

3.3.1 Number of research papers published per teacher in the Journals notified on UGC website during the last five years

Title of paper	Name of the author/s	Year of publication	ISSN number	Link to the recognition in UGC enlistment of the Journal /Digital Object Identifier (doi) number	
				Link to website of the Journal	Link to article / paper / abstract of the article
Vulnerability Aspects of Urban Flooding	Shritidhara kashyap (Co-author Dr. Ratul Mahanta)	2018 - 19	2322-0430	https://ijed.in/	https://www.indianjournals.com/ijor.aspx?target=ijor:ijed1&volume=14&issue=3&article=025
Estimating risk of breast cancer occurrences at different ages: Application of survival techniques	Dr. Nijara Rajbongshi	2018 - 19	1513-7368	http://journal.waocp.org/	http://journal.waocp.org/article_73827.html
Analysis of morphological features of benign and malignant breast cell extracted from FNAC microscopic image using the pearsonian system of curves	Dr. Nijara Rajbongshi	2018 - 19	0970-9371 / E-ISSN:0974-5165	https://www.jcytol.org/	https://www.jcytol.org/article.asp?issn=0970-9371;year=2018;volume=35;issue=2;spage=99;epage=104;aulast=Rajbongshi;type=0
Empowering Women Weavers by Up-Gradation of Handloom Industry of Assam through Microfinance	Dr. Dipti Baishya	2019 - 20	2278-3075	https://www.ijitee.org/	https://www.ijitee.org/wp-content/uploads/papers/v8i12/L31021081219.pdf
Traditional Cloth Production Techniques in Assam	Fancy Chutia	2020 - 21	2249-8958	https://www.ijeat.org/download/volume-9-issue-4/	https://www.ijeat.org/portfolio-item/d6490049420/
Marriage System in the Tribes of Assam with special mention to Missing, Tiwa and Karbi	Fancy Chutia	2020 - 21	2277-8616	http://www.ijstr.org/	http://www.ijstr.org/final-print/mar2020/Marriage-System-In-The-Tribes-Of-Assam-With-Special-Mention-To-Mising-Tiwa-And-Karbi.pdf
Influence of Ram Katha on Conventional Folk Literature of Assamese Society	Fancy Chutia	2020 - 21	2277-8616	http://www.ijstr.org/	http://www.ijstr.org/final-print/mar2020/Influence-Of-Ramkatha-On-Conventional-Folk-Literature-Of-Assamese-Society.pdf

Assamese Language as a Medium of Education-A Brief Analysis with Past, Present and Future Aspects of Social Condition of Assamese Society	Fancy Chutia	20 20 -	2277- 8616	http://www.ijs-tr.org/	https://www.ijstr.org/final-print/mar2020/Assamese-Language-As-A-Medium-Of-Education-A-Brief-Analysis-With-Past-Present-And-Future-Aspect-Of-Social-Condition-Of-Assamese.pdf
Studies on some Indigenous Herbal Medicine used against Jaundice in Goalpara district of Assam	Dr. Dipali Deka (Co-Author: G. C. Sarma)	20 20 -	0970- 3586	https://connectjournals.com/archives.php?bookmark=CJ-002857	https://connectjournals.com/achivestoc2.php?fulltext=3277601H_C_h-22_81.pdf&&bookmark=CJ-002857&&issue_id=01-02&&yaer=2020
Algal Diversity in Chandubi Beel, a Tectonic Water Body of North East India	Soumin Nath (Co-Author: Partha Pratim Baruah)	20 20 -	0976- 5069 (Print), 2455- 376X (Online)	http://www.nelumbo-bi.org/	http://www.nelumbo-bi.org/index.php/nlumbo/article/view/152221
Algal diversity in Deepor Beel of Assam: a Ramsar site of North East India	Soumin Nath (Co-Authors: Partha Pratim Baruah, Bishmita Boruah, Himamani Kalita and Shaswatee Bhattacharjee)	20 20 -	0976- 5069 (Print), 2455- 376X (Online)	www.nelumbo-bi.org	http://www.nelumbo-bi.org/index.php/nlumbo/article/view/153155
A Taxonomic Account on Phytoplankton of Rudrasagar Ramsar Site, Tripura (India): Chlorophyta and Euglenophyta	Soumin Nath (Co-Authors: Partha Pratim Baruah and Himamani Kalita)	20 20 -	0019- 4468 (Print), 2455- 7218 (Online)	www.indianjournals.com	https://www.indianjournals.com/ijor.aspx?target=ijor:jibs&volume=100&issue=3and4&article=001
Understanding Rurality in Salpara and Rowmari Village of Goalpara District of Assam from a Socio-	Samar Medhi (Co-authors Linso	20 20 -	2394- 3114	http://www.tpsindia.org/index.php/sipn	http://www.tpsindia.org/index.php/sipn/article/view/200

Economic Perspective	Timungpi)				
Contemplating Unregulated Growth of Brick Kiln: A Case Study of Dudhnoi Zone	Samar Medhi (Co-authors Linso Timungpi)	20 20 - 21	0971-765X	http://www.envirobiotechjournals.com/journal_details.php?jid=4	http://www.envirobiotechjournals.com/article_abstract.php?aid=11037&iid=322&jid=3
Beliefs and Practices Centering Round Silk Rearing and Weaving in Assam	Dr. Mridutpal Goswami	20 20 - 21	2347-7180	Printed version only	Printed version only
Cartesian Product of Automata	Mridul Dutta (Co-Authors: Sanjoy Kalita and Helen K. Saikia)	20 20 - 21	1857-8365 (Print); 1857-8438 (Online)	https://www.research-publication.com/amsj/	https://www.research-publication.com/amsj/uploads/papers/vol-09/iss-10/AMSI-2020-N10-25.pdf
Spatial Distribution pattern of Jhum cultivation and Land use Land cover status in Amri Block of Karbi Anglong District, Assam	Rashmi Sarkar	20 20 - 21	1567-214X	https://archives.palarch.nl/index.php/jae/index	https://archives.palarch.nl/index.php/jae/article/view/5006/4925
Iron Work Tradition in Assam	Dr. Mridutpal Goswami	20 20 - 21	2454-3837	https://sampritipublication.com/	https://drive.google.com/file/d/1TviqD-vYbiOMShx7fqiQ4hnaGylKr_9W/view?pli=1
The Strategy of Exhaustion and Intimidation: The British East India Company and the North East Frontier of India (1826-1857)	Dr. Sandipan Pathok	20 21 - 22	2454-3837	http://sampritipublication.com/	https://drive.google.com/file/d/1A9v14FRVxl9njKR53yAO4ocmvd tu6UJr/view
Ethno-Medicinal Herbs used for hair-care in Goalpara District of Assam: An Observation	Dr. Dipali Deka (Co-Author: G. C. Sarma)	20 21 - 22	0970-3586	https://connectjournals.com/archives.php?bookmark=CJ-002857	https://connectjournals.com/achivestoc.php?bookmark=CJ-002857&volume=34&year=2021&issue_id=01-02&issue_month=Jan-Dec
Checklist of phytoplankton of the foot hill belt of Arunachal Himalayas	Soumin Nath (Co-Author: Partha Pratim Baruah)	20 21 - 22	2278-7666	www.ajcb.in	https://www.ajcb.in/journals/full_papers_july_2021/AJCB-Vol10-No1-66497_Nath-Baruah.pdf
Foreign Direct Investment and Economic Development	Subhas Chandra Barman	20 21 -	0975-1386	http://www.wesleyanjournal.in/	

		22			
Indicator of Development : Per Capita Income to Human Development Index	Subhas Chandra Barman	20 21 - 22	1309-4653 (Online)	https://www.turcomat.org/index.php/turkbilmat	https://www.turcomat.org/index.php/turkbilmat/article/view/9178
Shifting Cultivation in relation to slope pattern and elevation in Karbi Anglong District of Assam	Rashmi Sarkar	20 21 - 22	0971-765X	http://www.envirobiotechjournals.com/	http://www.envirobiotechjournals.com/article_abstract.php?aid=11363&iid=329&jid=3
Radhakrishnan's Philosophy of Religion, an Analysis	Dr. Nilamoni Dutta	20 21 - 22	0975-1386	http://www.wesleyanjournal.in/	Print version only
Socio-economic Status and Drawback of Banana Growers: A Review on Asia's Largest Banana Market Daranggiri, Goalpara, Assam, India	Samar Medhi	20 21 - 22	0971-765X	http://www.envirobiotechjournals.com/journal_details.php?jid=3	http://www.envirobiotechjournals.com/article_abstract.php?aid=11787&iid=337&jid=3
Jiten Dekar Geetot Jatiyotabodh aaru Xomonoir Xur : Aek Obolokon	Raja Ram Rabha	20 22 - 23	2347-7180	Print Version only	Print Version only
Dhrupodi Bhaxar Morjyoda aaru Axomiya Bhaxa: Aek Bikhlekhonatomok Adhyan	Fancy Chutia	20 22 - 23	2347-7180	Print Version only	Print Version only
Bohurongi Geetot Sthaniyo Xamaj-Xangskritir Protichobi	Jahnabi Das	20 22 - 23	2347-7180	Dogo Rangsang Research Journal (print only) (Current Table of Content)	Print Version only
Understanding the Socio-ecological Drivers of Sand Mining and their Impact on Kulsi River, Assam, India	Samar Medhi	20 22 - 23	0971-765X	http://www.envirobiotechjournals.com/journal_details.php?jid=3	http://www.envirobiotechjournals.com/article_abstract.php?aid=12401&iid=348&jid=3
Automata on Genetic Structures	Mridul Dutta (Co-Authors: Sanjoy Kalita and Helen K. Saikia)	20 22 - 23	2382-9761 (Print), 2423-3447 (Online)	http://as.yazd.ac.ir/	http://as.yazd.ac.ir/article_2468.html
On the Diophantine Equation $7^x + 32^y = z^2$ and its Generalisation	Mridul Dutta (Co-Author: Padma	20 22 - 23	1553-1732 (Online)	http://math.colgate.edu/~integers/	http://math.colgate.edu/~integers/w29/w29.pdf

	Bhushan Borah)				
Automata in Chinese Remainder Theorem	Mridul Dutta (Co-Author: Helen K. Saikia)	20 22 - 23	0976-5905 (Print), 0975-8607 (Online)	https://www.rgnpublications.com/journals/index.php/cma	https://www.rgnpublications.com/journals/index.php/cma/article/view/1704
On Two Classes of Exponential Diophantine Equations	Mridul Dutta (Co-Author: Padma Bhushan Borah)	20 22 - 23	0976-5905 (Print), 0975-8607 (Online)	https://www.rgnpublications.com/journals/index.php/cma	https://www.rgnpublications.com/journals/index.php/cma/article/view/1676
Graphs in Automata	Mridul Dutta (Co-Authors: Sanjoy Kalita and Helen K. Saikia)	20 22 - 23	2090-729X (Online)	http://math-frac.org/Journals/EJMAA/	http://math-frac.org/Journals/EJMAA/Vol10(2) July 2022/Vol10(2) Papers/9)%20%20Vol.%2010(2)%20Jul.%202022,%20pp.%20105-114.pdf
Automata Rings	Mridul Dutta (Co-Author: Helen K. Saikia)	20 22 - 23	0972-7752 (Print), 2582-0850 (Online)	http://rsmams.org/journals/seajmams/home	http://rsmams.org/download/articles/2_1_8_1_762113840_AUTOMATA%20RINGS.pdf
Groundwater Arsenic Contamination in Different Parts of the World: A Hidden Health Threat	Rashmi Sarkar (Co-author Tirthankar Sarma, Pradi p Chandra Kalita)	20 22 - 23	ISSN 0044-0477	http://ymerdigital.com/	http://ymerdigital.com/archives/?cpage=4&issId=2109
Automata on Genetic Code	Mridul Dutta (Co-Authors: Sanjoy Kalita and Padma Bhushan Borah)	20 22 - 23	ISSN 2321-4635	https://pubs.thesciencein.org/journal/index.php/jist	https://pubs.thesciencein.org/journal/index.php/jist/article/view/474
ON THE SOLUTION OF A CLASS OF EXPONENTIAL DIOPHANTINE EQUATIONS	Mridul Dutta (Co-Author: Padma Bhushan Borah)	20 22 - 23	0972-7752 (Print), 2582-0850 (Online)	http://rsmams.org/journals/seajmams/home	http://rsmams.org/journals/articleinfo.php?articleid=760&tag=seajmams

SIMULATION OF TRANSMISSION OF HEAT ON VISCOUS FLUID FLOW WITH VARYING TEMPERATURES OVER A FLAT PLATE	Bamdeb Dey, Jintu Mani Nath, Tusar Kanti Das and Dimbeswar Kalita	20 22 - 23	P- ISSN: 0973- 5763	http://www.phmj.com/journals/jphmt.htm	http://dx.doi.org/10.17654/0973576322052
Numerical investigation on the thermal transportation of MHD Cu/Al ₂ O ₃ -H ₂ O Casson-hybrid-nanofluid flow across an exponentially stretching cylinder incorporating heat source	Ashish Paul, Tusar Kanti Das AND JINTU MANI NATH	20 22 - 23	0031-8949 - 1402-4896	https://iopscience.iop.org/journal/1402-4896	https://iopscience.iop.org/article/10.1088/1402-4896/ac7981/meta
An annotated checklist of cyanobacterial flora in Rudrasagar Ramsar site, Tripura, India	Soumin Nath (Co-author)	20 22 - 23	2278-7666	https://www.ajcb.in/	https://doi.org/10.53562/ajcb.76998
Algal Diversity in riparian lentic habitats of Brahmaputra Valley	Soumin Nath (Co-author)	20 22 - 23	0976-5069,2 - 455-376X	https://nelumbo-bis.org/	https://nelumbo-bis.org/index.php/nlmbis/issue/current
Dhrupadi Bhakhar Maryada aaru Axomiya Bhakha: Ek Bislekanatmak Adhyan	Fancy Chutia	20 22 - 23	2347-7180	https://www.journal-dogorangsang.in/	print version available only
Bharatiya Dhrupadi Bhakha- Ek Somu Bislekhan, Dwibhasik Rastrasewak	Fancy Chutia	20 22 - 23	2321-4945	Print Version only	print version available only
Covid-19 Pandemic and Indian Education System	Nabanita Borah	20 22 - 23	0976-6510	https://rbu.ac.in/home/page/103	Print version available only
Impact of Employment of Women on Nutritional Status of Children: A Study in Guwahati City of Assam	Debashree Kashyap	20 22 - 23	0974-5114	https://cswnn.edu.in/perspectives-in-social-work	https://cswnn.edu.in/perspectives-in-social-work
The Roll of Goalpara Zilla Boro Baro DAL: An Analytical Study	Purna Ch. Khakhalary	20 22 - 23	0972-7175	Print version only	Print version only
Dalit Movements in India: Problems and Prospects	Bondita Borbora	20 22 - 23	0970-7247	https://www.thirdconceptjournal.com/index.html	https://www.thirdconceptjournal.com/index.html

GRAPHS IN AUTOMATA

M. DUTTA, S. KALITA, H. K. SAIKIA

ABSTRACT. A graph consists of some points and lines called vertices and edges. It is a mathematical representation of a network in which edges represent the existence of a particular relation among the vertices. Automata is a five tuple consisting of a set of states, inputs, outputs, one transition function, and one output function between these three sets. In this paper, an attempt is made to study automata with the help of the properties of graphs. For two given automation, with the help of the operations, viz. addition, union, intersection, complement, ring sum, product, and composition of graphs, another automaton is derived. The objective is to identify and analyze the automaton obtained. In the study, some connections are observed between various automata produced as well as between the adjacency matrix of the graph, and outputs of the automaton.

1. INTRODUCTION

An automaton is a system that spontaneously gives an output from an input. The input may be energy, information, materials, etc. The system works without the intervention of man. Simply, an automaton (plural: automata or automatons) is a self-operating machine. Its synonym is ROBOT. The term “automation” was invented by an engineer named D.S. Harder, in the automobile industry, in about 1946 to describe the increased use of automatic devices and controls in mechanized production lines. The term is used widely in the context of manufacturing. It is also used in which there is a significant substitution of mechanical, electrical, or computerized action for human effort and intelligence. Finite state automata are significant in many different areas, including Electrical Engineering, Linguistics, Computer Science, Philosophy, Biology, Mathematics, and Logic.[6,7] In computer science, finite state machines are widely used in modelling application behavior, designing hardware digital systems, software engineering, compilers, network protocols, and the study of computation and language. The number of possible states of the automaton, and hence the amount of information it implicitly stores, is finite. Therefore, the automaton is a finite-state automaton. In this paper, the objective is to relate graphs and automata and to study some uses of graphical properties on automata.

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2. PRELIMINARIES

A *finite state automaton* consists of a finite set of states and a set of transitions from state to state that occur on input symbols from a set of alphabets. An *alphabet* is a finite, non-empty set of symbols denoted by A , e.g. $A = \{0, 1\}$, the set of binary alphabets. A *string* (or word) is a finite sequence of symbols chosen from the set A , e.g. 01101, 01, 1, 0 are some strings over an alphabet $A = \{0, 1\}$. An *automata* is a quintuples of the type $\Sigma = (Q, A, B, F, G)$, where Q is a finite set of states, A is a finite set of inputs, B is a finite set of outputs, $F : Q \times A \rightarrow Q$ and $G : Q \times Q \rightarrow B$ are functions usually known as state *transition function* and *output function* respectively.[2,5]

A *graph* $G(V, E)$ consists of a non-empty set of objects V called set of *vertices/nodes* and a set E called set of —it edges/arcs whose elements belong to the set $V \times V$. If $(u, v) \in E$, then we say that u and v are adjacent in G . If each edge of a graph G has a direction then the graph is called *directed* graph. If each edge of the graph G has no direction, the graph is said to be —it undirected graph. A *loop* is an edge (v_i, v_i) . A graph without loops and multiple edges is called a *simple* graph. A graph with a finite number of vertices as well as a finite number of edges is called a *finite* graph; otherwise, it is called an *infinite* graph.[1]

A graph that contains only an isolated node is called a *null* graph. The number of edges that are incident on the vertex is called the *degree* of the vertex. In a graph, if all vertices have the same degree, then it is called a *regular* graph. A simple graph, G is said to be *complete* if every vertex in G is connected with every other vertex. A *walk* is defined as a finite alternative sequence of vertices and edges. An *open walk* in which no vertex appears more than once is called a simple *path*. The cycle C_n , $n \leq 3$, is a closed path of n vertices and n edges. A matrix $A = [a_{ij}]$ of a labeled graph G with p points is the $n \times n$ matrix is called *adjacency matrix* in which $a_{ij} = 1$ if v_i is adjacent with v_j and $a_{ij} = 0$ otherwise.[1]

The *complement* G of \bar{G} is defined as a simple graph with the same vertex set as G and where two vertices u and v adjacent only when they are not adjacent in G . Let $G_1 = G(V_1, E_1)$ and $G_2 = G(V_2, E_2)$ be two graphs. Union of graphs G_1 and G_2 denoted by $G_1 \cup G_2$ is a graph $G = G(V, E)$ such that $V = V_1 \cup V_2$ and $E = E_1 \cup E_2$. Intersection of graphs G_1 and G_2 with at least one vertex in common, denoted by $G_1 \cap G_2$ is a graph $G = G(V, E)$ such that $V = V_1 \cap V_2$ and $E = E_1 \cap E_2$. Sum of graphs G_1 and G_2 , denoted by $G_1 + G_2$ is a graph $G = G(V, E)$ such that $V = V_1 \cup V_2$ and $E = E_1 \cup E_2 \cup \{(u, v) : u \in V_1, v \in V_2\}$. The ring sum of G_1 and G_2 , denoted by $G_1 \oplus G_2$ is the graph $G = G(V, E)$ such that $V = V_1 \cup V_2$ and $E = E_1 \cup E_2 - E_1 \cap E_2$. The product $G_1 \times G_2$ of graphs G_1 and G_2 is a graph $G = G(V, E)$, where any two points $u = (u_1, u_2)$ and $v = (v_1, v_2)$ in $V = V_1 \times V_2$ are adjacent in $G_1 \times G_2$ whenever $[u_1 = v_1 \text{ and } u_2 \text{adj. } v_2]$ or $[u_2 = v_2 \text{ and } u_1 \text{adj. } v_1]$. The composition $G_1 [G_2]$ also has $V = V_1 \times V_2$ and $u = (u_1, u_2)$ and $v = (v_1, v_2)$ in $V = V_1 \times V_2$ are adjacent whenever $u_1 \text{adj. } v_1$ or $(u_1 = v_1 \text{ and } u_2 \text{adj. } v_2)$. [1]

3. MAIN WORK (GRAPH OPERATIONS ON AUTOMATON)

Let $G_1 = G(V_1, E_1)$ and $G_2 = G(V_2, E_2)$ be two graphs. Applying automata theory to these two graphs, G_1 and G_2 and using graph operations viz. addition, union, intersection, complement, ring sum, product and composition of graphs on two automata, another automaton is derived.

Illustration: In this section, the impact of some graph operations on some automata are studied. Two automata are considered for two cycles C_3 and C_4 and an effort is made to define a new automata using some graphical operations and the effect of these operations are studied on the derivation of the new automata.[3,8]

Automaton on C_4 :

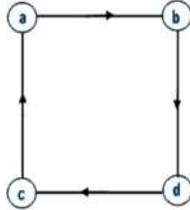


Fig. 1: Cycle C_4

Let us consider the finite state machine [2,5] for the above cycle C_4 is given by $\Sigma_1 = (Q_1, A_1, B_1, F_1, G_1, a)$ where $Q_1 = \{a, b, c, d\}$, $A_1 = \{1, 2, 3, 4\}$, $B_1 = \{0, 1\}$, a is the initial state,

the transition map $F_1 : Q_1 \times A_1 \rightarrow Q_1$ is defined by

$$F_1(a, 1) = b, F_1(a, 2) = c, F_1(a, 3) = -, F_1(a, 4) = -, F_1(b, 1) = a, F_1(b, 2) = -, F_1(b, 3) = -, F_1(b, 4) = d, F_1(c, 1) = -, F_1(c, 2) = a, F_1(c, 3) = d, F_1(c, 4) = -, F_1(d, 1) = -, F_1(d, 2) = -, F_1(d, 3) = c, F_1(d, 4) = b$$

and the output function $G_1 : Q_1 \times Q_1 \rightarrow B_1$ defined by

$$G_1(a, a) = 0, G_1(a, b) = 1, G_1(a, c) = 1, G_1(a, d) = 0, G_1(b, a) = 1, G_1(b, b) = 0, G_1(b, c) = 0, G_1(b, d) = 1, G_1(c, a) = 1, G_1(c, b) = 0, G_1(c, c) = 0, G_1(c, d) = 1, G_1(d, a) = 0, G_1(d, b) = 1, G_1(d, c) = 1, G_1(d, d) = 0$$

where 1 indicates that there is a path between the states and 0 indicates that there is no path between the states.

Table 1 : Transition table and Output table of C_4

F_1	1	2	3	4
a	b	c	-	-
b	a	-	-	d
c	-	a	d	-
d	-	-	c	b

G_1	a	b	c	d
a	0	1	1	0
b	1	0	0	1
c	1	0	0	1
d	0	1	1	0

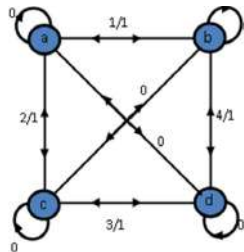


Fig. 2: State diagram of C_4

Automaton on C_3 :

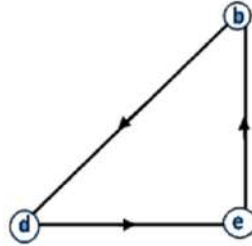


Fig. 3: State diagram of C_3

Let us consider the finite state machine for the above cycle C_3 is given by $\Sigma_2 = (Q_2, A_2, B_2, F_2, G_2, e)$ where $Q_2 = \{b, d, e\}$, $A_2 = \{4, 5, 6\}$, $B_2 = \{0, 1\}$, e is the initial state,

the transition map $F_2 : Q_2 \times A_2 \rightarrow Q_2$ is defined by

$$F_2(b, 4) = d, F_2(d, 4) = b, F_2(e, 4) = -, F_2(b, 5) = -, F_2(d, 5) = e, F_2(e, 5) = d, F_2(b, 6) = e, F_2(d, 6) = -, F_2(e, 6) = b$$

the output function $G_2 : Q_2 \times Q_2 \rightarrow B_2$ defined by

$$G_2(b, b) = 0, G_2(d, b) = 1, G_2(e, b) = 1, G_2(b, d) = 1, G_2(d, d) = 0, G_2(e, d) = 1, G_2(b, e) = 1, G_2(d, e) = 1, G_2(e, e) = 0$$

where 1 indicates that there is a path between the states and 0 indicates that there is no path.

Table 2 : Transition table and Output table of C_3

F_2	4	5	6
b	d	-	e
d	b	e	-
e	-	d	b

G_2	b	d	e
b	0	1	1
d	1	0	1
e	1	1	0

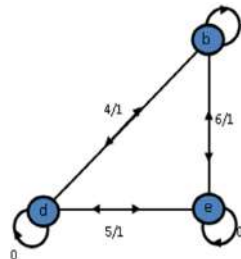


Fig. 4: State diagram of C_3

Automaton on $C_4 \cup C_3$:

The finite automata $C_4 \cup C_3$ can be obtained by using the union operation of graphs.

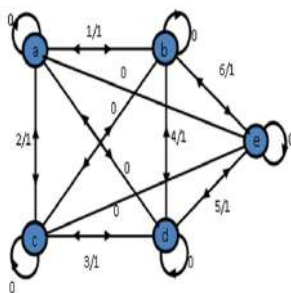


Fig. 5: State diagram of $C_4 \cup C_3$

Table 3 : Transition table and Output table of $C_4 \cup C_3$

F	1	2	3	4	5	6
a	b	c	-	-	-	-
b	a	-	-	d	-	e
c	-	a	d	-	-	-
d	-	-	c	b	e	
e	-	-	-	-	d	b

G	a	b	c	d	e
a	0	1	1	0	0
b	1	0	0	1	1
c	1	0	0	1	0
d	0	1	1	0	1
e	0	1	0	1	0

Automaton on $C_4 \cap C_3$:

The finite automata $C_4 \cap C_3$ can be obtained by using the intersection operation of graphs.

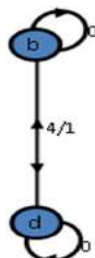


Fig. 6: State diagram of $C_4 \cap C_3$

Table 4 : Transition table and Output table of $C_4 \cap C_3$

F	1	2	3	4	5	6
a	-	-	-	-	-	-
b	-	-	-	d	-	-
c	-	-	-	-	-	-
d	-	-	-	b	-	-
e	-	-	-	-	-	-

G	a	b	c	d	e
a	0	0	0	0	0
b	0	0	0	1	0
c	0	0	0	0	0
d	0	1	0	0	0
e	0	0	0	0	0

Automaton on $\overline{C_3}$:

The finite automata $\overline{C_3}$ can be obtained by using the complement operation of graphs as follows

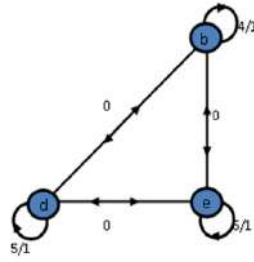


Fig. 7: State diagram of $\overline{C_3}$

Table 5 : Transition table and Output table of $\overline{C_3}$

F	4	5	6
b	b	-	-
d	-	d	-
e	-	-	e

G	b	d	e
b	1	0	0
d	0	1	0
e	0	0	1

Automaton on $C_3 \cup \overline{C_3}$:

The finite automata of $C_3 \cup \overline{C_3}$ is given by

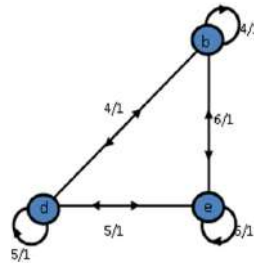


Fig. 8: State diagram of $C_3 \cup \overline{C_3}$

Table 6 : Transition table and Output table of $C_3 \cup \overline{C_3}$

F	4	5	6
b	d, b	-	e
d	b	e, d	-
e	-	d	b, e

G	b	d	e
b	1	1	1
d	1	1	1
e	1	1	1

Automaton on $C_4 \cup \overline{C_4}$:

The finite automata of $C_4 \cup \overline{C_4}$ can be obtained by using the union operation of graphs.

Automaton on $C_4 + C_3$:

The finite automata $C_4 + C_3$ can be obtained by using the addition operation of graphs.

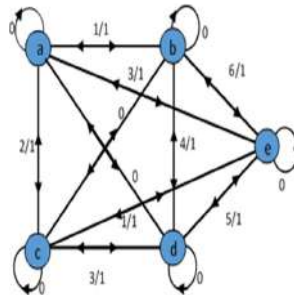


Fig. 9 : State diagram of $C_4 + C_3$

Table 7 : Transition table and Output table of $C_4 + C_3$

F	1	2	3	4	5	6
a	b	c	e	-	-	-
b	a	-	-	d	-	e
c	e	a	d	-	-	-
d	-	-	c	b	e	-
e	c	-	a	-	d	b

G	a	b	c	d	e
a	0	1	1	0	1
b	1	0	0	1	1
c	1	0	0	1	1
d	0	1	1	0	1
e	1	1	1	1	0

Automaton on $C_4 \oplus C_3$:

The finite automata $C_4 \oplus C_3$ can be obtained by using the ring sum operation of graphs.

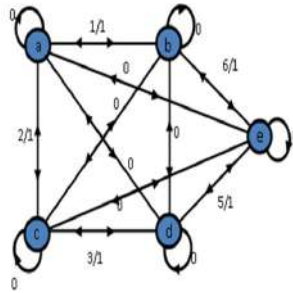


Fig. 10: State diagram of $C_4 \oplus C_3$

Table 8 : Transition table and Output table of $C_4 \oplus C_3$

F	1	2	3	4	5	6
a	b	c	-	-	-	-
b	a	-	-	-	-	e
c	-	a	d	-	-	-
d	-	-	c	-	e	-
e	-	-	-	-	d	b

G	a	b	c	d	e
a	0	1	1	0	0
b	1	0	0	0	1
c	1	0	0	1	0
d	0	0	1	0	1
e	0	1	0	1	0

Automaton on $C_4 \times C_3$:

The automata $C_4 \times C_3$ can be obtained by using the product operation of graphs as follows

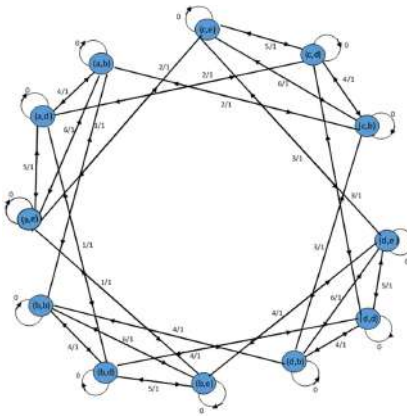


Fig. 11: State diagram of $C_4 \times C_3$

Table 9 : Transition table of $C_4 \times C_3$

F	1	2	3	4	5	6
(a, b)	(b, b)	(c, b)	-	(a, d)	-	(a, e)
(a, d)	(b, d)	(c, d)	-	(a, b)	(a, e)	-
(a, e)	(b, e)	(c, e)	-	-	(a, d)	(a, b)
(b, b)	(a, b)	-	-	(b, d), (d, b)	-	(b, e)
(b, d)	(a, d)	-	-	(b, b), (d, d)	(b, e)	-
(b, e)	(a, e)	-	-	(d, e)	(b, d)	(b, b)
(c, b)	-	(a, b)	(d, b)	(c, d)	-	(c, e)
(c, d)	-	(a, d)	(d, d)	(c, b)	(c, e)	-
(c, e)	-	(a, e)	(d, e)	-	(c, d)	(c, b)
(d, b)	-	-	(c, b)	(b, b), (d, d)	-	(d, e)
(d, d)	-	-	(c, d)	(d, b), (b, d)	(d, e)	-
(d, e)	-	-	(c, e)	(b, e)	(d, d)	(d, b)

Table 10 : Output table of $C_4 \times C_3$

G	(a, b)	(a, d)	(a, e)	(b, b)	(b, d)	(b, e)	(c, b)	(c, d)	(c, e)	(d, b)	(d, d)	(d, e)
(a, b)	0	1	1	1	0	0	1	0	0	0	0	0
(a, d)	1	0	1	0	1	0	0	1	0	0	0	0
(a, e)	1	1	0	0	0	1	0	0	1	0	0	0
(b, b)	1	0	0	0	1	1	0	0	0	1	0	0
(b, d)	0	1	0	1	0	1	0	0	0	0	1	0
(b, e)	0	0	1	1	1	0	0	0	0	0	0	1
(c, b)	1	0	0	0	0	0	0	1	1	1	0	0
(c, d)	0	1	0	0	0	0	1	0	1	0	1	0
(c, e)	0	0	1	0	0	0	1	1	0	0	0	1
(d, b)	0	0	0	1	0	0	1	0	0	0	1	1
(d, d)	0	0	0	0	1	0	0	1	0	1	0	1
(d, e)	0	0	0	0	0	1	0	0	1	1	1	0

Automaton on $C_4 [C_3]$:

The finite automata $C_4 [C_3]$ can be obtained by using the composition operation of graphs.

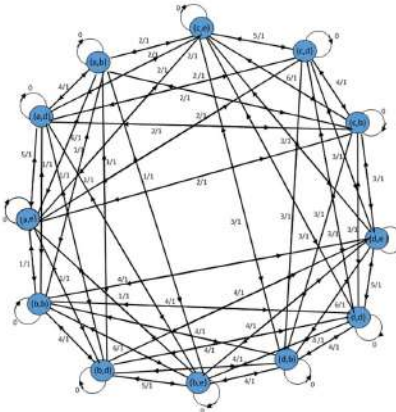


Fig. 12: State diagram of $C_4 [C_3]$

Table 11 : Transition table of $C_4 [C_3]$

F	1	2	3	4	5	6
(a, b)	(b, b), (b, d), (b, e)	(c, b), (c, d), (c, e)	-	(a, d)	-	(a, e)
(a, d)	(b, b), (b, d), (b, e)	(c, b), (c, d), (c, e)	-	(a, b)	(a, e)	-
(a, e)	(b, b), (b, d), (b, e)	(c, b), (c, d), (c, e)	-	-	(a, d)	(a, b)
(b, b)	(a, b), (a, d), (a, e)	-	-	(b, d), (d, b), (d, d), (d, e)	-	(b, e)
(b, d)	(a, b), (a, d), (a, e)	-	-	(b, b), (d, b), (d, d), (d, e)	(b, e)	-
(b, e)	(a, b), (a, d), (a, e)	-	-	(b, b), (d, b), (d, d), (d, e)	(b, d)	(b, b)
(c, b)	-	(a, b), (a, d), (a, e)	(d, b), (d, d), (d, e)	(c, d)	-	(c, e)
(c, d)	-	(a, b), (a, d), (a, e)	(d, b), (d, d), (d, e)	(c, b)	(c, e)	-
(c, e)	-	(a, b), (a, d), (a, e)	(d, b), (d, d), (d, e)	-	(c, d)	(c, b)
(d, b)	-	-	(c, b), (c, d), (c, e)	(b, b), (b, d), (b, e), (d, d)	-	(d, e)
(d, d)	-	-	(c, b), (c, d), (c, e)	(b, b), (b, d), (b, e), (d, b)	(d, e)	-
(d, e)	-	-	(c, b), (c, d), (c, e)	(b, b), (b, d), (b, e)	(d, d)	(d, b)

Table 12 : Output table of $C_4 [C_3]$

G	(a, b)	(a, d)	(a, e)	(b, b)	(b, d)	(b, e)	(c, b)	(c, d)	(c, e)	(d, b)	(d, d)	(d, e)
(a, b)	0	1	1	1	1	1	1	1	1	0	0	0
(a, d)	1	0	1	1	1	1	1	1	1	0	0	0
(a, e)	1	1	0	1	1	1	1	1	1	0	0	0
(b, b)	1	1	1	0	1	1	0	0	0	1	1	1
(b, d)	1	1	1	1	0	1	0	0	0	1	1	1
(b, e)	1	1	1	1	1	0	0	0	0	1	1	1
(c, b)	1	1	1	0	0	0	0	1	1	1	1	1
(c, d)	1	1	1	0	0	0	1	0	1	1	1	1
(c, e)	1	1	1	0	0	0	1	1	0	1	1	1
(d, b)	0	0	0	1	1	1	1	1	1	0	1	1
(d, d)	0	0	0	1	1	1	1	1	1	1	0	1
(d, e)	0	0	0	1	1	1	1	1	1	1	1	0

4. OBSERVATIONS

From above, it is seen that the graph-theoretic properties are applicable to automata and are helpful in deriving new automata from two known automata. It is also observed that the graphical representation of the resultant automaton contains the given automata as its subgraphs. From $C_4 \cup C_3 \subseteq C_4 \oplus C_3 \subseteq C_4 + C_3$, it is noted that the automaton obtained from the union is contained by the automaton obtained from the ring sum, and both of them are contained by the automaton obtained from the sum of the graphs. The output table of the resulting automaton can be obtained from the adjacency matrix of its graph.

5. FUTURE WORK AND DISCUSSION

From the above study, it is clear that there is a broad field of study on automata with other properties of the graph. With the help of the adjacency matrix and its eigenvalues, non-linear dynamical systems (automata) can be studied. A directed graph, on the other hand, will help to understand the direction of the transition in a finite automaton. So, there is a broad scope of study awaiting in this direction that can bring automata and graph theory together.[3,4]

6. CONCLUSION

Automata and graph theory both have great applications in different branches of science, viz., computer science, networking, communication, transportation, robotics, etc. So if a connection can be established between them, then it can be very helpful in studying various topics with the help of each other in all those branches where there are many applications. It is seen from the study that there is definitely a connection between graph theory and automata, and further study will bring out more fruitful results.

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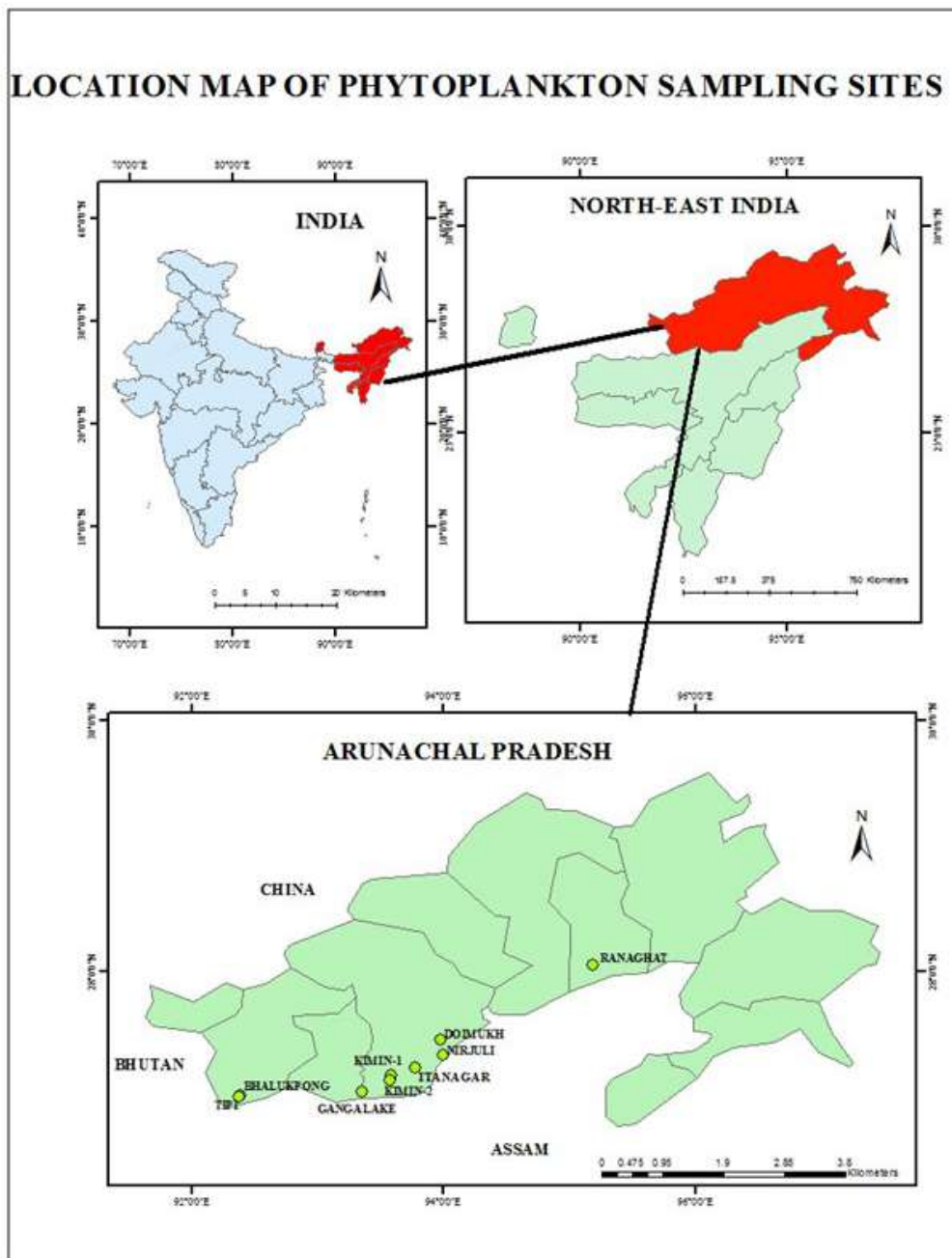


Figure 1. Map of Arunachal Himalaya showing phytoplankton sampling sites.

RESULTS

The current list contains one hundred and sixteen phytoplankton taxa belonging to six different algal phyla. With 34 taxa, Chlorophyta was the richest phylum followed by Charophyta (31), Bacillariophyta (27), Euglenozoa (14), Cyanobacteria (6) and Ochrophyta (4) respectively.

The top five species rich families of phytoplankton in this checklist were Desmidiaceae (19), Scenedesmaceae (13), Closteriaceae (11), Phacidae (9) and Hydrodictyaceae (7) respectively (Table 1). The top six species-rich genera were *Closterium*, *Cosmarium*, *Gomphonema*, *Pinnularia*, *Phacus* and *Trachelomonas* (Table 2).

Table 1. Top five species rich families of phytoplankton in foot hill belt of Arunachal Himalayas

Top 5 species-rich families		
Family	No. of Genera	No. of Species
Desmidiaceae	5	19
Scenedesmaceae	6	13
Closteriaceae	1	11
Phacidae	2	9
Hydrodictyaceae	6	7

Table 2. Top six species rich genera of phytoplankton in foot hill belt of Arunachal Himalayas

Top 6 species-rich Genera	
Genus	No. of Species
<i>Closterium</i>	11
<i>Cosmarium</i>	11
<i>Gomphonema</i>	5
<i>Pinnularia</i>	5
<i>Phacus</i>	5
<i>Trachelomonas</i>	5

Checklist:

The taxon names were systematically arranged for each record along with the information on place (s) of collection and previous report(s) from the region.

PHYLUM-BACILLARIOPHYTA**Family - Aulacoseiraceae**

1 Genus, 1 Species

Aulacoseira granulata (Ehrenberg) Simonsen 1979: 58 (Pl. 1, Fig. 1)

Previous report- Das and Adhikary (2012)

Place of Collection- Ganga lake (27°4' 33' N 93°34' 8' E)

Family - Bacillariaceae

1 Genus, 2 Species

Nitzschia reversa W.Smith 1853: 43, pl. 15: fig. 121 (Pl. 1, Fig. 2)

First record from Arunachal Pradesh

Place of Collection- Bhalukpong (27°01' 04' N 92°38' 17E), Doimukh (27°8' 52' N 93°45' 13' E)

Nitzschia umbonata (Ehrenberg) Lange-Bertalot 1978: 648, pls 1, 2, 4 (Pl. 1, Fig. 3)

First record from Arunachal Pradesh

Place of Collection- Ranaghat (28°5' 57' N 95°18' 24E)

Family - Catenulaceae

1 Genus, 1 Species

Amphora ovalis (Kützing) Kützing 1844: 107, pl. 5: figs 35, 39 (Pl. 1, Fig. 4)

First record from Arunachal Pradesh

Place of Collection- Tipi (27°01' 51' N 92°36' 59E), Doimukh (27°8' 52' N 93°45' 13' E)

Family - Cymbellaceae

1 Genus, 1 Species

Cymbella parva (W.Smith) Kirchner 1878: 118 (Pl. 1, Fig. 5)

First record from Arunachal Pradesh

Place of Collection- Ganga lake (27°4' 33' N 93°34' 8' E)

Family - Diadesmidaceae

1 Genus, 1 Species

Diadesmis confervacea Kützing 1844: 109, pl. 30: fig. 8 (Pl. 1, Fig. 6)

Previous report- Das and Adhikary (2012), Das (2016)

Place of Collection- Itanagar (27°4' 52' N 93°35' 39' E), Ranaghat (28°5' 57' N 95°18' 24E)

Family - Eunotiaceae

1 Genus, 2 Species

Eunotia bilunaris (Ehrenberg) Schaarschmidt in Kanitz 1880: 159 (Pl. 1, Fig. 7)

First record from Arunachal Pradesh

Place of Collection- Tipi (27°01' 51' N 92°36' 59E)

Eunotia naegelii Migula 1905: 203 (Pl. 1, Fig. 8)

First record from Arunachal Pradesh

Place of Collection- Bhalukpong (27°01' 04' N 92°38' 17E), Doimukh (27°8' 52' N 93°45' 13' E)

Family - Fragilariaceae

1 Genus, 1 Species

Fragilaria tenera (W.Smith) Lange-Bertalot 1980: 746 (Pl. 1, Fig. 9)

Previous report- Das and Adhikary (2012)

Place of Collection- Ranaghat (28°5' 57' N 95°18' 24E)

Family - Gomphonemataceae

2 Genera, 6 Species

Gomphonema affine Kützing 1844: 86, pl. 30: fig. 54 (Pl. 1, Fig. 10)

Previous report- Das (2016)

Place of Collection- Nirjuli (27°7' 56' N 93°44' 48' E)

Gomphonema hebridense W.Gregory 1854: 99, pl. 4: fig. 19 (Pl. 1, Fig. 11)

First record from Arunachal Pradesh

Place of Collection- Ganga lake (27°4' 33' N 93°34' 8' E), Itanagar (27°4' 52' N 93°35' 39' E)

Gomphonema lagenula Kützing 1844: 85, pl. 30: fig. 60 (Pl. 1, Fig. 12)

First record from Arunachal Pradesh

Place of Collection- Kimin (27°18' 4' N 93°58' 15' E), Ganga lake (27°4' 33' N 93°34' 8' E)

Gomphonema pseudoaugur Lange-Bertalot 1979: 202, figs 11-16 (Pl. 1, Fig. 13)

First record from Arunachal Pradesh

Place of Collection- Nirjuli (27°7' 56' N 93°44' 48' E)

Gomphonema pseudosphaerophorum H.Kobayashi in Ueyama & H.Kobayashi 1988: 452, pl. 1: figs 1-10 (Pl. 1, Fig. 14)

First record from Arunachal Pradesh

Place of Collection- Kimin (27°18' 13' N 93°58' 6' E)

Placoneis molestissima Metzeltin, Lange-Bertalot & García-Rodríguez (Pl. 1, Fig. 15)

First record from Arunachal Pradesh

Place of Collection- Tipi (27°01' 51' N 92°36' 59E)

Family - Melosiraceae

1 Genus, 1 Species

Melosira aequalis C.Agardh 1832: 64, no fig. (Pl. 1, Fig. 16)

First record from Arunachal Pradesh

Place of Collection- Nirjuli (27°7' 56' N 93°44' 48' E)

Family - Naviculaceae

1 Genus, 1 Species

Gyrosigma scalpoides (Rabenhorst) Cleve 1894: 118 (Pl. 1, Fig. 17)

First record from Arunachal Pradesh

Place of Collection- Kimin (27°18' 13' N 93°58' 6' E), Itanagar (27°4' 52' N 93°35' 39' E)

Family - Pinnulariaceae

1 Genus, 5 Species

Pinnularia acrosphaeria W.Smith 1853: 58, pl. XIX [19]: fig. 183 (Pl. 1, Fig. 18)

First record from Arunachal Pradesh

Place of Collection- Nirjuli (27°7' 56' N 93°44' 48' E)

Pinnularia interrupta W.Smith 1853: 59, pl. 19: fig. 184 (Pl. 1, Fig. 19)

Previous report- Das and Adhikary (2012)

Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E)
Pinnularia latarea Krammer 2000: 110, 224, pl. 80: figs 1-6; pl. 84: figs 13-15 (Pl. 1, Fig. 20)
 First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 13" N 93°58' 6" E)
Pinnularia subsimilis H.P.Gandhi (Pl. 1, Fig. 21)
 Previous report- Das and Adhikary (2012)
 Place of Collection- Nirjuli (27°7' 56" N 93°44' 48" E)
Pinnularia viridis (Nitzsch) Ehrenberg 1843: 305, 315 (adnot.), 385 [pl. 1: fig. 7] (Pl. 1, Fig. 22)
 Previous report- Das and Adhikary (2012)
 Place of Collection- Bhalukpong (27°01' 04" N 92°38' 17E), Itanagar (27°4' 52" N 93°35' 39" E)

Family - Rhopalodiaceae

1 Genus, 1 Species
Epithemia gibba (Ehrenberg) Kützing 1844: 35, pl. 4, fig. 22 (Pl. 1, Fig. 23)
 First record from Arunachal Pradesh
 Place of Collection- Nirjuli (27°7' 56" N 93°44' 48" E)

Family - Stephanodisceae

1 Genus, 1 Species
Discostella stelligera (Cleve & Grunow) Houk & Klee 2004: 208 (Pl. 1, Fig. 24)
 Previous report- Das and Adhikary (2012)
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E)

Family - Ulnariaceae

1 Genus, 3 Species
Ulnaria amphirhynchus (Ehrenberg) Compère & Bukhtiyarova in Bukhtiyarova & Compère 2006: 280 (Pl. 1, Fig. 25)
 Previous report- Das and Adhikary (2012)
 Place of Collection- Ranaghat (28°5' 57" N 95°18' 24E)
Ulnaria delicatissima (W.Smith) Aboal & P.C.Silva 2004: 361 (Pl. 1, Fig. 26)
 Previous report- Das and Adhikary (2012)
 Place of Collection- Ranaghat (28°5' 57" N 95°18' 24E)
Ulnaria ulna (Nitzsch) Compère 2001: 100 (Pl. 1, Fig. 27)
 First record from Arunachal Pradesh
 Place of Collection- Bhalukpong (27°01' 04" N 92°38' 17E)

PHYLUM-CHAROPHYTA

Family - Closteriaceae

1 Genus, 11 Species
Closterium aceromum Ehrenberg ex Ralfs 1848: 164, pl. XXVII [27]: fig. 2 a, b, d-e (Pl. 1, Fig. 28)
 Previous report- Das (2016)
 Place of Collection- Nirjuli (27°7' 56" N 93°44' 48" E)
Closterium bitangchoianum J.P.Keshri & D.Das in D.Das & J.P.Keshri 2016: 68, pl. XVIII [18]: figs 337, 338 (Pl. 1, Fig. 29)
 First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 13" N 93°58' 6" E)
Closterium gracile Brébisson ex Ralfs 1848: 221, pl. XXI [21]: figs 8-12 (Pl. 1, Fig. 30)
 First record from Arunachal Pradesh
 Place of Collection- Nirjuli (27°7' 56" N 93°44' 48" E)
Closterium incurvum Brébisson 1856: 150, pl. 2: fig. 47 (Pl. 1, Fig. 31)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E)
Closterium kuetzingii Brébisson 1856: 156, pl. 2: fig. 40 (Pl. 1, Fig. 32)

First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 13" N 93°58' 6" E)
Closterium lunula Ehrenberg & Hemprich ex Ralfs 1848: 163, pl. XXVII [27]: fig. 1 (Pl. 1, Fig. 33)
 First record from Arunachal Pradesh
 Place of Collection- Nirjuli (27°7' 56" N 93°44' 48" E), Itanagar (27°4' 52" N 93°35' 39" E)
Closterium navicula (Brébisson) Lütkenmüller 1905: 337 (Pl. 1, Fig. 34)
 Previous report- Das (2016)
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E)
Closterium pritchardianum f. *attenuatum* Irénée-Marie 1954: 38, pl. II [2]: fig. 5 (as '*attenuata*') (Pl. 1, Fig. 35)
 First record from Arunachal Pradesh
 Place of Collection- Nirjuli (27°7' 56" N 93°44' 48" E)
Closterium pseudocynthia J.P.Keshri & D.Das in D.Das & J.P.Keshri 2016: 83, pl. XX [20]: figs 365, 366 (Pl. 1, Fig. 36)
 First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 4" N 93°58' 15" E)
Closterium rostratum Ehrenberg ex Ralfs 1848: 175, pl. XXX [30]: fig. 3 (Pl. 1, Fig. 37)
 First record from Arunachal Pradesh
 Place of Collection- Nirjuli (27°7' 56" N 93°44' 48" E), Itanagar (27°4' 52" N 93°35' 39" E)
Closterium submoniliferum var. *malinvernianum* (De Notaris) Coesel in Coesel & Meesters 2007: 53, pl. 15: fig. 5 (Pl. 1, Fig. 38)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E)

Family - Desmidiaceae

5 Genera, 19 Species
Cosmarium forceps Brühl & Biswas 1926: 286, pl. 15: fig. 86 (Pl. 1, Fig. 39)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Kimin (27°18' 4" N 93°58' 15" E), Itanagar (27°4' 52" N 93°35' 39" E)
Cosmarium lundellii Delponte 1877: 13, pl. 7: figs 62-64 (Pl. 1, Fig. 40)
 First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 4" N 93°58' 15" E)
Cosmarium lundellii var. *ellipticum* West & G.S.West 1894: 5, pl. I [1]: fig. 11 (Pl. 2, Fig. 41)
 First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 13" N 93°58' 6" E)
Cosmarium norimbergense Reinsch 1867: 117, pl. 22: figs A-IV: 1-11 (Pl. 2, Fig. 42)
 First record from Arunachal Pradesh
 Place of Collection- Bhalukpong (27°01' 04" N 92°38' 17E)
Cosmarium norimbergense var. *depressum* (West & G.S.West) Willi Krieger & Gerloff 1969: 292, pl. 48: fig. 1 (Pl. 2, Fig. 43)
 First record from Arunachal Pradesh
 Place of Collection- Tipi (27°01' 51" N 92°36' 59E)
Cosmarium porteanum f. *pseudoporteanum* J.P.Keshri & D.Das in D.Das & J.P.Keshri 2016: 116, pl. VI [6]: figs 187, 188 (Pl. 2, Fig. 44)
 First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 13" N 93°58' 6" E)
Cosmarium pseudoretusum var. *inaequalipellucum* (West & G.S.West) Willi Krieger & Gerloff 1962: 97, pl. 20: fig. 20 (Pl. 2, Fig. 45)
 First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 4" N 93°58' 15" E)
Cosmarium regnellii Wille 1884: 16, pl. I [1]: fig. 34 (Pl. 2, Fig. 46)

Previous report- Das (2016)

Place of Collection- Tipi (27°01' 51"N 92°36' 59"E), Ganga lake (27°4' 33"N 93°34' 8"E)

Cosmarium regnesi Reinsch 1866: 116, pl. XXII [22]: A; III [3] (Pl. 2, Fig. 47)

First record from Arunachal Pradesh

Place of Collection- Ganga lake (27°4' 33"N 93°34' 8"E)

Cosmarium rosae Ruzicka 1949: 84, figs 1-9; pl. XV [15] (Pl. 2, Fig. 48)

First record from Arunachal Pradesh

Place of Collection- Kimin (27°18' 4"N 93°58' 15"E)

Cosmarium undulatum f. *reductum* Croasdale 1956: 59, pl. 3: fig. 9 (as '*var. alaskanum* f. *reductum*') (Pl. 2, Fig. 49).

First record from Arunachal Pradesh

Place of Collection- Ganga lake (27°4' 33"N 93°34' 8"E)

Euastrum denticulatum var. *quadrifarium* Willi Krieger 1937: 585, pl. 80: figs 20, 21 (Pl. 2, Fig. 50)



Photo plate 1. Fig. 1. *Aulacoseira granulata* 2. *Nitzschia revers* 3. *Nitzschia umbonata* 4. *Amphora ovalis* 5. *Cymbella parva* 6. *Diadesmis confervacea* 7. *Eunotia bilunaris* 8. *Eunotia naegelii* 9. *Fragilaria tenera* 10. *Gomphonema affine* 11. *Gomphonema hebridense* 12. *Gomphonema lagenula* 13. *Gomphonema pseudoaugur* 14. *Gomphonema pseudosphaerophorum* 15. *Placoneis molestissima* 16. *Melosira aequalis* 17. *Gyrosigma scalproides* 18. *Pinnularia acrosphaeria* 19. *Pinnularia interrupta* 20. *Pinnularia latarea* 21. *Pinnularia subsimilis* 22. *Pinnularia viridis* 23. *Epithemia gibba* 24. *Discostella stelligera* 25. *Ulnaria amphirhynchus* 26. *Ulnaria delicatissima* 27. *Ulnaria ulna* 28. *Closterium acerosum* 29. *Closterium bitangchoianum* 30. *Closterium gracile* 31. *Closterium incurvum* 32. *Closterium kuetzingii* 33. *Closterium lunula* 34. *Closterium navicula* 35. *Closterium pritchardianum* f. *attenuatum* 36. *Closterium pseudocynthia* 37. *Closterium rostratum* 38. *Closterium submoniliferum* var. *malinvernianum* 39. *Cosmarium forceps* 40. *Cosmarium lundellii* (Scale bar = 10 μ m)

First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 13" N 93°58' 6" E)
Euastrum elegans Ralfs 1848: 89, pl. XIV [14]: figs 7b-d (Pl. 2, Fig. 51)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Itanagar (27°4' 52" N 93°35' 39" E)
Euastrum luetkemulleri F.Ducellier 1918: 134, fig. 123a (as '*lütkemüllerii*') (Pl. 2, Fig. 52)
 First record from Arunachal Pradesh
 Place of Collection- Bhalukpong (27°01' 04" N 92°38' 17" E)
Euastrum spinulosum var. *lindiae* Grönblad & A.M.Scott 1958: 17: pl. VII [7]: figs 84-88, photo 347 (Pl. 2, Fig. 53)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Kimin (27°18' 13" N 93°58' 6" E)
Micrasterias foliacea Bailey ex Ralfs 1848: 210, pl. XXXV [35]: fig. 3 (Pl. 2, Fig. 54)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Tipi (27°01' 51" N 92°36' 59" E)
Micrasterias pinnatifida Ralfs 1848: 77, pl. X [10]: fig. 3 (Pl. 2, Fig. 55)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Kimin (27°18' 4" N 93°58' 15" E)
Pleurotaenium ehrenbergii (Ralfs) De Bary 1858: index, 75 (Pl. 2, Fig. 56)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Kimin (27°18' 13" N 93°58' 6" E), Nirjuli (27°7' 56" N 93°44' 48" E)
Staurastrum margaritaceum Meneghini ex Ralfs 1848: 134, pl. XXI [21]: fig. 9 a-e (Pl. 2, Fig. 57)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E)

Family - Zygnemataceae

1 Genus, 1 Species
Spirogyra parvula (Transeau) Czurda 1932: 170 (Pl. 2, Fig. 58)
 Previous report- Das and Adhikary (2012), Bhakta and Adhikary (2014)
 Place of Collection- Bhalukpong (27°01' 04" N 92°38' 17" E), Itanagar (27°4' 52" N 93°35' 39" E), Doimukh (27°8' 52" N 93°45' 13" E)

PHYLUM-CHLOROPHYTA

Family - Botryococcaceae

1 Genus, 1 Species
Botryococcus braunii Kützing 1849: 892 (Pl. 2, Fig. 59)
 Previous report- Das and Adhikary (2012)
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Kimin (27°18' 4" N 93°58' 15" E)

Family - Chlorellaceae

2 Genera, 2 Species
Actinastrum hantzschii var. *subtile* Woloszynska 1911: 227, pl. III [3]: fig. 3 (Pl. 2, Fig. 60)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E)
Dictyosphaerium granulatatum Hindák 1977: 39, pl. 11: figs 7-10 (Pl. 2, Fig. 61)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Kimin (27°18' 13" N 93°58' 6" E)

Family - Eremosphaeraceae

1 Genus, 1 Species
Neglectella solitaria (Wittrock) Stenclová & Kastovsky in Stenclová et al 2017: 1268 (Pl. 2, Fig. 62)
 First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 4" N 93°58' 15" E)

Family - Hydrodictyaceae

6 Genera, 7 Species
Hydrodictyon reticulatum (Linnaeus) Bory 1824: 506 (Pl. 2, Fig. 63)
 First record from Arunachal Pradesh
 Place of Collection- Nirjuli (27°7' 56" N 93°44' 48" E)
Lacunastrum gracillimum (West & G.S.West) H.McManus in McManus & al. 2011: 128, 129, fig. 4 (Pl. 2, Fig. 64)
 First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 4" N 93°58' 15" E), Ganga lake (27°4' 33" N 93°34' 8" E)
Pediastrum duplex Meyen 1829: 772, pl. XLIII [43]: figs 6-20 (Pl. 2, Fig. 65)
 First record from Arunachal Pradesh
 Place of Collection- Nirjuli (27°7' 56" N 93°44' 48" E), Ranaghat (28°5' 57" N 95°18' 24" E)
Sorastrum americanum (Bohlin) Schmidle 1899: 230 (Pl. 2, Fig. 66)
 First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18' 4" N 93°58' 15" E), Kimin (27°18' 13" N 93°58' 6" E)
Stauridium tetras (Ehrenberg) E.Hegewald in Buchheim & al. 2005: 1051 (Pl. 2, Fig. 67)
 Previous report- Das and Adhikary (2012)
 Place of Collection- Itanagar (27°4' 52" N 93°35' 39" E)
Stauridium tetras var. *tetraodon* (Corda) J.D.Hall & Karol 2016: 153 (Pl. 2, Fig. 68)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E)
Tetraëdron minimum (A.Braun) Hansgirg 1889: 133 (Pl. 2, Fig. 69)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Kimin (27°18' 4" N 93°58' 15" E)

Family - Scenedesmaceae

6 Genera, 13 Species
Coelastrum astroideum De Notaris 1867: 80, pl. IX [9]: fig. 93 (Pl. 2, Fig. 70)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Kimin (27°18' 4" N 93°58' 15" E)
Coelastrum microporum Nägeli in A.Braun 1855: 70, adnot. (Pl. 2, Fig. 71)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Doimukh (27°8' 52" N 93°45' 13" E)
Coelastrum pseudomicroporum Korshikov 1953: 347, fig. 318 (Pl. 2, Fig. 72)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E), Bhalukpong (27°01' 04" N 92°38' 17" E)
Desmodesmus abundans (Kirchner) E.H.Hegewald 2000: 1 (Pl. 2, Fig. 73)
 Previous report- Das and Adhikary (2012)
 Place of Collection- Ranaghat (28°5' 57" N 95°18' 24" E), Itanagar (27°4' 52" N 93°35' 39" E)
Desmodesmus armatus var. *longispina* (Chodat) E.Hegewald 2000: 5 (Pl. 2, Fig. 74)
 First record from Arunachal Pradesh

Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E)
Desmodesmus opoliensis var. *mononensis* (Chodat)
 E.Hegewald 2000: 15 (Pl. 2, Fig. 75)
 First record from Arunachal Pradesh
 Place of Collection- Ranaghat (28°5' 57" N 95°18' 24"E),
 Tipi (27°01' 51"N 92°36' 59"E)
Dimorphococcus cordatus Wolle 1887: 199, pl. CLX
 [160]: figs 30-38 (Pl. 2, Fig. 76)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E)

Scenedesmus pseudopoliensis Hortobágyi 1969: 48, 68,
 fi. 229, 230 (as '*pseudoopoliensis*') (Pl. 3, Fig. 77)
 Previous report- Das and Adhikary (2012), Bhakta and
 Adhikary (2014)
 Place of Collection- Nirjuli (27°7' 56" N 93°44' 48" E),
 Ganga lake (27°4' 33" N 93°34' 8" E)
Tetrademus dimorphus (Turpin) M.J.Wynne 2016: 84
 (Pl. 3, Fig. 78)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4' 33" N 93°34' 8" E),
 Itanagar (27°4' 52" N 93°35' 39" E)

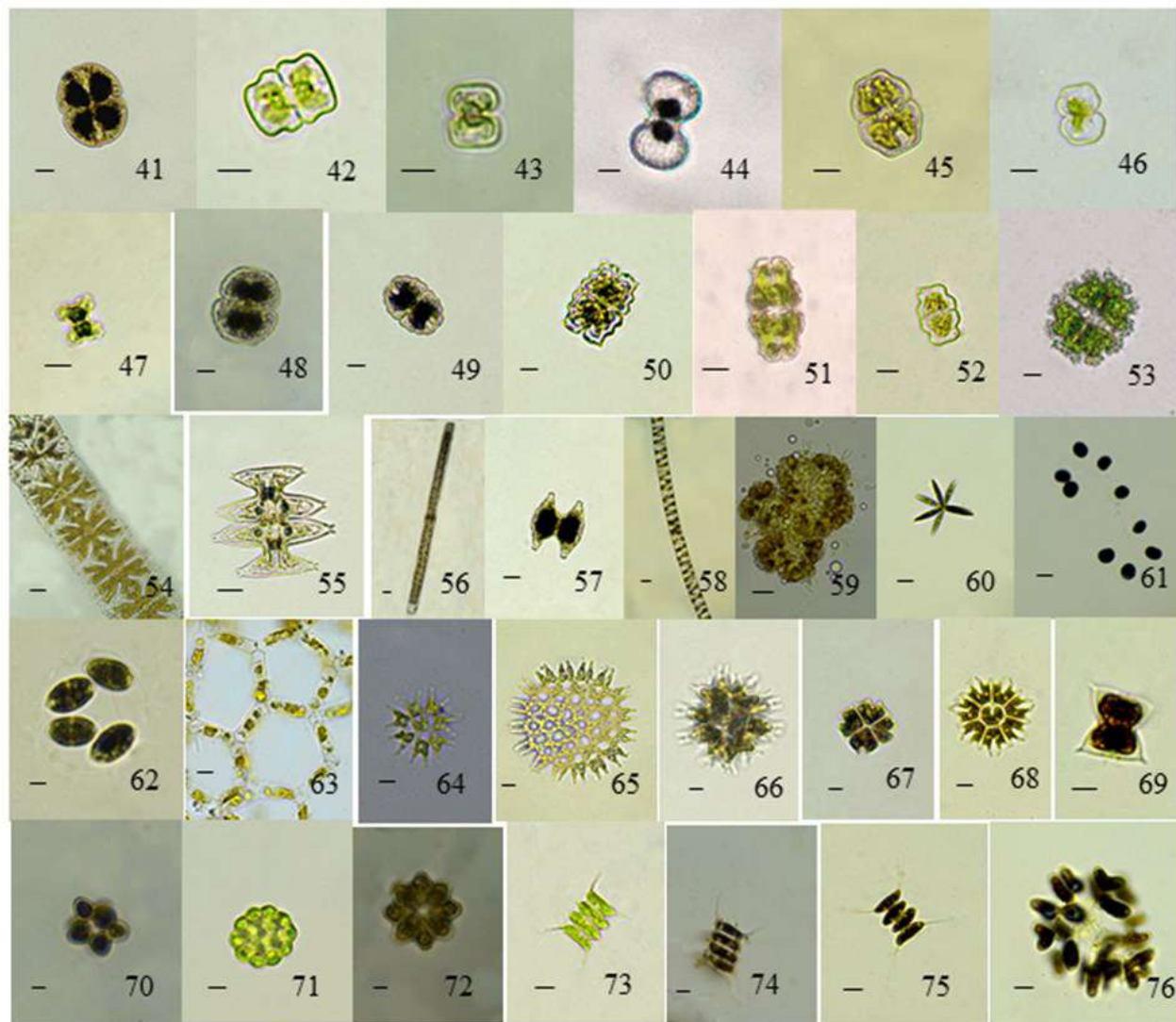


Photo plate 2. Fig. 41. *Cosmarium lundellii* var. *ellipticum* 42. *Cosmarium norimbergense* 43. *Cosmarium norimbergense* var. *depressum* 44. *Cosmarium porteanum* f. *pseudoporteanum* 45. *Cosmarium pseudoretusum* var. *inaequalipellucum* 46. *Cosmarium regnellii* 47. *Cosmarium regnesi* 48. *Cosmarium rosae* 49. *Cosmarium undulatum* f. *reductum* 50. *Euastrum denticulatum* var. *quadrifarium* 51. *Euastrum elegans* 52. *Euastrum luetkemulleri* 53. *Euastrum spinulosum* var. *lindiae* 54. *Micrasterias foliacea* 55. *Micrasterias pinnatifida* 56. *Pleurotaenium ehrenbergii* 57. *Staurastrum margaritaceum* 58. *Spirogyra parvula* 59. *Botryococcus braunii* 60. *Actinastrum hantzschii* var. *subtile* 61. *Dictyosphaerium granulatum* 62. *Neglectella solitaria* 63. *Hydrodictyon reticulatum* 64. *Lacunastrum gracillimum* 65. *Pediastrum duplex* 66. *Sorastrum americanum* 67. *Stauridium tetras* 68. *Stauridium tetras* var. *tetraodon* 69. *Tetraëdron minimum* 70. *Coelastrum astroideum* 71. *Coelastrum microporum* 72. *Coelastrum pseudomicroporum* 73. *Desmodesmus abundans* 74. *Desmodesmus armatus* var. *longispina* 75. *Desmodesmus opoliensis* var. *mononensis* 76. *Dimorphococcus cordatus* (Scale bar = 10 µm)

Tetradismus lagerheimii M.J.Wynne & Guiry 2016: 1 (Pl. 3, Fig. 79)

First record from Arunachal Pradesh

Place of Collection- Kimin (27°18'4" N 93°58'15" E)

Tetradismus obliquus (Turpin) M.J.Wynne 2016: 84 (Pl. 3, Fig. 80)

Previous report- Das and Adhikary (2012), Bhakta and Adhikary (2014)

Place of Collection- Ganga lake (27°4'33" N 93°34'8" E), Ranaghat (28°5'57" N 95°18'24" E)

Tetrastrum elegans Playfair 1917: 832, pl. 57: fig. 6 (Pl. 3, Fig. 81)

First record from Arunachal Pradesh

Place of Collection- Itanagar (27°4'52" N 93°35'39" E)

Tetrastrum glabrum (Y.V.Roll) Ahlstrom & Tiffany 1934: 504 (Pl. 3, Fig. 82)

First record from Arunachal Pradesh

Place of Collection- Nirjuli (27°7'56" N 93°44'48" E)

Family - Selenastraceae

3 Genera, 6 Species

Ankistrodesmus densus Korshikov 1953: 300, fig. 262 a-c (Pl. 3, Fig. 83)

Previous report- Das and Adhikary (2012)

Place of Collection- Ganga lake (27°4'33" N 93°34'8" E)

Ankistrodesmus falcatus (Corda) Ralfs 1848: 180, pl. XXXIV [34]: figs a-c (Pl. 3, Fig. 84)

Previous report- Das (2016)

Place of Collection- Ganga lake (27°4'33" N 93°34'8" E), Kimin (27°18'13" N 93°58'6" E)

Kirchneriella diana (Bohlin) Comas 1980: 4 (Pl. 3, Fig. 85)

First record from Arunachal Pradesh

Place of Collection- Ganga lake (27°4'33" N 93°34'8" E)

Monoraphidium contortum (Thuret) Komárková-Legnerová in Fott 1969: 104, pl. 18: figs 1-5 (Pl. 3, Fig. 86)

First record from Arunachal Pradesh

Place of Collection- Ganga lake (27°4'33" N 93°34'8" E)

Monoraphidium indicum Hindák 1977: 105, pl. 44 (Pl. 3, Fig. 87)

First record from Arunachal Pradesh

Place of Collection- Kimin (27°18'13" N 93°58'6" E), Doimukh (27°8'52" N 93°45'13" E)

Monoraphidium tortile (West & G.S.West) Komárková-Legnerová 1969: 103, pl. 17: figs 1-6 (Pl. 3, Fig. 88)

First record from Arunachal Pradesh

Place of Collection- Bhalukpong (27°01'04" N 92°38'17" E)

Family - Oedogoniaceae

1 Genus, 3 Species

Oedogonium undulatum A.Braun ex Hirn 1900: 257, pl. XLV [45]: figs 272-275 (Pl. 3, Fig. 89)

First record from Arunachal Pradesh

Place of Collection- Kimin (27°18'4" N 93°58'15" E)

Oedogonium varians Wittrock & Lundell ex Hirn 1900: 84, pl. IV [4]: fig. 23 (Pl. 3, Fig. 90)

First record from Arunachal Pradesh

Place of Collection- Itanagar (27°4'52" N 93°35'39" E)

Oedogonium tiffanyi Ackley 1929: 304, pl. XXXVI: figs 15, 16 (as '*Tiffanii*') (Pl. 3, Fig. 91)

First record from Arunachal Pradesh

Place of Collection- Nirjuli (27°7'56" N 93°44'48" E), Doimukh (27°8'52" N 93°45'13" E)

Family - Treubariaceae

1 Genus, 1 Species

Treubaria setigera (W.Archer) G.M.Smith 1933: 439 (Pl. 3, Fig. 92)

First record from Arunachal Pradesh

Place of Collection- Ganga lake (27°4'33" N 93°34'8" E)

PHYLUM-CYANOBACTERIA

Family - Aphanizomenonaceae

1 Genus, 1 Species

Dolichospermum circinale (Rabenhorst ex Bornet & Flahault) P.Wacklin, L.Hoffmann & J.Komárek 2009: 61 (Pl. 3, Fig. 93)

First record from Arunachal Pradesh

Place of Collection- Itanagar (27°4'52" N 93°35'39" E), Doimukh (27°8'52" N 93°45'13" E)

Family - Merismopediaceae

1 Genus, 1 Species

Aphanocapsa parasitica (Kützing) Komárek & Anagnostidis 1995: 16 (Pl. 3, Fig. 94)

First record from Arunachal Pradesh

Place of Collection- Ganga lake (27°4'33" N 93°34'8" E)

Family - Microcystaceae

1 Genus, 1 Species

Microcystis wesenbergii (Komárek) Komárek ex Komárek in Joosen 2006: 209 (Pl. 3, Fig. 95)

Previous report- Das and Adhikary (2012)

Place of Collection- Ganga lake (27°4'33" N 93°34'8" E)

Family - Nostocaceae

1 Genus, 1 Species

Anabaena oscillarioides Bory ex Bornet & Flahault 1886: 233 (Pl. 3, Fig. 96)

First record from Arunachal Pradesh

Place of Collection- Nirjuli (27°7'56" N 93°44'48" E), Itanagar (27°4'52" N 93°35'39" E)

Family - Oscillatoriaceae

2 Genera, 2 Species

Limnoraphis hieronymusii (Lemmermann) J.Komárek, E.Zapomelová, J.Smarda, J.Kopecký, E.Rejmánková, J.Woodhouse, B.A.Neilan & J.Komárková 2013: 45 (Pl. 3, Fig. 97)

First record from Arunachal Pradesh

Place of Collection- Kimin (27°18'13" N 93°58'6" E)

Oscillatoria anguina Bory ex Gomont 1892: 214, pl. VI/6: fig. 16 (Pl. 3, Fig. 98)

First record from Arunachal Pradesh

Place of Collection- Ganga lake (27°4'33" N 93°34'8" E)

PHYLUM-EUGLENOZOA

Family - Euglenidae

1 Genus, 5 Species

Trachelomonas armata f. *punctata* (Svirenko) Deflandre (as '*var. steinii* f. *punctata*') (Pl. 3, Fig. 99)

Previous report- Das and Adhikary (2012)

Place of Collection- Ganga lake (27°4'33" N 93°34'8" E), Itanagar (27°4'52" N 93°35'39" E)

Trachelomonas dubia Svirenko [Svirenko] 1914: 638, pl. 19: fig. 20 (Pl. 3, Fig. 100)

First record from Arunachal Pradesh

Place of Collection- Nirjuli (27°7'56" N 93°44'48" E), Doimukh (27°8'52" N 93°45'13" E)

Trachelomonas hispida var. *granulata* Playfair 1915: 21, pl. III [3]: figs 11, 12 (Pl. 3, Fig. 101)
 Previous report- Das and Adhikary (2012)
 Place of Collection- Kimin (27°18'4"N 93°58'15"E), Ganga lake (27°4'33"N 93°34'8"E)
Trachelomonas volvocina (Ehrenberg) Ehrenberg 1834: 315 (Pl. 3, Fig. 102)
 Previous report- Das and Adhikary (2012)
 Place of Collection- Ranaghat (28°5'57"N 95°18'24"E), Itanagar (27°4'52"N 93°35'39"E), Ganga lake (27°4'33"N 93°34'8"E), Kimin (27°18'13"N 93°58'6"E)
Trachelomonas volvocina var. *punctata* Playfair 1915: 9, pl. I [1]: fig. 2 (Pl. 3, Fig. 103)

Previous report- Das and Adhikary (2012), Das (2016)
 Place of Collection- Kimin (27°18'13"N 93°58'6"E), Kimin (27°18'4"N 93°58'15"E)

Family - Phacidae

2 Genera, 9 Species

Lepocinclis elongata (Swirenko) W.Conrad 1934: 234 (Pl. 3, Fig. 104)

First record from Arunachal Pradesh

Place of Collection- Itanagar (27°4'52"N 93°35'39"E)

Lepocinclis hungpanchiaensis S.P.Chu 1936: 280, fig. 13 (Pl. 3, Fig. 105)



Photo plate 3. Fig. 77. *Scenedesmus pseudopoliensis* 78. *Tetradesmus dimorphus* 79. *Tetradesmus lagerheimii* 80. *Tetradesmus obliquus* 81. *Tetrastrum elegans* 82. *Tetrastrum glabrum* 83. *Ankistrodesmus densus* 84. *Ankistrodesmus falcatus* 85. *Kirchneriella diana* 86. *Monoraphidium contortum* 87. *Monoraphidium indicum* 88. *Monoraphidium tortile* 89. *Oedogonium undulatum* 90. *Oedogonium varians* 91. *Oedogonium tiffanyi* 92. *Treubaria setigera* 93. *Dolichospermum circinale* 94. *Aphanocapsa parasitica* 95. *Microcystis wesenbergii* 96. *Anabaena oscillarioides* 97. *Limnoraphis hieronymusii* 98. *Oscillatoria anguina* 99. *Trachelomonas armata* f. *punctata* 100. *Trachelomonas dubia* 101. *Trachelomonas hispida* var. *granulata* 102. *Trachelomonas volvocina* 103. *Trachelomonas volvocina* var. *punctata* 104. *Lepocinclis elongata* 105. *Lepocinclis hungpanchiaensis* 106. *Lepocinclis oxyuris* 107. *Lepocinclis wangi* 108. *Phacus acuminatus* 109. *Phacus elegans* 110. *Phacus longicauda* 111. *Phacus rotundus* 112. *Centrtractus belonophorus* 113. *Phacus triquetus* 114. *Ophiocytium capitatum* 115. *Ophiocytium cochleare* 116. *Tetraplektron laevis* (Scale bar = 10 µm)

First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18'13"N 93°58'6"E)
Lepocinclis oxyuris (Schmarda) B. Marin & Melkonian in B. Marin & al. 2003: 104 (Pl. 3, Fig. 106)
 First record from Arunachal Pradesh
 Place of Collection- Nirjuli (27°7'56"N 93°44'48"E)
Lepocinclis wangi Chu (Pl. 3, Fig. 107)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4'33"N 93°34'8"E)
Phacus acuminatus A. Stokes 1885: 183, fig. 1 (Pl. 3, Fig. 108)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4'33"N 93°34'8"E), Nirjuli (27°7'56"N 93°44'48"E)
Phacus elegans Pochmann 1942: 199, fig. 107 (Pl. 3, Fig. 109)
 First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18'4"N 93°58'15"E), Doimukh (27°8'52"N 93°45'13"E)
Phacus longicauda (Ehrenberg) Dujardin 1841: 337, pl. 5 fig. 6 (Pl. 3, Fig. 110)
 First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4'33"N 93°34'8"E), Nirjuli (27°7'56"N 93°44'48"E)
Phacus rotundus (Pochmann) Zakryš & M. Lukomska in Lukomska-Kowalczyk & al. 2015: 1153, nom. illeg. (Pl. 3, Fig. 111)
 First record from Arunachal Pradesh
 Place of Collection- Doimukh (27°8'52"N 93°45'13"E)
Phacus triqueter (Ehrenberg) Dujardin 1841: 338 (as '*triquetera*') (Pl. 3, Fig. 113)
 First record from Arunachal Pradesh
 Place of Collection- Doimukh (27°8'52"N 93°45'13"E), Ganga lake (27°4'33"N 93°34'8"E)

PHYLUM-OCHROPHYTA

Family - Centritractaceae

1 Genus, 1 Species

Centritractus belonophorus (Schmidle) Lemmermann 1900: 274 (as '*Centritractus belonophora*') (Pl. 3, Fig. 112)

First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18'4"N 93°58'15"E), Itanagar (27°4'52"N 93°35'39"E)

Family - Ophiocytaceae

1 Genus, 2 Species

Ophiocytium capitatum Wolle 1887: 176; pl. CLVIII [158]: figs 3-7 (Pl. 3, Fig. 114)

First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18'4"N 93°58'15"E)
Ophiocytium cochleare (Eichwald) A. Braun 1855: 54 (Pl. 3, Fig. 115)

First record from Arunachal Pradesh
 Place of Collection- Kimin (27°18'13"N 93°58'6"E)

Family - Pleurochloridaceae

1 Genus, 1 Species

Tetraplektron laevis (Bourrelly) Ettl 1977: 561 (Pl. 3, Fig. 116)

First record from Arunachal Pradesh
 Place of Collection- Ganga lake (27°4'33"N 93°34'8"E)

DISCUSSION

This present checklist provides a comprehensive account of phytoplankton flora in the lower foothills of Arunachal Himalaya. A total of 116 algal species were

documented from the study areas which were belonging to 55 genera of 35 families under 6 algal phyla. Desmidiaceae with 19 species was the dominant family in the region which was followed by Scenedesmeaceae (13 species) and Closteriaceae (11 species) respectively. *Closterium* and *Cosmarium*, both belonging to phylum Charophyta were the dominant genera with 11 species each.

The number of phytoplankton species (116) documented during the present endeavour was much higher than that of any previous study made in Arunachal Himalayas (Das and Adhikary, 2012; Choudhary and Singh, 2013; Das, 2016; Ganie *et al.*, 2018; Das *et al.*, 2019; Radhakrishnan *et al.*, 2020). Das and Adhikary (2012) reported a total of 86 species from the entire Arunachal state from lower foot hills to alpine region and recorded around 39 species of Bacillariophyceae alone. Later, Das (2016) documented 66 species from the alpine lakes of Arunachal Himalaya, where also, the dominant class was the Bacillariophyceae with 36 species. During an exploration, Choudhary and Singh (2013) reported 35 Cyanobacterial species from the entire state. In contrast to Arunachal Himalayas, Sikkim Himalayan region was explored many times and more than 200 phytoplankton species have so far been recorded (Prasad and Mishra, 1987; Kumar and Rai, 2005; Suseela and Toppo 2006, 2007; Bhakta *et al.*, 2010; Das and Keshri, 2012; Das and Keshri, 2013 a, b, c; Das, 2015; Chetri and Thapa, 2016; Chetri *et al.*, 2020). It was also to be noted that in contrast to Sikkim Himalayas where no particular algal phylum was reported to be dominant, the water bodies of the lesser to upper Arunachal Himalayas were crowded with the members of Bacillariophyta. Interestingly the present study revealed that the chlorophycean members (34) were outnumbered in the water bodies of the foot hill belt of Arunachal Himalayas which was followed by Charophyta (31) and then only by Bacillariophyta (27). Chlorophycean dominance usually signifies the healthier nature of any water body (Descy, 1987). But little to moderate organic pollution in some occasions cannot be ruled out due to anthropogenic activities as reflected from the presence of few members of Euglenozoa (14 species) which were believed to be flourish in eutrophic environment (Das and Adhikary, 2012).

Out of 116 species recorded, a total of 90 phytoplankton species were reported for the first time from this region which signified that the foot hill tracts of Eastern Himalayas are very much unexplored in terms of algal research. So, the data generated by the present study on phytoplankton diversity of the region can serve as a baseline reference for identical upcoming studies.

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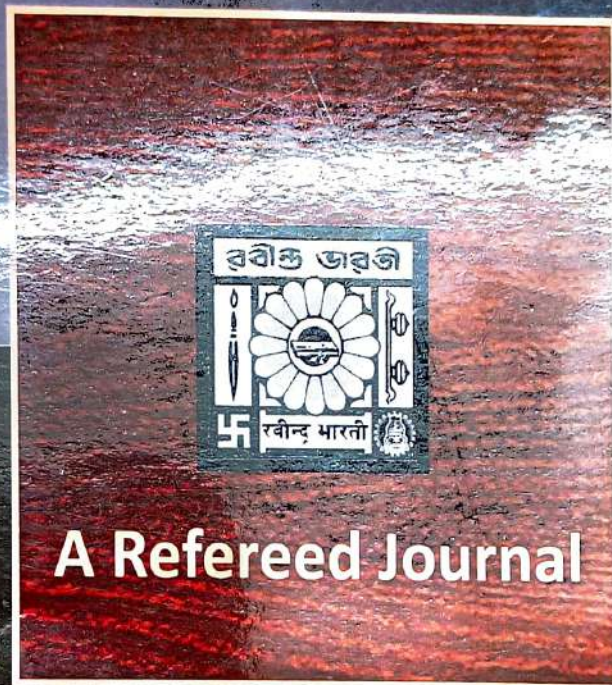


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ABSTRACT

SOCIAL CEREMONY

The Boros constitute a very important place among the ethnic groups and tribes in the State of Assam. Anthropologically they are included in the race of Mongoloid. At present, the Boros are not only settling in Assam but outside Assam also. Today, they are settling in the State of Nagaland, Meghalaya, Tripura and West Bengal. They are also found in the countries of Bangladesh, Nepal and Bhutan also. The researcher has tried to highlight the social ceremony of the Boros who are settling in the District of Goalpara. The Boros settling in the district of goalpara who are mainly believer of 'Bathoism', are included under the Jurisdiction of 'Goalpara Jilla Boro Baro Dal' (a social organization). They have their own Customary Law. Their day-to-day way of living is governed by the Law of custom which is related by social rites. Life of human being is full of transition in cyclic order. Life cycle of the Boros centres round the main three main rites. They are birth, marriage and death. To every event, they are many rites attached to it. These rites are to be performed during celebration.

KEY WORDS: Social ceremony, viz, Birth ceremony, Marriage ceremony and Death ceremony

AIMS OF THE STUDY

- i) To study various social structure of the Boros.
- ii) To study various social activities of the organization.

IMPORTANCE OF THE STUDY

- i) It is a premier organization
- ii) It generates unity and solidarity
- iii) It promotes social identity
- iv) It has own codified customary law

REVIEW OF LITERATURE

No written record is available regarding the social ceremony of the Boros who are under the Jurisdiction of 'Goalpara Jilla Boro Baro Dal'. We found some write-ups regarding the social ceremony. The organization has their own codified Customary Law book (a manuscript) by the name of 'Boroni Ashar Bikhanthi' (1905). No researcher has highlighted about the social ceremony of the Boros in the district of Goalpara.

DATA COLLECTION

Both primary and secondary sources of data collection have been adopted. As a primary source interview and field study have been done and as a secondary source book and periodical published source relating to the activities of the organization has been studied.

METHODOLOGY

Analytical Method has been adopted from the primary and secondary data collection.

HYPOTHESIS

- i) It regulates social structure
- ii) It generates socialization
- iii) It controls social deviant
- iv) To govern them they have own customary law

INTRODUCTION

The Bodos or Boros-Kacharies constitute a very important section among the ethnic groups and races in the state of Assam. Anthropologists included them in the race of Mongoloid. S.K Chatterji recognized them as the Bodos. About the Bodos he writesThe Bodos appear first to have settled over the entire Brahmaputra valley and extended west into North Bengal in Koch Bihar, Rangpur and Dinajpur districts; they may have pushed into North Bihar also.¹

At present, the Bodos or Boro-Kacharies are not only settling in Assam but outside Assam also. They are found at present in the country of Bangladesh, Nepal, Bhutan also. P.C Bhattacharya divided the Boro people as Western and Eastern branches. He writes about the Boros,

‘The Boro people including their Western and Eastern branches had royal glories as we gather from the records of history. The western section of the old Boros. Kacharies occupied the thrones of Koch- Bihar, Bijni, Darrang and Beltola. An eastern branch in the name of Chutiyas also established a powerful kingdom with its capital near sadia’.²

At present majority of the Boros have their Settlement in some Scattered packet areas throughout the state of Assam. The researcher here tried to high light the social ceremony especially the boros of Goalpara district which is included under the jurisdiction of Goalpara Jilla Boro Baro Dal (a social organization).

The Boros setling areas, Dhupdhara, Dudhnoi, and Krishnai areas in the district of Goalpara is known as ‘DAI-KHONG KHULA’ by the outsider Boros. The Boros inhabited in this areas are very backward in every aspect of lives. Before the constitution of ‘GOALPARA JILLA BORO BARA DAL’ (Habraghat Boro Sanmilloni, 1912). They have found no any social organization. They were unorganized. As a result, any problem has not discussed jointly. They were lagging behind in every aspect. Sidney Endle says;

‘In mental and intellectual power, they are undoubtedly far below their Hindu neighbors; for they possess neither the quickness of apprehension, or the astonishing power of memory etc., characteristic of the higher castes among the Hindu’s’.³

Life of human being is full of transitions in cyclic order which is called rites of passage or rites de passage. The life- cycle of the Boros mainly centres round the three main rites de passage. They are birth, marriage and death. In addition to these, there are a few ceremonies which are also to be solemnized during deferent period of life of passage. But they are not so important as composed with the above three i.e., birth, marriage and death.

1. BIRTH CEREMONY

There are some aims in marriage. They are generally of economic aim, social aim, biological aim which is related to procreation of children by increasing their lineage. After marriage all women have an eagerness to have more or less a child. Barrenness of women fertility deserves low status in the Boro Society. She is also restricted from some social and religious activities. Generally, the parents traditionally prefer male child. But now-a-days, preference is given equal to both.

i) DISCLOSURE OF PREGNANCY

After marriage when menstruation discontinues then the expectant mother discloses the real condition before husband and then next to other. Member of the family, especially before Mother-in-Law but not before father-in-law. In the Boros society expectant grandmother and grandfather become happy when they come to know about the pregnancy of their daughter-in-law, which is completely of psychological.

ii) PRECAUTION AND RESTRICTION

Among the Boros of Goalpara district, there is prevalent that after pregnancy, a pregnant woman has to follow some folk beliefs as a means of precaution and restriction. The pregnant women are not allowed to visit or touch any death body or cremation ground because of their is believed that there will be negative affect on unborn baby. Moreover, she is not allowed to visit any forest, collecting wood, fishing and also not allowed to cross the river. The Boros of Goalpara district, believe that the available evil spirits will harm the unborn child.⁴

iii) RESTRICTION OF FOOD

Just after being born some precaution measures should be adopted by mother. The Boros of this area believed that some foods and curry is not good for the health of the mother as well as for the new born baby. Usually 'NARJI INKHRI' (bitter dry jute curry), 'MWITHA' (sour jute curry), 'JWGWNAR' (sweet gourd) etc., are not allowed to the mother to eat. Pork is also not allowed. On the other hand, she is allowed to eat dry food, i.e., fried rice powder with pepper (DHWNGRA) finely cut ginger, fried salt and roasted garlic. After few days when health becomes normal, she is allowed to eat normal as well as usual food.

iv) CUTTING AND FASTANING UMBLICAL CORD

After being born of the new baby the umbilical cord is to tied up with GWPHWR AOA KHWNDWNG (white cotton thread) keeping a space of one inch, rounding three or five times. The umbilical cord is to cut off by means of sharp-edged slip of green bamboo skin which is called 'THEMAL' or 'KHATIMOLA' in Boro. In number, the bamboo skin slip must be five in case of male and six in case of female baby.⁵ The importance attached to it is of completely philosophical which relates their action organs. Because the Boros consider one more genital organ belong to female. Fastening and cutting umbilical activities are performed by the women folk. Sometimes if the females are unable to do the activity, then male members help the females. No widow or widower is allowed to perform the activity. Because it is believed that life longevity becomes very short.

(v) BIRTH PURIFICATION

Purification is different on the basis of sex. Male baby purification is to perform on the day of fifth and female baby purification is to perform on the day of sixth. On the day of occasion all the residential

houses are to smeared by the mixture of earth and cow dung, which is called in Boro as 'NO LIRNAI'. After that the appointed purifier performs the act of purification. The 'GWTHARI' (purifier) has to perform his duty by fetching the holy water from the neighbour. During the purification some materials are needed. They are BELBILAI (wood apple), THWLUNSI BILAI (holy basil leaves) and 'ASITHAM' (ring finger) of the appointed purifier. These Materials are in warded in holly water there after sprinkle around the houses, well, cowshed, chicken coop etc. After the realization of this act, the owner is assumed as purified one. The purifier has to cut off slight hair of the male child by means of sickle. It does not hold good in case of female child.

vi) MEANING OF HAIR CUTTING AND PURIFICATION

The Boros generally believe life cycle of rebirth. That is why, just after born they sprinkle holly water by means of holding basil leaves by singing a song.

'Oi gotha nongba godo mamon, Bangal na Jungal, Garo na Gongar, Harsa na Mephal mon? dinoiniphrai Boro jabay.⁶

English rendering, 'oh baby whether you were a Muslim, a Garo, a Bhutia or a Assamese or a Nepali you are from today became a Boro person.'

But the Boros of Goalpara district who are under the jurisdiction of Goalpara Jilla Boro Baro Dal believe in different way. To achieve human life the new born baby has to pass away through different stages of life span which are in the form of different creatures and insects. According to them the human live is the best among all of men. So, purification and hair cutting ceremony is to perform. All these activities have been executed by the appointed purifier. According to their custom any Law any family who has to perform these ceremonies has to bear cost of expenditure which is not more than Rs.- 10 and not less than Rs.- 10 as a remuneration of the 'GWTHARARI' (purifier). In addition to this the guardian has to offer some sort of food in the form of rice, sweets, fruits etc. The purifier cannot demand the same materials.

2. MARRIAGE

Life cycle of human being passes through three phases. They are birth, marriage and death. The Boros of Dwikhong Khula or Goalpara district believe that marriage bond is determined by the almighty god. The Goalpara District Boro Baro Dal recognized certain type of ways for performing the marriage ceremony. The organization has recognized 8 (eight) type of marriages.⁷

- (1) Marriage by negotiation
- (2) Marriage by negotiation offering garland to bride.
- (3) Elopement marriage
- (4) Adopted marriage
- (5) Widow and widower marriage
- (6) Widower adopted marriage
- (7) Register marriage
- (8) Marriage by capture

But nowadays marriage by capture has been dishonoured by the organization. In every marriage there has a different type of rites. The rites are not same for all the marriage. Bride prize system is seen among

them as follows-

1. Rs 80 for negotiation marriage
2. Rs 180 for marriage, offering garland.
3. Rs 180 for general elopement marriage and Rs 130 for widow elopement marriage.

3. DEATH CEREMONY

Just after confirmation of death, the death body is to taken out in the courtyard and then to clean with pure water. This activity is performed by the female folk. If the dead body is of female, then his body is tied with Dokna (Bodo women dress) and is of male then tied of Gamosa (male wearing dress), purifier or Ojah is not needed on the day of death body dispossession. But purifier must perform rites on the day of death ceremony day. The owner has to offer a feast. The feast offered is seen in three categories: (1) a feast with pork and fowl i.e., non veg's (2) a feast without non veg, i.e., vegetable and the last one is (3) a feast just simply of a cup of tea or wine. This type of a feast is generally dependent on the ability of the owner. Death ceremony of the Boros is to perform through different rites and rituals. Following are the materials that required during the day of dispossession of death body.

- (1) Four poles or posts
- (2) Five bundles of dry bamboo sticks
- (3) One earthen pot
- (4) One white cloth piece
- (5) Rice, Pulses and seed of oil
- (6) Some coins
- (7) A pair of betel nut
- (8) Cotton thread
- (9) Sandan, Wood apple and Mango leaves
- (10) Fire, water and Holy basil leaves

CONCLUSION

The Boros of Goalpara district who are included under the Jurisdiction of 'GOALPARA JILLA BORO BARO DAL' has their distinct identity. Different types of ceremonies are to perform according to their customary Law which are codified in form manuscript. This manuscript book is known by the name 'ASHAR BIKHANTHI'. 'Goalpara Jilla Boro Baro Dal' is playing a major role for protecting their cultural and social identity. It has protected their own rites and rituals. It has also protected from religions conversion and also process of cast continuum.

FOOTNOTES:

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7. Boroni Bisar Bikhanthi; 2019; P-66, Published by The Goalpara District Boro Baro Dal

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Iron Work Tradition in Assam

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Abstract

Iron is a strong and durable metal. It has played a key role in bringing revolutionary changes in the human civilization and has thereby outclassed copper, the earliest discovered metal. There are different areas in the world where iron ore is available in its earth crust. Assam in the past was one such region where naturally iron was available and was used by the local inhabitants.

Keywords: iron, ore, smelting,

Introduction

Assam in the past, used to be a region having iron in its earth crust. Iron ore was available in considerable quantity in different places like Borhat, Nagahat, Jaipur, Tirupathar, Hatigarh, Kacharihat, Bassa, Doyang, etc situated in Upper Assam (Phukan, 1973: 101-02) as well

as in the hilly regions like Naga Hills, Garo Hills, Khasi Hills, Jayantia Hills, Mikir Hills and Manipur (Rajguru, 1988: 333). Except Manipur, all these hilly regions of the North-East were part of Assam until recent past. Despite of abundance of iron in Assam in the past, however one fails to assign a definite period regarding the beginning of iron works in the region. Nothing much is known when in Assam iron ore was first discovered, extracted and products made out of it.

Area of Research

The paper covers Assam before its colonization by the British.

Objective

The paper attempts to:

- (i) Trace the antiquity of iron works in Assam,
- (ii) Assess the development attained in the field of iron works in Assam.

Methodology

An analytical discussion has been made on the basis of both primary and secondary sources.

Discussion

The classical writers like Pliny and Ammianus Marcellinus do refer to the existence of iron in Assam, particularly extraction of iron in the Khasi hills from early times. (Choudhury, 1987: 348) But the epigraphic records of ancient Assam does not refer to the existence of iron. Still, these epigraphic records do mention about arms made of metals. (Barpujari, 2004: 249) Again Chinese traveller Hiuen Tsang who visited Assam during the rule of the last Varman ruler King Bhaskaravarman of *Kamrupa* (ancient name of Assam) in the 7th century CE mentions that iron was a flourishing industry with iron ore being abundantly available in the Khasi Hills. (Handique, 1959: 2)

Even in the pre-historic period of Assam, we do find reference to iron vessels and swords. When Yuddhisthira, the eldest of the *Pandavas* performed *rajasuya* sacrifice after becoming the King of Indraprastha, King Bhagadatta of *Pragjyotishpura* (the earliest name of Assam) presented him iron vessel and swords with their handles made of pure ivory. (Barpujari, 2004: 82) There exist a general belief that the *kamars* or blacksmiths of this region did manufacture household articles like knives, sickles, spades, etc and weapons like swords, short javelins and tips of arrows among other items from early times. (Hamilton, 1987: 62)

Perhaps, the Khasis were the pioneer in the field of iron works in Assam. This metallurgical knowledge has transmitted from this Austric race people who were the earliest inhabitants of the region. K. L. Barua states that smelting of iron from ore was practised by the Khasis since pre-historic times. (Barua, 1973: 216) For smelting of iron, coal was needed which again provides us ample scope to believe that coal mining was practised in Assam from early times, may be the extraction in miniature form in comparison to the one started by the British in the colonial period. Even in the *Imperial Gazetteers of India* reference has been made that large quantity of iron ore was extracted from the coal mines in Upper Assam under the rule of the local rulers. (Eastern Bengal and Assam, 1909: 81)

Under the rule of the Varman, Salastambha and Pala dynasty in the pre-Ahom period, what we often refer as the ancient period, the traditional knowledge of the Khasis in iron works as already referred have spread out amongst the other inhabitants of the region. *Kamars* with their own iron workshops were there for manufacturing household items, farming implements and weapons. Before the entry of the Ahoms, the iron work developed as a tradition in *Kamrupa* (Baishya, 2009: 303) The Ahoms inherited this iron work tradition and developed it further into a prominent branch of metallurgy. The Ahoms ruled for almost 600 years from 1228-1826 CE over Assam dominating the entire medieval period of Assam history. Despite of being an alien to this land, the Ahoms like the Mughals in case of medieval Indian history, gradually accepted and adopted the indigenous culture of Assam encompassing different genres like agricultural practices, art and craft, religion, customs, etc and thereby developing in the process what we today collectively connote as the 'Assamese Culture'.

The Ahoms on entering the plains of Assam had to face stiff encounter from the tribes like the Morans, Chutiyas and Borahis who waged war with them and faced defeat. During the course of warfare with these tribes, the Ahoms had to move from one place to another crossing different river. Sukapha, the founder of the Ahom rule while crossing the Dikhow River drank its water and felt it comparatively heavier than that of the other rivers. Hence, after establishing his capital at Charaideo, Sukapha started operations to ascertain the cause of heaviness in the water of the Dikhow River. He moved upwards along

the bank of that river and found a stream flowing into the river through a hill having iron deposits. Smelting operations were started there by Sukapha by bringing iron smelters or *lo salias*. The hill was named hence forth as Tiru Hill and the stream flowing through it as Tiru. In the Tai language of the Ahoms, *ti* means smelting of iron and *ru* means caves. (Baishya, 2009: 300-01)

The Tiru Hill soon became a prominent centre of iron smelting in the Ahom kingdom and came to be known as the Tirulohakhat with the term *lohakhat* meaning the place where iron is manufactured. (Handique, 1959: 28) Iron smelting operations too started in the neighbouring areas and there developed three big villages of *lo salias* in an around the Tiru Hill, namely, Lohakhat, Pachikhat and Perakhat. These *lo salias* were mostly Kacharis and were also called as *tirumals* and were provided with land for settlement and cultivation by the Ahom kings. An officer called *tirukakoti* was appointed by the Ahom government to look after the entire iron smelting operation in an around the Tiru Hill. (Baishya, 2009: 301) This marked the beginning of organizing the *lo salias* into *kebels* or guilds in the Ahom period.

After the complete subjugation and occupation of the Chutiya kingdom, the Ahom King Suhungmung in the 16th century CE brought along with him many *kamars* whom he settled down in different places of Upper Assam. The Chutiya *kamars* were provided with workshops and were ordered to make weapons and implements. (Sarma, 1989: p. 312) Actually these *kamars* were prisoners of war and were liable to supply swords, guns and cannons to the royal storehouse from the iron smelted by the *lo salias*. (Purkayastha, 2005: 46) These *kamars* were organised into *kebels* with officials like *hazarika*, *saikia*, etc appointed from them to look after their activities. The organising of *kamars* into *kebels* or guilds soon proved to be fruitful as during the reign of Suhungmung itself the number of *kamars* in the Ahom kingdom rose to around 3000. (Barbarua, 1981: 466-67)

Pratap Singha, the Ahom king in 17th century CE brought *kamars* from Koch Bihar to teach advance knowledge of blacksmithy to the local *kamars* as well as the local people. This royal initiative proved to be successful as many people from the Koch, Kalita and other agricultural community started practicing blacksmithy and thereby popularising iron works in Assam. (Dasgupta, 1988: 496) Infact by

mid 17th century CE, the Assamese *kamars* acquired sound knowledge in iron metallurgy and they could cast variety of weapons. Shihabuddin Talish who accompanied Mir Jumla, the Mughal general in his expedition to Assam in 1662 CE mentioned that “the Assamese casted excellent matchlocks and *bachadar* artillery and showed great skill in that craft”. (Gait, 2003: 151)

As reported by Tavernier, Mir Jumla after occupying Garhgaon, the Ahom capital captured many war weapons which included 675 big piece cannons, 6750 matchlocks, 1343 *jambur* cannon and 1200 *ramchangis*. (Barpujari, 1994: 117) Such a large availability of weapons in the Ahom capital testifies the rich iron tradition in medieval Assam. Mir Jumla even ordered that the Assamese experts in the art of manufacturing matchlocks and gunpowder should be sent to Dacca. A wide variety of guns and cannons were there under Ahom possession like *batnaliya*, *jambur* and *ramchangis* (light field guns) and *pablangi*, *tubuki*, *holong*, *bahikbowa*, *manubmukbia* (long and big cannons). (Baruah, 1995: 452) Other weapons of war like *patharkalai*, *kamayana*, *kesai*, *pablangi*, *kboka*, *hilo*, *baghmura*, etc were also made of iron during the Ahom period. (Gogoi, 1961: 67-68)

Under the Ahom patronage, the iron works developed in Assam in two distinct groups, the *lo salias* associated with iron smelting and the *kamars* manufacturing products out of that iron. (Barbarua, 1981: 465) Iron mines were found over a wide range of areas both in plains (Upper Assam) and hills during the Ahom period and smelting of iron itself became an important industry. There were around 30 or 40 workshops established at Tiru Hill and Hatigarh for smelting of iron ore and manufacture of crude iron. The whole process did involve different stages of production and was a labour intensive work. In a day the *lo salias* in a workshop on an average could turn out 8 pieces of crude iron. Every iron smelting workshop (*lo sal*) as well as blacksmithy workshop (*kamar sal*) used to have atleast 5 to 6 persons (only male) of whom one used to be the master (*ojha*) and others as assistants (*palis*). (Barbarua, 1981:464)

A considerable amount of iron was also brought from the Barkhamti area in Upper Burma where the metal was wrought with considerable skill to a great perfection. (M’cosh, 1837: 58) The Barkhamti area was inhabited by the Kumung tribes who were excellent

in iron works. The agricultural implements made by this tribe were highly valued as these were made from superior quality of iron than produced in Assam. (Robinson, 1841: 35) The people of the Kumung tribes had racial affinity with the Kacharis, Chutiyas and Ahoms. All the *lo salias* and the *kamars* of Upper Assam in the Ahom period were mainly people from the Kachari, Chutiya and Ahom community. So, it was quite natural that other than the Khasis, the Kumung tribe of Upper Burma have also taught their fellow brethren of Assam the knowledge of iron works. (Purkayastha, 2005: 45-46)

Iron smelting operations were not done in Lower Assam as no iron mines were there. But *kamars* were there who were mostly from the Kalita and also from the Koch community. The *kamars* of Lower Assam did not manufacture weapons and their production included only domestic utensils and agricultural implements. They could even bring out their finished articles for sale in the market. (Jackson, 1906: 11-12) The technique of the *kamars* of Lower Assam was identical with that of Bengal as they had learnt blacksmithy from the *kamars* of Koch Bihar during the time of Ahom King Pratap Singha. While, in case of the *kamars* of Upper Assam, their technique was identical with that of the Khasis and Kumungs. (Purkayastha, 2005: 46) The Garos and the Khasis used to sell iron in the markets of Lower Assam which were even supplied to the *kamars* of Upper Assam. Palasbari was one such market where iron was sold from the hills and it was exchanged for paddy, mustard and other agricultural products. (Barbarua, 1981: 466)

The iron sold in Palasbari was soft in nature and could be melted easily for which it was considered to be best for the manufacture of nails, small size fire arms and inner tubes of large cannon. While, the iron of Upper Assam was best suited for the making of swords, axes, knives, shovels, hoes, etc. (Hannay, 1856: 333) There were royal workshops (*karkhanas*) in Upper Assam established by the Ahom kings for making war weapons. The Ahom kings used to force the *kamars* of Upper Assam to work in the *karkhanas* so that they could have large stocks of weapons which would facilitate them in carrying out their warfare activities. At times even the conquered people, prisoners of war and slaves were employed in iron works at the *karkhanas*. (Sharma, 1993: 210-12)

The Moamariya Rebellion of 1770s adversely affected the iron smithy practices in Assam. The iron smelting works were disrupted

resulting in less production of iron which again affected the working of the *kamars*. (Barbarua, 1981: 467) But from the reign of the Ahom King Gaurinath Singha (1780-94 CE) to Chandrakanta Singha (1810-18 CE), the *lo salias* and *kamars* once again continued their smelting and manufacturing works respectively under different *kbeldars*, *saikias*, *hazarikas* and *boras*. (Barpujari, 1994:102) Despite of continuation of the iron smithy practices, there was reduction in the number of *lo salias* and *kamars* in the Ahom kingdom. Towards the end of the reign of King Chandrakanta Singha, there were altogether around 500 *kbels* of *lo salias* and *kamars* in the Ahom kingdom and the number further reduced to around 100 because of Burmese invasions in Assam. (Barbarua, 1981: 467 & Hannay, 1856: 332)

Conclusion

The iron work did prevail in Assam from the early times and developed to a great height under the Ahoms transforming it into an indigenous or traditional industry in two distinct dimensions, the smelting of iron and manufacture of iron products. But as already stated the internal disturbances in the form of Moamariya Rebellion and external attack in the form of Burmese invasions created hazardous situation for the iron works in Assam and it faced acute crisis like all other artisanal crafts. A political stability was brought with the introduction of British rule. Under the new political set up the whole socio-economic set up changed bringing out structural changes in the traditional iron works. There was large scale importation of raw iron from outside leading to gradual decline in the iron smelting operations forcing the *lo salias* to abandon their occupation. No longer were the *kamars* of Upper Assam required to manufacture the weapons of war. The *karkhanas* were also not there. Hence, the *kamars* of Upper Assam like the *kamars* of Lower Assam has to channelize their metallurgical knowledge towards manufacture of domestic utensils, agricultural implements, etc for sale in the market. The blacksmithy did survive, but as a market oriented metal craft. □

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S.Radhakrishnan's Philosophy of Religion: An Analysis

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Abstract: Dr. Radhakrishnan is widely acknowledged as one of the most prominent and influential religious philosopher of the modern world. Contemporary Indian philosophy is greatly indebted to him for his contribution of immense scholarly works in the field of religious philosophy. Radhakrishnan's determination to defend Indian philosophy and the Vednātic system in particular, provided his work with a coherence and forcefulness. He was one of the most intriguing philosophers, who deeply interested in religion in a period of time when there was markedly decline of intrinsic significance of traditional religious belief for the modern society. In this paper I will try to explore certain basic ideas involves in Radhakrishnan's Philosophy of religion.

Keywords: Vedantic, Monistic, Religion, Society.

Article History

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Corresponding author: Dr. Nilamani Dutta

Introduction:

The twentieth century Indian philosophy takes an all-comprehensive view of life and existence. It takes full account of the empirical and the spiritual existence of man. Dr. Radhakrishnan is widely acknowledged as one of the most prominent and influential religious philosopher of the modern world. Contemporary Indian philosophy is greatly indebted to him for his contribution of immense scholarly works in the field of religious philosophy. Radhakrishnan's determination to defend Indian philosophy and the Vednātic system in particular, provided his work with a coherence and forcefulness. He was one of the most intriguing philosophers, who deeply interested in religion in a period of time when there was markedly decline of intrinsic significance of traditional religious belief for the modern society. In this paper I will try to find out certain basic ideas involves in Radhakrishnan's conception of religion.

Influences that shape Religious Idea of Radhakrishnan:

His basic philosophical position is an outcome of synthesis between the eastern and western traditions. He synthesizes Advaita Vedanta especially of Śaṅkara and Absolute idealism of the west. He brings out monastic character of the Vedāntic reality and combines it with some of the important aspects of absolute idealism. The spirit of Radhakrishnan's philosophy consists fundamentally in the attitude of synthesis or the concept of organic unity. As Charles A. Moore observed "His basic approach to philosophy is the recognition of and demand for organic unity of the universe and its many aspects of the many sides of the nature of man, of man and universe, of the finite and the infinite, the human and the Divine"¹(Charles,282). Hence he provides an interpretation of the philosophy which does justice to intuition and reason, philosophy and religion and this world and the other world. So it is clear that he provides inevitably a synthesis of the old and the new and of the east and the west in order to construct a philosophy of religion based on absolute idealism of Indian origin.

He says " I studied the classics of Hinduism, the Upanishads , *Bhāgavad-Gītā* , and the commentaries on Brahma-*Sūtra* by the chief *Acharyas*, Śaṅkara, Rāmānuja, Madhva and Nimbārka and others, the dialogues of Buddha as well as the scholastic works of Buddhism and Jainism. Among the western thinkers, the writings of Plato, Plotinus and Kant and those of Bradley and Bergson influence me a great deal. My relation with my great Indian contemporaries, Tagore and Gandhi were most friendly for nearly thirty years, and I realize the tremendous significance they had for me."²Thus, Radhakrishnan has two ancestral lines in theology, one in India, the other in the west³(Urumpackal,2) from which he develops his idea of religion.

Metaphysical basis of Radhakrishnan's conception of religion:

S. Radhakrishnan located his metaphysical basis of religion within the Advaita (non-dual) *Vedānta* tradition. Like other *Vedāntins* , he wrote commentaries on the *Prasthānatrayas* (main text books of Vedanta): the Upanishad (1953) Brahma *Sūtra* (1954) and *Bhāgavad-Gītā* (1948). As an *Advaitin*, Radhakrishnan embraces a metaphysical idealism which recognized the reality and diversity of the world of experience (*prakṛti*), while at the same time preserving the notion of a wholly transcendent absolute Brahman that is identical to the self (*Ātman*). Brahman is the source of the world and its manifestation, but those modes do not affect the integrity of Brahman.

As an idealist, Radhakrishnan believed that the natural outcome of a neutral and unprejudiced philosophy can only be monistic idealism. "The ultimate oneness of things is what the Hindu is required to remember every moment of his life."⁴ This monistic belief of Radhakrishnan can be seen in all his published work. It is from this monistic idealism that Radhakrishnan begins his religious quest to arrived at "Religious idealism"⁵

Basic characteristics of Radhakrishnan's idea of Philosophy of Religion are:

1. Perennial religion
2. Spirituality-essence of religion
3. Societal aspect
4. Evolutionary or Dynamism
5. Science and religion
6. Humanism
7. Religious experience

1. Perennial religion:

The Perennial philosophy is the philosophical concept, which states that each of the world's religious tradition shares a single truth. It asserts that there is a single divine foundation of all religious knowledge referred to as universal truth. Therefore perennial philosophy maintains that each world religion has flourished from the foundation of the same universal reality.

Religious philosophy of S. Radhakrishnan is a landmark in the history of philosophy of religion since he has given a panorama of central core of religion, apart from giving a authoritarian as well as institutional interpretation of religion. According to Radhakrishnan if we survey the historical view of different religions we will be able to obtain a more comprehensive vision and understanding of the spiritual truth. This spiritual unchanging substance of religion is the evolution of man's consciousness. Radhakrishnan regarding the history of religion he categorically admitted that a true religion is a perennial wisdom, it is eternal behind all religions that is "*Sanatan Dharma*"; a timeless tradition of human race.

2. Essence of religion: spirituality

According to Radhakrishnan it is not easy to find out an exact definition of religion. He basically emphasizes the universal aspect of religion. Influenced by absolutism and theism of *Śaṅkara* and *Rāmānuja* respectively and absolute idealism of Bradley and creative Evolution of Bergson, Radhakrishnan asserts that spirituality is the essence of religion. Of course spirituality is also the

essence of Indian tradition. According to Radhakrishnan in essence religion is the attempt of man to express his notion about perfect being, a perfect world, and a means by which we can have the experience of God. Radhakrishnan says "Religion is not creed or a code but an insight into reality."⁶ This insight will reveal that man is always confronted with something greater than himself which is somehow immanent in man himself. This absolute reality which is immanent as well as transcendent universally present in every man, which is the secret ground of human soul, can form the bridge between finite and infinite; insight into this reality as well as truth is the essence of religion.

3. Societal aspect:

Religion has a double dimension, inner and external. The inner is the God and outward is the service to fellow men.. The inner feelings of immediate experience of God are bound to issue in the service humanity. Radhakrishnan says " we affirm in loud tones that the service of man is the worship of God...no temples should be raised in the country which permit social discrimination. Temple should foster social discipline and solidarity."⁷

Like many modern thinkers Radhakrishnan's approach to religion has also a very strong social aspect.. He admits that religious sanction seems to be more effective for keeping man loyal and law abiding than any other technique such as prison and police. Radhakrishnan says "Religion is the device to give an emotional stimulus to the socially beneficent activities."⁸ He says "our sense of God is due to the pressure of society on us. An unapprehended God is invoked in support of current ethics."⁹ In other words God is the product of society. As Hick observed "The encompassing human group exercises the attribute of Deity in relation to its members and give rise in their mind to the idea of God , which is thus, in effect, a symbol for society."¹⁰ Thus Radhakrishnan maintains that religion is an integral element of a society and it represents the whole aspect of human being. According to him religion summons us to discharge the duties and responsibilities of society. He remarks "Religion is social cement, a way in which man express their aspiration and find solace for their frustration."¹¹

4. Dynamism:

According to Radhakrishnan the aim of religion is identification with the current of life and participation in its creative advance. Religion is a dynamic process, renewed effort of the creative impulse, seeking to uplift mankind to a new level. Every religion according to Radhakrishnan "is passing through self analysis and self criticism and is developing into a form

which is sympatric to other religions".¹²

Radhakrishnan's exposition of religion brings out dynamism as the very nature of religion. According to him religion has the capacity to adjust with the changes taking place around society. He says "If religion is to continue to have their original appeal, they must adapt themselves to the needs of the time. For religion there is no such thing as standing still. Stagnation is bound to overtake a religion, unless it is alive to the changes taking places around it".¹³ Regarding the progressive nature of religion Radhakrishnan observes, "if religion is not dynamic and progressive, if it does not penetrate every form of human life and influence every type of human activity, it is only a veneer and not a reality".¹⁴ Thus it is observed, according to Radhakrishnan, true religion should undergo a radical transformation for the needs of the time. Hence, Religion is a progressive concept it grows to meet the challenges of the world. As Radhakrishnan says, "this process of growth is securing for our civilization, a synthesis on the highest level of the forces of religion and culture and enabling their followers to co-operate as members of one great fellowship".¹⁵

5. Science and Religion:

It is generally observed that at the dawn of civilization, religion, science, art, morality was found intermingled together. The conflict between science and religion is due to historical circumstances.¹⁶ According to Radhakrishnan it is untrue to belief that there is an opposition between science and religion. Emile Durkheim in his book "Elementary Forms of Religious Life" promoted the idea that religion and science are similar. In Durkheim's thought religion and science were closely linked. Religion evolved first, and then science split from it. Radhakrishnan admits that there is a common platform regarding the origination of religion and science. As he observed, "Both in India and the west, science and religion had a common origin. The Seers and scientist were the same for the Vedic Asrama and in the Pythagorean brother wood".¹⁷ He holds that science which is known as 'Natural philosophy' and its history is an essential part of the spiritual history of mankind... The spirit of science leads to the refinement of religion. s. Radhakrishnan says, "science will triumph over ignorance and superstition, and religion over selfishness and fear, and nation will come together to build a great future for humanity, the brotherhood of which has been the vision of the prophets since the beginning of time".¹⁸ So it is observed in the light of Radhakrishnan's religious philosophy that science and religion are complementary to each other.

6. Religion and Humanism:

Radhakrishnan in developing his idea of religion was quite inspired by the traditional as well as contemporary Indian thought on the one hand and on the other by the western rational thinking. According to Radhakrishnan humanism is confessedly rationalistic, and ignores elements in life which cannot be dealt within an intellectual term. But the higher will in man becomes identified with the spirit in man. Without the recognition of such a spiritual centre, which helps us to coordinate the variety of unlike elements which help human nature to unite people of the world. So he says, "we cannot apply a mere mechanical rule, we must develop a living adjustment, a sure taste in any concrete case".¹⁹

Thus, Radhakrishnan was not in a position to accept humanism as substitute for religion. In Radhakrishnan's view humanism lacks that indefinable touch, that *élan* of religion which alone can produce that majestic faith, whose creativity is inexhaustible, whose hope is deathless and whose adventures are magnificent.

7. Religious experience:

Religious traditions of the world admit that we can apprehend the eternal being with directness and immediacy. According to Radhakrishnan religious experience is as old as our smiling and weeping, loving and forgiving;

According to Radhakrishnan religion is essentially an experience of living contact with ultimate reality. It is an apprehension of something that stands over against the individual. Reality of God cannot be proved in the manner as we proved the existence of a table or chair. He holds that God is not like the other object of the world, it is a spirit. He says, "Spirit is life, not things, energy, not immobility, something real in itself and by itself, and cannot be compared to any substance subjective or objective. The Divine is manifested in spiritual life or in experience. It is given to us in life and not established by ratiocination"²⁰

According to Radhakrishnan there is an ancient and widespread tradition that we can apprehend the supreme reality with directness and immediacy. According to Radhakrishnan, religious experience is unique and autonomous; it cannot be identified with other manifestation of spiritual activity such as scientific genius, artistic creation or moral heroism. It satisfies every side of our being. As Radhakrishnan observes, "in it the mind becomes irradiated with the divine light and obstinate questions of reason find an answer. The will loses its irresoluteness as it becomes one with the Divine will. Spiritual genius's possesses the highest that man can possess,

constant contact with the creative principle of which life is the manifestation, coincidence with the divine will, serene calm, inward peace which no persecution can dismay".²¹ He admits that religious experience is not mere "consciousness of value" (as Kant has said) nor it is a "form of knowledge" (as Kant has said). Enriched with Indian tradition he maintains that in religious experience there is a mystical element, an apprehension of the real and an enjoyment for its own sake.

Radhakrishnan idea of God:

S. Radhakrishnan's views on religion reflects that he based his idea of God on vedantic tradition of Indian philosophy.. According to him, the supreme reality is apprehended in a two-fold way, as personal and impersonal. The personal aspect is known as God whereas impersonal aspect is known as Absolute. In the early prose of Upanisads, *ātmanis* the principle of the individual consciousness and Brahman the super personal ground of the cosmos. Radhakrishnan explains that the different between the supreme as spirit and the supreme as person is one of the standpoint and not of essences. When we consider the abstract and impersonal aspect of the Supreme, we call it the Absolute; when we consider the supreme as self-aware and self-blissful being we get God. The distinction between Brahman in itself and Brahman in the universe, the transcendent beyond manifestation and transcendent in manifestation, the indeterminate and determinate, *nirgunaguni*, is not exclusive. The two are like two sides of one reality. So according to Radhakrishnan, Absolute and God are two different standpoint of the same reality.

He further says "We call the supreme the Absolute, when we view it apart from the cosmos, God in relation to the cosmos. The Absolute is the pre-cosmic nature of God, and God is the Absolute from the cosmic point of view²²". While the Absolute is the transcendent divine, God is the cosmic divine. Thus, Radhakrishnan clarifies the distinction further by saying that God is the truth of our intellect and the Absolute for our intuition and does not make God merely a principle of unreal creation as Sankara does.

Conclusion:

On the basis of observation of religious philosophy of S. Radhakrishnan, it may be say that, religion embraces whole aspect of human life and the world. Radhakrishnan based his conception of religion on monistic idealism of Indian vedantic tradition. His approach to religion is synthetic in nature. His thoughts are the harmonizing force in the world of religion. His synthetic approach to religion is meant to achieve harmony between the old and new, between

wisdom of the ages and the forces of rationality, science, progress etc. So, Radhakrishnan did a very excellent job by presenting Indian treasure of wisdom in contemporary terms to the cause of inter-religious and intercultural understanding. Thus, the spirit of Radhakrishnan's religious philosophy consists fundamentally in the attitude of synthesis or the concept of organic unity which has intrinsic value in interreligious dialogue of present society. With a profound grasp of the modern situation, especially in religion, Radhakrishnan greatly emphasized the importance of spiritual value in comparative religion, which is the most relevant to the present context of encounter between religions and cultures.

Radhakrishnan talks about the ideals of establishment of a world community based on the universal moral order. True religion will bring people of the world close to one another. Religion, is commitment to a kind or quality of life that purports to recognize a source beyond itself which conserve the value of life and society. A socio-political system based on the philosophy of spirit is an open system in the sense that it derives its force from a reality which is not exhausted by revealing itself in spacio- temporal texture. Such a philosophy has got unbounded relevance today for the contemporary society.

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The Strategy of Exhaustion And Intimidation: The British East India Company and the North East Frontier of India (1826-1857)

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Abstract

The establishment of the British rule in India is still an interesting debate in the academic field. There have been long debates and discussions on the nature of the annexation of the North Eastern Frontier of India by the British East India Company. However, no proper works have discussed about the British strategic policy in this region. The Company authorities adopted a multi-strategic policy in the North East Frontier, keeping the local condition in mind. Two such strategies were the strategy of exhaustion and intimidation. The climatic condition and other factors of the North East Frontier differed from mainland India. Therefore, the Company adopted the strategy of exhaustion to move cautiously. The chief objective of the Company after 1826 was to defend the North East Frontier from further Burmese aggression. Moreover, newly discovered tea industry

opened up profitable prospect of trade. The Company wanted to open up a trade route to china through the North East Frontier. All these factors led to the adoption of the strategies of exhaustion and intimidation in the region. These theories have been discussed by military historians after the First World War. This paper attempts to link these theories with British policy in the North East Frontier of India during the Company regime.

Keywords: North East Frontier, British East India Company, Policy, Strategy, Exhaustion, Intimidation.

1. Introduction:

The establishment of British rule in India is an important historical phenomenon. It is still an interesting topic in the academic field how a trading organization brought a vast country under its hold. The process of India's colonization involved many elements. One such element was the superior military policy of the British. British military superiority and its implementation accelerated British overseas expansion during the seventeenth and the eighteenth centuries. Other elements like a strong bureaucracy helped them expanding their empire in India. Like other parts of the Indian Subcontinent, North-East India was also a victim of British colonialism. Due to the fact that the region physically differed from mainland India, the British adopted a multi-strategic policy to keep the North-Eastern Frontier under their control.

1.1 Definition of Strategy:

The term 'strategy', originated from the ancient Greek word, *strategia* literally means 'the art of the general.' Strategy was initially believed to be an art that could only be fully understood by military personnel. On the other hand, the study of military strategy was popularized in the academic field after the publication of 'On War' by Carl von Clausewitz. It is difficult to make difference between political and military strategy as the two often overlap. The definition of military strategy is put forward by Giovanni Sartori as "a plan that describes how military means and concepts of employment are used to achieve military objectives" (Sartori, 1970). The effective distributions of man power and of supplies of material, finance and diplomacy, which are all within the sphere of statecraft, all are elements of war. The military is one of the means employed by the state to achieve its aims. Strategy therefore can be defined as the art or process of applying state's power to achieve the object of war. In general strategy comprises of political, military, naval and air strategy. Military strategists focused on

separate and distinct theories of strategy, such as annihilation, exhaustion, intimidation and subversion, as ways to achieve policy objectives.

1.2 Survey of Literature:

A good number of works have been done by researchers and academicians regarding the policies adopted by the British in the North East Frontier of India such as *Trade and Colony, the British Colonisation of North East India* by J.B. Bhattacharjee, *History of the Frontier Areas Bordering on Assam from 1883 to 1941* by Sir Robert Reid, L.W. Shakespeare's *History of the Assam Rifles*, *The Comprehensive History of Assam*, volumes IV and V, edited by H.K. Barpujari, Gunnel Cederlöf's book, *Founding an Empire on India's North-Eastern Frontiers, 1790-1840 (Climate, Commerce, Polity)*, Madan Paul Singh's book *Indian Army under the East India Company* etc. The North East Frontier of India has always been an interesting topic in the academic field. Particularly the different aspect of the colonial period has attracted serious discussions. British policy towards the people and the region has been discussed by many scholars and academicians. However, the military strategy, which was so instrumental in maintaining British supremacy in the North East, has not attracted much discussion. The colonial writers gave accounts of warfare of the different tribes in their narratives of expeditions. Some works have been done regarding recruitment policy in North East. However, no works seem to have connected modern military study with this prospect. In this paper, an attempt is made to analyze how the British East India Company used the strategy of exhaustion and the strategy of intimidation in the North East Frontier of India.

1.3 Objectives:

This paper shall discuss the following objectives:

- i) To give an idea about the strategies of Exhaustion and Intimidation.
- ii) To analyze the use of these strategies in the North East Frontier of India by the British East India Company.

2. Discussion:

2.1 The Strategy of Exhaustion and the North East Frontier:

The Company initially followed the strategy of exhaustion when it came to warfare. According to the Oxford Essential Dictionary of the US Military (2004), the strategy of exhaustion is defined as, "A strategy emphasizing the gradual and often indirect erosion of the enemy's military power and will to resist." It is also called the Fabian Strategy, because

Quintus Fabius Maximus Verrucosus, (nicknamed the Cunctator, meaning 'delayer') adopted a strategy of delaying during the Second Punic War (Bowditch, 2013:208). As a rule, it is used by the defending party when it was losing the war, or its resources were decreasing. Its execution depends on the situation, which was the very reason the Company adopted it. After 1826, the Company's primary objective was to defend the North East Frontier from the Burmese. More importantly, the Government of Calcutta was not willing to spend more money for that purpose. Moreover, the soldiers recruited from Oudh, Bihar and Bengal were anxious to return to their homes as they could not stand the 'unhealthy' climate of the region for long (Barpujari, 2007:189). The Company was lacking the necessary men power right after Yandabo. The Company was yet to assess the military strength and tactics of the communities inhabiting the region. Earlier in 1824, David Scott, the Governor General's Agent in the Frontier in his letter to George Swinton, Chief Secretary of Staff, Fort William expressed his lack of clarity regarding his knowledge of the military strength of the tribes when he wrote,

"The Nagas, the Singphos, the Khamtis and other tribes to the eastward of Assam are perhaps too little advanced in the art of governance and war" (Scott to Swinton, FSC, 1824)

Till that time, the Company had fought several wars in India and the Authority knew the futility of waging war without understanding the local condition. The British army utilized the local resources while framing their strategy in colonies (Deshpande, 2005:i). The British initially tried to avoid offence. They saw the success of the policy of exhaustion during the American War of Independence, when George Washington avoided direct collision with the British troops which helped him to save resources for a longer period (Randall, 2013:213). Before the First Anglo- Burmese War, the Company's troop was floundering hopelessly in jungles of the North East. There was an utmost necessity of carefully collecting all information likely to be of use in military operations in North East.

"The British policy was to wait and watch the existing conditions and then gradually they began to enter into a system of engagement with the hill tribes of the region. The engagements provided them an opportunity to secure the reaction of the cross country Powers and provided them with a basis of intercourse with the tribes" (Bose, 1979: 2).

Before engaging its strength with the tribes of the region, the Company had to ensure the defence of the frontier from the Burmese. For that purpose, Sadiya was identified as the most important military post.

There was provision for road communication from Dibrugarh and there was provision of water communication by the Brahmaputra. Moreover, the commercial potentiality of Sadiya lured the Company. Francis Jenkins in his report stated about the possibility of trade in Sadiya. A fort was erected at Sadiya with a brickwork magazine in the centre surrounded by a loop holed parapet. The fort had a storehouse which could hold four month's supply (Report, 1830:20-24). Jenkins advised to erect a stockade of strong timber to store arms and ammunitions. He further instructed to change the 12 pd Carronades of the gunboats with 4 pdr brass-guns. Local people were recruited as gunners and they were paid Rs.12 a month (Barpujari, 1995:9). It decreases the cost of maintaining gunboats to navigate the region. From Sadiya up to Lakhimpur on the north bank and Sivasagar on the south bank of the Brahmaputra, a series of forts were raised to assist the post at Sadiya in times of emergency. This is an example how the British used local resources. They started patrolling the area, twice a day to gain idea about the local response to the establishment of a British fort at Sadiya. The Field Service Regulation of the British Army prescribed for the provision of a proper supply line to military posts. Sadiya was selected as it was well connected by waterways and roads from Guwahati. To communicate with the neighbouring tribes, *kotokis* (interpreters) were appointed by the Company Government. The Company Government needed the tribes inhabiting the Sadiya region as its allies for the defence of the Frontier from the Burmese. The region was inhabited by the Khamtis, Singphos and the Matakas. Before the Treaty of Yandabo, the Singphos seemed to join the Burmese plunderers and took many peasants from Assam as captives. Most importantly, the Khamtis and the Singphos inhabited along the route through the hills between Assam and Upper Burma. Under these circumstances, Captain John Bryan Neufville, the Commander of the platoon of the region, was instructed to conciliate the tribes and to form an alliance with them (Barpujari, 200:134). He played off the influential Singpho chiefs, Beesa Gam and Daffa Gam and brought them to his side (Barooah, 2015:143). In 1826, David Scott made alliance with 16 Singpho chiefs. They agreed to supply the British troop with grain and to make and repair roads for them (Barooah, 2015:137). Other 12 Singpho chiefs were threatened that if they did not agree to British proposals, their properties would be confiscated. The Company used the Khamti soldiers against the Singphos (Barooah, 2015:144). For the defence of the region, proposals were made to form a local armed force by enlisting the Khamtis and the Matakas. These men were naturally peasants. To make them familiar with

military works, they were trained to build stockades, trench-work and making canoes (Bedingfield to Scott, B.S.P.C., 1826). However, to convince the natives of the permanent nature of British occupation of Sadiya, a regular Company troop of 600 men was stationed at the main outpost of Sadiya. In 1827, the Sadiya Militia was formed with strength of 450 men. The security of the Sadiya frontier was also necessary for the purpose of trade across the Assam-Burma border. After 1826, surveyor parties were sent to study possible trade routes in the frontier region. The route to Hukawng Valley that was used by the Burmese in 1817, 1820 and 1825 attracted the attention of the British authorities. There was possibility of profitable trade of woolen cloth and other European goods. Captain Neufville held a fair of European merchandize and gifted the Singpho chiefs with attractive items (Barooah, 2015:153). The reason for this was that, the route to the Hukawng Valley lay in the territories of Beesa Gam. This policy of conciliation was part of British strategy in the North Eastern Frontier.

But there was another problem. The Muttock kingdom, under the Bar Senapati, near Sadiya, was a tax-free territory. In 1826, the Bar Senapati acknowledged British supremacy. He was not asked to pay any tribute to the Company at that time. But the Company authority was eager to bring the fertile Muttock kingdom under its direct control for revenue purpose. Moreover, many subjects of Upper Assam and British districts used to migrate to the Bar Senapati's kingdom to get rid of taxation. The kingdom was found suitable for tea cultivation also. Under these circumstances, the British demanded a tribute of Rs 10,000. The Bar Senapati refused it and since then, the British were looking for an opportunity to annex his kingdom. The kingdom was divided into seven distinct tracts among the seven sons of the Bar Senapati. Captain Jenkins proposed to make separate agreements with his sons, but the Calcutta authority refused it as it would provoke the Bar Senapati against the British. For the security of Sadiya, maintenance of peace of the Muttock kingdom was necessary. Therefore, after the death of the Bar Senapati in January, 1839, the British agreed to acknowledge Maju Gohain as the new Bar Senapati provided he pay the tribute. Maju Gohain opposed it. However, he agreed to open up the waste lands for tea cultivation and acknowledged the appointment of a British officer to settle disputes between Europeans and the inhabitants of the Muttock Kingdom (Barpujari, 2007:121). It was a policy of gradual expansion of British penetration into the Muttock kingdom. The final opportunity emerged in the form of a clash between the Morans, a

community inhabiting the Muttock kingdom and the Bar Senapati. The British distorted the provisions of their treaty with the former Bar Senapati and supported the claim of the Morans for a free territory. The Bar Senapati did not comply and eventually, the Muttock country was annexed in December, 1839. This annexation shows the British strategy of gaining profit by interfering in internal politics of the kingdoms of the North Eastern frontier. This annexation provided them with the mastery over the Sadiya region and a country suitable for tea cultivation.

In 1839, the British had to face the boldest showcase of tribal warfare, when about six hundred Khamtis attacked the Sadiya outpost. The troops at Sadiya were not expecting any resistance and their retaliation was weak. The commanding officer was killed by the invaders. It was high time for the Company to showcase what its force could do. The Khamti villages were burnt down and their grains were destroyed. The Government shifted the outpost towards Saikhowa, so that supplies could reach easily. More troops were sent to Sadiya as rumors of a Burmese invasion were getting strong after the attack (Barpujari, 1996:149).

2.2 The Strategy of Intimidation and the North East Frontier:

The Company authorities avoided offensive measures in the North East Frontier as much as possible. The Home Government was eager to use the North Eastern Frontier as a trade route. For this, it was advised to adopt a conciliatory policy towards the groups. However, if there was disturbance, the Company adopted the strategy of intimidation. The strategy of intimidation is defined as the deterrence from some action by the threat or violence. Thomas Schelling described the relationship between physical force and the psychology of intimidation as:

“It is the threat of damage, or of more damage to come, that can make someone yield or comply. It is latent violence that can influence someone’s choice—violence that can still be withheld or inflicted, or that a victim believes can be withheld or inflicted. The threat of pain tries to structure someone’s motives, while brute force tries to overcome his strength. Unhappily, the power to hurt is often communicated by some performance of it. Whether it is sheer terroristic violence to induce an irrational response, or cool premeditated violence to persuade somebody that you mean it and may do it again, it is not the pain and damage itself but its influence on somebody’s behavior that matters. It is the expectation of more violence that gets the wanted behavior, if the power to hurt can get it at all” (Bowdish, 2013:223)

The strategy of intimidation is generally used to achieve an objective

intact without fighting. Effectively, the enemy is forced to give up the political objective without a fight by showcasing military might. The enemy is shown an invincible force, which may not be the reality. What created terror among the communities of the North East Frontier was, the use of fire-arms. The Company army was infantry depended. Infantries were divided into tactical units like battalions, regiments and brigades (Sok, 2015). It made continuous fire at the opponent possible. The Company forces fought as a unit. They marched in columns and formed up in line formation in front of the enemy. The troops would fire their muskets one after the other. So, if the line had 60 men, then 60 shots would ring out in a minute, sometimes in less than a minute. When the last man on one side had fired his weapon, the first man on the other end was ready for his next shot. This way, constant fire could be maintained. In the row formation, troops would form two rows, and the front row would kneel. All guns would open up at the same time. This tactic was called volley fire (Roy, 2004:89). In case the enemy broke past defenses and reached the line, the troops would fix bayonets and hold the advance. This was particularly effective against cavalry charges. Infantry was supported by the field artillery which played a crucial role in field warfare. Moreover, the use of screws to elevate the guns helped the British Army. The Company's soldiers had the Short-land Pattern .75 Calibre flintlock musket and the India pattern of the same musket. Popularly known as the Brown Bess, it was a high-performance musket, which was easier to load; in fact, it took about a minute (average 43 seconds for three shots) for an expert soldier to fire four rounds. Thus, increased firepower of the infantry-artillery gave the Company troops an advantage in close quarter combats. The Company's *sepoys* were better trained and led. They had better arms as well. The troops were well drilled and whatever be the circumstances, a British army would never break up and flee; they would hold their ground. It was this superior will to prevail that probably made all the difference. Thus the Company had superior military forces to expand and secure territories of their interest.

The hill communities were punished by burning their villages and destroying their grains. The Singpho chiefs were infuriated due to the increasing British influence, which made their position weak in the eyes of their people. One of the chiefs, Beesa opened up a rebellion against the British. To prevent such actions, the Company sent punitive expeditions as a means of controlling the frontier communities. The most effective way was burning of villages and destruction of granaries. The strategy of intimidation was particularly adopted against the Nagas. The Angami Nagas

created trouble in Cachar since 1835. To control them, police outposts were established in the territories inhabited by the Angami Nagas. But it did not bring any positive results. In 1836, more than 70 Cacharis, under the protection of the Company was killed by the Nagas. The Company authority decided to send a punitive expedition to pacify the Nagas. Military outposts at important Naga territories were established. The invading force, instead of attacking the Naga villages, met the headmen and tried to conciliate them. Though it was supposed to be a friendly gesture, but the showcase of British forces compelled the villagers to refrain from attacking the villages of Cachar. Moreover, they agreed to pay tribute. But the Nagas near the *duars* south of Sivasagar could not be pacified by such measure. Controlling them was not easy, as they learnt the use of fire-arms from the British. Their warfare was revolutionized. They introduced village fortification to prevent British artillery. Therefore, the Company Government withdrew military action in the Naga Hills. By this time, there arose a difference between the local officers and the Calcutta Government. The former advocated offensive measures in the hills, the later non-intervention. The further development was the outcome of the new strategy of the British Government in India under the Crown.

Since 1826, the Company was eager to connect Sylhet with Assam by a road across Khasi hills. The road would not only connect the Barak and Brahmaputra valleys, but also it would provide the British with access to the hill territories. In the dispute between the Khasi chiefs Tirut Singh and Chattar Singh, David Scott acted as the intermediary. He supported Tirut's claim as the Chief of Nongkhlaw and in return the Company gained his support to construct a road from Assam to Sylhet via Cherapoonji to be used to move the troops (Barooah, 2015:228). Another road was constructed through the Jayantia hills. The Jayantia king was 'under the protection' of the Company since 1824. This road passed through two Khasi principalities, i.e., Jowai and Nartiang. The chiefs of these two Khasi states, along with the chief of Gobha were important to maintain the balance of power between the Ahom kingdom and the Jayantia kingdom. After the Nongkhlaw massacre of 1829, the Company officers had their eyes on inter-tribal politics, as it was the key to the markets of the hills. In 1830, following a dispute with the Jayantia king, the chiefs of Jowai and Nartiang refused to take order from the King. The Company took it as an opportunity. The King of Jayantia had firm control over the plains, but his authority over the hills depended upon his relation with the Khasi chiefs. In the meantime, two British subjects were kidnapped by men from Jayantia

for the purpose of sacrificing them. They were able to escape and the Governor General warned the Jayantia King, though he was not responsible (Barpujari, 2007:107). After a few months, the Jowai chief needed men for a religious ceremony and the Jayantia king instructed the Gobha chief to provide them. This time, four British subjects were taken captive in the Gobha principality, only one could escape. The Company had a case of human sacrifice and a surviving victim to testify. It had the golden opportunity to take possession of the southern and northern lowlands of the erstwhile Jayantia kingdom. The British had their eyes on this region due to its fertility. Moreover, establishing control over the hills was a difficult task at that time; therefore the lowland seemed more important for them. The British demanded from the Jayantia king an annual tribute for their 'protection' of the region, known as the Seven Banks. Besides he was asked to deliver the persons associated with the human sacrifice ceremony. Delay from the King to execute the instructions led to the adoption of a Resolution by the Government of the British East India Company in India on 23rd February, 1835. By this Resolution, the Company annexed the plain territories of the Jayantia kingdom. The King surrendered his authority of the hills to the Company (Barpujari, 2007:113). This action of the Company indicates how the British took advantage of the internal disputes and hill politics to meet their need. In the case of human sacrifice, place names and other testimonials were changed to establish a strong case against the Jayantia King (Cederlöf, 2014:173). The Company was more interested, apart from the plain territories, on the arsenal of the King which stored 236 musket flints, 507 matchlocks and 213 bayonet muskets (Cederlöf, 2014:176).

The Company had the advantage of fire-arms and it used it to spread fear of British troops. After the annexation of Jayantia, the Company needed control over the hills. The chieftain of Jowai was targeted to set an example before the hill tribes. Captain Lister, the officer-in-charge of Jayantia, was ordered to raid Jowai and he was given a reinforced troop. But the guerrilla warfare of the Khasis compelled him to negotiate. Using the policy of threatening the villagers of burning the village and destroying their property, Lister humbled the Khasis of Jowai (Cederlöf, 2014:178). Thus, the Company dominated the Khasi hills.

Though Manipur was treated as a native state by the British, they manipulated the king against the Burmese. The reason was Manipur's location; it was a buffer state, which could be used as a protective shield against Burma. Since the 1820s, the policy makers of the Company had

planned to bring Tibet, Sichuan, Yunan, Arakan and Upper Laos under its subjugation and Manipur was identified as the centre of this plan (Cederlöf, 2014:197). The Company supported Gambhir Singh as the king of Manipur and supplied him with European arms and ammunition, including four 3-pounders, 100 Golundazes and trained his troop in modern fashion (Pamberton, 1991:52). During the First Anglo-Burmese War, Gambhir Singh's troops defeated a Burmese troop and entered the Burmese border near Chindwin. The Company neglected his aggression upon the Naga tribes and North Cachar. However, survey parties informed the Governor-General in Council regarding this aggression. In 1833, the Governor General William Bentinck expressed the Company's grand plan of securing the Manipur-Burma border. He instructed the officers of the North East Frontier to use the Nagas, Kukis, Cacharis, Gambhir Singh's troops and even the European planters in this strategy. He indirectly encouraged the king of Manipur to invade the Naga Hills to subjugate the hill tribes inhabiting the Manipur-Burma border region. The Company did not want to manpower and wealth on this matter. They were further instructed to make sure Gambhir Singh did not harm the interest of Purandar Singh, for the ruler of Upper Assam was also a part in Bentinck's policy (Cederlöf, 2014:197).

The post-Yandabo period was a period of consolidation for the Company in the North-East. Its forces were cut in two by the hills separating Assam from Sylhet and Cachar. A most urgent need for the British was to construct secure roads. The territories needed to be physically tied together. Though short roads were constructed for minor purposes, road planning was not done with more of a bird's eye view. The war with Burma and subsequent fear of more Burmese aggression made clear the need for broad, hard roads on which troops could be moved across the hills. In the 1830s, several survey expeditions were sent to explore the best route to connect Manipur with Jorhat, Cachar with Dhansiri Valley and Sylhet with Guwahati (Cederlöf, 2014:198). The Anglo-Burmese War had a devastating effect on Cachar, Manipur and Assam. These kingdoms were suffering socially and economically due to damaged crops fields, refugees and constant military presence. Particularly, Cachar took a long time to recover. Francis Jenkins, who had been sent with Pemberton to investigate the best route from Manipur to Assam in 1832, recorded the devastating effects of the War in South Cachar. They asked for soldiers from Cachar to be sent to Manipur to secure its protection and possibly advance further against Burma. Jenkins and Pemberton then moved towards the densely forested hill tracts of North Cachar with a troop of 1400. These areas were of

strategic importance as they connected Manipur, Jayantia, Cachar and Assam. Since the 1820s these territories were controlled by Tularam, while the areas to the south and east were under the Nagas. The surveyors set out from the lower hills to north Manipur took a circular route into Jayantia as the Nagas were not ready to help them. Jenkins placed 30 soldiers of the Assam Light Infantry at Muhong against a possible Naga attack. They started to construct a military road up to Dhansiri. Some villages were established along these routes and kept under military guard for getting supply to the troops. This route became important to moving goods and troops from Manipur and Cachar in the south to Guwahati and Jorhat on the Brahmaputra. The British gave high priority to the building of roads, the means by which the new territories could be physically brought together. It also helped them to consolidate the conquered lands and combining them into one unit administered within a single bureaucracy. In 1834, the Court of Directors of the Company noted with satisfaction the news that the road between Cachar and Manipur was perfectly safe from robbers and that the king of Manipur would supply the labour needed to repair it for military purpose (Cederlöf, 2014:89).

The *duar* areas of the then Kamrup, Lakhimpur and Darrang districts were in important locations. The *duars* of Kamrup were situated in the Bhutan border. They marked the geographic transition from the plains to the higher range. The neighboring communities exercised exclusive control over some *duars* and in some *duars*, the control was altered between the communities and the Ahom king. The Company Government retained this system and made the tribes exclusively dependent on the *duars*. It made them vulnerable to blockades. However, unlike the North-West Frontier of India, blockade was difficult due to the dense nature of the jungles (Barpujari, 2007:136-137). In 1837, the tribes controlling the Darrang and Lakhimpur *duars* were instructed to collect *posa* from a British officer instead of the villages of the plain areas. In the *duars* of the Bhutan frontier, law and order was often violated. The Company did not pay much attention towards this region. The traditional system was encouraged to prevail. However, military outposts were established but no strong measures were adopted. Bhutan's border officers encouraged the tribes to plunder villages of Assam. Gradually, the number of these raids increased and the Bhutan Government did not take any measure to stop it. The Company authorities sent a mission to settle the dispute, but no positive result came out. Finally, the Company took the extreme measure and annexed the Bhutan *duars* in 1841 (Barpujari, 2007:137).

3. Conclusion:

For the Company, possession over the North East Frontier of India was crucial. The region provided the Company with a base to thwart possible Burmese aggression. Moreover, the region was identified as a gateway of trade with South East Asian countries. The Company's primary concern was trade and hence it did not prefer severe warfare in the North-East. War meant the requirement of more European troops, more supply and a lot of expenditure. The Company authorities wanted to maintain its hold over the Frontier with minimum cost. Therefore, the strategies of exhaustion and intimidation were adopted. Well organized and highly trained army of the Company was a valuable asset for the Company. The Company could defend the region and searched for new trade routes. With the help of the surveys, the Company brought the Frontier physically and trade routes connecting Burma and China were discovered. During the period under the Company, the North-East witnessed military might of the British. The Frontier was well-guarded by a series of military outposts. However, after the British Crown took over the administration of India, British offensive was started in different parts of the North-East Frontier of India.

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