02	0.26[b]±0.03
Chymotrypsin[¶]	0.72[c]±0.02	0.29[b]±0.02	0.19[a]±0.01	0.28[b]±0.03
Alanine transaminase[•]	3.14[a]±0.03	3.44[b]±0.02	3.51[c]±0.02	4.25[d]±0.02
Aspartate transaminase[£]	3.24[a]±0.02	4.61[c]±0.03	4.38[b]±0.01	5.12[d]±0.02

[†]Diets with low (35% CP; LP), medium (40% CP; MP) and high (45% CP; HP) protein levels.

[‡]mg maltose liberated/mg protein/h.

[§]μg of tyrosine liberated/mg protein/min.

[#]μM of fatty acid liberated/mg protein/min.

[¶]mmol of 4-nitroaniline liberated/mg protein/min.

[•]μM of pyruvate formed/mg protein/min.

[£]μM of oxaloacetate formed/mg protein/min.

[abc]Means with different superscripts in a row differ significantly ($P<0.05$).

DISCUSSION

The optimum dietary protein requirement for *O. bimaculatus* larvae as observed in the present study appears to be 40% CP, promoting the highest weight gain. The study suggests that 40% CP in a diet would support better growth and survivability of the butter catfish larvae during early development. Our results are in agreement with some of the previous reports depicting 40% protein level optimal for growth and efficient feed utilization in juvenile red- and white-coloured fancy carp *Cyprinus carpio* var. Koi (Choi *et al.*, 2015). However, the finding of our experiment on protein requirement was somewhat higher than the earlier CP levels documented for the maximum growth of other catfishes viz., 35% CP level in the diet of *Horabargus brachysoma* fingerlings (Giri *et al.*, 2011); 30% CP for *O. bimaculatus* (Debnath *et al.,* 2018); 35% CP level in the diet of *O. bimaculatus* fingerlings (Biswas *et al.,* 2019) and 33.2% CP level in the diet of *O. pabda* fry (Paul *et al.,* 2012). On the contrary, still higher levels of CP requirements have also been suggested, e.g., 41-43% CP for grass carp fry (Dabrowski, 1977) and 47% CP for *Catla catla* fry (Singh *et al.*, 1988). Giri *et al.* (2011) reported that the total protein requirement for optimum growth in catfish varies from 25 to 50% of the diet. Protein requirement for younger catfish is higher than the adult ones (Paul and Giri, 2016). However, our study of 40% CP for *O. bimaculatus* was similar to the protein requirement of catfish as reported earlier (BIS, 2014). A reduced growth was recorded at high-protein diets i.e., at 45% CP in the diet. Many authors reported similar findings (Ye *et al.,* 2016).

In the present study, digestive enzymes such as amylase, protease, lipase, pepsin, trypsin, chymotrypsin were estimated in Ompok and the value was similar to the earlier observation by Parra *et al.* (2007). There were no significant ($P > 0.05$) changes observed in α-amylase activity in MP and HP groups but pepsin activity was significantly higher with the feeding of the MP diet. Trypsin and chymotrypsin activities were higher in LP and MP groups suggesting that MP group fishes were more carnivores in nature. Lemieux *et al.* (1999) observed that trypsin is a proteolytic enzyme, it also takes part in other pancreatic zymogens and also limit the growth rate of *Gadus morhua*. Different parts of the digestive tract such as the pancreas, pyloric cecum and liver of different teleosts have shown different activities of amylase (Deng *et al.,* 2010). Sabapathy and Teo (1993) reported a lower pepsin activity in herbivorous fish. Digestive enzymes might contribute towards efficient digestion of the dietary components, which could be reflected through the growth of the fishes. Thus, increased growth in fish associated with enhanced activities of the digestive enzymes might be indicative of improved nutrient utilization in fish as reported earlier (Mandal and Ghosh, 2018). The activities ALT and AST are indicators of liver function with the high activities being the indicator of poor liver function and the present study also revealed normal levels of ALT and AST.

DNA is a prerequisite for RNA synthesis, which in turn is a requirement for protein synthesis (Mitra and Mukhopadhyay, 2002). RNA/DNA ratio is the indicator of the growth of fish (Dey *et al.,* 2018) and also considered as a reliable indicator of protein synthesis (Gangadhar *et al.*, 1997). However, no variation was observed in the above parameters in the present study.

Overall, the present experiment revealed that 40% crude protein is sufficient for the optimum growth and survival of *O. bimaculatus* larvae.

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PENSOFT

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Effect of dietary lipid levels on growth, body composition, and enzyme activities of larvae of butter catfish, *Ompok bimaculatus* (Actinopterygii: Siluriformes: Siluridae)

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Abstract

The Indian butter catfish, *Ompok bimaculatus* (Bloch, 1794), is a high-value catfish that has gained immense consumer preference in South-East Asia. However, information on the nutritional requirements of this species is scanty. Hence, an experiment was conducted to evaluate the effects of varying dietary lipid levels on growth, body composition, and activities of digestive and metabolic enzymes in larvae. Three isonitrogenous (40% crude protein) diets were formulated by supplementing fish and vegetable oil (1:1) at 4.5% (D1), 7% (D2), and 9.5% (D3) levels (containing crude lipid 5.7%, 8.0%, and 10.45%, respectively in diets D1–D3) to a fish meal- and oilcake-based formulated diet. Experimental diets were fed to butter catfish larvae (0.15 ± 0.01 g) in triplicate groups for a period of 42 days. Proximate compositions of the experimental diets, as well as fish carcass, were analyzed using standard procedures (AOAC 2005). Digestive and metabolic enzyme activities were analyzed at the completion of the experiment by standard methodology. Butter catfish larvae fed the diet D2 (8% crude lipid) resulted in the best performance in terms of weight gain (final weight 1.40 ± 0.07 g), net weight gain (1.31 ± 0.06 g), specific growth rate (5.50 ± 0.05% · day^{-1}), and protein efficiency ratio (2.39 ± 0.17). The highest lipid deposition (2.90 ± 0.12%) in the carcass was also recorded in fish reared on diet D2. The final weight, net weight gain, protein efficiency ratio, and specific growth rate were significantly ($P < 0.05$) higher in D2 having 8% lipid. Moisture and lipid contents of the whole body were significantly ($P < 0.05$) higher in larvae fed diet D2. Amylase activity in fish significantly ($P < 0.05$) decreased with increasing dietary lipid levels. The maximum alkaline protease, pepsin, and lipase activities were noticed in the larvae fed diet D2. Progressive decrease in liver glucose-6-phosphate dehydrogenase activities and significant increase ($P < 0.05$) in the activities of neoglucogenic enzymes (glucose-6-phosphatase and fructose-1,6-bis phosphatase) were noticed with an increase in dietary lipid levels. Significantly lower ($P < 0.05$) activities of LDH, ALT, and AST were recorded in the group fed diet D2. Results of the study indicated that 8% crude lipid in the diet could assure optimum growth and survival of butter catfish larvae during early development. An appraisal on growth, body composition, and digestive as well as metabolic function in the butter catfish larvae recorded in the study might provide some important information to consider application of formulated diets for the larviculture of *Ompok bimaculatus*.

Keywords

lipid, larvae, *Ompok bimaculatus*, growth, lipase, metabolic enzyme

Introduction

The Indian butter catfish, *Ompok bimaculatus* (Bloch, 1794), is indigenous to the South East Asian countries (Giri et al. 2019) and has recently gained immense importance because of its good taste, high lipoprotein, low fat, soft bony structure, and competitive prices (Rawat et al. 2018). It is an excellent source of ω-3 and ω-6 fatty acids, vitamins, minerals, protein, and fat (Paul et al. 2018). The wild population of *O. bimaculatus* has sharply declined due to ecological changes and indiscriminate fishing. Thus, the species has been categorized under the "near threatened" category by the IUCN Red List and faces a risk of extinction in nature (Lakra et al. 2010; IUCN 2014). Considering high demand, price, and IUCN status, the species has been prioritized for diversification of aquaculture as well as for conservation and restocking programs (Debnath et al. 2016). Although its aquaculture potential has been realized, the species has not yet received adequate attention due to insufficient information on larval rearing and culture technology.

The successful culture of any fish species largely depends on the accessibility of nutritionally balanced practical diets. Although species of the genus *Ompok* have been generally recognized as carnivorous to omnivorous, reports on nutritional requirements of the species are scanty (Chakrabarti et al. 2012). Therefore, no commercially formulated diet has yet been available for this species. Since captive breeding of *O. bimaculatus* has been established (Raizada et al. 2013), it is necessary to develop larval diets to ensure growth and survivability of the species during the stages of early development, which is essential for reliable and regular supply of the fish for widespread commercial production. A previous study conducted on *O. bimaculatus* larvae determined a required level of 40% crude protein in the diets for this species (Paul et al. 2020).

However, dietary protein requirements are known to be affected by the amount of non-protein energy sources in the diet (NRC 2011). When non-protein energy is insufficient, a part of dietary protein may be catabolized to supply energy affecting the growth of the organism. Therefore, supplementation of energy-yielding nutrients, mainly lipid has been suggested as a strategy to improve protein utilization in fish (Sankian et al. 2017). Supplementation of lipid rather than carbohydrate as a source of non-protein energy is generally more effective for enhancing dietary energy level as lipid is an energy-dense nutrient that is readily metabolized by fish, particularly the carnivorous one (NRC 1993). Further, all-round development and well being of fish are known to be greatly influenced by dietary lipids that are not only important as an energy source but also for the supply of essential fatty acids as well as carrier of fat-soluble vitamins (Glencross 2009). Moreover, the incorporation of a proper amount of lipid seems to be important as lipid level determines the palatability of the diet (Boonyaratpalin 1991). Therefore, the presently reported study was conducted to determine the effects of dietary lipid levels on the growth, survivability, body composition, and activities of digestive as well as metabolic enzymes in butter catfish larvae.

Vegetable and fish oils are rich in different fatty acids, which were recognized as effective for diverse freshwater fish species (Paul et al. 2011). Hence, in the presently reported study, a practical diet was fortified with a combination of vegetable and fish oils (1:1) to have the desired lipid levels in the diets. The nutrient utilization and digestive physiology in fish are indicated by the activity of digestive and metabolic enzymes that ultimately affect the growth and development of fish (Chen and Zhang 2004; Wei et al. 2010). Therefore, the presently reported study considered an appraisal of digestive enzymes and some key metabolic enzymes to evaluate the effects of formulated diets with varying lipid levels. The results of the study could be helpful to provide some important information for feed formulation of *O. bimaculatus* larvae.

Materials and methods

Experimental diets

Three experimental diets were formulated by incorporating equal proportions of fish oil (cod liver oil) and vegetable oil (sunflower oil) (1:1) at 4.5% (D1), 7% (D2), and 9.5% (D3) levels to a basal mixture of fish meal (**FM**), soybean meal (**SBM**), and groundnut oil cake (**GNOC**). After analysis of lipid content of the feed, it was noticed to contain 5.7%, 8.0%, and 10.5% crude lipids, respectively. The amount of lipid sources used was adjusted at the expense of wheat flour. A vitamin–mineral premix was added to the diets as per Paul et al. (1997). Dietary ingredients were finely powdered, sieved to obtain uniform particle size (<400 μm in diameter), mixed thoroughly, and fortified with a calculated amount of vitamin-mineral premix and oil sources. The prepared powered feeds were stored in a freezer at –20°C until use.

Experimental fish and feeding trial

The experiment was conducted at the Regional Research Centre of ICAR-Central Institute of Freshwater Aquaculture, Rahara, Kolkata. Farm-raised larvae of the butter catfish were collected from ICAR-Central Institute of Freshwater Aquaculture, Kalyani Field Station, and acclimatized to the laboratory condition for one week in fiber-reinforced plastic (**FRP**) tanks with the provision of continuous aeration. During this period the larvae were fed a basal formulated diet and natural food (mixed zooplankton and chopped tubifex). After acclimatization, the larvae (mean weight 0.15 ± 0.02 g; length 22.65 ± 1.70 mm; 14 days old) were randomly distributed in 9 FRP tanks at a stocking density of 50 fish per tank. Thus, there were three replicates for each dietary group. The experiment was conducted in 150 L FRP tanks, each

containing 50 L of water, with continuous aeration and water exchange at every 5 days interval. The powdered feed mixtures were made to soft dough with distilled water and the fish were fed ad libitum to apparent satiation twice daily, at 10.00 and 16.00 h, for 42 days. Feed consumption and mortality in each tank were recorded separately, and the survival rate was calculated. During the experimental period, water quality parameters were monitored on weekly basis following the standard methods of the American Public Health Association (APHA 2005) and noticed to vary within the acceptable range (temperature 28–30°C; pH 6.8–7.7, dissolved oxygen 6.8–7.4 mg · L^{-1}, total alkalinity 230–240 mg · L^{-1}, ammonia 0.26–0.64 mg · L^{-1}, nitrite 0.001–0.003 mg · L^{-1}, nitrate 0.002–0.074 mg · L^{-1}).

Proximate composition of experimental diets and fish carcass

Proximate compositions of the experimental diets, as well as fish carcass, were analyzed using standard procedures portrayed by the Association of Official Analytical Chemists (AOAC 2005). Moisture content was determined by oven drying (initially at 100 ± 5°C for 30 min, thereafter at 60°C); crude protein (Nitrogen × 6.25), by a semi-automatic digestion system together with micro Kjeldahl distillation Unit (KelPlus-Elite Ex, Pelican Equipments, Chennai, India); crude lipid (ether extract; petroleum ether, 60–80°C), by a Soxhlet apparatus (Socsplus, Pelican Equipments, Chennai, India); and ash, by combustion at 550°C in a muffle furnace. Nitrogen-free extract (**NFE**) was calculated by subtracting the sum of values for crude protein, crude lipid, ash, crude fiber, and moisture from 100 (Maynard et al. 1979). The gross energy of the diets was measured with a bomb calorimeter (Lab-X, Kolkata, India). Proximate analyses of the fish carcass (whole body) were done on wet weight basis.

Growth parameters

At the end of the feeding trial fish were collected from each tank, weighed, and analyzed for calculating the growth parameters. Net weight gain [%], specific growth rate (**SGR** [% · day^{-1}]), feed conversion ratio (**FCR**), protein efficiency ratio (**PER**), apparent net protein utilization (**ANPU**), and survivability [%] were calculated following standard methods described by Castell and Tiews (1980). The daily growth coefficient (**DGC**) was calculated as per Cowey (1992).

Estimation of digestive enzymes

Digestive enzymes (amylase, alkaline protease, pepsin, and lipase) of fish from each experimental set were estimated at the termination of the experiment. For each replicate, digestive tracts of 20 experimental fish from each tank were dissected out, washed thoroughly with chilled distilled water, taken on an ice-cooled Petri plate, and weighed. A 10% homogenate with chilled 0.1 (M) phosphate buffer (pH 7) was prepared and centrifuged at 10 000 rpm (10 min, 4°C). The ensuing supernatant was used as the enzyme extract to appraise the activities of the digestive enzymes. The protein content of the extract was estimated after Lowry et al. (1951) using bovine serum albumin (**BSA**) as standard. Amylase (α-amylase) activity was determined using dinitro salicylic acid (**DNSA**) reagent following Bernfeld (1955). Amylase activity (unit) was expressed as mg maltose liberated mg^{-1} protein h^{-1}. Alkaline protease activity was estimated using Hammerstein casein substrate according to Walter (1984). One unit of enzyme activity was defined as µg of tyrosine liberated mg^{-1} protein h^{-1}. Pepsin activity was resolved after Anson (1938) with minor modifications, using 2% hemoglobin as a substrate. The specific activity was expressed as µg of tyrosine liberated mg^{-1} protein min^{-1}. Lipase activity was determined with the olive oil substrate following Bier (1955). Lipase activity was expressed as µ mole of fatty acid liberated mg^{-1} protein h^{-1}.

Estimation of metabolic enzymes

Following the collection of the digestive tracts, hepatic tissues were removed, collected separately and a 10% homogenate was made in sucrose solution (0.25 M, pH 7.4). Remains of the cell along with nuclei were removed by centrifugation (1000 g, 30 min, 4°C), and the supernatants were further centrifuged (10 000 g, 15 min, 4°C) to get the mitochondrial pellets (Biswas et al. 2006). The resultant supernatant was again centrifuged (12 500 g, 1 h, 4°C) and the cytosolic fraction thus obtained was used as the crude enzyme extract for other metabolic enzyme assays. The mitochondrial pellet was treated with triton X-100 (0.1%), washed with PBS (0.1 M, pH 7.4) and the supernatant was used as crude extracts for mitochondrial metabolic enzyme assays. The tissue fractions were kept at –20°C until use. The soluble protein content of the crude enzyme extracts was determined following Lowry et al. (1951).

Hexokinase (HK) activity was measured by the reduction of NADP to produce NADPH according to Tranulis et al. (1996). Enzyme activity was expressed as µM of NADPH formed mg^{-1} protein h^{-1}. Pyruvate kinase (PK) activity was assayed after Driedzic and Almeida-Val (1996) with minor modification. Enzyme activity was presented as µmole of pyruvate converted to NADH mg^{-1} protein min^{-1}. Glucose-6-phosphatase (G6P) and fructose-1, 6-bis phosphatase (FBP) activities were measured by estimating the amount of phosphorus released from the substrates, glucose-6-phosphate (Marjorie 1964) and fructose-di-phosphate (Freeland and Harper 1959), respectively. Release of phosphorus by both the enzymes was estimated after Fiske and Subbarow (1925), and activities were expressed as µg of phosphorus released mg^{-1} protein min^{-1}.

Glucose-6-phosphate dehydrogenase (G6PD) activity was analyzed using glucose-6-phosphate (substrate) and NADP following Kornberg and Horecker (1955). Enzyme activity was expressed as µM of NADPH formed mg^{-1} protein h^{-1}. NADP-malic enzyme (NADP-ME) activity was determined using L-malic acid as substrate (Hsu and Lardy 1967, modified by Murphy and Walker 1974). Enzyme activity was presented as µM of NADPH formed mg^{-1} protein h^{-1}. Lipid peroxidation (LPO) activity was measured according to Okhawa et al. (1979). Enzyme activity was expressed as thiobarbituric acid reactive substance (TBARS) formed mg^{-1} protein min^{-1}.

Alanine transaminase (ALT) activity was determined using α-ketoglutarate and DL-Alanine as substrates (Reitman and Frankel 1957). ALT activity was expressed as µM of pyruvate formed mg^{-1} protein min^{-1}. Likewise, Aspartate transaminase (AST) activity was measured with the substrate solution containing α-ketoglutarate and DL-aspartic acid (Reitman and Frankel 1957). AST activity was expressed as µM of oxaloacetate formed mg^{-1} protein min^{-1}. Glutamate dehydrogenase (GDH) activity of the crude mitochondrial enzyme extract was measured using sodium glutamate and tetrazolium salt (Lee and Lardy 1965). Enzyme activity was expressed as µM of formazan formed mg^{-1} protein h^{-1}.

Statistical analysis

The data were analyzed by one-way analysis of variance (ANOVA) as per Snedecor and Cochran (1994) to calculate the effect of dietary lipid level on growth performance and activities of the digestive as well as metabolic enzyme of fish and the least significance (LSD) was used for comparison of the mean values. Data are presented as treatment mean ± standard error of the mean (SE).

Results

The ingredients and proximate composition of the experimental diets are presented in Table 1. Experimental diets were isoproteinous (crude protein ≈ 40%). However, supplementation of fish oil and vegetable oil has led to varying crude lipid levels in the diets (D1–D3) as 5.7%, 8.0%, and 10.45%, respectively. All experimental diets were readily accepted by the *O. bimaculatus* larvae.

The growth performance of *O. bimaculatus* larvae fed varying levels of dietary lipid for 42 days is depicted in Table 2. The growth of the larvae was significantly ($P < 0.05$) affected by the dietary crude lipid levels. The net weight gain (%) of the larvae showed an increasing trend with increasing levels of the dietary lipid up to 8% and thereafter decreased. Butter catfish larvae fed diet D2 containing 8% crude lipid had the highest weight gain, which was significantly different ($P < 0.05$) from other dietary lipid levels. The highest values of PER and ANPU were recorded in fish fed diet D2. The value of FCR was the lowest for fish fed diet D2, however, didn't differ significantly between the diets D1 and D3. Butter catfish larvae in all treatment groups survived well (more than 80%) during the experimental period, and there were no significant differences among the groups.

Proximate carcass compositions of the butter catfish larvae fed experimental diets are presented in Table 3.

Table 1. Feed formulation and proximate composition (% DM Basis) of the experimental diets.

Parameter	Experimental diet		
	D1	D2	D3
Fish meal	53.00	53.0	53.00
Groundnut oil cake	15.00	15.0	15.00
Soybean meal	10.00	10.0	10.00
Wheat flour	10.50	8.0	5.50
Carboxy methyl cellulose	2.00	2.0	2.00
Fish:Veg. oil (1:1)	4.50	7.0	9.50
Vitamin-mineral mix*	5.00	5.0	5.00
Proximate composition [% DM basis]			
Dry matter	92.85 ± 0.06	92.37 ± 0.23	92.06 ± 0.05
Crude protein	40.46 ± 0.06	40.18 ± 0.49	40.61 ± 0.83
Crude lipid	5.70 ± 0.20	8.00 ± 0.25	10.45 ± 0.45
Total Ash	14.40 ± 0.30	15.40 ± 0.20	16.50 ± 0.30
Nitrogen free extracts	29.50 ± 0.37	27.61 ± 2.05	21.80 ± 0.28
Crude protein:crude fat	7:1	5:1	4:1
Energy [kJ g^{-1}]	13.85 ± 0.02	14.09 ± 0.08	14.39 ± 0.08

*Vitamin-mineral premix contains: Vitamin A (as acetate) 5000 I.U., cholecalciferol 1000 I.U., thiamine monocitrate 10 mg, riboflavin 10 mg, pyridoxine hydrochloride 5 mg, cyanocobalamine 15 µg, nicotinamide 75 mg, calcium pantothenate 10 mg, ascorbic acid 150 mg, α-tocopheryl acetate 25 mg, biotin 5 mg, folic acid 5 mg, menadione 100 mg, choline chloride 50 mg, PABA 5 mg, myoinositol 10 mg, calcium lactate 0.125, magnesium oxide 60 mg, dried ferrous sulphate 30 mg, manganese sulphate 2 mg, copper sulphate 2 mg, zinc sulphate 2 mg, sodium molybdate 0.25 mg, sodium bortate 0.80 mg, potassium iodate 20 mg, bicalcium phosphate 0.10 g, cobalt chloride 20 mg (Paul et al. 1997).

Table 2. Growth performance in *Ompok bimaculatus* larvae fed with graded levels of lipid.

Parameter	Experimental diet		
	D1	D2	D3
Initial weight [g]	0.15 ± 0.02	0.14 ± 0.01	0.15 ± 0.01
Final weight [g]	1.10 ± 0.12^{a}	1.40 ± 0.07^{b}	1.06 ± 0.03^{a}
Net weight gain	0.95 ± 0.12^{a}	1.31 ± 0.06^{b}	0.91 ± 0.03^{a}
Specific growth rate [%]	4.73 ± 0.35^{a}	5.50 ± 0.05^{b}	4.66 ± 0.22^{a}
Daily growth coefficient	0.73 ± 0.02^{a}	1.003 ± 0.05^{b}	0.76 ± 0.09^{a}
Survivability	83.85 ± 6.15	83.85 ± 6.15	79.55 ± 5.46
Number of dead fish	25	25	31
Feed conversion ratio	1.86 ± 0.10^{b}	1.39 ± 0.05^{a}	1.74 ± 0.07^{b}
Protein efficiency ratio	1.31 ± 0.09^{a}	2.39 ± 0.17^{b}	1.30 ± 0.08^{a}
Apparent net protein utilization	16.09 ± 0.92^{a}	23.19 ± 1.10^{b}	17.18 ± 0.82^{a}

Data are presented as mean ± standard error of the mean; mean values with different superscripts in a row differ significantly ($P < 0.05$).

Table 3. Carcass composition [g · 100 g^{-1}] of *O. bimaculatus* larvae fed different levels of lipid.

Constituent [g · 100 g^{-1}]	Experimental diet		
	D1	D2	D3
Moisture	79.37 ± 0.09^{a}	80.93 ± 0.22^{b}	79.80 ± 0.17^{a}
Crude protein	13.93 ± 0.09	14.40 ± 0.21	14.03 ± 0.08
Crude lipid	2.50 ± 0.06^{a}	2.90 ± 0.12^{b}	2.77 ± 0.07^{b}
Ash	1.70 ± 0.06	1.97 ± 0.09	1.80 ± 0.06

Data are presented as mean ± standard error of the mean; mean values with different superscripts in a row differ significantly ($P < 0.05$).

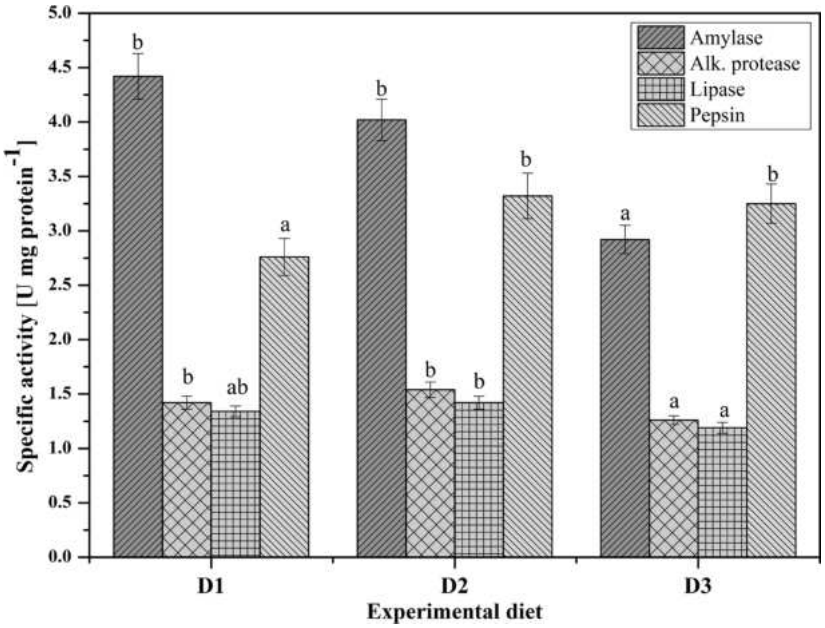

Figure 1. Specific activity of digestive enzymes of *Ompok bimaculatus* larvae fed varying levels of crude lipid. Mean values (± SE) with no common superscript letters are significantly different ($P < 0.05$).

Moisture and lipid contents of the whole body were significantly ($P < 0.05$) affected by the dietary lipid levels, being the highest in larvae fed diet D2 containing 8% crude lipid. However, varying dietary lipid had no significant effect on crude protein and ash contents of *O. bimaculatus* larvae at the tested lipid levels.

Digestive enzymes i.e., amylase, alkaline protease, lipase, and pepsin of the butter catfish larvae fed diets with varied lipid levels are given in Fig. 1. Overall, digestive enzymes were significantly ($P < 0.05$) affected by the dietary lipid levels. Amylase activity in *O. bimaculatus* larvae significantly ($P < 0.05$) decreased with increasing dietary lipid levels. The highest alkaline protease and lipase activities were noticed in the butter catfish larvae fed diet D2 consisting of 8% crude lipid, while it was not significantly ($P < 0.05$) different from the group fed diet D1. The highest pepsin activity was also documented in the fish fed diet D2, although it did not differ significantly from the larvae that received diet D3 with 10.45% dietary lipid.

Activities of the hepatic enzymes involved in the intermediary metabolism of carbohydrate, protein, and lipid are depicted in Table 4. Varying dietary lipid levels led to significant differences ($P < 0.05$) in the activities of PK, G6P, FBP, G6PD, LDH, ALT, and AST in *O. bimaculatus* larvae. While no significant differences were detected in the activities of HK, NADP-ME, GDH, and LPO, the activities of PK and two major neoglucogenic enzymes, G6P and FBP, significantly increased ($P < 0.05$) with the increase in the dietary lipid levels. The activity of G6PD, a key enzyme of lipogenesis, revealed a significant decrease ($P < 0.05$) with an increase in the dietary lipid level from 5.7% (D1) to 8% (D2). Further, significantly lower ($P < 0.05$) activities of LDH, ALT, and AST were recorded in *O. bimaculatus* larvae fed diet D2 with 8% dietary lipid.

Table 4. Specific activity [U mg protein^{-1}] of metabolic enzymes of *Ompok bimaculatus* larvae fed varying levels of lipid.

Enzyme	Experimental diet		
	D1	D2	D3
Hexokinase	9.82 ± 0.35	10.27 ± 0.47	10.54 ± 0.51
Pyruvate kinase	5.6 ± 0.24^{a}	6.2 ± 0.27^{b}	6.4 ± 0.29^{b}
Lactate dehydrogenase	0.845 ± 0.03^{c}	0.507 ± 0.02^{a}	0.690 ± 0.03^{b}
Malate dehydrogenase	2.35 ± 0.11	2.24 ± 0.09	2.20 ± 0.11
Glucose 6 phosphatase	4.05 ± 0.13^{a}	4.38 ± 0.17^{ab}	4.62 ± 0.22^{b}
Fructose 1,6 bis phosphatase	3.10 ± 0.11^{a}	3.42 ± 0.14^{ab}	3.72 ± 0.15^{b}
Alanine aminotransferase	3.88 ± 0.16^{b}	3.55 ± 0.09^{a}	3.78 ± 0.12^{b}
Aspartate aminotransferase	6.55 ± 0.17^{b}	6.15 ± 0.12^{a}	6.45 ± 0.14^{b}
Glutamate dehydrogenase	5.12 ± 0.20	5.20 ± 0.23	5.28 ± 0.27
Glucose-6-phosphate dehydrogenase	32.6 ± 0.81^{b}	27.5 ± 0.76^{a}	26.4 ± 0.72^{a}
Lipid peroxidation	0.92 ± 0.06	0.96 ± 0.004	1.02 ± 0.006

Data are presented as mean ± standard error of the mean; mean values with different superscripts in a row differ significantly ($P < 0.05$).

Discussion

During the experimental rearing of the *O. bimaculatus* larvae, water temperature varied within a narrow range (28–30°C) that was considered suitable since a temperature of around 30°C was suggested as optimum for the growth of catfish (Paul and Giri 2016). Other water quality parameters were also within the acceptable range as recommended elsewhere (Paul et al. 2000; Debnath et al. 2016). Apart from environmental factors, rearing of early larval stages under captive condition depends mostly on the availability of suitable diets that are readily acceptable and consists of nutrients at the required level to support growth and well being of the fish. Different larval stages of fish may have specific nutritional requirements (Malla and Banik 2015). Digestive systems of fish larvae are immature and therefore they depend on live food organisms to a great extent for the supply of exogenous

enzymes. Generally, fish larvae do not prefer artificial diets, even if larviculture with formulated diets is essential for large-scale production of any species. The limited success of the dry formulated diets in larval rearing might be attributed to insufficient feed intake, imbalanced protein (non-protein energy sources), impaired digestive, as well as metabolic functions (Lee et al. 2002).

In the presently reported study, formulated diets were readily accepted by the 14 day old *O. bimaculatus* larvae. The study suggests that 8% lipid in a diet with 40% crude protein might support the growth and survivability of the butter catfish larvae during early development. The required lipid level detected in the presently reported study was close to the suggested lipid levels documented for other catfishes. For example, 6.5% and 7% optimum dietary lipid requirements were reported for *Ompok pabda* (Hamilton, 1822) fry (Paul et al. 2011) and *Mystus montanus* (Jerdon, 1849) (see Raj et al. 2007), respectively. Among carps, 6.5% lipid in the diets of *Ctenopharyngodon idella* (Valenciennes, 1844) (see Jin et al. 2013) and 7% lipid for the juveniles of common carp, *Cyprinus carpio* Linnaeus, 1758 (see Choi et al. 2015) supported maximum growth. On the contrary, elevated lipid requirements have also been suggested. For example, lipid levels of 10% for larvae of magur, *Clarias batrachus* (Linnaeus, 1758) (see BIS 2014b) and 17% for far eastern catfish, *Silurus asotus* Linnaeus, 1758 (see Kim et al. 2012) were reported. Therefore, the majority of the preceding studies suggested varying lipid requirement levels between 6% and 10% in diverse fish species, with few exceptions. Hence, the presently reported study considered this narrow level of variation for evaluation of the lipid levels. The ability of the fish to use lipid as a source of energy was noticed to vary among diverse fish species (Jauncey (1982)). Thus, different fish species at different life stages might require different dietary lipid levels and it needs to be evaluated separately for individual fish species. Our results were in agreement with some of the previous reports depicting 8% lipid requirement as optimal for a minor carp, *Barbonymus gonionotus* (Bleeker, 1849) (see Paul et al. 2010) and fingerlings of rohu, *Labeo rohita* (see Mishra and Samantaray 2004). BIS (2014a) also suggested an 8% crude lipid requirement for carp spawn and fry.

The presently reported study revealed that an increase in the dietary lipid level from 5.7% to 8% was associated with maximum growth and increased SGR [% · day−1] of the butter catfish larvae. Similarly, the lowest FCR and the maximum PER and ANPU values were recorded in the larvae fed diets with 8% crude lipid (D2). Our result was in compliance with the preceding reports indicating that increase in the dietary lipid up to a certain level might aid in efficient protein utilization that results in improved growth of the fish (Jauncey 1982; Kim et al. 2012). Similar results were recorded for the stinging catfish, *Heteropneustes fossilis* (Bloch, 1794) (see Akand et al. 1991) and rohu, *L. rohita* (see Mishra and Samantaray 2004). In contrast to these observations, high dietary lipid might cause to reduce fish growth, as documented for gibel carp, *Carassius gibelio* (Bloch, 1782); and Chinese long snout catfish, *Leiocassis longirostris* Günther, 1864 (see Pei et al. 2004). In the presently reported study, the group of larvae fed diet D3 with 10.45% crude lipid was associated with poor growth, which was in agreement with Pei et al (2004). When the non-protein energy source in the diet becomes insufficient or inaccessible, the protein is used as a source of energy instead of growth (Mohanta et al. 2009). In the presently reported study, the groups reared with diets D1 (5.7% lipid) and D3 (10.45% lipid) portrayed relatively poor growth that might be indicative of poor utilization of the non-protein energy source (Wang et al. 2018). Further, in the presently reported study, around 80% survivability of the butter catfish larvae was achieved with the formulated diets during the feeding trial. Previously, 52.18% and 45.82% survivability of the *O. bimaculatus* larvae with egg custards and compound feed was documented by Malla and Banik (2015), which was relatively lower than the presently reported findings. Improved survivability accomplished in the presently reported study could be due to improved feed utilization by the larvae.

An increase in dietary lipid levels seems to be an important consideration for the food fishes as it might have a significant effect on the carcass quality (Cowey 1993). There might be a positive correlation between lipid levels in the diets and carcass lipid deposition (Cowey 1993), which was in harmony with the presently reported study. Similar observations have been recorded in several species, e.g., rockfish, *Sebastes schlegelii* Hilgendorf, 1880 (see Lee et al. 2002); Eurasian perch; *Perca fluviatilis* Linnaeus, 1758 (see Mathis et al. 2003); cobia, *Rachycentron canadum* (Linnaeus, 1766) (see Craig et al. 2006); and grouper, *Epinephelus malabaricus* (Bloch et Schneider, 1801) (see Williams 2007). On the contrary, Paul et al. (2011) could not find any difference in carcass lipid in another species of butter catfish, *O. pabda* by feeding different levels of lipid. In the presently reported study, carcass protein content was not significantly affected by the dietary lipid levels, which was consistent with previous reports on the juveniles of pike perch, *Sander lucioperca* (Linnaeus, 1758) (see Schulz et al. 2008) and cobia (Webb et al. 2010). Overall, the carcass composition of the *O. bimaculatus* larvae detected in the presently reported study was similar to the previous report by Debnath and Sahoo (2013).

Although the ontogeny of the digestive enzymes during the early development of the *O. bimaculatus* has been documented by some authors (Pradhan et al. 2013; Chowdhury et al. 2019), to the authors' knowledge, there is no information on the diet-related changes in the digestive enzymes in the butter catfish. Adaptations of the digestive system in different species exhibit close association with their diet (Fernandez et al. 2001). Thus, changes in digestive enzyme activity could be correlated with the biochemical composition of food and feeding behavior of fish (Kuzmina 1996). In the presently reported study, amylase activity in *O. bimaculatus* larvae was noticed to be significantly decreased with elevated dietary

lipid levels. Previously, amylase activity in gilthead sea bream, *Sparus aurata* Linnaeus, 1758, was noticed to be influenced by dietary lipid levels (Fountoulaki et al. 2005). While, maximum activities of the alkaline protease, pepsin, and lipase were recorded with the group that was fed 8% lipid (D2) and achieved the highest growth. Digestive enzymes might contribute towards efficient digestion of the dietary components, which could be reflected through the growth of the fishes. Thus, increased growth in fish (fed 8% dietary lipid) associated with enhanced digestive enzyme activities might be indicative of better nutrient utilization in fish as stated elsewhere (Mandal and Ghosh 2018).

The presently reported study appraised activities of some major metabolic enzymes to evaluate the effects of the varying dietary lipid levels. Activities of the amino acid catabolizing enzymes were influenced by the dietary lipid levels. The fish liver is the hotspot for transdeamination with ALT and AST as the major enzymes (Enes et al. 2006; Kumar et al. 2008). A decrease in the activities of ALT, AST, and LDH might suggest reduced protein catabolism in fish fed diet D2 with 8% lipid. LDH is the enzyme of the glycolytic pathway that mediates the bidirectional conversion of pyruvate to lactate. A hike in LDH activity could be noticed under stress (Chatterjee et al. 2006). Thus, reduced LDH activity in the fish reared on D2 might indicate no or negligible stress on the experimental fish. In the presently reported study, increased activities of the gluconeogenic enzymes (G6P and FBP) coincided with an increase in the dietary lipid levels. Gluconeogenesis is a major pathway for glucose homeostasis, where glucose is produced from non-carbohydrate precursors (e.g., amino acid, lactate, glycerols). Increased activity of the neoglucogenic enzymes associated with decreased activity of digestive amylase might be indicative of the production of glucose by gluconeogenesis to meet the energy demand in this carnivorous species. No significant variation was noticed in the activity of the major glycolytic enzyme, HK. G6PD is the key enzyme catalyzing the first step of the HMP-shunt (pentose phosphate pathway) that generates NADPH for lipogenesis and stress management (Pandolfi et al. 1995). In the presently reported study, the activity of the lipogenic enzyme (G6PD) was inhibited by an increase in the dietary lipid, which was similar to the observations recorded in juveniles of Senegalese sole, *Solea senegalensis* Kaup, 1858 (see Dias et al. 2004; Guerreiro et al. 2012). Further, NADP-ME, GDH, and LPO activities were more or less unaffected by the dietary lipid levels. NADP-ME is responsible for NADP-dependent oxidative decarboxylation (malate to pyruvate and carbon dioxide) with the generation of NADPH that may be utilized for lipid biosynthesis, while GDH had been considered as a sensitive indicator of stress (Susan et al. 2010). Therefore, the results of the presently reported study might suggest that increased dietary lipid levels are neither required to augment lipid biosynthesis by the fish nor to induced stress on the experimental fish.

Conclusion

Results of the presently reported study indicated that 8% crude lipid in the diet with 40% crude protein might assure optimum growth and survival of *Ompok bimaculatus* larvae during early development. An appraisal on growth, body composition, and digestive as well as metabolic function in the butter catfish larvae recorded in the study might provide some important information to consider the application of formulated diets for the larviculture of *Ompok bimaculatus*.

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Optimization of dietary protein and lipid levels for butter catfish, (*Ompok bimaculatus*) (Bloch, 1794) fingerlings: An appraisal on growth, body composition, digestive enzymes, and metabolic function

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ABSTRACT

A completely randomized 3 × 3 factorial feeding trial was conducted to evaluate the effects of dietary protein and lipid levels on growth, feed utilization, body composition, and digestive as well as metabolic enzymes of the butter catfish (*Ompok bimaculatus*) fingerlings. Fish (average weight 0.66 ± 0.12 g; 30 d) were fed nine experimental diets containing three protein levels (35%, 40%, 45%) and three lipid levels (5%, 10%, 15%) in triplicate groups for a period of 90 days. The formulated diets were named P35L05, P35L10, P35L15, P40L05, P40L10, P40L15, P45L05, P45L10, and P45L15 (P = Protein; L = Lipid) respectively. The results indicated no protein-sparing effect of lipid in *O. bimaculatus* fingerlings beyond 35% dietary protein. Overall, diets P40L5 and P35L10 had significantly ($P < 0.05$) higher SGR (% day^{-1}) and lower FCR than other experimental groups. The highest weight gain (10.89 ± 0.07 g) and carcass protein (16.71 ± 0.2%) were recorded in fish fed diet P40L05. Increasing dietary lipid levels brought about an increase in carcass lipid in fish. Activities of α-amylase and acid-protease were decreased (except at 5% lipid), whereas alkaline-protease was increased with increasing dietary protein. An increase in pyruvate kinase (PK, glycolytic enzyme) activity and decrease in glucose-6-phosphate dehydrogenase (G6PD, lipogenic enzyme) activity were noticed with increasing dietary lipid content. A decrease in PK and increase in G6PD activities were observed with increasing dietary protein levels. Activities of the gluconeogenic enzymes (glucose-6-phosphatase, fructose-1,6-phosphatase) increased significantly ($P < 0.05$) with increasing dietary protein and lipid levels. Amino acid catabolizing enzymes, alanine transaminase and aspartate transaminase, were slightly increased with increasing dietary protein levels. Considering growth, body composition, metabolic function, and survivability (>95%), the diet containing 40% crude protein with 5% lipid might be suggested as optimum for *O. bimaculatus* fingerlings under the tested conditions.

KEYWORDS

Body composition; digestive enzymes; feed efficiency; metabolic enzymes; *Ompok bimaculatus*

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Introduction

The butter catfish, *Ompok bimaculatus* (Bloch, 1794), although indigenous to India, are also distributed in rivers, lakes, floodplains, and wetlands of other South East Asian countries, e.g., Bangladesh, Borneo, Java, Sumatra, Laos, Sri Lanka, Nepal, Malaya, Myanmar, Pakistan, Thailand, Cambodia, and Vietnam (Giri et al. 2019). The species has immense consumer preference and economic importance due to its excellent taste, balanced nutrient profile, soft bony structure, and high market price, especially in the east and north east of India as well as Bangladesh (Banik, Goswami, and Malla 2012; Paul et al. 2020a). It has been recognized as an excellent source of ω-3 and ω-6 fatty acids, lipoproteins, vitamins, and minerals together with easily digestible low fat content (Paul et al. 2020b). The wild population of *O. bimaculatus* has intensely declined due to anthropogenic activities like indiscriminate fishing and habitat degradation leading to ecological changes (Paul et al. 2020a). Considering restricted distribution and reduced abundance, the species has been categorized under near threatened category by the International Union for the Conservation of Nature and Natural Resources (IUCN) red list experiencing a risk of extinction in nature (IUCN 2014; Lakra et al. 2010). Because of high demand, competitive prices, and IUCN status, the species has been prioritized as a candidate for diversification of aquaculture and *in situ* conservation along with restocking through ranching programs (Debnath et al. 2016; Paul et al. 2020a). However, even though the aquaculture potential of *O. bimaculatus* has been recognized of late, the species has not yet attracted adequate attention for captive rearing, and thus information on the nutritional requirements of this species at different life stages is scarce (Biswas et al. 2020, 2019; Chakrabarti et al. 2012; Paul et al. 2021, 2020a).

Standardization of breeding protocol and feeding strategy accompanied by nutritionally balanced formulated diets are the prerequisites to establishing captive culture conditions for any fish species. Captive breeding of *O. bimaculatus* has already been established (Banik, Goswami, and Malla 2012; Raizada et al. 2013). Other studies conducted very recently indicated dietary requirements of 40% crude protein (Paul et al. 2020a) and 8% crude lipid (Paul et al. 2021) to assure optimum growth and survival of the *O. bimaculatus* larvae during early development. Requirement of around 35% dietary protein was suggested for the fingerlings of this species (Biswas et al. 2020). However, to the authors' knowledge, studies on dietary requirements of the major nutrients for the fingerlings of *O. bimaculatus* have not yet been reported. Thus, it was considered reasonable to appraise the nutritional requirements of *O. bimaculatus* fingerlings to ensure regular and reliable supply of the fingerlings for commercial production and conservation issues.

Protein is the most important and often an expensive dietary component; determination of its requirement levels is fundamental to formulating high-quality as well as cost-effective diets (Wang et al. 2013). Adequate levels of good-quality protein in fish feed is necessary to support high growth at the younger stages. If added in excess, the surplus protein would be converted to energy through catabolism of amino acids, and that should be avoided as it would increase the feed cost and nitrogenous waste output (National Research Council 2011; Wu and Gatlin 2014). Therefore, it is important to improve protein utilization for synthesis of body protein and important biomolecules rather than for energy purposes (Lee, Jeon, and Lee 2002). Dietary protein requirements in fish could be affected by the amount of nonprotein energy sources in the diet. Elevated lipid or carbohydrate levels in the diet could spare protein without negatively affecting growth and feed utilization efficiency in fish (De Silva, Gunasekera, and Shim 1991; Wang et al. 2013). Species under the genus *Ompok* have been generally recognized as carnivorous to omnivorous and prefer natural food items like zooplankton and tubifex (Malla and Banik 2015). Similarly, the carnivorous to omnivorous feeding aptitude of *O. bimaculatus* has been established (for review, see Gupta 2015). In carnivorous fish species, lipid is generally preferred as a nonprotein energy source since lipid is an energy-dense nutrient that is readily metabolized, and carbohydrate is less available in their natural food (Lee, Jeon, and Lee 2002). In addition, dietary lipids serve as the source of essential fatty acids and a carrier of fat-soluble vitamins. However, excessive lipid in the diet could disrupt the health and growth of fish because of abnormal lipid deposition in the body, and thus careful considerations must be given regarding protein-to-lipid ratios in formulated diets (Lee, Jeon, and Lee 2002; Shapawi et al. 2014; Wang et al. 2013). Thus, the present study was conducted to optimize dietary protein and lipid levels for formulation of practical diets for butter catfish fingerlings. Moreover, the present study evaluated the protein-sparing potential of lipid and appraised whether an interaction of protein and lipid existed for growth performance, body composition, and enzyme activities in *O. bimaculatus* fingerlings.

As requirement levels for protein and lipid may vary in different species and at different life stages, designing species-specific and age-specific diets can improve performance of the fish under commercial aquaculture. Optimization of the dietary protein:lipid ratio and their interaction has been studied in diverse fish species (Guerreiro et al. 2012; Kim and Lee 2009; Sagada et al. 2017; Wang et al. 2013). However, no commercial formulated diet has yet been available for the fingerlings of *O. bimaculatus*. Considering different protein and lipid levels studied for diverse fish species and reports on the nutrient requirements of the *O. bimaculatus* larvae, in the present study, practical diets were formulated with three protein (35%, 40%, 45%) and three lipid levels (5%, 10%, 15%) in a 3 × 3 factorial design to optimize the dietary protein and lipid

levels. Therefore, the present study considered an appraisal of digestive enzymes along with some key metabolic enzymes to evaluate the effects of formulated diets with varying protein and lipid levels. The results of the study might be helpful in making some important information available for formulation of diets for *O. bimaculatus* fingerlings.

Material and methods

Fish and culture conditions

Butter catfish (*O. bimaculatus*) fry and fingerlings were raised in the wet laboratory of the Department of Zoology, The University of Burdwan. Fish were handled and the experiment was performed following the approved guidelines of the Institutional Ethical Committee. Prior to the experiment, the fish were acclimated to the experimental conditions for one week in fiber-reinforced plastic (FRP) tanks (150 L) with continuous aeration; during this period fish were fed a formulated diet containing 40% crude protein and 8% lipid. After acclimatization, the fingerlings (average weight 0.66 ± 0.12 g; average length 4.8 ± 0.20 cm; 30 d old) were randomly distributed in 27 FRP tanks (nine experimental sets in triplicates) at a stocking density of 100 fish per tank. The fish were manually fed to apparent satiation twice a day at 10:00 and 16:00 hours, and it was ensured that no feed was leftover. Feed consumption and mortality in each tank were recorded separately, and survivability (%) was calculated. Seasoned groundwater was used for rearing of the experimental fish. The experiment was conducted for 90 days with continuous aeration and daily exchange of 25% water to ensure good water quality. During the experimental period, water quality parameters (temperature, pH, and dissolved oxygen) were monitored on a regular basis using a portable multiparameter analyzer (Orion Star™ A329) that utilizes the standard methods of American Public Health Association (American Public Health Association [APHA] 2012). Total alkalinity was determined by titration of the water sample with H_2SO_4 (0.1 N) and expressed as $CaCO_3$ equivalent (APHA 2012). Water quality parameters were noticed to vary within a narrow range: temperature 28°C–30°C, pH 6.8–7.7, dissolved oxygen 6.8–7.4 mg/L, and total alkalinity 230–240 mg/L.

Experimental design and diets

The experiment had a completely randomized 3 × 3 factorial design with triplicate groups. Nine experimental diets were formulated consisting of three protein levels (35%, 40%, 45%) and three lipid levels (5%, 10%, 15%). The formulated diets were named P35L05, P35L10, P35L15, P40L05, P40L10, P40L15, P45L05, P45L10, and P45L15 (P = Protein, L = Lipid) respectively.

Proximate compositions of the dietary ingredients were determined and diets were formulated using WinFeed software (Version 2.8). A blending of soybean meal (SBM), groundnut oil cake (GNOC), and casein along with fish meal (FM) at varied levels served as the protein sources; a combination of vegetable and fish oils (1:1) at different inclusion levels met the requirement of desired lipid levels in the diets. Crude protein (CP) and crude lipid (CL) levels of the major ingredients were: SBM (CP 45%, CL 2.5%), GNOC (CP 39%, CL 8%), and FM (CP 55%, CL 8%). All dry ingredients were finely powdered with a laboratory grinder, sieved to obtain uniform particle size (<400 μm, diameter), and mixed thoroughly with the required amount of vitamin-mineral premix (Supradyn, Piramal Enterprises Ltd., Mumbai, India) and oil sources. Carboxymethyl-cellulose (1%) was added as a binder, and the mixture was made to stiff dough with an appropriate amount of lukewarm water. The dough was pelleted (1 mm in diameter) with an electrically operated pelletizer and dried initially in the sun (6 h) and further in a hot air oven at 60°C (96 h). The dried pellets were crumbled, packed in airtight plastic bags, and stored in a refrigerator at 4°C until use. Formulation and proximate composition of the experimental diets are depicted in Table 1.

Proximate compositions of diets

Analyses of proximate compositions of the experimental diets (dry weight) were carried out following the procedures of the Association of Official Analytical Chemists (Association of Official Analytical Chemists [AOAC] 2005). Dry weight was determined by oven drying (initially at 100 ± 5°C for 30 min, thereafter at 60°C) until constant weight. Crude protein (N × 6.25) was determined by a semi-automatic Kjeldahl system (KjelTRON, Tulin Equipments, Chennai, India); crude lipid by ether extraction (petroleum ether, 60 to 80°C) using a Soxhlet apparatus (Socsplus, Pelican Equipments, Chennai, India); crude fiber as loss on ignition of dried fat-free residues after digestion with 1.25% H_2SO_4 and 1.25% NaOH using a Fibraplus system (Pelican Equipments, Chennai, India); and ash by combustion at 550°C in a muffle furnace. Nitrogen-free extract (NFE) was determined by subtracting the sum of values for crude protein, crude lipid, crude fiber, ash, and moisture from 100 (Maynard et al. 1979). Gross energy of the experimental diets was measured with a bomb calorimeter (Lab-X, Kolkata, India).

Growth parameters

After termination of the experiment, 20 fish were randomly picked from each tank, weighed, and analyzed to evaluate the growth parameters. Live weight gain (%), specific growth rate (SGR; % day^{-1}), protein efficiency ratio (PER), feed conversion ratio (FCR), apparent net protein utilization (ANPU %), and

Table 1. Ingredient composition and proximate composition of the experimental diets on a dry matter (%) basis.

	Diets								
Ingredients (g/100 g)	P35L05	P35L10	P35L15	P40L05	P40L10	P40L15	P45L05	P45L10	P45L15
Fishmeal	18	18	18	29	29	29	40	40	40
Wheat flour	37	32	27	26	22	17	16	11	6
Casein	10	10	10	10	10	10	10	10	10
Soybean meal	15	15	15	15	15	15	15	15	15
Ground nut oil cake	15	15	15	15	15	15	15	15	15
Fish oil + veg. oil (1:1)	2	7	12	2	6	11	1	6	11
Vitamin + mineral*	2	2	2	2	2	2	2	2	2
Carboxy methyl cellulose	1	1	1	1	1	1	1	1	1
Proximate composition (% dry matter)									
Dry matter	93.02 ± 1.51	92.87 ± 1.45	92.67 ± 1.46	93.12 ± 1.32	92.31 ± 1.40	92.05 ± 1.37	91.91 ± 1.38	91.72 ± 1.35	91.52 ± 1.47
Protein	35.42 ± 4.1	35.11 ± 4.0	34.9 ± 3.7	40.76 ± 3.8	40.22 ± 3.4	40.09 ± 3.1	45.58 ± 2.1	45.24 ± 2.7	44.82 ± 2.9
Lipid	5.15 ± 0.24	10.21 ± 0.17	15.40 ± 0.19	5.0.±0.25	9.87 ± 0.17	14.85 ± 0.12	5.19 ± 0.22	10.09 ± 0.16	14.92 ± 0.14
Ash	10.50 ± 0.74	10.15 ± 0.56	9.81 ± 0.62	10.02 ± 0.47	9.78 ± 0.68	9.56 ± 0.87	9.67 ± 0.54	9.45 ± 0.69	9.25 ± 0.78
Crude fiber	22.78 ± 2.14	21.54 ± 2.12	20.78 ± 2.14	20.52 ± 1.97	19.52 ± 2.15	18.98 ± 1.78	17.98 ± 1.69	17.74 ± 1.75	16.95 ± 1.85
NFE	26.15 ± 2.84	22.99 ± 2.69	19.12 ± 1.78	23.63 ± 1.67	20.61 ± 1.48	16.52 ± 1.47	21.58 ± 1.65	17.48 ± 1.47	14.06 ± 1.54
KJ/g	18.86	20.02	21.22	19.28	20.35	21.49	19.69	20.79	21.87
P:E ratio (mg/KJ)	18.78	17.54	16.45	21.14	19.76	18.66	23.15	21.76	20.49

*Vitamin+mineral contains Vitamin A I.P.(as acetate) 10,000 I.U, Cholecalciferol I.P.(Vitamin D3) 1000 I.U., Thiamine mononitrate I.P. 10 mg, Riboflavine I.P. 10 mg, Pyridoxine Hydrochloride I.P. 3 mg, Cyanocobalmin I.P. 15 mcg, Nicotinamide I.P. 100 mg, Calcium Pantothenate I.P. 16.30 mg, Ascorbic Acid I.P. 150 mg, α Tocopheryl Acetate I.P. 25 mg, Biotin U.S.P. 0.25 mg, Tribasic Calcium Phosphate I.P. 129 mg, Magnesium Oxide Light I.P. 60 mg, Dried Ferrous Sulfate I.P. 32.04 mg, Manganese Sulfate Monohydrate B.P. 2.03 mg, Total Phosphorus in the preparation 25.80 mg, Copper Sulfate Pentahydrate B.P. 3.39 mg, Zinc Sulfate I.P. 2.20 mg, Sodium Molybdate Dihydrate B.P. 0.25 mg, Sodium Borate B.P. 0.88 mg.

survivability (%) were determined following standard methods outlined by Steffens (1989), a detailed description of which was depicted in Ghosh and Mondal (2015).

Digestive enzymes

Activities of the digestive enzymes (α-amylase, alkaline protease, pepsin, and lipase) in fish were determined at the initiation and completion of the experiment. Digestive tracts of 20 fish from each experimental tank were taken out, cleaned properly with chilled distilled water, kept on an ice-cooled Petri plate, and weighed. Pooled samples collected from each tank were used for a replicate; thus there were three replicates for each experimental set. A 10% homogenate was prepared with chilled phosphate buffer (0.1 M, pH 7.4) and centrifuged at 10,000 rpm (10 min, 4°C). The resulting supernatant was used as the enzyme extract for estimation of digestive enzymes. Protein content of the supernatant was analyzed using bovine serum albumin as a standard (Lowry et al. 1951). Amylase activity was determined after Bernfeld (1955) using dinitro salicylic acid (DNSA) reagent, and unit activity (U) was expressed as mg maltose liberated mg^{-1} protein hr^{-1}. Alkaline protease activity was measured following Walter (1984), using Hammerstein casein substrate and presented as μg of tyrosine liberated mg^{-1} protein hr^{-1} (U). Acid protease (pepsin) activity was determined using hemoglobin (2%) substrate according to Anson (1938) with minor alterations as described in Worthington (1991) and expressed as μg of tyrosine liberated mg^{-1} protein min^{-1} (U). Lipase activity was measured after Bier (1955) using olive oil substrate and documented as μ mole of fatty acid liberated mg^{-1} protein hr^{-1} (U).

Metabolic enzymes

For determination of metabolic enzymes, hepatic tissues were collected and a 10% homogenate (in 0.25 M sucrose, pH 7.4) was prepared. Following removal of cellular debris by centrifugation (1,000 g, 30 min, 4°C), the supernatant was further centrifuged at 10,000 g (15 min, 4°C) to obtain mitochondrial pellets (Biswas et al. 2006). The supernatant was centrifuged at 12,500 g (1 h, 4°C), and the resultant fraction was used as the source of cytosolic metabolic enzymes. Although the mitochondrial pellet was further processed with triton X-100 (0.1%) and repeatedly washed (10,000 *g*, 30 min, 4°C) with PBS (0.1 M, pH 7.4), the supernatant thus obtained was used as the source of mitochondrial metabolic enzymes. The tissue fractions were stored in −20°C until use.

Among carbohydrate metabolizing enzymes, hexokinase (HK) was determined after Tranulis et al. (1996) through the reduction of NADP to generate NADPH. HK activity was presented as μM of NADPH formed mg^{-1} protein

h^{-1} (U). Pyruvate kinase (PK) was measured following Driedzic and Almeida-Val (1996) with minor alteration. PK activity was expressed as μmole of pyruvate converted to NADH mg^{-1} protein min^{-1} (U). Gluconeogenic enzymes, glucose-6-phosphatase (G6P), and fructose-1,6-bis phosphatase (FBP) were determined through the amount of phosphorus (Pi) released from glucose-6-phosphate (Marjorie 1964) or fructose-di-phosphate (Freeland and Harper 1959) as substrates respectively. Release of Pi was measured following Fiske and Subbarow (1925). G6P and FBP activities were expressed as μg of phosphorus released mg^{-1} protein min^{-1} (U).

Among lipogenic enzymes, glucose-6-phosphate dehydrogenase (G6PD) was determined using glucose-6-phosphate as the substrate and NADP (Kornberg and Horecker 1955). G6PD activity was expressed as μM of NADPH formed mg^{-1} protein hr^{-1} (U). NADP-malic enzyme (NADP-ME) activity was measured using L-malic acid as the substrate following Hsu and Lardy (1967) with alterations proposed by Murphy and Walker (1974). NADP-ME activity was expressed as μM of NADPH formed mg^{-1} protein h^{-1} (U).

Amino acid catabolizing enzymes, alanine transaminase (ALT) and aspartate transaminase (AST), were measured using α-ketoglutarate and DL-Alanine or DL-Aspartic acid substrates respectively (Reitman and Frankel 1957). ALT activity was presented as μM of pyruvate formed mg^{-1} protein min^{-1} (U); AST activity was expressed as μM of oxaloacetate formed mg^{-1} protein min^{-1} (U). Mitochondrial glutamate dehydrogenase (GDH) activity was determined after Lee and Lardy (1965) using sodium glutamate and tetrazolium salt. GDH activity was expressed as μM of formazan formed mg^{-1} protein h^{-1} (U).

Compositions of fish carcass

Analyses of proximate compositions of the fish carcass (wet weight) were carried out by standard procedures of the Association of Official Analytical Chemists (AOAC 2005) as described in a previous section.

Statistical analysis

Data were presented as mean ± standard error (SE). Data were analyzed by one-way (dietary treatments) and two-way (dietary protein and lipid levels) analysis of variance (ANOVA) following Zar (2010). Multiple comparisons were made by Tukey's post hoc HSD test to analyze significant differences ($P < 0.05$) between the means of experimental groups.

Results

Data pertaining to growth performance, feed utilization, and survivability of *O. bimaculatus* fingerlings fed diets with different protein and lipid levels for 90 days are presented in Table 2. Results of the one-way ANOVA indicated that net weight gain, SGR (% per day), FCR, and protein utilization were significantly ($P < 0.05$) influenced by varying levels of dietary protein and lipid. The highest weight gain was recorded in fish fed diet P40L5. Overall, diets with 45% crude protein produced fish with lower SGR, PER, and ANPU. Increasing lipid levels from 5% to 15% resulted in a decrease in growth and protein utilization in fish fed diets with 40% or 45% crude protein. Survivability rates in butter catfish fingerlings were >90% except the groups fed diets P45L10 and P45L15. Analysis by two-way ANOVA revealed that SGR, FCR, PER, ANPU, and survivability were significantly affected by the dietary protein and lipid levels ($P < 0.05$). Further, except for survivability, there were significant interaction between the dietary protein and lipid levels on the growth and feed utilization parameters (e.g., SGR, FCR, PER, and ANPU) of *O. bimaculatus* fingerlings.

Activities of the digestive enzymes are depicted in Table 3. Overall, one-way ANOVA indicated that activities of α-amylase and acid protease were decreased (except at 5% lipid, up to 40% CP), whereas alkaline protease was increased with increasing levels of dietary protein. The maximum α-amylase and acid protease activities were noticed in the fish fed diet P35L10, though it was not significantly different from the groups fed diets P35L15 and P40L05. Significantly ($P < 0.05$) higher alkaline protease activity was recorded with the fish fed diets with 45% crude protein irrespective of tested lipid levels, when compared to other protein levels. Lipase activity increased significantly with increasing dietary lipid from 5 to 10 at the 35% CP level. Although the maximum lipase activity was noticed in the fish fed diet P45L05, that didn't differ significantly ($P < 0.05$) with the other groups receiving 40% or 45% crude protein in the diets. Thus, at higher CP levels, lipase activity didn't differ significantly with increasing lipid levels. According to two-way ANOVA, activities of the tested digestive enzymes were significantly affected ($P < 0.05$) by dietary protein and lipid levels and their interaction.

Some of the key hepatic enzymes concerned with intermediary metabolism of protein, lipid, and carbohydrate are portrayed in Table 4. One-way ANOVA showed that varying dietary protein and lipid levels led to significant differences in the activities of PK, G6P, FBP, G6PD, ALT, and AST in *O. bimaculatus* fingerlings; differences were not significant for the activities of HK, ME, and GDH. Activity of the glycolytic enzyme PK significantly decreased with increasing dietary protein levels but increased by increasing lipid levels at the same protein level. Activities of two major neoglucogenic enzymes, G6P and FBP, significantly increased with increases in the dietary

Table 2. Growth performance and feed utilization efficiency of *Ompok bimaculatus* fingerlings fed varying dietary protein and lipid levels for 90 days.

Experimental diets	Initial (g)	Final Weight (g)	Live weight gain	FCR$^{\alpha}$	SGR$^{\beta}$	PER$^{\gamma}$	ANPU$^{\Sigma}$	Survivability
P35/L05	0.652 ± 0.12	10.05 ± 0.06^{ab}	9.40 ± 0.08^{ab}	1.46 ± 0.01^{b}	2.77 ± 0.02^{b}	1.95 ± 0.02 ^{f}	32.06 ± 0.39^{c}	96 ± 0.57^{b}
P35/L10	0.661 ± 0.11	11.08 ± 0.06^{e}	10.43 ± 0.10^{e}	1.37 ± 0.01^{a}	3.00 ± 0.04 ^{cd}	2.09 ± 0.01 ^{g}	35.00 ± 0.6^{d}	93 ± 1.52^{b}
P35/L15	0.656 ± 0.12	10.43 ± 0.07^{bcd}	9.78 ± 0.09^{bcd}	1.57 ± 0.01^{c}	2.75 ± 0.02^{b}	1.82 ± 0.02^{d}	30.26 ± 0.48^{c}	92 ± 1.15^{b}
P40/L05	0.657 ± 0.13	11.54 ± 0.08^{f}	10.89 ± 0.07 ^{f}	1.34 ± 0.01^{a}	3.08 ± 0.04^{d}	1.86 ± 0.02^{e}	31.44 ± 0.20^{c}	95 ± 1.15^{b}
P40/L10	0.672 ± 0.16	10.86 ± 0.07^{e}	10.21 ± 0.09^{e}	1.51 ± 0.01^{bc}	2.91 ± 0.03^{c}	1.65 ± 0.01^{c}	27.66 ± 0.40^{b}	93 ± 0.57^{b}
P40/L15	0.681 ± 0.19	10.42 ± 0.10^{bcd}	9.77 ± 0.06^{bcd}	1.63 ± 0.02 ^{cd}	2.71 ± 0.03^{b}	1.53 ± 0.01^{b}	25.40 ± 0.44^{b}	90 ± 2.30^{ab}
P45/L05	0.654 ± 0.12	9.99 ± 0.06^{a}	9.34 ± 0.06^{a}	1.67 ± 0.02^{d}	2.41 ± 0.02^{a}	1.33 ± 0.02^{a}	21.56 ± 0.52^{a}	91 ± 2.08^{ab}
P45/L10	0.665 ± 0.14	10.08 ± 0.08^{ac}	9.43 ± 0.07^{ac}	1.71 ± 0.03^{de}	2.37 ± 0.02^{a}	1.30 ± 0.02^{a}	20.92 ± 0.57^{a}	88 ± 1.52^{ab}
P45/L15	0.654 ± 0.11	10.28 ± 0.10^{ad}	9.63 ± 0.06^{ad}	1.76 ± 0.02^{e}	2.3 ± 0.02^{a}	1.27 ± 0.02^{a}	20.14 ± 0.37^{a}	83 ± 3.00^{a}
Means of main effect								
P35	–	10.52	9.87	1.46^{A}	2.84^{B}	1.94^{B}	32.44^{B}	93.66
P40	–	10.94	10.29	1.49^{A}	2.90^{B}	1.82^{B}	28.16^{B}	92.66
P45	–	10.12	9.46	1.71^{B}	2.36^{A}	1.29^{A}	20.87^{A}	87.33
L5	–	10.53	9.88	1.49	2.75	1.84	28.35	94.00
L10	–	10.67	10.02	1.53	2.76	1.67	27.86	91.33
L15	–	10.38	9.72	1.65	2.59	1.54	25.26	88.33
Two-way ANOVA (P value)								
Protein	–	0.001	0.001	P < 0.001	0.005	P < 0.001	P < 0.001	0.003
Lipid	–	P < 0.001	P < 0.001	P < 0.001	P < 0.001	P < 0.001	P < 0.001	P < 0.001
Interaction	–	P < 0.001	P < 0.001	P < 0.001	0.032	P < 0.001	P < 0.001	0.744

Note. Data are presented as Mean ± SE of three determinations (n = 3). Means with different superscripts in a column differ significantly (P < 0.05).
$^{\alpha}$Feed conversion ratio, $^{\beta}$Specific growth rate, $^{\gamma}$Protein efficiency ratio, $^{\Sigma}$Apparent net protein utilization.

Table 3. Activities of digestive enzymes in *Ompok bimaculatus* fingerlings fed varying dietary protein and lipid levels for 90 days.

Experimental diets	Amylase	Alkaline protease	Lipase	Pepsin
P35/L05	10.86 ± 0.08^{c}	1.63 ± 0.03^{a}	1.37 ± 0.02^{a}	3.35 ± 0.06^{b}
P35/L10	12.25 ± 0.10^{e}	1.68 ± 0.01^{ab}	1.61 ± 0.03^{bc}	3.65 ± 0.07^{b}
P35/L15	11.96 ± 0.12^{de}	1.74 ± 0.03^{ac}	1.56 ± 0.03^{b}	3.42 ± 0.06^{b}
P40/L05	11.86 ± 0.11^{de}	1.82 ± 0.02^{bcd}	1.72 ± 0.03^{bd}	3.55 ± 0.07^{b}
P40/L10	11.5 ± 0.12^{d}	1.94 ± 0.04^{de}	1.81 ± 0.04^{d}	2.89 ± 0.05^{a}
P40/L15	9.65 ± 0.12^{b}	1.96 ± 0.03^{df}	1.78 ± 0.03^{d}	2.92 ± 0.05^{a}
P45/L05	10.52 ± 0.07^{c}	2.12 ± 0.04^{fg}	1.86 ± 0.04^{d}	2.75 ± 0.05^{a}
P45/L10	9.95 ± 0.15^{b}	2.16 ± 0.04^{g}	1.78 ± 0.04^{cd}	2.64 ± 0.06^{a}
P45/L15	8.77 ± 0.11^{a}	2.06 ± 0.04^{efg}	1.71 ± 0.03^{bd}	2.61 ± 0.05^{a}
Means of main effect				
P35	11.69	1.68^{A}	1.51	3.47^{B}
P40	11.00	1.91^{B}	1.77	3.36^{AB}
P45	9.74	2.11^{C}	1.78	3.13^{A}
L05	11.08	1.86	1.65	3.45
L10	11.23	1.93	1.73	3.37
L15	10.12	1.92	1.68	3.14
Two-way ANOVA (P value)				
Protein	$P < 0.001$	0.024	0.019	$P < 0.001$
Lipid	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$
Interaction	$P < 0.001$	0.027	$P < 0.001$	$P < 0.001$

Note. Data are presented as Mean ± SE of three determinations ($n = 3$). Means with different superscripts in a column differ significantly ($P < 0.05$).

protein and lipid levels. Activity of the lipogenic enzyme, G6PD, revealed a significant decrease with an increase in the dietary lipid levels and increased with an increase in the dietary protein levels. Further, activities of amino acid catabolizing enzymes, ALT and AST, revealed a marginal increase with an increase in the dietary protein levels for all of the tested lipid levels.

Based on one-way ANOVA, whole body lipid and protein were significantly affected by varying levels of dietary proteins and lipids, although moisture and ash contents remained statistically neutral (Table 5). The highest crude protein in the carcass was recorded in the group P40L05, although it did not differ significantly ($P < 0.05$) with the groups P35L10 and P40L10. Further, an increase in dietary lipid levels at both 40% and 45% crude protein resulted in a decrease in carcass protein deposition in fish. The maximum crude lipid in the carcass was noticed in fish fed diet P40L15, which was not significantly different ($P < 0.05$) to the fish fed diets P35L10, P40L05, and P40L10. An increase in dietary lipid levels brought about an increase in carcass lipid contents in fish at the same protein level, although the difference was significant with only 35% crude protein. The two-way ANOVA indicated that dietary protein and lipid levels and their interaction had a significant influence on carcass protein and lipid of *O. bimaculatus* fingerlings. However, there was no significant interaction between dietary protein and lipid levels on carcass ash and moisture contents.

Table 4. Hepatic metabolic enzymes of *Ompok bimaculatus* fingerlings fed varying dietary protein and lipid levels for 90 days.

	Glycolytic enzyme		Gluconeogenic enzyme	
Experimental Diets	Hexokinase	Pyruvate Kinase	Glucose 6 Phosphatase	Fructose 1,6 Phosphatase
P35/L05	10.43 ± 0.27	7.25 ± 0.06^{d}	4.15 ± 0.03^{a}	2.87 ± 0.05^{a}
P35/L10	10.56 ± 0.27	8.67 ± 0.08 ^{f}	4.27 ± 0.05^{ab}	3.15 ± 0.06^{ab}
P35/L15	10.72 ± 0.27	9.89 ± 0.12 ^{g}	4.38 ± 0.03^{bc}	3.35 ± 0.06^{bc}
P40/L05	11.23 ± 0.26	6.01 ± 0.06^{b}	4.42 ± 0.04^{bcd}	3.67 ± 0.07 ^{cd}
P40/L10	11.52 ± 0.27	6.82 ± 0.06^{c}	4.57 ± 0.06^{cde}	3.75 ± 0.07^{de}
P40/L15	10.89 ± 0.25	7.65 ± 0.05^{e}	4.61 ± 0.05^{def}	3.96 ± 0.07^{de}
P45/L05	11.67 ± 0.28	5.35 ± 0.05^{a}	4.82 ± 0.05 ^{f}	4.03 ± 0.07^{ef}
P45/L10	10.96 ± 0.29	6.21 ± 0.05^{bd}	5.21 ± 0.04 ^{g}	4.27 ± 0.08 ^{fg}
P45/L15	10.76 ± 0.27	6.96 ± 0.06 ^{cd}	5.37 ± 0.04 ^{g}	4.42 ± 0.07 ^{g}
Means of main effect				
P35	10.57	8.6	4.27^{A}	3.12^{A}
P40	11.21	6.83	4.53^{A}	3.79^{B}
P45	11.13	6.17	5.13^{B}	4.24^{B}
L05	11.11	6.2	4.46	3.52
L10	11.01	7.23	4.68	3.72
L15	10.79	8.17	4.78	3.91
Two-way ANOVA (P value)				
Protein	0.871	P < 0.001	P < 0.001	P < 0.001
Lipid	0.368	P < 0.001	P < 0.001	P < 0.001
Interaction	0.494	P < 0.001	0.005	0.555

(*Continued*)

Table 4. (Continued).

	Lipogenic enzymes		Amino acid catabolizing enzymes		
Experimental diets	Glucose 6 phosphate dehydrogenase	Malic enzyme	Alanine aminotransferase	Aspartate aminotransferase	Glutamate dehydrogenase
P35/L05	29.72 ± 0.26^{b}	2.52 ± 0.14	3.65 ± 0.06^{ab}	6.10 ± 0.06^{b}	5.60 ± 0.10
P35/L10	26.42 ± 0.41^{a}	2.47 ± 0.15	3.54 ± 0.04^{a}	5.96 ± 0.06^{ab}	5.55 ± 0.06
P35/L15	24.34 ± 0.55^{a}	2.38 ± 0.17	3.56 ± 0.05^{a}	5.62 ± 0.07^{a}	5.53 ± 0.08
P40/L05	34.54 ± 0.48^{d}	2.75 ± 015	3.80 ± 0.09^{ad}	6.55 ± 0.09^{b}	5.65 ± 0.08
P40/L10	33.17 ± 0.34^{cd}	2.68 ± 0.13	3.65 ± 0.06^{a}	6.25 ± 0.07^{ab}	5.62 ± 0.09
P40/L15	31.65 ± 0.34^{bc}	2.62 ± 0.14	3.71 ± 0.03^{ac}	6.17 ± 0.10^{ab}	5.56 ± 0.08
P45/L05	39.67 ± 0.80^{e}	2.95 ± 0.13	4.06 ± 0.05^{de}	6.97 ± 0.06^{c}	5.70 ± 0.05
P45/L10	37.43 ± 0.82^{e}	2.81 ± 0.10	3.92 ± 0.08^{bcde}	6.80 ± 0.10^{c}	5.65 ± 0.07
P45/L15	34.27 ± 0.49^{cd}	2.75 ± 0.12	3.78 ± 0.04^{ae}	6.83 ± 0.08^{c}	5.62 ± 0.05
Means of main effect					
P35	26.82^{A}	2.46^{A}	3.58^{A}	5.89^{A}	5.56
P40	33.12^{B}	2.68^{B}	3.72^{AB}	6.32^{A}	5.61
P45	37.12^{B}	2.84^{B}	3.92^{B}	6.87^{B}	5.65
L05	34.64	2.74	3.84	6.54	5.65
L10	32.34	2.65	3.7	6.34	5.6
L15	30.08	2.58	3.71	6.21	5.57
Two-way ANOVA (P value)					
Protein	$P < 0.001$	0.395	0.011	$P < 0.001$	0.473
Lipid	$P < 0.001$	0.011	$P < 0.001$	$P < 0.001$	0.342
Interaction	0.112	0.997	0.395	0.115	0.999

Note. Data are presented as Mean ± SE of three determinations ($n = 3$). Means with different superscripts in a column differ significantly ($P < 0.05$).

Table 5. Whole body carcass composition (%) of *Ompok bimaculatus* fingerlings fed varying dietary protein and lipid levels for 90 days.

Experimental diets	Moisture	Crude protein	Crude lipid	Crude ash
P35/L05	79.75 ± 2.19	16.21 ± 0.05^{b}	2.5 ± 0.02^{a}	1.78 ± 0.02
P35/L10	79.54 ± 1.25	16.61 ± 0.04^{d}	2.71 ± 0.02^{b}	1.81 ± 0.02
P35/L15	78.67 ± 1.57	16.42 ± 0.03^{c}	2.89 ± 0.03^{e}	1.83 ± 0.01
P40/L05	78.82 ± 2.54	16.71 ± 0.02^{d}	2.82 ± 0.02 ^{cd}	1.86 ± 0.03
P40/L10	79.27 ± 2.28	16.52 ± 0.03 ^{cd}	2.85 ± 0.04^{de}	1.76 ± 0.01
P40/L15	79.06 ± 1.42	16.40 ± 0.04^{c}	2.91 ± 0.01^{e}	1.74 ± 0.02
P45/L05	79.98 ± 2.25	16.04 ± 0.02^{ab}	2.74 ± 0.01^{bc}	1.84 ± 0.01
P45/L10	78.57 ± 2.05	15.95 ± 0.03^{a}	2.76 ± 0.01^{bd}	1.76 ± 0.01
P45/L15	78.86 ± 2.78	15.87 ± 0.04^{a}	2.82 ± 0.02 ^{cd}	1.76 ± 0.03
Means of main effect				
P35	79.32	16.41^{B}	2.70	1.80
P40	79.05	16.54^{B}	2.86	1.78
P45	79.13	15.95^{A}	2.77	1.78
L05	79.51	16.32	2.68	1.82
L10	79.12	16.36	2.77	1.77
L15	78.86	16.23	2.87	1.77
Two-way ANOVA (P value)				
Protein	0.897	$P < 0.001$	$P < 0.001$	0.388
Lipid	0.913	$P < 0.001$	$P < 0.001$	0.387
Interaction	0.951	$P < 0.001$	$P < 0.001$	0.434

Note. Data are presented as Mean ± SE of three determinations ($n = 3$). Means with different superscripts in a column differ significantly ($P < 0.05$).

Discussion

Nutritional requirements are the reflection of growth and physiology in fish, as dietary nutrients are utilized for energy metabolism, tissue restoration, and growth (Wang et al. 2013). The present study aimed at determining the optimal combination of dietary protein and lipid levels to support growth, feed utilization, and metabolic functions in *Ompok bimaculatus* fingerlings under captive conditions. The use of lipid in the diets has to be critically evaluated as excessive lipid may not only interfere with pellet quality and shelf life of the diets but also growth and feed utilization in fish (Li et al. 2010). Thus, an appropriate lipid level in fish diets is of great importance. On the other hand, dietary protein is the major factor affecting growth of fish along with feed cost (Lovell 1989). In general, increasing the dietary protein level could be linked with improved fish production, especially for carnivorous fish (Lee, Jeon, and Lee 2002). Dietary lipid levels might have considerable influence on the effect of protein on the growth and normal well-being of fish. To the best of our knowledge, this is the first report on the effects of varying dietary protein and lipid levels on growth, feed utilization, body composition, and metabolic enzymes of *O. bimaculatus* fingerlings. In the presently reported study, the maximum weight gain and SGR were noticed in *O. bimaculatus* fingerlings fed the diet P40L05 with 40% crude protein and 5% lipid. However, SGR and FCR did not vary significantly from the fish fed diet with 35% crude protein and 10% lipid (P35L10). Therefore, improved growth and feed utilization efficiency associated with increasing lipid content of the diet from 5% to 10% at

the 35% dietary protein level might indicate the protein-sparing effect of dietary lipid in *O. bimaculatus* fingerlings, as suggested elsewhere (Sagada et al. 2017). Such protein-sparing effect was also noticed in several fish species, including bagrid catfish (*Pseudobagrus fulvidraco*) (Kim and Lee 2005), blunt snout bream (*Megalobrama amblycephala*) (Li et al. 2010), Asian catfish (*Pangasius hypophthalmus*) (Liu et al. 2011), juvenile northern snakehead fish (*Channa argus*) (Sagada et al. 2017), and Juvenile Yellow Drum (*Nibea albiflora*) (Wang et al. 2018).

In the present report, an increase of crude protein from 35% (with 10% lipid) to 45% did not cause significant improvement in fish growth and feed utilization efficiency. This could be an indication that the minimal amino acid requirement was met at 35% protein and beyond which excess protein might be extravagantly converted to energy and nitrogenous excreta. Similar observations were documented in previous reports on diverse fish species (Sagada et al. 2017; Tu et al. 2015), including fingerlings of *O. bimaculatus* (Biswas et al. 2020). Further, SGR tended to decrease and FCR tended to increase with increasing the lipid levels from 5% to 15% in the diets with higher levels of protein (40% and 45%). This might indicate that elevating the dietary lipid levels from 5% to 15% did not induce protein-sparing action in *O. bimaculatus* fingerlings fed diets with ≥ 40% dietary protein. In accordance to our report, Wang et al. (2013) indicated that golden pompano (*Trachinotus ovatus*) reared in net pens attained higher weight gain (%) at the dietary lipid level of 6.5% than at 12.5% when fed with varying dietary protein levels (33%–50%). Similarly, juveniles of ayu (*Plecoglossus altivelis*) (Lee, Jeon, and Lee 2002) and flounder (*Paralichthy solivaceus*) (Lee and Kim 2005) exhibited faster growth at the dietary crude lipid levels of 6.0%–6.5% than at 13%–19%. Thus, as in the presently reported study, previous works also confirmed that protein-sparing action could not be sustained beyond certain levels of dietary protein and lipid (Sagada et al. 2017). Furthermore, the present study recorded a marginal improvement in weight gain (%) with increasing the protein level from 35% (diet P35L10, 10% lipid) to 40% (diet P40L05, 5% lipid). Incorporation of 40% crude protein for *O. bimaculatus* was in agreement with the protein requirement of catfish, as reported previously (BIS 2014).

Growth is extremely influenced by digestive and absorptive physiology, which affects utilization of the ingested nutrients in an organism (Sagada et al. 2017). The capability of fish to efficiently utilize a given diet could be apprehended by the activity of digestive enzymes and their responsiveness toward diverse dietary compositions (Pérez-Jiménez et al. 2009). Thus, adaptations of the digestive enzymes to feeding and related metabolic alterations might be used as a clue for formulation of nutritionally effective diets (Lundstedt, Melo, and Moraes 2004). However, to the

authors' knowledge, diet-related changes in the activity of digestive enzymes in the butter catfish fingerlings appears to be mostly unexplored and warrants more insight for better understanding of the relationship between digestive as well as metabolic enzymes and growth performance. In the presently reported study, increasing dietary protein and lipid levels were inversely proportional to dietary carbohydrate content and associated with a decrease in α-amylase activity. Our study was in accordance with the results obtained in hybrid catfish (*Clarias batrachus* × *C. gariepinus*) fed diets with high protein levels (Giri et al. 2003) and contradicted with African catfish *C. gariepinus* (Ali and Jauncey 2004). The present study noticed to enhance alkaline protease activity with increasing dietary protein levels, which was in agreement with the preceding reports on hybrid catfish (*Clarias batrachus* × *C. gariepinus*) (Giri et al. 2003), spotted sorubim (*Pseudoplatystoma corruscans*) (Lundstedt, Melo, and Moraes 2004), silver barb (*Puntius gonionotus*) (Mohanta et al. 2008), and rice field eel (*Monopterus albus*) (Ma et al. 2014). Thus, it could be suggested that dietary protein levels might ascertain protease secretion and augment proteolytic activities in the digestive tract (Huang, Zhao, and Luo 2013). Although results on the acid protease activity recorded in the present study did not comply with this hypothesis, it was similar to the observation of Santos et al. (2020) depicting an increase in the CP level from 36% to 42% associated with a decrease in acid protease activity. On the contrary, protease activity was not significantly affected by dietary protein levels in gibel carp (*Carassius auratus gibelio*) (Ye et al. 2015) and juvenile northern snakehead fish (*C. argus*) (Sagada et al. 2017). Several studies reported a positive correlation between intestinal lipase activity and dietary lipid levels (Sagada et al. 2017; Wang et al. 2018). However, in the present study, lipase activity didn't differ significantly with increasing lipid contents at higher CP levels, supporting our observation that there was no protein-sparing effect of lipid in juvenile *O. bimaculatus* at ≥ 40% dietary protein level.

The present study evaluated activities of some key metabolic enzymes to appraise consequences of the varying dietary protein-lipid levels in juvenile *O. bimaculatus*. Neoglucogenesis is an important pathway for glucose homeostasis, where glucose is synthesized from noncarbohydrate precursors (e.g., amino acid, glycerol, lactate). The present study recorded increased activities of the neoglucogenic enzymes (G6P and FBP) with an increase in both dietary protein and lipid levels. Enhanced activity of the neoglucogenic enzymes noticed in this study linked with reduced activity of digestive amylase might indicate production of glucose by neoglucogenesis so as to accomplish the energy demand in *O. bimaculatus*, which is supposed to be a carnivorous fish (Paul et al. 2021). The major glycolytic enzyme, HK, was not significantly affected by the varying dietary protein and lipid levels in the present study.

However, activity of another glycolytic enzyme PK decreased and neoglucogenic enzyme FBP increased with an increase in the dietary protein, which was in accordance with the observation made by Wang et al. (2018) in brown trout (*Salmo trutta fario*).

The lipogenic enzyme, G6PD, catalyzes the first step of the HMP-shunt (pentose phosphate pathway) generating NADPH for lipid biosynthesis and stress management (Pandolfi et al. 1995). The present study noticed around 10 times higher activity of G6PD than that of ME with an increase in dietary protein levels, suggesting that NADPH production for lipogenesis is mainly obtained from the pentose-phosphate pathway (Sá, Pousão-Ferreira, and Oliva-Teles 2007). Further, activity of the G6PD was inhibited in the present study by an increase in the dietary lipid, which was similar to the observations recorded in brown trout (*Salmo trutta fario*) (Wang et al. 2018) and Senegalese sole (*Solea senegalensis*) (Guerreiro et al. 2012). In contradiction, Sá, Pousão-Ferreira, and Oliva-Teles (2006) couldn't detect a significant effect of dietary protein or lipid levels on G6PD activity in White sea bream (*Diplodus sargus*). ME is associated with NADP-dependent oxidative decarboxylation (malate to pyruvate and carbon dioxide) generating NADPH that is likely to be utilized for lipid biosynthesis; GDH is considered a sensitive stress indicator (Paul et al. 2021; Susan et al. 2010). ME and GDH activities were more or less unaffected by the dietary protein and lipid levels, which was consistent with the findings of Wang et al. (2018) in brown trout. Consequently, results of the present study might suggest that increasing dietary lipid at the same protein level could neither improve lipogenesis nor induce stress in *O. bimaculatus* fingerlings.

ALT and AST are the main transaminases in fish liver (Sá, Pousão-Ferreira, and Oliva-Teles 2007). In the present study, activities of the amino acid-catabolizing (ALT and AST) enzymes were influenced by the dietary protein and lipid levels. The activities of ALT and AST were proportional to the increasing dietary protein levels, which was similar to the observations made by Sá, Pousão-Ferreira, and Oliva-Teles (2007) in White Sea bream and Wang et al. (2018) in brown trout. Increased ALT and AST activities might be indicative of increased protein catabolism at high dietary protein levels corroborated with the increased activities of alkaline proteases. Further, increased dietary lipid at the same protein level was associated with a decrease in the activities of both ALT and AST, suggesting use of lipid as an energy source along with reduced catabolism of protein. Similar observations were reported in other species, e.g., *Sparus aurata* (Fernández et al. 2007) and *Salmo trutta fario* (Wang et al. 2018).

Increasing dietary lipid levels might have a significant effect on the carcass quality of fish (Cowey 1993). The presently reported study noticed an increased accumulation of body lipid with an increase in the dietary

lipid contents at each protein level. Similar effects were also detected in numerous species, e.g., rockfish (*Sebastes schlegelii*) (Lee, Jeon, and Lee 2002), Eurasian perch (*Perca fluviatilis*) (Mathis, Feidt, and Brun-Bellut 2003), bagrid catfish (*P. fulvidraco*) (Kim and Lee 2005), cobia (*Rachycentron canadum*) (Craig, Schwarz, and McLean 2006), Malabar grouper (*Epinephelus malabaricus*) (Williams 2007), brown-marbled grouper (*Epinephelus fuscoguttatus*) (Shapawi et al. 2014), and juveniles of snakehead fish (*Channa argus*) (Sagada et al. 2017). In contrast, Paul et al. (2011) could not detect any difference in carcass lipid in another species of butter catfish (*O. pabda*) by feeding different levels of lipid. In the present study, the diets containing the maximum protein level were not associated with the highest whole body protein in *O. bimaculatus* fingerlings, which was comparable with the other findings (Rahimnejad et al. 2015; Tuan and Williams 2007). On the contrary, several studies suggested a significant increase in the body protein content with the increase in the dietary protein level (Chen et al. 2010; Wang et al. 2016). Further, whole body moisture and ash contents of *O. bimaculatus* fry in the present study were not affected by the dietary treatments. In accordance, varying dietary protein and lipid levels did not have any effect on whole body ash content of the grouper (*E. fuscoguttatus*) (Shapawi et al. 2014). Although numerous studies indicated a decrease in whole body moisture content with increasing dietary protein (Sagada et al. 2017; Wang et al. 2016) and lipid levels (Lim et al. 2009; Luo et al. 2005; Sagada et al. 2017).

Conclusion

Considering the highest weight gain (%) and SGR (% per day), the lowest FCR, and 95% survivability achieved with the diet P40L05 together with the carnivorous nature of the species, it may be concluded that 40% crude protein with 5% lipid was optimum for the growth and feed utilization of *O. bimaculatus* fingerlings. In addition, since no protein-sparing effect of lipid in juvenile *O. bimaculatus* was noticed beyond the 35% dietary protein level, excessive dietary lipid should be avoided for economic diet formulation as well as health concerns (Craig, Schwarz, and McLean 2006). Variations in some key intermediary metabolic enzymes owing to alterations in the dietary components recorded in the present study might suggest high metabolic adaptability of this species to the varying dietary protein and lipid levels. Moreover, information generated on growth, body composition, and digestive as well as metabolic function of the butter catfish fingerlings might aid in the formulation of practical diets for captive rearing of the highly valued catfish *O. bimaculatus*.

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SL. NO. 14

DEVELOPMENT OF LARVAL DIET FOR *Ompok bimaculatus* A HIGH VALUE FISH OF REGIONAL IMPORTANCE

FINAL PROJECT REPORT

DURATION: 01/04/2017 - 31/03/2020

ICAR-Central Institute of Freshwater Aquaculture
(ISO 9001:2015 Certified Institute)
(Indian Council of Agricultural Research)
RRC,Rahara, 700118,West Bengal

ANNEXURE -VI

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

CHECKLIST FOR SUBMISSION OF FINAL RESEARCH PROJECT REPORT (RPP-III)

(For Guidelines Refer ANNEXURE – XI (F))

1. Institute Project Code: I-95-G

2.Investigators as approved in RPP-I, If any change attach IRC proceedings:

Principal Investigator	CC-PI	Co-PI
Dr. B.N.Paul		Dr. S Adhikar Dr.P.P.Chakrabarti Dr. N Mandal Mr. A Das Dr. K Ghosh (Burdwan University)

3.Any change in objectives and activities No
(If yes, attach IRC proceedings)

	Date of Start & Date of Completion (Actual). If any extension granted enclose IRC proceedings		Yes	
	Whether all objectives met		Yes	
	All activities completed		Yes	
	Salient achievements/major recommendations included		Yes	
	Annual Progress Reports (RPP-II) submitted	1st Year	Yes	
		2nd Year	Yes	
		3rd Year	Yes	
		nth year		No
	Reprint of each of publication attached		Yes	

	Action for further pursuit of obtained results indicated	Yes	No
	Report presented in Divisional seminar (enclose proceedings & action taken report)	Yes	No
	Report presented in Institute seminar (enclose proceedings & action taken report)	Yes	
	IRC number in which the project was adopted	IRC No: I-95-G	
	Any other Information		

4.Signature:

Project Leader	Co-PI	Co-PI	Co-PI	Co-PI
(Dr. B.N. Paul)	(P.P. Chakrabarti)	(Dr. S. Adhikari)	(Dr. R.N. Mandal)	(Mr. A. Das)

Co-PI

(Dr. K. Ghosh)

HOD/PD/I/c.

ANNEXURE – VII

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
FINAL RESEARCH PROJECT REPORT (RPP- III)
(For Guidelines Refer ANNEXURE – XI(G))

1. Institute Project Code : I-95-G
2. Project Title: **Development of Larval diet for *Ompok bimaculatus*, a high- valued fish of regional importance**
3. Key Words: *Ompok bimaculatus,*Ontogeny, larvae, egg, enzyme,larval diet and nutrient composition
4. (a) Name of the Lead Institute : ICAR-Central Institute of Freshwater Aquaculture,
5. (b) Name of Division/ Regional Center/ Section: Regional Research Center, ICAR-CIFA, Rahara

   (a) Name of the Collaborating Institute(s): University of Burdwan

   (b) Name of Division/ Regional Center/ Section of Collaborating Institute(s)

   Dept. of Zoology, Burdwan Rajbati, Raiganj, Burdwan, West Bengal 713104
6. Project Team(Name(s) and designation of PI, CC-PI and all project Co-PIs, with time spent)

Sl. No.	Name, designation and institute	Status in the project (PI/CC-PI/ Co-PI)	Time to be spent (%)	Work components assigned to individual scientist
1	Dr. B.N.Paul	PI	50	Planning, Nutrient analysis, evaluation of larval feed, data analysis and reporting
2.	Dr.P.P.Chakrabarti	Co-PI	25	Brood stock development of high value species
2	Dr. S Adhikari	Co- PI	25	Water quality parameters and reporting.
3	Dr. R.N Mandal	Co-PI	25	Production of Live food organisms ,data analysis and reporting

4	Mr. A Das	Co-PI	25	Production of larvae, Evaluation of larval feed, data analysis and reporting
Collaborating University: University of Burdwan, West Bengal				
5.	Dr. K. Ghosh	Co-PI	25	Ontogeny study of larvae and enzyme analysis.

7. Priority Area: Aquaculture Diversification.

8. Project Duration: Date of Start – **01.04.2017**

Date of Completion – **31.03.2020**

9. a. **Objectives**

1. To study nutrient composition of egg and different stages of larvae

2. To study the ontogeny of larval development.

3. To formulate larval feed and evaluation

b**. Practical utility**

Ompok bimaculatus, popularly known as the 'butter catfish', is a freshwater teleost species native to the South-East Asia. It is piscivorous as well as carnivorous fish. Due to its air-breathing nature, it could become a very good candidate species for stocking small, shallow seasonal ponds and tanks which are oxygen-deficient and could grow to required marketable size in just 6months. Over the years, the natural occurrence of this fish species has been depleted due to some anthropogenic activities and hence it has been listed under Near Threatened (NT) category of IUCN Red List (2010). This fish has a high commercial value and preferred in Eastern and North-Eastern India. *O. bimaculatus* was also declared as the State Fish of Tripura in the year 2007.The captive breeding of *O. bimaculatus* has opened a new road map for successful aquaculture of the species. During its metamorphosis, larval rearing is a big challenge. The larval stage is a critical stage in fish life cycle that necessitates an appropriate exogenous nutrition once the embryonic yolk is used up. Research has been carried out over the few decades to reduce the period over which live pray must be used, using better understanding of larval behavior and physiology and

improvement in microparticle formulation. The success of larval rearing is greatly influenced by first feeding regimes and the nutritional quality of starter diets. Thus to domesticate the species larval rearing is a bottleneck, especially the larval feed. Thus the present proposal is aimed at development of larval feed for *O. bimaculatus* so that the mortality will be reduced and more stocking material would be available for successful growout of *O. bimaculatus.*

Keeping in view of the above concept an attempt has been taken up to domesticate *Ompok bimaculatus* in terms of its understanding of larval nutrition and feed development.

Collaborating University: University of Burdwan

10. Final Report on the Project (materials and methods used, results and discussion, objective wise achievements and conclusions)

1. **Material** : *Ompok bimaculatus*

2. **Techniques/Methodology** :

3. The larval feed development for the *O. bimaculatus* is critical as the species requires exogenous nutrition once the embryonic yolk is exhausted. The development of exogenous larval feed is very essential at this stage. The study of ontogeny of larvae will give a guideline ragarding the enzyme status and metamorphosis of its digestive system. Co-feeding strategy to be evolved

for proper feeding of the larvae with natural and formulated feed. Further the exogenous formulated feed will be developed for the larvae.

4. Sample Analysis:

5. The samples were collected as per the method of Sankar (2010).The nutrient analysis of brood fish, egg and larvae and feed samples were done as per AOAC (2005). Water quality was studied as per APHA (2005).

6. Fatty acid analysis:

7. Extraction of pooled samples for fatty acid analysis was done as per Folch *et al*. (1957). Preparation of Fatty acid Methyl Esters (FAME) was done as per Metcalfe *et al.* (1966). The prepared samples were quantified by injecting into Gas Chromatograph (GC) (Perkin Elmer; CLARUS 480). GC operating software 'Total Chrom' was used and identification of individual Fatty Acid was done by comparison of retention time to those of standards (SUPELCO, Cat.No. 47885-U). Data were subjected to statistical analysis as per Snedecor and Cochran (1994) and the least significance difference (LSD) was used for comparison of the mean values.

Gas Chromatograph (GC) (Perkin Elmer; CLARUS 480).

8.

9. Enzyme assay: Digestive enzymes was assayed as per Reitman and Frankel (1957).

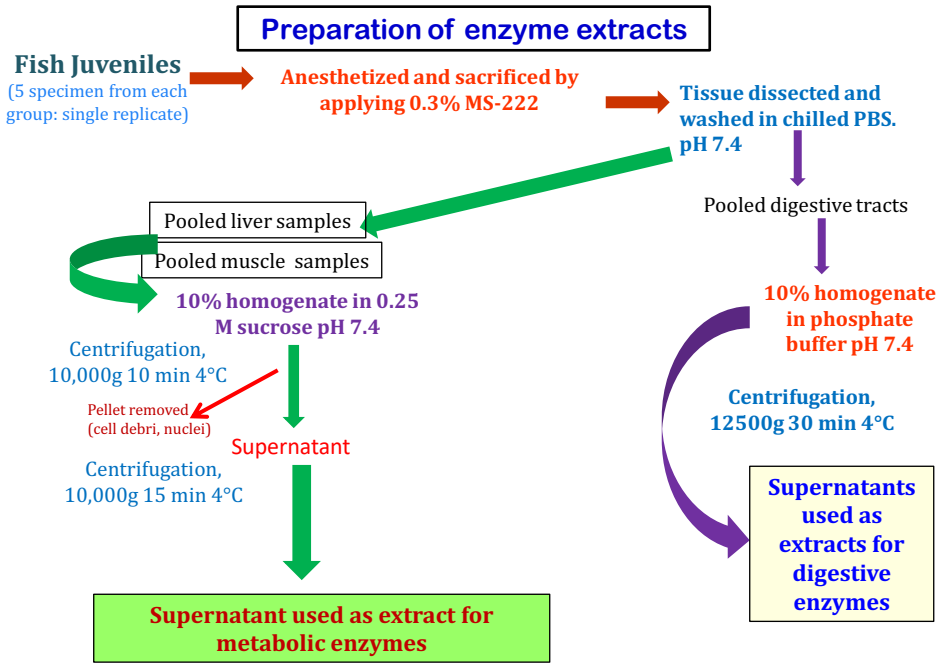
1. Protease, amylase and lipase activities was measured after Walter (1984), Bernfeld (1955) and Bier (1955), respectively
2. Estimation of trypsin and chymotrypsin activity according to Erlanger et al. (1961)
3. Apart from digestive enzymes, the following metabolic enzymes were studied as key enzymes of the major metabolic pathways:

Glucose 6 phosphate dehydrogenase (De Moss, 1955), cytosolic NADP malate dehydrogenase (Hsu and Lardy, 1967), mitochondrial NAD malate dehydrogenase (Englard and Siegel, 1969), alanine

transaminase (Reitman and Frankel,1957), aspartate transaminase (Reitman and Frankel, 1957), glucose-6-phosphatase (Marjoric, 1964), fructose- 1,6-bisphosphatase (Freeland and Harper, 1959) and hexokinase (Tranulis et al., 1996)

4. Changes in the profile of proteolytic enzymes through ontogeny was studied through separation and characterization of proteases by substrate SDS-PAGE after Garcıa-Carreno et al. (1993).

Average live weight gain (%), specific growth rate (SGR: % day−1), feed conversion ratio (FCR), protein efficiency ratio (PER) and apparent net protein utilization (ANPU%) were worked out as per (Steffens, 1989).



7

Objective1. To study nutrient composition of egg and different stages of larvae

Nutrient composition Egg, Brood fish and Larvae

The proximate and fatty acid composition of *Ompok bimaculatus* (pabda) brood fish, egg and larvae was assayed to have an insight of the nutrient metamorphosis during early life of the species and vis-à-vis parental nutrient composition. The collected brood fish, eggs and larvae were analyzed for proximate and fatty acid composition.

The brood fish and its egg were collected from ICAR-Central Institute of Freshwater Aquaculture, Kalyani field station. Soon after hatching the *O. bimaculatus* larvae were also collected from Kalyani Field Station. The collected samples of brood fish, egg and larvae of ompok were iced immediately and sent for analysis. Sampling procedure and sample preparation was done as per the standard methodology of Sankar *et al.* (2010).

The proximate composition of Pabda brood, egg and larvae are presented in Table 1. The data revealed that the crude protein, fat and ash content of brood fish, egg and larvae were 14.4±0.07, 25.90±0.20, 12.23±0.88; 1.06±0.07, 0.64±0.15, 0.42±0.04 and 2.33±0.05, 1.61±0.10 and 1.79±0.04 (%) respectively.. The studies revealed that the crude protein content was significantly ($P<0.01$) higher in pabda egg however moisture, crude lipid and total ash (%) was significantly ($P>0.01$) lower pabda egg. The result of the study also concluded that the moisture, crude lipid and total ash (%) was significantly ($P<0.01$) higher in pabda brood.

Table 1: Proximate composition of Brood pabda, egg and larvae

Particulars	Brood Pabda	Pabda Egg	Pabda Larvae
Moisture	80.09 ± 0.64^{b}	61.84 ± 1.40^{a}	82.02 ± 0.62^{b}
Crude Protein	14.44 ± 0.07^{a}	25.90 ± 0.20^{b}	12.23 ± 0.88^{a}
Crude Fat	1.06 ± 0.07^{b}	0.64 ± 0.15^{a}	1.61 ± 0.10^{a}
Total Ash	2.33 ± 0.05^{b}	1.61 ± 0.10^{a}	1.79 ± 0.04^{a}

Data presented as Mean± S.E. Superscripts ^{ab} in a row differs significantly ($P<0.01$)

Table 2: Fatty acid (% of total fatty acid) composition of Pabda brood, egg and larvae

Particulars	Pabda brood	Pabda Egg	Pabda Larvae
Butyric Acid	0.02 ± 0.01^{a}	0.01 ± 0.001^{a}	2.08 ± 0.05^{b}
Myristic acid (C14:0)	0.12 ± 0.01^{a}	0.22 ± 0.03^{a}	4.03 ± 0.57^{b}
Palmitic acid (C16:0)	87.81 ± 1.53^{b}	66.15 ± 0.77^{a}	22.52 ± 0.64^{a}
Arachidic acid (C20:0)	0.2 ± 0.03^{a}	0.05 ± 0.001^{a}	2.31 ± 0.12^{b}
Others	0.33 ± 0.02^{a}	9.59 ± 0.19^{b}	17.85 ± 0.52^{c}
ΣSFA	88.48 ± 0.66^{c}	76.02 ± 0.98^{b}	48.6 ± 0.66^{a}
Pentadecanoic acid (C15:1)	0.62 ± 0.05^{b}	0.4 ± 0.001^{a}	1.29 ± 0.015^{c}
Oleic acid (C18:1n9c)	0.61 ± 0.001^{a}	12.08 ± 0.09^{c}	4.29 ± 0.08^{b}
Elaidic acid (C18:1n9t)	6.03 ± 0.02^{a}	ND	11.02 ± 0.1^{b}
Others	0.41 ± 0.02^{a}	1.43 ± 0.07^{b}	1.42 ± 0.02^{b}
ΣMUFA	7.67 ± 0.12^{a}	13.91 ± 0.24^{b}	18.02 ± 0.02^{c}
Linolelaidic acid (C18:2n6t)	0.02 ± 0.01^{a}	0.06 ± 0.01^{a}	7.03 ± 0.08^{b}
Linoleic acid (C18:2n6c)	1.89 ± 0.09^{b}	4.25 ± 0.09^{c}	0.47 ± 0.01^{a}
ϒ-Linolenic acid (C18:3n6)	0.05 ± 0.01^{a}	0.43 ± 0.02^{b}	0.56 ± 0.02^{c}
α-Linolenic acid (C18:3n3)	0.1 ± 0.01^{a}	0.21 ± 0.01^{b}	1.58 ± 0.045^{a}
Eicosadienoic acid (C20:2)	0.28 ± 0.006^{a}	0.51 ± 0.01^{b}	1.4 ± 0.01^{c}
Eicosatrienoic acid (C20:3n6)	0.64 ± 0.02^{a}	1.68 ± 0.02^{b}	11.17 ± 0.06^{c}
Eicosatrienoic acid (C20: 3n3)	ND	0.05 ± 0.01^{a}	0.32 ± 0.02^{b}
Arachidonic acid (C20:4n6)	ND	0.07±0.01	ND
EPA (C20:5n3)	0.73 ± 0.03^{b}	0.23 ± 0.01^{a}	2.71 ± 0.01^{c}
DHA(C22:6n3)	0.8 ± 0.02^{a}	2.56 ± 0.04^{b}	6.87 ± 0.03^{c}
ΣPUFA	4.52 ± 0.03^{a}	10.05 ± 0.02^{b}	33.35 ± 0.40^{c}
ω 3	1.63 ± 0.06^{a}	3.05 ± 0.04^{b}	11.5 ± 0.02^{c}
ω 6	2.6 ± 0.07^{a}	6.49 ± 0.08^{b}	19.23 ± 0.01^{c}

Data presented as Mean± S.E. Superscripts ^{abc} in a row differs significantly ($P<0.05$)

ND: Not detected

Haul of pabda brood fish at Kalyani Field Station

Brood fish (*O. bimaculatus*)

***O.bimaculatus* brood fish**

The fatty acid profile obtained by GC analysis are presented in Table 2. The fatty acid composition revealed that the saturated fatty acid (SFA) content (% of total fatty acid) of brood pabda, eggs and larvae were 88.48%; 76.04% and 48.60%. Among the MUFA, oleic acid and elaidic acid was significantly ($P<0.05$) higher in pabda larvae. The poly unsaturated fatty acid (PUFA) content (% of total fatty acid) of brood pabda, eggs and larvae were 4.5%; 10.05% and 33.35% respectively in brood fish, egg and larva. The EPA and DHA contents were 2.71% and 6.87% in larve; which was significantly ($P<0.05$) higher in comparison to brood fish (EPA-0.73% and DHA-0.80%) and egg (EPA-0.23% and DHA-2.56%). Among PUFA, total ω-3 content was 1.63, 3.05 and 11.5 (%) respectively in pabda brood, egg and larvae

The studies regarding nutritional characterization of brood fish, eggs and larvae of *Ompok bimaculatus* revealed that crude protein content was higher in egg whereas crude fat and ash content was higher in brood fish. However, PUFA, EPA and DHA content was higher in larvae.

Objective 2. To study the ontogeny of larval development.

The Ontogeny of *Ompok bimaculatus* was studied with the hatched larvae at ICAR-CIFA, Kalyani field station.he ontogeny and enzyme study was done at Burdwan University, which is the collaborating University in the project.The digestive tract of *O. bimaculatus* comprised of a straight tube dorsally attached to the yolk sac. Table 3. Describes the ontogeny development of *O.bimaculattus* larvae. It was observed that at 2 day post hatching (dph) mouth opened, teeth were visible and exogenous feeding started. The yolk sac disappeared within 3 dph. In course of the study, *O. bimaculatus* larvae were fed *Artemia* nauplii from 2 dph mixed zooplankton and chopped Tubifex during 4–7 dph, and only chopped Tubifex from 7 dph onwards.

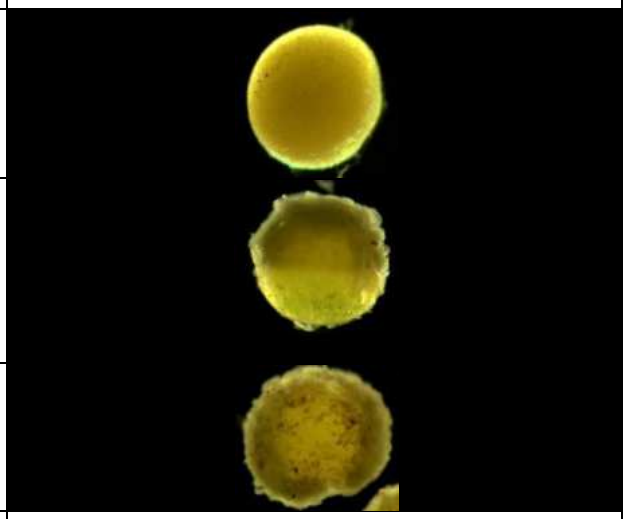
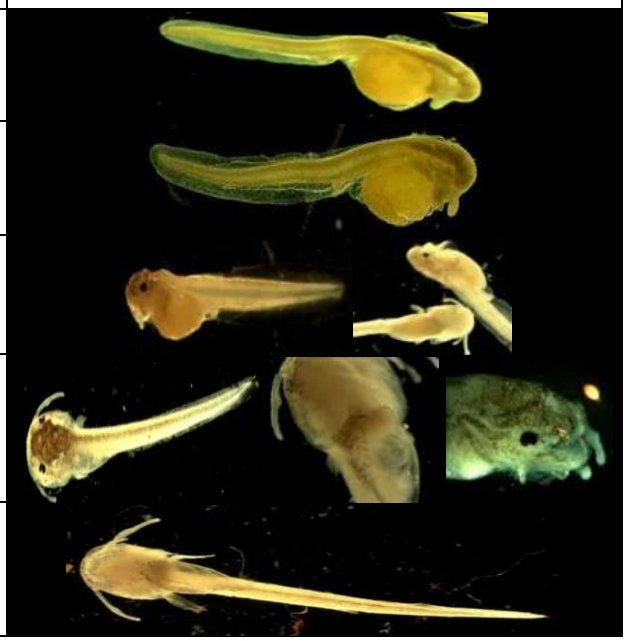
Catching of hatched out *O.bimaculatus* larvae

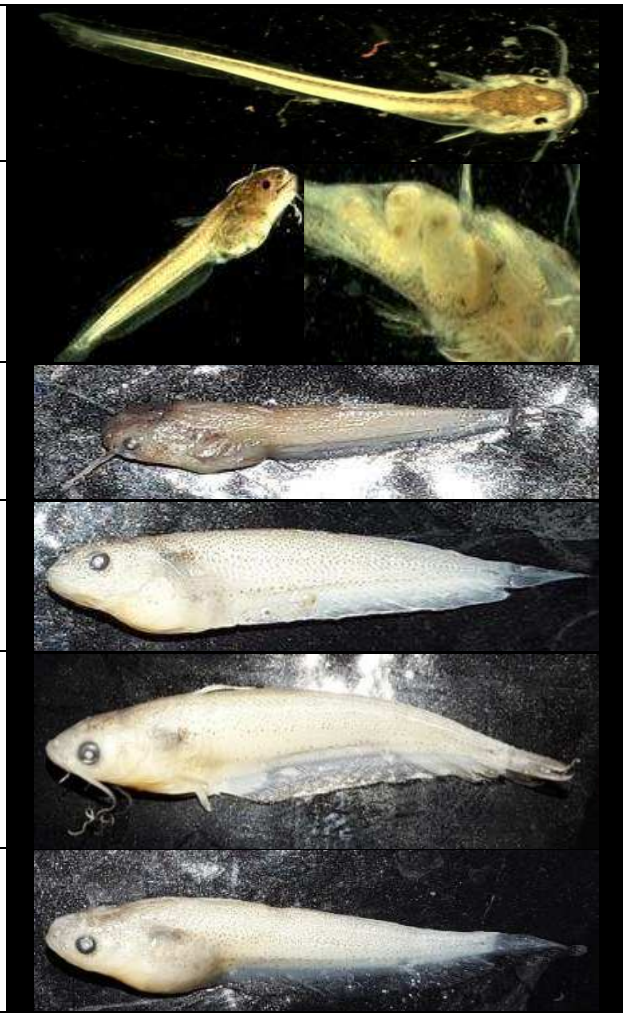
Collection of *O. bimaculatus* larvae

Collection of *O. bimaculatus* larvae

Collection of *O. bimaculatus* larvae

Table 3. Ontogeny: study of morphology

Time	Observation	Photograph(s)
3 hour post fertilization (HPF)	Gastrulation starts	
5:30 HPF	Dorsal (prospective head) and ventral (prospective tail) ends cover half of the egg; embryonic shield observed; ectoderm expands through epiboly	
8 HPF	Head and tail buds appear close together and cover entire yolk	
11 HPF	First movement starts near anal region; movement proceeds through tail region and tail detaches from yolk; eye spot becomes prominent.	
14 HPF	Embryo rotates circularly and outer layer of egg expands; anterior portion of head detaches from yolk	
15:30 HPF	Tail becomes visible outside the egg case	
17 HPF	Hatching starts and larva emerges from egg case; larval weight 0.5 mg, length 0.3 cm	
6 hour post hatching (HPH)	Anal opening becomes prominent and head becomes condensed	
1 day post hatching (DPH)	Larva with yolk sac and small barbells; weight 0.9 mg, length 0.5cm	
2 DPH	Yolk sac almost absorbed and mouth opens, teeth become visible; weight 1.20 mg, length 0.5-0.6 cm	
3 DPH	Weight 1.45 mg, length 0.8cm	

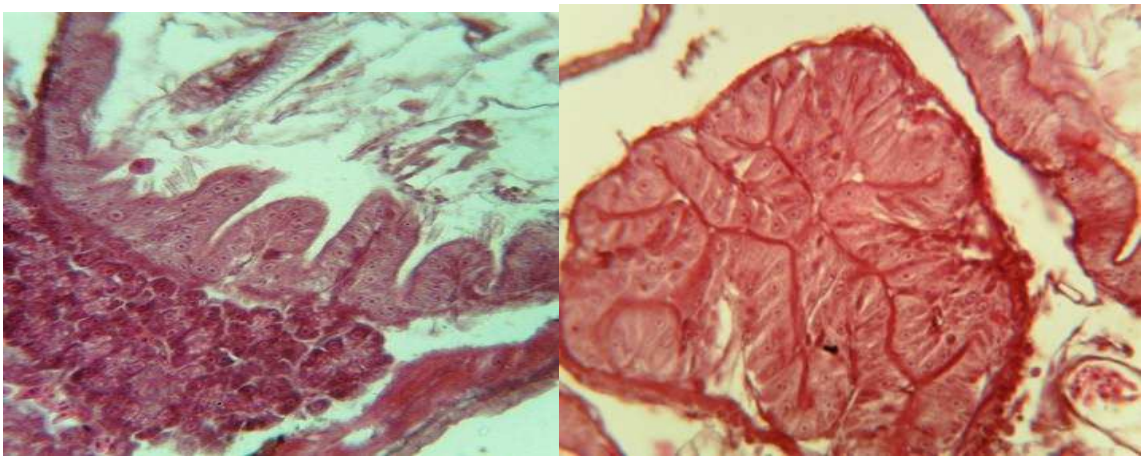
4 DPH	Fin rays become prominent; weight 3.4 mg, length 1 cm	
8 DPH	Intestine coiled and stomach divided; weight 62.6 mg, length 1.4 cm	
12 DPH	Weight 92.4 mg, length 1.7 cm, barbell 0.3 cm, gape of mouth 0.2 cm	
16 DPH	Weight 131.1 mg, length 2.4 cm, barbell 0.6 cm, gape of mouth 0.3 cm	
20 DPH	Weight 141.4 mg, length 3.2 cm, barbell 0.8 cm, gape of mouth 0.4 cm	
24 DPH	Weight 214.4 mg, length 4.5cm, barbell 1.0 cm, gape of mouth 0.6 cm	

Sample collection at Kalyani Field station

Sample preparation for enzyme analysis

Enzyme assay at the University of Burdwan

Figure 1. Ontogeny: histological study



A **B**

Fig: (A) Section of intestinal villi with food particles and (B) section of non glandular stomach at 7 day post hatching

Table 4. Digestive enzymes activities of *O. bimaculatus* from day 4 to day 24.

Day post hatching	Amylase	Total Protease	Trypsin	Chymotrypsin	Pepsin	Lipase
4	12.73±0.62	2.19±0.15	0.45±0.02	0.26±0.02	0.09±0.08	1.89±0.02
8	14.56±0.73	1.40±0.20	0.60±0.02	0.48±0.02	0.26±0.01	2.17±0.11
12	19.53±0.78	3.31±0.14	1.29±0.04	0.87±0.03	0.34±0.02	8.0±0.12
16	13.76±0.63	1.59±0.21	1.01±0.04	0.67±0.02	0.57±0.02	4.84±0.08
20	9.98±0.42	1.80±0.12	1.38±0.04	0.72±0.03	0.74±0.02	5.16±0.06
24	15.78±0.75	2.43±0.08	1.58±0.05	0.92±0.06	1.19±0.53	5.92±0.06

1. Trypsin and chymotrypsin activities (U) = 1µmol of 4-nitroaniline liberated min^{-1} mg^{-1} protein
2. Lipase activity (U) = 1µmol of free fatty acid liberated min^{-1} mg^{-1} protein
3. α-amylase activity (U) = µg maltose liberated min^{-1} mg^{-1} protein
4. Protease activity (U) = µg tyrosine liberated min^{-1} mg^{-1} protein
5. Pepsin activity (U) = µg tyrosine liberated min^{-1} mg^{-1} protein

Figure 2. Protein enzymes activity of *O. bimaculatus* larvae

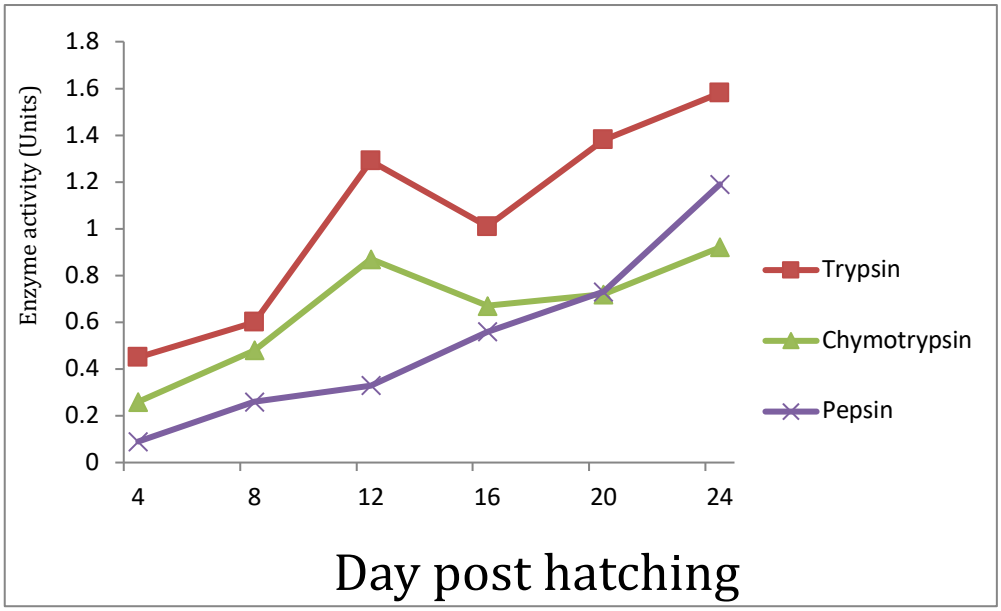


Figure 3. Digestive enzymes activity of *O. bimaculatus* larvae

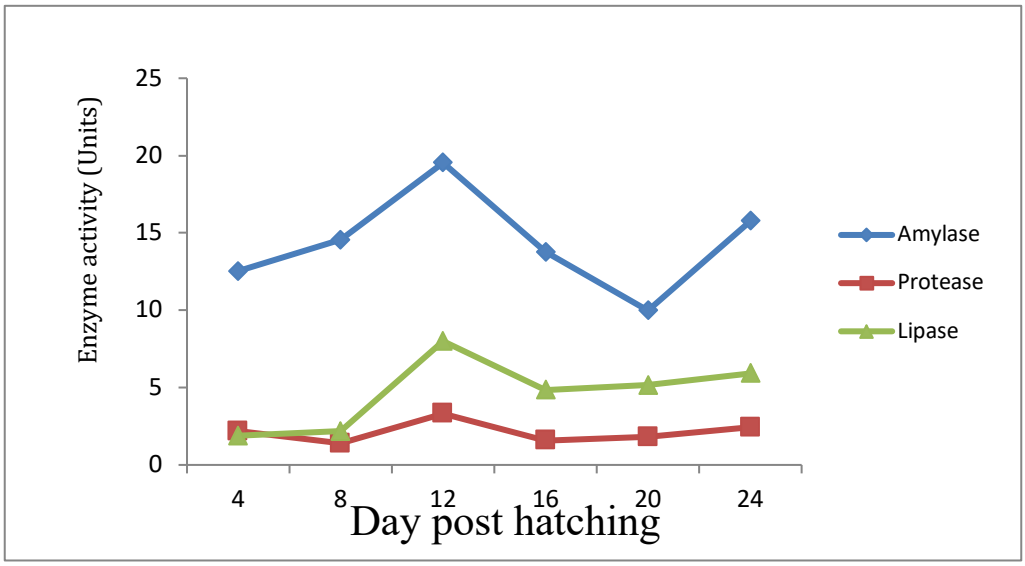


Figure 2 & 3 and table 4 describes the protein and digestives enzymes activity of *O. bimaculatus* larvae from day 4 to 24. Ther is gradual increase in the activity of the acid protease (pepsin) was noticed after formation of stomach, i.e. 8th day onward. Activities of amylase, lipase, trypsin and chymotrypsin were also detected in course of development post hatching

The activity of digestive enzymes indicated that enzymes involved in the digestion of proteins, lipids and carbohydrates were present in *O. bimaculatus* larvae since hatching (Figure 4 & 5), except pepsin. Coiling of intestine and presence of stomach were noticed by 8 dph, which was marked with the appearance of pepsin. Activities of the amylase, trypsin and chymotrypsin were increased initially after the onset of exotrophic phase, and decreased thereafter during 12 to 20 dph corresponding to the increase of pepsin. Thus, a change in the digestive physiology was indicated by progressive shift in the activity from alkaline (trypsin and chymotrypsin) to acid (pepsin) proteases.

Figure 4. Digestive Enzymes activities of *O. bimaculatus* larvae

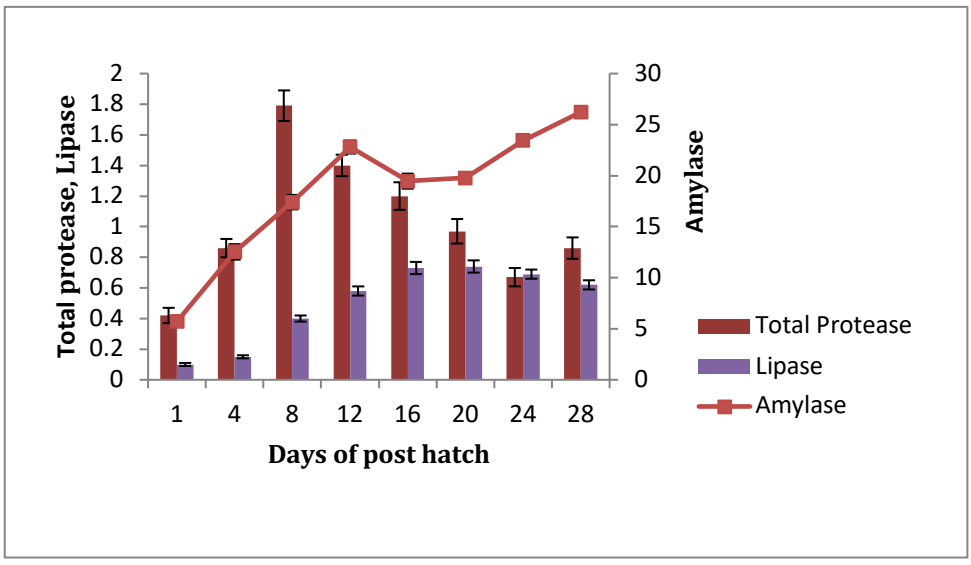


Figure 5. Protein enzymes activities of larvae

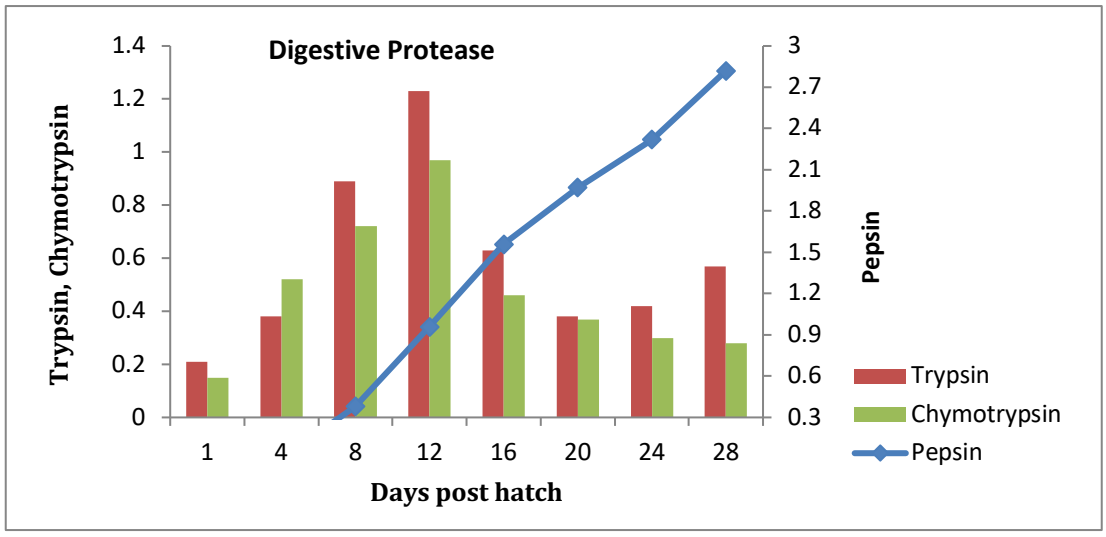


Figure 6. Carbohydrate metabolism enzymes of *O. bimaculatus* larvae

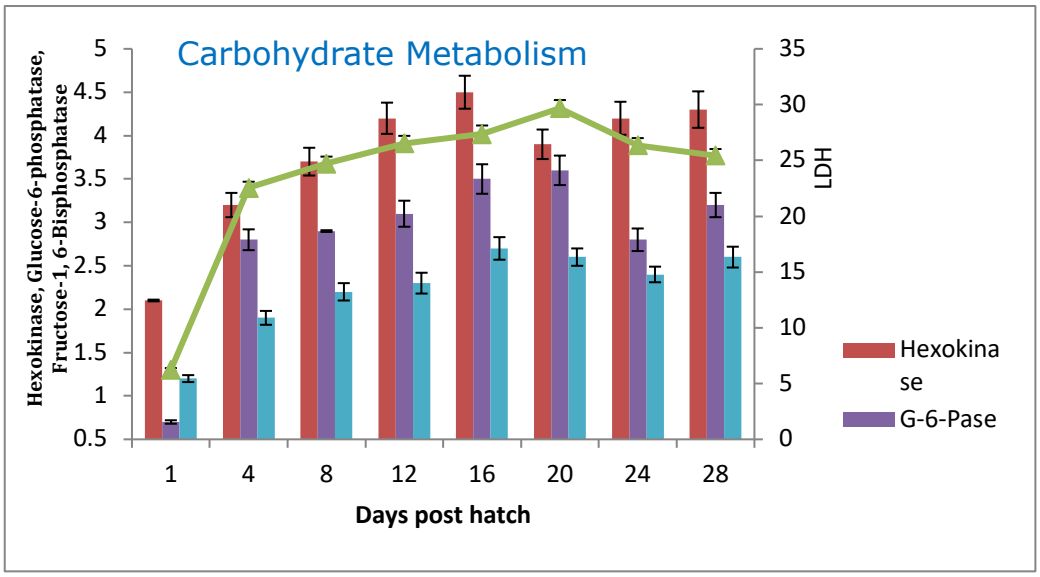


Figure 7. Amino Acid metabolism enzymes of larvae

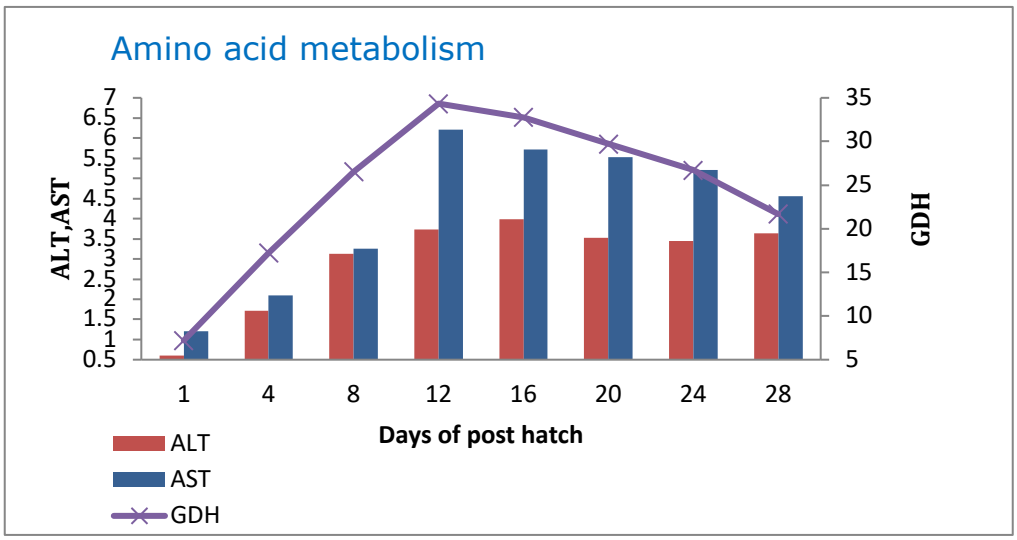


Figure 8. Carbohydrate Metabolic Enzymes of *O. bimaculatus* larvae

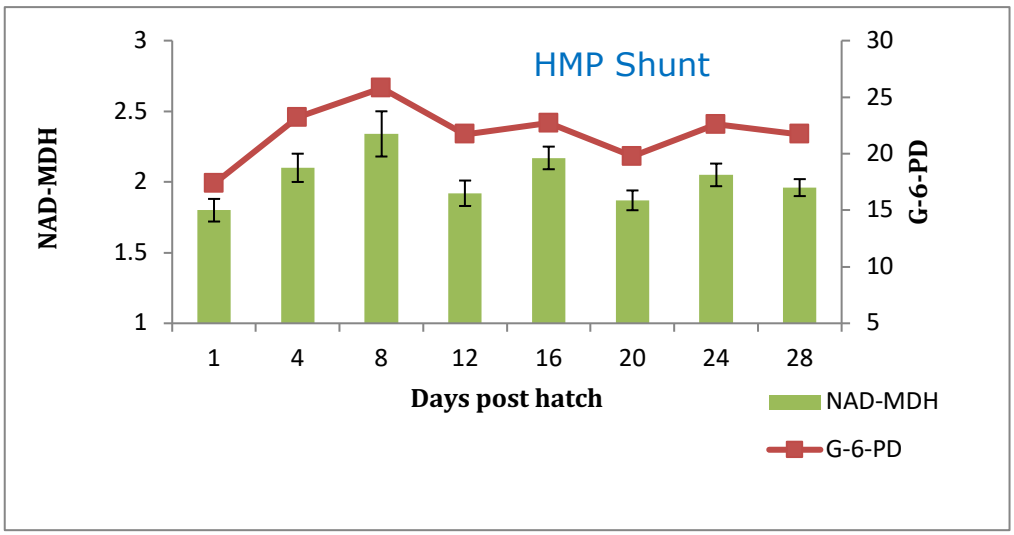


Figure 6, 7 and 8 shows the metabolic enzymes activities of *O. bimaculatus* larvae. The increase in Lactate dehydrogenase (LDH) activity from 4 to 20 dph was noticed, that could be indicative of stress. During this phase, increase in the activities of neoglucogenic enzymes (Glucose-6-phosphatase, Fructose-1, 6-bisphosphatase) was also noticed. However, a decreasing trend of LDH was apparent with increase in the Hexokinase

activity. Further, augmented Mitochondrial NAD-glutamate dehydrogenase activity coupled with increased Aspartate transaminase (and Alanine transaminase) at 12 dph was noticed signifying protein catabolism during this phase. Reduced neo glucogenic pathway at 4-8 dph was associated with high Glucose-6-phosphate dehydrogenase and cytosolic NADP-malate dehydrogenase activities that might indicate stress management and lipogenesis in this species during early development.

Activities of the enzymes indicated ontogenetic shift during the period of 8 to 20 dph, which could be associated with changes in food, gut morphology and shift in the activity pattern of digestive and metabolic enzymes. Overall, enzyme activities remained more or less stable beyond 20 dph.

Objective 3. To formulate larval feed and evaluation

Experiment No. 1: Feed evaluation with different levels of protein:

An experiment was conducted for 22 days initiated to study the protein requirement of *O. bimaculatus* larvae. The initial weight and length of *O. bimaculatus* larvae were 0.11±0.01 g and 20.49±0.70 mm. In the present experiment 3 formulated feeds were prepared with different graded levels of protein viz., Feed 1 (35%), Feed 2 (40%) and Feed 3 (45%). Fish meal, ground nut cake, soybean meal, wheat flour, vitamin and mineral mix and oil were used as feed ingredients in different proportions for preparation of experimental feed.

The feed formulations and proximate compositions of different feeds are presented in Table 5. The protein content of different feeds was 35.33±2.55, 40.69±0.55 and 45.23±0.17 respectively in Feed 1-3. Different proportions of fish meal, ground nut cake, soyabean meal, wheat flour etc were used to prepare the feed. Because of the graded increase in protein levels, the total ash contents of diets increased linearly from 15.40±0.39 to 16.37±0.39, which could be attributed to the presence of higher levels of fish meal as a major feed ingredient.

Water quality parameters were recorded as 28-30^{0}C, 7.4-7.8, 5.0-5.8 mg/l and 235-240mg/l $CaCO_3$ for temperature, pH, dissolved oxygen and total alkalinity respectively. Dissolved oxygen play a vital role in rearing of larvae because larvae require optimum level of oxygen for sustaining their physiological condition

The growth performance of *Ompok* larvae feed with different levels of Protein (Table no 6). Initially the larvae were fed with natural food and their formulated feed. The initial body weight, net weight gain, specific growth rate, feed conversion ratio, protein efficiency ratio and survivability are shown in Table 6. The initial weight of larvae were 0.11±0.004, 0.106±0.004 and 0.106±0.004 (g) in different feed Treatments (Feed 1-3) respectively while the average final weights after 22 days of experimental period was 0.34±0.06, 0.91±0.15 and 0.36±0.07 (g) in the respective treatments. The net weight gain were 0.23±0.05, 0.81±0.15 and 0.26±0.06 (g)respectively in Feed 1-3, which showed that the highest gain in weight of the larvae was 0.81±0.15 (g) in treatment Feed 2 followed by Feed 1 and Feed 3 . The net weight gain was significantly ($P<0.01$) higher in Feed 2 (Table 6 and Fig 9). The survival (%) was 73.0±2.02, 71.0±1.0 and 59.0±4.7 respectively in Feed 1-3. Significantly higher specific growth rate (SGR) was observed in Feed 2 and followed by Feed 1 and Feed 3. The final weight, net weight gain and

specific growth rate was significantly (P<0.05) higher in Feed 2 compared to those of Feed 1 and Feed 3. The value of feed conversion ratio (FCR) was significantly (P>0.05) lower in Feed 2 while protein efficiency ratio (PER) was non-significant among all the Feed treatments. Lowest FCR in Feed 2 indicated that lower amount of feed needed to produce one unit of fish biomass. So lower the FCR is, better the efficiency of the feed is and such type of feed in the present experiment was Feed 2.

Table 5. Ingredients and proximate composition (%DM basis) of experimental diets

Particulars	Feed 1	Feed 2	Feed 3
Fish Meal	44	53	65
Ground nut cake	15	15	15
Soyabean Meal	10	10	5
Wheat flour	19	10	03
CMC	2	2	2
Vit. & min. Mixture	5	5	5
Veg oil	5	5	5
Proximate Composition (% DM basis)			
Dry Matter	93.02±0.93	92.39±0.22	92.34±1.33
Crude Protein	35.33±2.25	40.69±0.55	45.23±0.17
Crude lipid	9.11±0.47	9.49±0.31	9.61±0.31
Total ash	15.40±0.39	16.35±0.09	16.37±0.39

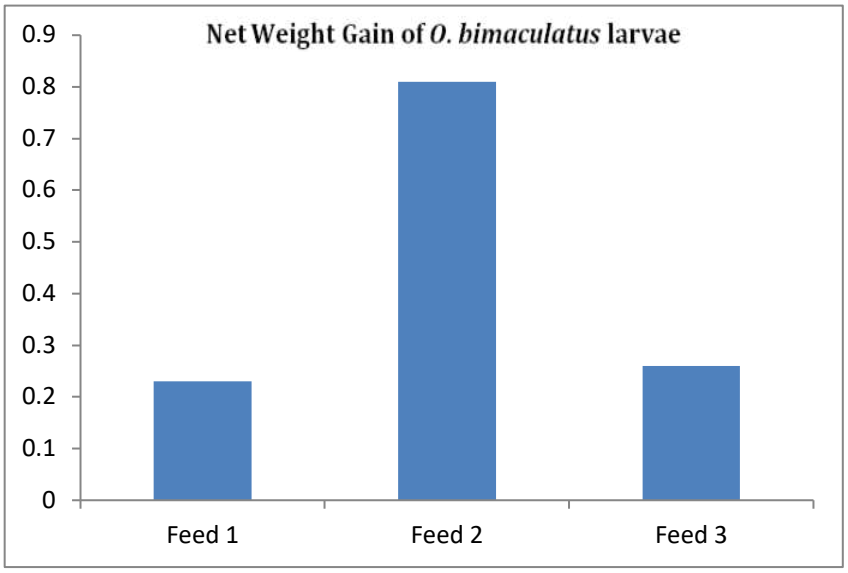
Data are presented as Mean± S.E. CMC- Carboxy methyl cellulose.

Table 6. Growth of *O.bimaulatus* larvae fed with different levels of Protein.

Particulars	Feed 1	Feed 2	Feed 3
Initial weight(g)	0.11±0.004	0.106 ±0.008	0.106±0.008
Final weight(g)	0.34 ± 0.06^{a}	0.91 ± 0.15^{b}	0.36 ± 0.07^{ab}
NWG(g/22d)	0.23 ± 0.05^{a}	0.81 ± 0.15^{b}	0.26 ± 0.06^{a}
SGR(%/d)	4.54 ± 0.60^{a}	7.97 ± 0.76^{b}	5.30 ± 0.53^{a}
FCR	3.62 ± 0.51^{b}	1.93 ± 0.43^{a}	3.68 ± 0.35^{b}
PER	0.82±0.13	1.42±0.33	0.62±0.05
Survivability	73.5±2.02	71.0±1.0	59.0±4.7
DNA(µg/mg)	30.59±0.30	34.31±0.43	31.04±0.54
RNA(µg/mg)	34.86±0.41	45.16±0.36	35.65±0.31
RNA/DNA	1.14±0.07	1.32±0.04	1.15±0.04

Data are presented as Mean± S.E. ^{a,b} Means with different superscripts in a row differ significantly ($P<0.01$)

Figure. 9. Net weight gain of *O.bimaculatus* fed with different levels of Protein



Sampling of *O.bimaculatus* larvae

Weight measurement

Length measurement

Table 7. Enzyme contents of *O. bimaculatus* larvae fed with different levels of Protein

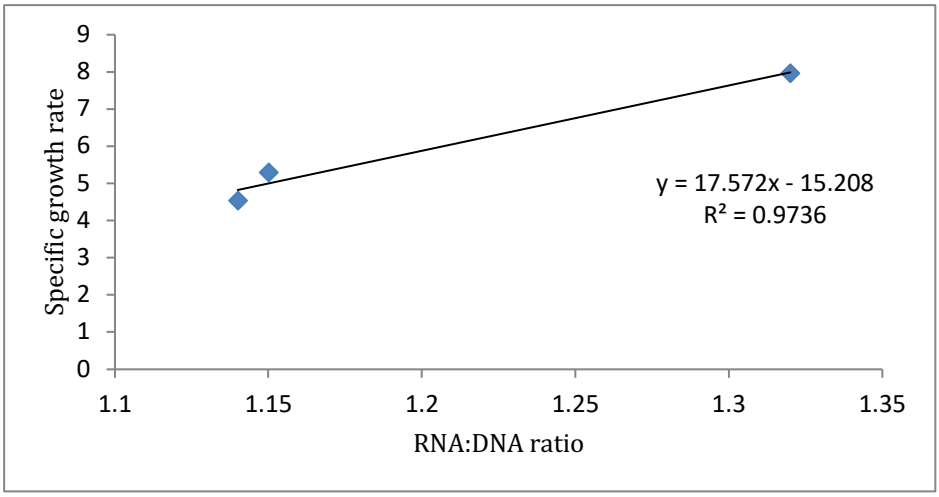
Particulars	Initial	Feed 1	Feed 2	Feed 3
Amylase*	17.4±0.33^{a}	23.87±0.17^{b}	25.36±0.34^{c}	25.46±0.47^{c}
Total Protease$^{¥}$	1.76±0.03^{d}	0.67±0.02^{a}	0.81±0.01^{b}	0.73±0.01^{c}
Lipase$^{\#}$	0.4±0.01^{a}	0.57±0.02^{b}	0.69±0.03^{d}	0.61±0.02^{c}
Pepsin$^{¥}$	0.38±0.01^{a}	2.53±0.02^{b}	2.67±0.01^{c}	2.49±0.01^{b}
Trypsin¶	0.89±0.02^{d}	0.20±0.01^{a}	0.18±0.02^{a}	0.26±0.03^{c}
Chymotrypsin¶	0.72±0.02^{c}	0.29±0.02^{b}	0.19±0.01^{a}	0.28±0.03^{b}
ALT(Alanine transaminase) $^{€}$	3.14±0.03^{a}	3.44±0.02^{b}	3.51±0.02^{c}	4.25±0.02^{d}
AST(Aspartate transaminase) ^{ƨ}	3.24±0.02^{a}	4.61±0.03^{c}	4.38±0.01^{b}	5.12±0.02^{d}

Data are presented as Mean± S.E. ^{a,b} Means with different superscripts in a row differ significantly (P<0.05)

* mg maltose liberated mg^{-1} protein h$^{-1,}$ $^{¥}$µg of tyrosine liberated mg^{-1} protein min^{-1}, $^{\#}$ µM of fatty acid liberated mg^{-1} protein min^{-1}, ¶1µmol of 4-nitroaniline liberated min^{-1} mg^{-1} protein Enzyme activity units mg^{-1} protein min^{-1}, $^{€}$ µM of pyruvate formed mg^{-1} protein min^{-1}, ^{ƨ} µM of oxaloacetate formed mg^{-1} protein min^{-1}

Perusal of table 7 reveals that Amylase activity of feed 1 was significantly differed from feed 2 and feed 3 diet. Lipase and pepsin activity was significantly (P<0.05) higher in feed 2. Trypsin and Chymotrypsin activity significantly (P>0.05) lower in feed 2. ALT and AST activities changes were significantly (P<0.05) higher in Feed 3 but both AST and ALT activities were significantly (P>0.05) lower in feed 2.

Figure 10. Relation between SGR and RNA-DNA ratio in *O. bimaculatus* Larvae



The DNA, RNA and RNA/DNA ratio of larvae was non significant among the fed treatments. . The Relationship between SGR and RNA/DNA ratio in *O. bimaculatus* has depicted that RNA/DNA ratio was highly correlated with Feed 2 having 40% protein vis-à-vis other Groups(Figure 10). The present experiment revealed that 40% crude protein was sufficient for the optimum growth and survival of *O. bimaculatus* larvae and it also revealed that the amylase, lipase and pepsin enzymes was significantly ($P<0.05$) higher in Feed 2 having 40% protein.

Experiment No. 3: Feed evaluation with Lipid requirement for *Ompok bimaculatus* larvae

An experiment was conducted 42 days to study the lipid requirement of *O. bimaculatus* larvae. The initial weight and length of *O. bimaculatus* larvae were 0.15±0.003 g and 22.65±1.70 mm. In the present experiment 3 formulated feeds were prepared having different lipid levels viz., Feed 1 (4.5%), Feed 2 (7.0%) and Feed 3 (9.5%).

The Proximate composition and feed formulation is presented in Table 8. The feed ingredients viz., fish meal, ground nut cake, soyabean meal, wheat flour, fish and vegetable oil (1:1) and vitamin and mineral mixture were used in different proportions for preparation of feed. Perusal of table 8 reflects that the protein content of different feeds were 40.46±0.06, 40.18±0.49 and 40.61±0.83 (%) respectively in Feeds1-3. The analysed lipid content of different feeds were 5.7±0.2, 8.0±0.25 and 10.45±0.45 respectively in Feed treatments 1-3.

Experimental work at wet Laboratory of RRC, Rahara

Table 8: Feed formulation and proximate composition (%DM Basis)

Particulars	Feed 1	Feed 2	Feed 3
FM	53	53	53
GNOC	15	15	15
SBM	10	10	10
Wheat flour	10.50	8.0	5.50
CMC	2.0	2.0	2.0
Fish :Veg oil (1:1)	4.5	7.0	9.5
Vit-Min mix	5	5	5
Proximate composition (%DM Basis)			
Dry matter	92.85±0.06	92.37±0.23	92.06±0.05
Crude protein	40.46±0.06	40.18±0.49	40.61±0.83
Crude lipid	5.7±0.2	8.0±0.25	10.45±0.45
Total Ash	14.4±0.3	15.4±0.2	16.5±0.3

Fig. 11: Net weight gain of *O. bimaculatus* larvae fed with different lipid levels

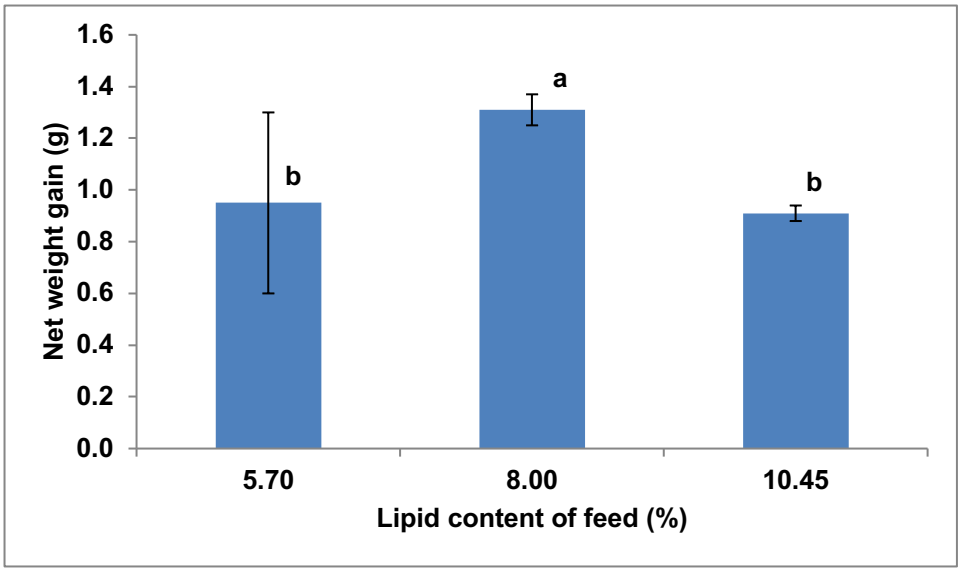


Table 9: Growth Performance of *O. bimaculatus* larvae fed with different level of lipids

Particulars	Feed 1	Feed 2	Feed 3
Initial Weight (g)	0.15±0.003	0.14±0.01	0.15±0.01
Final Weight (g)	1.10±0.12^{a}	1.40±0.07^{b}	1.06±0.03^{a}
Net weight gain (g/42d)	0.95±0.12^{a}	1.31±0.06^{b}	0.91±0.03^{a}
Specific Growth Rate (%/day)	4.73±0.35^{a}	5.50±0.05^{b}	4.66±0.22^{a}
DGC	0.73±0.02^{a}	1.003±0.05^{b}	0.76±0.09^{a}
Survivability (%)	83.85±6.15	83.85±6.15	79.55±5.46
FCR	1.86±0.10^{b}	1.39±0.05^{a}	1.74±0.07^{b}
PER	1.31±0.09^{a}	2.39±0.17^{b}	1.30±0.08^{a}

Data are presented as Mean± S.E. ^{a,b} Means with different superscripts in a row differ significantly (P<0.01)

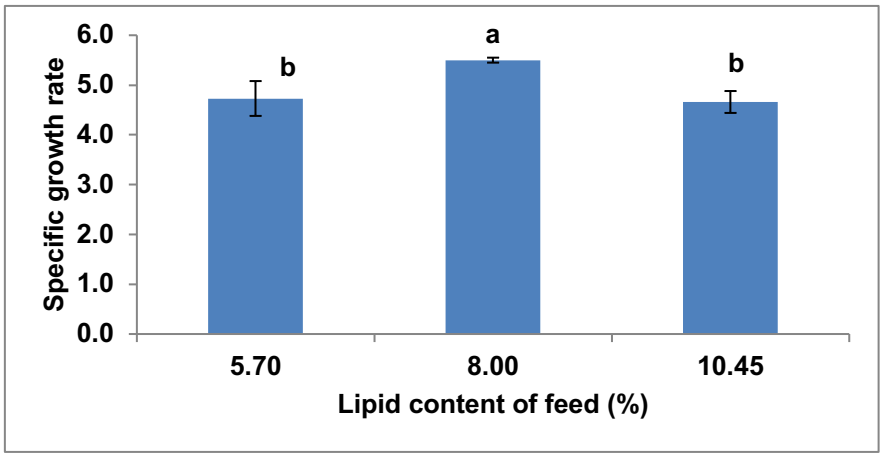
Sampling of *O. bimaculatus* larvae

The water quality parameters were: temp 28-30^{0}C, pH 6.8-7.7, dissolved oxygen 6.8-74 mg/l and total alkalinity 230-240 mg/l. Perusal of Table 9 shows the growth performance of *O. bimaculatus* larvae reared with different lipid levels. The final weight of fish were 1.10±0.12, 1.40±0.07 and 1.06±0.03 g respectively in Feed 1-3. The final weight was significantly (P<0.01) higher in Feed 2 having 8 % lipid. The net weight gain were 0.95±0.12, 1.31±0.06 and 0.91±0.03 (g) respectively in feed treatments Feed 1-3 (Figure 11). The specific growth rate (SGR) were 4.73±0.35, 5.50±0.05 and 4.66±0.22 respectively in Feed 1-3. The net weight gain, DGC and specific growth rate was significantly (P<0.05) higher in Feed 2 having 8% lipid. The Survivability

(%) were 83.85±6.15, 83.85±6.15 and 79.55±5.46 respectively in Feeds 1-3. The feed conversion ratio (FCR) were1.86±0.10, 1.39±0.05 and 1.74±0.07 in Feed treatments 1-3. He FCR was significantly (P< 0.05) lower in Feed 2 group.

***O.bimaculatus* larvae after 42 days of experiment**

Fig. 12: Specific Growth rate of *O. bimaculatus* larvae reared with different lipid levels



The protein efficiency ratio (PER) were 1.31±0.09, 2.39±0.17 and 1.30±0.08 respectively in Feed 1-3. The protein efficiency ratio was significantly (P<0.05) higher in Feed 2 (Figure 12).

Recording of length of pabda larvae Recording of weight of pabda larvae

Table 10 Carcass composition (% as such) of *O.bimaculatus* larvae fed different level of lipid

Particulars	Feed 1	Feed 2	Feed 3
Moisture	79.37±0.09^{a}	80.93±0.22^{b}	79.80±0.17^{a}
Crude Protein	13.93±0.09	14.40±0.21	14.03±0.08
Fat	2.50±0.06^{a}	2.90±0.12^{b}	2.77±0.0^{b}
Ash	1.70±0.06	1.97±0.09	1.80±0.06

Data are presented as Mean± S.E. ^{a,b} Means with different superscripts in a row differ significantly (P<0.01)

The carcass composition of *O. bimaculatus* larvae are presented in table 10. Perusal of table 10 reflects that the moisture and fat content carcass tissue of pabda larvae differed significantly (P<0.05) among the feed treatments. The moisture and fat content was significantly higher in Feed 2, and it did not differ significantly with Feed 3. Protein and ash content did not differ significantly among the feed treatments.

Table 11 Digestive enzyme activity of *O.bimaculatus* larvae

Particulars	Feed 1	Feed 2	Feed 3
Amylase$^{\alpha}$	4.42^{b}±0.21	4.02^{b}±0.19	2.92^{a}±0.13
Protease$^{\beta}$	1.42^{b}±0.06	1.54^{b}±0.07	1.26^{a}±0.04
Lipase$^{\pi}$	1.34^{b}±0.05	1.42^{b}±0.06	1.19^{a}±0.07

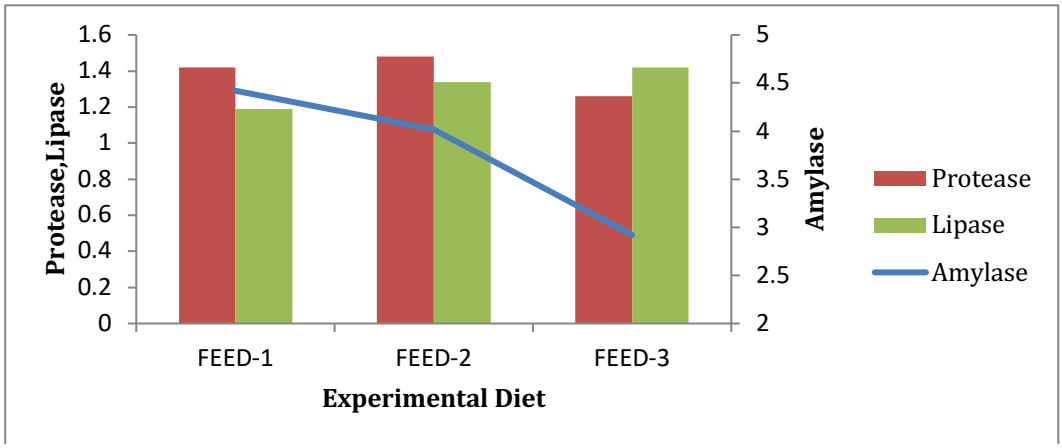
Data are presented as Mean± S.E. ^{a,b} Means with different superscripts in a row differ significantly (P<0.05)

$^{\alpha}$Amylase activity (U) = µg maltose liberated min^{-1} mg^{-1} protein

$^{\beta}$Protease activity (U) = µg tyrosine liberated min^{-1} mg^{-1} protein

$^{\pi}$Lipase activity (U) = 1µmol of free fatty acid liberated min^{-1} mg^{-1} protein

Fig. 13: Digestive enzyme activities of *O. bimaculatus* larvae fed different levels of lipids



The activities of digestive enzymes in *O. bimaculatus* were assayed by feeding different levels of lipids as given in Table 11. The activities of digestive enzymes in pabda larvae revealed that amylase, Protease and lipase activity was significantly ($P<0.05$) higher in F_2 and it did not differ significantly with F_1.

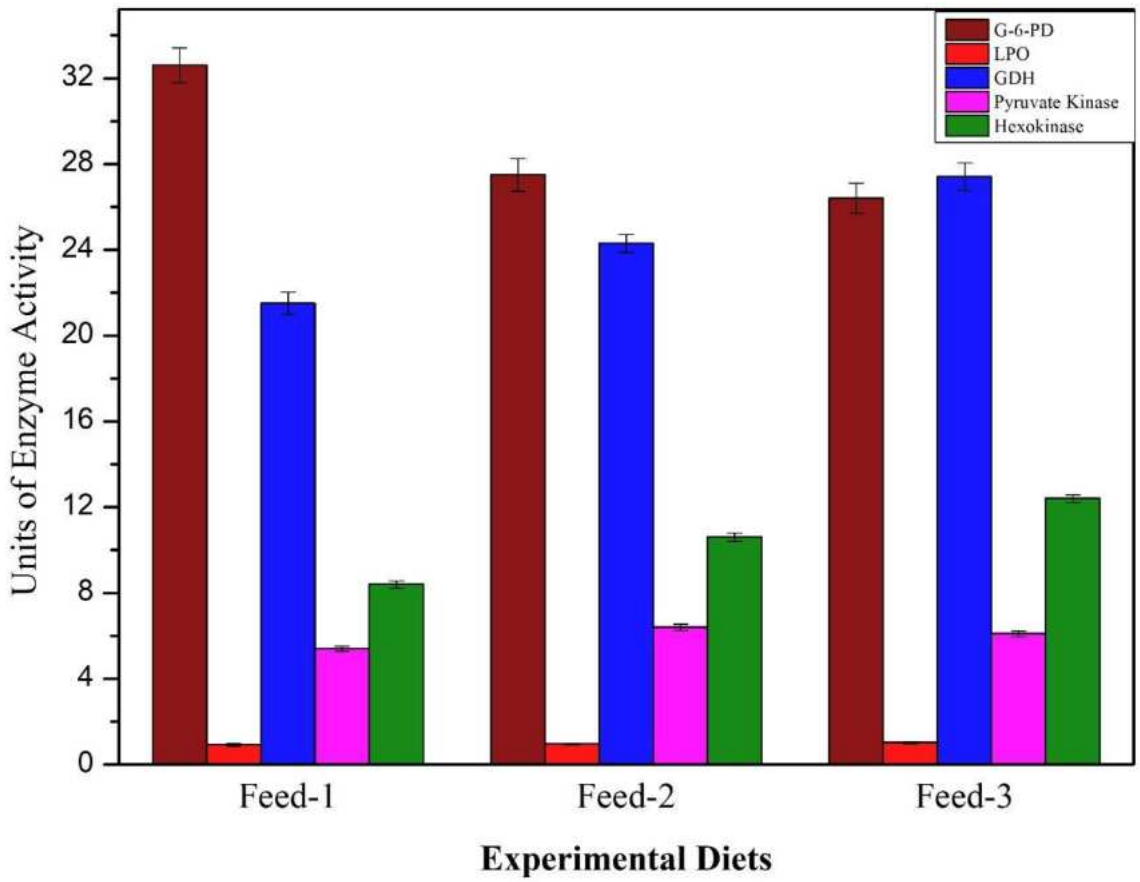
Table 12 Metabolic enzymes of *O.bimaculatus* larvae fed with different levels of lipid

Particulars	Feed 1	Feed 2	Feed 3
Glucose 6 Phosphate Dehydrogenase$^{\alpha}$	$32.6^{a}\pm0.81$	$27.5^{b}\pm0.76$	$26.4^{b}\pm0.7$
Glutamate Dehydrogenase$^{\beta}$	$21.5^{a}\pm0.53$	$24.3^{b}\pm0.42$	$27.4^{c}\pm0.65$
Pyruvate kinase$^{\mu}$	$5.4^{a}\pm0.14$	$6.4^{b}\pm0.14$	$6.1^{b}\pm0.14$
Hexokinase$^{\epsilon}$	$8.4^{a}\pm0.17$	$10.6^{b}\pm0.19$	$12.4^{c}\pm0.17$
Lipid Peroxidation$^{\phi}$	0.92 ± 0.06	0.96 ± 0.04	1.02 ± 0.06

Data are presented as Mean± S.E. ^{a,b} Means with different superscripts in a row differ significantly ($P<0.05$)

$^{\alpha}$G-6-PD(U)& NAD-MDH(U) = µM of NADPH formed mg protein^{-1} h^{-1}
$^{\beta}$GDH(U)= µM of Fomazan formed mg protein^{-1} h^{-1}
$^{\mu}$Pyruvate kinase^{+}µM of NAD formed mg protein^{-1} h^{-1}
$^{\epsilon}$Hexokinase(U)= µM of NAD formed mg protein^{-1} h^{-1}
$^{\phi}$Lipid Peroxidation (U)= µM thiobarbituric acid reactive substance (TBARS) formed mg protein^{-1} min^{-1}

Figure 14. Metabolic enzymes of *O.bimaculatus* larvae fed with different levels of lipid



The metabolic enzymes activity is presented on table 12. Glutamate dehydrogenase and Hexokinase enzyme was significantly ($P<0.05$) higher in larvae fed feed-3. Glucose 6 phosphatase dehydrogeanse and pyruvate kinase was significantly ($P<0.05$) higher in F_2 and it did not differ significantly with F_3. He lipid peroxidation enzyme did not differ significantly among the feed treatments. The present experiment reveals that 8% lipid is sufficient for the optimum growth and survival of *O. bimaculatus* larvae. The present experiment reveals that 8% lipid is sufficient for the optimum growth and survival of *O. bimaculatus* larvae.

Experiment no. 4: Feed evaluation with different feed additives for *O. bimaculatus*

The study aimed at evaluation of animal protein (on wet basis) supplemented to dry formulated feed of the butter catfish, *Ompok bimaculatus* (Bloch) juveniles. Hatchlings were produced by induced breeding of mature *O. bimaculatus* using a hormone analogue (synthetic GnRH) at the Department of Zoology, University of Burdwan, Golapbagh, Burdwan, West Bengal. Juveniles were raised in the laboratory and 30 day old juveniles (0.44±0.02 g) were stocked in five groups in triplicate for 50 days. A formulated basal diet (40% crude protein) was fed to the control group (D1), whereas diets supplemented with (10%, wet weight) blood meals (D2), chicken viscera (D3), egg albumin (D4) and mussel meat (D5) were fed to the experimental groups for 90 days.

Five experimental diets were prepared along with Fish meal, Soya bean meal, Ground nut cake, wheat flour, veg. oil & Vitamin and mineral mixture with 40 % protein. Feeds were prepared, sterilized and stored at -20^0 C and fresh protein sources viz., blood meal,chicken viscera, egg albumin and mussel meat were mixed daily before feeding. The experimental fish were fed twice daily at 09:00h and 15:00h at a fixed feeding rate. Water quality was maintained in all all experimental tanks by daily renewal of 30% of their total volume.

The feed ingredient composition and proximate composition is presented in Table 13. In diet D-2, D-3, D-4 and D-5; animal protein component (10% w/w) viz., Blood Meal (D-2), Chicken Viscera (D-3), Egg albumin (D-4) and Mussel meat (D-5) were supplemented in the control diet. The protein content of different feeds were 40.14±0.55, 40.89±0.41, 41.64±0.67, 41.24±0.54 and 41.56±0.72 (%) respectively in diets D-1 to D-5.

The growth performance and feed utilization efficiencies of *O. bimaculatus* juveniles fed with different animal protein supplements is presented in Table 14 and Figure 15. The final weight were 4.81±0.07, 4.65±0.06, 5.36±0.05, 5.85±0.06 and 5.46±0.04 (g) respectively in diets D-1 to D-5.

Table 13. Ingredient and Proximate composition (% DM) of different Experimental diets

Particulars	D-1	D-2	D-3	D-4	D-5
Fish Meal	53	53	53	53	53
Soybean Meal	15	15	15	15	15
Groundnut cake	10	10	10	10	10
Wheat Flour	10	10	10	10	10
Sunflower oil	5	5	5	5	5
Agrimin (Vit. & Min. Mix.)	5	5	5	5	5
Carboxy methyl cellulose	2	2	2	2	2
Animal protein supplement (10% w/w)	-	Blood Meal	Chicken Viscera	Egg albumin	Mussel Meat
Proximate composition					
Dry Matter	92.39±0.32	92.86±0.41	93.94±0.56	92.95±0.53	93.62±0.74
Crude Protein	40.14±0.55	40.89±0.41	41.64±0.67	41.24±0.54	41.56±0.72
Crude Lipid	9.48±0.31	9.67±0.24	9.64±0.35	9.51±0.47	9.78±0.36
Ash	16.35±0.09	16.45±0.12	16.76±0.04	16.48±0.07	16.53±0.36

The final weight was significantly ($P<0.05$) higher in Diet-4 vis-à-vis other diets. The FCR and SGR were 1.63±0.08, 1.69±0.10, 1.51±0.07, 1.32±0.06 and 1.38±0.06; 2.65±0.06, 2.62±0.05, 2.80±0.4, 2.87±0.07 and 2.78±0.05 respectively in Diets D-1 to D-5. The FCR was significantly ($P<0.05$) lower in D-4 and SGR was significantly higher in D-4.. The ANPU were 24.20±0.45, 22.43±0.35, 26.53±0.52, 33.76±0.47 and 28.28±0.6 respectively in D-1 to D-5. The ANPU was significantly ($P<0.05$) higher in D-4 group.

The diet D4 exhibited better performance in terms of growth, feed conversion ratio, specific growth rate, protein efficiency ratio and apparent net protein utilization. The mortality(%) was significantly lower in D-4 and D-2.

Table14. Growth performances and feed utilization efficiencies in *Ompok bimaculatus*

Particulars	D-1	D-2	D-3	D-4	D-5
Initial weight(g)	0.44±0.20				
Final weight (g)	4.81±0.07^{a}	4.65±0.06^{b}	5.36±0.05^{c}	5.85±0.06^{d}	5.46±0.04^{c}
FCR	1.63±0.08^{b}	1.69±0.10^{b}	1.51±0.07^{a}	1.32±0.06^{a}	1.38±0.06^{a}
SGR	2.65±0.06^{a}	2.62±0.05^{a}	2.80±0.4^{b}	2.87±0.07^{b}	2.78±0.05^{b}
Mortality (%)	17.14±0.71^{b}	14.29±0.10^{a}	18.21±0.71^{b}	14.29±0.12^{a}	21.42±0.95^{c}
ANPU	24.20±0.45^{a}	22.43±0.35^{a}	26.53±0.52^{b}	33.76±0.47^{d}	28.28±0.61^{c}
PER	1.52±0.03^{b}	1.37±0.03^{a}	1.53±0.04^{b}	1.84±0.04^{d}	1.68±0.04^{c}

Data are Means ± Standard error (n=3). Means with different superscript in a row are significant ($P < 0.05$)

The PER were 1.52±0.03, 1.37±0.03, 1.53±0.04, 1.84±0.04 and 1.68±0.04 respectively in diets D-1 to D-5. The PER was significantly ($P<0.05$) higher in D-4 group.

Table 15. Carcass composition of *O.bimaculatus* juveniles feed with different Protein supplements (w/w)

Particulars	D-1	D-2	D-3	D-4	D-5
Moisture	77.37±0.57^{a}	77.17±0.54^{a}	77.99±0.59^{a}	78.23±0.52^{b}	77.93±0.53^{a}
Protein	14.84 ±0.22^{a}	14.98±0.24 ^{a}	15.49±0.26^{b}	16.19±0.27^{c}	15.79±0.28^{b}
Lipid	2.47±0.12 ^{a}	2.46±0.90 ^{a}	2.55±0.14^{b}	2.51±0.10 ^{a}	2.88±0.13^{b}

Data are Mean ± S.E. Means with different superscript in a row are significant ($P < 0.05$)

The carcass composition of juvenile *O. bimaculatus* are presented in Table 15. The moisture and protein content were significantly ($P<0.05$) higher in D-4. However, the lipid content was significantly ($P<0.05$) higher in D-3and D-5. The experimental diet D4 exhibited significantly ($P<0.05$) higher growth, feed conversion ratio, specific growth rate and carcass protein deposition.

Table 16. Activities of enzymes of *Ompok bimaculatus* fed with different feed additives

Enzymes	D-1	D-2	D-3	D-4	D-5
Amylase	11.40 ± 0.52^{a}	16.59 ± 0.62^{b}	17.60 ± 0.54^{b}	16.22 ± 0.53^{b}	12.77 ± 0.54^{a}
Protease	1.13 ± 0.07^{c}	1.32 ± 0.04^{c}	0.79 ± 0.05^{b}	0.55 ± 0.04^{a}	0.54 ± 0.06^{a}
Lipase	1.82 ± 0.04^{a}	1.70 ± 0.04^{a}	2.24 ± 0.05^{c}	2.35 ± 0.06^{c}	2.01 ± 0.04^{b}
Pepsin	3.25 ± 0.06^{a}	3.35 ± 0.07^{a}	3.89 ± 0.09^{b}	4.35 ± 0.12^{c}	4.0 ± 0.10^{b}
Trypsin	0.57 ± 0.04^{c}	0.56 ± 0.06^{c}	0.43 ± 0.05^{b}	0.37 ± 0.05^{a}	0.36 ± 0.04^{a}
Chymotrypsin	0.43 ± 0.05^{b}	0.54 ± 0.06^{b}	0.33 ± 0.04^{a}	0.27 ± 0.05^{a}	0.23 ± 0.05^{a}
Alanine transaminase (ALT)	1.65 ± 0.09^{c}	1.75 ± 0.12^{c}	1.62 ± 0.08^{b}	1.36 ± 0.08^{a}	1.67 ± 0.09^{b}
Asparate transaminase (AST)	5.77 ± 0.12^{b}	6.03 ± 0.14^{c}	5.73 ± 0.10^{b}	5.49 ± 0.13^{a}	5.78 ± 0.08^{b}

Data are Mean ± S.E. Means with different superscript in a row are significant ($P < 0.05$)

Trypsin and chymotrypsin activities (U) = 1µmol of 4-nitroaniline liberated min^{-1} mg^{-1} protein

Lipase activity (U) = µmol of free fatty acid liberated min^{-1} mg^{-1} protein

α-amylase activity (U) = µg maltose liberated min^{-1} mg^{-1} protein

Protease activity (U) = µg tyrosine liberated min^{-1} mg^{-1} protein

Pepsin activity (U) = µg tyrosine liberated min^{-1} mg^{-1} protein

ALT & AST (U) = nmol sodium pyruvate released min^{-1} mg^{-1} protein

The enzymes activities of *Ompok bimaculatus* fed with different feed additives are presented in Table 16 and figure 16 & 17. Activities of amylase and lipase were significantly higher in groups D3 and D4, respectively, as compared to the other groups. Diet D4 sustained the highest pepsin activity (4.35±0.12 U); however, activities of the alkaline proteases (Trypsin, Chymotrypsin) were reduced in fish fed diets D4 and D5. Significantly lower aspartare aminotransferase (AST) and alanine amniotransferase (ALT) activities in the liver were recorded in *O.bimaculatu*s juveniles fed Diets D4 and D5, respectively.

Figure15.GrowthPerformanceof*O.bimaculatus*

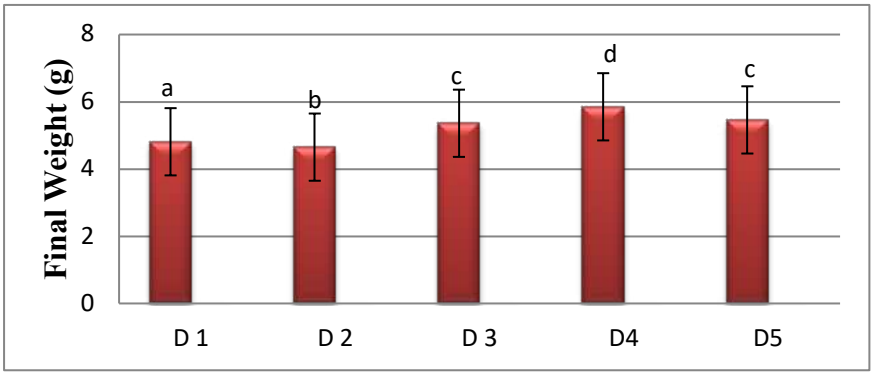


Fig 16. Activities of Protease, Lipase and Amylase in *O. bimaculatus* fed with different Feed additives

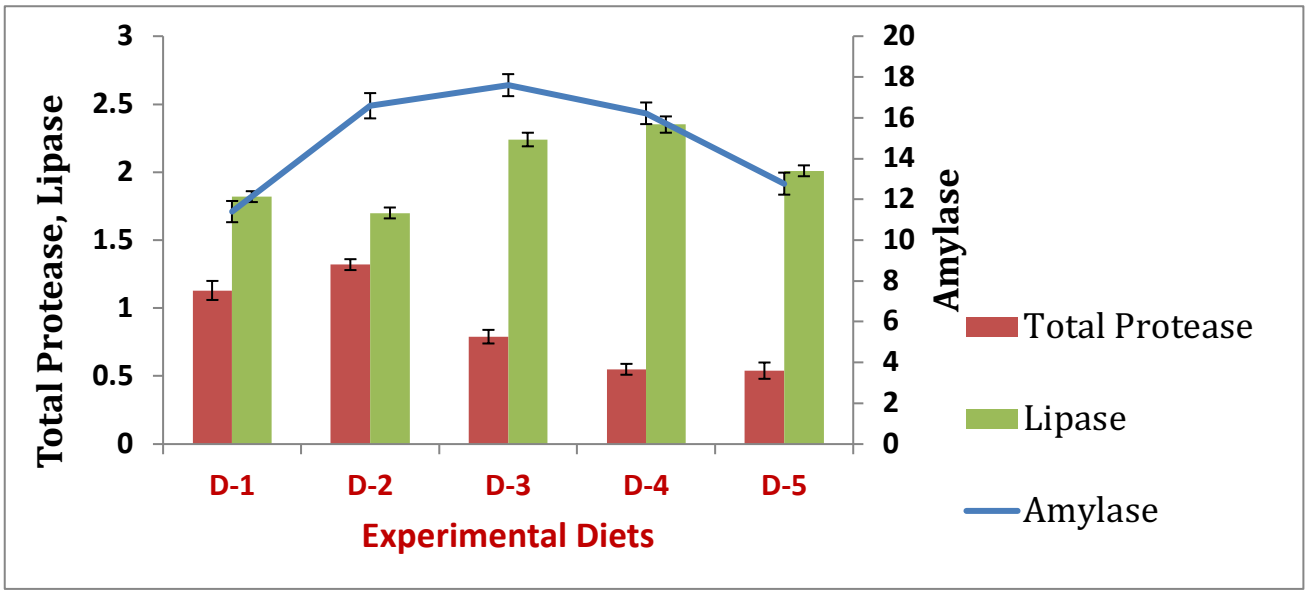
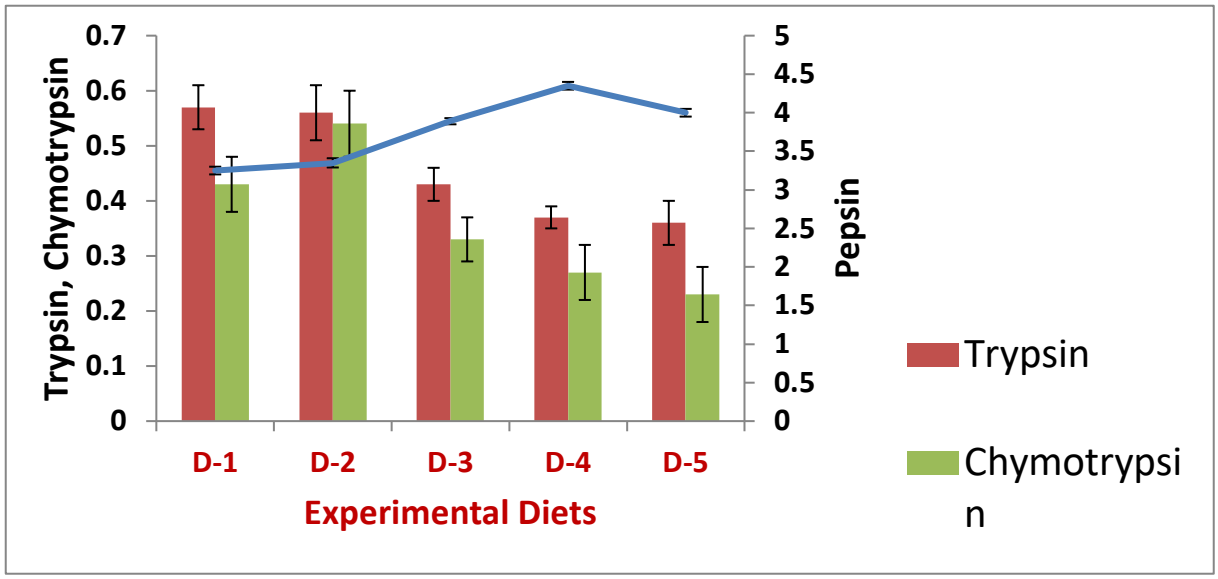


Fig 17. Activity of protein enzymes of *Ompok bimaculatus* fed with different Feed additives



Considering growth performance and survivability of the juveniles, the study suggests that supplementation of egg albumin might be practiced to make the *O. bimaculatus* juveniles adaptive to the formulated diets. The present experiment suggests that a formulated feed having 40% crude protein along with 10% of egg albumin is a better feeding strategy when compared with blood meal, chicken viscera and mussel meat. The study suggests that supplementation of egg albumin might be effective to make the *O. bimaculatus* larvae and juveniles adaptive to the formulated diets for its domestication in freshwater ecosystem..

11. Financial Implications (in Lakhs)

11.1 Expenditure on

(a) Manpower: 33.57 lakhs

(b) Research/Recurring Contingencies: 8.50 lakhs

(c) Non-Recurring Cost (Including cost of equipment): Nil

(d) Any Other Expenditure Incurred: Nil

11.2 Total Expenditure:

Item	Year (1)	Year (2)	Year (3)	Total (Lakhs)
Grand Total	14.19	14.19	13.69	42.07

12. Cumulative Output

a. Special attainments/innovations

1. The proximate and fatty acid composition of *Ompok bimaculatus* (pabda) brood fish, egg and larvae was assayed to have an insight of the nutrient metamorphosis during early life of the species and vis-a-vis parental nutrient composition. The studies regarding nutritional characterization of brood fish, eggs and larvae of *Ompok bimaculatus* revealed that crude protein content was higher in egg whereas crude fat and ash content was higher in pabda brood fish. However, PUFA, EPA and DHA content was higher in larvae.

2. Ontogeny Study of *O. bimaculatus* larvae suggests that the digestive tract of larvae comprised a straight tube dorsally attached to the yolk sac. At 2 dph, mouth opened, teeth were visible and exogenous feeding started. The yolk sac disappeared within 3 dph. Coiling of intestine and presence of stomach were noticed by 8 dph, which was marked with the appearance of pepsin. Activities of the enzymes indicated ontogenetic shift during the period of 8 to 20 dph, which could be associated with changes in food, gut morphology and shift in the activity pattern of digestive and metabolic enzymes. Overall, enzyme activities remained more or less stable beyond 20 dph.

3. A experiment was conducted to study the protein requirement of *O. bimaculatus* larvae 22 for days . The experimental data revealed that 40% crude protein was sufficient for the optimum growth and survival of *O. bimaculatus* larvae and it also recorded that the amylase, lipase and pepsin enzymes was significantly ($P<0.05$) higher in Feed 2 having 40% protein.

4. An experiment was conducted for 42 days to study the lipid requirement of *O. bimaculatus* larvae and it was observed that 8% lipid is sufficient for the optimum growth and survival of *O. bimaculatus* larvae. The activities of digestive enzymes in *O. bimaculatus* were assayed by feeding different levels of lipids. The activities of digestive enzymes in pabda larvae revealed that lipase activity was significantly ($P<0.05$) higher in Feed 2 having 8% lipid.

5. The experiment evaluation of supplementation of different protein sources (w/w basis) suggests that a feed having 40% crude protein along with 10% of egg albumin is a better feeding strategy when compared with blood meal, chicken viscera and mussel meat. The study suggests that supplementation of egg albumin might be effective to make the *O. bimaculatus* larvae and juveniles adaptive to the formulated diets.

b. List of Publications (one copy each to be submitted if not already submitted)

i. Research papers ; 2 nos

Paul, B .N., A. Das, A., R.N. Mandal,R.N., Singh,P., Adhikari, S., Ghosh, K.,Chowdhury,D., Chakrabarti,P.P. and Giri,S.S. (2020) Protein requirement of *Ompok bimaculatus* (Bloch, 1794) larvae. Animal Nutrition and Feed technology (**Communicated)**.

Paul, B .N., A. Das, A., R.N. Mandal,R.N., Singh,P., Adhikari, S., Chakrabarti,P.P. and Giri,S.S. (2020) Proximate and Fatty acid composition of brood fish, egg and larvae of *O.bimaculatus*. Indian Journal of animal Nutrition (**Communicated)**.

i. Reports/Manuals ; 3 training manuals

ii. Working and Concept Papers

iii. Popular articles

iv. Books/Book Chapters: 1

Paul,B.N. and Giri, .S. (2018). Nutrition and Feeding of catfish larvae. S.K.Sahoo, R.Kumar, P.K.Tiwari, B.R.Pillai, S.S.Giri. (Eds.) 2018 Training Manual on Mass Breeding and culture Techniques of Catfishes. SAARC Agriculture Centre, Dakha, Bangladesh pp 73-82.

v. Extension Bulletins

b. Intellectual Property Generation

(Patents - filed/obtained; Copyrights- filed/obtained; Designs- filed/obtained; Registration details of variety/germplasm/accession if any)

c. Presentation in Workshop/Seminars/Symposia/Conferences

(Relevant to the project in which Scientists have participated)

- Paul, B.N**.,** Das, A., Bhowmick, S., Mandal, R.N., S., Singh, Adhikari, S., Ghosh, K., Chowdhury, D. and Chakrabarti, P.P. (2019). Protein Requirement of *Ompok bimaculatus* Larvae. Golden Jubilee International Conference on "Trends in Zoology". January, 03-04, 2019 held at The University of Burdwan, Golapbag, Burdwan, India. Pp 88.

- Chowdhury, D., Paul, B.N. and Ghosh, K. (2019). Profiles of Digestive and Metabolic Enzymes in Butter Catfish, *Ompok bimaculatus* (Bloch, 1794) during early development. Golden Jubilee International Conference on "Trends in Zoology". January, 03-04, 2019 held at The University of Burdwan, Golapbag, Burdwan, India. Pp 90.

- Paul, B.N., Das, A., Mandal, R.N., Singh, P. And Adhikari, S. 2019. Proximate and Fatty acid composition of brood fish, egg and larvae of *Ompok bimaculatus*. Fourth PAF Congress on "Increasing Aquaculture Production in India through Synergetic Approach between Multinational Industries, Domestic Entrepreneurs and Aquaculturists" held at ICAR-CIFA, Bhubaneswar during 15-17 November, 2019. Pp. 27.

- Chowdhury, D., Paul, B.N. and Ghosh, K. 2019. Evaluation of Formulated Diets for Survival, Growth, Digestive Enzymes and Metabolic Functions in Butter Catfish*,* *Ompok bimaculatus* (Bloch) juveniles. International Conference on Animal Nutrition on "Nutritional Strategies for Improving Farm Profitability and Clean Animal Production" held at Biswa Bangla Convention Centre, Kolkata, 17-19 December, 2019.pp 392.

d. Details of technology developed

(Crop-based; Animal-based, including vaccines; Biological – biofertilizer, biopesticide, etc; IT based – database, software; Any other – please specify)

e. Trainings/demonstrations organized

Organised a Training programme on Applications and Practices of fish feed was organised at RRC, CIFA, Rahara during 23-28 Oct.,2017

Organised a Training programme on Application of Farm Made Feed for Sustainable Aquaculture Production was organised at RRC, CIFA, Rahara during 03-07 Dec.,2018

Organised a Training programme on Fish Nutrition and Feeding of Fish at RRC, CIFA, Rahara during 17-21 June ,2019

Organised a Training programme on 'Captive breeding and seed production of indigenous catfishes with emphasis on *Ompok* and *Mystus* Species' at Kalyani Field Station, RRC Rahara during 30.07.2019 to 03.08.2019.

f. Training received

➢ Mr. Arabinda Das, Scientist received a training on 'Experimental design and statistical data analysis' during January 3-16, 2019 at ICAR-IASRI, New Delhi.

g. Any other relevant information

13. (a) Extent of achievement of objectives and outputs earmarked as per RPP-I

Objective wise	Activity	Envisaged output of monitorable target(s)	Output achieved	Extent of Achievement (%)
1. To study nutrient composition of egg and different stages of larvae	1. Brood stock development of *O.bimaculatus* 2. Production of egg and larvae of *O.bimaculatus* 3. Nutrient composition of egg and larva	Production of Larvae through good brood stock development and production of larvae for experimental work. To know the nutrient profile of brood pabda, egg and larvae.	Sufficient larvae were produced for the experimental work. The nutrient composition data revealed that the crude protein content of brood fish, egg and larvae were 14.4±0.07, 25.90±0.20, 12.23±0.88 (%) respectively and crude protein content was significantly higher in pabda egg.	100%

	4. Collection of Literature, Planning and design of experiment		The fatty acid composition revealed that the saturated fatty acid (SFA) content (% of total fatty acid) of brood pabda, eggs and larvae were 88.48%; 76.04% and 48.60%. The poly unsaturated fatty acid (PUFA) content of brood pabda, eggs and larvae were 4.5%; 10.05% and 33.35% respectively. The EPA and DHA contents were 2.71% and 6.87% in larvae; which was significantly higher in brood fish and egg. It may be summarized crude protein content was higher in egg whereas crude fat and ash content was higher in brood fish. However, PUFA, EPA and DHA content was higher in larvae.	
	Ontogeny and enzyme study	Ontogeny of *O. bimaculatus* was worked out.he yolk sac disappears within 3 days.the overall enzyme activities remained stable after 20days of post hatching.	Ontogeny Study of *O. bimaculatus* larvae: The digestive tract of larvae comprised a straight tube dorsally attached to the yolk sac. At 2 dph, mouth opened, teeth were visible and exogenous feeding started. The yolk sac disappeared within 3 dph. Coiling of intestine and presence of stomach were noticed by 8 dph, which was marked with	100%

			the appearance of pepsin. Activities of the enzymes indicated ontogenetic shift during the period of 8 to 20 dph, which could be associated with changes in food, gut morphology and shift in the activity pattern of digestive and metabolic enzymes. Overall, enzyme activities remained more or less stable beyond 20 dph.	
3.To formulate larval feed and evaluation	1. Feed formulation and Feeding of larvae of *O. bimaculatus* with live and exogenous feed 2. Production of Live food organisms. 3. Monitoring of Water Quality parameters 4. Data analysis and preparation of final report	Development of larval feed for *O.bimaculatus* larvae. A larval feed was developed with 40% protein and 8% lipid. Supplementation of 10% egg albumen (w/w) with the feed should be the feeding protocol for the species to domesticate them in the Aquaculture production system.	(i) **Protein requirement of larvae** An experiment was conducted to study the protein requirement of *O. bimaculatus* larvae for 22 days. During the experiment the water quality parameters were monitored from time to time. The experimental data revealed that 40% crude protein was sufficient for the optimum growth and survival of *O. bimaculatus* larvae and it also recorded that the amylase, lipase and pepsin enzymes was significantly ($P<0.05$) higher in Feed 2 having 40% protein. (ii) **Lipid requirement study of *O. bimaculatus* larvae.** An experiment was conducted 42 days to	100%

			study the lipid requirement of *O. bimaculatus* larvae and it was observed that 8% lipid is sufficient for the optimum growth and survival of pabda larvae. The activities of digestive enzymes in the species were assayed by feeding different levels of lipids. The activities of digestive enzymes in pabda larvae revealed that lipase activity was significantly ($P<0.05$) higher in Feed 3 having 8% lipid. **(iii)Supplementation of live protein supplements** The experimental data suggests that a formulated feed having 40% crude protein along with 10% of egg albumin is a better feeding strategy when compared with blood meal, chicken viscera and mussel meat. Considering growth performance and survivability of the juveniles, the study suggests that supplementation of egg albumin might be practiced to make the *O. bimaculatus* juveniles adaptive to the formulated diets.	

(b) Reasons of shortfall, if any: Nil

14. Efforts made for commercialization/technology transfer

The experimental results obtained are disseminated with the fish famers, fishery extension officers, students, feed manufactures and entrepreneurs in various training programmes organised at RRC, Rahara and its field station at Kalyani, CIFA HQs, farmers field and KVKs. In those training programmes delivered lectures on larval Nutrition, ontogeny of the *O.bimaculatus* larvae and emphasized about the use of precise nutrients(quality fish meal) and fish oil required to prepare the feed for the species.

15. (a) How the output is proposed to be utilized?

The output is proposed to be utilized at farmers field through KVKs, stake holders, feed manufacturers and other fisheries developmental agencies.

(b) How it will help in knowledge creation

The knowledge of ontogeny Study of *O. bimaculatus* larvae was known and it helped to develop the larval feed. The digestive tract of larvae comprised a straight tube dorsally attached to the yolk sac. At 2 dph, mouth opened, teeth were visible and exogenous feeding started. The yolk sac disappeared within 3 dph. Coiling of intestine and presence of stomach were noticed by 8 dph, which was marked with the appearance of pepsin. Activities of the enzymes indicated ontogenetic shift during the period of 8 to 20 dph, which could be associated with changes in food, gut morphology and shift in the activity pattern of digestive and metabolic enzymes. Overall, enzyme activities remained more or less stable beyond 20 dph. The nutrient requirement of larvae was worked out viz., Protein and Lipid required by the species are 40 and 8 (%) respectively. The findings were presented in National and International Seminars and data will also be published in peer reviewed journals.

16. Expected benefits and economic impact(if any)

The feed and feeding protocol of *O. bimaculatus* has been worked out. The larval feed having 40 % protein and 8 % lipid has been developed. As there was no larval feed of *O. bimucalatus*, thus this feed will cater the needs of the sector and help in increasing the butter catfish production in the region.

17. Future line of research work/other identifiable problems

Nutragenomics study on the nutrients of larval feed of butter catfish *O. bimaculatus* would be a line for future research work.

18. Details on the research data (registers and records) generated out of the project deposited with the institute for future use: The register and data generated are maintained and submitted to the Institute in the form of RPF-II and III and Annual Report.

19. Signature of PI, CC-PI(s), all Co-PIs

Project Leader	Co-PI	Co-PI	Co-PI	Co-PI
(Dr. B.N. Paul)	(P.P. Chakrabarti)	(Dr. S. Adhikari)	(Dr. R.N. Mandal)	(Mr. A. Das)

Co-PI

(Dr. K. Ghosh)

20. Signature of Head of Division

21. Observations of PME Cell based on Evaluation of Research Project after Completion

22. Signature (with comments if any along with rating of the project in the scale of 1 to 10 on the overall quality of the work) of JD (R)/ Director

ANNEXURE - VIII

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

(For Guidelines Refer ANNEXURE – XI (H))

PROFORMA FOR RESEARCH PERFORMANCE EVALUATION OF INDIVIDUAL SCIENTIST

23. Institute Project Code * I-95-G

1. Evaluation by PI on the contribution of the team in the project including self

Sl. No.	Name	Status in the project (PI/CC-PI/Co-PI)	*Rating in the scale of 1 to 10
1.	Dr. B.N.Paul	PI	10
2.	Dr.S.Adhikari	Co-PI	10
3.	Dr.P.P.Chakrabarti	Co-PI	10
4.	Dr. R.N Mandal	Co-PI	10
5.	Mr. A. Das	Co-PI	10
6.	Dr. K.Ghosh (Burdwan University)	Co-PI	10

2. Signature of PI

* Individual scientists participating in the project would be assessed for their performance through an appraisal system in a scale of 1 to 10 for each of the following attributes:

No.	Criteria	Marks
1.	Percentage of the assigned activity completed	**40**
2.	Quality of the completed activity	**10**
3.	Authenticity/reliability of the data generated	**10**
4.	Enthusiasm and sincerity to work	**10**
5.	Inferences made	**10**
6.	Collaboration and cooperation demonstrated in performing the task at hand	**10**
7.	Amenability to scientific/academic/laboratory discipline	**10**
	l Score	**100**

ANNEXURE - IX

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

(For Guidelines Refer ANNEXURE – XI (I))

PROFORMA FOR EVALUATION OF A RESEARCH PROJECT AFTER COMPLETION BY PI

10. Institute Project Code

11. Evaluation research project after completion by PI

	Criteria	**Methodology**	**Marks (output)**	**Evaluation by PI**
	Achievements against approved and stipulated outputs under project	**Qualitative and quantitative assessment of objectives and stipulated outputs under the project will be carried out**	**75**	
		a) Activity Input /Projected Output/ Output Achieved	35	**35**
		b) Extent to which standard design methodology, experimental designs, test procedures, analytical methods followed	10	**10**
		c) Does the data justify the conclusions?	05	**05**
		d) Innovativeness and creating of new knowledge	10	**10**
		e) Additional outputs over those stipulated under the project	05	**05**
		f) Creation of linkages for commercialization of technology developed under the project	05	**05**
		g) Is scientific input commensurate to output (manpower, Financial input and time duration)?	05	**05**
	Publication/ awards	A essment will be done in respect of: Research papers; Reports/Manuals; Working and Concept Papers; Books/Book Chapters/Bulletins. Quality of publication (s) and Awards /Scientific recognitions received llowing publications were made during the project work: Research papers-2 (communicated to peer reviewed journals), Book chapter -1, Training Manual-3 nos. and Conference/Seminar presentations 4. (International -3 and National level -1)	**10**	**10**

	Additional facilities created	Facilities created in terms of laboratory. Research set-up, instrumentation, etc. during the project. Fatty acid analysis facility was created in the Laboratory with preparation of Fatty Acid Methyl Ester and analysis in gas Chromatography. institute collaboration was developed with University of Burdwan where Dr. Koushik Ghosh was the collaborator. Ontogeny study protocol of *O.bimaculatus* was developed along with study of enzymes during early stage of larvae in collaboration with University of Burdwan. Feeding protocol *O.bimaculatus* was worked out in the project.	**05**	**05**
	Human Resource Development (Scientific and Technical)	Scientist trained in different areas Arabinda Das, Scientist trained on a Programme 'Experimental design and statistical data analysis' during January 3-16, 2019 at ICAR-IASRI , New Delhi. B.N.Paul, attended two International and one National Conferences, Dr. R.N.Mandal attended one International conference. B.N.Paul and Mr. A.Das attended one National Conference. All the Scientist participated and presented paper in the above seminars during technical discussions.	**05**	**05**
	Revenue generated under the project/ avenues created for revenue generation	Resources and revenues generated different training programmes were conducted 1.Organised a Training programme on Applications and Practices of fish feed was organised at RRC, CIFA, Rahara during 23-28 Oct.,2017 2.Organised a Training programme on Application of Farm Made Feed for Sustainable Aquaculture Production was organised at RRC, CIFA, Rahara during 03-07 Dec.,2018 3.Organised a Training programme on Fish Nutrition and Feeding of Fish at RRC, CIFA, Rahara during 17-21 June ,2019 Revenue generated from the training programme were 2.04 Lakhs	**05**	**05**

	Product/Process/Technology/ IPR / commercial value of the technology developed	Details to be provided on a) Products: The larval feed was developed for *O.bimaculatus* larvae. b) Process: Preparation of larval feed process was developed with different quality fish meal and fish oils alonf with other feed ingredients. c) Technology: Feed and feeding protocol was developed for the *O.bimaculatus* larvae d) IPR e) Registration of the varieties	**10**	**06**
	Quality of available documents of the project duly authenticated	Research Project Files, Data, Reports etc. records are available with the Centre	**05**	**05**
Total Marks			**115**	**111**
	Time lines of execution of the project	Marks will be deducted if extension sought over the approved project duration beyond recorded and officially granted extension with recorded reasons		
		Up to 5%		
		Up to 10%		
		Up to 30 %		
		Beyond 30 %		
Score: Score obtained to be counted out of 100 to compensate for activities not relevant to the project				

However, looking into the requirements of different research institutes and disciplines, IRC may modify the indicators, their weights and total scores. The time gap for assessment of different indicators may also be decided by IRC

12. Signature of PI

भाकृअनुप
ICAR

ICAR-Central Institute of Freshwater Aquaculture
(ISO 9001:2015 Certified Institute)
(Indian Council of Agricultural Research)
RRC,Rahara, 700118,West Bengal

CIFA

पश्चिमबङ्गा पश्चिम बंगाल WEST BENGAL

Z 818458

Sl. NO. 15

Umbrella Memorandum of Understanding

between

ICAR-Central Institute of FreshwaterAquaculture
(An ISO 9001:2008 Certified Institution)
(Indian Council of Agriculture Research)
Kausalyaganga, Bhubaneswar 751002, Odisha

and

The University of Burdwan, Burdwan 713104, West Bengal

University/DU [Within NARS (AUs/ICAR DUs) or **Outside NARS** (Central/State Govt./Public Sector Funded Institutions/**State Universities**/Autonomous Bodies/Private Universities or Institutions)]

for facilitating

Students' Training/Postgraduate Research

This Memorandum of Understanding (hereinafter referred to as MoU) is made on this twenty seventh day of the month of March in the year 2018 by and between the **ICAR-Central Institute of Freshwater Aquaculture** (Name of the ICAR Institute) having its

Jatindra Kumar Sundaray Dalu Ram Dangi

Head Office at **KAUSALYAGANGA, BHUBANESWAR 751002, ODISHA** [hereinafter called **"ICAR-CIFA"**/ First party], a constituent Research Institution of the Indian Council of Agricultural Research, Krishi Bhavan, New Delhi-110 001 on the ONE PART and the **The University of Burdwan** [Name of the AU/ICAR-DU (Within NARS) or Central/State Govt./Public Sector Funded Institution/State University/Autonomous Body/Private University or Institution] having its headquarters at **BURDWAN 713104, WEST BENGAL** [hereinafter called **"BU"**/ Second party] on the OTHER PART (who for the purpose of this MoU are hereinafter collectively referred to as the parties).

The parties, having discussed fields of common research interests and allied activities between the two institutions, have decided to enter into long-term collaboration for promotion of students' training and quality postgraduate research in cutting edge areas in accordance with the provisions contained in the Guidelines issued *vide* Letter No. 2-8/2012-HRD dated 11th December, 2012 or as revised from time to time.

WHEREAS the "**ICAR-CIFA**" is involved in the studies on Freshwater Aquaculture (fish nutrition and physiology; fish health management; fish genetics and biotechnology; fisheries extension, economics and information sciences),

AND WHEREAS the "**BU**", established on 15th June 1960 by **Govt. of West Bengal** *vide* **Act No. XXIX** of **1959** and recognized by University Grants Commission (under Section 12B of the UGC Act, 1956) at its **Department of Zoology** is involved in studies on various disciplines of Aquaculture and Fisheries (fish nutrition and probiotics, aquatic ecology and toxicology, fish diseases and immunology),

AND WHEREAS it has been considered expedient to agree in writing to participate jointly in the projects requiring expertise and logistics from both the parties.

Now this instrument witnesses as follows:

Jitendra Kumar Sundaray

(Signature of First Party)

निदेशक/DIRECTOR
भा.कृ.अनु.प.-सीफा/ICAR-CIFA
पो.-कौशल्यागंग/P.o-Kausalyaganga
भुवनेश्वर/Bhubaneswar-751002

27.3.18

(Signature of Second Party)

REGISTRAR
THE UNIVERSITY OF BURDWAN
BURDWAN - 713104

Article 1. Scope

1.1 The **BU** will recognize the **ICAR-CIFA** as an Institute for conducting research related to the thesis requirement of the research students for Ph.D./M.Phil./Masters. The **BU** will recognize Scientists of the **ICAR-CIFA** as recommended by its Director in accordance with the University rules and regulations for guiding students working for the said degree.

1.2 Operational details of research effort and collaboration will be made in common research programmes and/or projects restricted to specific mandated domain within the approved disciplines/divisions. The objective(s) for research work for a student coming from a Second party outside NARS should be exclusively different as far as possible.

1.3 Research instrumentation facility and library facilities available with the **ICAR-CIFA** and the **BU** will be made available to the faculty and research scholars. However, the costs of specific consumables will be borne by the respective organizations.

1.4 There shall be an exchange of students for academic, research and training purposes. Accommodation in the Hostel shall be arranged, wherever possible, as per extant rates. The duration of exchange visits will be determined by mutual consent between both the parties.

Article 2. Management

2.1 Director of the **ICAR-CIFA** and the Vice-Chancellor/Head of the Institution of the **BU** will be responsible to work out operational details of co-operation between the two organizations and ensure proper and effective implementation of this MoU.

2.2 The Advisory Committee will meet at least once in a year alternatively in the institutions of the First party and the Second party to review the activities. This meeting shall include presentation on the academic and research activities, which should be open to the students, faculty and scientists.

Article 3. Exchange of Information

3.1. The term "information" includes scientific or technical data, results and/or methods of investigation, and other information intended to be provided, exchanged, or arising under project descriptions entered into pursuant to this MoU.

3.2. The parties support the widest possible dissemination of information. Each party in joint projects shall be given the right to use, disclose, publish or disseminate such information for any and all purposes.

Article 4. General Provisions

4.1 It is understood that the **ICAR-CIFA** and the **BU** subscribe to the principle of equal opportunity and do not discriminate on the basis of race, sex, age, caste or religion. Both the Institutions shall abide by these principles in the administration of this agreement and neither party shall impose criteria for exchange of scholars or students, which violate principles of non-discrimination.

Jitendra Kumar Sundaray

(Signature of First Party)

29.3.18

(Signature of Second Party)

निदेशक/DIRECTOR
भा.कृ.अनु.प.-सीफा/ICAR-CIFA
पो.-कौशल्यागंग/P.o-Kausalyaganga
भुबनेश्वर/Bhubaneswar-751002

REGISTRAR
THE UNIVERSITY OF BURDWAN
BURDWAN - 713104

4.2 Both parties understand that all financial agreements will have to be negotiated separately and will depend on the availability of funds.

4.3 Both parties acknowledge that exchange of students from one party to the other shall be subject to the availability of funds and shall comply with the regulations and policies of the First party and the Second party.

4.4 Any research publications arising will be jointly published in accordance with the provisions laid out in Item 3.2.1C of the Guidelines for the students to conduct research for their degree programme as trainees at ICAR institutions as notified *vide* Letter No. 2-8/2012-HRD dated 11th December, 2012 or revised guidelines, if any, as may be issued from time to time.

4.5 A copy of the thesis/dissertation submitted by the research students affiliated to the **ICAR-CIFA** will be deposited to the **ICAR-CIFA** after the award of the degree by the **BU**.

4.6 All questions related to this MoU arising during its term will be settled by the parties by mutual agreement. Disagreements at the operating level shall be forwarded to respective higher officials for appropriate resolution failing which an arbitrator of mutual acceptance may be identified for the settlement of dispute, if any.

4.7 All questions not foreseen related to this MoU will be handled by the parties by mutual agreement.

4.8 Nothing in this MoU is intended to affect other cooperation or collaborations between the parties.

Article 5. Intellectual Property Rights

5.1 The **BU** will be expected to ensure protection of the Intellectual Property Rights generated or likely to be generated during the student's research work. The **ICAR-CIFA** and the **BU** shall be the joint applicants for IPRs and the students and involved scientific staff shall be included as the inventor/breeder/author. The 'ICAR Guidelines for Intellectual Property Management and Technology Transfer/Commercialization' as amended from time to time shall be the reference for exploitation of the generated intellectual property, whose management and benefits sharing shall be mutually decided in each case, by the parties hereto.

Article 6. Admission and Fees

6.1 All those who wish to register as trainees or for Master/Doctoral programme under this MoU must apply for admission at the **BU**. The allocation of Major Guide/Advisor would be finalized before the registration and will be governed by the provisions laid out in Items 3.2.1A and 3.2.2A of the Guidelines for the students to conduct research for their degree programmes as trainees at ICAR institutions as notified *vide* Letter No. 2-8/2012-HRD dated 11th December, 2012 or revised Guidelines, if any, as may be issued from time to time, for the students from within NARS and outside NARS, respectively.

6.2 Admission of the students and the award of degrees for different programmes will be the responsibility of the **BU** as per the rules and regulations.

6.3 Allotment of the students at the **ICAR-CIFA** will be done by the approval of Director of the **ICAR-CIFA** and Vice-Chancellor/Head of the Institution of the **BU**.

6.4 The **ICAR-CIFA** and **BU** would have the right to screen the student's eligibility for admission based on their academic period.

Jatindra Kumar Sundaray

(Signature of First Party)

27.3.18

(Signature of Second Party)

निदेशक/DIRECTOR
भा.कृ.अनु.प.-सीफा/ICAR-CIFA
पो.-कौशल्यागंग/P.o-Kausalyaganga
भुबनेश्वर/Bhubaneswar-751002

REGISTRAR
THE UNIVERSITY OF BURDWAN
BURDWAN - 713104

6.5 The PME Cell of the **ICAR-CIFA** in consultation with the representative of the **BU** shall decide the location and sharing quantum of research work.

6.6 The number of student(s) at any particular time will be subjected to the availability of research facilities and scientists' time to guide thesis research at the **ICAR-CIFA**.

6.7 Any student(s) admitted to the **ICAR-CIFA** for training/postgraduate research, if found violating the rules and regulations laid down by the **ICAR-CIFA** or indulge in such activities that amount to tarnishing the image of the Institute, or cause damage to the property, the registration of such student(s) would be summarily terminated. The **BU** will not complete the formalities of issuing the certificates to such students until they compensate the losses to the **ICAR-CIFA**.

6.8 Fees will be charged from the students by the **ICAR-CIFA** as per Guidelines for the students to conduct research for their degree programmes as trainees at ICAR institutions *vide* Letter No. 2-8/2012-HRD dated 11th December, 2012 or revised Guidelines, if any, as may be issued from time to time. No fee may be charged by the First party from the students registered with AU/DU within NARS. However a student registered with a Second party, outside NARS, will deposit fee of Rs. 10,000/- for training duration of 3 months (not leading to a degree/dissertation) and Rs. 30,000/- per semester (six months) for training, research, dissertation exceeding three months. Any change in fee structure by ICAR will be applicable from the date of revision and shall be charged by the **ICAR-CIFA**.

Article 7. Entry into effect, modification and termination

7.1. This MoU shall become effective on the date it is signed by the parties and shall be valid for three years extendable up to five years. Both parties shall review the status of the MoU at the end of each five year period to determine any modification, whenever necessary. The period of validity of this MoU may be extended by mutual consent up to five years. This MoU may be amended by mutual written agreement and may be terminated at any time by either party upon written notification signed by the competent authority of the party initiating termination. Such notification must be given to the other party at least six months in advance from the effective date of termination.

7.2. All joint activities not completed at the expiration or termination of the MoU may be continued until their completion under the terms of this MoU.

7.3 No amendment or modification of the MoU shall be valid unless the same is made in writing by both the parties or their authorized representatives and specifically stating the same to be amendment of the MoU. The modifications/changes shall become part of the MoU and shall be effective from the date on which they are made/executed, unless otherwise agreed to.

Jitendra Kumar Sundaray

(Signature of First Party)

निदेशक/DIRECTOR
भा.कृ.अनु.प.-सीफा/ICAR-CIFA
पो.-कौशल्यागंग/P.o-Kausalyaganga
भुवनेश्वर/Bhubaneswar-751002

27.3.18

(Signature of Second Party)

REGISTRAR
THE UNIVERSITY OF BURDWAN
BURDWAN - 713104

This MoU has been executed in two originals, one of which has been retained by the **ICAR-CIFA** and the other by the **BU**).

IN WITNESS WHEREOF, the parties have executed this MoU on the 27. March 2018 first above written and represent that they approve, accept and agree to terms contained herein.

ICAR-Central Institute of Freshwater Aquaculture Kausalyaganga, Bhubaneswar 751002 Odisha	**The University of Burdwan Burdwan 713104, West Bengal**
Name of the Director of the First Party	**Name of Head of the Institution of the Second Party**
DR J K SUNDARAY	**DR D K PANJA**
Tel No. (0674) 2465421, 2465446	**Tel. No. (0342) 2634 015**
Date	**Date** 27-03-2018
Signature with Seal Jatindra Kumar Sundray 27.3.18 निदेशक/DIRECTOR भा.कृ.अनु.प.-सीफा/ICAR-CIFA पो.-कौशल्यागंग/P.o-Kausalyaganga भुवनेश्वर/Bhubaneswar-751002	**Signature with Seal** THE UNIVERSITY OF BURDWAN RAJBATI BURDWAN 713104 REGISTRAR THE UNIVERSITY OF BURDWAN BURDWAN - 713104

Witness 1 ..... Witness 1 Anandamay Barik 27/03/18

C.P. Mahanty, Sr. Scientist, ICAR-CIFA, Bhubaneswar

Dr ANANDAMAY BARIK
Associate Professor & Head
Department of Zoology
The University of Burdwan
Golapbag, Burdwan-713104

Witness 2 ..... Witness 2 ..... 27/03/18

CA. BARAT
PRINCIPAL SCIENTIST
ICAR-CIFA.
Bhubaneswar.

DR. KOUSHIK GHOSH
ASSOCIATE PROFESSOR
DEPARTMENT OF ZOOLOGY
THE UNIVERSITY OF BURDWAN
GOLAPBAG, BURDWAN-713104, W.B., INDIA

पश्चिमबङ्गा पश्चिम बंगाल WEST BENGAL

Z 816631

Sl.NO.--16

MEMORANDUM OF AGREEMENT

This MEMORANDUM OF AGREEMENT is made on this **twenty first** day of **May** Two thousand and **Eighteen** BY AND BETWEEN President of India, acting through **Secretary**, Department of Biotechnology, Ministry of Science and Technology, Government of India, New Delhi, hereinafter referred to as the 'DBT' (which expression unless excluded by or repugnant to the subject shall mean and include its successor-in-office and assigns) of the ONE PART;

AND

The University of Burdwan , a society under the Societies Registration Act – 1860, having its registered office at **Rajbati, Burdwan,** hereinafter referred to as **BU** (which expression shall where the context so admits include its successors and permitted assigns) of the OTHER PART;

REGISTRAR (Officiating)
THE UNIVERSITY OF BURDWAN
BURDWAN-713104

WHEREAS DBT being desirous of cancer immunology decided to support a project submitted by **Dr. Anupam Basu** for the attainment of the objectives, hereinafter described in the Annexure I annexed hereto;

This Memorandum of Agreement (MoA) defines the role and responsibilities of the participating agencies, monitoring and other matters related to the **"Study on the role of TLR-4 signaling in breast cancer progression"**

NOW THE PARTIES HERETO AGREE AS FOLLOWS:-

1.0 . ROLE OF DEPARTMENT OF BIOTECHNOLOGY, NEW DELHI

To provide funds to the extent of **81,30,600/-** over a period of **3** years from the date of sanction of the project, to **The University of Burdwan** for undertaking activities as detailed in Annexure 1. Details of the funds to be provided are given in Annexure II.

2.0. ROLE OF THE UNIVERSITY OF BURDWAN (Institute)

2.1. To provide their contribution of **81,30,600/-** for **3** years from date of sanction of the project as detailed in Annexure – II. *(if a jointly supported project)*

2.2. To provide existing facilities as mentioned in the project document.

2.3. To be responsible for accomplishing objectives identified and activities listed.

2.4. To allow the Scientists authorized by DBT to work with the Research & Development team of the center in all stages of process development and production.

2.5. To recruit all scientific and non-scientific staff as sanctioned by DBT.

2.6. To prepare and submit all periodical reports and other documents that would be required by DBT.

2.7. To maintain a separate audit head of account for the grants received from DBT for the project.

2.8. To submit an annual audited statement of expenditure incurred under the project.

2.9. To ensure effective utilization of the grant given by DBT for the purpose for which it was granted and to ensure timely progress of project work.

2.10. The manpower, both scientific and non-scientific, recruited shall be purely on contractual terms & conditions such that the contract for engagement of the manpower shall run concurrently with the said project period only.

REGISTRAR (Officiating)
THE UNIVERSITY OF BURDWAN
BURDWAN-713104

3.0 DURATION OF PROJECT

3.1 Duration of project shall be **3** years from the date the Project has been sanctioned by DBT.

Dr. Anupam Basu
PROFESSOR
Department of Zoology
The University of Burdwan

4.0 RIGHTS OF OWNERSHIP/TECHNOLOGY TRANSFER AND UTILIZATION

4.1 The know-how generated from the project by **Dr. Anupam Basu** will be the joint property of **The University of Burdwan** and DBT, Government of India. It shall

4.2 be the responsibility of **Dr. Anupam Basu & The University of Burdwan** to take necessary action for protection of the intellectual property arising out of the PROJECT through proper instruments, such as, patents, copy rights, etc.

4.3 The know-how developed may be transferred to other entrepreneurs on a non-exclusive basis on such terms and conditions as may be determined by DBT.

4.4 All the assets including the equipment and produce acquired will be the property of DBT and shall not be utilized for purposes other than those for which the grant has been sanctioned. The rights of **The University of Burdwan** under this MoA shall not be transferred to any other party without prior approval in writing of DBT.

4.5 It shall be the responsibility of **Dr. Anupam Basu** to ensure that support of DBT is suitably acknowledged in the publications (papers, reports, etc.) arising out of the PROJECT.

5. SECRECY

It is hereby agreed that the participating agencies shall keep information and data collected completely secret provided that the right to transfer the technology shall rest with the DBT.

6. MONITORING

6.1 The progress of implementation of the project and proper utilization of grant shall be reviewed by the DBT and by the Monitoring Committee set up by DBT.

6.2 The periodic progress of physical achievements and the utilization of funds, statement of expenditure shall be evaluated by the Monitoring Committee.

6.3 The Comptroller and Auditor General of India, at his discretion shall have the right of access to the books and accounts of **The University of Burdwan** for the grants received from DBT for this project.

6.4 The DBT may terminate the grant at any stage if it is convinced that the grant has not been properly utilized or appropriate progress has not been made. In the event, DBT terminates the grant, **Dr. Anupam Basu & The University of Burdwan** shall hand over all documents including technical details and equipment purchased related to the project.

REGISTRAR (Officiating)
THE UNIVERSITY OF BURDWAN
BURDWAN-713104

Dr. Anupam Basu
PROFESSOR
Department of Zoology
University of Burdwan

7.0 DURATION OF MEMORANDUM OF AGREEMENT

This MoA will remain inforce for the duration of the project and until all claims are settled between DBT and **The University of Burdwan**

8.0 ARBITRATION

In the event of any question, dispute or difference whatsoever arising between the parties to this Agreement out of or relating to the construction, meaning, scope, operation or effect of this Agreement or the validity of the breach thereof shall be referred to an Arbitrator to be appointed by mutual consent of both the parties herein. If the parties cannot agree on the appointment of the Arbitrator within a period of one month from the notification by one party to the other of existence of such dispute, then the Arbitrator shall be nominated by the Secretary, Department of Legal Affairs, Ministry of Law & Justice, Government of India. The provisions of the Arbitration and Conciliation Act, 1996 will be applicable and the award made thereunder shall be final and binding upon the parties hereto, subject to legal remedies available under the law. Such differences shall be deemed to be a submission to arbitration under the Indian Arbitration and Conciliation Act, 1996, or of any modifications or reenactments thereof.

9.0. GOVERNING LAW

This Contract shall be governed by the Law of India for the time being in force.

IN WITNESS WHEREOF the parties hereto have signed, sealed and delivered this Agreement on the day, month and year first above written in presence of:

Witnesses:

1.

REGISTRAR (Officiating)
THE UNIVERSITY OF BURDWAN
BURDWAN-713104

2.

Dr. Anupam Basu
PROFESSOR
Department of Zoology
University of Burdwan

Dr ANANDAMAY BARIK
Associate Professor & Head
Department of Zoology
The University of Burdwan
Golapbag, Burdwan-713104

Signed by ----------

(Designation)

For and on behalf of The President of India

Witnesses:

1.

2.

Signed by ----------

Registrar (officiating)
THE UNIVERSITY OF BURDWAN
For and on behalf of
The University of Burdwan

TERMS & CONDITIONS OF THE GRANT

(To be signed and enclosed with concern filled proforma)

1. Approval of the Research proposal and the grant released would be for the specific project mentioned in paras I to V of this proposal and grant should be exclusively spent on the project for which it has been sanctioned within the stipulated time. The Institute is not permitted to seek or utilise funds from any other organisation (Government, Semi Government, Autonomous or Private) for this research project. Any unspent part of amount would be surrendered to the Govt. of India through an account payee demand draft drawn in favour of the "Drawing and Disbursing Officer, Department of Biotechnology, New Delhi", and carry forward of funds of the next financial year for utilization for the same project may be considered only with the specific approval of the Department of Biotechnology (DBT).

2. For permanent/semi-permanent assets acquired solely or mainly out of the grant, an audited record in the form of a register in the prescribed proforma (enclosed at **Appendix-'A'**) shall be maintained by the Institute. The term **"assets"** means (I) immovable property and (II) movable property of a capital nature, where the value exceeds Rs. 1000/- The grant will not be utilised for construction of any immovable property, Full facilities by way of accommodation, etc. for the project will be given by the Institute.

3. All the assets acquired from the grant will be the property of Govt. of India and should not without the prior sanction of the Deptt. of Biotechnology, be disposed of, or encumbered or utilised for purpose other than those for which the grant has been sanctioned.

4. At the conclusion of the project, the Govt. of India will be free to sell or otherwise dispose of assets which are the property of the Government. The Institute shall render to Govt. necessary facilities for arranging the sale / disposal of these assets. **The Government may, however, consider the request of host institutions to retain the assets created under a project for carrying out similar work for the promotion of science.**

5. The implementing Institute/PI will furnish progress report of work on the project every six months. The progress of the project will also be reviewed/monitored at least once a year by the concerned Task Force/Project Monitoring Committee, etc. In addition the DBT shall designate Scientists/Specialists to visit the Institute periodically for reviewing the progress of work and for suggesting such measures as to ensure early realisation of the objectives of the project. On completion of the project five copies of a consolidated report of the work done on the subject would be submitted to the Department of Biotechnology.

6. The Institute is required to send to DBT a list of assets referred to at Sl. No. 2 above at the end of each financial year as well as at the time of seeking further installments of the grant.

7. The Institute would furnish to the Deptt. of Biotechnology a Utilization Certificate (Copy enclosed at **Appendix - 'B'**) and an audited statement of expenditure (**Copy enclosed at Appendix - 'C'**) duly signed by the P.I., the Head of the Institute and the Head of the Finance wing, pertaining to the grant at the end of each financial year as well as a consolidated statement of expenditure at the end of the completion of the project.

8. A stamped receipt be sent to the Deptt. of Biotechnology on receipt of the Cheque/ Demand draft towards each release.

9. The Comptroller and Auditor-General of India at his discretion shall have the right of access to the books and accounts of the Institute for the grant received from the Government.

10. The Institute would maintain separate audited accounts for the project. If it is found expedient to keep a part or whole of the grant in a bank account earning interest, the interest thus earned should be reported to the Deptt. of Biotechnology.

11. Sale proceeds, if any, as a result of the development of the project arising directly from funds granted by the Deptt. of Biotechnology shall be reported to the Govt. of India. The Govt. of India may at its discretion allow a portion of such receipt to be retained by the Institute for its utilisation for the project activities.

12. Investigators/Institutes wishing to publish papers based on the research work done under Deptt. of Biotechnology projects should acknowledge the financial support received from the Deptt. of Biotechnology.

13. Investigators/Institutes may utilize various resources such as the Bioinformatics resources, experimental materials, reagents, cell lines, animals, etc. from the National facilities/Institutes/Centres established by this Department as per the terms of transactions followed by them. More information may be obtained about such facility from DBT websites: http://www.dbtindia.org// www.dbtindia.nic.in, www.btisnet.ac.in.

14. Investigators / Institutes shall follow the detailed instructions on technology transfer and Intellectual Property Rights (IPR) as given at Annexure - V. The same has the approval of the Ministry of Finance, Govt. of India vide Deptt. of Expenditure, Plan Finance II – Division Letter No. 33 (5) /PF.II/99 dated 22nd February, 2000. Any deviation from these instructions may be brought to the notice of this Department.

15. Investigators / Institutes may file patents with the help of the Biotechnology Patents Facilitating Cell (BPFC) established at DBT on priority bases. The format for filing the patents may be seen at Annexure –VI.

16. The Govt. of India (Deptt. of Biotechnology) will have the right to call for drawings, specifications and other data necessary to enable the transfer of know-how to other parties and the Institute shall supply all the needed information at the request of the Department of Biotechnology which will ensure confidentiality. The information required for commercializing Biotechnologies may be furnished to this Deptt. as per the format enclosed at Annexure – VII. More information on commercialization can be found at the website www.ebc.nic.in.

17. The Institute may not entrust the implementation of the work for which the grant is being sanctioned to another institution and to divert the grant receipts as assistance to the latter institution. However, in such situations the express permission of DBT may be obtained. In case the grantee is not in a position to execute or complete the project, it may be required to refund forthwith to the Govt. of India (Department of Biotechnology) the entire amount of grant received by it.

18. The human resources that may be engaged for the project by the Institute are not to be treated as employees of the Govt. of India and the deployment of such human resource at the time of completion or termination of project, will not be the concern/responsibility of the Govt. of India. The Organisation may make reservations for Scheduled Castes, Schedule Tribes etc. in the human resource to be engaged for the project in accordance with the instruction issued by the Govt. of India from time to time.

19. The Deptt. of Biotechnology reserves the right to terminate the grant at any stage and also to recover the amounts already paid if it is convinced that the grant has not been properly utilized or the work on the project has been suspended for any unduly long period or appropriate progress is not being made.

20. The project will become operative with effect from the date of release of the first installment for the project.

21. If the Investigator to whom a grant for a project has been sanctioned leaves the institution where the project is being implemented, he shall submit five copies of complete and detailed report of the work done by him on the project and the money spent till the date of his/her release and shall also arrange to refund the unspent balance , if any.

22. The organisation should maintain subsidiary accounts of the Govt. of India grant and furnish it to the Audit Officer as and when the recurring and non-recurring expenditure exceeds the limits of Rs. 5.00 lakhs.

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Date :

Signature and stamped of Principal Investigator :
Date :

Dr. Anirban Basu
Professor
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Original Paper

Screening and optimization of indole-3-acetic acid production by bacterial strain isolated from rice rhizosphere and its effects on plant growth

Environmental and Experimental Biology

ISSN 2255-9582

UNIVERSITY OF LATVIA

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Abstract

The present study deals with the isolation of plant growth-promoting bacterial strains from rhizospheric soil collected from a rice field of Purba Bardhaman District, West Bengal, India. Among the isolated five strains, A5 was the best-performing strain as it had, plant growth promoting traits like, production of indole-3-acetic acid (IAA), siderophore, hydrogen cyanide and exopolysaccharides, ammonia, phosphate solubilization, nitrogen fixation etc. Strain A5, identified as *Bacillus xiamensis* by phenotypic characters and 16S rDNA sequence-based homology, was able to produce a copious amount of IAA, particularly in the case of 42-h culture with 1.5% L-tryptophan as a precursor. Media optimization with different carbon and nitrogen sources was conducted for maximum production of IAA. Strain A5 used fructose and casamino acid most efficiently as carbon and nitrogen sources, respectively. Growth parameters were increased in A5-treated seedlings of mung bean compared to control seedlings. Considering the observed traits, strain A5 can definitely be considered as a novel plant growth-promoting bacterial strain that may serve very well as a biofertilizer in agricultural fields.

Key words: *Bacillus xiamensis*, indole-3-acetic acid, plant growth-promoting rhizobacteria, plant growth promoting traits.
Abbreviations: ACC, 1-aminocyclopropane carboxylic acid;EPS, exopolysaccharide; IAA, indole-3-acetic acid; OD, optical density; PGPR, plant growth-promoting rhizobacteria

Introduction

The rhizosphere is the portion of soil surrounding the plant root and this region of soil is greatly influenced by plant root activity and metabolism (Prasad et al. 2019). A number of beneficial microbes inhabit the rhizosphere, among which bacteria are a dominant group. One gram of soil contains about 10^8 to 10^9 bacteria, 10^3 to 10^6 fungi, 10^7 to 10^8 actinomycetes, 10^3 to 10^6 algae, 10^6 to 10^8 archaea, 10^3 to 10^5 protozoa and 10 nematodes (Rughöft et al. 2016). Some groups of bacteria that have the capacity to utilize organic compounds released by plant roots (Jones 1990), and the plant forms a microenvironment where these few groups of bacteria can survive (Marilley et al. 1999; Barriuso et al. 2008). The groups of bacteria that are associated with plant roots have important roles in plant growth and productivity, and are collectively known as plant growth promoting rhizobacteria (PGPR) (Backer et al. 2018). PGPR are soil bacteria that colonize on the exterior and interior portion of the root (Backer et al. 2018). These bacteria belong to genera such as *Microbacterium, Alcaligenes, Pantoea, Achromobacter, Rhizobium, Pseudomonas, Bacillus, Burkholderia, Erwinia, Azospirillum, Serratia* etc. (Egamberdiyeva 2000; Tilak et al. 2005). PGPR have several traits by which they can accelerate plant growth via direct or indirect methods like phosphate solubilization, indole-3-acetic acid (IAA) production, atmospheric nitrogen fixation, ammonia production, HCN production, exopolysaccharide production etc. (Rodriguez et al. 1999).

IAA is the most active plant hormone of the auxin family and has important physiological roles in plants, such as embryo development, geotropism, phototropism, root initiation and root elongation etc. (Finet, Jaillais 2012). In addition, IAA contributes in root hair development and in the development of lateral branches of roots, facilitating nutrient uptake from the soil (Datta et al. 2000). Both plants and PGPR can synthesize physiologically active amounts of

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ORIGINAL PAPER

Effectiveness of Phosphate-Solubilizing *Aspergillus fumigatus* MCC 1721 in Boosting Fenugreek Yield in Red Laterite Soil

Biyas Mukherjee[1] · Sanchali Roy[2] · Nasrin Parvin[2] · Sikha Dutta[2]

Received: 3 May 2024 / Accepted: 7 October 2024

Abstract
Phosphorus is an essential nutrient vital for the growth of plants, rapidly becomes immobile and inaccessible to plants when applied as fertilizer. Rock phosphate (RP), abundantly present in Indian soils, serves as phosphate source. Phosphate-solubilizing fungi (PSF) possess the capacity to solubilize insoluble forms of phosphate, rendering it bioavailable and thereby enhancing plant growth. PSF were isolated and screened based on in vitro plant growth-promoting traits. The best-performing strain was identified using molecular tools. The phosphate-solubilizing capacity of the selected isolate was assessed in vitro. A 2-year field experiment was conducted to investigate the impact of RP and PSF, alone or together on fenugreek in red laterite soil. The result was compared against the use of chemical fertilizer (di-ammonium phosphate) and arbuscular mycorrhizal fungus (*Funneliformis mosseae*) focusing primarily on crop yield and soil fertility. Six PSF were obtained among them AP2 was selected and identified as *Aspergillus fumigatus*. AP2 demonstrated significant growth promoting properties and effectively solubilized various insoluble phosphate forms. Additionally, AP2 produced acid phosphatase and various organic acids while growing with different insoluble phosphate. The combined application of AP2 alongside RP fertilization showed enhanced growth and total phosphate uptake in fenugreek, surpassing the effects of other treatments. Moreover, soil fertility exhibited notable improvement where AP2 were inoculated alongside RP fertilization compared to other treatments. The findings suggested that incorporating AP2 with RP fertilization offers a promising solution for farmers seeking to reduce dependence on chemical phosphorus fertilizers while advocating for environmentally-friendly agricultural practice.

Keywords *Aspergillus fumigatus* · Di-ammonium phosphate · *Funneliformis mosseae* · Phosphate solubilizing fungi · Red laterite soil · Rock phosphate

1 Introduction

Phosphorus (P) stands as a crucial macronutrient pivotal for the growth and development of plants, following nitrogen (Hameeda et al. 2008; Sharma et al. 2013). In recent years, in response to the escalating demand for crop yields, various phosphate fertilizers have been extensively employed in agricultural contexts. However, plants fail to fully utilize the total amount of applied fertilizers due to the rapid conversion of inorganic phosphate into insoluble forms (Chen et al. 2006a; Goldstein 1986). Approximately 99% of soil P forms complexes with various cations such as iron (Fe), calcium (Ca), and aluminum (Al) (Son et al. 2006), leaving only a minute portion soluble and directly accessible to plants (Barroso and Nahas 2005). Consequently, plants endure P deficiency, impeding their growth.

Additionally, prolonged use of chemical fertilizers and pesticides has led to a decline in both the diversity of soil microbes and their beneficial relationships with plants within the plant's ecosystem (Huang et al. 2019). The experimental site, characterized by red laterite soil, is notably deficient in nutrient content. Regarding phosphate compounds, it is predominantly rich in iron phosphate, with occluded phosphate, calcium phosphate, and aluminium phosphate present in lesser amounts (Sarkar et al. 2013). Hence, restoring

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RESEARCH ARTICLE

Characterization of a potent plant growth promoting fungal strain *Aspergillus fumigatus* MCC 1721 with special reference to indole-3 -acetic acid production

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Abstract

In the present study, indole-3-acetic acid (IAA) producing plant growth promoting fungus was isolated from rice field of Purba Bardhaman district, West Bengal, India. Among the isolated 6 strains, AP2 (*Aspergillus fumigatus*) was selected as best-performing plant growth promoting fungal strain as it was an efficient indole-3-acetic acid producer as well as exhibits different plant growth promoting ability viz, phosphate solubilization, siderophore production, ammonia and hydrogen cyanide production etc. Media and different growth conditions (pH, temperature, concentration of sodium chloride) were optimized for augmentation of the indole-3-acetic acid production. The genus of the selected isolate AP2 was identified as *Aspergillus fumigatus* both by 18S rDNA sequence-based homology and MALDI-TOF analyses of ribosomal protein. Plant growth promoting ability of *Aspergillus fumigatus* has been confirmed by measuring different morphological and biochemical growth parameters in *Trigonella foenum-graecum* L. So, AP2 (*Aspergillus fumigatus*) can be considered as novel plant growth promoting fungal strain that can be applied as bio-inoculants on agricultural field.

Keywords

Aspergillus, IAA producing fungi, indole-3-acetic acid, plant growth promoting fungi

Introduction

Now-a-days, pesticides and chemical fertilizers are excessively used in crop production (1). Although, these chemical fertilizers may increase crop nutrient in adverse condition but it has many negative impact in our environment (2). Chemical fertilizer made up of phosphate, potassium, nitrate salts are potential source of heavy metals and radio-active elements that may accumulate in soil and may enter into plant body (2). In this point, there is an extreme thrust for an alternative eco-friendly and environmentally sustainable method. A sustainable agricultural practice significantly reduces the use of hazardous chemical input to the agricultural field to ensure protection of the environment but should maintain the nutrient quality of crops (1).

Current research has focused on different soil borne plant growth promoting microbes that can be a good alternative of the harmful chemical fertilizers (1). Several rhizosphere fungi plays important role in growth and productivity of host plant (3). Different fungal stains that inhabit in rhizosphere region of host plants are able to increase the plant growth and productivity in various ways (4). Some commonly reported plant growth

SL. NO. 18

BMC Genomics

RESEARCH

Open Access

Delving into the lifestyle of Sundarban Wetland resident, biofilm producing, halotolerant *Salinicoccus roseus*: a comparative genomics-based intervention

Bhramar Dutta[1], Urmi Halder[1], Annapurna Chitikineni[2,3], Rajeev K. Varshney[2,3] and Rajib Bandopadhyay[1*]

Abstract

Background Microbial community played an essential role in ecosystem processes, be it mangrove wetland or other intertidal ecologies. Several enzymatic activities like hydrolases are effective ecological indicators of soil microbial function. So far, little is known on halophilic bacterial contribution and function on a genomic viewpoint of Indian Sundarban Wetland. Considering the above mentioned issues, the aims of this study was to understand the life style, metabolic functionalities and genomic features of the isolated bacterium, *Salinicoccus roseus* strain RF1H. A comparative genome-based study of *S. roseus* has not been reported yet. Henceforth, we have considered the inclusion of the intra-species genome comparison of *S. roseus* to gain insight into the high degree of variation in the genome of strain RF1H among others.

Results *Salinicoccus roseus* strain RF1H is a pink-red pigmented, Gram-positive and non-motile cocci. The bacterium exhibited high salt tolerance (up to 15% NaCl), antibiotic resistance, biofilm formation and secretion of extracellular hydrolytic enzymes. The circular genome was approximately 2.62978 Mb in size, encoding 574 predicted genes with GC content 49.5%. Presence of genomic elements (prophages, transposable elements, CRISPR-Cas system) represented bacterial virulence and multidrug-resistance. Furthermore, genes associated with salt tolerance, temperature adaptation and DNA repair system were distributed in 17 genomic islands. Genes related to hydrocarbon degradation manifested metabolic capability of the bacterium for potential biotechnological applications. A comparative pangenome analysis revealed two-component response regulator, modified C4-dicarboxylate transport system and osmotic stress regulated ATP-binding proteins. Presence of genes encoding arginine decarboxylase (ADC) enzyme being involved in biofilm formation was reported from the genome. In silico study revealed the protein is thermostable and made up with ~ 415 amino acids, and hydrophilic in nature. Three motifs appeared to be evolutionary conserved in all *Salinicoccus* sequences.

Conclusion The first report of whole genome analysis of *Salinicoccus roseus* strain RF1H provided information of metabolic functionalities, biofilm formation, resistance mechanism and adaptation strategies to thrive in climate-change induced vulnerable spot like Sundarban. Comparative genome analysis highlighted the unique genome content that contributed the strain's adaptability. The biomolecules produced during metabolism are important sources of compounds with potential beneficial applications in pharmaceuticals.

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such as amino acid composition, extinction coefficient, instability index, aliphatic index and grand average of hydropathy (GRAVY) of the ADC proteins of *S. roseus* RF1H, *S. carnicancri*, *S. cyprini*, *S. halodurans* and *S. sediminis* were calculated by using Expasy ProtParam tool [https://web.expasy.org/protparam/]. Secondary structure prediction of ADC was carried out by SOPMA from the NPS server [https://npsa-pbil.ibcp.fr/cgi-bin/npsa_automat.pl?page=/NPSA/npsa_sopma.html]. *S. roseus* strain RF1H was selected to predict the tertiary structure of ADC. SWISS-MODEL [https://swissmodel.expasy.org/] was used to build 3D models and the model quality was assessed by ProSA-web [https://prosa.services.came.sbg.ac.at/prosa.php]. Multiple protein sequences were aligned with COBALT tool [https://www.ncbi.nlm.nih.gov/tools/cobalt/re_cobalt.cgi] to understand the amino acid differences in the structure. The conserved protein motifs were analyzed by MEME tool [https://meme-suite.org/meme/index.html]. The deduced domains were subjected to find protein family using the NCBI conserved domain database (CDD) [https://www.ncbi.nlm.nih.gov/cdd].

Biochemical characteristics

Qualitative detection of extracellular hydrolytic enzymes like amylase, cellulase, protease, lipase/esterase, catalase and carbohydrate fermentation using various sugars like-ribose, fructose, starch, mannose and triple sugar (lactose, sucrose, glucose and iron) were performed on agar plate assays [63].

Statistical analyses

Statistical analyses of the basic genomic features like genome length, GC content, number of CDS etc. were performed with a t-test in R Studio [47]. The p-value of < 0.05 was considered as significant threshold. Experiments were performed in triplicates. Standard errors were calculated and shown in charts as error bars.

Abbreviations

ABC transporter	ATP-binding cassette transporter
ADC	Arginine decarboxylases
AGEs	Accessory Genomic Elements
AI	Autoinducer
AIP	Autoinducing Peptide
AMP	Antimicrobial Peptides
ANI	Average nucleotide identity
BLAST	Basic Local Alignment Search Tool
CGViewer	Circular Genome Viewer
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
EHT	Electron High Tension
GBDP	Genome BLAST Distance Phylogeny
GI	Genomic Island
HGT	Horizontal Gene Transfer
KEGG	Kyoto Encyclopedia of Genes and Genomes
MES	Microbial Electrochemical Systems
MHA	Mueller–Hinton Agar
NCBI	National Centre for Biotechnology Information
QS	Quorum Sensing
RAST	Rapid Annotations using Subsystems Technology
SEM	Scanning Electron Microscopy
TEM	Transmission Electron Microscope
TYGS	Type (Strain) Genome Server

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12864-023-09764-w.

Additional file 1: Supplementary Table S1. Matrix consisting of Average Nucleotide Identity (ANI) values of the fourteen genomes of Salinicoccus. **Supplementary Table S2.** RAST subsystem analysis for proteins involved in various metabolic activities of Salinicoccus roseus RF1H. **Supplementary Table S3.** Functional annotation of genes present in Genomic Islands of S. roseus strain RF1H. **Supplementary Table S4.** Assembly and annotation report of all available Salinicoccus roseus genomes from NCBI GenBank. **Supplementary Table S5.** Features assigned to subsystems from RAST server present in all S. roseus strains. **Supplementary Table S6.** Antibiotic sensitivity of Salinicoccus roseus strain RF1H. **Supplementary Table S7.** ResFinder FESA server generated antimicrobial test results of S. roseus RF1H. **Supplementary Table S8.** Distribution of three motifs with best possible amino acid. **Supplementary Figure S1.** Osmoadaptation strategies of S. roseus revealed by genome analysis.

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Authors' contributions

RB: Conceptualization, supervision. BD: Experimental work, data analysis and draft manuscript writing. UH: Annotation. AC and RKV: sequencing and assembly. All authors reviewed the manuscript.

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Availability of data and materials

The whole genome shotgun project of *Salinicoccus roseus* strain RF1H has been deposited in NCBI GenBank under the accession number JAIMFU010000000.1 (BioProject number PRJNA756885 and BioSample number SAMN20929570).
Supplementary material related to this article is available online.

Declarations

Ethics approval and consent to participate

The research does not involve any studies with human participants and/or animals.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Article

Synthesis, Kinetics, Reaction Mechanism, and Bioactivity Assays of a Dimeric Palladium Complex

Anwesha Dey,[#] Ramesh Kumar,[#] Bhramar Dutta, Rajib Bandopadhyay, Sankha Chakrabortty, Moonis Ali Khan, Byong Hun Jeon,* and Alak Kumar Ghosh*

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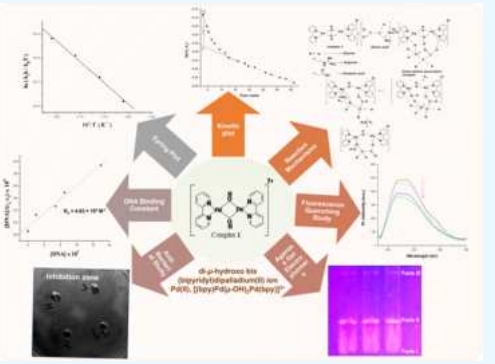
ABSTRACT: A dimer of Pd(II), $[(bpy)Pd(\mu\text{-}OH)_2Pd(bpy)]^{2+}$, (complex **1**) (where bpy = 2,2′-bipyridyl) has been synthesized at physiological pH (7.4) and characterized by electronic spectroscopy, electrospray ionization mass spectrometry (ESI-MS) spectroscopy, and Fourier transform infrared (FT-IR) analysis. Reaction kinetics of **1** with glycine (L^1H), L-glutamic acid (L^2H), and L-arginine (L^3H) were investigated in an aqueous medium at pH of 7.4 and constant ionic strength via a spectrophotometer as a function of temperature and different concentrations of substrate-complex and ligand. The interactions were supported by two discrete successive steps, i.e., ligand-dependent and ligand-independent steps. The equilibrium constant of complex formation (outer-sphere association) and the rate constant during complex-substrate−ligand interaction were calculated. The Eyring equation was applied to evaluate activation factors ($\Delta H^{\ddagger}$ and $\Delta S^{\ddagger}$), and associative mechanisms of all reactions were proposed. Thermodynamic parameters ($\Delta H°$ and $\Delta S°$) were also estimated from the standard plot of ln K_E against $10^3/T$. Spectroscopic titration of **1** at pH 7.4 in Tris−HCl buffer with calf thymus DNA, electronic emission titration with ethidium bromide (EtBr), antimicrobial activities, and an agarose gel electrophoresis run of **1** on pBR322 plasmid DNA have shown strong evidence of anticancer activity. Moreover, it has nontoxic water molecules as leaving groups.



1. INTRODUCTION

Metal-based anticancer chemotherapeutic drugs that are less toxic to normal cells and more effective to cancerous cells have been in search ever since the successful clinical application of cisplatin, *cis*-diamminedichloroplatinum(II) (*cis*-DDP) in cancer therapy.[1,2] However, various types of side effects, such as vomiting, nausea as well as nephrotoxicity, neurotoxicity, hemolytic anemia, and ototoxicity, have limited the wide application of cisplatin as an anticancerous drug.[3] Other newly synthesized Pt(II)-based anticancer drugs viz. carboplatin, nedaplatin, lobaplatin, and oxaliplatin are not as successful as cisplatin due to severe side effects and no longer have the clinical advantages.[4,5] Moreover, inherent and acquired resistances have marred the success of cisplatin and limited its efficacy during chemotherapy.[6] The adverse effect of Pt(II)-based anticancer drugs leads the attention toward the less toxic[7] but similar efficacy of Pd(II) complexes showing isostructural pattern (square planar) and analogues with Pt(II) complexes.[8,9] Moreover, Pd(II) complexes could attain rapid equilibrium in comparison to Pt(II) (10^5 times faster)[10,11] analogues which might be applied as a model complex for studying the mechanism of interaction of Pt-analogues with DNA.[12]

From this background, we have chosen Pd(II)[13] as the metal center and an aromatic ligand having an N,N donor center (2,2′-bipyridine)[14,15] as a building block considering the donor center of cis-DDP to explore its kinetic and mechanistic behavior for in vitro studies using three selected amino acids: glycine, L-arginine, and L-glutamic acids. In addition, such metal complexes interrelate noncovalently with DNA due to their planar aromatic rings, which have the potential of powerful anticancerous drugs.[16,17] The calf thymus (ctDNA) has been used primarily for DNA binding studies during the development of metallodrugs for chemotherapeutic applications using different metal-based complexes such as Pd, Cu, Zn, and Ru.[14,18] In vitro studies, such as evaluation of the linear Stern−Volmer quenching constant (K_{sv}), ability to cleave plasmid DNA (pBR 322), and antimicrobial activity of the complex and ligand, are beneficial to understand the

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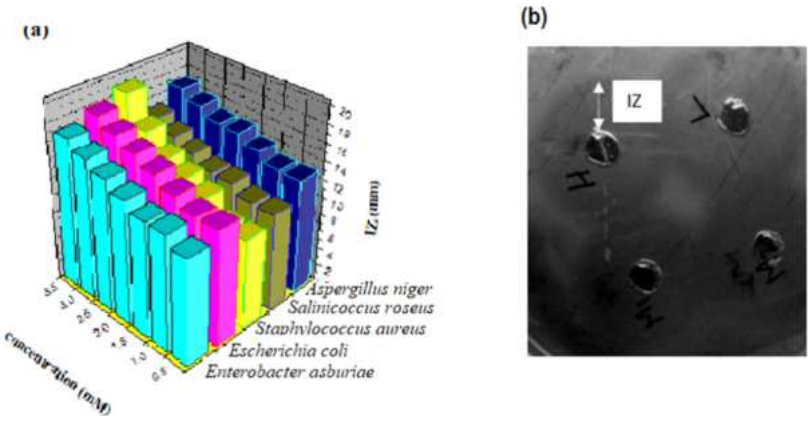

Figure 15. (a) Plot of inhibition zone versus concentration of antimicrobial study of **1** and (b) inhibition zone of bacterial agar Petri dish.

4. CONCLUSIONS

The dimer of the Pd(II) complex was synthesized at pH 7.4 and characterized by electronic spectroscopy, FT-IR, and ESI-MS spectroscopy. Reaction kinetics of **1**'s substitution reactions with the three selected amino acids containing N and O donor centers at 7.4 pH in the aqueous solution have been studied to optimize reactivity and selectivity. Low positive values of enthalpy of activation ($\Delta H_1^{\neq}$ and $\Delta H_2^{\ddagger}$) and high negative values of entropy of activation ($\Delta S \neq 1$ and $\Delta S \neq 2$) for the three reactions suggest a reasonable degree of ligand participation in the associative mode of the transition state, which implies ligand-dependent step I. In contrast, step II is ligand-independent ring closure. The high nucleophilicity of glycine among the three amino acids leads to greater stabilization of the transition state with the Pd(II) dimer and requires the lowest activation enthalpy. In vitro DNA binding studies suggest a strong interaction of **1** with ctDNA. The antimicrobial and antifungal activities reveal that **1** can be active against selected bacterial and fungal strains. Comparing the K_b and K_{SV} values (Table 6), it is found that **1** has a higher value than **2** but a lower value than the other (Pd 1, Pd 2, Pd 3, and Pd 4). So, dimerization from **2** to **1** increases DNA binding capacity. In the case of Pd 2, Pd 3, Pd 4, and Pd 5, though they are dimers having a higher DNA binding value than **1**, each of the four has toxic chloride (Cl^-) as a leaving group, while **1** has a nontoxic water molecule as a leaving group.

Further studies can be carried out to evaluate its pharmacological properties in vivo and the definite mechanism of its bioactivity. However, the results of this study can be beneficial in understanding the reaction kinetics and the interaction of the Pd(II) complex with amino acids, DNA, and selected microbes. It can encourage the development and production of superior anticancer therapeutic reagents. The following points summarize the novelty of this study, such as a correlation between kinetic study and bioactivity assay in an aqueous medium at physiological pH, optimization between reactivity and selectivity, optimum rate, nontoxic side product (H_2O), and antimicrobial activity.

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Author Contributions

#A.D. and R.K. equally contributed to this work.

Notes

The authors declare no competing financial interest.

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Detailed genomic and biochemical characterization and plant growth promoting properties of an arsenic-tolerant isolate of *Bacillus pacificus* from contaminated groundwater of West Bengal, India

Ashutosh Kabiraj [a], Urmi Halder [a], Anindya Sundar Panja [b], Annapurna Chitikineni [c, d], Rajeev K. Varshney [c, d], Rajib Bandopadhyay [a, *]

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ARTICLE INFO

Handling Editor: Dr. Ching Hou

Keywords:
Arsenic
Bioremediation
Ars operon
Comparative genomics
FTIR
EDS

ABSTRACT

In this study, arsenic tolerating bacteria *Bacillus pacificus* (AKS1a) was isolated from arsenic contaminated groundwater of Purbasthali, Purba Bardhaman, West Bengal, India and its bioremediation potential was preliminary screened. This multimetal resistant strain was able to grow against more than 20 mM arsenate and 10 mM arsenite salts. The genome was more than 5.16 Mb in length, with an average of around 35.2% GC content, bearing 5403 protein coding genes. Arsenic resistant genes like *arsC*, *arsB*, *arsR*, etc. were also identified. Rapid Annotation using Subsystem Technology (RAST) identified 328 subsystems within the genome. Presence of six Genomic Islands (GIs) and five phage virus genomic parts indicated its ecological adaptations to overcome environmental stresses. The production of about 415 μg mL^{-1} indole acetic acid (IAA), 258.0 μg mL^{-1} gibberellic acid (GA), and 183 μg mL^{-1} proline by the bacterium, along with nitrogen fixation ability under *in-vitro* conditions, indicate its plant growth promoting potential. This was further confirmed through rice seedling growth enhancement under arsenic stress. Beside arsenite oxidation to arsenate, its arsenic adsorption property was confirmed through X-ray Fluorescence spectroscopy (XRF), Fourier Transform Infrared spectroscopy (FTIR), and Energy Dispersive X-ray spectroscopic (EDS) analysis. Genomic comparisons among 25 different strains of *B. pacificus* showed that there are tremendous genetic differences in respect to their accessory genome content. In future, this strain can be applied as biofertilizer or biostimulant for improving rice plant growth.

1. Introduction

Arsenic and its detrimental impacts on different organisms are well established today (Sher and Rehman, 2019). Arsenic, a metalloid, is ubiquitously distributed in environment and its presence markedly dependent on biotic and abiotic factors like nature of soil, microbial population, pH, water content, etc. Background concentration of arsenic ranges from 0.1 to 40 mg kg^{-1} in soil and <0.5 to

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Copper removal capability and genomic insight into the lifestyle of copper mine inhabiting *Micrococcus yunnanensis* GKSM13

Krishnendu Majhi [a,b], Moitri Let [a], Urmi Halder [a], Annapurna Chitikineni [c,d], Rajeev K. Varshney [c,d], Rajib Bandopadhyay [a,*]

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ARTICLE INFO

Handling Editor: Aijie Wang

Keywords:
Bioremediation
Copper mining
Copper homeostasis
Copper removal
Multimetal resistant

ABSTRACT

Heavy metal pollution in mining areas is a serious environmental concern. The exploration of mine-inhabiting microbes, especially bacteria may use as an effective alternative for the remediation of mining hazards. A highly copper-tolerant strain GKSM13 was isolated from the soil of the Singhbhum copper mining area and characterized for significant copper (Cu) removal potential and tolerance to other heavy metals. The punctate, yellow-colored, coccoid strain GKSM13 was able to tolerate 500 mg L^{-1} Cu^{2+}. Whole-genome sequencing identified strain GKSM13 as *Micrococcus yunnanensis*, which has a 2.44 Mb genome with 2176 protein-coding genes. The presence of putative Cu homeostasis genes and other heavy metal transporters/response regulators or transcription factors may responsible for multi-metal resistance. The maximum Cu^{2+} removal of 89.2% was achieved at a pH of 7.5, a temperature of 35.5 °C, and an initial Cu^{2+} ion concentration of 31.5 mg L^{-1}. Alteration of the cell surface, deposition of Cu^{2+} in the bacterial cell, and the involvement of hydroxyl, carboxyl amide, and amine groups in Cu^{2+} removal were observed using microscopic and spectroscopic analysis. This study is the first to reveal a molecular-based approach for the multi-metal tolerance and copper homeostasis mechanism of *M. yunnanensis* GKSM13.

1. Introduction

The term "heavy metal" refers to the group of metallic elements and metalloids with high molecular weight and atomic density greater than 5 g cm^{-1} (Dhaliwal et al., 2020). The non-degradable and persistent metals such as copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), arsenic (As), nickel (Ni), cobalt (Co), zinc (Zn), and mercury (Hg) (Kumar et al., 2021) exacerbate the negative impacts on the ecosystem. The bioaccumulation and biomagnification of these heavy metals in ecosystems pose an acute threat to the entire food chain (Duruibe et al., 2007; Das et al., 2022). These pollutants are cytotoxic in nature, create gastrointestinal complications, short time memory loss, mental retardation, etc. even at low concentrations (Priyadarshanee and Das, 2021). In addition, adverse effects on human are generally dose-dependent and metal specific. For example, Pb causes oxidative damage by forming reactive oxygen species (ROS), Cr (VI) and Cd effect on cellular integrity, As and Hg form toxic derivatives of methyl and thiol groups, and Fe cause lipid peroxidation (Balali-Mood et al., 2021; Priyadarshanee and Das, 2021).

Among the heavy metals, copper (Cu) is considered an essential micronutrient and acts as a cofactor for multiple enzymes and proteins involved in photosynthesis, oxidation, nitrogen fixation, and other cellular metabolisms (Rehman et al., 2019). According to the World Health Organization (WHO), the permissible limit of Cu in drinking water is 2 mg L^{-1} (Chan et al., 2022). However, several natural and anthropogenic activities such as soil erosion, leaching, mining, smelting, automobile exhaust, coal combustion, municipal compost, fertilizers, pesticides, and fungicides are the major contributors for the excessive Cu inputs into the environment (Kumar et al., 2021; Saha et al., 2022). This may cause vegetation loss, soil nutrient depletion, and human health risks (Shabbir et al., 2020). In humans, Cu toxicity generates free radicals within the cell and causes nausea, headache, vomiting, diarrhoea, respiratory infections, liver and kidney failure (Rathi and Yogalakshmi, 2021; Shabbir et al., 2020). Nevertheless, the excessive Cu

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Copper removal capability and genomic insight into the lifestyle of copper mine inhabiting *Micrococcus yunnanensis* GKSM13

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ARTICLE INFO

Handling Editor: Aijie Wang

Keywords:
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ABSTRACT

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1. Introduction

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SHORT COMMUNICATION

Splachnobryum (Splachnobryaceae A.K. Kop.) a New Generic Record to the Mosses of Sikkim Himalaya, India

S. S. Dash[1] · Subhajit Lahiri[2] · Pamela Saha[2] · Asok Ghosh[3] · B. K. Sinha[1]

Received: 14 March 2018 / Revised: 3 August 2018 / Accepted: 9 January 2020 / Published online: 30 January 2020

Abstract *Splachnobryum obtusum* (Brid.) C. Muell. (Splachnobryaceae A.K. Kop.) has been recently collected from Dzongri regions of west district of Sikkim at an altitude of 3732 msl. The collection of this species from such a higher elevation in Sikkim indicates its greater adaptability to survive in a varied range of habitats in Sikkim Himalaya and also an indication for possible climate change. The description of the species along with an illustration is provided in the present paper. Occurrence of the genus *Splachnobryum* has been recorded for the first time from Sikkim Himalaya and also from a subalpine region.

Keywords Moss · Eastern Himalaya · New · Generic record · Sikkim · *Splachnobryum*

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Introduction

The genus *Splachnobryum* Muller: 1896 (Splachnobryaceae), consisting of about 10 species [1, 2], is distributed worldwide in the northern tropical and subtropical regions, except a few species that are introduced in temperate glasshouses in South America and Europe. The plants are usually grown in moist and wet inorganic calcareous subtracts, and commonly at low altitudes, extending up to 1870 m [1]. It has greatly been considered that many species that were previously considered under this genus in family Splachnaceae were amalgamation of many taxonomic complexes which were subsequently transferred to many allied genera *Bryum, Syrrhopodon, Distichophyllum, Archidium,* and *Gymnostomiella*or reduced to synonyms [1, 3]. The genus *Splachnobryum* is characterised by small unbranched dioicous gametophytes, erect slender stem, leaves largely deformed, crowded towards apex, median large laminal cells, with a variable shape, smaller towards the margin and large towards the costa; pair of axillary hairs near leaf insertion, rhizoids in the lower part of stem; terminal clustered antheridia solitary-necked archegonia, while the sporophyte is solitary, with a thin, smooth seta and erect, cylindrical theca. In the current circumscription, the genus is represented in India by three species: *Splachnobryum aquaticum* C. Muell. (known from Uttarakhand and Gujarat); *Splachnobryum assamicum* Dixon (known from Uttarakhand and Assam); and *Splachnobryum obtusum* (Brid.) C. Muell. known from Gangetic South Bengal, Orissa, Western Himalaya, and Western Ghats [1, 4].

During identification of some of the recent moss collections, we came across an interesting specimen of *Splachnobryum* Muller. collected from a place between Tshoka and Phedang (3732 m), 27° 27′ 34.24″ N, 88° 10′

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A contribution to the flora of Kanchenjunga Biosphere Reserve, Sikkim, India

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कांचनजंधा जीवमंडल रिजर्व, सिक्किम, भारत की वनस्पतिजात में संयोजन

सुभोजित लाहिड़ी, सुधांशु शेखर दाश, अशोक घोष, बी. के. सिन्हा

सारांश

कांचनजंधा जीवमंडल रिजर्व, सिक्किम में बाइस पादप जातियों का संयोजन हुआ है । इसके अतिरिक्त सिक्किम हिमालय क्षेत्र से प्रथम बार रूबस लासियोस्टाइलस फोके यहां प्रतिवेदित किया गया है । उचित अभिनिर्धारण के लिए प्रत्येक जाति के पुष्पण अवधि व पारिस्थितिकी पर एक विस्तृत विवरण व जानकारी प्रदान की गई है ।

ABSTRACT

Twenty two species reported here as addition to the Flora of Kanchenjunga Biosphere Reserve, Sikkim. Besides *Rubus lasiostylus* Focke reported here for the first time from Sikkim Himalaya. A comprehensive description, information on phenology and ecology of each of the species has been provided here for easy identification.

Keywords: Floristic Diversity, KBR, New Additions, Sikkim

INTRODUCTION

The Kanchenjunga Biosphere Reserve (KBR) is located in West and North district of Sikkim between 27°15′-27°57′N latitude and 88°02′-88°40′E longitude. The biosphere reserve comprises an area of 2619.92 sq. km of which the core zone is about 1784 sq. km and the buffer zone is 835.92 sq. km. Due to its great biodiversity along with multi-ethnic culture, UNESCO acknowledged this biosphere reserve as World Heritage Site in the year 2018. The biosphere reserve falls within the Himalaya global biodiversity hotspot and shows an unrivaled range of sub-tropical to alpine ecosystems. Khangchendzonga Biosphere Reserve is covers 25% of the State of Sikkim, recognized as one of India's most noteworthy biodiversity concentrations. Maity & al., (2018) enumerated 1584 species of flowering plants from the area while dealing the Flora of Kanchenjunga Biosphere Reserve. However, certain parts of the KBR are yet to be explored and documented. Recently, during our visit to KBR in connection with setting up permanent plots under the project "Biodiversity Assessment through Long-term Monitoring Plots in Indian Himalayan Landscape" for monitoring of plant diversity change in the Dzongri-Gocha La area, we have collected a total of 400 plant specimens. Interestingly, 22 species belonging to 13

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SL. NO. 21

University of Calcutta

Senate House, Kolkata - 700073

Date of Enrollment : **14th March 2016**
Registration Number : **04407/Ph.D.(Sc.)Proceed/2018**
Date of Registration : **18th June 2018**
Date of Letter : **20th June 2018**
(Please quote the above Number and Date in all future Correspondence)

From:
The Registrar,
University of Calcutta

To:
Smt Piu Banerjee
23/A/4, A.K.Banerjee Lane,
P.O.- Konnagar, Dist.- Hooghly,
Pin- 712235.

Madam,

I am desired to inform you that you have been granted registration for the Ph.D. programme under this University in **Zoology** in terms of 4.8 of the Regulations for the Degree of Doctor of Philosophy (Ph.D.) .

This registration shall remain valid for next five years with effect from the date of registration as indicated above.

You are to comply with the usual rules of migration in case you have passed the qualifying examinations for the Ph.D. programme from a University/Institute other than the University of Calcutta.

Title of Thesis

"Diversity, Biosystematics And Management Of Mites Infesting Tea Plantations Of Himalayan And Sub-Himalayan Regions Of West Bengal, India."

Name of the Supervisor : **Prof. Dr. Goutam Kumar Saha**
Name of the Joint Supervisor : **Dr. Sanjoy Poddar**
Name of the Associate Supervisor : **X**

Yours faithfully,

21 JUN 2018
Dy. Registrar

Piu Banerjee

University of Calcutta
Senate House, Kolkata - 700073

Date of Enrollment : **19th June 2017**
Registration Number : **00980/Ph.D.(Sc.)Proceed/2019**
Date of Registration : **21st February 2019** Date of Letter : **25th February 2019**
(Please quote the above Number and Date in all future Correspondence)

From:
Dy. ~~The~~ Registrar (Actg.),
University of Calcutta

To:
Sri Arghya Laha
44, Haran Chandra Laha Main Road,
Suksanatantala, P.O.- Chandannagar,
Dist.- Hooghly, Pin- 712136.

Dear Sir,

I am desired to inform you that you have been granted registration for the Ph.D. programme under this University in **Zoology** in terms of **6.6** of the Regulations for the Degree of Doctor of Philosophy (Ph.D.), C.U., framed under UGC Guidelines, **2016.**

This registration shall remain valid for next six years with effect from the date of enrolment as indicated above.

You are to comply with the usual rules of migration in case you have passed the qualifying examinations for the Ph.D. programme from a University/Institute other than the University of Calcutta.

Title of Thesis

"Identification Of Susceptible Genetic Variants Associated With Food Allergy Within Population Of West Bengal, India."

Name of the Supervisor : **Prof. Dr. Goutam Kumar Saha**
Name of the Joint Supervisor : **Dr. Sanjoy Poddar**
Name of the Associate Supervisor : **X**

Yours faithfully,

28/2/19
Dy. Registrar (Actg.)
552

N.B. Please see the instructions overleaf.

NIBMG

राष्ट्रीय जैव-चिकित्सा जीनोमिकी संस्थान

(भारत सरकार का स्वायत्त संस्थान, जैवप्रौद्योगिकी विभाग)

NATIONAL INSTITUTE OF BIOMEDICAL GENOMICS

(An Autonomous Institution of the Government of India, Department of Biotechnology)

AGREEMENT TO COLLBORATIVE WORK (ATC)

ON

"NEXT GENERATION SEQUENCING SERVICE"

BETWEEN

THE

NATIONAL INSTITUTE OF BIOMEDICAL GENOMICS, HAVING ITS REGISTERED OFFICE AT **PO: N.S.S, KALYANI, DISTRICT: NADIA, WEST BENGAL, INDIA, PIN: 741251**, HEREIN REFERRED TO AS

"NIBMG"

AND

THE UNIVERSITY OF BURDWAN, RAJBATI, PURBO BARDHAMAN: 713104, HEREIN REFERRED TO AS

"BU",

AND

ON AND FROM 11th. October, 2018 TO 11th. October, 2019

1. Statement of Purpose

1.1 The purpose of this agreement is to establish a framework for research experimentation between **BU** and NIBMG on "Next Generation Sequencing"

2. Statement of Work

2.1 Where as **BU** is desirous of undertaking research on ' Next generation Sequencing " and has the necessary expertise for the overall conduct of the study.

2.2 Whereas NIBMG has the necessary scientific expertise and technology platform required for the said work and is desirous of sharing the same with MBHGL through its **Core Technology Research Initiative** (herein referred to as **CoTeRI**).

2.4 BU will provide NIBMG with required quality and quantity of biospecimens (DNA samples) as required and specified by NIBMG.

2.5 NIBMG shall carry out the necessary sequencing work in it's facility .

2.6 NIBMG will provide the generated sequencing data to the Principal investigator of BU for which due credit will be provided to NIBMG with the clause "Next generation sequencing was performed at the National Institute of Biomedical Genomics, Kalyani, India" in the acknowledgement section of any publication/s arising from the data generated at the NIBMG.

2.7 BU will bear costs of all reagents, consumables and associated costs as estimated by NIBMG and provide the same to NIBMG in advance of initiation of work, which may be phased out as mutually agreed.

2.8 NIBMG shall provide Principal investigator of BU with an acknowledgement of the receipt of the money and **invoice** , immediately after receiving the fund as well as statement of expenditure and utilization certificate for the funds remitted by BU within three months after the completion of the work.

2.9 Any intellectual property arising out of this work shall be shared jointly by BU and NIBMG based on the due contribution of the both the side and cost sharing and by mutual understanding.

2.10 NIBMG will maintain complete confidentiality of the work as well as the data and the scientific conclusions drawn therein.

2.11 Remainder, if any, of bio specimens provided by Principal Investigator (PI) of BU to NIBMG for experiments carried out in NIBMG shall be returned by NIBMG to BU after the due completion of the required experiments.

3. General Provisions

3.1 This agreement will be effective upon placement of signature of authorized signatories of BU and NIBMG.

3.2 This agreement may be amended by mutual consent of BU and NIBMG.

3.3 This agreement may be reviewed and terminated by BU or NIBMG by providing a notice to the other parties at least 90 days in advance of the termination date.

3.4 Any dispute arising out of the collaborative work between BU and NIBMG may be settled jointly by Principal Investigator/ Authorised signatory of BU and of NIBMG.

3.5 Principal Investigator of BU undertakes that the required institutional ethics approval for the said work has been duly obtained and that NIBMG is not responsible for any question or dispute that may arise in future regarding the ethics approval required for conducting the experiments in NIBMG.

4. Specific Provisions

4.1 Principal Investigator of BU shall submit samples of DNA/RNA, of appropriate quantity and purity as required by NIBMG.

4.2 Based on the experimental need, Principal Investigator of BU will provide specific sequencing requirements (Whole exome/ Whole genome/ expanded exome/Trascriptome/or others) to **CoTeRI,** NIBGM. Accordingly, **CoTeRI,** will provide cost /per sample to the Principal Investigator of BU.

4.2. Principal Investigator of BU will provide the Cost of required minimum of samples size to the NIBGM, which will be decided by the **CoTeRI,** NIBMG, based on the experimental condition. BU shall transfer total cost of samples to NIBMG's bank account in advance of initiation of work.

For and on behalf of BU

Name: Dr. T. Hossain

Designation: Registrar

Place: Rajbati, Burdwan

Signature: 11.10.18

Seal: REGISTRAR (Officiating) THE UNIVERSITY OF BURDWAN BURDWAN-713104

Witness:

Name : Dr. Anuapm Basu

Principal Investigator, Dept. of Zoology, BU

Signature: 4/10/2018

Dr. Anupam Basu PROFESSOR Department of Zoology The University of Burdwan

For and on behalf of NIBMG

Name: Dr. Saumitra Das

Designation: Director

Place: Kalyani, West Bengal

Signature:

Seal: सौमित्र दास / Saumitra Das निर्देशक / DIRECTOR राष्ट्रीय जैव-चिकित्सा जीनोमिकी संस्थान NATIONAL INSTITUTE OF BIOMEDICAL GENOMICS पी.ओ.:एन.एस.एस., कल्याणी-741251, जिला.नदीया, (प०बं०) P.O.:N.S.S., Kalyani-741251, Dist.-Nadia.(W.B.)

Witness:

Name : Dr. Arindam Maitra

Associate Professor, NIBMG

Signature:

National Institute of Biomedical Genomics

(An Autonomous Institution of Govt. of India, Dept. of Biotechnology)

Core Technologies Research Initiative (CoTeRI)

Principal Investigator
Prof. Anupam Basu
Principal Investigator,
DBT /SERB Funded project
Molecular Biology and Human Genetics Laboratory
Department of Zoology
The University of Burdwan
Purbo Bardhaman: 713104

Date: 24.09.2018
Reference Number: CoTeRI/BU/001/2018-19

Project Name: Expanded Exome Sequencing

1. Some of the experiments to be carried out in this project require expertise and instrumentation of NIBMG. Hence, the Principal Investigator (PI) of BU would like the help of NIBMG in carrying out the experiments in a collaborative manner.

2. PI shall submit 16 samples of genomic DNA of optimal quality and quantity (500 ng DNA per sample) for expanded exome Sequencing.

3. NIBMG will perform quantitation, exome enrichment, sequencing library preparation and 2 x 100 bp paired end read sequencing for samples to generate 30X average sequence depth per sample.

4. The results of the experiments and data will be shared jointly between PI and NIBMG. NIBMG should be provided due credit for the experimental work performed at NIBMG.

5. NIBMG is providing below a statement of cost required for execution of the experiments which will be remitted by PI to NIBMG in advance.

6. NIBMG will provide PI with details of its bank account for the same. NIBMG will also provide PI with an acknowledgement of the receipt of the money.

7. NIBMG will provide PI with the statement of expenditure and utilization certificate for the collaborative work done on the project from funds remitted by PI within three months after the completion of the work.

8. Actual time required for completion of the project is dependent upon the delivery times of all reagents and consumables required for the work and also the queue of work scheduled for the platform at the time of transfer of samples to NIBMG. Projected time required and schedule of experiments will be provided by NIBMG after the receipt of samples.

9. **Reagents and consumables cannot be purchased by NIBMG without transfer of the total money required for the entire project from PI. Partial remittance shall not be accepted by NIBMG.**

Cost Details:

S. No.	Item	No. of Samples	Total Cost (₹)
1.	DNA quantitation, Sequencing library preparation and 2 x 100 bp sequencing in NovaSeq 6000 S2 flowcell (30X average sequence depth per sample)	16	4,94,400.00
GST @ 18%			88,992.00
Total			**5,83,392.00**

Total Cost: Rupees five lakhs eighty three thousand three hundred ninety two only.

अरिंदम मैत्रा पीएचडी / Arindam Maitra Ph.D.
सह-प्रोफेसर / Associate Professor
राष्ट्रीय जैव-चिकित्सा जीनोमिकी संस्थान
NATIONAL INSTITUTE OF BIOMEDICAL GENOMICS
पी.ओ.: एन.एस.एस., कल्याणी-741251, जिला.:नदीया, (प०ब०)
P.O.: N.S.S., Kalyani-741251, Dist.-Nadia.(W.B.)

BANK ACCOUNT DETAILS of NIBMG

Name of the Beneficiary Account	National Institute of Biomedical Genomics (CoTeRI)
Bank Account Number	**0 5 7 9 0 1 0 4 5 9 1 1 2**
Nature of Bank Account	Saving Bank Account
MICR No.	7 0 0 0 2 7 3 0 3
Name of the Bank	*United Bank of India*
Name and Address of the Bank Branch	Kalyani Branch, Plot No. A-9/7(S), Kalyani, Nadia-741235 91-33-2582-8520 bmkyi@unitedbankofindia.co.in
Bank Branch code	**KYI030**
IFSC Code	**U T B I 0 K Y I 0 3 0** 

SL NO. 22

DAAD Deutscher Akademischer Austauschdienst
German Academic Exchange Service

Letter of Award

Name:	Trinetra Mukherjee
Date of birth:	14/03/89
Personal ref. no.:	91649472
Funding programme/-ID:	Research Grants - Bi-nationally Supervised Doctoral Degrees, 2017/18 (57299293)
Nationality:	India

You are being granted a DAAD scholarship.

Start of funding	End of funding	Destination country	Institution
01/10/17	30/09/18	Germany	Ruhr-Universität Bochum

The scholarship includes the following benefits:

Preparatory language course

Start of course	End of course	Course location	Organiser
01/08/17	30/09/17	Marburg	speak and write

Costs for the above language course totalling: EUR 2.700,00.
DAAD transfers this scholarship directly to the course organiser, who covers the costs of the course and accommodation with these funds and pays you pocket money of 410,00 EUR a month.

Scholarship and supplementary benefits

Benefit	Destination country	Amount	Payment	From	To
Scholarship instalment	Germany	1,000.00 EUR	monthly	01/10/17	30/09/18
Research allowance	Germany	460.00 EUR	01/10/17		
Travel allowance	Germany	350.00 EUR	01/08/17		
Travel allowance Germany	Germany	50.00 EUR	01/10/17		

For months with a funding period of less than 23 days, the scholarship payment will be calculated on a daily basis and the exact number of funding days paid. The payments listed above are subject to possible changes.

Insurance benefits

- Primary health insurance (fully comprehensive insurance)

  Unless you hear otherwise, you will be automatically registered for health insurance by the DAAD with Continentale for the duration of your language course and your scholarship. You are required to inform yourself about the conditions of your health insurance cover in Germany by reading chapter 1.5.1. „General information“ and Point II in the brochure „Ihr DAAD-Stipendium/Your DAAD-scholarship“.

- Insurance for accident and personal liability

The enclosed booklet „Ihr DAAD-Stipendium/Your DAAD-scholarship“ is an integral and complimentary part of this Letter of Award and therefore legally binding.

Conditions and requirements
The flat-rate travel allowance for your return travel will be paid together with your final scholarship instalment. The amount payable will be in accordance with the subsidy rates valid at the point in time.

Other comments

§ 34 of the Ordinance Governing Residence applies to this scholarship. According to this, the visa for academics and scientists and dependants (spouses or partners, if the marriage or civil partnership already existed upon arrival in Germany, and minor, unmarried children) accompanying or subsequently joining them is not subject to the approval of the foreigners' authorities if the scientists are assigned a place by German scientific organisations or a German public body and in this connection are receiving a publicly funded scholarship in Germany.

The scholarship granted as part of the above funding programme is financed entirely from federal public funds.

Bonn, 12/04/17

Secretary General of the German Academic Exchange Service

Personal ref. no.:	91649472
Section in charge:	Section ST34
Head of Section:	Hannelore Bossmann
Person in charge:	Melanie Lemke
Telephone number:	+49 228 882-8958

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Microstructural, electrical and mechanical characterizations of green-synthesized biocompatible calcium phosphate nanocomposites with morphological hierarchy

Tuli Chatterjee [a], Moumita Maji [c], Shrabani Paul [b], Monidipa Ghosh [c], Swapan Kumar Pradhan [b,**], Ajit Kumar Meikap [a,*]

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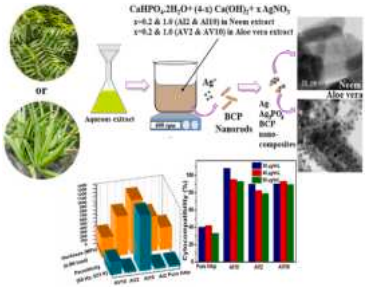
[b] Materials Science Division, Dept. of Physics, The University of Burdwan, Golapbag, Burdwan, 713104, India
[c] Department of Biotechnology, National Institute of Technology, Durgapur, 713209, India

HIGHLIGHTS

- $Ag–Ag_3PO_4$-BCP nanocomposites hydrothermally synthesized in neem and aloe vera media.
- Epitaxial attachments of metallic phases to mesoporous uniaxial BCP nanorods.
- Biocompatibility and stability up to high dosage for 72 h studied on healthy cells.
- High interfacial polarization and surface charge retention ability for osteoconduction.
- Bulk porosity and unique structure-dependent dielectric and mechanical properties.

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Nanocomposites
Electron microscopy
Porosity
Dielectric properties
Impedance
Mechanical properties

ABSTRACT

The present work reports the development of novel ternary silver-silver phosphate-biphasic calcium phosphate nanocomposites by plant-extract mediated hydrothermal route. Unique epitaxial morphological growth of the $Ag–Ag_3PO_4$ core-shell structure influences the internal grain-grain boundary arrangement. The green-assisted development of the constituent phases helps significant biocompatibility enhancement (~89–93% for 50 μg/mL; 72 h). Hence long-term bone-replacement purposes and polar fluid osmosis are favorable due to higher cell attachment on the rough surface of the mesoporous nanocomposites. The heterogeneous attachment between the three phases creates defect states indicating intense interfacial polarization, as elucidated by the dielectric spectroscopic studies. The surface charge essential for bone regeneration is likely to be developed. Besides, the porous nanocomposite compacts exhibit superior phase-composition-dependent mechanical (Hardness ~1.3 GPa; load 4.9 N) and dielectric properties (permittivity ~1.2×10^3; 200 Hz, 613 K) helping in conduction through bones. Thus the green-synthesized ternary nanocomposites exhibit the essential aspects of a promising bone-implant material.

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Grain size mediated electrical and thermoelectric performances of mechanically alloyed Sb_2Te_3 nanoparticles

Shrabani Paul [a], Umapada Pal [b], Swapan Kumar Pradhan [a, *]

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Keywords:
Thermoelectric materials
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ABSTRACT

Antimony telluride (Sb_2Te_3) nanoparticles of different sizes were fabricated by mechanical alloying (MA) of elemental Sb and Te powers for different durations. The powder nanostructures were pelletized, annealed in Ar ambient, and characterized by XRD, FESEM, TEM to study the effect of milling time and thermal treatment on particle size, grain growth, and crystallinity. The annealed and unannealed pelletized nanostructures were analyzed in a PPMS to study the effect of grain growth on their electrical and thermoelectric properties. Room temperature electrical conductivity of the p-type semiconductor nanostructures improved significantly (from ~10^3 to ~ 10^5 mho/m) due to thermal annealing and results in the considerable improvement in thermoelectric figure of merit (ZT). Thermal annealing-induced grain growth also transforms the semiconducting nature of the sample to metallic. The reduced thermal conductivity of the nanostructures with reduced grain size improves the ZT. The temperature-dependent Lorenz number ($L_{effective}$) is used to find the electronic contribution of total thermal conductivity, and it is explained by the non-parabolic Kane model.

1. Introduction

Thermoelectric materials are efficient converters of waste heat into useable electrical energy due to their high Seebeck coefficients [1,2]. Thermoelectric figure of merit ZT defines the performance of a thermoelectric material in converting thermal energy to electricity. The ZT is defined as, $ZT = S^2\sigma T/K$, where S,σ, and K represent the Seebeck coefficient, electrical conductivity, the thermal conductivity of the material, respectively, and T is the temperature in K [3]. The $S^2\sigma$ term is defined as the power factor. Owing to the demand for alternative energy sources, the quest for new materials with an improved figure of merit (ZT) has increased globally at a rapid rate [4,5].

In general, semiconductors are better thermoelectric materials compared to metals [6]. According to Wiedemann-Franz law [7], most metals have a nearly constant electrical to thermal conductivity ratio, and increasing electrical conductivity is difficult without increasing their thermal conductivity. However, a good ZT value requires a high electrical conductivity and simultaneously a lower thermal conductivity. Hence, for metals or metallic alloys, the only possible way to obtain a significant figure of merit is to have a high value of the Seebeck coefficient. Unfortunately, most metals show very small Seebeck coefficients (~10 μV/K), and their thermoelectric efficiencies are only fractions of a percent. On the other hand, semiconductors with comparatively higher Seebeck coefficient values (~100 μV/K) had drawn strong attention as thermoelectric materials since 1920 [8]. Low bandgap semiconductors possess high electrical conductivity, comparable to metals. Compared to bulk materials, nanomaterials have low thermal conductivity because of lower lattice thermal conductivity resulting from the increased phonon scattering due to smaller grain size [9–12]. Thus, nanostructured semiconductors of smaller bandgaps are considered the most favorable thermoelectric materials as they produce a reasonably higher figure of merit values.

Antimony telluride (Sb_2Te_3), a low bandgap semiconductor, has been considered as one of the promising thermoelectric materials for low-temperature applications [13–15]. Nano-structured Sb_2Te_3 thin films fabricated by physical vapor deposition [16], metal-organic chemical vapor deposition [17,18], thermal co-evaporation [19], flash evaporation [20], electrochemical method [21], ion beam sputtering [22], molecular beam epitaxy [23] etc. have shown good thermoelectric conversion efficiency. On the other hand, single-phase Sb_2Te_3 nanoparticles synthesized by microwave-assisted

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0925-8388/

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Improved thermoelectric performance of nanostructured Bi_2Te_3 fabricated by solvent-free mechanical alloying

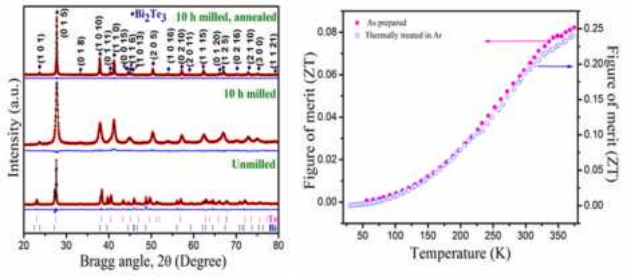
Shrabani Paul [a], Umapada Pal [b,**], Swapan Kumar Pradhan [a,*]

[a] Department of Physics, The University of Burdwan, Golapbag, Burdwan, 713104, West Bengal, India
[b] Instituto de Fisica, Benemérita Universidad Autónoma de Puebla, Apdo. Postal J-48, Puebla, Pue.72570, Mexico

HIGHLIGHTS

- Nanostructured Bi_2Te_3 has been synthesized by facile mechanical alloying method.
- Microstructures of the samples are characterized by XRD and FESEM.
- The semiconducting nature of the sample changes to metallic after annealing.
- Grain growth and associated band gap reduction is noticed after annealing at 573K.
- About three times increase in thermoelectric figure of merit owing to annealing.

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Nanostructures
Microstructure
X-ray diffraction
Thermoelectrics

ABSTRACT

Thermoelectric materials convert waste heat energy efficiently to electricity in an eco-friendly manner. Bi_2Te_3 is a known thermoelectric material, which can convert waste heat and solar energy into electricity in the 200–400 K temperature range. Bi_2Te_3 nanocrystals are prepared in powder form by solvent-free mechanical alloying of elemental Bi and Te powder mixtures under an inert Ar atmosphere. The crystallite size and composition of the Bi_2Te_3 nanocrystals are analyzed using X-ray diffraction, field-emission scanning electron microscope and energy-dispersive X-ray spectroscopy. Thermal and electrical behaviours and the effect of thermal annealing are studied on the 10 h ball-milled sample in a physical properties measurement system in the 30–375 K temperature range. It is observed that the high-temperature thermal annealing induces significant grain growth, reduces lattice strain, along with a reduction of bandgap energy of the mechanically alloyed Bi_2Te_3 nanostructures. Thermoelectric properties and the figure of merit of the nanostructures have improved significantly upon thermal annealing. Enhanced thermoelectric performance of the annealed nanostructures has been explained considering the change in their thermal conductivity, electrical resistivity, and crystallite size induced by thermal treatment.

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COLLABORATION WITH BOTANICAL SURVEY OF INDIA (BSI), GOVERNMENT OF INDIA

NAME OF THE CANDIDATE	TITLE OF Ph.D. PROGRAMME	NAME OF THE BSI SCIENTIST INVOLVED	NAME OF THE GUIDE FROM THE UNIVERSITY OF BURDWAN	DATE OF THESIS SUBMISSION AND DATE OF AWARD	PUBLICATIONS RELATED TO THIS RSEARCH	COMMENT
Dr. Subhajit Lahiri	STUDIES ON ALPINE AND SUBALPINE VASCULAR PLANT DIVERSITY AND COMMUNITY STRUCTURE OF TWO LANDSCAPES OF SIKKIM HIMALAYA	Dr. Sudhansu Sekhar Das, Scientist F, BSI	Dr. Asok Ghosh, Professor, Department of Botany, B.U.	Date of Submission- 25.02.2022 Date of award- 17.05.2022	1. Lahiri, Subhajit & Dash, Sudhansu Sekhar & Ghosh, Asok. (2022). An Annotated Checklist to the Alpine and Sub Alpine Flowering Plant Diversity of Dzongri-Goecha La Area, West Sikkim, India. Nelumbo. 64. 29-55. 10.20324/nelumbo/v64/2022/170943 . 2. Dash, Sudhansu Sekhar & Lahiri, Subhajit & Ghosh, Asok & Sinha, Bk. (2020). Notes on two lesser known Codonopsis (Campanulaceae) from eastern Himalaya, India. Rheedea. 30. 286. 10.22244/rheedea.2020.30.02.05. 3. Lahiri, Subhajit & Dash, Sudhansu Sekhar & Ghosh, Asok & Sinha, Bk. (2019). A contribution to the flora of Kanchenjunga Biosphere Reserve, Sikkim, India. 61. 10.20324/nelumbo/v61/2019/146248	Registration No. R-Ph.D./Regn. /Sc/Bot./211 Dated- 24.07.2019
Kasturi Chakraborty	SYSTEMATIC STUDIES ON	Dr. Avishek Bhattacharjee	Dr. Asok Ghosh,	Not yet, Registration	1. Chakraborty, Kasturi & Bhattacharjee, Bandana & Ghosh,	Registration No. R-

	THE SUBTRIBE CONYZINAE SCH. BIP. (ASTERACEAE) IN INDIA WITH SPECIAL REFERENCE TO MOLECULAR PHYLOGENY ALONG WITH MACRO- AND MICRO-MORPHOLOGY OF CYPSELA	, Scientist E, BSI	Professor, Depatment of Botany, B.U.	date- 26.07.2023	Asok & Bhattacharjee, Avishek. (2024). Rediscovery of Erigeron jaeschkei (Asteraceae: Astereae: Conyzinae) and notes on its correct protologue and typification. Phytotaxa. 674. 275-280. 10.11646/phytotaxa.674.3.4.	Ph.D./Pro.Regn. /Sc/2022/ E-6 Dated - 05.12.2024

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An annotated checklist to the alpine and sub alpine Flowering plant diversity of Dzongri-Goecha La area, West Sikkim, India

Subhajit Lahiri[1], Sudhansu Sekhar Dash*[2] and Asok Ghosh[3]

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[2]Botanical Survey of India, 3rd MSO Building, 6th Floor, CGO Complex, DF Block, Sector-1, Salt Lake, West Bengal 700064, India.
[3]Department of Botany, University of Burdwan, Burdwan 713104, West Bengal, India.
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भारत में पश्चिम सिक्किम के जोंगरी-गोएचा ला क्षेत्र के पुष्पीय पादप विविधता संबंधी अल्पाइन तथा सब-अल्पाइन का एक विस्तृत चेकलिस्ट

सुभाजित लाहिड़ी, सुधांसु सेखर दाश तथा असोक घोष

सारांश

पश्चिम सिक्किम के जोंगरी-गोएचा ला क्षेत्र से कुल 254 पादप जातियों को संग्रहित किया गया है जो 151 वंशों तथा 47 कुलों से संबंधित है। अध्ययन क्षेत्र में शामिल कुल वंशों के 52.75% में प्रथम दस कुलों की बहुलता है तथा 37. 74 % में प्रथम दस वंशों की बहुलता है। अध्ययन के दौरान इस क्षेत्र के लिए 22 नए टैक्सा ज्ञात किए गए हैं।

ABSTRACT

A total of 254 plant species belonging to 151 genera and 47 families were collected from alpine and subalpine regions of Dzongri Goecha La area. Of the total species collected, the first ten dominating family contributed more than 52.75% while the first ten dominating genera contributed 37.74 % of total genera of the studied area. 22 taxa have been reported new to region during the study.

Keywords: Checklist, flora, vascular plants, Khangchendzonga, Biosphere Reserve. Alpine plants

INTRODUCTION

One of the prerequisites for biodiversity assessments and strategy for plant conservation is to the document the plant diversity of a region. The Himalaya has a remarkable range of biodiversity in its diverse habitats and ecosystems. The distribution of plant species in fragile alpine ecosystems is dynamic and need to be recorded at different intervals to understand the pattern and potential migration of plant species to different habitats. Keeping in this in mind, this study has been carried out in the alpine and subalpine region of Dzongri-Goecha La of West Sikkim to document the plants occurring on the region. Exploration was done between July 2016 to September 2020 for collection of plant specimens along different altitudinal gradient towards the partial fulfilment of the objective of the project entitled "*Biodiversity Assessment through Long-term Monitoring Plots in Indian Himalayan Landscape*" under National Mission of Himalayan Studies.

The Dzongri-Goecha La area is well-known for its pristine natural landscapes and mesmeric meadows of alpine flowers. This is also one of the highest fragile ecosystems listed under UNESCO World Heritage Site *i.e.*, Khangchendzonga Biosphere Reserve (KBR). The vegetation of the area comprises of subalpine *Rhododendron* Forest, alpine scrubs and meadows. Though includes a smaller area, but due to high variations in elevation from 3000–4800 m asl. plant diversity of the area is remarkably high and unique. Recent study shows that, the biodiversity of this region under threat due to various factors such as heavy grazing, over exploitation of plant resources and high influx of tourist etc.

MATERIAL AND METHODS

The Dzongri Goecha La trekking starts from Yuksom, situated at an elevation of 1760 m asl. and ends at Goecha

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Notes on two lesser known *Codonopsis* (Campanulaceae) from eastern Himalaya, India

Dash S.S.[1]*, Lahiri S.[2], Ghosh A.[3] & B.K. Sinha[1]

[1]Botanical Survey of India, CGO Complex, Salt Lake, Kolkata, West Bengal – 700 064, India
[2]Central National Herbarium, Botanical Survey of India, Howrah, West Bengal – 711 103, India
[3]UGC CAS Department of Botany, The University of Burdwan, Golapbag, Burdwan, West Bengal – 713 104, India
*E-mail: ssdash2002@gmail.com

Abstract: Two lesser known species of *Codonopsis* Wall. (Campanulaceae), *viz*. *C. benthamii* Hook.f. & Thomson and *C. subsimplex* Hook.f. & Thomson were collected after a lapse of more than a century from Sikkim Himalaya, India. The authors evaluated the phenology of the above species in the last hundred years which shows a significance alteration. In this paper, information about the taxonomy, habitat, distribution and phenology are discussed along with photographic images.

Keywords: *Codonopsis benthamii*, *C. subsimplex*, Phenology, Rediscovery, Sikkim, Taxonomy.

Introduction

The genus *Codonopsis* Wall. (Campanulaceae) is widely distributed in temperate to alpine region of Asia and Europe and includes about 64 species (Hong, 2015b). The genus includes perennial erect herbs or herbaceous twiners characterized by solitary and large campanulate flowers, generally with a peculiar foul odour (Haridasan & Mukherjee, 1996; Hong, 2015a; Mabberley, 2017). Clarke (1881) reported 10 species of *Codonopsis* from the then British India under two sections: *Campanumoea* Blume and *Cyclocodon* Griff. Recent field studies in Himalayas (Dash, 2018), revealed the occurrence of 15 species in India, of which *C. ovata* Benth., *C. clematidea* (Schrenk) C.B.Clarke and *C. rotundifolia* Benth. show an extended distribution in Western Himalaya, while the rest 12 species are restricted to eastern Himalaya.

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During field explorations in the East district of Sikkim, two species of *Codonopsis* were came across in Kyongnosla Alpine Sanctuary. After consulting the relevant literature (Hooker & Thomson, 1858; Clarke, 1881; Komarov, 1908; Hong *et al*., 2011; Hong, 2015a), type specimens, protologue and other specimens housed in different herbaria (A, ARUN, ASSAM, BSHC, CAL, DD, E, GH, K, LWG, PE), they were identified as *C. benthamii* Hook.f. & Thomson and *C. subsimplex* Hook.f. & Thomson. *C. benthamii* is rediscovered after 110 years while *C. subsimplex* after a gap of 50 years after their last collection in India.

Material and Methods

Flowering specimens were collected from Kyongnosla Alpine Sanctuary (East district, Sikkim, India) and voucher specimens were prepared as per standard procedure (Jain & Rao, 1977). Photographs were taken in field with a Sony HX 400V camera. The micromorphological characters of flowers were studied using stereo-zoom microscope (Olympus SZ61, Japan). Detailed description was based on field observations and herbarium specimens (A, ARUN, ASSAM, BSHC, CAL, DD, E, GH, K and LWG; acronyms as per Thiers, 2020 continuously updated). To evaluate the change in flowering time of these two species in the last hundred years, Primack *et al*. (2004) was followed.

Taxonomic treatment

Codonopsis benthamii Hook.f. & Thomson, J. Proc. Linn. Soc., Bot. 2: 14. 1857. *Lectotype*

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A contribution to the flora of Kanchenjunga Biosphere Reserve, Sikkim, India

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कांचनजंधा जीवमंडल रिजर्व, सिक्किम, भारत की वनस्पतिजात में संयोजन

सुभोजित लाहिड़ी, सुधांशु शेखर दाश, अशोक घोष, बी. के. सिन्हा

सारांश

कांचनजंधा जीवमंडल रिजर्व, सिक्किम में बाइस पादप जातियों का संयोजन हुआ है । इसके अतिरिक्त सिक्किम हिमालय क्षेत्र से प्रथम बार रूबस लासियोस्टाइलस फोके यहां प्रतिवेदित किया गया है । सरल अभिनिर्धारण के लिए प्रत्येक जाति के पुष्पण अवधि व पारिस्थितिकी पर एक विस्तृत विवरण व जानकारी प्रदान की गई है ।

ABSTRACT

Twenty two species reported here as addition to the Flora of Kanchenjunga Biosphere Reserve, Sikkim. Besides *Rubus lasiostylus* Focke reported here for the first time from Sikkim Himalaya. A comprehensive description, information on phenology and ecology of each of the species has been provided here for easy identification.

Keywords: Floristic Diversity, KBR, New Additions, Sikkim

INTRODUCTION

The Kanchenjunga Biosphere Reserve (KBR) is located in West and North district of Sikkim between 27°15′-27°57′N latitude and 88°02′-88°40′E longitude. The biosphere reserve comprises an area of 2619.92 sq. km of which the core zone is about 1784 sq. km and the buffer zone is 835.92 sq. km. Due to its great biodiversity along with multi-ethnic culture, UNESCO acknowledged this biosphere reserve as World Heritage Site in the year 2018. The biosphere reserve falls within the Himalaya global biodiversity hotspot and shows an unrivaled range of sub-tropical to alpine ecosystems. Khangchendzonga Biosphere Reserve is covers 25% of the State of Sikkim, recognized as one of India's most noteworthy biodiversity concentrations. Maity & al., (2018) enumerated 1584 species of flowering plants from the area while dealing the Flora of Kanchenjunga Biosphere Reserve. However, certain parts of the KBR are yet to be explored and documented. Recently, during our visit to KBR in connection with setting up permanent plots under the project "Biodiversity Assessment through Long-term Monitoring Plots in Indian Himalayan Landscape" for monitoring of plant diversity change in the Dzongri-Gocha La area, we have collected a total of 400 plant specimens. Interestingly, 22 species belonging to 13

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Rediscovery of *Erigeron jaeschkei* (Asteraceae: Astereae: Conyzinae) and notes on its correct protologue and typification

KASTURI CHAKRABORTY[1,3], BANDANA BHATTACHARJEE[1,4], ASOK GHOSH[2,5] & AVISHEK BHATTACHARJEE[1,6,*]

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Abstract

Erigeron jaeschkei (Asteraceae: Astereae: Conyzinae) has been rediscovered after more than 15 decades from the Spiti valley of Himachal Pradesh, India. The protologue of this species name had been cited wrongly in several published literature sources and online databases, which is corrected in the present treatment. Apart from a brief diagnosis and types, no detailed modern description, illustration or photograph was available for this species. Therefore, a detailed description and a colour photo-plate based on our collection are provided for the first time to facilitate identification of this less-known species. A lectotype is also designated from the original collection by Dr. Jäschke.

Key words: Compositae, endemic, Falori Pass, Jäschke, lectotype, recollection

Introduction

The genus *Erigeron* Linnaeus (1753: 863) belongs to the subtribe Conyzinae under the tribe Astereae of the family Asteraceae / Compositae (Nesom 2008). The genus has *c.* 390 species (Nesom 2006) with a cosmopolitan distribution, and is represented by 21 species with 2 varieties in India (Karthikeyan *et al.* 2020). In connection with a field survey (in search for species of *Aster* Linnaeus (1753: 872) and their look-alike taxa) under SERB-CRG project (CRG/2021/000790), few specimens of an uncertain species of *Erigeron* were collected from two locations in Spiti Valley, Lahaul and Spiti District of Himachal Pradesh, India. The species was later identified as *E. jaeschkei* Vierhapper (1926: 12) based on our detailed study of specimens, consultation of the protologue and original materials of *E. jaeschkei*, and also by our morphological comparisons with other related species of *Erigeron*.

While describing *E. himalajensis* Vierhapper (1906: 491) as a new species, Friedrich (Karl Max) Vierhapper compared it with another, yet unnamed species by stating "Am Faloripaß hat Jaeschke noch eine andere (einjährige?) Art gesammelt (Faloripaß, Jaeschke: hb. U. V.), welche vielleicht ebenfalls den *Pleiocephali* angehört. Sie unterscheidet sich von *E. Himalajensis* durch dünnere Stengel, viel länger gestielte Basalblätter mit bedeutend breiterer, breit elliptischer oder verkehrt-eiförmiger Lamina, breitere Stengelblätter und insbesondere durch das ziemlich gleichmäßige, abstehend dicht-haarige, nicht drüsige Indument der Vegetationsorgane". Later, Vierhapper validly published a name of that unnamed species as *E. jaeschkei* Vierhapper (1926: 12) by providing a diagnosis; he also cited specimens (syntypes) and indicated the herbarium where the specimens were preserved.

Erigeron jaeschkei is endemic to India with a very restricted distribution in Himachal Pradesh. The species was described based on the specimens collected by Heinrich August Jäschke from Falori Pass, Lahaul, Himachal Pradesh, either between 1856–1864 or 1865–1868. Though the year of collection is neither mentioned in the protologue, nor in the label data of Jäschke's collection, it has been traced out on a study of Jäschke's biography published by Bray (1983).

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An annotated checklist to the alpine and sub alpine Flowering plant diversity of Dzongri-Goecha La area, West Sikkim, India

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[1]Central National Herbarium, Botanical Survey of India, Howrah 711103, West Bengal, India.
[2]Botanical Survey of India, 3rd MSO Building, 6th Floor, CGO Complex, DF Block, Sector-1, Salt Lake, West Bengal 700064, India.
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भारत में पश्चिम सिक्किम के जोंगरी-गोएचा ला क्षेत्र के पुष्पीय पादप विविधता संबंधी अल्पाइन तथा सब-अल्पाइन का एक विस्तृत चेकलिस्ट

सुभाजित लाहिड़ी, सुधांसु सेखर दाश तथा असोक घोष

सारांश

पश्चिम सिक्किम के जोंगरी-गोएचा ला क्षेत्र से कुल 254 पादप जातियों को संग्रहित किया गया है जो 151 वंशों तथा 47 कुलों से संबंधित है। अध्ययन क्षेत्र में शामिल कुल वंशों के 52.75% में प्रथम दस कुलों की बहुलता है तथा 37. 74 % में प्रथम दस वंशों की बहुलता है। अध्ययन के दौरान इस क्षेत्र के लिए 22 नए टैक्सा ज्ञात किए गए हैं।

ABSTRACT

A total of 254 plant species belonging to 151 genera and 47 families were collected from alpine and subalpine regions of Dzongri Goecha La area. Of the total species collected, the first ten dominating family contributed more than 52.75% while the first ten dominating genera contributed 37.74 % of total genera of the studied area. 22 taxa have been reported new to region during the study.

Keywords: Checklist, flora, vascular plants, Khangchendzonga, Biosphere Reserve. Alpine plants

INTRODUCTION

One of the prerequisites for biodiversity assessments and strategy for plant conservation is to the document the plant diversity of a region. The Himalaya has a remarkable range of biodiversity in its diverse habitats and ecosystems. The distribution of plant species in fragile alpine ecosystems is dynamic and need to be recorded at different intervals to understand the pattern and potential migration of plant species to different habitats. Keeping in this in mind, this study has been carried out in the alpine and subalpine region of Dzongri-Goecha La of West Sikkim to document the plants occurring on the region. Exploration was done between July 2016 to September 2020 for collection of plant specimens along different altitudinal gradient towards the partial fulfilment of the objective of the project entitled "*Biodiversity Assessment through Long-term Monitoring Plots in Indian Himalayan Landscape*" under National Mission of Himalayan Studies.

The Dzongri-Goecha La area is well-known for its pristine natural landscapes and mesmeric meadows of alpine flowers. This is also one of the highest fragile ecosystems listed under UNESCO World Heritage Site *i.e.*, Khangchendzonga Biosphere Reserve (KBR). The vegetation of the area comprises of subalpine *Rhododendron* Forest, alpine scrubs and meadows. Though includes a smaller area, but due to high variations in elevation from 3000–4800 m asl. plant diversity of the area is remarkably high and unique. Recent study shows that, the biodiversity of this region under threat due to various factors such as heavy grazing, over exploitation of plant resources and high influx of tourist etc.

MATERIAL AND METHODS

The Dzongri Goecha La trekking starts from Yuksom, situated at an elevation of 1760 m asl. and ends at Goecha

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Notes on two lesser known *Codonopsis* (Campanulaceae) from eastern Himalaya, India

Dash S.S.[1]*, Lahiri S.[2], Ghosh A.[3] & B.K. Sinha[1]

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[2]Central National Herbarium, Botanical Survey of India, Howrah, West Bengal – 711 103, India
[3]UGC CAS Department of Botany, The University of Burdwan, Golapbag, Burdwan, West Bengal – 713 104, India
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Abstract: Two lesser known species of *Codonopsis* Wall. (Campanulaceae), *viz*. *C. benthamii* Hook.f. & Thomson and *C. subsimplex* Hook.f. & Thomson were collected after a lapse of more than a century from Sikkim Himalaya, India. The authors evaluated the phenology of the above species in the last hundred years which shows a significance alteration. In this paper, information about the taxonomy, habitat, distribution and phenology are discussed along with photographic images.

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The genus *Codonopsis* Wall. (Campanulaceae) is widely distributed in temperate to alpine region of Asia and Europe and includes about 64 species (Hong, 2015b). The genus includes perennial erect herbs or herbaceous twiners characterized by solitary and large campanulate flowers, generally with a peculiar foul odour (Haridasan & Mukherjee, 1996; Hong, 2015a; Mabberley, 2017). Clarke (1881) reported 10 species of *Codonopsis* from the then British India under two sections: *Campanumoea* Blume and *Cyclocodon* Griff. Recent field studies in Himalayas (Dash, 2018), revealed the occurrence of 15 species in India, of which *C. ovata* Benth., *C. clematidea* (Schrenk) C.B.Clarke and *C. rotundifolia* Benth. show an extended distribution in Western Himalaya, while the rest 12 species are restricted to eastern Himalaya.

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Taxonomic treatment

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KASTURI CHAKRABORTY[1,3], BANDANA BHATTACHARJEE[1,4], ASOK GHOSH[2,5] & AVISHEK BHATTACHARJEE[1,6,*]

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SL. NO. 26

पश्चिमबङ्गा पश्चिम बंगाल WEST BENGAL

AB 960366

MEMORANDUM OF AGREEMENT

This MEMORANDUM OF AGREEMENT is made on this **twenty seventh** day of **June** Two thousand and **nineteen** BY AND BETWEEN President of India, acting through **Advisor & scientist 'G"**, Department of Biotechnology, Ministry of Science and Technology, Government of India, New Delhi, hereinafter referred to as the 'DBT' (which expression unless excluded by or repugnant to the subject shall mean and include its successor-in-office and assigns) of the ONE PART;

AND

The University of Burdwana society under the Societies Registration Act – 1860, having its registered office in/at **Rajbati, Burdwan,** hereinafter referred to as **BU** (which expression shall where the context so admits include its successors and permitted assigns) of the OTHER PART;

WHEREAS DBT being desirous of **Research on Human Genetics & Genomics** decided to support a project submitted by **Prof. Anupam Basu** for the attainment of the objectives, hereinafter described in the Annexure I annexed hereto;

This Memorandum of Agreement (MoA) defines the role and responsibilities of the participating agencies, monitoring and other matters related to the **"A Genetic Algorithm-Based Targeted Approach for Understanding the Phenotypic Heterogeneity of Thalassemia Syndromes in Northern and Eastern Indian Population"**

02.08.19
Dr. D. Mondal
Joint Registrar
The University of Burdwan

Dr. Anupam Basu
PROFESSOR
Department of Zoology
University of Burdwan

NOW THE PARTIES HERETO AGREE AS FOLLOWS:-

1.0 . ROLE OF DEPARTMENT OF BIOTECHNOLOGY, NEW DELHI

To provide funds to the extent of **7379121.00**over a period of **3** years from the date of sanction of the project, to **The University of Burdwan** for undertaking activities as detailed in Annexure 1. Details of the funds to be provided are given in Annexure II.

2.0. ROLE OF THE UNIVERSITY OF BURDWAN (Institute)

2.1. To provide their contribution of **NIL**for**NIL** years from date of sanction of the project as detailed in Annexure – II. *(if a jointly supported project)*

2.2. To provide existing facilities as mentioned in the project document.

2.3. To be responsible for accomplishing objectives identified and activities listed.

2.4. To allow the Scientists authorized by DBT to work with the Research & Development team of the center in all stages of process development and production.

2.5. To recruit all scientific and non-scientific staff as sanctioned by DBT.

2.6. To prepare and submit all periodical reports and other documents that would be required by DBT.

2.7. To maintain a separate audit head of account for the grants received from DBT for the project.

2.8. To submit an annual audited statement of expenditure incurred under the project.

2.9. To ensure effective utilization of the grant given by DBT for the purpose for which it was granted and to ensure timely progress of project work.

2.10. The manpower, both scientific and non-scientific, recruited shall be purely on contractual terms & conditions such that the contract for engagement of the manpower shall run concurrently with the said project period only.

3.0 DURATION OF PROJECT

3.1 Duration of project shall be **3** years from the date the Project has been sanctioned by DBT.

4.0 RIGHTS OF OWNERSHIP/TECHNOLOGY TRANSFER AND UTILIZATION

4.1 The know-how generated from the project by **Prof. Anupam Basu** will be the joint property of **The University of Burdwan** and DBT, Government of India. It shall be the responsibility of **Prof. Anupam Basu & The University of Burdwan** to take necessary action for protection of the intellectual property arising out of the PROJECT through proper instruments, such as, patents, copy rights, etc.

The know-how developed may be transferred to other entrepreneurs on a non-exclusive basis on such terms and conditions as may be determined by DBT.

02.08.19
Dr. D. Mondal
Joint Registrar
The University of Burdwan
Burdwan-713104, W.B.

Dr. Anupam Basu
PROFESSOR
Department of Zoology
University of Burdwan

4.3 All the assets including the equipment and produce acquired will be the property of DBT and shall not be utilized for purposes other than those for which the grant has been sanctioned. The rights of **The University of Burdwan**. under this MoA shall not be transferred to any other party without prior approval in writing of DBT.

4.4 It shall be the responsibility of **Prof. Anupam Basu** to ensure that support of DBT is suitably acknowledged in the publications (papers, reports, etc.) arising out of the PROJECT.

5. SECRECY

It is hereby agreed that the participating agencies shall keep information and data collected completely secret provided that the right to transfer the technology shall rest with the DBT.

6. MONITORING

6.1 The progress of implementation of the project and proper utilization of grant shall be reviewed by the DBT and by the Monitoring Committee set up by DBT.

6.2 The periodic progress of physical achievements and the utilization of funds, statement of expenditure shall be evaluated by the Monitoring Committee.

6.3 The Comptroller and Auditor General of India, at his discretion shall have the right of access to the books and accounts of **The University of Burdwan** for the grants received from DBT for this project.

6.4 The DBT may terminate the grant at any stage if it is convinced that the grant has not been properly utilized or appropriate progress has not been made. In the event, DBT terminates the grant, **Prof. Anupam Basu** shall hand over all documents including technical details and equipment purchased related to the project.

7.0 DURATION OF MEMORANDUM OF AGREEMENT

This MoA will remain inforce for the duration of the project and until all claims are settled between DBT and **The University of Burdwan.**

8.0 ARBITRATION

In the event of any question, dispute or difference whatsoever arising between the parties to this Agreement out of or relating to the construction, meaning, scope, operation or effect of this Agreement or the validity of the breach thereof shall be referred to an Arbitrator to be appointed by mutual consent of both the parties herein. If the parties cannot agree on the appointment of the Arbitrator within a period of one month from the notification by one party to the other of existence of such dispute, then the Arbitrator shall be nominated by the Secretary, Department of Legal Affairs, Ministry of Law & Justice, Government of India. The provisions of the Arbitration and Conciliation Act, 1996 will be applicable and the award made thereunder shall be final and binding upon the parties hereto, subject to legal remedies available under the law. Such differences shall be deemed to be a submission to arbitration under the Indian Arbitration and Conciliation Act, 1996, or of any modifications or amendments thereof.

02.08.19
Dr. D. Mondal
Joint Registrar
The University of Burdwan
Rajbati, Burdwan-713104 W.B.

Dr. Anupam Basu
PROFESSOR
Department of Zoology
University of Burdwan

9.0. GOVERNING LAW

This Contract shall be governed by the Law of India for the time being in force.

IN WITNESS WHEREOF the parties hereto have signed, sealed and delivered this Agreement on the day, month and year first above written in presence of:

Witnesses:

1.

2.

Signed by ----------

(Designation)

For and on behalf of The President of India

Witnesses:

1. Dr. SOUMENDRANATH CHATTERJEE Associate Professor & Head Dept. of Law The University of Burdwan Golapbag, Burdwan-713104

2. Anupam Basu 23/6/09 Dr. Anupam Basu PROFESSOR Department of Law The University of Burdwan

Signed by 02.08.19

Dr. D. Mondal
Joint Registrar
The University of Burdwan
Golapbag, Burdwan-713104, W.B.

THE UNIVERSITY OF BURDWAN RAJBATI BURDWAN 713104

For and on behalf of
The University of Burdwan

TERMS & CONDITIONS OF THE GRANT

(To be signed and enclosed with concern filled proforma)

1. Approval of the Research proposal and the grant released would be for the specific project mentioned in paras I to V of this proposal and grant should be exclusively spent on the project for which it has been sanctioned within the stipulated time. The Institute is not permitted to seek or utilize funds from any other organization (Government, Semi Government, Autonomous or Private) for this research project. Any unspent part of amount would be surrendered to the Govt. of India through an account payee demand draft drawn in favor of the "Drawing and Disbursing Officer, Department of Biotechnology, New Delhi", and carry forward of funds of the next financial year for utilization for the same project may be considered only with the specific approval of the Department of Biotechnology (DBT).

2. For permanent/semi-permanent assets acquired solely or mainly out of the grant, an audited record in the form of a register in the prescribed proforma (enclosed at **Appendix-'A'**) shall be maintained by the Institute. The term **"assets"** means (I) immovable property and (II) movable property of a capital nature, where the value exceeds Rs. 1000/- The grant will not be utilized for construction of any immovable property, Full facilities by way of accommodation, etc. for the project will be given by the Institute.

3. All the assets acquired from the grant will be the property of Govt. of India and should not without the prior sanction of the Dept. of Biotechnology, be disposed of, or encumbered or utilized for purpose other than those for which the grant has been sanctioned.

4. At the conclusion of the project, the Govt. of India will be free to sell or otherwise dispose of assets which are the property of the Government. The Institute shall render to Govt. necessary facilities for arranging the sale / disposal of these assets. **The Government may, however, consider the request of host institutions to retain the assets created under a project for carrying out similar work for the promotion of science.**

5. The implementing Institute/PI will furnish progress report of work on the project every six months. The progress of the project will also be reviewed/monitored at least once a year by the concerned Task Force/Project Monitoring Committee, etc. In addition the DBT shall designate Scientists/Specialists to visit the Institute periodically for reviewing the progress of work and for suggesting such measures as to ensure early realization of the objectives of the project. On completion of the project five copies of a consolidated report of the work done on the subject would be submitted to the Department of Biotechnology.

6. The Institute is required to send to DBT a list of assets referred to at Sl. No. 2 above at the end of each financial year as well as at the time of seeking further installments of the grant.

7. The Institute would furnish to the Dept. of Biotechnology a Utilization Certificate and an audited statement of expenditure duly signed by the P.I., the Head of the Institute and the Head of the Finance wing, pertaining to the grant at the end of each financial year as well as a consolidated statement of expenditure at the end of the completion of the project.

A stamped receipt be sent to the Dept. of Biotechnology on receipt of the Cheque/ Demand draft towards each release.

02.08.19
Dr. D. Mondal
Joint Registrar
The University of Burdwan
Rajbati, Burdwan-713104, W.B.

Dr. Anupam Basu
PROFESSOR
Department of Zoology
The University of Burdwan

9. The Comptroller and Auditor-General of India at his discretion shall have the right of access to the books and accounts of the Institute for the grant received from the Government.

10. The Institute would maintain separate audited accounts for the project. If it is found expedient to keep a part or whole of the grant in a bank account earning interest, the interest thus earned should be reported to the Dept. of Biotechnology.

11. Sale proceeds, if any, as a result of the development of the project arising directly from funds granted by the Dept. of Biotechnology shall be reported to the Govt. of India. The Govt. of India may at its discretion allow a portion of such receipt to be retained by the Institute for its utilization for the project activities.

12. Investigators/Institutes wishing to publish papers based on the research work done under Dept. of Biotechnology projects should acknowledge the financial support received from the Dept. of Biotechnology.

13. Investigators/Institutes may utilize various resources such as the Bioinformatics resources, experimental materials, reagents, cell lines, animals, etc. from the National facilities/Institutes/Centers established by this Department as per the terms of transactions followed by them. More information may be obtained about such facility from DBT websites: http://www.dbtindia.org// www.dbtindia.nic.in, www.btisnet.ac.in.

14. Investigators / Institutes shall follow the detailed instructions on technology transfer and Intellectual Property Rights (IPR) as given at Annexure - V. The same has the approval of the Ministry of Finance, Govt. of India vide Dept. of Expenditure, Plan Finance II – Division Letter No. 33 (5) /PF.II/99 dated 22nd February, 2000. Any deviation from these instructions may be brought to the notice of this Department.

15. Investigators / Institutes may file patents with the help of the Biotechnology Patents Facilitating Cell (BPFC) established at DBT on priority bases. The format for filing the patents may be seen at Annexure –VI.

16. The Govt. of India (Dept. of Biotechnology) will have the right to call for drawings, specifications and other data necessary to enable the transfer of know-how to other parties and the Institute shall supply all the needed information at the request of the Department of Biotechnology which will ensure confidentiality. The information required for commercializing Biotechnologies may be furnished to this Dept. as per the format enclosed at Annexure – VII. More information on commercialization can be found at the website www.ebc.nic.in.

17. The Institute may not entrust the implementation of the work for which the grant is being sanctioned to another institution and to divert the grant receipts as assistance to the latter institution. However, in such situations the express permission of DBT may be obtained. In case the grantee is not in a position to execute or complete the project, it may be required to refund forthwith to the Govt. of India (Department of Biotechnology) the entire amount of grant received by it.

02-08-09

Dr. D. Mondal
Joint Registrar
The University of Burdwan
Rajbati, Burdwan-713104, W.B.

18. The human resources that may be engaged for the project by the Institute are not to be treated as employees of the Govt. of India and the deployment of such human resource at the time of completion or termination of project, will not be the concern/responsibility of the Govt. of India. The Organization may make reservations for Scheduled Castes, Schedule Tribes etc. in the human resource to be engaged for the project in accordance with the instruction issued by the Govt. of India from time to time.

27/8/09

Dr. Anupam Basu
PROFESSOR
Department of Zoology
The University of Burdwan

19. The Dept. of Biotechnology reserves the right to terminate the grant at any stage and also to recover the amounts already paid if it is convinced that the grant has not been properly utilized or the work on the project has been suspended for any unduly long period or appropriate progress is not being made.

20. The project will become operative with effect from the date of release of the first installment for the project.

21. If the Investigator to whom a grant for a project has been sanctioned leaves the institution where the project is being implemented, he shall submit five copies of complete and detailed report of the work done by him on the project and the money spent till the date of his/her release and shall also arrange to refund the unspent balance, if any.

22. The organization should maintain subsidiary accounts of the Govt. of India grant and furnish it to the Audit Officer as and when the recurring and non-recurring expenditure exceeds the limits of Rs. 5.00 lakhs.

Signature of Project Coordinator
(Applicable only for multi-Institutional projects)

Dr. Anupam Basu
PROFESSOR
Department of Zoology
The University of Burdwan

Date: 27/6/19

02.08.19

Signature of Registrar
of Univer[illegible]

Joint Registrar
The University of Burdwan
[illegible]-713104, W.B.

Date:

Signature and stamped of Principal Investigator
The University of Burdwan
Date: 27/06/19

Dr. Anupam Basu
PROFESSOR
Department of Zoology
The University of Burdwan

UNIVERSITY OF BURDWAN
RAJBATI
BURDWAN
713104
WEST BENGAL

SL. NO. 26

पश्चिमबङ्गा पश्चिम बंगाल WEST BENGAL

Z 816631

MEMORANDUM OF AGREEMENT

This MEMORANDUM OF AGREEMENT is made on this **twenty first** day of **May** Two thousand and **Eighteen** BY AND BETWEEN President of India, acting through **Secretary**, Department of Biotechnology, Ministry of Science and Technology, Government of India, New Delhi, hereinafter referred to as the 'DBT' (which expression unless excluded by or repugnant to the subject shall mean and include its successor-in-office and assigns) of the ONE PART;

AND

The University of Burdwan , a society under the Societies Registration Act – 1860, having its registered office at **Rajbati, Burdwan,** hereinafter referred to as **BU** (which expression shall where the context so admits include its successors and permitted assigns) of the OTHER PART;

REGISTRAR (Officiating)
THE UNIVERSITY OF BURDWAN
BURDWAN-713104

WHEREAS DBT being desirous of cancer immunology decided to support a project submitted by **Dr. Anupam Basu** for the attainment of the objectives, hereinafter described in the Annexure I annexed hereto;

This Memorandum of Agreement (MoA) defines the role and responsibilities of the participating agencies, monitoring and other matters related to the **"Study on the role of TLR-4 signaling in breast cancer progression"**

NOW THE PARTIES HERETO AGREE AS FOLLOWS:-

1.0 . ROLE OF DEPARTMENT OF BIOTECHNOLOGY, NEW DELHI

To provide funds to the extent of **81,30,600/-** over a period of **3** years from the date of sanction of the project, to **The University of Burdwan** for undertaking activities as detailed in Annexure 1. Details of the funds to be provided are given in Annexure II.

2.0. ROLE OF THE UNIVERSITY OF BURDWAN (Institute)

2.1. To provide their contribution of **81,30,600/-** for **3** years from date of sanction of the project as detailed in Annexure – II. *(if a jointly supported project)*

2.2. To provide existing facilities as mentioned in the project document.

2.3. To be responsible for accomplishing objectives identified and activities listed.

2.4. To allow the Scientists authorized by DBT to work with the Research & Development team of the center in all stages of process development and production.

2.5. To recruit all scientific and non-scientific staff as sanctioned by DBT.

2.6. To prepare and submit all periodical reports and other documents that would be required by DBT.

2.7. To maintain a separate audit head of account for the grants received from DBT for the project.

2.8. To submit an annual audited statement of expenditure incurred under the project.

2.9. To ensure effective utilization of the grant given by DBT for the purpose for which it was granted and to ensure timely progress of project work.

2.10. The manpower, both scientific and non-scientific, recruited shall be purely on contractual terms & conditions such that the contract for engagement of the manpower shall run concurrently with the said project period only.

REGISTRAR (Officiating)
THE UNIVERSITY OF BURDWAN
BURDWAN-713104

3.0 DURATION OF PROJECT

3.1 Duration of project shall be **3** years from the date the Project has been sanctioned by DBT.

Dr. Anupam Basu
PROFESSOR
Department of Zoology
The University of Burdwan

4.0 RIGHTS OF OWNERSHIP/TECHNOLOGY TRANSFER AND UTILIZATION

4.1 The know-how generated from the project by **Dr. Anupam Basu** will be the joint property of **The University of Burdwan** and DBT, Government of India. It shall

4.2 be the responsibility of **Dr. Anupam Basu & The University of Burdwan** to take necessary action for protection of the intellectual property arising out of the PROJECT through proper instruments, such as, patents, copy rights, etc.

4.3 The know-how developed may be transferred to other entrepreneurs on a non-exclusive basis on such terms and conditions as may be determined by DBT.

4.4 All the assets including the equipment and produce acquired will be the property of DBT and shall not be utilized for purposes other than those for which the grant has been sanctioned. The rights of **The University of Burdwan** under this MoA shall not be transferred to any other party without prior approval in writing of DBT.

4.5 It shall be the responsibility of **Dr. Anupam Basu** to ensure that support of DBT is suitably acknowledged in the publications (papers, reports, etc.) arising out of the PROJECT.

5. SECRECY

It is hereby agreed that the participating agencies shall keep information and data collected completely secret provided that the right to transfer the technology shall rest with the DBT.

6. MONITORING

6.1 The progress of implementation of the project and proper utilization of grant shall be reviewed by the DBT and by the Monitoring Committee set up by DBT.

6.2 The periodic progress of physical achievements and the utilization of funds, statement of expenditure shall be evaluated by the Monitoring Committee.

6.3 The Comptroller and Auditor General of India, at his discretion shall have the right of access to the books and accounts of **The University of Burdwan** for the grants received from DBT for this project.

6.4 The DBT may terminate the grant at any stage if it is convinced that the grant has not been properly utilized or appropriate progress has not been made. In the event, DBT terminates the grant, **Dr. Anupam Basu & The University of Burdwan** shall hand over all documents including technical details and equipment purchased related to the project.

REGISTRAR (Officiating)
THE UNIVERSITY OF BURDWAN
BURDWAN-713104

Dr. Anupam Basu
PROFESSOR
Department of Zoology
University of Burdwan

7.0 DURATION OF MEMORANDUM OF AGREEMENT

This MoA will remain inforce for the duration of the project and until all claims are settled between DBT and **The University of Burdwan**

8.0 ARBITRATION

In the event of any question, dispute or difference whatsoever arising between the parties to this Agreement out of or relating to the construction, meaning, scope, operation or effect of this Agreement or the validity of the breach thereof shall be referred to an Arbitrator to be appointed by mutual consent of both the parties herein. If the parties cannot agree on the appointment of the Arbitrator within a period of one month from the notification by one party to the other of existence of such dispute, then the Arbitrator shall be nominated by the Secretary, Department of Legal Affairs, Ministry of Law & Justice, Government of India. The provisions of the Arbitration and Conciliation Act, 1996 will be applicable and the award made thereunder shall be final and binding upon the parties hereto, subject to legal remedies available under the law. Such differences shall be deemed to be a submission to arbitration under the Indian Arbitration and Conciliation Act, 1996, or of any modifications or reenactments thereof.

9.0. GOVERNING LAW

This Contract shall be governed by the Law of India for the time being in force.

IN WITNESS WHEREOF the parties hereto have signed, sealed and delivered this Agreement on the day, month and year first above written in presence of:

Witnesses:

1.

REGISTRAR (Officiating)
THE UNIVERSITY OF BURDWAN
BURDWAN-713104

2.

Dr. Anupam Basu
PROFESSOR
Department of Zoology
University of Burdwan

Dr ANANDAMAY BARIK
Associate Professor & Head
Department of Zoology
The University of Burdwan
Golapbag, Burdwan-713104

Signed by ----------

(Designation)

For and on behalf of The President of India

Witnesses:

1.

2.

Signed by ----------

Registrar (officiating)
THE UNIVERSITY OF BURDWAN
For and on behalf of
The University of Burdwan

TERMS & CONDITIONS OF THE GRANT

(To be signed and enclosed with concern filled proforma)

1. Approval of the Research proposal and the grant released would be for the specific project mentioned in paras I to V of this proposal and grant should be exclusively spent on the project for which it has been sanctioned within the stipulated time. The Institute is not permitted to seek or utilise funds from any other organisation (Government, Semi Government, Autonomous or Private) for this research project. Any unspent part of amount would be surrendered to the Govt. of India through an account payee demand draft drawn in favour of the "Drawing and Disbursing Officer, Department of Biotechnology, New Delhi", and carry forward of funds of the next financial year for utilization for the same project may be considered only with the specific approval of the Department of Biotechnology (DBT).

2. For permanent/semi-permanent assets acquired solely or mainly out of the grant, an audited record in the form of a register in the prescribed proforma (enclosed at **Appendix-'A'**) shall be maintained by the Institute. The term **"assets"** means (I) immovable property and (II) movable property of a capital nature, where the value exceeds Rs. 1000/- The grant will not be utilised for construction of any immovable property, Full facilities by way of accommodation, etc. for the project will be given by the Institute.

3. All the assets acquired from the grant will be the property of Govt. of India and should not without the prior sanction of the Deptt. of Biotechnology, be disposed of, or encumbered or utilised for purpose other than those for which the grant has been sanctioned.

4. At the conclusion of the project, the Govt. of India will be free to sell or otherwise dispose of assets which are the property of the Government. The Institute shall render to Govt. necessary facilities for arranging the sale / disposal of these assets. **The Government may, however, consider the request of host institutions to retain the assets created under a project for carrying out similar work for the promotion of science.**

5. The implementing Institute/PI will furnish progress report of work on the project every six months. The progress of the project will also be reviewed/monitored at least once a year by the concerned Task Force/Project Monitoring Committee, etc. In addition the DBT shall designate Scientists/Specialists to visit the Institute periodically for reviewing the progress of work and for suggesting such measures as to ensure early realisation of the objectives of the project. On completion of the project five copies of a consolidated report of the work done on the subject would be submitted to the Department of Biotechnology.

6. The Institute is required to send to DBT a list of assets referred to at Sl. No. 2 above at the end of each financial year as well as at the time of seeking further installments of the grant.

7. The Institute would furnish to the Deptt. of Biotechnology a Utilization Certificate (Copy enclosed at **Appendix - 'B'**) and an audited statement of expenditure (**Copy enclosed at Appendix - 'C'**) duly signed by the P.I., the Head of the Institute and the Head of the Finance wing, pertaining to the grant at the end of each financial year as well as a consolidated statement of expenditure at the end of the completion of the project.

8. A stamped receipt be sent to the Deptt. of Biotechnology on receipt of the Cheque/ Demand draft towards each release.

9. The Comptroller and Auditor-General of India at his discretion shall have the right of access to the books and accounts of the Institute for the grant received from the Government.

10. The Institute would maintain separate audited accounts for the project. If it is found expedient to keep a part or whole of the grant in a bank account earning interest, the interest thus earned should be reported to the Deptt. of Biotechnology.

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13. Investigators/Institutes may utilize various resources such as the Bioinformatics resources, experimental materials, reagents, cell lines, animals, etc. from the National facilities/Institutes/Centres established by this Department as per the terms of transactions followed by them. More information may be obtained about such facility from DBT websites: http://www.dbtindia.org// www.dbtindia.nic.in, www.btisnet.ac.in.

14. Investigators / Institutes shall follow the detailed instructions on technology transfer and Intellectual Property Rights (IPR) as given at Annexure - V. The same has the approval of the Ministry of Finance, Govt. of India vide Deptt. of Expenditure, Plan Finance II – Division Letter No. 33 (5) /PF.II/99 dated 22nd February, 2000. Any deviation from these instructions may be brought to the notice of this Department.

15. Investigators / Institutes may file patents with the help of the Biotechnology Patents Facilitating Cell (BPFC) established at DBT on priority bases. The format for filing the patents may be seen at Annexure –VI.

16. The Govt. of India (Deptt. of Biotechnology) will have the right to call for drawings, specifications and other data necessary to enable the transfer of know-how to other parties and the Institute shall supply all the needed information at the request of the Department of Biotechnology which will ensure confidentiality. The information required for commercializing Biotechnologies may be furnished to this Deptt. as per the format enclosed at Annexure – VII. More information on commercialization can be found at the website www.ebc.nic.in.

17. The Institute may not entrust the implementation of the work for which the grant is being sanctioned to another institution and to divert the grant receipts as assistance to the latter institution. However, in such situations the express permission of DBT may be obtained. In case the grantee is not in a position to execute or complete the project, it may be required to refund forthwith to the Govt. of India (Department of Biotechnology) the entire amount of grant received by it.

18. The human resources that may be engaged for the project by the Institute are not to be treated as employees of the Govt. of India and the deployment of such human resource at the time of completion or termination of project, will not be the concern/responsibility of the Govt. of India. The Organisation may make reservations for Scheduled Castes, Schedule Tribes etc. in the human resource to be engaged for the project in accordance with the instruction issued by the Govt. of India from time to time.

19. The Deptt. of Biotechnology reserves the right to terminate the grant at any stage and also to recover the amounts already paid if it is convinced that the grant has not been properly utilized or the work on the project has been suspended for any unduly long period or appropriate progress is not being made.

20. The project will become operative with effect from the date of release of the first installment for the project.

21. If the Investigator to whom a grant for a project has been sanctioned leaves the institution where the project is being implemented, he shall submit five copies of complete and detailed report of the work done by him on the project and the money spent till the date of his/her release and shall also arrange to refund the unspent balance , if any.

22. The organisation should maintain subsidiary accounts of the Govt. of India grant and furnish it to the Audit Officer as and when the recurring and non-recurring expenditure exceeds the limits of Rs. 5.00 lakhs.

Signature of Executive Authority of Institute/ University With seal

REGISTRAR (Officiating)
THE UNIVERSITY OF BURDWAN
BURDWAN-713104

Date :

Signature and stamped of Principal Investigator :
Date :

Dr. Anirban Basu
Professor
Department of Zoology
The University of Burdwan

Signature and stamped of Co-Investigator
Date :

Dr ANANDAMAY BARIK
Associate Professor & Head
Department of Zoology
The University of Burdwan
Golapbag, Burdwan-713104

बैंक ऑफ़ बड़ौदा
Bank of Baroda

SL NO. 27

TO WHOMSOEVER IT MAY CONCERN

This is to certify that **Mr. Arijit Saha**, student of University of Burdwan of MBA (Financial Management), Burdwan has successfully completed his summer internship in our Bank as a part fulfilment of the academic requirement and under Bank's Scheme for imparting Summer Training to the students of Management University.

The internship project was titled **'Job Description vis-à-vis Financial Management'** and its Analysis at Bank of Baroda, Burdwan Region and the study was carried out in the Burdwan Region from 15.05.2023 to 08.07.2023 under guidance of Branch Head of Bank of Baroda, Burdwan Branch under Regional Office, Burdwan Region.

His conduct during the internship was found to be satisfactory.

We wish him all the best in all the future endeavours'.

Yours faithfully,

(Amiya Kumar Mondal)
Dy Regional Manager
Regional Office, Burdwan Region

बर्द्धमान क्षेत्रीय कार्यालय, द्वितीय तल, 54, जी. टी. रोड, भांगाकुठी, जिला - बर्द्धमान, पिन-713101, पश्चिम बंगाल (भारत)
Burdwan Regional Office, 2nd Floor, 54, G.T. Road, Bhangakuthi, Dist. - Burdwan, Pin-713101, W.B. (India)
दूर./Ph.: 0342-2658287, ई./Email: rm.wbengalsikkim@bankofbaroda.com, वेब/Web: www.bankofbaroda.com

SL NO. 27

BFH/HR-Comm/2023/687

29 June, 2023

TO WHOM IT MAY CONCERN

This is to certify that **Mr. Aakash Dhara** student of The University of Burdwan pursuing his MBA has successfully completed his training period at our institute.

He worked as an Intern with Bengal Faith Hospital from **22nd May 2023** to **28th June,2023** as part of the training required for his academic pursuit.

During this period, he has worked diligently in the assigned area (Department of Marketing) and has shown keenness to learn.

We wish him success in all future endeavors.

Thanking You,

For *Bengal FAITH Hospital*

Authorized Signatory

SL NO. 27

TO WHOMSOVER IT MAY CONCERN

To,

Mr./Ms. Souvik Ghosh
The University of Burdwan

Subject: Internship Completion Certificate

This is to certify that Mr./Ms. Souvik Ghosh student of The University of Burdwan has successfully completed internship with India Post Payments Bank from 22/05/2023 to 30/06/2023 at Burdwan, West Bengal.

As part of internship, he/she has done project on " Understanding financial inclusion through a behavioral finance lens: insights from IPPB internship".

During his/her tenure with IPPB, Mr./Ms. Souvik Ghosh was found to be sincere and result oriented.

India Post Payments Bank wishes Mr./Ms. Souvik Ghosh all the best for future endeavours.

Date: 26-04-2024

Place- New Delhi

Authorised Signatory

India Post Payments Bank Ltd.

SL NO. 27

TO WHOMSOVER IT MAY CONCERN

To,

Mr./Ms. Molla Sayem Mostafa
The University of Burdwan

Subject: Internship Completion Certificate

This is to certify that Mr./Ms. Molla Sayem Mostafa student of The University of Burdwan has successfully completed internship with India Post Payments Bank from 22/05/2023 to 30/06/2023 at Burdwan, West Bengal.

As part of internship, he/she has done project on " Promotion of India Post Payments Bank in the Rural Sector of India ".

During his/her tenure with IPPB, Mr./Ms. Molla Sayem Mostafa was found to be sincere and result oriented.

India Post Payments Bank wishes Mr./Ms. Molla Sayem Mostafa all the best for future endeavours.

Date: 26-04-2024 Place- New Delhi

Authorised Signatory

India Post Payments Bank Ltd.

Centre For HRD
Durgapur Steel Plant

SL NO. 27

rom
SM(HRD)
Centre for HRD

Ref. No.: 202

The vacation training of SHUBHRA SHANKHA MANDAL of BURDWAN UNIVERSITY having College Roll/Id No. BUR MBA 2023/026 as re
Mr./Ms. SUBRATA BASU THAKUR, T/No. 334999 is hereby confirmed from 27-05-2024 to 07-06-2024 for 11 working days approximately.

The student must report at Centre for HRD (CHRD), Durgapur Steel Plant, Durgapur, West Bengal, on the starting date at 10:00AM comply
following:

1. To bring two recent passport sized color photos of the student with blue background.
2. To bring original student's Photo ID Card as issued by college/institution.
3. To bring this original confirmation slip, Aadhar Card along with a photo copy.
4. ~~To bring DSP Medical Booklet (only for Diploma Engg. student).~~
5. Must come wearing industrial safety shoes from reporting date.

Centre for Human Resource Development DSP

विनांक
Date 8/5/24

Signature of CHRD Official
(with date & stamp)

Note : **Starting date and/or time as given in this confirmation slip may be changed/cancelled due to unforeseen circumsta**

10.141.4.76/chrd/vtonline/main.php#

Centre For HRD
Durgapur Steel Plant

SL NO. 27

From
GM(HRD)
Centre for HRD

Ref. No.: 20

The vacation training of ANNESHA CHANDRA of BURDWAN UNIVERSITY having College Roll/Id No. BUR MBA 2023/003 as requested PRADIP DAS, T/No. 342401 is hereby confirmed from 27-05-2024 to 07-06-2024 for 11 working days approximately.

The student must report at Centre for HRD (CHRD), Durgapur Steel Plant, Durgapur, West Bengal, on the starting date at 10.00AM comply following:

1. To bring two recent passport sized color photos of the student with blue background.
2. To bring original student's Photo ID Card as issued by college/institution.
3. To bring this original confirmation slip, Aadhar Card along with a photo copy.
4. To bring DSP Medical Booklet (only for Diploma Engg. student)
5. Must come wearing industrial safety shoes from reporting date.

दिनांक –
Date

Signature of CHRD Official
(with date & stamp)

Note : Starting date and/or time as given in this confirmation slip may be changed/cancelled due to unforeseen circumsta

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पश्चिमबंगाल पश्चिम बंगाल WEST BENGAL 25AA 960587

UMBRELLA MEMORANDUM OF UNDERSTANDING

BETWEEN

SL,NO, 30

TEZPUR UNIVERSITY
NAPAAM, TEZPUR, ASSAM 784028
AND
TRIPURA UNIVERSITY
SURYAMANINAGAR, AGARTALA, TRIPURA, 799022
AND

THE UNIVERSITY OF BURDWAN, BURDWAN-713 104, WEST BENGAL

This Agreement made and entered into on this 30th day of October 2020, between THE UNIVERSITY OF BURDWAN, RAJBATI, BURDWAN, WEST BENGAL 713104, INDIA (hereinafter called "BU" which expression shall where the context so admits include its successors and permitted assignees) with its having administrative office at Rajbati, Burdwan 713 104, West Bengal of the one part, AND TEZPUR UNIVERSITY, NAPAAM, TEZPUR, ASSAM 784028, INDIA (hereinafter called "TEZU" which expression shall where the context so admits include its successors and permitted assignees) and the other part, AND TRIPURA UNIVERSITY, SURYAMANINAGAR, AGARTALA, TRIPURA, 799022, INDIA (hereinafter called "TU" which expression shall where the context so admits include its successors and permitted assignees) and the other part.

The parties will discuss in the fields of common research interests and allied activities between the three institutions, for long-term collaboration for promotion of students' interests development of competencies and quality research in cutting edge areas in accordance with the provisions contained in the Guidelines of STRIDE Project, UGC.

AND WHEREAS the "BU", established on 15th June 1960 by Govt. of West Bengal vide Act No. XXIX of 1959 and recognized by University Grants Commission (under Section 12B of the UGC Act, 1956) at its Department of Commerce is involved in studies on various disciplines of AND WHEREAS it has been considered expedient to agree in writing to participate jointly in the projects requiring expertise and logistics from both the partnering parties.

1.0 PREAMBLE

Whereas, "THE UNIVERSITY OF BURDWAN (BU)" is one part and ""TEZPUR UNIVERSITY (TEZU)" and "TRIPURA UNIVERSITY (TU)" are the other, all are parties to this MoU:

Whereas, "TEZPUR UNIVERSITY (TEZU)" is a leading University in Assam engaged in teaching and research in different fields of knowledge and learning and has brief competencies on the area. And has competencies and expertise on the proposed area of collaboration

Whereas, "TRIPURA UNIVERSITY (TU)" is a leading University in Tripura engaged in teaching and research in different fields of knowledge and learning and has brief competencies on the area. And has competencies and expertise on the proposed area of collaboration

Whereas, "THE UNIVERSITY OF BURDWAN (BU)" is a leading University in West Bengal engaged in teaching and research in different fields of knowledge and learning and has brief competencies on the area and has competencies and expertise on the proposed area of collaboration

All the parties are entering into this MoU for Research and Academic Collaboration in respect of taking part jointly in a research project under "STRIDE" of the University Grants Commission, India. The parties have discussed about their common research interest and submitted a project proposal to the University Grants Commission under the scheme named "STRIDE"

2.0 OBJECTIVES OF THE MOU

a) Joint collaboration in Research and Academic fields under "STRIDE-III" of the University Grants Commission, India.
b) Development of competencies and expertise on the proposed area of collaboration
c) Improvement in the areas of common research of interest.

3.0 PROPOSED MODES OF COLLABORATION

(a) As per understanding among them following steps have been (or will be) initiated for common interest:

(i) **The name of the project is entitled as: Socially Responsible Business Practices: Analysis of the Indian Scene.**

(ii) The said project if accepted by the University Grants Commission, will be lead (Principal Investigator, herein after called as PI) by Professor Santanu Kumar Ghosh of the Department of Commerce of the University of Burdwan.

(iii) Co-investigators are:

Sl No	Name of Co-investigators
1	Prof. Arindam Das of the Department of Commerce of the University of Burdwan
2	Dr. Arindam Laha of the Department of Commerce of the University of Burdwan
3	Dr. Som Sankar Sen of the Department of Commerce of the University of Burdwan
4	Dr. Sumit Kumar Maji of the Department of Commerce of the University of Burdwan
5	Dr. Manidipa Das Gupta of the Department of Commerce of the University of Burdwan and
6	Dr Santi Gopal Maji of the Department of Commerce of Tezpur University, Assam (On lien from NEHU as Assistant Professor w.e.f. 12.12.2019 to 11.12.2021) and
7	Dr. Subir Kumar Sen of the Department of Commerce of Tripura University, Tripura

(b) **Steps of Collaboration**:

(i) The Department of Commerce of the University of Burdwan will be the Nodal Centre. Tezpur University and Tripura University will be two Research Station associated with the Nodal Centre in respect of the concerned project.

(ii) The financial expenses to run the activities of the Nodal Centre at The University of Burdwan will be borne by all three participating institutions. The common costs and the proportion of responsibility to be shared by each institution will be identified by the PI and the Co-PIs. Here, the expenses and costs mentioned above will be borne out of the funds received or to be received from the UGC for the purpose of the STRIDE-III Project as mentioned in 3.0(a) (i) above.

(iii) **The financial responsibility of all the researchers will be personal and the institutions will in no way become liable except for the duties which they are required to perform as per the existing rules of the University Grants Commission and the university concerned.**

(iv) All researchers will be jointly liable to conduct the research study as mentioned in 3.0 (a) (i) above.

(v) Researchers will make decisions jointly under the leadership of the PI, as mentioned in 3.0 (a) (ii) above.

(vi) All researchers will follow the requirements laid down in the submitted project to the University Grants Commission, India and the associated scheme.

(vii) All academic as well as administrative matters relating to the functioning of the Research Stations (at Tezpur University and Tripura University) concerning this project, will be settled by the respective university in consultation with the PI of the project.

(viii) All researchers will be liable to complete the duties relating to the execution of the research project mentioned in 3.0 (a) (i) above as per the sanctioned terms and conditions of the University Grants Commission, India.

(ix) For conducting joint activities relating to the Project as mentioned in 3.0 (a) (i) above, the expenditure/cost of data collection, T.A, D.A and other relevant expenditure of the research team will be borne by the fund allocated to the respective Research Station as mentioned in the Project.

(xi) The Research Station located at Tripura University will be responsible to conduct survey in Tripura and Lower Assam and all expenses relating thereto will be borne from the fund allocated to this research station.

And

Accordingly the survey related expenditure of Meghalaya and Upper Assam will be borne by the Research Station located at the Tezpur University from the fund allocated to this Research Station.

And

It is also agreed that all the activities (including financial matters) related to this research Project as mentioned in 3.0 (a) (i) above, will be closely monitored by the Nodal centre located at the Bardwan University.

(xi) Hereinafter, it is also stated that, for any visit of the Researchers, Experts, Enumerators and any other staff related to the Project as mentioned in 3.0 (a) (i) above, to any Research Station, associated expenditures will be borne by the host Research Station from their allocated funds. All visits to the Research Stations from the Nodal Centre will be funded by the respective Research Station situated at Tezpur and Tripura.

(c) When the collaboration matures, possibility of similar research and/or academic collaborations in other fields of studies may be explored with mutual consent and discussion.

4.0 CONFIDENTIALITY

a. During and for a period of three years from the date of disclosure, each party agrees to consider as confidential all information disclosed by the other party in written or tangible form or, if orally disclosed confirmed in writing within thirty days of disclosure and identified as confidential by the disclosing party.

b. The obligations above shall not extend to any confidential information for which the receiving party can prove that, this information:

- is in the public domain at the time of disclosure or comes within the public domain without fault of the receiving party.
- is already known or become known to the receiving party,
- is received from a third party having no obligations of confidentiality to the disclosing party.
- is independently developed by the receiving party, or
- is required to be disclosed by law or court order.

5.0 NON-EXCLUSIVITY

The relationship of the parties under this MOU shall be nonexclusive and both parties, including their affiliates, subsidiaries and divisions, are free to pursue other agreements or collaborations of any kind. However, when entering into a particular business, partnership, or dealership agreement, the participants may agree to limit each party's right to collaborate with others on that subject.

6.0 TERMS AND TERMINATION

This MOU, unless extended by mutual written agreement of the parties, shall expire 3 years after the effective date specified in the opening paragraph and can be renewed through mutual interest. This MOU may be amended or terminated earlier by mutual written agreement of the parties at any time. Either party shall have the right to unilaterally terminate this MOU upon 90 days prior written notice to the other party. However, no such early termination of this MOU, whether mutual or unilateral, shall affect the obligations of the participants under any Business Agreement, Confidentiality clause as referenced in clause 4 above, or any other agreement entered into pursuant to this MOU, which obligations shall survive any such termination.

7.0 RELATIONSHIP

Nothing in this MOU shall be construed to make party a partner, an agent or legal representative of the other for any purpose. Now onwards, till the validity of this agreement, both the parties may mention the name and LOGO of the other in their documents as "COLLABORATOR" for purposes as may be required to carry out the research under the scheme for which this MOU is made. But such an instance should be communicated by the user to the other party in writing beforehand.

8.0 INTELLECTUAL PROPERTY RIGHTS (IP)

Intellectual property rights of both the parties will continue to be maintained as is and no party will have rights to any IP already existing with each party. In case of any IP developed jointly, both parties would sign a separate agreement on a mutually agreed basis for such an instance and terms of the same would NOT be guided through this MOU.

9.0 ASSIGNMENTAND SCOPES

It is understood by the Parties herein this MOU is based on the professional competence and expertise of each party and hence neither Party shall transfer or assign this Agreement, or rights or obligations arising hereunder, either wholly or in part, to any third party.

10.0 AMENDMENTS

Amendments or changes to this agreement or MoU shall be made in writing and signed by the duly authorized Representatives of the parties.

11.0 FUNDING

The initial stage of this agreement would not be funded by any of the parties; however, each party would be responsible for the cost of their travel and living expenses.

After the inception, when the collaboration matures, the funding may be realized on application to University Grant Commission (UGC). The Parties can submit joint project proposals to relevant funding agencies and the funding applications should be made by the participating parties with their mutual consent and discussions regarding the scope and extent of such funded program and its goals.

12.0 COSTS OF THE MOU

Each Party shall bear the respective costs of carrying out the obligations under this MOU

13.0 POINT OF CONTACTS

Each Party will nominate its own representatives who would be responsible for all measures to be undertaken under this agreement and they would be called point of contact (PoC). The point of contact for each of the parties is mentioned below:

FOR TEZPUR UNIVERSITY

Dr. Santi Gopal Maji, Associate Professor, Department of Commerce, Tezpur University, Napaam, Tezpur, Assam 784028, India
Email: sgmaji2010@gmail.com; Phone No. +91-9434030244
(On lien from NEHU as Assistant Professor w.e.f. 12.12.2019 to 11.12.2021)

FOR TRIPURA UNIVERSITY

Dr. Subir Kumar Sen, Assistant Professor, Department of Commerce, Tripura University, Suryamaninagar, Agartala-799022, Tripura, India
Email: subirkumarsen@gmail.com; Phone No. +91-9089880888

FOR THE UNIVERSITY OF BURDWAN

Prof Santanu Kumar Ghosh, Department of Commerce, The University of Burdwan, Golapbag, P.O.-Rajbati, Dist- East Burdwan, West Bengal-713104, India
Email: shantanu.kaizen@gmail.com, Phone: +919434360561

14.0 MODIFICATIONS TO MOU

Any amendment or modifications of this MOU shall be in writing by both parties.
The modifications/changes shall be effective from the date on which they are made/ executed, unless otherwise agreed to.

15.0 FORCE MAJEURE

Neither party shall be held responsible for non-fulfillment of their respective obligation under this MoU due to circumstances beyond their control but not limited to war, flood, cyclones, riots, strikes etc. If such condition continues beyond six months, the parties shall then mutually decide about the future course of action. Either party shall intimate each other of any such event.

In witness whereof, the parties hereto have signed this MOU on the 9th Day of October 2020

a) SIGNED IN DUPLICATE

This MOU is executed in duplicate with each copy being an official version of the Agreement and having equal legal validity.

BY SIGNING BELOW, the parties, acting by their duly authorized officers, have caused this Memorandum of Understanding to be executed, effective as of the day and year first above written.

On behalf of	On behalf of	On behalf of
Tezpur University, Assam	**Tripura University, Tripura**	**The University of Burdwan, West Bengal**
By :	By : 12/10/2020	By :
Name : Dr. Biren Das	Name : DR. K.B. JAMATIA	Name : PROF. ABHIJIT MAZUMDAR
Title : The Registrar, Tezpur University	Title : The Registrar, Tripura University	Title : The Registrar, The University of Burdwan
Date :	Date :	Date : 09.10.2020
SEAL	SEAL	SEAL

Registrar
Tezpur University
Napaam, Tezpur

(Dr K.B. Jamatia)
Registrar (i/c)
Tripura University

REGISTRAR (Officiating)
THE UNIVERSITY OF BURDWAN
BURDWAN-713104

Witness:

1. Preferably the HoD	1. Preferably the HoD	1. Preferably the HoD
Head, Department of Commerce, Tezpur University	(Dr Chinmoy Roy) Professor & Head Department of Commerce Tripura University	HEAD DEPARTMENT OF COMMERCE THE UNIVERSITY OF BURDWAN
2. Preferably the PoC	2. Preferably the PoC	2. Preferably the PoC
S.G. Maji Associate Professor Department of Commerce Tezpur University Napaam, Assam- 784028 Co-PI	co-PI and Assistant Professor Department of Commerce Tripura University	PI UGC STRIDE-III

NTLAB, UAB
Company code: 125309151
VAT ID number: LT100009501517
Švenčionių g. 112, LT-15168 Nemenčinė,
LITHUANIA
Tel.: +37061695418

sl.no. 31

05.06.2020
Ref.No. 3

To: Dr. Anindya Bose, Professor
The University of Burdwan, Department of Physics Golapbag, Burdwan 713104, West Bengal, INDIA

Subject: Letter of Interest
Enclosures: Memorandum of understanding and cooperation

Dear Dr. Anindya Bose,

As we know, the University of Burdwan (BU) is engaged in research of navigation products and services.

NTLAB UAB (NTLab) is developing chipsets for navigation receivers and offering chips, modules and an open hardware platform, is interested in international research projects and the use of its products by customers from India.

To establish our cooperation of mutual research, components supply (from NTLab) and other possible collaboration in GNSS area, we invite you to sign the Memorandum of understanding and cooperation (ENCLOSURE 1) targeted to the following:

1. Performance study of NTLab modules under conditions of the radionavigation field of India.
2. Usage of NTLab modules during research and in the learning process.
3. Assisting clients in India in implementing their own algorithms on NTLab hardware.
4. Joint research projects.
5. Creating, on the basis of BU, NTLab's center of scientific competence and customer support in India.

Sincerely,

Dmitri Tcherniakovski

Director

NTLAB, UAB JSC

e-mail: info@ntlab.lt
www.ntlab.lt

SL NO. 35

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Department of Geodesy and Geoinformation
A.o. Univ.-Prof. DI Dr. Guenther Retscher

Research Division Engineering Geodesy
Wiedner Hauptstrasse 8-10/E120-05
1040 Wien, AUSTRIA
Tel.: +43/1/58801-12847
https://www.geo.tuwien.ac.at/

To:
Whom It May Concern

Vienna, 19 August 2021

LETTER OF INTEREST

Dear Sir / Madam,

I am very pleased to invite Dr. Anindya Bose to collaborate and bring his expertise as advisor in the course of the Erasmus+ Capacity Building in Higher Education project entitled 'Curricula Enrichment delivered through the Application of Location-based Services to Intelligent Transport Systems / LBS2ITS'. The LBS2ITS project has a duration of 3 years and started on January 15, 2021. Participating Universities are the EU programme countries' Universities Technische Universitaet Dresden (TU Dresden), Germany, and National Technical University of Athens (NTUA), Greece, under the lead of Technische Universtaet Wien (TU Wien), Austria. The partner country in this project is Sri Lanka with the four Sri Lankan partner Universities Sabaragamuwa University of Sri Lanka (SUSL), University of Moratuwa (UOM), University of Sri Jayewardenepura (USJ) and General Sir John Kotelawala Defence University (KDU).

Location-based Services (LBS) are an important application in Positioning, Navigation and Timing (PNT) and especially for Intelligent Transport Systems (ITS). Global Navigation Satellite Systems (GNSS) play thereby a crucial role and for the LBS users in the Indian sub-continental region the Indian Regional Satellite Constellation NavIC and the Satellite Based Augmentation System (SBAS) GAGAN provide great opportunities for research and education. Due to the great expertise of Dr. Bose in the PNT field, the collaboration and exchange of research ideas can benefit all involved institutions. A train-the-teachers course on PNT technologies is held in early May 2022 in Sri Lanka at SUSL. We would like to invite Dr. Bose to contribute and participate in this course. Another starting point of our collaboration would be that Dr. Bose joins as a member of a supervisory panel for a master students from SUSL.

We are confident that the collaboration with the Dr. Bose and Burdwan University will be of mutual benefit for all involved partners. Further acquisition of funding for joint research projects forms an integral part of our intended collaboration and will be sought-after.

Yours sincerely,

Guenther Retscher
TU Wien - Vienna University of Technology
https://lbs2its.net/

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Contents lists available at ScienceDirect

Chaos, Solitons and Fractals

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Spatiotemporal modulated solitons in a quasi-one-dimensional spin-1 Bose–Einstein condensates

Fei-Yan Liu [a], Su-Yong Xu [b], Houria Triki [c], Amitava Choudhuri [d], Qin Zhou [a,e,*]

[a] Research Group of Nonlinear Optical Science and Technology, Research Center of Nonlinear Science, School of Mathematical and Physical Sciences, Wuhan Textile University, Wuhan 430200, China
[b] College of Optical, Mechanical and Electrical Engineering, Zhejiang A&F University, Lin'an 311300, China
[c] Radiation Physics Laboratory, Department of Physics, Faculty of Sciences, Badji Mokhtar University, P.O. Box 12, 23000 Annaba, Algeria
[d] Department of Physics, The University of Burdwan, Golapbag 713104, West Bengal, India
[e] State Key Laboratory of New Textile Materials and Advanced Processing Technologies, Wuhan Textile University, Wuhan 430200, China

ARTICLE INFO

Keywords:
Bose–Einstein condensates
Bright/dark solitons
Hirota bilinear method

ABSTRACT

In this paper, we investigate the nonautonomous bright/dark solitons in a quasi-one-dimensional spi Bose–Einstein condensates through a three coupled Gross–Pitaevskii (GP) system with space–time-depend external potential and temporally modulated gain/loss distributions. Based on the Hirota bilinear method, analytically construct the bright soliton solutions when the coupled GP system exhibits attractive interactic while we obtain the dark soliton solutions when the coupled GP system exhibits repulsive interactic The influence of spatiotemporal modulated external potentials, such as the gain/loss distribution $\Gamma(t)$, bright/dark soliton dynamics is analyzed in detail via the analytical solutions. By taking different $\Gamma(t)$, obtain different types of bright solitons, including periodic, dromion-like and parabolic solitons, and derive dark solitons on different backgrounds, such as periodic, parabolic and kink backgrounds. We anal the regulatory effects of different wavenumber ratios on the attraction and squeezing of bound-state solit Through the asymptotic analysis, we find that the interactions between two solitons are elastic. In additi we conduct research on the forward and inverse problems of the above results via the parallel hard-constra physical informed neural network (phPINN) method. The predicted solitons and potential functions are in g agreement with the exact solitons and potential in the system.

1. Introduction

Bose–Einstein condensation (BEC) represents one of the most specific and fascinating quantum phenomena in nature [1]. In essence, it is a genuinely quantum-mechanical phase transition which is driven by the particle statistics and not by their interaction. Especially, a spinor BEC is a BEC with an internal atomic spin degree of freedom displaying a rich variety of magnetic effects [2]. In such interesting multi-component condensed system, there exist several phases below the transition temperature and the phases are dependent on the nature of the interaction. It should be mentioned here that in a conventional magnetic traps, the spin degrees of freedom are frozen and the BEC is described by a scalar order-parameter. In contrast, when the BEC is trapped using an optical potential, the spin of each atom is free to evolve due to the interparticle interaction. The order-parameter describing a BEC with spin internal degrees of freedom is referred to as a spinor BEC [3–6]. Usually, spinor BECs feature an intrinsic three component structure, which is due to the differences between differ hyperfine spin states of atoms [5]. It is also to be noted that such a system has been first experimentally realized in a gas of ^{23}Na ato with hyperfine spin $F = 1$, in an optical dipole trap [4]. Moreove has been reported that due to the interparticle interaction, the direct of atomic spins can change, and therefore, spinor BECs exhibit cert spin textures [7–9]. Nowadays, spinor BECs have an important rol physics because the spin degrees of freedom can generate rich quant dynamics and abundant phenomena, including spin texture (i.e., spatial variation of the spin direction [2]), magnetic crystallization, fractional vortices [10–12]. Importantly, experimental and theoret studies on spinor BECs have revealed various interesting phen ena, such as quantum junction [13], polarity to ferromagnetic ph transition [14], condensation excited by Magnon [15], and vari nonlinear excitations composed of dark/bright solitons [16–23], ro waves [24], soliton complexes [25], vortices [26–28], etc..

* Corresponding author at: Research Group of Nonlinear Optical Science and Technology, Research Center of Nonlinear Science, School of Mathematical Physical Sciences, Wuhan Textile University, Wuhan 430200, China.
E-mail address: qinzhou@whu.edu.cn (Q. Zhou).

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Received 28 February 2024; Received in revised form 27 April 2024; Accepted 28 April 2024
Available online 3 May 2024

SL.no. 33

MEMORANDUM OF UNDERSTANDING

Between

THE UNIVERSITY OF BURDWAN

RAJBATI, BURDWAN, WEST BENGAL, 713104

INDIA

and

SHIVAJI UNIVERSITY

KOLHAPUR 416 004

MAHARASHTRA

INDIA

This MOU is entered into on the **eighteenth** day of **January 2021**

BETWEEN

THE UNIVERSITY OF BURDWAN, RAJBATI, BURDWAN, WEST BENGAL 713104, INDIA (hereinafter called "BU" which expression shall where the context so admits include its successors and permitted assignees) of the one part,

AND

SHIVAJI UNIVERSITY, KOLHAPUR 416 004, MAHARASHTRA, INDIA ((hereinafter called "SUK" which expression shall where the context so admits include its successors and permitted assignees) and the other part

1.0 Preamble:

Whereas, "THE UNIVERSITY OF BURDWAN (BU)" is one part and "Shivaji University, Kolhapur (SUK) is the other, both are parties to this MoU.

Whereas, SUK has set up Space Research Center, (SRC) located on the mountain top near Panhala fort (16.8°N, 74.2°E, Altitude: 968 meters) for the space research and application The location of Panhala with magnetic dip latitude of 10.60 is situated in between the crest and trough locations of the plasma fountain effect that exists in the upper atmosphere. This place is ideal for the study of the ionospheric anomalies near equatorial regions. SUK has also installed an Indian Regional Navigation Satellite System (IRNSS): NavIC system Automatic weather monitoring system, Sudden Ionospheric Disturbance (Super-SID) space weather monitor. Relative Ionospheric Opacity Meter (RIO-Meter) at Space Research Center, Panhala, Kolhapur, Whereas, Satellite Synchronized ULF induction magnetometer, Proton Presetion Magnetometer (PPM), Celestron C5XLT OTA, Schmidt-Cassegrain Telescope (SCT), etc are available in the department.

Whereas The University of Burdwan is a leading University in West Bengal engaged in teaching and research in different fields of knowledge and learning. One of the fields of training and research of the University is use of space-based technologies and satellite-based navigation systems (GNSS, hereinafter). The University has a GNSS laboratory used for training and research purposes. Both universities are agreed to extend the collaborative research and academic activities using existing and upcoming GNSS systems, particularly for GNSS Research.

Both the parties are entering into this MoU for Research and Academic Collaboration for GNSS Research in mutually beneficial and befitting manner.

2.0 Effective Date and Duration of MoU:

This MoU is effective from the date of its signing and is valid for a duration 3 (Three) years from the date of signing. It may be extended further in writing based on mutual consent.

3.0 Scope of MoU:

Scope of the MoU involves research and academic collaboration in the field of GNSS which includes but not limited to Navigation Data collection, sharing and analysis for mutually agreed topics of research for both parties, joint academic programs and joint application for possible funding from appropriate funding agencies.

4.0 PROPOSED MODES OF COLLABORATION

SUK and BU propose to collaborate through

a) Establishing collaboration between GNSS research Centre and Department of Physics in the field of GNSS as a Research Partner

b) Mutual sharing of IRNSS/ NavIC/ GNSS data for research, those are not restricted for distribution by any other legal/ ethical obligations

c) Shared data shall be used for Academic research purpose only.

d) Due acknowledgment of data provider institute and ISRO in case of IRNSS/ NavIC data used in joint publications.

e) When the collaboration matures, possibility of similar research and/ or academic collaborations in other fields of studies may be explored with mutual consent

5.0 CONFIDENTIALITY

a. During and for a period of three years from the date of disclosure, each party agrees to consider as confidential all information disclosed by the other party in written or tangible form or, if orally disclosed confirmed in writing within thirty days of disclosure and identified as confidential by the disclosing party.

b. The obligations above shall not extend to any confidential information for which the receiving party can prove that, this information:

- is in the public domain at the time of disclosure or comes within the public domain without fault of the receiving party.
- is already known or become known to the receiving party
- is received from a third party having no obligations of confidentiality to the disclosing party,
- is independently developed by the receiving party or
- is required to be disclosed by law or court order.

6.0 NON-EXCLUSIVITY

The relationship of the parties under this MOU shall be nonexclusive and both parties, including their affiliates, subsidiaries and divisions, are free to pursue other agreements or

collaborations of any kind. However, when entering into a particular business, partnership, or dealership agreement, the participants may agree to limit each party's right to collaborate with others on that subject.

7.0 TERMS AND TERMINATION

This MOU, unless extended by mutual written agreement of the parties, shall expire 3 years after the effective date specified in the opening paragraph and can be renewed through mutual interest. This MOU may be amended or terminated earlier by mutual written agreement of the parties at any time. Either party shall have the right to unilaterally terminate this MOU upon 90 days prior written notice to the other party. However, no such early termination of this MOU, whether mutual or unilateral, shall affect the obligations of the participants under any Business Agreement, Confidentiality clause as referenced in clause 4 above, or any other agreement entered into pursuant to this MOU, which obligations shall survive any such termination.

8.0 RELATIONSHIP

Nothing in this MOU shall be construed to make either party a partner, an agent or legal representative of the other for any purpose. Now onwards, till the validity of this agreement, both the parties may mention the name and LOGO of the other in their documents as "COLLABORATOR" for purposes as may be required. But such an instance should be communicated by the user to the other party in writing beforehand.

9.0 INTELLECTUAL PROPERTY RIGHTS (IP)

Intellectual property rights of both the parties will continue to be maintained as is and no party will have rights to any IP already existing with each party. In case of any IP developed jointly, both parties would sign a separate agreement on a mutually agreed basis for such an instance and terms of the same would NOT be guided through this MOU.

10.0 ASSIGNMENT

It is understood by the Parties herein this MOU is based on the professional competence and expertise of each party and hence neither Party shall transfer or assign this Agreement, or rights or obligations arising hereunder, either wholly or in part, to any third party.

11.0 AMENDMENTS

Amendments or changes to this agreement or MoU shall be made in writing and signed by the duly authorized Representatives

SHIVAJI UNIVERSITY शिवाजी विद्यापीठ KOLHAPUR

THE UNIVERSITY OF BURDWAN RAJBATI BURDWAN 713104

12.0 FUNDING

The initial stage of this agreement would not be funded by any of the parties, however, each party would be responsible for the cost of their travel and living expenses.

After the inception, when the collaboration matures, the funding may be realized on application to various funding agencies of relevance. The Parties can submit joint project proposals to relevant funding agencies and the funding applications should be made by the participating parties with their mutual consent and discussions regarding the scope and extent of such funded program and its goals.

13.0 COSTS OF THE MOU

Each Party shall bear the respective costs of carrying out the obligations under this MOU

14.0 POINT OF CONTACTS

Each Party will nominate its own representatives who would be responsible for all measures to be undertaken under this agreement and they would be called point of contact (PoC). The point of contact for each of the parties are mentioned below:

FOR SHIVAJI UNIVERSITY:

Dr. Rajiv Shrikant Vhatkar,
Asst. Professor and Co-ordinator, Space Research Center, Panhala
Department of Physics, Shivaji University,
Kolhapur-416004, Maharashtra, India
Email: drvhatkar@gmail.com Cell: (0)7588246170

FOR THE UNIVERSITY OF BURDWAN

Dr Anindya Bose,
Senior Scientific Officer,
Department of Physics, The University of Burdwan
Golapbag 713 104, West Bengal
abose@phys.buruniv.ac.in; Cell: (0)9434004478

15.0 Modifications to MoU:

15.1 Any amendment or modifications of this MOU shall be in writing by both parties.

15.2 The modifications/changes shall be effective from the date on which they are made/ executed, unless otherwise agreed to.

16.0 Force Majeure:

Neither party shall be held responsible for non-fulfillment of their respective obligation under this MoU due to circumstances beyond their control but not limited to war, flood, cyclones,

decide about the future course of action. Either party shall intimate each other of any such event.

In witness whereof, the parties hereto have signed this MOU on the **eighteenth** Day of **January 2021.**

17.0 SIGNED IN DUPLICATE

This MOU is executed in duplicate with each copy being an official version of the Agreement and having equal legal validity.

BY SIGNING BELOW, the parties, acting by their duly authorized officers, have caused this Memorandum of Understanding to be executed, effective as of the day and year first above written.

On behalf of

Shivaji University, Kolhapur

By :

REGISTRAR
Shivaji University
Kolhapur

Name :

Title :

Date : 18/01/2021

SEAL

Witness:

1. Dr. Rajiv S. Vhatkar
Coordinator,
Space Research Center, Panhala,
Shivaji University, Kolhapur

2. (Dr. N.L. Tarwal)
Dr. N. L. Tarwal
Assistant Professor,
Department of Physics,
Shivaji University, Kolhapur-416 004

On behalf of

The University of Burdwan, Burdwan

By :

18.01.2021

Name : Prof A Mazumdar

The Registrar (Officiating)
The University of Burdwan
Rajbati, Burdwan-71
West Bengal

Title : Registrar,
The University of Burdwan

Date : 18/01/2021

SEAL

Witness:

1. (PARTHA MITRA)
Professor & Head
Department of Physics
The University of Burdwan
Burdwan-713104

2. 18.01.2021
(ANINDYA BOSE)
DR ANINDYA BOSE
SENIOR SCIENTIFIC OFFICER
DEPARTMENT OF PHYSICS
BURDWAN UNIVERSITY, GOLAPBAG
BURDWAN-713 104, INDIA

पश्चिमबंगा पश्चिम बंगाल WEST BENGAL AF 987349

MEMORANDUM OF AGREEMENT (MOA)

This Memorandum of Agreement is made and entered into force this day 18th May of 2021 at New Delhi.

SL. No.-- 34

AMONG

The University Grants Commission, a Statutory Body established under the UGC Act, 1956 having its office at Bahadur Shah Zafar Marg, New Delhi - 110 002, represented by its Secretary (hereinafter referred to as "UGC") which expression shall unless the context requires otherwise, mean and include its successors, representatives and permitted assigns of the FIRST PART.

University of Burdwan, Bardhaman established on 15th June, 1960 having its office at the University of Burdwan, Rajbati, Bardhaman – 713104 West Bengal, represented by its Registrar (hereinafter referred to as "BU") Which expression shall, unless the context requires otherwise, mean and include its successors, representatives and permitted assigns of the SECOND PART.

AND

Suyro Chatterjee, the candidate selected as Associate Professor under the UGC- Programme on "Operation Faculty Recharge" (FRP) in the discipline of Biological Sciences and posted in the department/ School of Biotechnology, University of Burdwan, in the State of West Bengal and having his permanent residence at Janai, Hooghly, West Bengal (hereinafter referred to as "UGC-FRP-Faculty") forming the THIRD PART.

WHEREAS, the "UGC" has launched a novel scheme called, "Operation Faculty Recharge Programme (FRP)" for national level recruitment of faculty in Science, Engineering & Technology to strengthen high quality research in Science - related disciplines at internationally competitive levels and promote innovative teaching in the Universities through induction of fresh talent at the levels of Assistant Professors, Associate Professors and Professors.

Therefore, all the three to this Memorandum of Agreement agreed and undertake to abide by the following terms and conditions:

(i) Qualifications for various faculty positions under the programme shall be the same as provided in the UGC Regulations on "Minimum Qualifications for appointment of teachers and other academic staff in Universities and Colleges and measures for the maintenance of standards in higher education, 2010" and as amended from time to time.

(ii) The 'Faculty Recharge' position shall initially be for a tenure of five years. However, depending upon the peer group expert assessment report, the positions may either be extended or elevated to the next higher levels or in unsuccessful cases in peer group expert assessment could even be terminated.

(iii) The period of appointment of the incumbents in these FRP-positions shall be the same as prescribed for teachers in the central universities by the UGC and the Government of India from time to time with the tenure of the FRP-Faculty may be extended every five years up to the age of 65 years subject to (ii) above.

(iv) Nationally selected candidates under the "Faculty Recharge Programme" will be located/placed through harmonization of their own preference, response of the

host university and availability of infrastructure for discharge of the duties earmarked for these UGC-Faculty positions

(v) The recurrent financial implications of all the 'Faculty Recharge positions' shall be met by UGC. Such positions shall be made available to both Central and State Universities, which are eligible for receiving UGC funds under section 12-B of UGC Act, 1956, and which are signing this Memorandum of Agreement (MoA) with UGC.

(vi) The "MOA" is intended to facilitate the legal and technical requirements for the recipient Universities to accept the Faculty - Recharge positions. The Universities shall also authenticate and undertake to UGC that all academic & administrative facilities will be extended to the appointees under the Faculty Recharge Programme as per the terms and conditions of appointment to be decided and communicated separately to both appointee and university.

(vii) It shall also be mandatory for the recipient Universities to accept and implement all norms & guidelines pertaining to the "UGC' Operation Faculty Recharge Scheme" from time to time.

(viii) It shall be incumbent on the part of the recipient Universities to provide teaching, research, co-curricular & extra-curricular facilities to the faculty recharge programme teachers.

(ix) Subsequent to all the above conditions are agreed to by the recipient Universities, annual release of funds towards the faculty recharge positions provided will be made by UGC to the recipient Universities on a recurrent basis subject to the UGC - fund release norms applicable to Central/State Universities and the recipient Universities shall submit Utilization Certificates and Audited Statement of Accounts annually to UGC as per UGC norms.

(x) The work load of each faculty in term of contact hours, presence on the campus and other activities relating to teaching, research, examination, evaluation, curricular development, self study and preparation for lectures with increased commitment on innovative research shall be as per the norms/service rules separately prescribed by the University Grants Commission under this

"Faculty Recharge Programme".

(xi) Every faculty member appointed under 'FRP' shall abide by the Code of Conduct framed by the University Grants Commission in its Regulations, 2010.

(xii) Any faculty member in FRP may, at any time, terminate his contract by giving the University-UGC three month's notice in writing or on payment of three month's salary in lieu thereof.

(xiii) Notwithstanding anything contained in this MOA, it is clarified between the "PARTIES" to this MOA that the detailed terms and conditions of service of persons to be appointed under the "FRP" shall be specified separately in the letter of appointment and through separate service rules for FRP to be communicated to the appointee and the University at the time of appointment of the faculty.

IN WITNESS THEREOF, the parties hereto have signed this Memorandum of Agreement on the 18th day of May Two thousand Twenty One.

For and behalf of University Grants Commission	For and on behalf of University
Signature Name: Prof. Rajnish Jain Designation : Secretary, UGC Official Stamp प्रो0 रजनीश जैन / Prof. RAJNISH JAIN सचिव / Secretary विश्वविद्यालय अनुदान आयोग University Grants Commission शिक्षा मंत्रालय, भारत सरकार Ministry of Education, Govt. of India Bahadur Shah Zafar Marg, New Delhi-110 002	Signature Name: Dr. Debidas Mondal Designation : Registrar Official Stamp Registrar (Officiating) The University of Burdwan Rajbati, Burdwan-713104 West Bengal
Signature of the Witness Name: Suvro Chatterjee Designation : Associate Professor Permanent Address: Jahai, Hooghly, West Bengal, 712304	

Address for Communication: Department of Biotechnology University of Burdwan Golapbag Campus Bardhaman West Bengal 713104	
Name & Address of Witness 1..... 2.....	Name & Address of Witness 1. Indrani Chandra Dr. INDRANI CHANDRA Teacher-in-Charge Dept. of Biotechnology The University of Burdwan 2. Chatterjee University Engineer The University of Burdwan BURDWAN

SL NO. - 26

पश्चिमबङ्गा पश्चिम बंगाल WEST BENGAL

AB 960366

MEMORANDUM OF AGREEMENT

This MEMORANDUM OF AGREEMENT is made on this **twenty seventh** day of**June** Two thousand and **nineteen** BY AND BETWEEN President of India, acting through **Advisor & scientist 'G"**, Department of Biotechnology, Ministry of Science and Technology, Government of India, New Delhi, hereinafter referred to as the 'DBT' (which expression unless excluded by or repugnant to the subject shall mean and include its successor-in-office and assigns) of the ONE PART;

AND

The University of Burdwana society under the Societies Registration Act – 1860, having its registered office in/at **Rajbati, Burdwan,** hereinafter referred to as **BU** (which expression shall where the context so admits include its successors and permitted assigns) of the OTHER PART;

WHEREAS DBT being desirous of **Research on Human Genetics & Genomics** decided to support a project submitted by **Prof. Anupam Basu** for the attainment of the objectives, hereinafter described in the Annexure I annexed hereto;

This Memorandum of Agreement (MoA) defines the role and responsibilities of the participating agencies, monitoring and other matters related to the **"A Genetic Algorithm-Based Targeted Approach for Understanding the Phenotypic Heterogeneity of Thalassemia Syndromes in Northern and Eastern Indian Population"**

02.08.19
Dr. D. Mondal
Joint Registrar
The University of Burdwan

Dr. Anupam Basu
PROFESSOR
Department of Zoology
University of Burdwan

NOW THE PARTIES HERETO AGREE AS FOLLOWS:-

1.0 . ROLE OF DEPARTMENT OF BIOTECHNOLOGY, NEW DELHI

To provide funds to the extent of **7379121.00**over a period of **3** years from the date of sanction of the project, to **The University of Burdwan** for undertaking activities as detailed in Annexure 1. Details of the funds to be provided are given in Annexure II.

2.0. ROLE OF THE UNIVERSITY OF BURDWAN (Institute)

2.1. To provide their contribution of **NIL**for**NIL** years from date of sanction of the project as detailed in Annexure – II. *(if a jointly supported project)*

2.2. To provide existing facilities as mentioned in the project document.

2.3. To be responsible for accomplishing objectives identified and activities listed.

2.4. To allow the Scientists authorized by DBT to work with the Research & Development team of the center in all stages of process development and production.

2.5. To recruit all scientific and non-scientific staff as sanctioned by DBT.

2.6. To prepare and submit all periodical reports and other documents that would be required by DBT.

2.7. To maintain a separate audit head of account for the grants received from DBT for the project.

2.8. To submit an annual audited statement of expenditure incurred under the project.

2.9. To ensure effective utilization of the grant given by DBT for the purpose for which it was granted and to ensure timely progress of project work.

2.10. The manpower, both scientific and non-scientific, recruited shall be purely on contractual terms & conditions such that the contract for engagement of the manpower shall run concurrently with the said project period only.

3.0 DURATION OF PROJECT

3.1 Duration of project shall be **3** years from the date the Project has been sanctioned by DBT.

4.0 RIGHTS OF OWNERSHIP/TECHNOLOGY TRANSFER AND UTILIZATION

4.1 The know-how generated from the project by **Prof. Anupam Basu** will be the joint property of **The University of Burdwan** and DBT, Government of India. It shall be the responsibility of **Prof. Anupam Basu & The University of Burdwan** to take necessary action for protection of the intellectual property arising out of the PROJECT through proper instruments, such as, patents, copy rights, etc.

The know-how developed may be transferred to other entrepreneurs on a non-exclusive basis on such terms and conditions as may be determined by DBT.

02.08.19
Dr. D. Mondal
Joint Registrar
The University of Burdwan
Burdwan-713104, W.B.

Dr. Anupam Basu
PROFESSOR
Department of Zoology
University of Burdwan

4.3 All the assets including the equipment and produce acquired will be the property of DBT and shall not be utilized for purposes other than those for which the grant has been sanctioned. The rights of **The University of Burdwan**. under this MoA shall not be transferred to any other party without prior approval in writing of DBT.

4.4 It shall be the responsibility of **Prof. Anupam Basu** to ensure that support of DBT is suitably acknowledged in the publications (papers, reports, etc.) arising out of the PROJECT.

5. SECRECY

It is hereby agreed that the participating agencies shall keep information and data collected completely secret provided that the right to transfer the technology shall rest with the DBT.

6. MONITORING

6.1 The progress of implementation of the project and proper utilization of grant shall be reviewed by the DBT and by the Monitoring Committee set up by DBT.

6.2 The periodic progress of physical achievements and the utilization of funds, statement of expenditure shall be evaluated by the Monitoring Committee.

6.3 The Comptroller and Auditor General of India, at his discretion shall have the right of access to the books and accounts of **The University of Burdwan** for the grants received from DBT for this project.

6.4 The DBT may terminate the grant at any stage if it is convinced that the grant has not been properly utilized or appropriate progress has not been made. In the event, DBT terminates the grant, **Prof. Anupam Basu** shall hand over all documents including technical details and equipment purchased related to the project.

7.0 DURATION OF MEMORANDUM OF AGREEMENT

This MoA will remain inforce for the duration of the project and until all claims are settled between DBT and **The University of Burdwan.**

8.0 ARBITRATION

In the event of any question, dispute or difference whatsoever arising between the parties to this Agreement out of or relating to the construction, meaning, scope, operation or effect of this Agreement or the validity of the breach thereof shall be referred to an Arbitrator to be appointed by mutual consent of both the parties herein. If the parties cannot agree on the appointment of the Arbitrator within a period of one month from the notification by one party to the other of existence of such dispute, then the Arbitrator shall be nominated by the Secretary, Department of Legal Affairs, Ministry of Law & Justice, Government of India. The provisions of the Arbitration and Conciliation Act, 1996 will be applicable and the award made thereunder shall be final and binding upon the parties hereto, subject to legal remedies available under the law. Such differences shall be deemed to be a submission to arbitration under the Indian Arbitration and Conciliation Act, 1996, or of any modifications or amendments thereof.

02.08.19
Dr. D. Mondal
Joint Registrar
The University of Burdwan
Rajbati, Burdwan-713104 W.B.

Dr. Anupam Basu
PROFESSOR
Department of Zoology
University of Burdwan

9.0. GOVERNING LAW

This Contract shall be governed by the Law of India for the time being in force.

IN WITNESS WHEREOF the parties hereto have signed, sealed and delivered this Agreement on the day, month and year first above written in presence of:

Witnesses:

1.

2.

Signed by ----------

(Designation)

For and on behalf of The President of India

Witnesses:

1. Dr. SOUMENDRANATH CHATTERJEE Associate Professor & Head Dept. of Law The University of Burdwan Golapbag, Burdwan-713104

2. Anupam Basu 23/6/09 Dr. Anupam Basu PROFESSOR Department of Law The University of Burdwan

Signed by 02.08.19

Dr. D. Mondal
Joint Registrar
The University of Burdwan
Golapbag, Burdwan-713104, W.B.

THE UNIVERSITY OF BURDWAN RAJBATI BURDWAN 713104

For and on behalf of
The University of Burdwan

TERMS & CONDITIONS OF THE GRANT

(To be signed and enclosed with concern filled proforma)

1. Approval of the Research proposal and the grant released would be for the specific project mentioned in paras I to V of this proposal and grant should be exclusively spent on the project for which it has been sanctioned within the stipulated time. The Institute is not permitted to seek or utilize funds from any other organization (Government, Semi Government, Autonomous or Private) for this research project. Any unspent part of amount would be surrendered to the Govt. of India through an account payee demand draft drawn in favor of the "Drawing and Disbursing Officer, Department of Biotechnology, New Delhi", and carry forward of funds of the next financial year for utilization for the same project may be considered only with the specific approval of the Department of Biotechnology (DBT).

2. For permanent/semi-permanent assets acquired solely or mainly out of the grant, an audited record in the form of a register in the prescribed proforma (enclosed at **Appendix-'A'**) shall be maintained by the Institute. The term **"assets"** means (I) immovable property and (II) movable property of a capital nature, where the value exceeds Rs. 1000/- The grant will not be utilized for construction of any immovable property, Full facilities by way of accommodation, etc. for the project will be given by the Institute.

3. All the assets acquired from the grant will be the property of Govt. of India and should not without the prior sanction of the Dept. of Biotechnology, be disposed of, or encumbered or utilized for purpose other than those for which the grant has been sanctioned.

4. At the conclusion of the project, the Govt. of India will be free to sell or otherwise dispose of assets which are the property of the Government. The Institute shall render to Govt. necessary facilities for arranging the sale / disposal of these assets. **The Government may, however, consider the request of host institutions to retain the assets created under a project for carrying out similar work for the promotion of science.**

5. The implementing Institute/PI will furnish progress report of work on the project every six months. The progress of the project will also be reviewed/monitored at least once a year by the concerned Task Force/Project Monitoring Committee, etc. In addition the DBT shall designate Scientists/Specialists to visit the Institute periodically for reviewing the progress of work and for suggesting such measures as to ensure early realization of the objectives of the project. On completion of the project five copies of a consolidated report of the work done on the subject would be submitted to the Department of Biotechnology.

6. The Institute is required to send to DBT a list of assets referred to at Sl. No. 2 above at the end of each financial year as well as at the time of seeking further installments of the grant.

7. The Institute would furnish to the Dept. of Biotechnology a Utilization Certificate and an audited statement of expenditure duly signed by the P.I., the Head of the Institute and the Head of the Finance wing, pertaining to the grant at the end of each financial year as well as a consolidated statement of expenditure at the end of the completion of the project.

A stamped receipt be sent to the Dept. of Biotechnology on receipt of the Cheque/ Demand draft towards each release.

02.08.19
Dr. D. Mondal
Joint Registrar
The University of Burdwan
Rajbati, Burdwan-713104, W.B.

Dr. Anupam Basu
PROFESSOR
Department of Zoology
The University of Burdwan

9. The Comptroller and Auditor-General of India at his discretion shall have the right of access to the books and accounts of the Institute for the grant received from the Government.

10. The Institute would maintain separate audited accounts for the project. If it is found expedient to keep a part or whole of the grant in a bank account earning interest, the interest thus earned should be reported to the Dept. of Biotechnology.

11. Sale proceeds, if any, as a result of the development of the project arising directly from funds granted by the Dept. of Biotechnology shall be reported to the Govt. of India. The Govt. of India may at its discretion allow a portion of such receipt to be retained by the Institute for its utilization for the project activities.

12. Investigators/Institutes wishing to publish papers based on the research work done under Dept. of Biotechnology projects should acknowledge the financial support received from the Dept. of Biotechnology.

13. Investigators/Institutes may utilize various resources such as the Bioinformatics resources, experimental materials, reagents, cell lines, animals, etc. from the National facilities/Institutes/Centers established by this Department as per the terms of transactions followed by them. More information may be obtained about such facility from DBT websites: http://www.dbtindia.org// www.dbtindia.nic.in, www.btisnet.ac.in.

14. Investigators / Institutes shall follow the detailed instructions on technology transfer and Intellectual Property Rights (IPR) as given at Annexure - V. The same has the approval of the Ministry of Finance, Govt. of India vide Dept. of Expenditure, Plan Finance II – Division Letter No. 33 (5) /PF.II/99 dated 22nd February, 2000. Any deviation from these instructions may be brought to the notice of this Department.

15. Investigators / Institutes may file patents with the help of the Biotechnology Patents Facilitating Cell (BPFC) established at DBT on priority bases. The format for filing the patents may be seen at Annexure –VI.

16. The Govt. of India (Dept. of Biotechnology) will have the right to call for drawings, specifications and other data necessary to enable the transfer of know-how to other parties and the Institute shall supply all the needed information at the request of the Department of Biotechnology which will ensure confidentiality. The information required for commercializing Biotechnologies may be furnished to this Dept. as per the format enclosed at Annexure – VII. More information on commercialization can be found at the website www.ebc.nic.in.

17. The Institute may not entrust the implementation of the work for which the grant is being sanctioned to another institution and to divert the grant receipts as assistance to the latter institution. However, in such situations the express permission of DBT may be obtained. In case the grantee is not in a position to execute or complete the project, it may be required to refund forthwith to the Govt. of India (Department of Biotechnology) the entire amount of grant received by it.

02-08-09

Dr. D. Mondal
Joint Registrar
The University of Burdwan
Rajbati, Burdwan-713104, W.B.

18. The human resources that may be engaged for the project by the Institute are not to be treated as employees of the Govt. of India and the deployment of such human resource at the time of completion or termination of project, will not be the concern/responsibility of the Govt. of India. The Organization may make reservations for Scheduled Castes, Schedule Tribes etc. in the human resource to be engaged for the project in accordance with the instruction issued by the Govt. of India from time to time.

27/8/09

Dr. Anupam Basu
PROFESSOR
Department of Zoology
The University of Burdwan

19. The Dept. of Biotechnology reserves the right to terminate the grant at any stage and also to recover the amounts already paid if it is convinced that the grant has not been properly utilized or the work on the project has been suspended for any unduly long period or appropriate progress is not being made.

20. The project will become operative with effect from the date of release of the first installment for the project.

21. If the Investigator to whom a grant for a project has been sanctioned leaves the institution where the project is being implemented, he shall submit five copies of complete and detailed report of the work done by him on the project and the money spent till the date of his/her release and shall also arrange to refund the unspent balance, if any.

22. The organization should maintain subsidiary accounts of the Govt. of India grant and furnish it to the Audit Officer as and when the recurring and non-recurring expenditure exceeds the limits of Rs. 5.00 lakhs.

Signature of Project Coordinator
(Applicable only for multi-Institutional projects)

Dr. Anupam Basu
PROFESSOR
Department of Zoology
The University of Burdwan

Date: 27/6/19

02.08.19

Signature of Registrar
of Univer[illegible]

Joint Registrar
The University of Burdwan
[illegible]-713104, W.B.

Date:

Signature and stamped of Principal Investigator
The University of Burdwan
Date: 27/06/19

Dr. Anupam Basu
PROFESSOR
Department of Zoology
The University of Burdwan

UNIVERSITY OF BURDWAN
RAJBATI
BURDWAN
713104
WEST BENGAL

SL. NO. 35

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Department of Geodesy and Geoinformation
A.o. Univ.-Prof. DI Dr. Guenther Retscher

Research Division Engineering Geodesy
Wiedner Hauptstrasse 8-10/E120-05
1040 Wien, AUSTRIA
Tel.: +43/1/58801-12847
https://www.geo.tuwien.ac.at/

To:
Whom It May Concern

Vienna, 19 August 2021

LETTER OF INTEREST

Dear Sir / Madam,

I am very pleased to invite Dr. Anindya Bose to collaborate and bring his expertise as advisor in the course of the Erasmus+ Capacity Building in Higher Education project entitled 'Curricula Enrichment delivered through the Application of Location-based Services to Intelligent Transport Systems / LBS2ITS'. The LBS2ITS project has a duration of 3 years and started on January 15, 2021. Participating Universities are the EU programme countries' Universities Technische Universitaet Dresden (TU Dresden), Germany, and National Technical University of Athens (NTUA), Greece, under the lead of Technische Universtaet Wien (TU Wien), Austria. The partner country in this project is Sri Lanka with the four Sri Lankan partner Universities Sabaragamuwa University of Sri Lanka (SUSL), University of Moratuwa (UOM), University of Sri Jayewardenepura (USJ) and General Sir John Kotelawala Defence University (KDU).

Location-based Services (LBS) are an important application in Positioning, Navigation and Timing (PNT) and especially for Intelligent Transport Systems (ITS). Global Navigation Satellite Systems (GNSS) play thereby a crucial role and for the LBS users in the Indian sub-continental region the Indian Regional Satellite Constellation NavIC and the Satellite Based Augmentation System (SBAS) GAGAN provide great opportunities for research and education. Due to the great expertise of Dr. Bose in the PNT field, the collaboration and exchange of research ideas can benefit all involved institutions. A train-the-teachers course on PNT technologies is held in early May 2022 in Sri Lanka at SUSL. We would like to invite Dr. Bose to contribute and participate in this course. Another starting point of our collaboration would be that Dr. Bose joins as a member of a supervisory panel for a master students from SUSL.

We are confident that the collaboration with the Dr. Bose and Burdwan University will be of mutual benefit for all involved partners. Further acquisition of funding for joint research projects forms an integral part of our intended collaboration and will be sought-after.

Yours sincerely,

Guenther Retscher
TU Wien - Vienna University of Technology
https://lbs2its.net/

SL. NO. 36

Hon'ble M.13

Dr. Arijit Chatterjee
Joint Director – Lifelong Learning
&
In Charge – Research Section

The University of Burdwan
Rajbati, Burdwan- 713104, W.B
M-9434740604
E-mail : jtdirector_lll@buruniv.ac.in

No.R-Ph.D./Regn. /Sc/Env.Sc/58

Dated: 26.06.2023

Under UGC's New Regulation - 2016

To:

Ms. Tanumita Pan
C/O- Prof. Srimanta Gupta,
Dept. of Environmental Science, B.U.

Sub: Grant of Registration as a candidate for Ph.D. degree in Environmental Science with effect from 09.09.2021

Sir/Madam,

I am to inform you that the Faculty Council for P.G. Studies in Arts/ Science at its meeting held on **06.06.2023** permitted you to get yourself registered as a candidate for Ph.D. degree, mentioned above, the title of your thesis being , " **MEDICAL GEOLOGICAL APPRAISAL OF FLUORIDE CONTAMINATION IN GROUNDWATER OF SOUTH DINAJPUR DISTRICT, WEST BENGAL WITH THE DEVELOPMENT OF A MAGNETIC NANO-MATERIAL BASED DEFLUORIDATION TECHNIQUE**" Subject to fulfillment of the requirements set forth in the University Ordinances relating to Doctoral Degrees and such terms and conditions as may be laid down by the appropriate authorities of the University from time to time.

You will now be required to deposit the Ph.D. Registration fee of **Rs. 8,000/- (Eight thousand only)** for enrolment of your name in the Register of candidates for Ph.D. degree, **positively within a month from the date of issue of this letter**, failing which your case will not be considered for Registration as a Ph.D. candidate and **the relevant copy of the cash receipt should be submitted to the Ph.D Unit.**

In this connection you are requested to note that ---

a) You have been permitted to do research work under **Prof. Srimanta Gupta, Dept. of Environmental Science, B.U. & Prof.Rama Ranjan Bhattacharjee, Dept. of Chemistry, Sister Nivedita University,Kolkata (Co-supervisor)** as your Supervisor / Co- Supervisors.

b) You will be **required to get yourself registered as a student of this University** on migration after completing all the necessary formalities prescribed in this behalf, unless you are already a registered student of this University.

c) You will be **required to deliver one seminar talk before submission of the thesis** pertaining to the project of your research you have undertaken within the period of your research work and before submission of the thesis.

d) i) You will have to **published at least one research paper related to your research work** in a referred journal / peer reviewed journal and ii) Make two presentation in Conference/Seminar before submission of the thesis and produce evidence for the same in the form of acceptance letter / reprint /certificate of presentation as applicable at the time of submission of your thesis.

e) You will have to **submit your thesis within six years from the date of your registration** for Ph.D. degree mentioned above, but **not earlier than 09.09.2024 (three years including course work)** in the prescribed manner along with the fee of **Rs. 8,000/- (Eight thousand only)** or as may be fixed by the Executive Council from time to time towards submission of thesis.

f) i) You will be required to appear before **Research Advisory Committee** once in six months to make a presentation of the progress of his/her work for evaluation and further guidance. This six-monthly report shall be submitted by the Research Advisory Committee to the Board of Research Studies with a copy to the research scholar.

ii) In case the progress of the research scholar is unsatisfactory, the Research Advisory Committee shall record the reasons for the same and suggest corrective measures. If the research scholar fails to implement these corrective measures, the Research Advisory Committee may recommend to the Faculty Council for PG Studies concerned through the Board of Research Studies with specific reasons for cancellation of the registration of the research scholar.

g) The women candidate & persons with disability (More than 40%)may be allowed a relaxation of two years for Ph.D Programme in the maximum duration. The women candidates may avail **Maternity Leave/Child care Leave once in the entire duration of Ph.D Programme upto 240 days** with the permission of the Chairman, Doctoral Committee.

h) In your case , ***four/five copies*** of the thesis along with a C.***D. in PDF format*** (containing the Synopsis and the Thesis) be submitted and one copy be retained by you as a reference copy.

i) At the time of submission of thesis, a certificate in the prescribed form furnished by your Supervisor(s) will have to be pasted on all the copies of the thesis.

j) **The registration granted under this letter will remain valid for six years from the date of registration**. In the event of failure of submission of the thesis within the stipulated period, re-registration may be sought for and the same may be granted after observing all the formalities required in this behalf and on the receipt of the prescribed fee(s).Application for **re-registration may be sought within the stipulated period i.e.within six years.**

k) The registration granted herein may be cancelled by the concerned authority/ body of the University in the event of failure of the candidate to fulfill any of the prescribed requirements at any stage.

l) Residential requirements should be fulfilled and maintained .

m) While submitting for evaluation, the thesis shall contain an undertaking from the research scholar and a certificate from the research Supervisor(s) attesting to the **Originality of the work, vouching that there is no Plagiarism and that the work has not been submitted for the award of any other degree/diploma of the University or to any other institution.**

n) You will be required to submit six typed copies of Synopsis/Abstract of the thesis (not exceeding ten pages) along with the certificate mentioned in Clause(l) above and a certificate of delivering Seminar talk(s) and the Clearance Certificate from the Librarian of the Central Library, Burdwan University at the time of submission of thesis.

Yours faithfully,

Bhattacharjee

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Research Section

No. R/Ph.D./Regn./ Sc/Env.Sc/581(4) Dated: 26.06.2023

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3) The Secretary, Faculty Council for P.G. Studies in Science B.U.

4) The Finance Officer, B.U.

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Research Paper

Mn-doped $NiWO_4$ quantum dots with superior electrochemical and conductivity performance for energy storage application

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ABSTRACT

Monoclinic amorphous $Ni_{1-x}Mn_xWO_4$ (x = 0.00, 0.02) compounds have been successfully synthesized by hydrothermal technique for achieving better capacitive and conductive performances. Different characterization techniques like X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), ultraviolet-visible (UV–Vis) and photoluminescence (PL) spectroscopy have been employed to investigate their structural, microstructural, and optical properties. Mn-ion incorporation in the $NiWO_4$ lattice reduces the particle size of the sample to ~4.5 nm, compared to the pure undoped $NiWO_4$ sample (~18 nm), confirmed from the transmission electron microscopy image and Brunauer–Emmett–Teller analyses (BET). Tauc plot of $Ni_{0.98}Mn_{0.02}WO_4$ sample exhibits a significant increase in bandgap energy, compared to pure undoped $NiWO_4$ sample due to the quantum confinement effect. The electrochemical performance of electrodes made with these materials has been revealed by cyclic voltammetry (CV), galvanostatic charge-discharge (GCD) properties and electrochemical impedance spectroscopy (EIS). Moreover, the addition of 2 % Mn in $NiWO_4$ causes an increase in specific surface area (117.390 m^2/g) due to the reduced particle size of the material, resulting in excellent specific capacitance of 463 $F\,g^{-1}$ at 0.5 $A\,g^{-1}$ current density. The detailed charge storage mechanism for the improvement of conductivity and electrochemical performance of the Mn-doped $NiWO_4$ has been revealed in different studies. An asymmetric supercapacitor device (ASC) has been fabricated using Mn-doped $NiWO_4$ electrode material as positive electrode. The device shows superior cyclic stability upto 5000 cycles, can retain 88.4 % of its initial value.

1. Introduction

Electrochemical storage devices such as supercapacitors, fuel cells, and Li-ion batteries are more sustainable clean energies to deal with the global warming issues [1–3]. Among all three renewable energy sources, a supercapacitor is more promising than Li-ion batteries due to its fast charging, longer recyclability, better power density, and easy maintenance. Supercapacitors are classified into two categories, (i) electric double-layer capacitors (EDLC) and (ii) pseudocapacitors [2–5]. Researchers are continuously trying to improve the energy density of [6,7]. However, some drawbacks of using metal oxides in electrochemical applications include poor conductivity, low energy density, and poor cycle stability [8,9]. It has been revealed from recent works that the electrochemical properties of some complex oxides (such as $NiCo_2O_4$ and $MnCo_2O_4$) are superior to single oxides like NiO, MnO_2, and Co_3O_4 because of multiple oxidation states of different metal cations [10–12]. The $NiWO_4$ compound is an attractive material in the electrochemical field because of its high electrical conductivity of $\sim 10^{-7}$–10^{-3} $S\,cm^{-1}$ [13–15], which is higher than NiO (10^{-13} $S\,cm^{-1}$), and $CoWO_4$ compounds [16]. It was reported that the incorporated W

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Advanced asymmetric supercapacitor with $NiCo_2O_4$ nanoparticles and nanowires electrodes: A comparative morphological hierarchy

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ABSTRACT

In the present work, hydrothermal and wet chemical methods are adopted to fabricate $NiCo_2O_4$ nanowires (NiCo-NW) and $NiCo_2O_4$ nanoparticles (NiCo-NP) respectively. Owing to the mesoporous nature of these subunits, fast and convenient electron-ion transport and redox reaction, NiCo-NW achieves excellent electrochemical performance. Structure and microstructural characterizations of these samples are carried out by analyzing X-ray diffraction data employing the Rietveld method of structure refinement method and analyzing HRTEM, FESEM images and FTIR spectra. The low dimensional NiCo-NP is found to provide superior electrochemical performance than the NiCo-NW (~13 nm) due to its smaller particle size (~9 nm). This porous structure effectively helps in better transport of ions in the electrolyte. It manifests high specific capacitance 1066.03 F g^{-1} and enormous areal capacitance up to 5.96 F cm^{-2} whereas NiCo-NW exhibits specific capacitance up to 880.72 F g^{-1} and high areal capacitance of 4.93 F cm^{-2}. An asymmetric supercapacitor (ASC) has been fabricated with NiCo-NP and activated carbon as positive and negative electrodes respectively in 1 M Na_2SO_4 electrolyte medium. This device offers maximum specific energy 59.56 Wh Kg^{-1} and maximum power density 3403 W kg^{-1} with a high energy density of 4.197 Wh Kg^{-1} and shows excellent cyclic stability.

1. Introduction

In recent years, enormous attention has been drawn to develop novel materials and devices for the new renewable and sustainable energy sources with high efficiency, high reliability and high energy density. The supercapacitor has been used massively in last few decades as a green energy storage device combining the features of the conventional capacitor (high power density, long cycling life) and rechargeable batteries (high energy density) [1–8]. Based on the charge storage mechanism supercapacitors are of two types: (i) electric double-layer capacitor(EDLC), and (ii) pseudocapacitors. For EDLCs electric energy is stored by separation of charge in Helmholtz double-layer and for pseudocapacitor storage of electric energy is achieved by a faradaic redox reaction with charge transfer [8–10]. Various carbonaceous materials like activated carbon, CNT, graphene are being used as electrode materials for EDLCs for their higher surface area with a porous surface and electrically intercalated networks. EDLCs show high power density, better cycle life than pseudocapacitor but possess very low specific capacitance. However, due to fast multi electro-redox reaction, pseudocapacitors possess higher specific capacitance, higher energy density than observed in EDLCs [11,12], but it leads to deficient cycle stability because of redox reaction like a battery.

The primary focus of the present work is to improve cell voltage and energy density by developing an ASC device in which (EDLC) electrode has been used as the negative electrode and redox-active transition metal oxides as a positive electrode. The maximum operating voltage in the cell system can be reached by using different potential windows of the two-electrode system. Primarily, activated carbon has been used as the negative electrode and transition metal oxides as a positive electrode. So, the main focus of ASC is to develop better metal oxides for advanced positive electrode [3,13].

Various metal oxides and hydroxides with their variable valence states had been widely used for electrode materials in pseudocapacitors [14,15]. Attempts had been made to prepare inexpensive metal oxides like Co_3O_4 [16,17], NiO [10,18], MnO_2 [19], V_2O_5 [20], Fe_2O_3 [21] for high theoretical capacitance and low toxicity. Both Ni and Co-based materials were considered to be the most admirable

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Enhanced electrochemical properties of Co_3O_4 with morphological hierarchy for energy storage application: A comparative study with different electrolytes

sl.no. 38

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ABSTRACT

A facile hydrothermal route synthesizes Co_3O_4 nanocrystals with urchin spine-like morphology. Structure and microstructural characterizations of the sample are carried out. Electrochemical properties have been explored in the presence of different electrolytes. In order to find out the best electrolyte, three electrolytes (Na_2SO_4, NaOH and Na_2SO_4 with Hq) of fixed concentration (1 M) are used to record the cyclic voltammetry data. In the presence of Na_2SO_4 as an electrolyte, specific capacitance becomes 218 F g^{-1}, possibly because of low ionic conductivity of SO_4^{2-}, higher charge transfer resistance. When NaOH and Na_2SO_4 (with Hq) are used as electrolytes, high specific capacitances of 1720 F g^{-1} and 2433 F g^{-1} respectively are obtained due to extra pseudocapacitive effect of redox reaction. It is worth noting that the semicircle diameter in the EIS plot is highest for Na_2SO_4 and lowest for Na_2SO_4 (with Hq) electrolyte. The R_{ct} value depends on the type of electrode and the interaction between electrolyte ions with the electrode.

1. Introduction

Nowadays, one of the primary focuses of the scientific community is to harvest new sustainable energy materials to cope up with the continuous changes in the global climate. The demand for energy, however, is increasing day by day. It becomes very urgent for a scientist to develop new renewable energy sources with high power and better efficiency. It is now well known that supercapacitors have emerged as an alternative energy storage device with better efficiency than a rechargeable battery [1,2]. Supercapacitors exhibit higher energy efficiency, excellent reversibility, higher energy density than a conventional capacitor. Generally, supercapacitors can be classified into three types based on the charge storage mechanism: (i) electrical double-layer capacitor (EDLC), (ii) pseudocapacitors, and (iii) hybrid system. The energy storage mechanism in the electrochemical capacitor is of two types: faradaic and non-faradaic. The non-faradaic reaction arises in the EDLC due to ion adsorption at the electrode/electrolyte [3]. Various carbonaceous materials such as activated carbon, carbon nanotube (CNT), graphene oxide belong to the EDLCs. Such carbonaceous materials possess a large surface area with a porous surface with the interlaced network [4]. However, EDLCs cannot fulfill the requirement for the peak power assistance in the vehicle since EDLC offers low energy density. Instead, the faradaic pseudocapacitors are based on the fast reversible redox reaction within electroactive materials on the electrode, and its energy density is at least one order of magnitude higher than EDLCs [3,4].

In contrast, various inexpensive transition metal oxides such as Co_3O_4 [1,5–8], NiO [4,9], MnO_2 [10], and Fe_3O_4 [11], $NiCo_2O_4$ [12] are mainly used as electrode materials for pseudocapacitors. They provide enhanced electrochemical performance over EDLCs because of their higher specific capacitance generating from rapid and productive redox reaction. Finding cheap material with superior pseudocapacitive performance has thus attracted enormous attention. Among all these transition metal oxides, Co_3O_4 has been studied extensively for its supercapacitor application due to its high surface area, easily tunable surface area, multiple oxidation states and tunable structural properties. The Co_3O_4 is a p-type direct optical bandgap semiconductor that shows the high theoretical capacity, excellent corrosion stability and can act as

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Superior photocatalytic performance and photo disinfection of bacteria of solvothermally synthesized mesoporous La-doped CeO_2 under simulated visible light irradiation for wastewater treatment

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ABSTRACT

A simple, cost-effective, and facile solvothermal approach has been adopted to synthesize mesoporous CeO_2 nanostructures with varying La-doping (2, 4, and 6 mol%) concentrations. Photocatalytic and antibacterial performances are investigated against the inactivation of *Escherichia coli* and *Bacillus licheniformis* bacteria cells. Structural and microstructural characterizations of La-doped CeO_2 nanostructures are performed by analyzing X-ray diffraction (XRD) data employing the Rietveld refinement method, scanning electron (SEM) and transmission electron microscopy (TEM) images, Brunauer–Emmett–Teller (BET), energy-dispersive X-ray (EDX), and X-ray photoelectron spectroscopy (XPS) spectra. Among three doped samples, the 4 mol% La-doped CeO_2 (LCe4) has exhibited high oxygen and Ce^{3+} concentrations, high microstrain, small crystallite size, and lowest band gap energy, as are revealed by the analysis of XPS, UV–VIS absorption spectra,

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Ultrastable Asymmetric Supercapacitor Device with Chemically Derived and Mechanically Activated $NiCo_2O_4$

Mahasweta Chatterjee, Adwaita Kundu, Sachindranath Das, and Swapan Kumar Pradhan*

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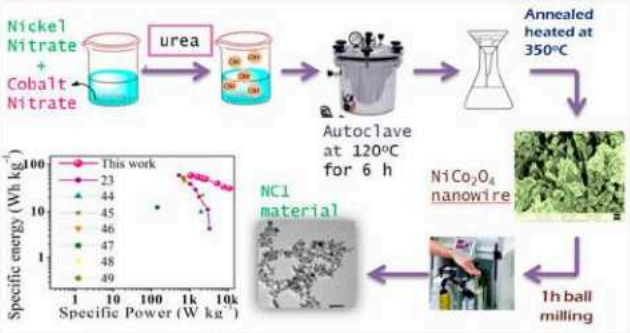
ABSTRACT: We report the effect of mechanical alloying on the chemically synthesized $NiCo_2O_4$ nanowire for better electrochemical performance. The nickel cobaltite nanowires (NC) were successfully synthesized via the hydrothermal method without any surfactant. Then they were milled for 1 h (NC1) and 2 h (NC2) to boost the electrochemical performance. The structural and microstructural parameters, shape, size, and morphology of these samples are revealed by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and transmission electron microscopy (TEM) techniques. The Brunauer–Emmett–Teller (BET) characterization and Barrett–Joyner–Halenda (BJH) model reveal that the NC1 sample offers the highest specific surface area among all three samples with its one-dimensional mesoporous structure (pore diameter, ~7 nm). The NC1 sample displays an excellent specific capacitance and rate capability (1234 F g^{-1} at a scan rate of 2 mV s^{-1}). However, upon further milling (2 h) the electrochemical performance of the sample decays rapidly due to an increase in particle size and reduction in specific surface area. A remarkable specific capacity of 1196 F g^{-1} is achieved in the 1 h milled sample at the lowest current density of 12 A g^{-1}, and at 40 A g^{-1} and 129.2 F g^{-1} specific capacitance can be retained. We further demonstrate an asymmetric device based on the NC1 sample as a positive electrode, which produces an excellent energy density of 59.221 Wh kg^{-1} at a power density of 1065.4 W kg^{-1}. The assembled device can attain an outstanding power density of 10.992 kW kg^{-1} at an enormous high current density of 13.33 A g^{-1} and demonstrates an excellent cyclic performance of 91.7% retention after 5000 cycles.



INTRODUCTION

Due to the rapid growth of portable energy storage systems, mobile systems, and other electronic gadgets, the main interest of scientists in these fields is to develop advanced new generation high energy and power density devices.[1−3] Various transparent energy storage systems are used in commercial and industrial areas. A supercapacitor can be recognized as an efficient, clean energy storage candidate due to its excellent cycle life, high power density, and better cycle stability. Typically, the charge storage mechanism of a supercapacitor is of two types: one is the capacitive type and the other is the pseudocapacitive type. Generally, the charge storage process of the capacitive type is an electric double-layer capacitor that relies on electrostatic charge storage separation of ions at the electron electrolyte interface.[4,5]

In contrast, in a pseudocapacitor, capacitance is produced by a fast multielectron faradaic surface redox reaction. The capacitance performance is much better than the electric double-layer capacitor (EDLC), especially in energy density. Several transition metal oxides (NiO, $NiCo_2O_4$, $CoFe_2O_4$, MnO_2, and Co_3O_4) and sulfides are vastly used and studied as positive electrodes for their different pseudocapacitive nature.[6−10] The binary oxides manifest extraordinary electrochemical performance than a single metal oxide because of their redox reaction between valence states, large electrode–electrolyte contact surfaces, and many defects, which improves pseudocapacitance as well as the energy density of the material.[11−13] The crucial parameters which regulate the electrochemical performance are the porosity, particle size, specific surface area, oxygen vacancy, and surface defects. Scientists these days try to incorporate an optimized amount of oxygen vacancy and surface defects to balance the electrochemical performance of the material in a well-mannered way.[14−16] Since metal oxide with a higher oxygen vacancy ensures a higher CV current and higher positive potential, forming an oxygen vacancy becomes one of the main choices for getting higher electrochemical performance by an easy and economical technique. In metal oxides or ceramics with

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Superior photocatalytic performance and photo disinfection of bacteria of solvothermally synthesized mesoporous La-doped CeO_2 under simulated visible light irradiation for wastewater treatment

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ABSTRACT

A simple, cost-effective, and facile solvothermal approach has been adopted to synthesize mesoporous CeO_2 nanostructures with varying La-doping (2, 4, and 6 mol%) concentrations. Photocatalytic and antibacterial performances are investigated against the inactivation of *Escherichia coli* and *Bacillus licheniformis* bacteria cells. Structural and microstructural characterizations of La-doped CeO_2 nanostructures are performed by analyzing X-ray diffraction (XRD) data employing the Rietveld refinement method, scanning electron (SEM) and transmission electron microscopy (TEM) images, Brunauer–Emmett–Teller (BET), energy-dispersive X-ray (EDX), and X-ray photoelectron spectroscopy (XPS) spectra. Among three doped samples, the 4 mol% La-doped CeO_2 (LCe4) has exhibited high oxygen and Ce^{3+} concentrations, high microstrain, small crystallite size, and lowest band gap energy, as are revealed by the analysis of XPS, UV–VIS absorption spectra, photoluminescence (PL) spectra, and Rietveld refinement result. The LCe4 sample with the highest number of oxygen vacancies and high surface area shows superior photocatalytic activity (~95% Rhodamin B (RhB) degradation in 130 min, ~70% Methylene Blue (MB) degradation within 30 min, and ~95% phenol degradation in 180 min under solar radiation). It shows a striking photo-disinfection effect and enhanced antibacterial activity (almost identical to a pure drug) against gram-positive and gram-negative bacteria under visible light irradiation. This novel disinfection and catalytic property of the LCe4 sample is attributed to the mesoporous structure of materials and surface activity, which lowers the electron-hole recombination rate and transports more photogenerated electrons and holes. The nanostructured mesoporous LCe4 material has been used as an effective visible light-activated photocatalyst and photo disinfection for treating wastewater containing organic dyes and gram-negative and gram-positive bacteria.

1. Introduction

Water pollution from mixing hazardous materials and heavy metals has become a serious global issue. Because of water pollution, various water-born diseases become vulnerable to humanity in most developing countries due to the lack of adequate purifier systems like UV radiation and chlorofication, particularly in rural areas. Thus, the availability of purified drinking water becomes a critical issue for the increasing population. Photocatalytic degradation of pollutants is a facile green chemical, sustainable and cost-effective method to remove contaminants from wastewater containing organic dyes [1–3].

CeO_2 is considered one of the most abundant rare earth oxides frequently used in electrochemical cells, energy storage and optical devices, photocatalysis, and as a biomaterial. CeO_2 is an n-type semiconductor material with various chemical and physical properties, like pollutant elimination with non-toxicity [5–7]. The main feature of CeO_2 is the transformation of the Ce^{4+} to Ce^{3+} valence state, which causes oxygen vacancies and a high stoichiometry deviation, consequentially increasing visible light absorbance [4–8]. Various reports on CeO_2 as a photocatalyst with different morphologies, like nanocube, nanowire, and nanodisc, using different templates are available. The present study intends to develop CeO_2 nanomaterials with an optimum mesoporous structure and

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Research Paper

Mn-doped $NiWO_4$ quantum dots with superior electrochemical and conductivity performance for energy storage application

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ABSTRACT

Monoclinic amorphous $Ni_{1-x}Mn_xWO_4$ (x = 0.00, 0.02) compounds have been successfully synthesized by hydrothermal technique for achieving better capacitive and conductive performances. Different characterization techniques like X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), ultraviolet-visible (UV–Vis) and photoluminescence (PL) spectroscopy have been employed to investigate their structural, microstructural, and optical properties. Mn-ion incorporation in the $NiWO_4$ lattice reduces the particle size of the sample to ~4.5 nm, compared to the pure undoped $NiWO_4$ sample (~18 nm), confirmed from the transmission electron microscopy image and Brunauer–Emmett–Teller analyses (BET). Tauc plot of $Ni_{0.98}Mn_{0.02}WO_4$ sample exhibits a significant increase in bandgap energy, compared to pure undoped $NiWO_4$ sample due to the quantum confinement effect. The electrochemical performance of electrodes made with these materials has been revealed by cyclic voltammetry (CV), galvanostatic charge-discharge (GCD) properties and electrochemical impedance spectroscopy (EIS). Moreover, the addition of 2 % Mn in $NiWO_4$ causes an increase in specific surface area (117.390 m^2/g) due to the reduced particle size of the material, resulting in excellent specific capacitance of 463 F g^{-1} at 0.5 A g^{-1} current density. The detailed charge storage mechanism for the improvement of conductivity and electrochemical performance of the Mn-doped $NiWO_4$ has been revealed in different studies. An asymmetric supercapacitor device (ASC) has been fabricated using Mn-doped $NiWO_4$ electrode material as positive electrode. The device shows superior cyclic stability upto 5000 cycles, can retain 88.4 % of its initial value.

1. Introduction

Electrochemical storage devices such as supercapacitors, fuel cells, and Li-ion batteries are more sustainable clean energies to deal with the global warming issues [1–3]. Among all three renewable energy sources, a supercapacitor is more promising than Li-ion batteries due to its fast charging, longer recyclability, better power density, and easy maintenance. Supercapacitors are classified into two categories, (i) electric double-layer capacitors (EDLC) and (ii) pseudocapacitors [2–5]. Researchers are continuously trying to improve the energy density of supercapacitors without hampering their power density and cycle life. Pseudocapacitor materials store more energy than an electric double-layer capacitor.

For this reason, various binary and ternary metal hybrid oxides with different morphologies were synthesized for supercapacitor applications [6,7]. However, some drawbacks of using metal oxides in electrochemical applications include poor conductivity, low energy density, and poor cycle stability [8,9]. It has been revealed from recent works that the electrochemical properties of some complex oxides (such as $NiCo_2O_4$ and $MnCo_2O_4$) are superior to single oxides like NiO, MnO_2, and Co_3O_4 because of multiple oxidation states of different metal cations [10–12]. The $NiWO_4$ compound is an attractive material in the electrochemical field because of its high electrical conductivity of $\sim 10^{-7}$–10^{-3} S cm^{-1} [13–15], which is higher than NiO (10^{-13} S cm^{-1}), and $CoWO_4$ compounds [16]. It was reported that the incorporated W atoms had improved the electrical conductivity and electrochemical activity of the compound [17]. Recent reports on core-shell heterostructures with multi-component, such as $MnCo_2O_4/NiWO_4$, Ni.Co.Zn oxide/$NiWO_4$, and $NiWO_4/NiCO_2O_4$ grown on nickel foam showed enormous high electrochemical performance than the $NiWO_4$ lattice

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Synthesis and characterization of a novel nanocarrier for biocompatible targeting of an antibacterial therapeutic agent with enhanced activity

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ABSTRACT

This study reveals a new strategy to enhance the activity of an antibacterial drug by conjugating it with a Cu–Ag-based nanocarrier. The Cu–Ag–Co_3O_4–TiO_2 nanocomposite is successfully synthesized by mechanical alloying and applied for biocompatible targeting of an antibacterial drug by conjugating the drug (10 wt%) with the nanocarrier. The samples have been well-characterized by the Rietveld refinement of the XRD pattern and by analyzing TEM, FESEM images, and FTIR spectra. The successful formation of the drug conjugated nanocomposite sample has also been verified from the EDS and UV–Vis absorption spectra. Both the samples are non-toxic to the normal human cells which have been confirmed by cell viability assay on human normal lung fibroblast WI38 cells. Antibacterial activities of both the samples against the bacteria *E. coli* have been investigated by the agar cup diffusion method and minimum inhibitory concentration (MIC) study. The 10 wt% amoxicillin conjugated nanocomposite shows the same effect as the pure (100 wt %) drug. The enhanced activity of the drug conjugated nanocomposite is due to the more significant interaction of the drug conjugated nanocomposite with the cell wall and membrane of the bacteria as compared to the pure drug. It is confirmed by measuring the change of conductivity and total protein leakage in the culture filtrate of the nanocomposite, pure drug, and drug conjugated nanocomposite treated culture of *Bacillus subtilis*. This strategic protocol is found to have great importance for enhancing the efficacy of a standard antibiotic drug.

1. Introduction

In recent days, the world faces a growing antimicrobial resistance problem, as some pathogens have become resistant to a comprehensive class of antibiotics [1,2]. The overuse of antibiotic drugs is the most significant driver of this antimicrobial resistance [3]. The bacterial resistance against these β-lactam antibiotics is due to the production of β-lactamases primarily produced by gram-negative bacteria. It breaks the β-lactam ring of the antibiotic and provides antibiotic resistance [4]. This kind of resistance can be overcome by conjugating the antibiotic with nanostructured composite materials [5]. These nanoparticles are reported to possess antibacterial activities and can be used in targeted drug delivery. The potency of a large number of antibiotics is limited due to low membrane transport. The drug conjugated nanoparticle/nanocomposite (ND) can enter the cell by endocytosis, thus facilitating intracellular entry [6]. The interactions with the surface lipids help to achieve membrane penetration. Thus they provide physical protection against the various mechanism of bacterial resistance [7].

Nanoparticles inhibit bacterial growth by multiple mechanisms, which are as follows: (a) they interact with the bacterial cell wall, (b) damage the bacterial cell membrane by ROS generation, (c) the biofilm formation can be inhibited due to the effect of nanoparticles [8,9]. The main advantage of nanoparticles is their small size and the large surface-to-volume ratio [10]. They can protect antimicrobial compounds against enzymes that can break the structure of the drugs. Thus they can deliver the antibiotics actively to the desired site.

Amoxicillin is a β-lactam antibiotic. It inhibits the cell wall synthesis of bacteria. The transpeptidation process can be inhibited due to the

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Phase crossover induced by dynamical many-body localization in periodically driven long-range spin systems

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Dynamical many-body freezing occurs in periodic transverse field-driven integrable quantum spin systems. Under freezing conditions, quantum dynamics causes practically infinite hysteresis in the drive response, maintaining its starting value. We find similar resonant freezing in the Lipkin-Meshkov-Glick (LMG) model. In the LMG, the freezing conditions in the driving field suppresses the heating postulated by the *eigenstate thermalization hypothesis* (ETH) by inducing *dynamical many-body localization*, or DMBL. This is in contrast to many-body localization (MBL), which requires disorder to suppress ETH. DMBL has been validated by the inverse participation ratio (IPR) of the quasistationary Floquet modes. Similarly to the TFIM, the LMG exhibits high-frequency localization only at freezing points. IPR localization in the LMG deteriorates with an inverse system size law at lower frequencies, which indicates heating to infinite temperature. Furthermore, adiabatically increasing frequency and amplitude from low values raises the Floquet state IPR in the LMG from nearly zero to unity, indicating a phase crossover. This occurrence enables a future technique to construct an MBL engine in clean systems that can be cycled by adjusting drive parameters only.

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I. INTRODUCTION

In the past few years, periodically driven quantum many-body systems have been of considerable theoretical and experimental interest [1,2]. Under certain conditions in the drive parameters, they can experience dynamical many-body freezing (DMF), which causes the response to freeze completely to its initial value at all times [3–5]. This arises as a consequence of additional approximate symmetries that occur at the freezing points [6]. DMF has been demonstrated via the rotating wave approximation (RWA) in the driven transverse field Ising model (TFIM) with nearest-neighbor interactions [7] and is shown to be protected when translational invariance is explicitly broken (say, by disorder) [8,9].

The utilization of Floquet theory simplifies the analysis of time-periodic systems. For closed quantum systems governed by the time-dependent Schrödinger equation, the *Floquet Hamiltonian* allows for a mapping of the time-dependent dynamics into the dynamics of a time-independent effective Hamiltonian, provided the system is strobed at integer multiples of the time period of the drive. The time-independent eigenstates of the effective Hamiltonian correspond to quasistationary *Floquet Modes* of the original Hamiltonian. The temporal progression of the system comes from phase coefficients that capture the dynamics [10,11].

Any sufficiently complex nonintegrable many-body system is expected to thermalize according to the eigenstate thermalization hypothesis (ETH) despite the fact that closed quantum dynamics preserves the memory of the initial state of the system. This arises due to the properties of the matrix elements of observables in typical states [12]. The ETH can be readily adapted to time-periodic systems using Floquet theory (the Floquet-ETH, or FETH [13–16]). Nonetheless, the conditions for ETH to hold are not particularly strong, and the density matrix of the system can fail to approach one that is described by a thermal expression. Thermal systems must conduct because they exchange energy and particles internally during thermalization. Thus, insulating systems can be naturally athermal; many-body localization (MBL) is a well-studied case [17]. This phenomenon is stable against local perturbations, and constitutes an exotic state of matter with far-reaching implications in theoretical physics, as well as in practical applications [18].

The addition of disorder has been identified as a crucial component in the onset of MBL. In that case, thermalization is prevented by disorder-induced localization. Nonetheless, alternative approaches to MBL in strongly interacting disorder-free systems [19–21], inhomogeneous systems [22–25], and by inducing disorder in the emergent physics [26] and by other effective means [24] (albeit with strong finite-size effects), have been reported. An alternative approach to realizing MBL in disorder-free *homogeneous* many-body systems involve *Floquet engineering*, where a time-periodic drive is introduced, and the drive parameters tuned to introduce a clustering of quasistationary energies in a manner similar to localization [12].

In this article, we use the fact that emergent approximate symmetries can be engineered in Floquet systems [6,27] and apply it to long-range interactions. This results in *dynamical many-body localization* (DMBL) at specific values of the drive parameters, and complete thermal behavior at other values.

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PAPER

Time crystal embodies chimeralike state in periodically driven quantum spin system

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Abstract

Chimera states are a captivating occurrence in which a system composed of multiple interconnected elements exhibits a distinctive combination of synchronized and desynchronized behavior. The emergence of these states can be attributed to the complex interdependence between quantum entanglement and the delicate balance of interactions among system constituents. The emergence of discrete-time crystal (DTC) in typical many-body periodically driven systems occurs when there is a breaking of time translation symmetry. Coexisting coupled DTC and a ferromagnetic dynamically many-body localized (DMBL) phase at distinct regions have been investigated under the controlled spin rotational error of a disorder-free spin-1/2 chain for different types of spin-spin interactions. We contribute a novel approach for the emergence of the DTC-DMBL-chimeralike state, which is robust against external static fields in a periodically driven quantum many-body system.

1. Introduction

The phenomenon of a *chimera state* is observed in coupled systems of identical nonlinear oscillators, when spontaneous synchronized and desynchronized dynamics coexist simultaneously [1, 2]. Kuramoto *et al* first detected this phenomena in a network of non-locally coupled phase oscillators in 2002. Two domains of coherent oscillations with unique frequencies and incoherent oscillations with distributed frequencies were observed. [1]. These patterns were called 'chimera states' by Strogatz [3]. Chimeras have been widely explored in classical systems over the last decade [4–6]. The origin of the chimera lay in the symmetry-breaking bifurcation in the Kuramoto model, which led to a breakdown of global synchronization. This gave rise to a chimera state where spatially distinct regions exhibit different synchronization behaviors [7]. The coexistence of synchronized and desynchronized states in a chimera state can be considered a manifestation of spontaneous symmetry breaking in the context of nonlinear dynamics [8]. In the physical realm, chimera states serve as a possible explanation of unihemispheric slow wave sleep (UHSW) in migrating birds, seals and domestic chicks [9–11]. Chimeras have also been observed in models of electrical power grids, where a synchronous state can be stabilized by tuning the parameters of the generator [12, 13].

Eventually, chimera states were realized in the quantum regime as an ordered phase of matter [14]. However, it has been difficult to extend classical chimeras, which are heavily reliant on nonlinear dynamics, to purely quantum systems with linear unitary dynamics. As a result, quantum chimeras have had to be described in the semi-classical realm. Nonetheless, the possibility of chimeras in closed quantum systems remains, although one needs to take a different approach to create a quantum system where two different dynamics coexist. In fact, states in which two different dynamics coexist in the same quantum system have already been proposed and reported [15–17].

Interest in the formation of chimeras in magnetic systems has recently increased. Curie-Weiss-type models, such as the Ising model [18], are used to represent systems of interacting quantum spins where order

LINKAGE FOR ACADEMIC COLLABORATION

SL.NO-- 43

Linkage for Academic Collaboration

This Academic Linkage is made and entered into force this 2nd **February 2021**

Between

Dr. PRADIP KUMAR SENGUPTA,

Associate Professor
Department of Education
Ramakrishna Mission Sikshanamandira
Belur Math, Howrah- 711202, West Bengal (**First Party**)

And

Dr. RAJIBA LOCHAN MOHAPATRA
Assistant Professor
Department of Education
The University of Burdwan
Purba Bardhaman, 713104,West Bengal (**Second Party**)

1. INTRODUCTION

After detailed discussion, the first party and the second party chalked down the areas of cooperation in detail and agreed to provide research consultancy to the students / scholars in the field of Education. Both parties decided that an academic linkage will be of much help in this regard and agreed to establish an academic linkage.

Now both the parties agreed to establish the academic linkage with the following conditions

2. OBJECTIVES OF THE LINKAGE:

The Objectives of this Academic Linkage are as follows:

1. To provide academic support in research work in the field of education.

2. To held discussion, whenever necessary, for the purpose of setting and defining research problem.

3. To provide support in the task of literature review and to identify research gap for the research work.

4. To provide support in tool development and validation for research work.

5. To provide support in arranging data collection from academic institutions.

LINKAGE FOR ACADEMIC COLLABORATION

3. RESPONSIBILITIES OF DR. PRADIP KUMAR SENGUPTA

1. As and when necessary, Dr. Rajiba Lochan Mohapatra will communicate Dr. Pradip Kumar Sengupta for the necessary consultation (as per mentioned areas in the objectives). Dr. Pradip Kumar Sengupta will fix a schedule for the consultation as per convenience of both the parties. Both the parties will meet in the institution and necessary assistance will be given by Dr. Pradip Kumar Sengupta to Dr. Rajiba Lochan Mohapatra or his students/ scholars.
2. In case of review of research literatures, on the intimation regarding library work by Dr. Rajiba Lochan Mohapatra necessary arrangement will be made by Dr. Pradip Kumar Sengupta for the library work in his institution.
3. For tool validation, Dr. Rajiba Lochan Mohapatra will send the tool with a forwarding letter to Dr. Pradip Kumar Sengupta. On receiving the tool, Dr. Pradip Kumar Sengupta will validate the tool and return the validated tool having signed on it within 10-15 days to Dr. Rajiba Lochan Mohapatra.
4. For the purpose of data collection, Dr. Pradip Kumar Sengupta will provide support and arrange condition to collect data from his institution i.e. Ramakrishna Mission Sikshanamandira. He may also give necessary information and introduction to other places where from data can be collected.

4. RESPONSIBILITIES OF DR. RAJIBA LOCHAN MOHAPATRA

1. As and when necessary, Dr. Pradip Kumar Sengupta will communicate Dr. Rajiba Lochan Mohapatra for the necessary consultation (as per mentioned areas in the objectives). Dr. Rajiba Lochan Mohapatra will fix a schedule for the consultation as per convenience of both the parties. Both the parties will meet in the institution and necessary assistance will be given by Dr. Rajiba Lochan Mohapatra to Dr. Pradip Kumar Sengupta or his students/ scholars.
2. In case of review of research literatures, on the intimation regarding library work by Dr. Pradip Kumar Sengupta, necessary arrangement will be made by Dr. Rajiba Lochan Mohapatra for the library work in her institution.
3. For tool validation, Dr. Pradip Kumar Sengupta will send the tool with a forwarding letter to Dr. Rajiba Lochan Mohapatra. On receiving the tool, Dr. Rajiba Lochan Mohapatra will validate the tool and return the validated tool having signed on it within 10-15 days to Dr. Pradip Kumar Sengupta.
4. For the purpose of data collection, Dr. Rajiba Lochan Mohapatra will provide support and arrange condition to collect data from her institution. He may also give necessary information and introduction to other places where from data can be collected.

5. FINANCIAL ARRANGEMENTS

There is no financial obligation under this Linkage.

LINKAGE FOR ACADEMIC COLLABORATION

6. TERMINATION OF LINKAGE

This Linkage may be terminated by either Dr. Pradip Kumar Sengupta or Dr. Rajiba Lochan Mohapatra commits breach of any of the terms hereof and shall have failed to rectify such breach within thirty days of the notice.

In addition to the reasons for termination as set forth above, this Linkage may be terminated forthwith if either of them voluntarily or involuntarily enters into official dilution.

7. DURATION-

This Academic Linkage shall remain valid for a period of 5 years only from the date of signing the Linkage. After this 5 years' time period, this Linkage may be terminated or may be renewed after judging the then situation.

8. SETTLEMENT

Upon termination of the Linkage, all rights granted to and the obligations by Dr. Rajiba Lochan Mohapatra and Dr. Pradip Kumar Sengupta hereto, shall cease to exist forthwith.

9. AMENDMENTS TO THE LINKAGE

No amendment or modification of this Linkage shall be valid unless the same is made in writing by both Dr. Pradip Kumar Sengupta and Dr. Rajiba Lochan Mohapatra; to be an amendment of this Linkage. The modifications/ changes shall be effective, from the date on which they are made/executed; unless otherwise agreed to. In general, the Linkage will be amended on yearly basis, IF AT ALL REQUIRED, on mutually agreed terms.

10. SIGNATURE OF THE PARTIES

This Linkage has been executed in two originals, one of these has been retained by Dr. Pradip Kumar Sengupta and the other has been retained by Dr. Rajiba Lochan Mohapatra.

In witness whereof the parties hereto have signed this Linkage the day, month and year mentioned herein before.

Institute	Ramakrishna Mission Sikshanamandira	The University of Burdwan
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Department	Department Education	Department of Education
Party	First Party	Second Party

LINKAGE FOR ACADEMIC COLLABORATION

Name	Dr. Pradip Kumar Sengupta	Dr. Rajiba Lochan Mohapatra
Designation	Associate Professor	Assistant Professor
Signature with official seal & Date	Pradip Kumar Sengupta 02/02/21 Dr. Pradip Kumar SenGupta Associate Professor Ramakrishna Mission Sikshanamandira, Belur Math Howrah - 711202	Rajiba Lochan Mohapatra 02/02/21 Assistant Professor Department of Education Burdwan University Burdwan
Full Signatures of the witnesses	1. Satyajit KM 02/02/2021	1 Chitralekha Mehera. 02.02.2021
	2. Madan Mohan Mandal 02/02/21	2

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Enhanced optical power limiting and visible luminescence in colloidal dispersion of ultra-small Au nanoclusters synthesized by single-pot chemical technique

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ABSTRACT

Here, we present a detailed investigation on the synthesis and nonlinear multiphoton absorption properties of the colloidal solution of Au nanoclusters (AuNCs) which contains the atomic clusters, with the number of atoms per cluster (NAC) of only one (Au_1NC) and two (Au_2NC). These AuNCs are synthesized by an easy single step one-pot simple chemical process and by using dimethylformamide (DMF) both as reducer and stabilizer. The presence of both Au_1NC and Au_2NC are found in the sample by their distinct signature in the UV–Vis. absorption spectrum as well as in the high-resolution mass spectrum. The synthesized material has been found to exhibits a strong and stable blue-luminescence with a moderately high quantum yield (QY) of 12.4% when excited with UV light. The nonlinear optical two-photon absorption (2PA) properties of Au_1, Au_2NC solutions are being reported here by *Z*-scan studies, for the first time, by using both 10 *ns* and 100 *fs* pulse laser radiations having wavelength of 532 nm. It is significantly noted here that the synthesized AuNCs are found to exhibit reverse saturable absorption (RSA) when excited either by *ns* or by *fs* laser pulses. A high third-order nonlinear susceptibility ($\chi^{(3)}$) of the order of 10^{-13} (esu) of the synthesized materials are obtained under *fs* laser excitation and it is attributed to the 2PA through electronic band to band transition. In contrast, the variation of the 2PA coefficient (β) with input intensity (I_0) represents the footprint of free carrier involvement in the enhanced nonlinear absorption in the case of *ns* excitation. Furthermore, through the non-saturable nonlinear multiphoton absorption, the synthesized AuNCs exhibit excellent optical power limiting phenomenon with the limiting threshold (F_{th}) of 9.1 mJ/cm^2 (*fs* excitation) and 2.02 J/cm^2 (*ns* excitation) owing to their enhanced 2PA coefficient. Therefore, we believe that our synthesized ultra-small colloidal AuNCs can be used as the promising candidate material for advanced photonics application in the future.

1. Introduction

Thanks to the high polarizability of sub-nanometer AuNCs, having molecular-like electronic structures, due to the appearance of strong quantum size effect. Hence, a high-luminescence along with a very high nonlinear optical (NLO) response can be achieved in AuNCs due to the interaction with the strong electromagnetic field of an incident laser light [1–9]. However, the optical properties of AuNCs can be tuned elegantly by playing with the number of atoms per cluster (NAC). Hence, AuNCs have stimulated considerable interest in the research community having importance not only in fundamental research [1,2] but also for their potential applications in photonics [3], optical limiting [4], and optical switching [5]. Previously, Thomas et al. have demonstrated the enhancement in NLO response in AuNCs in comparison to that of Au nanoparticles (AuNPs) [4]. Mendez et al. have successfully demonstrated that the polarizability per atom for Au_{34}NC would be 5.59 Å^3, whereas it would increase to 7.15 Å^3 in case of Au_6NC [6]. In another study, Brevet et al. have reported that the value of the hyperpolarizability for Au_{25}NC is 109×10^{-30} esu, which has been increased to 509×10^{-30} esu for Au_{15}NC [7]. Therefore, one can expect that by reducing the value of NAC in AuNCs stronger NLO response can be achieved. Previously, nonlinear multiphoton absorption in Au and AgNCs with different NAC (=10, 15, 25, 38, 144, *etc.*) have been reported [8–11]. But till now there is no report on NLO properties of AuNCs with NAC being less than 10. The synthesis of stable AuNCs continues to remain a considerable challenge in compared to the synthesis of gold nanoparticles (AuNPs). Previously, syntheses of PAMAM [1], thiol [2], polyethylenimine [10] stabilized AuNCs have been reported.

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Research Paper

Syntheses of flower and tube-like $MoSe_2$ nanostructures for ultrafast piezocatalytic degradation of organic dyes on cotton fabrics

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ABSTRACT

The synthesis of few-layered transition metal dichalcogenides (TMDCs) with abundant exposure of the active site, *viz.*, is an important key to achieve excellent dye degradation performance. Here, we have reported synthesis and ultrafast dye degradation performance of flowers-like $MoSe_2$ nanostructure (FMN) with ~230 nm in diameter and its transformation to tube-like $MoSe_2$ microstructure (~1 μm in length) by tuning the solvothermal reaction time. The piezoelectric devices are developed using the FMNs delivers the highest open-circuit voltage of ~ 2.12 V, which is ~21 times higher than that of the developed device with the tube-like $MoSe_2$ microstructure. The piezoelectric property of the synthesized samples has been judiciously utilized further for ultrafast degradation of organic dyes within 60–120 s only under the low-frequency (40 kHz) ultrasonication vibration in the dark. The estimated dye degradation efficiencies of the FMNs-based piezocatalyst are found to be ~86% and 85% for degradation of Rhodamine B (RhB) and methylene blue (MB) dye within the 60 s, respectively. Also, the FMN has exhibited an excellent piezocatalytic dye degradation capability for RhB-MB dye mixture and dye loaded on a cotton fabric with an efficiency of ~98% (60 s) and 84% (120 s), respectively. The piezocatalytic dye degradation mechanism of FMNs has also been explained theoretically.

1. Introduction

The existing water is being polluted gradually by different toxic dyes coming from the different textiles industries and environmental pollutants. Therefore, the treatment of organic dyes present in wastewater has fascinated significant and long-term consideration (Borgarello et al., 1981; Kabra et al., 2004). The wastewater treatment is also a major problem area in energy research (Borgarello et al., 1981; Kabra et al., 2004). Recently, researchers are extensively utilizing semiconductor nanoparticle-based photocatalysts to degrade organic pollutants by creating strong oxidizing free species under light illumination (Sharma et al., 2009; Xiao et al., 2021). But due to the limitation of the band gap matching of the semiconductor photocatalysts with the illuminated light irradiation, the photocatalytic dye degradation is not applicable at all times. Additionally, for fast degradation, the semiconductor nanomaterial must show a high capability to generate and separate electron–hole (e^-–h^+) pairs under optical irradiation. So far, a number of strategies such as doping, use of high reaction temperature, and designing of heterostructured materials have been tried to enhance photocatalytic dye degradation (Ajmal et al., 2014). However, these materials and methods are also limited due to their low solar energy conversion efficiency (<20%), and low light transmission in intensely dyed toxins (Banin et al., 2021). Therefore, novel environment-friendly, recyclable, highly efficient methods and materials are necessary for forthcoming wastewater purification techniques. Mechanical energy is a sustainable abundant natural energy that can be harvested by employing piezoelectric materials (Wu et al., 2018, 2016, 2017; Mushtaq et al., 2018; Lan et al., 2017; Lin et al., 2017). Piezoelectric materials can produce an electric field in reaction to an external force. A built-in electric field powerfully increases the separation of free carriers (Wu et al., 2018, 2016, 2017; Mushtaq et al., 2018; Lan et al., 2017; Lin et al., 2017). Thus, piezoelectric materials have been widely used in photocatalytic dye degradation. Thus, the innovative studies associated to piezoelectric water treatment are paid significant attention (Wu et al., 2018, 2016, 2017; Mushtaq et al., 2018; Lan et al., 2017; Lin et al., 2017). Recently, researchers have investigated the piezocatalytic

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****

No.R-Ph.D./Regn./Env. Sc/E-32 Dated: 31.12.2024

To:

Sm Meghla Mukherjee

C/O- Prof. Srimanta Gupta,

Dept. of Environmental Science , B.U.

UNDER UGC's REGULATION 2022

Sub: Grant of Registration as a candidate for Ph.D. degree in **Environmental Science** with effect from **25-07-2023**

Sir/Madam,

I am to inform you that the Faculty Council for P.G. Studies in Science at its meeting held on **24.10.2024** permitted you to get yourself registered as a candidate for Ph.D. degree, mentioned above, the title of your thesis being , " **ASSESSING THE HYDROGEOCHEMISTRY OF URANIUM IN CONTAMINATED GROUNDWATER OF SOME SELECTED BLOCKS OF BIRBHUM DISTRICT, WEST BENGAL WITH A STRATEGY FOR ITS EFFECTIVE REMOVAL**" Subject to fulfillment of the requirements set forth in the University Ordinances relating to Doctoral Degrees and such terms and conditions as may be laid down by the appropriate authorities of the University from time to time.

You will now be required to deposit the Ph.D. Registration fee of **Rs. 8,000/- (Eight thousand only)** for enrolment of your name in the Register of candidates for Ph.D. degree, **positively within a month from the date of issue of this letter**, failing which your case will not be considered for Registration as a Ph.D. candidate and **the relevant copy of the cash receipt should be submitted to the Ph.D Unit**.

In this connection you are requested to note that ---

a) You have been permitted to do research work under **Prof. Srimanta Gupta ,Dept. of Environmental Science , B.U. & Dr. Pradip Kumar Sukul, Dept. of Chemistry, Amity University,Kolkata (Co-supervisor)** as your Supervisor / Co- Supervisors.

b) You will be **required to get yourself registered as a student of this University** on migration after completing all the necessary formalities prescribed in this behalf, unless you are already a registered student of this University.

c) You will be **required to deliver one seminar talk before submission of the thesis** pertaining to the project of your research you have undertaken within the period of your research work and before submission of the thesis.

d) i) You will have to **publish at least one research paper related to your research work** in a referred journal / peer reviewed journal and ii) Make two presentation in Conference/Seminar before submission of the thesis and produce evidence for the same in the form of acceptance letter / reprint /certificate of presentation as applicable at the time of submission of your thesis.

e) You will have to **submit your thesis within six years from the date of your registration** for Ph.D. degree mentioned above, but **not earlier than 25-07-2026 (three years including course work)** in the prescribed manner along with the fee of **Rs. 8,000/- (Eight thousand only)** or as may be fixed by the Executive Council from time to time towards submission of thesis. A maximum of **an additional two (2) years** can be given through a process of re-registration provided, however, that the total period of completion of a Ph.D programme **should not exceed 8 (eight) years** from date of admission

f) i) You will be required to appear before **Research Advisory Committee** once in six months to make a presentation of the progress of his/her work for evaluation and further guidance. This six-monthly report shall be submitted by the Research Advisory Committee to the Board of Research Studies with a copy to the research scholar.

ii) In case the progress of the research scholar is unsatisfactory, the Research Advisory Committee shall record the reasons for the same and suggest corrective measures. If the research scholar fails to implement these corrective measures, the Research Advisory Committee may recommend to the Faculty Council for PG Studies concerned through the Board of Research Studies with specific reasons for cancellation of the registration of the research scholar.

g) The women candidate & persons with disability (More than 40%) may be allowed **an additional relaxation of 2 (two) years** for Ph.D Programme. However, the total period for completion of a Ph.D in such cases **should not exceed 10 (Ten) years** from date of admission. The women candidates may avail **Maternity Leave/Child care Leave once in the entire duration of Ph.D Programme upto 240 days** with the permission of the Chairman, Doctoral Committee.

h) In your case , ***four/five copies*** of the thesis along with a ***Pendrive*** (containing the Synopsis and the Thesis in PDF Format) be submitted and one copy be retained by you as a reference copy.

i) At the time of submission of thesis, a certificate in the prescribed form furnished by your Supervisor(s) will have to be pasted on all the copies of the thesis.

j) **The registration granted under this letter will remain valid for six years from the date of registration**. In the event of failure of submission of the thesis within the stipulated period, re-registration may be sought for and the same may be granted after observing all the formalities required in this behalf and on the receipt of the prescribed fee(s). Application for **re-registration may be sought within the stipulated period i.e.within six years.**

k) The registration granted herein may be cancelled by the concerned authority/ body of the University in the event of failure of the candidate to fulfill any of the prescribed requirements at any stage.

l) While submitting for evaluation, the thesis shall contain an undertaking from the research scholar that there is no plagiarism and a certificate from the research Supervisor(s) attesting to the **Originality of the work, vouching that there is no Plagiarism and that the work has not been submitted for the award of any other degree/diploma of the University or to any Higher Educational institution**.

n) You will be required to submit **six typed copies of Synopsis/Abstract** of the thesis (not exceeding ten pages) along with the certificate mentioned in **Clause(i)** above and a **certificate of delivering Seminar talk(s)** and the **Clearance Certificate** from the Librarian of the Central Library, Burdwan University at the time of submission of thesis.

Yours faithfully,

Chatterjee

In Charge
Research Section

THE UNIVERSITY OF BURDWAN
PURBA BARDHAMAN
713104
WEST BENGAL, INDIA

Copy forwarded for information to:

1) The Head of the Department of **Environmental Science**, B.U.

2) Supervisor(s) of the candidate: **Prof. Srimanta Gupta ,Dept. of Environmental Science , B.U. & Dr. Pradip Kumar Sukul, Dept. of Chemistry, Amity University,Kolkata (Co-supervisor)**

3) The Senior Secretary, Faculty Council for P.G. Studies in **Science**, B.U.

4) The Finance Officer, B.U.

पश्चिमबङ्ग पश्चिम बंगाल WEST BENGAL AN 480022

SL. NO--- 46

Memorandum of Understanding (MoU)

between

CSIR-National Physical Laboratory (CSIR-NPL)

and

The University of Burdwan (BU)

AGREEMENT between CSIR-National Physical Laboratory, New Delhi, India and The University of Burdwan, West Bengal, India, India

L.1 THE AGREEMENT

L.1.1 THIS AGREEMENT made and entered into on this **5th** day of **October 2023** between **the COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH (CSIR),** a Society registered under the Societies Registration Act **(XXI of 1860)**,

having its registered office at Anusandhan Bhawan, 2, Rafi Marg, New Delhi – 110001 through its one of the constituent laboratories, **CSIR-NATIONAL PHYSICAL LABORATORY**, Dr. K.S. Krishnan Road, New Delhi (India) (hereinafter called **CSIR-NPL** which expression shall wherever the context so admits include its successors and permitted assigns) of the first Party.

&

L.1.2 THE UNIVERSITY OF BURDWAN, 'Grade A' University accredited by NAAC with its location at Rajbati, Bardhaman, West Bengal - 713104 (hereinafter called the Burdwan University or **BU** which expression shall where the context so admits include its successors and permitted assigns) of the other part.

L.2 PREAMBLE:

L.2.1 WHEREAS, CSIR-NPL is mandated to be India's "National Measurement Institute" (NMI) by the act of Parliament and its associated rules for legal metrology. CSIR-NPL is the custodian of "National Standards" with a responsibility of realization, establishment, upgradation, maintenance, and dissemination of standards at par to international level. CSIR-NPL is serving the Indian industry, academia, and strategic sectors to excel in their endeavours by providing APEX level testing and calibration facilities.

L.2.2 WHEREAS, The University of Burdwan is engaged in R&D activities on GNSS basically focused on study of NavIC, exploring cost-effective and compact GNSS modules, development of low-cost GNSS Modules for positioning, timing, and ionospheric probing.

AND WHEREAS, CSIR-NPL being the NMI of India has capability to provide traceability to SI units. CSIR-NPL intends to collaborate with The University of Burdwan for joint work under which exchange of students will be selected by mutual agreement between the home institution and the host institution. Furthermore, information sharing on research and educational programs, sharing of teaching/learning materials and other literature and scientific equipment relevant to their educational and research programs would be made on mutual agreement during the tenure of MoU.

L.3 SCOPE OF AGREEMENT

L.3.1 Short and Long-term Scientists /Faculty Exchange

L.3.2 Training of all students and faculty will be as per the HRD norms of the respective institutes.

L.3.3 Collaborative research will be carried out under the outreach programme of the respective institutes.

L.3.4 Current proposal for the mutual collaboration includes Global Navigation Satellite System (GNSS) and NavIC based Positioning & Timing applications.

L.3.5 Other mutually agreed educational or research or field programs (rural development programs, material science research, Metrology of various physical parameters etc.,) will be formulated by a joint committee from either party.

L.3.5 Joint project proposals to R&D funding agencies will be with clear mention of separate budget distribution.

L.4 FINANCIAL ARRANGEMENTS

L.4.1 Activity Agreements should make financial costs and obligations explicit. Collaborating units are encouraged to work together to identify and secure any outside funding which may be needed. Projects requiring funding must be approved by both institutions.

i) Lumpsum

a. Training charges as per HRD.

ii) Royalty: The royalty will be on case-to-case basis if required for Technology transfer.

L.5 MODALITIES

L.5.1 In consideration of financial arrangements as provided in clause L.4, CSIR-NPL hereby agrees to provide continuous services to **The University of Burdwan** for SI traceability and for the period of this agreement.

L.5.2 The AGREEMENT shall come into force from date of the signing of the AGREEMENT (herein after called the effective date) and shall remain valid till further joint meeting.

L.6 MUTUAL RESPONSIBILITIES

L.6.1 Short and Long-term Scientists/Faculty Exchange.

L.6.2 Training of all students and faculty will be as per the HRD norms of the respective institutes.

L.6.3 Collaborative research will be carried out under the outreach programme of the respective institutes.

L.6.4 Other mutually agreed educational or research or field programs (popularization of metrology, rural development programs, scientific social responsibility etc.,) will be formulated by a joint committee from either party.

L.6.5 Joint project proposals to R&D funding agencies will clear mention of separate budget distribution.

(Before implementing these activities, the parties will discuss the opportunities and challenges presented and will thereafter enter into specific activity agreements based on the mutually agreed objectives and outcomes.)

CSIR NPL Responsibility

CSIR-NPL reserves the right to perform a separate risk assessment on the legal, tax and other liabilities that may arise under each Activity Agreement and to structure its deliverables under the Activity Agreement in a way that maximizes the cost and liability efficiencies for CSIR-NPL.

We at CSIR-NPL will define what is Activity Agreement: Like for example, for people called in and out for very specific purpose (talks, committee meetings, assessment reports, etc etc) will be completely hosted by the hosting Univ./Instt etc

L.7 CALENDAR OF EVENTS: At the start of every year, for which the MoU is valid, a clear active plan may be defined for whole year.

L.8 GENERAL PROVISIONS

L.8.1 This AGREEMENT shall be the sole repository of the terms and conditions agreed to herein by the between CSIR-NPL and The University of Burdwan.

L.8.2 Either Party to this AGREEMENT shall be entitled to request an amendment or modification to this AGREEMENT by submitting its request in writing to the other Party. If the other Party agrees to amend this AGREEMENT, the amendment shall take effect after it is signed by both Parties.

L.8.3 Prior to the effectiveness of any such amendment, original terms and conditions of this AGREEMENT shall remain in full force and shall only be superseded after the signature of the amendment by both the Parties and then only to the extent specifically provided in such amendment.

L.8.4 The Parties may cancel the AGREEMENT either wholly or in part by giving three (3) months written notice due to a breach of material conditions that were not cured or were impossible to cure.

L.8.5 If necessary, AGREEMENT review process can be done yearly or as per 6.2 the frequency mutually decided.

L.8.6 The University of Burdwan will not use the name or logo of CSIR or CSIR-NPL, nor of any member of **CSIR** or **CSIR-NPL's** program staff, in any publicity, advertising, or news release without the prior written approval of an authorized representative of **CSIR-NPL** will not use the name or logo of The University of Burdwan, or of its any employee of, in any publicity, advertising, or news release without the prior written approval of The University of Burdwan.

L.8.7 Prevailing Language - English version of this Memorandum of Understanding represents the understanding of both Parties. Any other language version is provided as a translation. In the event of any conflict between the two versions, the English version will prevail.

L.8.8 Non-Binding – This Agreement is non-binding and solely for the purpose of establishing a basis upon which the two parties will continue discussions. Either of the parties may at its sole discretion terminate discussions for any reason by giving written notice of termination to the other. In the case of a dispute that arises relating to any aspect of cooperation under this Agreement, the parties may attempt to resolve such dispute through friendly negotiation, or either party may elect to terminate the agreement pursuant to the previous provision. Upon termination, the parties will have no further obligations hereunder.

L.9 MANAGEMENT

L.9.1 An apex body with Director, CSIR-NPL, and **Prof. Venugopal Achanta** or its representative and **Registrar, The University of Burdwan** or his representative as members shall monitor the implementation of this AGREEMENT and provide decision on managerial and financial related matters.

L.9.2 A team appointed by Director, CSIR-NPL and **Registrar, The University of Burdwan** shall hold periodic discussions on scientific and technical matters and resolve issues, if any.

L.9.3 Any unresolved issue shall be referred to the apex body.

L.10 FORCE MAJEURE

L.10.1 The purpose of this clause is to establish the consequences of FORCE MAJEURE events preventing either Party from complying with any of its responsibilities under this AGREEMENT.

L.10.2 For the purpose of this Article, the term FORCE MAJEURE shall refer to unforeseen and irresistible events extrinsic to this AGREEMENT and which are beyond the reasonable control of the party such as wars, riots, serious floods typhoons and earthquake leading to the damage or destruction of the facilities required for the services. The term shall not include strikes or other events caused by labour disputes, unless such strikes or other events are part of national or regional disputes.

L.10.3 The party affected by FORCE MAJEURE event shall send notification of this to the other party without undue delay and shall send to the other Party by registered / speed post mail within fourteen (14) days, a confirmation certificate issued by the authorities or departments concerned along with a detailed explanation.

L.10.4 During the period of effect of the FORCE MAJEURE event, the execution of any services requirement agreed between the Parties under this AGREEMENT shall be suspended without damages for the Party affected by such a FORCE MAJEURE event.

L.10.5 In case of a FORCE MAJEURE event, the parties agree to do their utmost to minimize the negative impact on the other party of the suspension, and each Party shall do its best to execute the service requirements already initiated.

L.10.6 Should the FORCE MAJEURE event last for more than two (2) consecutive months, each Party shall have the option of terminating the AGREEMENT; the Party wishing to terminate this AGREEMENT shall notify the other Party of its intention in writing.

L.11 ARBITRATION

In case of any disputes or differences arising between the Parties in relation to this AGREEMENT, such disputes or differences shall be amicably settled by mutual discussions between the Parties at the level of their respective Executive Directors or such officials so authorized by the parties. Except as hereinbefore provided, all disputes arising out of or in connection with the AGREEMENT shall be referred to Delhi International Arbitration Centre, Delhi High Court, New Delhi. Arbitration proceedings shall be conducted in the English Language.

L.12 CONFIDENTIALITY

L.12.1 Each Party shall have the responsibility to keep confidentiality of the techniques, technical documents and information obtained from the other Party. Both Parties shall not disclose any of them to any third party unless otherwise explicitly agreed by the Parties.

L.12.2 Neither of the two Parties shall disclose the content of this AGREEMENT to any third party without the written permission of the other Party.

L.13 ASSIGNMENT

L.13.1 The rights and/or liabilities arising to any Party of this AGREEMENT shall not be assigned except with the written consent of the other Party and subject to such terms and conditions as may be mutually agreed upon.

L.13.2 This AGREEMENT executed between CSIR-NPL and **Registrar, The University of Burdwan,** at New Delhi on **5th October 2023**. IN WITNESS WHERE OF, the Parties hereto have entered and agreed to this AGREEMENT effective at as of the day and year first above written.

SEAL OF PARTIES

In witness whereof the Parties hereto have signed this agreement on the day, month and year mentioned herein before:

Signature :	**Signature:** REGISTRAR THE UNIVERSITY OF BURDWAN BURDWAN - 713104
Name: Dr Jiji T J Pulikkotil Date : 05 October 2023 Position: **Head, HRD, CSIR-NPL, New Delhi** Affiliation & Seal: CSIR-NPL	Name: Dr Sujit Kumar Chowdhury Date : 05 October 2023 Position: **Registrar, The University of Burdwan** Affiliation & Seal: The University of Burdwan
Signature (Witness1) Ashish Agarwal	Signature (Witness 1) Professor & Head Department of Physics The University of Burdwan Burdwan-713104
Name: Dr Ashish Agarwal Date: 05 October 2023 Position: Sr. Pr. Scientist, CSIR-NPL	Name: Prof Atis Chandra Mondal Date: 05 October 2023 Position: Head, Department of Physics, BU
Signature (Witness 2) Preeti Kandpal	Signature (Witness 2) Anindya Bose
Name: Ms Preeti Kandpal Date: 05 October 2023 Position: Scientist, CSIR-NPL	Name: Dr Anindya Bose Date: 05 October 2023 Position: Senior Scientific Officer, BU

Key Contacts at CSIR-NPL New Delhi:

Name	Organisation	Role	Telephone	Email
Dr. Venugopal Achanta	CSIR-NPL	Director	45609301/ 45609302	dnpl@nplindia.org
Dr. Ashish Agarwal	CSIR-NPL	Sr. Pr. Scientist	45608384, 45608525	ashish@nplindia.org

Key Contacts at The University of Burdwan:

Name	Organisation	Role	Telephone	Email
Prof S Karforma	BU, West Bengal	Dean, Faculty of Science University of Burdwan	9474553590/ 7384456418	dean_science@buruniv.ac.in
Prof A C Mondal	BU, West Bengal	HoD, Physics Department University of Burdwan	7001399026	hod@phys.buruniv.ac.in

SL. NO. 47

Project Number: **DST/INT/POL/P-41/2020**

INDO-POLAND BILATERAL PROJECT

entitled

"DEVELOPMENT OF A SMART SCAFFOLD FOR ASSISTING EFFICIENT BONE REPAIR"

Sanctioned Date: **01.03.2021**

INDIA

Project Investigator: Dr. K. Ravichandran

Co-Investigator: Dr. Suvro Chatterjee

POLAND

Project Investigator: Professor dr hab. inż. Elżbieta Pamuła

Financed by

Ministry of Science and Technology

Department of Science and Technology (DST)

Government of India

Journal of *Functional Biomaterials*

MDPI

Article

Characterization and In Vitro Evaluation of Porous Polymer-Blended Scaffolds Functionalized with Tricalcium Phosphate

Iwona Pudełko-Prażuch [1], Mareeswari Balasubramanian [2], Sundara Moorthi Ganesan [2], Stanisław Marecik [1], Kamila Walczak [1], Kinga Pielichowska [1], Suvro Chatterjee [3], Ravichandran Kandaswamy [2,*] and Elżbieta Pamuła [1,*]

[1] Department of Biomaterials and Composites, Faculty of Materials Science and Ceramics, AGH University of Krakow, Al. Mickiewicza 30, 30-059 Krakow, Poland; ipudelko@agh.edu.pl (I.P.-P.); smarecik@agh.edu.pl (S.M.); kamwalczak@agh.edu.pl (K.W.); kingapie@agh.edu.pl (K.P.)
[2] Department of Rubber and Plastics Technology, Madras Institute of Technology Campus, Anna University, Chromepet, Chennai 600 044, Tamil Nadu, India; venibala18@gmail.com (M.B.); sundaramoorthi1997@gmail.com (S.M.G.)
[3] Department of Biotechnology, Golapbag Campus, University of Burdwan, Burdwan 713 104, West Bengal, India; soovro@yahoo.ca
* Correspondence: ravi@mitindia.edu (R.K.); epamula@agh.edu.pl (E.P.)

Abstract: Bone tissue is one of the most transplanted tissues. The ageing population and bone diseases are the main causes of the growing need for novel treatments offered by bone tissue engineering. Three-dimensional (3D) scaffolds, as artificial structures that fulfil certain characteristics, can be used as a temporary matrix for bone regeneration. In this study, we aimed to fabricate 3D porous polymer scaffolds functionalized with tricalcium phosphate (TCP) particles for applications in bone tissue regeneration. Different combinations of poly(lactic acid) (PLA), poly(ethylene glycol) (PEG with molecular weight of 600 or 2000 Da) and poly(ε-caprolactone) (PCL) with TCP were blended by a gel-casting method combined with rapid heating. Porous composite scaffolds with pore sizes from 100 to 1500 µm were obtained. ATR-FTIR, DSC, and wettability tests were performed to study scaffold composition, thermal properties, and hydrophilicity, respectively. The samples were observed with the use of optical and scanning electron microscopes. The addition of PCL to PLA increased the hydrophobicity of the composite scaffolds and reduced their susceptibility to degradation, whereas the addition of PEG increased the hydrophilicity and degradation rates but concomitantly resulted in enhanced creation of rounded mineral deposits. The scaffolds were not cytotoxic according to an indirect test in L929 fibroblasts, and they supported adhesion and growth of MG-63 cells when cultured in direct contact.

Keywords: PLA; polymer scaffolds; porous scaffolds; polymer blends; TCP; polymer functionalization

Citation: Pudełko-Prażuch, I.; Balasubramanian, M.; Ganesan, S.M.; Marecik, S.; Walczak, K.; Pielichowska, K.; Chatterjee, S.; Kandaswamy, R.; Pamuła, E. Characterization and In Vitro Evaluation of Porous Polymer-Blended Scaffolds Functionalized with Tricalcium Phosphate. *J. Funct. Biomater.* **2024**, *15*, 57. https://doi.org/10.3390/jfb15030057

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Accepted: 22 February 2024
Published: 26 February 2024

1. Introduction

In recent years, bone tissue was the second most transplanted tissue after blood [1,2]. This growing demand for new solutions provided by bone tissue engineering is caused by common trauma or pathologies, different diseases, and the ageing population [3]. The aim of bone tissue engineering is to design biomaterials that temporarily mimic the three-dimensional structure and functions of bone to promote cell adhesion, proliferation, and differentiation [4].

Bone tissue has a very complex and highly organized structure. When it comes to its chemical composition, it consists of from 50% to 70% inorganic constituents (mainly hydroxyapatite), 20% to 30% organic constituents (type I collagen), 5% to 10% water, and 3% lipids. While if its architecture is taken into account, bone tissue can be classified as hard cortical bone (with a porosity of 10–30%) or spongy cancellous bone (with a

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SL.NO.--- 48

MEMORANDUM OF UNDERSTANDING

BETWEEN

STESALIT SYSTEMS LTD, KOLKATA

AND

THE UNIVERSITY OF BURDWAN, BURDWAN

This Agreement made and entered into on this 02 day of Feb 2015 between **Stesalit Systems Ltd**, Kolkata, India (hereinafter called STESALIT) situated at Stesalit Towers, Salt Lake Electronics Complex, Kolkata 700 091, India and **The University of Burdwan, Burdwan, India** (hereinafter called Burdwan University which expression shall include its successors and permitted assignees) with its having administrative office at Rajbati, Burdwan 713 104, West Bengal

1. OBJECTIVES OF THE MOU

The objective of this Memorandum of Understanding is:

a. To form a technical collaboration in the field of Global Navigation Satellite Systems (GNSS)
b. To provide a formal basis for initiating interaction between STESALIT and Burdwan University.

THE UNIVERSITY OF BURDWAN RAJBATI BURDWAN 713104

STESALIT SYSTEMS LIMITED Kolkata

2. PROPOSED MODES OF COLLABORATION

STESALIT and Burdwan University propose to collaborate through

a. Development of algorithms and applications using joint competency of STESALIT & Burdwan University in the field of GNSS and mobility solutions for GPS/ GNSS Devices in different sectors and verticals.
b. STESALIT would bring in the competencies in higher accuracy GNSS segment with details of software and hardware suites, including the other mobility devices from STESALIT.
c. Burdwan University would bring in the competencies of developing algorithms and solutions for improved accuracy to be integrated with STESALIT solution frameworks.
d. It is decided that STESALIT and Burdwan University would work together in the GNSS and related markets where Burdwan University would offer its expertise for enhancing user Experience on STESALIT devices
e. It is decided that STESALIT and Burdwan University would form collaboration through a MOU by which STESALIT would officially declare Burdwan University, Burdwan as a Solution Development Partner.
f. Burdwan University and STESALIT teams will jointly work to ensure that they Abov. will actively participate in ensuring their developed applications and compliers will get integrated into STESALIT GNSS/ GPS devices
g. Burdwan University and STESALIT will jointly work to add features to the developed application to make the product offering more attractive to existing and future customers of STESALIT devices.

3. TECHNICAL AREAS OF COLLABORATION

The principal technical areas of collaboration between STESALIT and Burdwan University will be in the points of Algorithms/ Solutions development and testing to enhance Features and Functionalities of STESALIT GNSS Devices.

4. CONFIDENTIALITY

a. During and for a period of three years from the date of disclosure, each party agrees to consider as confidential all information disclosed by the other party in written or tangible form or, if orally disclosed confirmed in writing within thirty days of disclosure and identified as confidential by the disclosing party.
b. The obligations above shall not extend to any confidential information for which the receiving party can prove that, this information:
   - is in the public domain at the time of disclosure or comes within the public domain without fault of the receiving party.
   - is already known or become known to the receiving party
   - is received from a third party having no obligations of confidentiality to the disclosing party,
   - is independently developed by the receiving party or
   - is required to be disclosed by law or court order.

THE UNIVERSITY OF BURDWAN RAJBATI BURDWAN 713104

STESALIT SYSTEMS LIMITED Kolkata

5. NON-EXCLUSIVITY

The relationship of the parties under this MOU shall be nonexclusive and both parties, including their affiliates, subsidiaries and divisions, are free to pursue other agreements or collaborations of any kind. However, when entering into a particular business, partnership, or dealership agreement, the participants may agree to limit each party's right to collaborate with others on that subject.

6. TERMS AND TERMINATION

This MOU, unless extended by mutual written agreement of the parties, shall expire 3 years after the effective date specified in the opening paragraph and can be renewed through mutual interest. This MOU may be amended or terminated earlier by mutual written agreement of the parties at any time. Either party shall have the right to unilaterally terminate this MOU upon 90 days prior written notice to the other party. However, no such early termination of this MOU, whether mutual or unilateral, shall affect the obligations of the participants under any Business Agreement, Confidentiality clause as referenced in clause 4 above, or any other agreement entered into pursuant to this MOU, which obligations shall survive any such termination.

7. BRANDING

The STESALIT Devices and its Installed Software Applications shall continue to be sold under STESALIT's existing brands SXtreo or any others and STESALIT would give due credit to Burdwan University for the solutions provided. For certain products, developed jointly by both the Parties, Co-branding may be done by signing a separate agreement on a mutually agreed basis for such an instance and terms of the same would NOT be guided through this MOU.

8. RELATIONSHIP

Nothing in this MOU shall be construed to make either party a partner, an agent or legal representative of the other for any purpose. Now onwards, till the validity of this agreement, both the parties may mention the name and LOGO of the other in their brochures/ flyers/ websites/ documents as "TECHNICAL COLLABORATOR" for purposes as may be required. But, such an instance should be communicated by the user to the other party in writing beforehand.

9. INTELLECTUAL PROPERTY RIGHTS (IP)

Intellectual property rights of both the parties will continue to be maintained as is and no party will have rights to any IP already existing with each party. In case of any IP developed jointly, both parties would sign a separate agreement on a mutually agreed basis for such an instance and terms of the same would NOT be guided through this MOU.

10. ASSIGNMENT

It is understood by the Parties herein this MOU is based on the professional competence and expertise of each party and hence neither Party shall transfer or assign this Agreement, or rights or obligations arising hereunder, either wholly or in part, to any third party.

THE UNIVERSITY OF BURDWAN RAJBATI BURDWAN 713104

STESALIT SYSTEMS LIMITED Kolkata

11. AMENDMENTS

Amendments or changes to this agreement or MoU shall be made in writing and signed by the duly authorized Representatives

12. FUNDING

The initial stage of this agreement would not be funded by any of the parties, however, each party would be responsible for the cost of their travel and living expenses.

After the inception, when the collaboration matures, the funding may be realized on application to various funding agencies of relevance. The Parties can submit joint project proposals to relevant funding agencies and the funding applications should be made by the participating parties with their mutual consent and discussions regarding the scope and extent of such funded program and its goals.

STESALIT, may, at its discretion extend financial support in the form of "Consultancy Charges" to The University of Burdwan for supporting research in a particular technical area of GNSS. Both the parties sign a separate agreement on a mutually agreed basis for such an instance and terms of the same would NOT be guided through this MOU.

13. COSTS OF THE MOU

Each Party shall bear the respective costs of carrying out the obligations under this MOU

14. POINT OF CONTACTS

Each Party will nominate its own representatives who would be responsible for all measures to be undertaken under this agreement and they would be called point of contact (PoC). The point of contact for each of the parties are mentioned below:

FOR STESALIT:

Mr. Pratyush Talukdar
Asst Technical Lead
Software Department
Stesalit Limited, Kolkata
Email: praryush.talukdar@stesalit-inc.com
Mobile No.: +91 98308 80591

FOR THE UNIVERSITY OF BURDWAN

Dr Anindya BOSE,
Scientific Officer
Department of Physics, The University of Burdwan
Golapbag, Burdwan 713 104
Email: abose@phys.buruniv.ac.in
Mobile No: +91 94340 04478

THE UNIVERSITY OF BURDWAN * KAJBATI BURDWAN 713104 *

STESALIT SYSTEMS LIMITED * Kolkata *

The Industry Institute Partnership Cell (IIPC), The University of Burdwan will support the communications and implementation of the program.

15. SIGNED IN DUPLICATE

This MOU is executed in duplicate with each copy being an official version of the Agreement and having equal legal validity.

BY SIGNING BELOW, the parties, acting by their duly authorized officers, have caused this Memorandum of Understanding to be executed, effective as of the day and year first above written.

On behalf of

STESALIT SYSTEMS LTD, Kolkata

By :

Name : JAYANTA SOM

Title : Zonal Manager

Date : 2/2/2015

Witness :

1. PRATYUSH TALUKDAR

2. Sibayan Chakraborty

On behalf of

The University of Burdwan, Burdwan

By : (RAJAT BHATTACHARY

REGISTRAR

Name : THE UNIVERSITY OF BURDWAN

Title : BURDWAN-713104

Date : 02/2/15

Witness :

1. Anindya Bose (ANINDYA BOSE)

2. (SARBESWAR CHAUDHURI)

Sl.NO.-- 49

Memorandum of Understanding
Between
The University of Burdwan, West Bengal, India
and
the University of Dhaka, Bangladesh

The University of Burdwan (hereinafter called B.U.) and the University of Dhaka (hereinafter called D.U.) establish hereby a formal understanding of co-operation and friendship which is intended to further the academic objectives of each Institution and to further develop academic co-operation, strengthen cultural ties between the two countries and thereby improve mutual understanding and relationships. Under this MOU the two Institutions will proceed to implement the following endeavours and exchanges of materials and personnel.

Areas of Co-operation

Co-operation shall be carried out subject to availability of funds and the approval of the competent authority of Burdwan University and Dhaka University, through such activities or programmes as:

(1) Exchange of Faculty Members and scholars
(2) Inter-disciplinary and result oriented joint research activities and field studies
(3) Participation in Seminar and academic meetings
(4) Exchange of Academic materials and other information
(5) Short term Academic Programmes

The terms of such mutual co-operation shall be mutually discussed and agreed upon in writing by both the Instiutions. Both the Burdwan University and the Dhaka University agree to waive all regular fees for the exchange programme under this MOU. Both the Institutions agree to provide rent free accommodation at their respective Guest House for the participants of the exchange programme under this MOU.

The present MOU will be effective from the date of its signature and will in force for a period of three years. It shall be automatically extended for an additional period of three years unless either Institutions notify its intention to terminate the MOU, at least six months before the date of expiry

Signed in Dhaka University, Bangladesh

Signed for the University of Burdwan

22.10.14

Dr. Shorosimohan Dan
Pro-Vice-Chancellor
University of Burdwan
West Bengal, India

Syed Rezaur Rahman
Registrar
Dhaka University

Signed for the University of Dhaka

22/10/2014

Professor Dr. Md. Kamal Uddin
Treasurer
University of Dhaka
Bangladesh.

पश्चिमबङ्ग पश्चिम बंगाल WEST BENGAL 85AB 082119

आज़ादी का अमृत महोत्सव

ZOOLOGICAL SURVEY OF INDIA 1916

THE UNIVERSITY OF BURDWAN

REGISTRAR
THE UNIVERSITY OF BURDWAN
BURDWAN - 713104

SL.NO. 50

MEMORANDUM OF UNDERSTANDING

FOR SCIENTIFIC AND ACADEMIC COOPERATION BETWEEN ZOOLOGICAL SURVEY OF INDIA AND THE UNIVERSITY OF BURDWAN, BURDWAN

Zoological Survey of India(ZSI), since its establishment on 1st July, 1916, has been pioneering on taxonomic research on animals, focusing on exploring, collecting, identifying, describing, classifying the animal taxa for inventorying, documentation and digitization of the Indian fauna. It has maintained its primary objectives of taxonomic research, survey and

डा. धृति बैनर्जी
Dr. Dhriti Banerjee
निदेशक / Director
भारतीय प्राणि सर्वेक्षण
Zoological Survey of India
प.व.एवं ज. प. मंत्रालय, भारत सरकार
MoEF&CC. Govt. of India
कोलकाता / Kolkata-700053

ক্রমিক নং 20564 তারিখ 19.6.23

ক্রেতা Sujit Chowdhury

সাকিম BU BWN

ষ্ট্যাম্পের মূল্য 10/-

বর্ধমান ট্রেজারী ১নং ষ্ট্যাম্প খরিদ তারিখ 15-6-23

ষ্ট্যাম্প ভেন্ডার সঞ্জয় আচার্য্য

জেলা জজ্ আদালত (বর্ধমান)

লাইসেন্স নং- ১/২০০৪-০৫

Sanjoy Acharyya.

documentation of Indian fauna. The scope and functions of ZSI have been considerably expanded, particularly in the light of the Convention on Biological Diversity, ratified by the Govt. of India in 1994. To meet the challenges of biodiversity conservation, sustainable utilization and dissemination of knowledge on faunal diversity to all stake holders, ZSI acquired modern tools and techniques such as scanning electron microscopes, stereo zoom microscopes, GIS tools, Data basing tools and the DNA barcoding technology, augmenting the research infrastructure of ZSI.

The **University of Burdwan (BU)** with a motto *Learning Leads to Emancipations*, was established on 15th June, 1960, a premier university of eastern India. Since inception it has reached several milestones such as: university NIRF ranking is 86 (2023), and the university has been accredited with Grade 'A' by NAAC in the year 2016 and India Today rank for the year 2021 is 16.

Presently it has 22 Post-graduate departments of faculty of Arts & Humanities and 17 Post Graduate departments, faculty of Science. An engineering college, named as University Institute of Technology, has been established with the approval from All India Council for Technical Education (AICTE). Other Academic Depts: UGC-HRDC, SVARC, NSS, RTC, Sports Board, Life long Learning etc.

Academically, **The University Burdwan** has affiliated colleges: Burdwan district: 26; Hooghly district: 27 and Birbhum district: 19. Its territorial jurisdiction extends over three districts –Purba Burdwan, Hooghly, Birbhum. These constitute the greater part of Rarh Bengal, the cradle of ancient civilization of India. The university now offers courses on diverse disciplines. These include physical education, B.Ed., foreign languages, computer applications, population education, etc. There are also an Adult Continuing Education Center and the Academic Staff College. The university has a museum and art gallery at Rajbati that displays even the pottery of

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Zoological Survey of India
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REGISTRAR
THE UNIVERSITY OF BURDWAN
BURDWAN - 713104

prehistoric age. The university has its Distance Education wing imparting Post-graduate education in different subjects as well as in some professional courses at Under-graduate level.

With social responsibilities in mind, the university actively patronized the construction of a Science Centre and a Planetarium, named as Meghnad Saha Planetarium. The University has established a Rural Technology Centre to impart vocational training and to create scope of self-employment for the rural youth.

The **Zoological Survey of India** and **The University of Burdwan**, Burdwan, agree that for encouragement and development of cooperation and exchange in areas of mutual academic interest, it is desirable to enhance research and academic processes at both ZSI and the **University of Burdwan** to strengthen mutual understanding between their respective staff, scholars and students. **The Zoological Survey of India**, represented by **the Director, ZSI** and **The University of Burdwan, Burdwan, represented by the Vice Chancellor, The University of Burdwan, Burdwan**, hereby, enter into an agreement for academic and educational cooperation and have set forth the following Articles of Mutual Agreement:

Article 1

The **University of Burdwan, Burdwan** and the **Zoological Survey of India** agree on, but is not limited to, the following based on their academic and educational needs:

1. For collaborative research work with the **Zoological Survey of India (ZSI)** or the students intending to pursue research works at ZSI, enrolment to Ph.D programme under the University of Burdwan (BU) will be carried out through the Common Research Eligibility Test (RET) conducted by the BU only.

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MoEF&CC. Govt. of India
कोलकाता / Kolkata-700053

REGISTRAR
THE UNIVERSITY OF BURDWAN
BURDWAN - 713104

2. The bonafide students and research scholars of both the Institutions will have access to research facilities at **The University of Burdwan**, Burdwan and **Zoological Survey of India**.
3. The scientists of **Zoological Survey of India** conducting research shall be recognised as **Supervisors/Co-supervisors** for Doctoral under **The University of Burdwan**, as per the extant Ph.D regulations of the BU and UGC as adopted by the BU to be amended time to time.
4. In the research publications published from the thesis work of the candidate registered with the **University of Burdwan**, the affiliation of the concerned student should appear as **The University of Burdwan** and **Zoological Survey of India**.
5. Joint Research activities, developing research projects, funding, organising and participating in conferences, academic meetings, courses, seminars, symposiaand lectures will be undertaken with due acknowledgement to both institutions.
6. Exchange of biological materials will be subjected to provisions under the Biodiversity Act (2002) and or any other such legal bindings by the Govt. of India.
7. Under this agreement, there will be no financial liability on **The University of Burdwan** or on the **Zoological Survey of India** from either side.

Article 2

The exchange programmes and/or projects are not intended to be legally binding documents. They are meant to describe the nature and suggest the guidelines of the programme or project. Nothing, therefore, shall diminish the full autonomy of either university/ institution, nor will any constraint be imposed by either upon the other carrying out the agreement.

Dhriti Banerjee

डॉ. धृति बैनर्जी
Dr. Dhriti Banerjee
निदेशक / Director
भारतीय प्राणि सर्वेक्षण
Zoological Survey of India
प.व.एवं ज. प. मंत्रालय, भारत सरकार
MoEF&CC. Govt. of India
कोलकाता / Kolkata-700053

Sujit Kumar Chandra

REGISTRAR
THE UNIVERSITY OF BURDWAN
BURDWAN - 713104

Article 3

In order to carry out and fulfil the goals of this agreement both **The University of Burdwan** and **Zoological Survey of India** shall designate a programme coordinator to develop and co-ordinate the specific programmes and projects agreed upon. The programme coordinators will be responsible for the evaluation of activities under this agreement. Letters of agreement will be approved by both sides according to the normal procedures adopted by the signatory parties.

Article 4

This MoU will come into force upon affixing of the signatures of the representatives of the both organizations and will remain in effect for five (5) years. This MoU will be renewed upon its expiry, as per mutual agreement of both organizations. If either organization wishes to terminate the MoU at the end of the five years period or in between the period of five years, it must notify the other organization not less than six months prior to the expiry of the MoU. The event of termination will not affect participants from completing their activities at the host institution already initiated or ongoing unless otherwise mutually agreed. Modifications to MoU will be made by mutual consent and any amendment or extension to the MoU will be formalized by the exchange of letters and or emails between the two institutions.

Article 5

In the event of any unforeseen issues or matters not covered herein or any controversy, dispute or difference arising out of or in connection with this MoU, the same shall be resolved amicably by both the organizations. This MoU and further agreements will in all respect be governed by and construed in accordance with the laws of Govt. of India. This MoU shall be signed in counterpart. Each counterpart will constitute an original document

Dhriti Banerjee

डॉ. धृति बैनर्जी
Dr. Dhriti Banerjee
निदेशक / Director
भारतीय प्राणि सर्वेक्षण
Zoological Survey of India
प.व.एवं ज. प. मंत्रालय, भारत सरकार
MoEF&CC, Govt. of India
कोलकाता / Kolkata-700053

Sujit Kumar Chowdhury

REGISTRAR
THE UNIVERSITY OF BURDWAN
BURDWAN - 713104

and these counterparts taken together, shall constitute one and the same MoU.

As witness to their consent to this agreement, the appropriate authorities here unto provide their signatures.

For the Zoological Survey of India, Kolkata, India	For The University of Burdwan, Burdwan, India
Director (as the case may be)	Registrar (as the case may be)

Dr. Dhriti Banerjee
Director
Zoological Survey of India
Kolkata

Date: 01.07.2023

डॉ. धृति बैनर्जी
Dr. Dhriti Banerjee
निदेशक / Director
भारतीय प्राणि सर्वेक्षण
Zoological Survey of India
प.व.एवं ज. प. मंत्रालय, भारत सरकार
MoEF&CC. Govt. of India
कोलकाता / Kolkata-700053

Dr. Sujit Kumar Choudhury
Registrar
The University of Burdwan
Burdwan

Date: 01.07.2023

REGISTRAR
THE UNIVERSITY OF BURDWAN
BURDWAN - 713104

Witness 1: .....

DR. GURUPADA MANDAL
SCIENTIST - 'E' M.Sc., Ph.D
GOVT. OF INDIA
MINISTRY OF ENV., FORESTS & CLIMATE CHANGE
ZOOLOGICAL SURVEY OF INDIA
M - BLOCK, NEW ALIPORE, KOL - 53

Witness 2: .....

Dr. Mamta Nashkar
Scientist 'C'
Zoological Survey of India
Ministry of Environment, Forest
Kolkata - 700053

Witness 1: .....

Dr. SANJOY PODDER
Professor & Head
Department of Zoology
The University of Burdwan
Golapbag, Burdwan-713104

Witness 2: .....

Dr. A. Mazumdar
Professor
Department of Zoology
The University of Burdwan
Burdwan-713104, W.B., India

THE UNIVERSITY OF BURDWAN
RAJBATI
BURDWAN
713104

Tel: 26588204-26588662-26589620

sl. no. 51

तार / GRAM : विज्ञानी / SCIENTIFIC
Web-site : www.icmr.nic.in
E-mail : icmrhqds@sansad.nic.in

भारतीय आयुर्विज्ञान अनुसंधान परिषद
INDIAN COUNCIL OF MEDICAL RESEARCH

वी. रामलिंगस्वामी भवन, अन्सारी नगर, पोस्ट बॉक्स 4911, नई दिल्ली - 110 029
V. RAMALINGASWAMI BHAWAN, ANSARI NAGAR, POST BOX 4911, NEW DELHI - 110 029

F. No.:- 52/10/2022-BIO/BMS **Date: 17.09.2024**

To

The Registrar,
University of Burdwan,
Rajbati, Burdwan West Bengal-713104

The project entitled "Decoding the role of the transcription factor, Sterol Regulatory element Binding Protein during hepatic stellate cell activation under Dr. Survo Chatterjee, University of Burdwan, Rajbati, Burdwan West Bengal-713104

Sir/Madam,

The Director General of the ICMR sanctions the above mentioned research scheme initially for a period of **One Year** with effect from **20.11.2023** subject to extension up to the total duration as specified in para five below :-

The Director General of the Council also sanctions the budget allotment of **Rs.** 11,92,227 /-

as detailed in the attached statement for the period from **20.11.2023 to 19.11.2024** grant-in-aid will be given subject to the following conditions.

1. The payment of the grant will be made in lump-sum to the Head of the Institute. The first instalment of the grant will be paid generally as soon as report regarding appointment of the staff is received by the Council. The Staff appointed on the project should be paid as indicated in the budget statement.
2. The staff on the project will be recruited as per the rules and procedure of the host institute and second part of the undertaking be obtained from the employees of the project. The staff grant will not be released unless the required undertaking [part-II] from Head of the Institute is received in this office.
3. The Host Institute shall utilize the grant after following the provisions laid down in the GFRs 2017 and TA rules. The demand for payment of the subsequent instalment of the grant should be placed with the Council in the prescribed Performa. The approved duration of the scheme is **Three Years**. The annual extension will be given after review of the work done on the scheme during the previous year.
4. Five copies of the annual progress report in the attached prescribed Performa should be submitted to the ICMR every year after completion of ten months of the project giving complete actual details of the research work done. Failure to submit the report in time may lead to termination of project.
5. Subject to the condition that the grant will be utilize after following the provisions laid down in the GFRs-2017 & TA Rules. Please keep the fund in a separate Saving Bank Account opened for ICMR funded Research Projects so that interest earned thereon is credited in to this account.

The receipt of this letter may please be acknowledged.

Yours faithfully,

20/9/24

Sr. Admn. Officer
for Director General

Copy together with a copy of the budget statement forwarded to information to :-

Accounts - V

1. Dr. Madan Kumar Perumal, Scientist, Deptt. Of Biochemistry, CSIR-Central Food Technological Institute (CSIR-CFTRI) MYSURU- 570020.
2. Dr. Survo Chatterjee, University of Burdwan, Rajbati, Burdwan West Bengal-713104
3. IRIS ID :- 2021-8886

Sr. Admn. Officer
for Director General

Tel: 26588204-26588662-26589620

तार / GRAM : विज्ञानी / SCIENTIFIC
Web-site : www.icmr.nic.in
E-mail : icmrhqds@sansad.nic.in

भारतीय आयुर्विज्ञान अनुसंधान परिषद
INDIAN COUNCIL OF MEDICAL RESEARCH

वी. रामलिंगस्वामी भवन, अन्सारी नगर, पोस्ट बॉक्स 4911, नई दिल्ली - 110 029
V. RAMALINGASWAMI BHAWAN. ANSARI NAGAR. POST BOX 4911. NEW DELHI - 110 029

F. No. :- 52/10/2020-BIO/BMS **Date: 17.09.2024**

The project entitled "Decoding the role of the transcription factor, Sterol Regulatory element Binding Protein during hepatic stellate cell activation under Dr. Survo Chatterjee, University of Burdwan, Rajbati, Burdwan West Bengal-713104

MEMORANDUM

The Director General of the ICMR sanctions grant of Rs. 11,92,227 /-(Rupees Eleven Lakh, Ninety Two Thousand Two Hundred and Twenty Seven only) as the 1st& 2nd instalment of 1st year grant for the period from **20.11.2023 to 19.11.2024** for incurring expenditure in connection with the above mentioned project.

The amount of **Rs.** 11,92,227/-may be debited under the provision made of **Rs. 11,92,227/-** on the above mentioned research project for the year 2023-2024.

A formal bill for **Rs.11,92,227/-**is sent herewith for payment released by NEFT/RTGS of **Rs. 11,92,227/-**in favour of the Registrar, University of Burdwan, Rajbati, Burdwan, West Bengal-713104 is issued with the concurrence of the Finance Division, RFC No. BMS/Adhoc/09/2023-2024 dated 26 Sep. 2023, RFC Register for the FY 2023-2024

Project technical support-III for 3 year @28,000/- + HRA 9% = 2520/-	3,66,240
Equipment	2,50,000
consumables	4,00,000
Contingency	1,00,000
Travel	50,000
Over Head(3%)	25,987
Total	11,92,227

17/9/24

Sr. Admn. Officer
for Director General

Copy to:-

1. The Registrar, University of Burdwan, Rajbati, Burdwan West Bengal-713104
2. Dr. Madan Kumar Perumal,,CSIR-Central Food Technological Institute (CSIR-CFTRI), MYSURU-570020.
3. Dr. Survo Chatterjee, University of Burdwan, Rajbati, Burdwan, West Bengal-713104
4. Accounts – V
5. IRIS ID :- 2021-8886

Sr. Admn. Officer
For Director General

Nelumbo *Vol 64 (1): (68-72) 2022*
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sl.no ..03

ISSN (Print) : 0976-5069
ISSN (Online) : 2455-376X

Poa leptoclada (Poaceae) - An Afro-Arabian species: First record from India for South Asia

Althaf Ahamed Kabeer K[1], Ravikiran Arigela[2], Ruma Bhadra[3]*, J.H.F. Benjamin[4], Saikat Naskar[5] and P.V. Prasanna[6]

[1]Botanical Survey of India, Central Botanical Laboratory, P.O. Botanic Garden, Howrah -711103, West Bengal, India
[2]Botanical Survey of India, Deccan Regional Centre, Rooms 228-238, Kendriya Sadan, Sultan Bazar, Koti, Hyderabad – 500095, Telangana, India
[3]Botanical Survey of India, Central National Herbarium, P.O. Botanic Garden, Howrah - 711 103, West Bengal India
[4]Botanical Survey of India, Sikkim Himalayan Regional Centre, P.O. Rajbhawan, Gangtok - 737 103, Sikkim, India
[5]Department of Botany, The University of Burdwan–703 104, West Bengal, India
[6]C-109, Cyber-e-park, Alkapur, Puppalaguda Manikonda, Hyderabad–500 089, Telangana, India
*Corresponding author: rumabhadra93@gmail.com

पोआ लेप्टोक्लेडा (पोएसी)- एक अफ्रीकी-अरबियन प्रजाति: दक्षिण एशिया के लिए भारत से प्रथम आलेख

अल्ताफ अहमद कबीर के, रविकिरण अरिगेला, रुमा भद्रा, जे.एच.एफ. बेंजामिन, सैकत नसकर एवं पी. वी. प्रसन्ना

सारांश

पोआ लेप्टोक्लेड़ा होच्स्ट. एक्स ए. रिच. को तमिलनाडु में पलनी हिल्स स्थित कोड़ईकनल वन्यजीव अभयारण्य से संग्रहीत किया गया है और इसे दक्षिण एशिया के संकलन में शामिल किया गया है। इस जाति का विस्तृत बाह्य आकृतिकी, क्षेत्रात्मक वितरण तथा फोटो- प्लेट इस शोध में उल्लेख किया गया है।

ABSTRACT

Poa leptoclada Hochst. ex A. Rich., collected from Kodaikanal Wildlife Sanctuary, Palni Hills, Tamil Nadu is reported here as addition to South Asia. Detailed exo-morphology, distribution and plate are provided.

Keywords: New Record, *Poa leptoclada*, Poaceae, Tamil Nadu, South Asia

INTRODUCTION

The genus *Poa* L. (Linnaeus, 1753) belongs to the subfamily Pooideae, supertribe Poodae, tribe Poeae and subtribe Poinae (Soreng & al., 2017) consists 580 species (Soreng & al., 2020) and distributed worldwide in Temperate to Subarctic & Subantarctic and Mountains of Tropics (Clayton & al., 2020). In India, out of 67 taxa (64 spp., 02 subsp. and 01 var. (Prasanna & al., 2020) of *Poa* known to occur, 5 species are reported from Tamil Nadu (Kabeer & Nair, 2009) -*P. annua* L., *P. gamblei* Bor, *P. nemoralis* L., *P. stapfiana* Bor and *P. trivialis* L. Intensive plant explorations at Kodaikanal WLS, Palni Hills (Western Ghats), Tamil Nadu conducted under the BSI action plan project, yielded a taxon of *Poa*, hitherto unidentified and not reported. Critical study on morphological characters, thorough characterization, herbaria consultation, literature survey (Richard, 1850; Clayton, 1970; Phillips, 1989; Soreng & al., 2020) and type specimen consultation, confirmed the specimen as *Poa leptoclada* Hochst. ex A. Rich. Incidentally, Matthew (1999) collected 13 specimen of *Poa* from Palni Hills. Though his provided description and illustration resemble the

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sl.no. 03

J. Jpn. Bot. **97**(4): 203–206 (2022)

Lectotypification of the Names of *Poa stapfiana* (*Poaceae*) and Its Variety

Ruma Bhadra[1], P. V. Prasanna[2], K. Althaf Ahamed Kabeer[3] and Saikat Naskar[4,*]

[1]Botanical Survey of India, Central National Herbarium,
P.O. Botanic Garden, Howrah, West Bengal, 711103 INDIA;
[2]C-109, Cyber-e-park, Alkapur, Puppalaguda Manikonda, Hyderabad, Telangana, 500089 INDIA;
[3]Botanical Survey of India, Central Botanical Laboratory,
P.O. Botanic Garden, Howrah, West Bengal, 711103 INDIA;
[4]Department of Botany, The University of Burdwan, West Bengal, 713104 INDIA
*Corresponding author: saikatnaskar@rediffmail.com

(Accepted on April 25, 2022)

The new name *Poa stapfiana* Bor (*Poaceae*) was proposed for a later homonym *P. tremula* Stapf, non Lam. Bor also proposed a new combination of the variety *P. stapfiana* var. *micranthera* (Stapf) Bor based on *P. tremula* var. *micranthera* Stapf. The names of *P. stapfiana* Bor and *P. stapfiana* var. *micranthera* (Stapf.) Bor are lectotypified here from original material for their precise application.

Key words: India, lectotype, *Poa stapfiana*, *Poa stapfiana* var. *micranthera*.

Poa stapfiana Bor (1949: 239) is widely distributed from Iran and Pakistan to the Eastern Himalayas, including Nepal and Tibet (Clayton et al. 2021) though Zhu et al. (2006) could not confirm its occurrence in Tibet may be in the absence of any recent collections. Zhu et al. (2006) placed this species under *Poa* L. sect. *Homalopoa* Dumort., which was later shifted to *Poa* subgen. *Poa* supersect. *Homalopoa* (Dumort.) Soreng & L.J. Gillespie (Gillapsie et al. 2007: 432). Zhu et al. (2006) stated that *P. stapfiana* has a close affinity with *P. himalayana* Steudel (1854: 256) and *P. hirtiglumis* Hook.f. (1896: 343). The main difference between *P. stapfiana* and *P. himalayana* is that the former one has a longer ligule whereas the latter one has a very short ligule. In addition, *P. stapfiana* mainly differs from *P. hirtiglumis* by having lower glume shorter than the lowest lemma and leaf sheath shorter than leaf blade, whereas, in *P. hirtiglumis*, the lower glume and leaf sheath is longer than the lowest lemma and leaf blade, respectively.

Stapf (1896) described *P. tremula* Stapf and its variety *P. tremula* var. *micranthera* Stapf. The species was based on the collections mentioned in the protologue as "TEMPERATE & ALPINE HIMALAYA; from Kashmir, alt. 8–15000 ft., *Jacquemont*, &c., to Garwhal, *Duthie*. WESTERN TIBET; Ladak, *Thomson, Schlagintweit*". Stapf also indicated the specimens as "P. altaica, *Munro in Herb. Jacquemont* (n. 277). P. nepalensis, & nemoralis, *Herb. Ind. Or. Hf. & T. (in part)*. P. trivialis *Griseb. in Goett. Nachr.* (1868) 75;

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Lectotypification of names of three species of *Poa* (Poaceae) and their morphological affinities

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Abstract

Poa aitchisonii, *P. falconeri* and *P. wardiana* are lectotypified with nomenclatural notes. In absence of proper icons with analysis, worked out plant parts of two species from voucher specimens are provided as photoplates. Due to high degree of variability and in absence of concrete morphological features to distinguish species, morphological affinities of the three species with that of other close species are provided.

Keywords: India, lectotypification, *Poa aitchisonii, P. falconeri*, *P. wardiana*

Introduction:

With over 500 species, the *Poa* Linnaeus (1753: 67) is one of the largest genus within Poaceae. Gillespie & Soreng (2005) indicated 575 species of *Poa* which are distributed worldwide in temperate, boreal, and arctic habitats and in many regions a high degree of its endemism is evident. According to Clayton *et al.* (2020+), 63 species of *Poa* occur in Indian subcontinent of which 13 species are endemic to this region. Bor (1952a, 1952b) reported 49 species of *Poa* in his revisionary work on the genus in India where he included some species which occur nearing the border areas of India in other countries (Afghanistan, Bhutan, China, Nepal and Pakistan) to assume that sooner or later these species will be recorded from Indian territory as there has no physical barrier to prevent their dispersal. In India, the species of *Poa*, mainly occur in high altitudes of Himalaya, Khashi hills and Western Ghats.

After a gap of almost 70 years, we have initiated revisionary work on *Poa* in India under the *Flora India Project*. In the meantime some works (Chowdhery & Wadhwa 1984, Karthikeyan *et al.* 1989, Gaur & Nautiyal 1995, Gaur & Nautiyal 1996, Hajra & Verma 1996, Gaur & Nautiyal 1997, Kandwal *et al.* 2003, Kandwal & Gupta 2009, Nautiyal & Gaur 2017) also focused on the species of *Poa* in India without sufficient detailing especially for nomenclatural issues and typification. Besides, Rajbhandari (1991) also dealt with Himalayan *Poa* and provided a descriptive and illustrative account of the species but did not explicitly cite the type specimens of the names except for few without proper justifications. Recently, Kellogg *et al.* (2020) have prepared a 'Checklist of the grasses of India' but it lacks any new lectotype designation of the species of *Poa*.

The widespread occurrences of apomixis and introgression in *Poa* make it a taxonomic difficult genus (Bor 1952a). Soreng (1990) assumed that many species are possibly of hybrid origin. Extensive polyploidy and hybridization added to a few useful morphological characters making *Poa* taxonomically very complicated (Gillespie & Soreng 2005). Gillespie & Boles (2001) also found significant infraspecific cpDNA variation in some species. Hitherto, no morphological basis of classification of *Poa* of the world is available since no one person involved in the revision of the *Poa* from the world (Gillespie & Soreng 2005). Bor (1952a) proposed 14 sections of Indian *Poa* based on morphological parameters. Gillespie & Soreng (2005) recognized three subgenera within *Poa* to make the genus monophyletic based on a molecular phylogenetic study. They take into consideration only 98 species and significant omission of Indian taxa. Consequently, the species of *Poa* in India are principally unplaced in phylogenies.

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Биология и экология гидробионтов

УДК 504.064.36:574

PHYTOPLANKTON-BASED BIOMONITORING IN ASSESSING THE POLLUTION LEVEL OF A LENTIC FRESHWATER BODY IN HOOGHLY DISTRICT, WEST BENGAL, INDIA

© 2020 S. Pore[1], S. Ghosh[2], J. P. Keshri[3], S. S. Barinova[4]*

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[2]Mahadevananda Mahavidyalaya of the West Bengal State University, India
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Abstract. Phytoplankton is the base of every aquatic food web. During the assessment of the trophic status of the investigated lentic water body (within Lake City Housing Complex, Mankundu, Hooghly, West Bengal, India), phytoplankton composition and its temporal variation are proved to be the most important. In this study, 30 phytoplankton taxa have been recorded in various arrangements throughout the season. The maximum number of phytoplankton species with the highest Shannon–Weaver diversity index value represented the pre-monsoon season, whereas the least number of phytoplankton taxa and the lowest diversity indicators characterized the post-monsoon season. The development of algal bloom by one specific taxon, *Botryococcus braunii*, in the post-monsoon season indicates the change in the trophic status of this particular water body. As a criterion for the beginning of the algal bloom, an exceedance of 1 mg/L in nitrate concentration can be considered. The phytoplankton composition, values of various diversity indices, its density and species distribution pattern, and selected environmental parameters have been investigated, as well as the results of the analysis of rank abundance curves, which allowed for evaluation of the ecological status of this lentic water body. This study describes the change or shift in the ecosystem of the investigated water body towards eutrophication and establishes its pollution level as moderate to light.

Keywords: phytoplankton, diversity, biomonitoring, climatic seasons, West Bengal, India

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Effective lectotypification of three names in *Poa* (Poaceae), proposed by N.L. Bor

Ruma Bhadra[1], Saikat Naskar[2,*], Althaf A. Kabeer[3] & Parigi V. Prasanna[4]

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Bhadra R., Naskar S., Kabeer A.A. & Prasanna P.V. 2023: Effective lectotypification of three names in *Poa* (Poaceae), proposed by N.L. Bor. — *Ann. Bot. Fennici* 60: 197–201.

Poa asperifolia Bor, *P. lhasaensis* Bor and *P. nitidespiculata* Bor are lectotypified (second-step lectotypification), as Norman L. Bor cited gatherings rather than a single specimen as their type. Notes are given to clarify the rationale of the second-step lectotypifications.

The genus *Poa* (Poaceae) comprises over 580 species (Soreng *et al.* 2020) distributed worldwide from temperate to subarctic and subantarctic zones, and in the mountains of the tropics (https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:30001404-2). Norman Loftus Bor (1893–1972), an Irish-born British botanist who served in Indian Forest Service from 1921 to 1948 (Stafleu & Mennega 1993), described 16 genera, 188 species and 25 infraspecific taxa in the family Poaceae, including 31 species in *Poa*, 20 of which are from India (https://www.ipni.org/?f=f_specific&q=family%3APoaceae%7Cgenus%3APoa%7Cname%20author%3ABor). While revising the genus *Poa* in India, we found that three *Poa* species described by Bor, *viz. P. asperifolia*, *P. lhasaensis* and *P. nitidespiculata*, required a second-step lectotype designation according to Art. 9.17 of Turland *et al.* (2018), as Bor indicated gatherings rather than a single specimen as their type. We obtained the protologues from BHL (https://www.biodiversitylibrary.org). Information on Bor and his collections were obtained from TL-2 (https://www.sil.si.edu/DigitalCollections/tl-2/browse.cfm?vol=9#page/337). Type specimens from CAL (sheets), DD (sheets) and K (digital images) were consulted. Lectotypes (second-step) were designated following Turland *et al.* (2018). Herbarium acronyms follow *Index Herbariorum* (https://sweetgum.nybg.org/science/ih/).

Poa asperifolia Bor

Kew Bull. 7: 130. 1952. — Type: China. Xizang, Pemba La, 10–15 miles north of Lhasa, September 1904 *H.J. Walton s.n.* — Lectotype (designated here): K barcode K000789517 image! (Fig. 1); isolectotypes: CAL barcodes CAL0000002469! & CAL0000033988!, K barcodes K000789516 image! & K000789518 image!.

Bor (1952: 130) described *P. asperifolia* based

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Improved thermoelectric performance of nanostructured Bi_2Te_3 fabricated by solvent-free mechanical alloying

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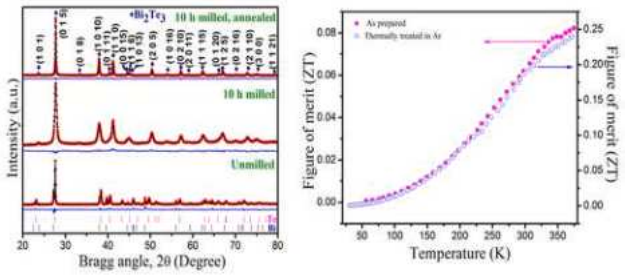
HIGHLIGHTS

- Nanostructured Bi_2Te_3 has been synthesized by facile mechanical alloying method.
- Microstructures of the samples are characterized by XRD and FESEM.
- The semiconducting nature of the sample changes to metallic after annealing.
- Grain growth and associated band gap reduction is noticed after annealing at 573K.
- About three times increase in thermoelectric figure of merit owing to annealing.

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Nanostructures
Microstructure
X-ray diffraction
Thermoelectrics

ABSTRACT

Thermoelectric materials convert waste heat energy efficiently to electricity in an eco-friendly manner. Bi_2Te_3 is a known thermoelectric material, which can convert waste heat and solar energy into electricity in the 200–400 K temperature range. Bi_2Te_3 nanocrystals are prepared in powder form by solvent-free mechanical alloying of elemental Bi and Te powder mixtures under an inert Ar atmosphere. The crystallite size and composition of the Bi_2Te_3 nanocrystals are analyzed using X-ray diffraction, field-emission scanning electron microscope and energy-dispersive X-ray spectroscopy. Thermal and electrical behaviours and the effect of thermal annealing are studied on the 10 h ball-milled sample in a physical properties measurement system in the 30–375 K temperature range. It is observed that the high-temperature thermal annealing induces significant grain growth, reduces lattice strain, along with a reduction of bandgap energy of the mechanically alloyed Bi_2Te_3 nanostructures. Thermoelectric properties and the figure of merit of the nanostructures have improved significantly upon thermal annealing. Enhanced thermoelectric performance of the annealed nanostructures has been explained considering the change in their thermal conductivity, electrical resistivity, and crystallite size induced by thermal treatment.

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Grain size mediated electrical and thermoelectric performances of mechanically alloyed Sb_2Te_3 nanoparticles

Shrabani Paul [a], Umapada Pal [b], Swapan Kumar Pradhan [a, *]

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Thermoelectric properties

ABSTRACT

Antimony telluride (Sb_2Te_3) nanoparticles of different sizes were fabricated by mechanical alloying (MA) of elemental Sb and Te powers for different durations. The powder nanostructures were pelletized, annealed in Ar ambient, and characterized by XRD, FESEM, TEM to study the effect of milling time and thermal treatment on particle size, grain growth, and crystallinity. The annealed and unannealed pelletized nanostructures were analyzed in a PPMS to study the effect of grain growth on their electrical and thermoelectric properties. Room temperature electrical conductivity of the p-type semiconductor nanostructures improved significantly (from ~10^3 to ~ 10^5 mho/m) due to thermal annealing and results in the considerable improvement in thermoelectric figure of merit (ZT). Thermal annealing-induced grain growth also transforms the semiconducting nature of the sample to metallic. The reduced thermal conductivity of the nanostructures with reduced grain size improves the ZT. The temperature-dependent Lorenz number ($L_{effective}$) is used to find the electronic contribution of total thermal conductivity, and it is explained by the non-parabolic Kane model.

1. Introduction

Thermoelectric materials are efficient converters of waste heat into useable electrical energy due to their high Seebeck coefficients [1,2]. Thermoelectric figure of merit ZT defines the performance of a thermoelectric material in converting thermal energy to electricity. The ZT is defined as, $ZT = S^2\sigma T/K$, where S,σ, and K represent the Seebeck coefficient, electrical conductivity, the thermal conductivity of the material, respectively, and T is the temperature in K [3]. The $S^2\sigma$ term is defined as the power factor. Owing to the demand for alternative energy sources, the quest for new materials with an improved figure of merit (ZT) has increased globally at a rapid rate [4,5].

In general, semiconductors are better thermoelectric materials compared to metals [6]. According to Wiedemann-Franz law [7], most metals have a nearly constant electrical to thermal conductivity ratio, and increasing electrical conductivity is difficult without increasing their thermal conductivity. However, a good ZT value requires a high electrical conductivity and simultaneously a lower thermal conductivity. Hence, for metals or metallic alloys, the only possible way to obtain a significant figure of merit is to have a high value of the Seebeck coefficient. Unfortunately, most metals show very small Seebeck coefficients (~10 μV/K), and their thermoelectric efficiencies are only fractions of a percent. On the other hand, semiconductors with comparatively higher Seebeck coefficient values (~100 μV/K) had drawn strong attention as thermoelectric materials since 1920 [8]. Low bandgap semiconductors possess high electrical conductivity, comparable to metals. Compared to bulk materials, nanomaterials have low thermal conductivity because of lower lattice thermal conductivity resulting from the increased phonon scattering due to smaller grain size [9–12]. Thus, nanostructured semiconductors of smaller bandgaps are considered the most favorable thermoelectric materials as they produce a reasonably higher figure of merit values.

Antimony telluride (Sb_2Te_3), a low bandgap semiconductor, has been considered as one of the promising thermoelectric materials for low-temperature applications [13–15]. Nano-structured Sb_2Te_3 thin films fabricated by physical vapor deposition [16], metal-organic chemical vapor deposition [17,18], thermal co-evaporation [19], flash evaporation [20], electrochemical method [21], ion beam sputtering [22], molecular beam epitaxy [23] etc. have shown good thermoelectric conversion efficiency. On the other hand, single-phase Sb_2Te_3 nanoparticles synthesized by microwave-assisted

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Microstructural, electrical and mechanical characterizations of green-synthesized biocompatible calcium phosphate nanocomposites with morphological hierarchy

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sl.no. 55

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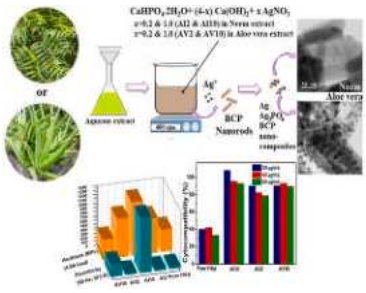
[b] Materials Science Division, Dept. of Physics, The University of Burdwan, Golapbag, Burdwan, 713104, India
[c] Department of Biotechnology, National Institute of Technology, Durgapur, 713209, India

HIGHLIGHTS

- Ag–Ag_3PO_4-BCP nanocomposites hydrothermally synthesized in neem and aloe vera media.
- Epitaxial attachments of metallic phases to mesoporous uniaxial BCP nanorods.
- Biocompatibility and stability up to high dosage for 72 h studied on healthy cells.
- High interfacial polarization and surface charge retention ability for osteoconduction.
- Bulk porosity and unique structure-dependent dielectric and mechanical properties.

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Nanocomposites
Electron microscopy
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Dielectric properties
Impedance
Mechanical properties

ABSTRACT

The present work reports the development of novel ternary silver-silver phosphate-biphasic calcium phosphate nanocomposites by plant-extract mediated hydrothermal route. Unique epitaxial morphological growth of the Ag–Ag_3PO_4 core-shell structure influences the internal grain-grain boundary arrangement. The green-assisted development of the constituent phases helps significant biocompatibility enhancement (~89–93% for 50 μg/mL; 72 h). Hence long-term bone-replacement purposes and polar fluid osmosis are favorable due to higher cell attachment on the rough surface of the mesoporous nanocomposites. The heterogeneous attachment between the three phases creates defect states indicating intense interfacial polarization, as elucidated by the dielectric spectroscopic studies. The surface charge essential for bone regeneration is likely to be developed. Besides, the porous nanocomposite compacts exhibit superior phase-composition-dependent mechanical (Hardness ~1.3 GPa; load 4.9 N) and dielectric properties (permittivity ~1.2×10^3; 200 Hz, 613 K) helping in conduction through bones. Thus the green-synthesized ternary nanocomposites exhibit the essential aspects of a promising bone-implant material.

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Available online 27 December 2022

THE UNIVERSITY OF BURDWAN
Department of Physics

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Senior Scientific Officer
Senior Member, URSI; Fellow, IETE; Member, ASI; IGNSS
Chairman, IETE Burdwan Sub Centre
Principal Investigator, ITR-DRDO sponsored Project
Convenor, Industry-Institute Partnership Cell (IIPC)

The University of Burdwan
Vice-Chancellor's Secretariat
Receiving Section
Memo No. 164 Date 31/3/21
Received by

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Memo No.-FI
Received By
Date

sl.no. 56

No: AB/ 2021/17

Date: 31 March, 2021

To
The Registrar
The University of Burdwan
Rajbati, Burdwan 713 104

Through: Head of the Department of Physics, The University of Burdwan

Sub: Offer from M/S NTLab, Belarus for providing hardware support for Research

Dear Sir,

This is for your kind information and necessary action please. M/S NTLab having their Head Office at 4th floor, 41 Surganova str., 220013 Minsk, Republic of Belarus is a major manufacturer of GNSS hardware including NavIC. We have contact with M/S NTLab as a vendor and knowing our expertise in the field of GNSS/ NavIC research, they offered for collaborative research and signing of MoU. The proposal for signing of MoU has been sent to Govt of West Bengal for necessary approval.

Recently, M/S NTLab has sent us an offer to provide us few hardware free of cost as a part of active cooperation (email dt 26 March, 2021 is attached along with). They have offered us to provide NTL 102.1, NTL 103.1, NTL 107 and NTL Eva Boards complimentarily for research. In a subsequent email dt 30 March, 2021 they also offered to pay the delivery cost. For the purpose we only need to send them a formal letter requesting for free samples of the above-mentioned modules.

It would be beneficial for us and the researchers if we get the modules for our research because, as of now, NTLab is the only manufacturer of L5+S Band compact NavIC modules and the cooperation would support our research. In this respect, I would request you to:

Kindly approve the proposal for receiving the complimentary hardware from M/S NTLab, so that I can send the formal letter requesting them to send free samples of the modules.

I hope, you will kindly consider the proposal and would permit us favourably.

With best regards,

Sincerely Yours
Anindya Bose
(Anindya Bose)

DR ANINDYA BOSE
SENIOR SCIENTIFIC OFFICER
DEPARTMENT OF PHYSICS
BURDWAN UNIVERSITY, GOLAPBAG
BURDWAN-713 104, INDIA

Enclo: a.a.

31.03.2021.
Professor & Head
Department of Physics
The University of Burdwan
Burdwan-713104

Hon'ble V.C.
'A'. May be permitted.
31.03.2021.

F.O.
Please opine
31.03.21

Physics Department, Burdwan University, Golapbag, Burdwan 713 104, INDIA
Cell: +91 94 34 00 44 78, FAX: +91 342 2530 452
Email: abose@phys.buruniv.ac.in; anibose@gmail.com; Twitter : @dranibose
Web : http://bugnss.in

NTLab is a fabless microelectronic company located at Belarus. As University policy permits free offer of foreign company with no liability, may be permitted as proposed.
31.03.21
Hon'ble Vice-Chancellor pl.

Place before E.C.
31.03.21

SL NO. 31

THE UNIVERSITY OF BURDWAN

Extract from the minutes of the meeting of the Executive Council held on 17.07.2020

Item no-74

To consider the application of Dr Anindya Bose, Senior Scientific Officer, Department of Physics to consider the proposal for signing of Memorandum of Understanding and Collaboration with M/S NTLabsUAB, LITHUANIA for collaborative research work in radionavigation.

Resolution

The Council considered the application of Dr Anindya Bose, Senior Scientific Officer, Department of Physics to consider the proposal for signing of Memorandum of Understanding and Collaboration with M/S NTLabsUAB, LITHUANIA for collaborative research work in radionavigation. It was resolved that the proposal of signing of Memorandum of Understanding and Collaboration with M/S NTLabsUAB, LITHUANIA for collaborative research work in radionavigation be approved in principle and the matter be referred to the Higher Education Department, Govt. of West Bengal for necessary permission for the purpose.

Draft for approval

17.07.2020

Registrar (officiating) & Secretary
Executive Council

Dr. Anindya Bose

20/07/2020

Approved

17.07.2020

Vice-Chancellor & Chairman
Executive Council

SL NO. 56

NTLab IC

DATE	INVOICE NO
August 24, 2021	IC-D01-210824
DATE	**PURCHASE ORDER NO**
21 April, 2021	AB/ 2021/19

Invoice

RECIPIENT:

Department of Physics, University of Burdwan,
Golapbag, Burdwan 713104, West Bengal, INDIA
Attn.: Dr. Anindya Bose
Tel: M: +91 6295766760/ 9434004478

SHIPPER:

NTLab-IC, LLC
Tax ID number:191060307
415, No. 41, Surganova Str., 220013 Minsk, Republic of Belarus
Tel.: +375 17 300 0408
Fax: +375 17 300 0444

No.	DESCRIPTION	HS CODE	Q-TY, pc.	UNIT PRICE, USD	TOTAL, USD	NET WEIGHT Per pc, kg	TOTAL WEIGHT, kg NET	TOTAL WEIGHT, kg GROSS	BOX NO.
							NET	GROSS	
2	Promo sample of Demonstration Kit HTMP.468993.073 NTL107.2	8529909700	1	5.00	5.00	0.06	0.06	0.26	
		GRAND TOTAL			5.00		0.06	0.26	1

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TERMS AND CONDITIONS:

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Payment terms: FREE PROMO SAMPLES.
Country of origin: Belarus
Marking: NTLab
Reason for export: final shipment according to the "Request for free promo samples" No. AB/ 2021/19 dated 2 April, 2021 for using in the university as promotional demonstration sample.

I declare that the cargo transferred according to this invoice, are packed and handed over to the carrier in compliance with all safety rules This cargo does not contain objects and substances that are prohibited for transportation by an aircraft (explosives, firearms and ammunition radioactive, corrosive, depriving of viability or capacity substances). The contents of the consignment fully comply with the enclose documents. We are aware that incorrectly provided data on the nature of the cargo may be subject to administrative and criminal liability. I case of the dangerous goods transportation, all substances and components are declared in accordance with ICAO and IATA regulations. Th airline or its agent has the right to inspect the cargo for hidden dangerous goods, request additional documents or refuse to transport th incorrectly declared cargo.

Production Deputy Director Sergei Reutovich

РЕСПУБЛИКА БЕЛАРУСЬ ОБЩЕСТВО С ОГРАНИЧЕННОЙ ОТВЕТСТВЕННОСТЬЮ «НТЛаб-ИС» г. МИНСК