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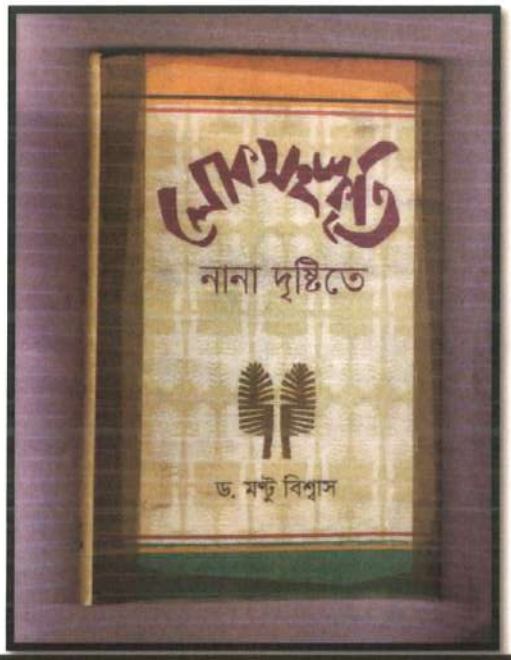

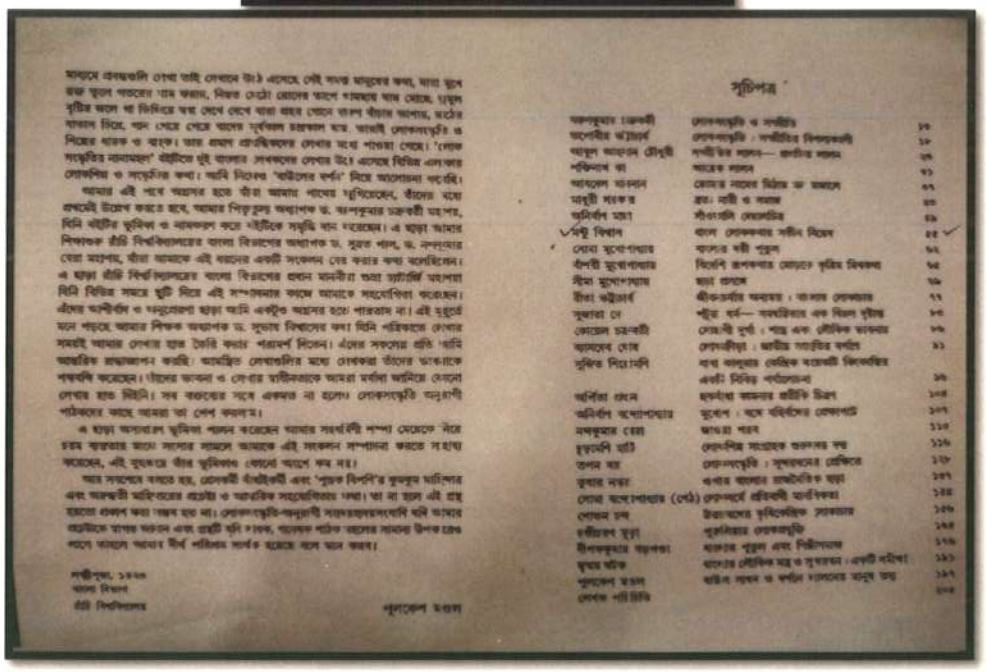

সূচিপত্র

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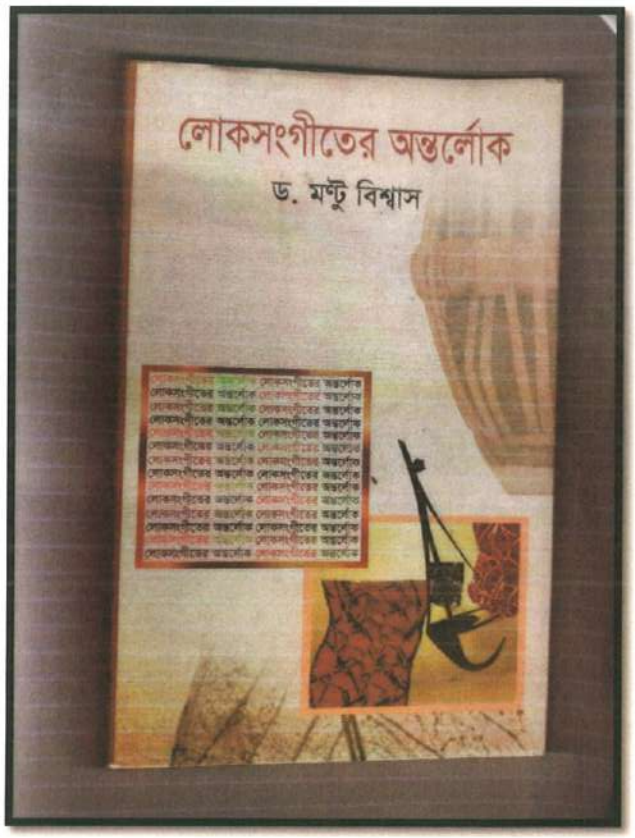

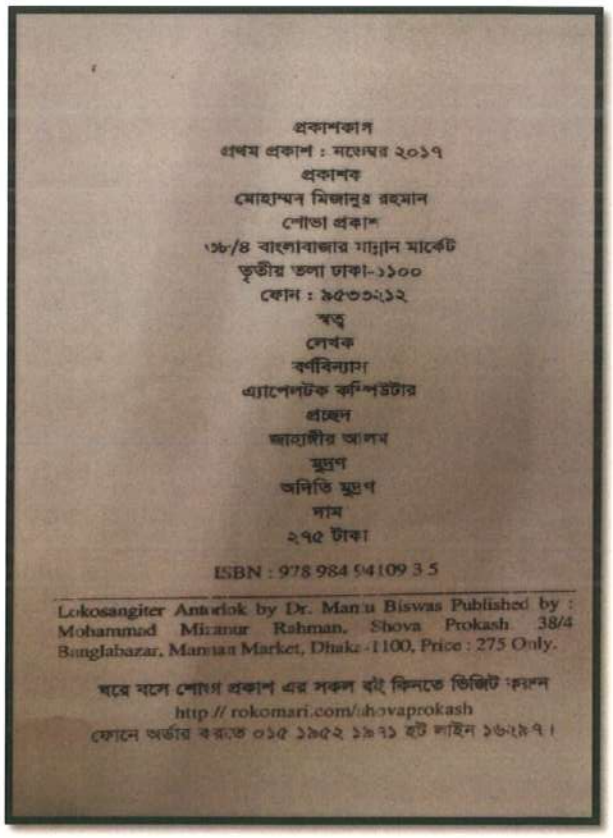
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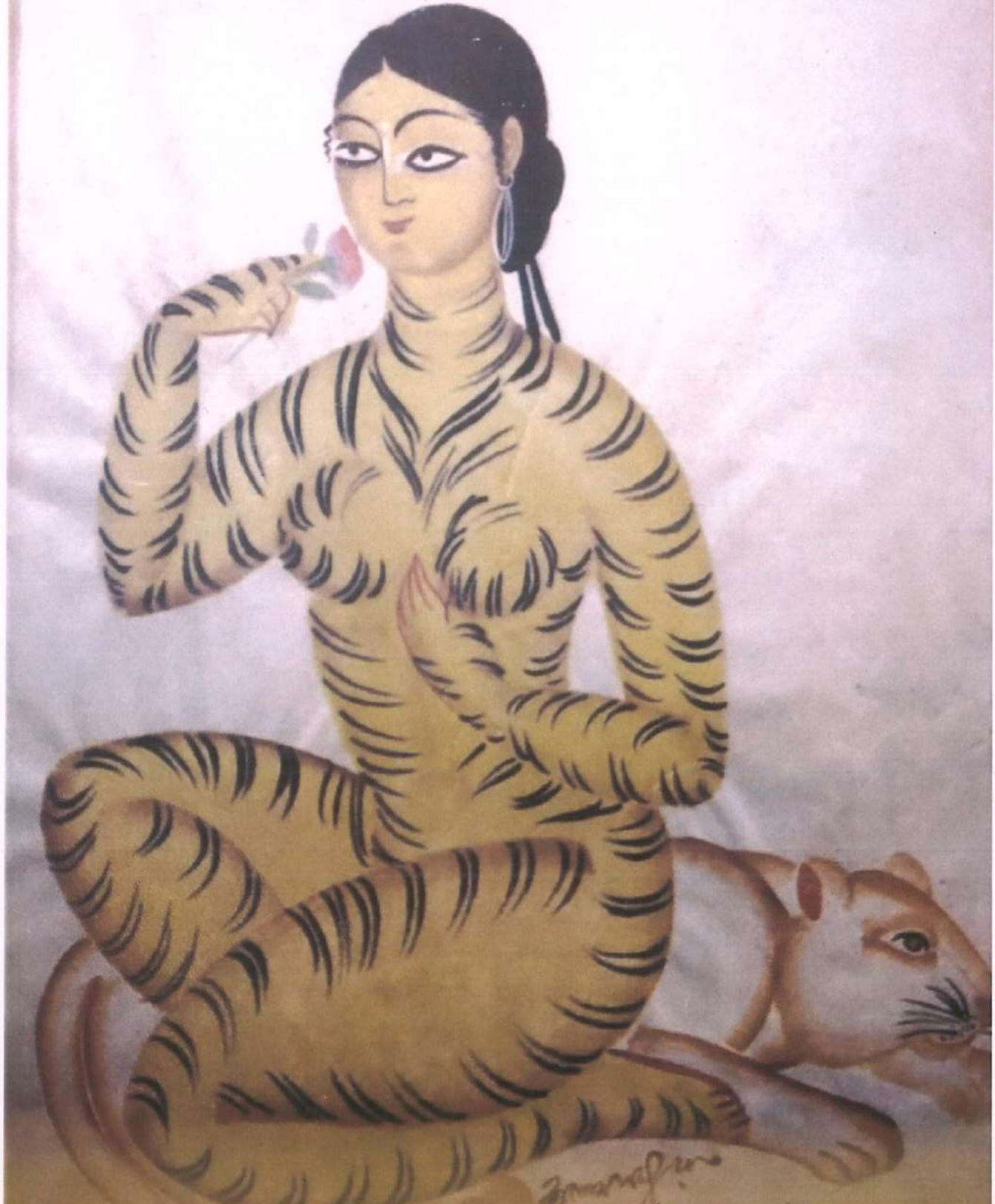

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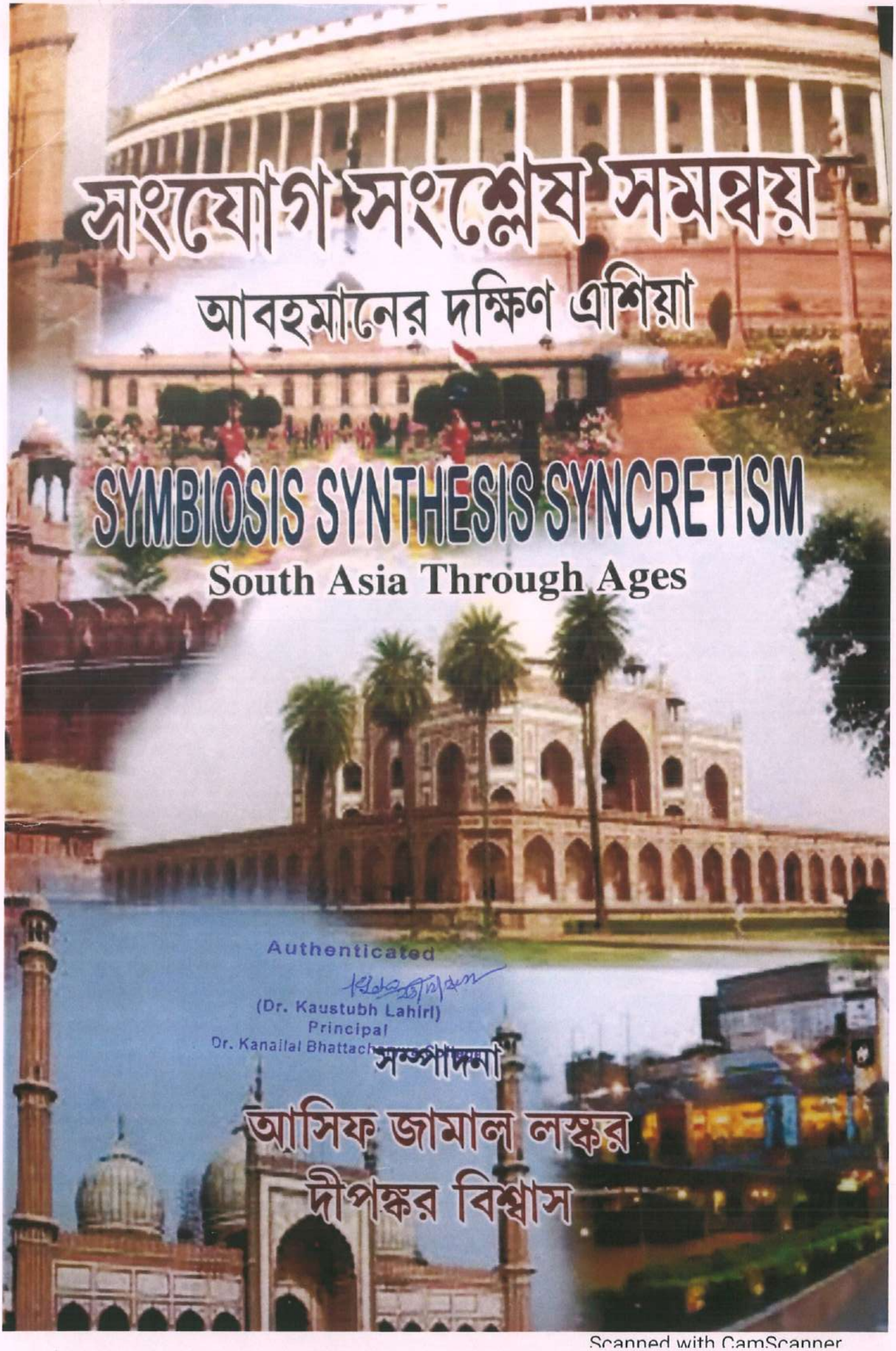

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The Nature of Literary Experience According to *The Natyasastra*

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Abstract

In an oral tradition like India, all ancient literature and literary theory must be studied in the context of the anonymity of their authorship. In the philosophical context, the composer is a Yogi, who yokes his mind to the object and gives form to the substance. 'The Natyashastra' (150 BC) was composed in this cultural background where elements of Vedic concepts of life, Hindu mythology, Brahmanic ritual , art, architecture, Ayurveda, linguistics, the varna system etc.were accumulated to achieve a synthesis . This ancient unique text on dramaturgy does not only theorize about oral/performing arts but also is an important cultural icon when it comes to answering the question of the purpose of literature in society. In the Sanskrit tradition all art is craft. Thus while laying the foundation stones of the performing arts, the text establishes the utility of literature as an oral discourse of knowledge. The text enunciates for the first time in the tradition that literary experience is very close to experience of absolute bliss.

Keywords: rasa, bhava, fifth veda, rasanubhuti, sadharanikarana.

'The Natyashastra' recognizes 'kavya' or literature as the *fifth* veda- a source of knowledge. Indian literary theories are empirical responses to what still is an oral culture - even the term for verbal compositions, *vangmaya*, literally means ' that which has existence in / which is permeated by speech'. Literary theories that are applied to Indian compositions must take into account their orality and what flows from this dimension - the anonymity or serial authorship of the texts, and hence the non-pertinence of authorial meaning and the need to designate the author as 'composer' (rather than writer) and the receiver of the text as 'auditor' rather than 'reader'. The concepts of creativity and the creative process are found to be completely different from the West. The paradigm artist in Indian thought, for example, is the potter as against the carpenter in Western (Greek) thought. The carpenter cuts, segments and re-arranges his material reality (the wood) and is therefore a 'maker'. The potter's material reality (the clay) is like water in the ocean not measurable or segmentable and the potter therefore does not 'make'- he merely makes manifest a form that inheres in the material and is present to him in his mind. The potter is not the 'master' but a *sadhaka*, a devotee, a Yogi who yokes his mind to the object and gives form to the substance. It is against this background of the potter being the paradigm artist in the Indian tradition, that all literature and literary theory got composed. It is in this tradition of orality and a deliberate anonymity maintained by traditions of composers that an attempt has been made to understand 'The Natyashastra'in the cultural background in which it was composed.

The doctrine of Rasa emerges in a concrete shape, fully developed in all its varied ramifications in 'The Natyashastra' of Bharata. This big work of 37 chapters, purporting to deal with the art of histrionics, treats of a variety of kindred arts and sciences ancillary to it: and among them are poetry, literary criticism, dramaturgy etc. The printed text as we have it in the 'Kavyamala', comprises_passages in 3 different styles- (i)Anubaddha verses in the Arya and the Anustubh metre (ii) Sutra –bhasya (iii)Karikas- which show that the work is a gradual evolution from the original. The nucleus of the Natyasastra appearing after the rise of the Sanskrit drama , could at the earliest be placed at the latter half of the second century BC.

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Bharata, the mythological composer of 'The Natyashastra', subscribed to a common world-view and enunciated a well defined discourse drawing upon several established disciplines. This is evident from the internal evidence of the text. The sources of 'The Natyashastra' also highlight the state of knowledge it reveals. That Bharata had a thorough knowledge of the Vedas including their status in the hierarchy of knowledge and their individual form and content, is evident from a reading of the first chapter and several other chapters of the text. Thus, a theory of aesthetics and a structure of drama could be derived from the Vedas. From the Rig-Veda, Bharata took the concept of 'pathya' or the transmitted word, a significant premise of 'The Natyashastra'. From the Yajur-Veda, the text-book on rituals, he took body-language and gestures. The author went further to compare a theatrical performance (natya) with a Vedic ritual (yajna). This alludes to the methodological and structural pervasiveness of 'yajna's during Bharata's time. The source of the sung note in 'The Natyashastra' is the Sama-Veda. The concept of 'sattvika' in 'The Natyashastra' emerges from the Atharva-Veda in its understanding of the human body as a physio-psychical system. Thus throughout 'The Natyashastra', the Vedas emerge as a source of immediate human experience. It may be surmised that the text was composed in a living tradition of the Vedas and the Brahmanas.

'The Natyashastra' emerged in a society where the 'Trinity' of Brahma, Vishnu and Maheswara were not yet known. During this time, the god Brahma was referred to as a principle of centrality as in the 'brahmamandala'(on stage), 'brahmasthana'etc and also Vishnu, who was considered as a principle of the triangle as in 'vaishnavasthana'. While Shiva is mentioned, there is no mention of Nataraja. The various dance movements are mentioned without any reference to the 'tandava' dance of Nataraj. Lord Krishna also does not find any mention in the text. Indra still occupies an important position as is evident from other contemporary Sanskrit works and also Indian sculpture. Ganesha and the other 'avataras' of Vishnu are also absent. An important point to note is the various gifts Bharata receives after the successful performance. Indra gave his auspicious banner (dhvaja), Brahma a 'kutilaka', Varuna a golden pitcher (bhringara), Shiva success (siddhi) and Saraswati visibility and audibility (chapter 1). There are similar passages occurring in the Brahmanas where similar gifts are given at the time of rituals. These suggest that Bharata was employing a familiar mythology and cosmology in his universe of the theatre.

There is an important description regarding the performance of 'puja' on the stage after the 'natya mandapa' has been constructed. Bharata makes it obligatory to offer 'puja' before the start of the play and calls it equivalent to Vedic 'yajna'. Though Bharata carries the analogy of the 'yajna' right through the text, yet he emphasizes the need for consecrating and sacralising the space through 'puja'. This later practice is 'agamic' or Dravidian. There was a co-existence of the two systems and Bharata plays the role of a synthesizer. There is however no mention of image worship. The entire stage was to be consecrated. 'The Natyashastra' was thus composed at a date prior to temple construction in India.

Brahmans really created the drama, and kings protected it. Bearing out this point is the ritual aspect of their relations. 'The Natyashastra' offers a detailed description of three rituals – two connected with the foundation and consecration of the templar theatre, and one performed immediately preceding the drama. As Chapter II of 'The Natyashastra' has it, the building of the theatre influenced the entire country when it started on an auspicious

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day appointed by Brahmans .Close attention belonged even to the measuring rope. If it tore in two, it forebode death to the patron of the theatre (the 'Svamin', by which the treatise means King); if in three, the country was on the threshold of unrest; and if in four, the ' Prayoktar', leader of the company, was doomed to die (chapter 1)

The building of the theatre demanded from the start the participation of the king and the Brahman, closely connected with him – the Natyacharya (chapter 2). Both the king and the priest attended the ceremonial laying of the foundation stone, accompanied by the ' puja', during which flowers, fruit, fragrances and food were sacrificed to the cardinal and midway points. At the end of the 'puja', both received sacrificial gifts – the king a potion of honey and milk, and the priest, treacled rice (chapter 2). Both also took part in the ritual of pillar erection. The pillars symbolized the four principal Varṇas of the Ancient Indian society – the Brahmaṇas, the Kṣhatriyas, the Vaisyas and the Sudras, and their erection demanded the utmost caution. They were by no means to be shaken, budged or turned as whatever movement portended national calamities – droughts, deaths or enemy invasions (chapter 2).

It is possible to re-construct the various groups of people and their languages from a reading of 'The Natyashastra'. It recognizes the various languages and dialects used by various groups of people and also the mention of Barbaras, Kiratas and Chandalas throws light on their general social acceptance. From the regional differences emerge the concept of 'pravrittis'. The country was said to be divided into cultural zones.

The composer's acquaintance with a flourishing system of medicine, namely Ayurveda is seen when he enumerates the physical and psychological processes of the human body. In the chapters relating to acting (abhinaya), Bharata shows his familiarity with the functions of joints. This was the emphasis of contemporary anatomy where the muscles were of secondary importance in a dance performance. The five elements, namely, 'agni','vayu', 'prithvi', 'jal' and 'akasha' according to Ayurveda are responsible for maintaining equilibrium between the motor and sensory systems. The nature of the aesthetic experience, ie. Rasa as also the aesthetic object and character types accept the primacy of the relationship of the psychical and physical. Bharata's deep understanding of the relationship between the intellect, brain and body is revealed in the *Rasa Sutra* itself. He betrays his knowledge of the inner states of consciousness. The 'bhava's are the distinct states of being emerging in diverse configurations. It is the totality of a human being or, the various 'bhava's that constitute art.

The theory of Rasa is as attempt to explain the rise and nature of the 'aesthetic pleasure' that a responsive audience experiences while witnessing the skilful enactment of a play. Bharata , in an aphoristic statement , says: 'vibhavanubhavavyabhicarisamyogad rasanispattih'-(chapter_6). Bharata further elucidates that just as flavour comes from a combination of many spices, herbs and other substances, so rasa emerges from many bhavas. Flavour, being latent in food, remains in a passive state. Only when it is tasted does it become active. In other words, it is transmitted in a process. This process of transmission of flavour points to the participation of a perceiver. Hence the ultimate taste of rasa is in its being tasted or perceived.

At the time of the composition of 'The Natyashastra' all creative and critical texts moved within the parameters of a world-view that subscribed to the goals of life as the four

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purusharthas .Though the text clearly identifies the four *purusharthas* as *dharma, artha, kama* and *moksha* it makes radical departure from the boundaries of *varna* hierarchy. Bharata creates a fifth Veda and calls it Natya-Veda to make it accessible to all castes and classes thereby transcending norms of inclusion and exclusion. The author of 'The Natyashastra' was familiar with kings and a sophisticated urban culture, and also of a vast variety of populace both tribal and rural, is evident from the use of such technical terms as 'sabhastava', 'svamin', 'yuvaraja', 'senapati'etc.

It can be summarized that for texts like 'The Natyashastra' the cultural background serves to make the reader exprience the essence of the world-view that is projected in the text. Such a text is open ended. Its categories adjust themselves to literature of the present times. It is a text that participates in the living tradition where there is a long practice of textual exegesis. As a student of English literature, I was overwhelmed by the structural analysis of literary texts that an ancient theory could provide. Rasa theory is perhaps the world's only complete aesthetic theory with its own grounding in the Indian philosophical systems. The methodology of studying 'The Natyashastra' would be to analyse its categories with reference to its internal evidences. It does not record historical events. It should be read as a cultural product of a group of learned and empathetic scholars.

Bharata states that rasa is an inherent property of the self. Still the reader /spectator does not constantly experience it, nor does everyone experience it to the same degree. This is because only when the experience-vibhavas- etc. has been truly and completely understood that *bhava* is experienced as rasa. Again, what is needed is *sahrdayata* which makes it possible to grasp the true (general) nature of a literary experience. On account of that the quality of relish of generalised vibhavas is determined by the degree of sahrdayata. Where there is total empathy, the self takes the form of *ananda* and the reader/spectator is immersed in this. This state of complete bliss is rasa. In the case of literary experience, the *citta* itself is transformed into *ananda*, bliss or happiness. Therefore, *kavyananda* is different from *visayananda* and *brahmananda*. This rasa experience may be characterised either as cognising intellect or intellectual cognition, that is, consciousness modified by the awareness of the *bhava*, or the *bhava* qualified by consciousness. Thus, in effect, the theory claims that the rasa-bhava is within us.

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ISSUES AND CHALLENGES

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Amit Bhowmick
Elias Olukorede Wahab

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26/11/2021
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- ISSUES AND CHALLENGES

Edited by

AMIT BHOWMICK

ELIAS OLUKOREDE WAHAB

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POLITICAL ACTIVISM AMONG WORKING WOMEN IN THE FORMAL SECTOR:

A Case Study of Bank Employees and Teachers in South Kolkata

ANASUA CHATTERJEE

"Political culture is the pattern of individual attitudes and orientation towards politics among the members of a political system."

– (Almond and Powell, 1966, Ch 3, pp. 50)

Such individual orientations involve several components: a) *cognitive orientations*; knowledge of political objects and beliefs, b) *affective orientations*; felling of attachment, involvement or rejection about political objects and c) *evaluative orientations*; judgments and opinions about political objects. Hence, an individual may have a high degree of political knowledge about how the political system works, who are the leading figures, what are the different Government structures through which decisions are taken but he/she may have feelings of alienation or rejection towards the system and therefore would not respond in terms of political participation like voting, involvement in political meetings etc.

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– ISSUES AND CHALLENGES

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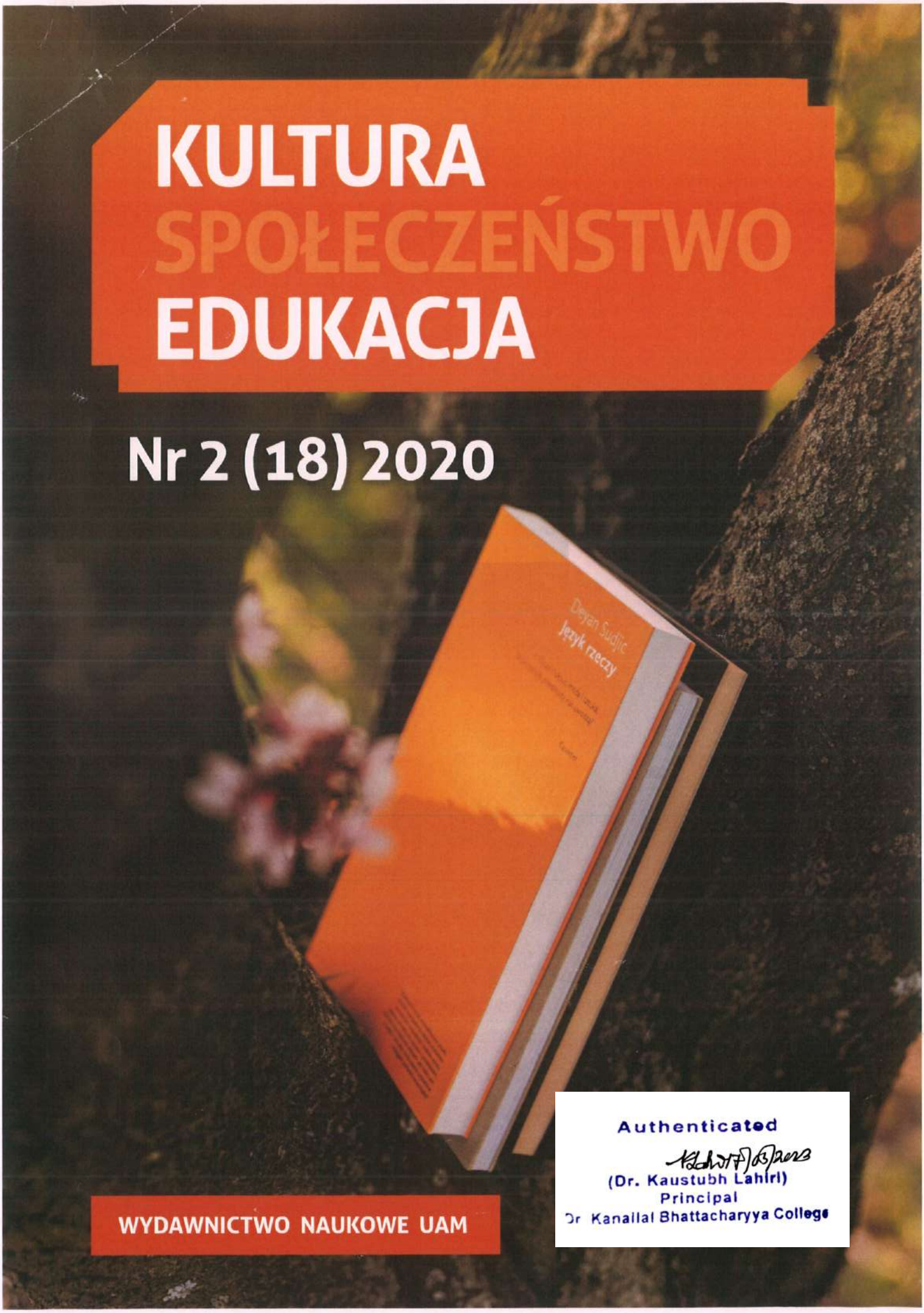

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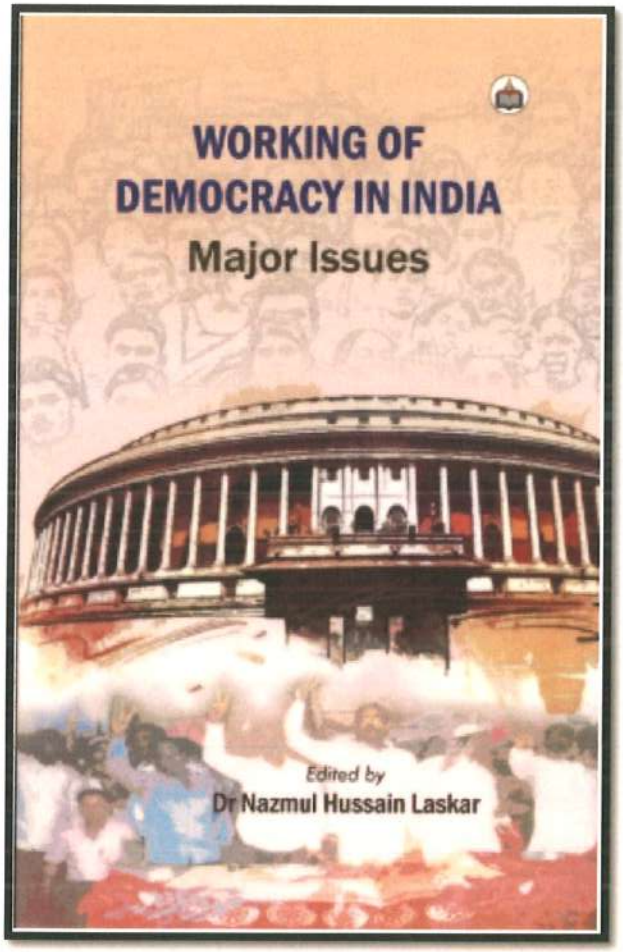

BOOK

Political interest and pattern of Voting Behaviour: a study of choice of decision-making among street vendors & domestic workers of south Kolkata.

Prof. Anasua Chatterjee

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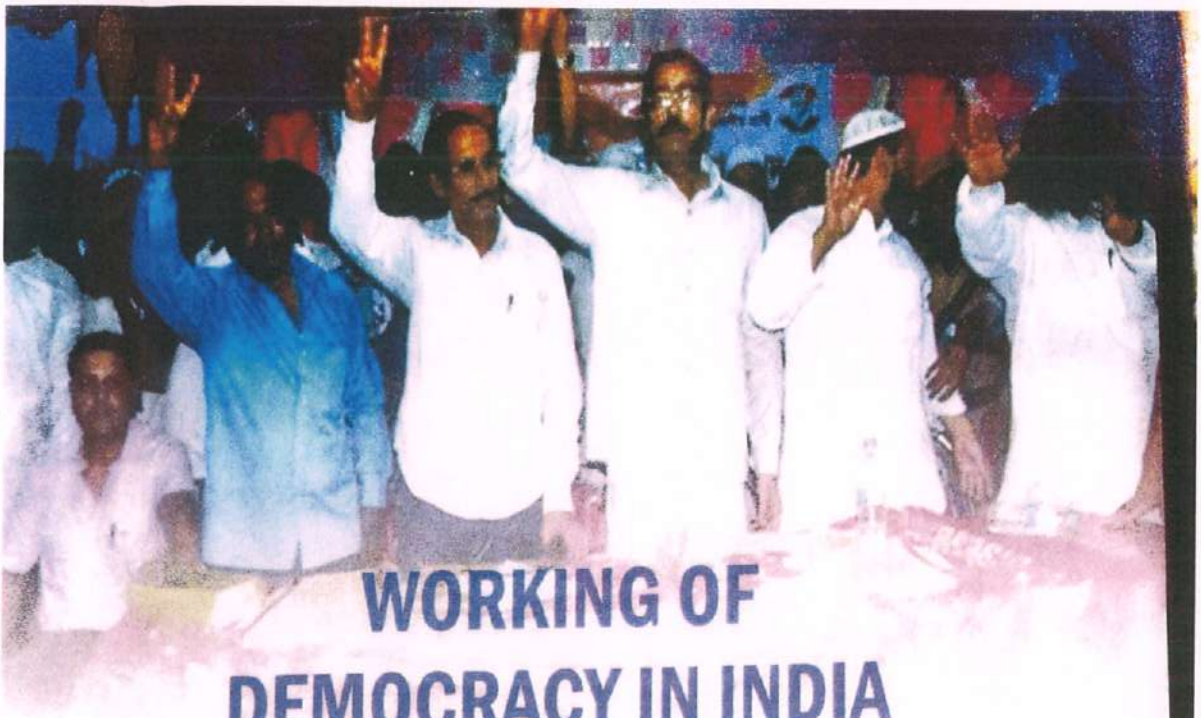

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Political Interest and the Pattern of Voting Behaviour: A Study of Street Vendors & Domestic Workers in South Kolkata

Anasua Chatterjee

Introduction

Political participation is a complex phenomenon liable to be influenced by different variables. It denotes a series of activities which have a bearing on the political process. To be more specific, these activities mainly are (1) voting at the polls, (2) supporting possible pressure groups by being a member of them, (3) personally communicating directly with legislators, (4) participating in political party activity (5) engaging in habitual dissemination of political opinion. It is to be noted that more people discuss politics than vote, and many more vote than join parties or work in campaigns (Woodward, J. L., et. al., 1972, pp.133). Some other empirical studies also show that most people are just not especially politically oriented and political participation is not a "natural" concomitant of citizenship. As Eakin's (1972,pp. 97)study, based on survey research, shows that only small percentages, probably fewer than 10 per cent in all democratic countries, belong to a political class. It has been pointed out that to exercise political influence is a special kind of political involvement in which female citizens, no matter where they live, or what their level of education is, find it very hard to engage in. Women's roles are such in which political passivity is perceived as the norm. Women in political systems are heavily dominated by men. (Christy C A, 1984). In this society, women are

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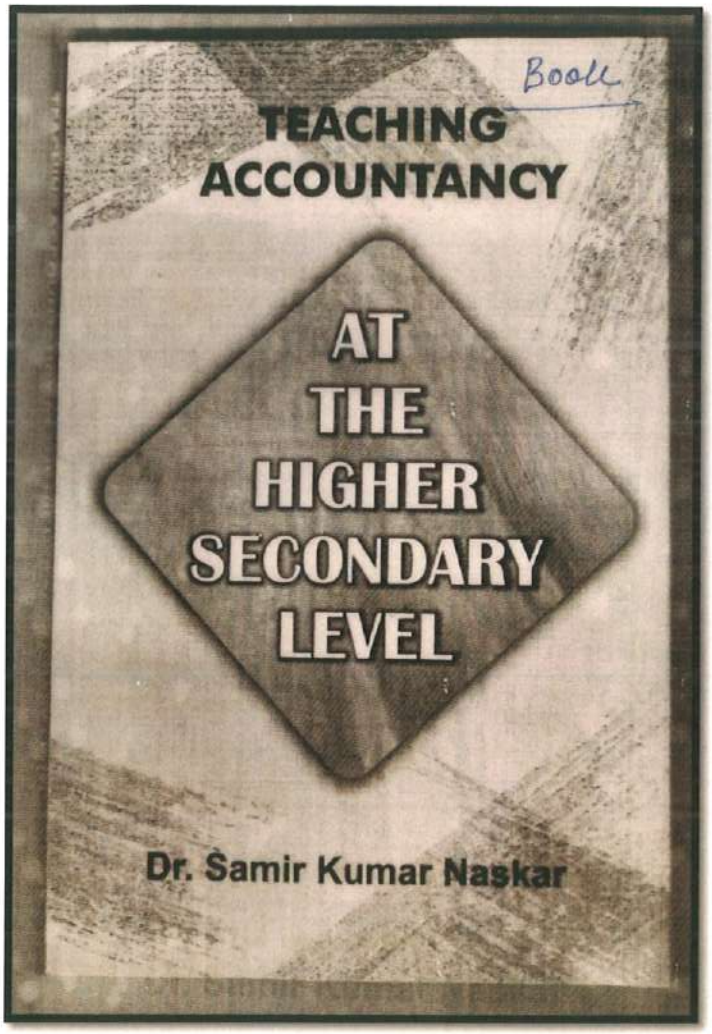

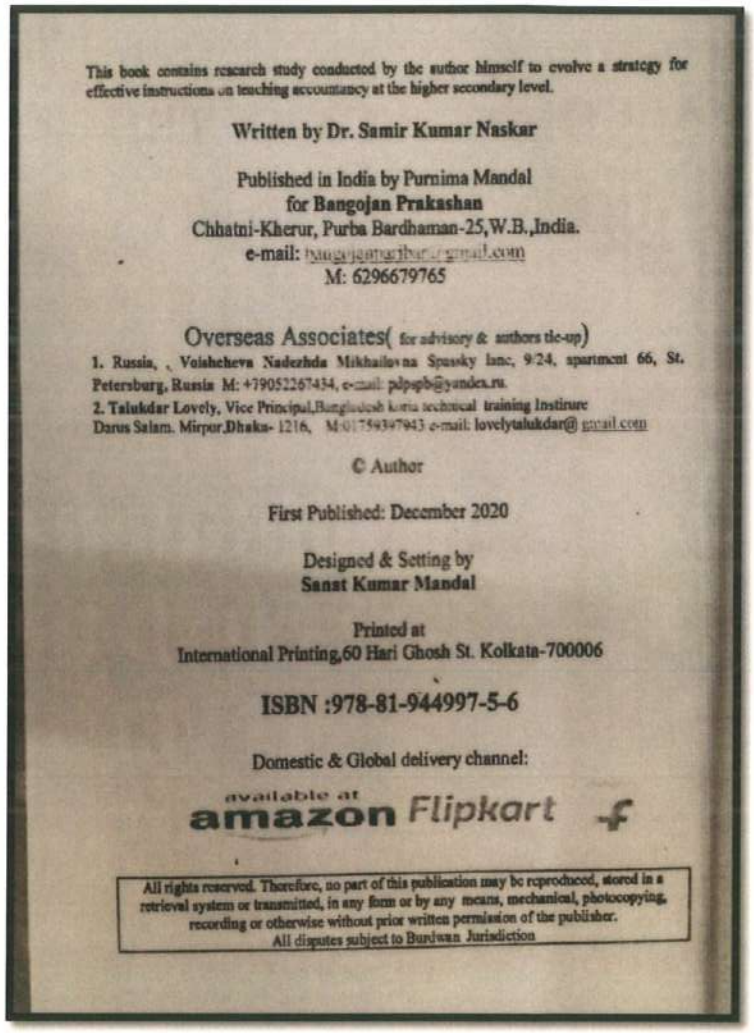
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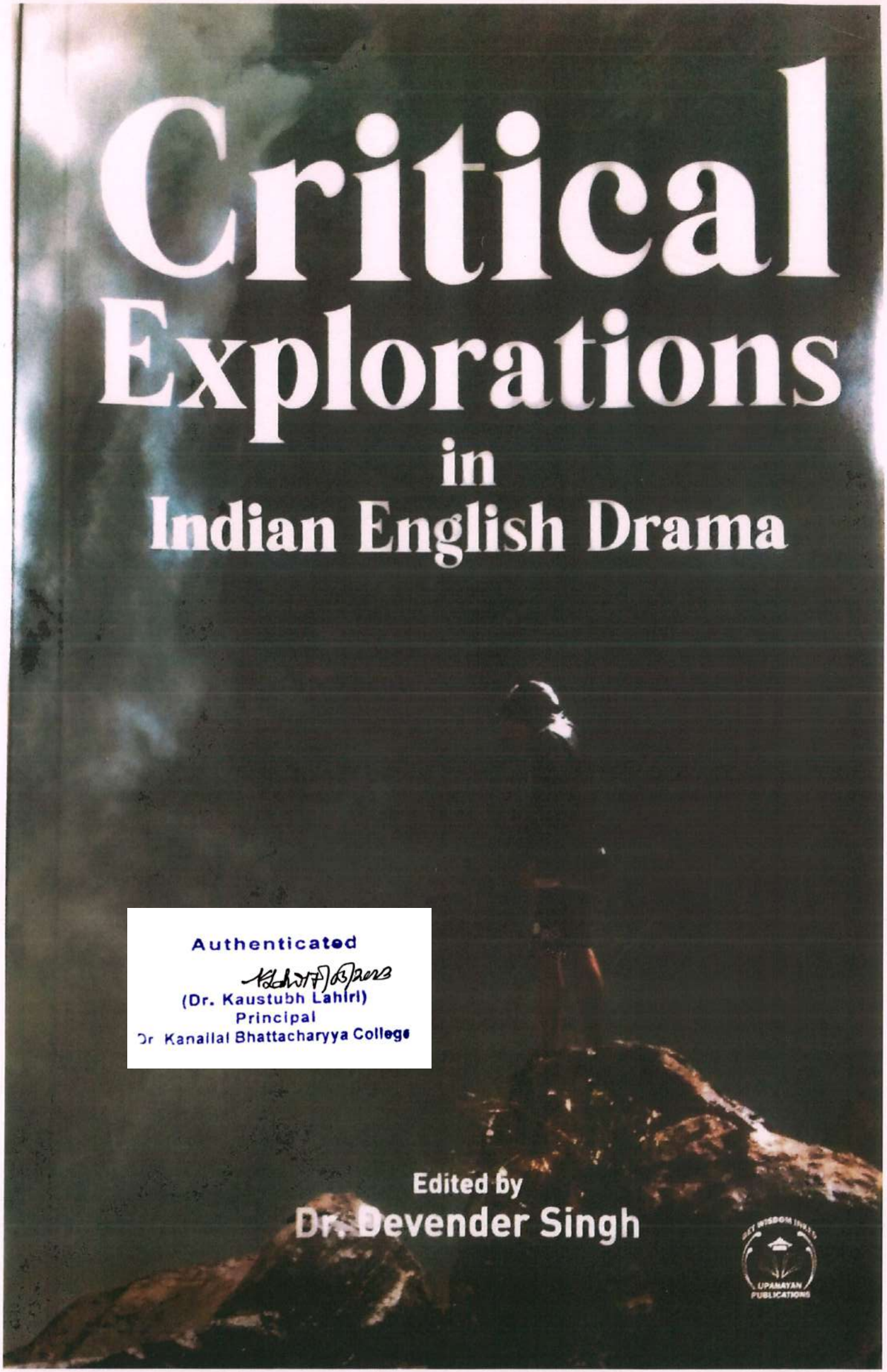
Critical Explorations in Indian English Drama



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7

Subaltern Voices and Gender Stereotypes in Mahesh Dattani's Selected Plays : *Dance Like a Man* and *Bravely Fought the Queen*

SRIJEETA ADHIKARY*

Abstract: Gender discrimination and subaltern identity are indisputably some important social concerns that Mahesh Dattani has depicted through his works. Dattani, being a prolific playwright, screen writer and stage director, takes up theatre as a tool to express the inertia of his thoughts and the intricate pictures of contemporary India. This paper aims to highlight Dattani's take on postcolonial scenario of Indian society and how the idea of gender has been stereotyped over the years. In Dance Like a Man and Bravely Fought the Queen, Dattani, on one hand, seems quite domestic in talking about the apparent ashamed and hidden issues of life, on the other, he is voicing the subaltern people, the marginalized section of society and providing a new direction towards the notion of 'gender'. The paper also enunciates the writer's apprehension with the postcolonial discourse, associated with queer identity, patriarchal hierarchy in society and preordained gender roles.

Introduction

Theatre is a lively representation of the dynamics of society and human lives. We intuit art as indispensable to human culture and we perceive this raw pleasure of art by its various representation in several mediums. Unlike other forms of art, theatre is such a medium which imposes a greater impact on the audience. Therefore, from Shakespeare to Bernard Shaw, plenty of playwrights have emerged and used theatre as an operating tool to convey their thoughts,

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feelings, desires, perceptions and to raise issues concerning the social and political conflicts.

Mahesh Dattani is an Indian playwright, screenwriter, filmmaker, and stage director who came with the revolutionary idea to change the entire scenario of Indian drama and theatre. It would be misleading to say that Dattani caters only the niche audience, rather he narrates his plays for a prodigious group of people, dealing with the problems and difficulties that seem very common to them. While rendering with lofty philosophical matters, Dattani prefers to dredge up the dark secrets of humanity and society. On one hand, he seems quite domestic in talking about the apparent ashamed and hidden issues of life, on the other, he is voicing the subaltern people, the marginalized section of society and providing a new direction towards the notion of 'Gender'.

Dattani's plays show his concern as a writer and dramatist. Basically, they demonstrate innovative subject matters and thematic concerns as well as his experiment with stage craft. Here I have chosen two popular Dattani's plays— *Dance Like a Man and Bravely Fought the Queen* which vividly express the writer's apprehension with the post colonial discourse, associated with homosexuality, male chauvinism, and gender discrimination.

Dance Like a Man

Dattani's second play *Dance Like a Man* is one of the finest and most popular play in Indian theatre. As the title suggests, the play redefines the idea of 'gender', a new perspective of male identity, with the help of 'dance' as a method or tool. These two acts play first enacted at Chowdiah Memorial Hall, Bangalore, on 22nd September 1989. Later, under Dattani's direction and he himself as an actor within the play, it was subsequently performed at the NCPA Experimental Theatre, Mumbai, on 14th February 1990.

Dance Like a Man is a beautiful fusion of art of dance and philosophy. In this play, Dattani does not uplift the darkness of life, but he shows the little nuances and suppressed desires that we all possess with a subtle but decent admixture of art of dance. The play primarily tells the story of three generations and mostly revolves around the lives of the dancing couple Jairaj and Ratna. However, Jairaj here stands out as the subaltern voice, the subjugated persona who endlessly fights with his life, his family, especially with his father and then struggles to cope with the age-old norms of the society. It is

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quite evident for Dattani's readers and audiences that gender issue is a kind of 'pet' subject matter for him but surprisingly in this play, he almost challenges all the gender stereotypes prevalent in Indian culture and propels his audience to such an extent that they can think beyond the conventions. Jairaj is a passive figure who always aims to be a classical dancer from his childhood. Here, Dattani quite skillfully delineates that Jairaj does not perceive dancing as the sole item to be achieved to acquire fame and satisfactory position in society, but he admires the classical genre of dancing, that is Bharatnatyam. For Jairaj, dancing is a subjective medium with which he can identify himself and moreover, as a suppressed character, he can express his desires, thoughts, pain, and agony only through dancing.

This play heightens its intensity with the contrastive nature of the characters. The fatherson relationship is one of the interesting points of view that Dattani tries to depict. Amritlal loves his son, Jairaj and so let him pursue dancing just as a hobby while he was a boy. But he never imagines that Jairaj can ever take 'dancing' as the chief occupation to run his family and to establish his social recognition. Amritlal Parikh is unable to understand and appreciate his son's devotion to Bharatnatyam as he is totally ensconced in his own traditional values and beliefs that he considers Bharatnatyam is associated with prostitutes and brothels. What Dattani tries to exhibit here is the narrow social boundaries seeming essential for people to follow and obey and the one who is fortunate enough to decline the traditional path, is considered not as a rebel whom we should celebrate but as an outcast, the 'other' amongst the mainstream. However, Dattani does not ponder over the argument that whether Amritlal's concern for Jairaj was right or wrong because, perhaps he worries about his son's condition and doubts Jairaj's sexuality, but Amritlal is an utter failure to realize Jairaj's sufferings and personal cravings. Though Amritlal allows his daughter-in-law, Ratna for dancing but he warns Jairaj by saying: "A woman in the man's world may be considered as being progressive. But man in woman's world is pathetic." (*Collected Plays* 427) Amritlal somehow knows that social patriarchy will easily accept Ratna's endeavors, but it will be a hindrance for Jairaj.

Mahesh Dattani poses important questions regarding the gender role of a person. Amritlal is part of the same patria[illegible]framework who imposes preordained traits on Jairaj depending[illegible] that a man should be masculine in nature but at the[illegible] an afraid father also who thinks that practice of da[illegible]

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Jairaj's personality negatively that he might become an effeminate person. Amritlal used to be a freedom fighter, a spokesperson for for liberty in society. But one can ask what does liberty stand for? This is quite vivid that surprisingly Amritlal does not really understand Jairaj's situation and though he claims himself to be an open-minded, liberated person, he ties up his son with the shackles of social taboos.

Mahesh Dattani further goes on with Jairaj and Ratna's discordant relationship where he shows how a man can be a suppressed entity in a marital relationship. "*Dance Like a Man* questions the propriety of a man overstepping his jurisdiction by taking to dancing, Bharatnatyam. He is ostracized for he chooses to dance like a woman though his dancing is a way of expressing his identity". (Ignatius 108)

Jairaj is overpowered with social prejudices that do not allow men to associate themselves with the art of dancing. Even his wife, Ratna is aware of Jairaj's social status.

However, if it is not Dattani's intention to portray Ratna as a shrewd wife but it is evident that Ratna's overreaching ambitions are responsible for Jairaj's passivity. Following Judith Butler's concept of Gender Performatives, Dattani embellishes the idea that social taboo demands from people a certain role to play and when something unexpected happens, it marginalizes the 'other'. In case of Jairaj and Ratna, everyone including Amritlal, can accept Ratna's devotion to dance, though earlier he did not support both his son and daughter-in-law as he thinks Bharatnatyam is the craft to prostitutes but Jairaj's fidelity to dance is unacceptable. For Ratna, however, dance is not only the way for achieving her goal, but it is also her passion that drives her throughout the actions of the play. Ratna seems a complex character who marries Jairaj to get the support for her career but lately, both carry a hollow conjugal relationship. Ratna tries to shape her daughter Lata's career according to her own wish but for Jairaj, Lata's involvement with dancing, seems the fulfillment of his own dream. Moreover, Jairaj's non-resistant attitude makes him silent even when he lost his son, Shankar. Being a father, he is unable to to utter a word against Ratna whose insincerity is responsible for Shankar's demise.

Dance Like a Man is knitted in multiple dimensions. Dattani's treatment of gender stereotypes is indeed commendable because gender for him is something not to someone's sex or body but to their psyche. This play portrays the grey sides of every character, especially Jairaj seems unique, rather, presumably considered as the docile, subaltern figure. The play proposes fundamental

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doubts our social ethics. Yet Dattani, as in the words of Asha Kuthari Choudhuri, excels his own dramatic artistry in the fine blending of the sense of art along with "the merits of multiplicity, transcending mere 'tolerance' to recognition and empathy". (36)

Bravely Fought the Queen

Unlike his other plays, Dattani's *Bravely Fought the Queen* is extremely urban. The play chiefly revolves around the lives of the Trivedi brothers, Jiten and Nitin, their mother, Baa, and their wives, Dolly and Alka, yet at the same time, the play is full of symbolic figures and catalytic characters. Though very dark, *Bravely Fought the Queen*, is a domestic play that captures the subaltern emptiness of the middle-class family in the swirl of capitalism. It was first written in 1991 and performed at the Sophia Bhaba Hall, Mumbai on 2nd August, 1991. The play mainly oscillates between two spaces—firstly, the superficial lives of the characters where their hypocrisy is hidden by a mask, occurred at the center stage and secondly, a simultaneous projection of rear backdrop where the inner conflicts of the characters and their intricate psychological upheavals are exhibited.

In the essay *Can Subaltern Speak?*, Gayatri Chakravorty Spivak assumes "that within the world of subaltern, women are 'doubly effected'". (521) Dattani very finely incorporates this view in this play by the portrayal of his female characters. As the title suggests, it is the battle of women in domestic as well as social levels, to get rid of all the shackles and to get out of their cocoons. Although at the end the play, we wonder, how well the female figures fought against patriarchy or whether Dattani ironically mocks the entire situation of women who have been silenced by their family and society as well. Dattani's one of the pet concerns, the social expectations regarding the gender stereotypes are highlighted in the play. He makes this play more complex while introducing the issue of alternate sexuality. Therefore, *Bravely Fought the Queen* is not only a domestic tragedy but also it is the nexus of several dimensions and phases that all the oppressed and submissive personas go through and endure. The plot is centered on an Indian family. Jiten and Nitin are two brothers and their wives Dolly and Alka happen to be sisters. Baa, the mother of Trivedi's brothers, is entrenched in her memories and continually moves back and forth within a specific timeline to get h existence. Apparently, the entire Trivedi family pretends to b but the undercurrents of their normal family life a

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we see the ugly truths and the hypocrisy of each individuals who participate in a clash between the patriarchy and subaltern.

Lalitha and Sridhar are the outsiders who often get caught up in the action of Trivedi family. Both the brothers work in an advertising agency. Jiten and Nitin seem shockingly different in nature and stand in two opposite poles. Jiten is the patriarchal emblem, a perfect resemblance of his father and masculinity, whereas Nitin is more a submissive, docile being, certainly alike his mother, Baa. The marital relationships of none of the brothers are successful. Dolly, like Baa, is dissatisfied with this marriage as she gradually becomes the victim of patriarchal oppression. But in case of Nitin and Alka, both become the sufferer where Nitin's own struggles against the age-old norms of social patriarchy and consequently, his excessive selfish and passive nature are responsible for Alka's misery and helplessness. In the entire play, we get to see that Alka is the most fragile entity who is bearing a meaningless, hollow conjugal life. Moreover, she has nothing to fight for or fight against. Dattani presents Alka in her extreme vulnerability.

Homosexuality is one of the major thematic concerns in *Bravely Fought the Queen*. Like *On a Muggy Night in Mumbai*, this play also illustrates the plight of marginalized group of people irrespective of class, gender, sexuality. Not only Dolly, Alka or Baa, here Nitin also go through several problems and obstacles in his life for not being a 'normal' fellow as per the social code of conduct. He is quite conscious of his sexual orientation for which he is humiliated everywhere at every level. This is very easy for the mainstream to alienate the 'other' at the periphery of social structure as soon it declares those marginalized people as 'sick', 'abnormal' or 'different'. Being a victim Nitin must be silenced and as a result he is afraid of revealing his own identity. Alka is betrayed both by her brother Praful and husband Nitin, but we need to understand that Nitin is almost forced to marry Alka, as he is completely manipulated and tricked by his love interest, Praful who convinced Nitin that after this fake marriage, they can continue this illegitimate relationship without any doubt. However, Praful naturally betrays him and surprisingly, both Nitin and Alka become the sufferer, trapped in a dismantled relationship.

Nitin and Jiten contrast each other in every respect. Jiten epitomizes the male chauvinism. His thoughts towards women are extremely derogatory. Once he comments: "Men would want to buy it for their women! That's our market. Men. Men would want their women dressed up like that. And they have the buying pov

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So, there's no point in asking a group of screwed up women what they think of it. They'll pretend to feel offended and say, 'oh, we are always being treated like sex objects'". (*Collected Plays* 276). Even Baa says about Jiten: "Jiten is just like his father, just like him" (*Collected Plays* 284) that he inherits all violence, temper and anger of his father and develops a disparaging perspective as well as attitude towards women. But Nitin solely represents his mother, belongs to a different world altogether.

In *Bravely Fought the Queen*, the portrayal of the women figures is very vivid and Dattani consciously upholds their vulnerability and steadfast determination to get over all dire circumstances. The two sisters share a kind of toxic relationship and remain indifferent in each other's misery. In his invigorating projection of characters. Dattani is capturing the post-modern emptiness of human lives, trapped in the middle-class moralities and ethics. Dolly is a proper instance of patriarchal oppression and domestic violence. She exposes Jiten's brutality when she says: "And you hit me! Jitu, you hit me up! I was carrying Daksha and you beat me up!" (*Collected Plays* 311). But, at the end of the play, Dolly proves herself to be a rebel, stands up against patriarchy, and becomes an apt representation of the great historical figure, Rani Lakshmi Bai. She becomes capable of confronting the misdeeds happened with her and fighting for her liberty and womanhood. On the other hand, Alka is totally subjugated, leading her life towards a dead end. To escape from the reality, she often indulges herself into alcohol. Alka also knows that for Nitin's inability, she has no hope for having her own children. Besides all these actions, Dattani introduces Lalitha, an outsider, who symbolizes the world of social reality. Lalitha also feels incomplete as she has no child. Such emptiness of Lalitha's life is substituted by her excessive obsession with 'bonsai'. She cares for the 'bonsai' as her own child.

Bravely Fought the Queen narrates both the dark and bright sides of the characters. We witness Dattani's attempt to debunk the gender stereotypes. He deliberately infused the symbolic figures to raise fundamental questions. For instance, Kanhaiya is all about forbidden love and sexuality. The image of Kanhaiya is perceived at the psyche of Dolly and Alka, emerged from their dissatisfied and unfulfilled love in conjugal lives. Furthermore, Dattani uses Naina Devi's thumri as the chief music in the play to evoke the sense of wom
Naina Devi shows us a different sort of heroism. She ba
the social vices and prejudices as she was branded as a 'w

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society but she is ultimately acknowledged to be a queen by virtue of her own will power. The thumri has been continuously played in the background and everyone including Baa, Dolly, Alka, Lalitha seem to admire the song. Mahesh Dattani here tries to manifest the marginalized position of women in the social framework. He further incorporates the issues regarding insecurity, low self-esteem and identity crisis which have been finely crafted by Nitin's character. *Bravely Fought the Queen* is not only the tale of women suffering but it also narrates the distress and anxiety of the subjugated entities.

Conclusion

Mahesh Dattani has tried to question the predicament of a modern man. He chose theatre as an effective medium to convey his thoughts and opinions. Gender stereotypes and gender discriminations are something which always influenced him. His plays are the mirror of his mind where we find the echoes of subaltern voices. Whether it is *Dance Like a Man* or *Bravely Fought the Queen*, the character have their own stories to tell. None of his characters are perfect but they are unique in their own way. Through his plays, he tries to unveil the crude realities of society and the bare face of humanity. He goes beyond the convention and makes his plays significant works of art that evoke in our minds an intellectual response even though it engages our private emotional involvement.

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IN VITRO CLONAL PROPAGATION IN *CENTELLA ASIATICA*

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Abstract:

Clonal propagation aims at the production of disease free, true-to-type plant production in larger numbers, in quicker time. In *C. asiatica*, many reliable approaches have been developed for *in vitro* regeneration at commercial level. Effective regeneration of *C. asiatica* using pre-existing meristems is affected by many internal and external factors and *in vitro* conditions and has been comprehensively covered here. Specific requirements during clonal propagation, like the culture establishment, shoot bud multiplication, root induction and acclimatization are discussed here. There are some cost effective methods also. In *C. asiatica*, there are several reports which indicate rapid regeneration and multiplication through organogenesis or by the process of somatic embryogenesis. There are also reports which suggest increase in amount of active compound in tissue culture.

Keywords: *Centella asiatica, In vitro*, Organogenesis, Rooting, Shoot multiplication, Somatic Embryogenesis

Abbreviations: IAA- indole-3-acetic acid; IBA- indole-3-butyric acid; Kn- kinetin; NAA-α-naphthaleneacetic acid, PGR- plant growth regulator; TDZ- thidiazuron; 2,4-D- 2,4-Dichlorophenoxyacetic acid

Introduction:

Clonal propagation is a type of asexual reproduction where genetically similar copies of a plant are produced and the plant population derived from this process is known as clone. *In vitro* clonal propagation is known as micropropagation. Totipotency is the characteristic feature of a plant cells by which plant cell can produce a whole plant (Reinert and Backs, 1968; Verdeil *et al.,* 2007). There are five stages of micropropagation (George and Debergh, 2008): First stage is called Stage 0— i.e. pre-treatments stage. Second stage is Stage 1— also known as establishment of culture; this stage is followed by Stage 2, where shoot bud multiplication occurs. The next stage after the shoot bud multiplication is Stage 3 — i.e. root induction: and the final stage is

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Stage 4 or acclimatization stage. In Stage 0, selection and pre-treatments of mother plants are carried out successfully (George and Debergh, 2008). For clonal propagation, stock plants need to be pre-treated. Some pre-treatments can be necessary either for reducing the contamination of the stock plant in order to be able to have successful surface sterilization of explants or for enabling or improving the growth of explants in subsequent *in vitro* conditions. In Stage 1 explants are surface sterilized so that they can survive and grow under controlled conditions. After successful initiation of culture (i.e. culture without any contamination) shoot bud multiplication is achieved during Stage 2. Shoot bud multiplication depends on various factors, such as plant species, cultivar or genotype; organic and inorganic compounds, plant growth regulator (PGR) content and some culture conditions such as light, temperature, vessel humidity etc. This stage involves the development of *in vitro* shoot bud. During Stage 3 shoots originated from Stage 2 are then transferred for root induction either under *in vitro* or under *ex vitro* conditions. Successful rooting also depends on several factors. Transfer of tissue culture grown plantlets to the natural environment occurs during Stage 4. This process is a crucial step for commercial use of micropropagation. Micropropagated plants are not totally dependent on photosynthesis. In culture tube or any culture vessels humidity is very high that results in some morphological and physiological modifications of plants which results rapid water loss of plants when transferred to external conditions. During acclimatization process humidity is decreased step-by-step and concomitant increase in light intensity.

Centella asiatica L., a member of Apiaceae, commonly known in India as 'Indian Pennywort' or 'Mandookaparni'. It is a perennial herb, prostrate in nature, slightly aromatic stoloniferous, stem glabrous, petiole long with fleshy leaves, roots present at node. *C. asiatica* grows in India up to an altitude of 600 m above sea level (Patra *et al.,* 1998). In Indian medicine, *Centella* is used as reputed nerve tonic and also used for curing of asthma, bronchitis, dropsy, elephantiasis, gastric catarrh, kidney troubles, leprosy, leucorrhoea, skin disease and urethritis (Kakkar, 1988) with antibacterial, antifeedant, antifilarial, antileprotic, antistress, antituberculosis activities and wound-healing properties (Chakraborty *et al.,* 1996; Srivastava *et al.,* 1997). Leaves of *Centella* are rich in carotenoids, vitamins B and C. The plant also shows good therapeutic effects on peptic ulcers. It is reported that *C. asiatica* inhibits the growth of human uterine carcinoma, human gastric carcinoma and murine melanoma cells *in vitro*. *C. asiatica* contains different glycosides like indocentelloside, theankuniside, brahmoside, asiaticoside, brahminoside, and isothankuniside. Asiaticoside is used for the treatment of tuberculosis and leprosy as well.

Having high therapeutic potential, it is very important in pharmaceutical industries which escort to its overexploitation resulting in the loss of the population of *C. asiatica* from their natural habitat (Nayar and Sastry, 1987). *C. asiatica*, thus recognized as threatened medicinal

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herb (Sharma and Kumar, 1998; Singh, 1989) is endemic to Western Ghats of South India (Nayar, 1996). So, this is why we need some alternative methods for conservation of this plant. Tissue culture technique is helpful for the mass propagation of plant and conservation of rare, threatened and endangered germplasm (Rao, 2004). Seasonal dependence and slow growth are the demerits of conventional propagation. Important features of *in vitro* propagation procedure are its enormous multiplicative capacity within a short time span; production of healthy and disease free plants; and its ability to generate propagules throughout the year.

Process of *in vitro* clonal propagation:

The success of micropropagation is influenced by different parameters. The critical points for the effective *in vitro* culture establishment are the efficient sterilization technique of explants. It is dependent on explants type, genotype, process of sterilization, different conditions like physical, chemical etc.

Choice of explants:

Explants choice is very important for production of true-to-type progenies. In *Centella* nodes or apical buds have been used as explants due to their genetic stability (Das *et al.,* 2008; Kaensaksiri, 2011; Karthikeyan *et al.,* 2009).

Sterilization:

Explants can be collected from those stock plants grown in a controlled environment, such as a greenhouse to get the better result. This process is better than the use of field-grown plants because it reduces microbial contamination (Webster and Jones, 1989; Yepes and Aldwinckle, 1994; Preece, 2001; Preece and Read, 2003). There are several methods for surface sterilization. Explants were thoroughly washed under running tap water and the leaves and roots were trimmed off from the plant. Shoot pieces were excised from the stolons and kept in tap water for 30 minutes. Then nodal explants were washed in mild detergent like 1% (v/w) Teepol, for 5 min with constant agitation. The explants were surface sterilized with aqueous mercuric chloride (0.1% $HgCl_2$) for 3 min. After this treatment the solution was drained off (Thangapandian *et al.,* 2012) followed by rinsing with double distilled water for 4-5 times. Kaensaksiri (2011) in his experiment, treated the 1.5 cm long shoot tips with a mixture of 2 g L^{-1} Funguran and 2 g L^{-1} Orthocite for 30 minutes and then soaked with 70 % EtOH for 60 seconds. Next, the shoot tips were sterilized with 3 % sodium hypochlorite solution containing 0.1 % Tween 80 for 10 minutes and rinsed thrice using autoclaved water. Cetrimide, bavistin and others could be use as sterilizing agent (Moghaddam, 2011)

Culture medium and culture conditions:

The most commonly used medium for micropropagation of *C. asiatica* was MS basal medium (Murashige and Skoog, 1962). Though application of other medium had also been

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reported but MS medium was also efficient for *in vitro* culture. In general 3% (w/v) sucrose had been used as carbohydrate source. Carbohydrate in the medium serves as energy and carbon source. The pH was adjusted to 5.6-5.8 with 1N NaOH or 1N HCl. 0.8% (w/v) agar was used for solidification of medium and autoclaved at 121° C for 15-20 min. The cultures were incubated at 24±2° C under 16-hr photoperiod.

Shoot multiplication:

The success of *in vitro* propagation depends on the mode and rate of shoot multiplication. The of shoot bud multiplication is controlled by different factors, like genotype, composition of medium, different factors, PGR etc. Shoot multiplication is hormonally controlled mainly by cytokinin but sometimes in combination with auxin. Shoot multiplication of *Centella* is based on medium supplemented with cytokinin as the major PGR. The effects of different PGRs are genotype dependent. It is found that a mixture of cytokinin with auxin in 3:1 proportion resulted in better for shoot elongation. BAP in combination with IAA (4:1) showed good response in shoots elongation. In another report, within 30 days higher shoot multiplication was found in a media containing 1.5 mg l^{-1} BAP and 0.5 mg l^{-1} IAA (Thangapandian *et al.,* 2012). The highest percentage of multiple shoot bud induction was 76.67% on the medium augmented with 4.0 mg l^{-1} BAP+0.1 mg l^{-1} NAA followed by 70.00% on the medium consisting of 3.0 mgl^{-1} BAP and 0.1 mgl^{-1} NAA. Lowest percentage of multiple shoot bud induction (10.00%) was found on the medium containing BAP (7.0 mg l^{-1}) along with NAA (0.1 mg l^{-1}). The highest shoot development (10.2 ± 0.38 per explants) was obtained on the medium having 4.0 mgl^{-1} BAP and 0.1 mgl^{-1} NAA followed by 8.0±0.38 shoots per explant in the medium fortified with 3.0 mgl^{-1} BAP + 0.1 mgl^{-1} NAA. On the other hand, the minimum number of shoots was 1.1±0.20 per explants, obtained when cultured on the medium supplemented with BAP (1.0 mgl^{-1}) and NAA (0.1 mg l^{-1}). For shoots elongation, same medium was used. MS medium containing 4.0 mg l^{-1} BAP+0.1 mgl^{-1} NAA was found to be the best treatment for the highest multiple shoot induction as well as maximum number of shoots per explants (Das *et al.,* 2008). Similar results were also reported in other medicinal plants, such as *Celastrus paniculatus* (Martin *et al.,* 2006); *Heracleum candicans* (Wakhlu and Sharma, 1998); *Spilanthes mauritiana* (Bais *et al.,* 2002); *Coleus blumei* (Rani *et al.,* 2006). Kaensaksiri (2011) found that when explants (shoot tip) were cultured in liquid MS medium with thidiazuron (TDZ) (4.54 µM) for 15 days, 8.9 shoots developed per explant. Moghaddam (2011) proposed that the synergistic combination of use of BAP along with NAA in 2 mg/L and 0.1 mg/L concentrations respectively, resulted in sprouted shoots at optimum level 93 ± 0.667, shoot bud number 5.2 ± 0.079 per explants, length of shoot 4.1 ± 0.67 cm when cultured in Duchefa medium in comparison to MS medium. According to Tiwari *et al.* (2000) exogenous supply of BAP was required for bud breaking but the synergistic combination of BAP and NAA (22.2 μM and 2.68 μM concentrations respectively) was found to

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be optimum for shoot formation (91%) as well as number of shoot developed (4 to 5 shoots/ node). So BAP was most potent PGR in shoot multiplication of this plant. Subculturing enabled healthy shoot production. MS medium containing 6.7 μM BAP and 2.88 μM IAA was found most suitable for shoot elongation.

Rooting:

Successful root induction process before establishment in soil is a prerequisite for any propagation method. Auxin hormone was added exogenously to *in vitro* generated shoots promotes root formation. Tiwari *et al.* (2000) found that rooting was highest (90%) on MS medium (full strength) containing 2.46 µM IBA. According to Moghaddam (2011) rooting frequency, number of roots per shoot and mean root length occurred at optimum level (95.2 ± 0.81%, 7.5 ± 0.107 and 4.5 ± 0.133 cm respectively) when shoots that were cultured on MS medium (full strength) containing indole-3-butyric acid (IBA) 0.5 mg/L. According to Karthikeyan *et al.* (2009) 0-3mg/L NAA, IBA, IAA was also helpful for root induction. After isolation from culture tube, when well developed shoots were cultured on MS media having different concentrations of IBA for root induction. According to Das *et al.* (2008) the highest parentage of root induction was 90.00% on the MS medium with 1.0 mg l^{-1} IBA. After 40 days well rooted plantlets were obtained (73.33%) on the medium with 1.5 mgl^{-1} IBA. On the other hand, the lowest percentage of rooting was 10.00% on the medium augmented with 3.0 mg l^{-1} IBA. Highest number of roots per shoots was 10.6±0.93 from the medium augmented with 1.0 mgl^{-1} IBA followed by 8.2±0.96 roots per shoot on the medium with 1.5 mg l^{-1} IBA. On the contrary, the lowest number of roots per shoot was 0.8±0.06 in the medium fortified with 3.0 mg l^{-1} IBA. Use of IBA was the ideal treatment for root induction. Low concentration of IBA was more potent than that of higher concentration. Similar results were also reported in different medicinal plants, such as *Heracleum candicans*, *Plumbaga zeylanica*, *Cassia alata* and *Solanum trilobatum* (Wakhlu and Sharma 1998; Jawahar *et al.*, 2004; Chaplot *et al.*, 2006, Hasan *et al.*, 2008).

Acclimatization:

The transfer of plantlets from *in vitro* to *ex vitro* conditions is a very important step in the structural and physiological adaptation of plants; this is the beginning of the autotrophic life of plants. Micropropagated plants require their successful acclimatization and subsequent transfer to the field. Difficulties during acclimatization include rapid desiccation of plantlets and their susceptibility to bacterial and fungal diseases. There are several methods for acclimatization. Tiwari *et al.* (2000), in their experiment, removed plantlets from culture medium followed by washing the roots in tap water so that no agar is present in roots, plantlets were then transferred to a plastic cup that contain a mixture of sterilized garden soil or soilrite and were covered with

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polythene bag. The potted plants were maintained inside a culture room at 24±2°C for 16 h/day illumination with cool-white fluorescent light (20 μmol $m^{-2}s^{-1}$). After 7 days, polythene bag was removed, then for another 2 weeks those plants were nursed in the culture room, followed by field transfer. According to Tiwari *et al.* (2000) the *in vitro* plants of *C. asiatica* were transferred into plastic cup containing only soilrite had 90% survival rate, after acclimatization, the plantlets were established in field successfully. Sivakumar *et al.* (2006) demonstrated that for acclimatization, well-developed rooted plants were transplanted to the tray filled with soil mixture, containing Canadian *Sphagnum* peat moss, perlite and vermiculite and were maintained in the growth chamber for two weeks. Then plantlets were transferred to the glasshouse and potted in red soil for another 2 weeks. Then plants were kept outside, and the survival rate was 95%. Kaensaksiri (2011) successfully acclimatized *in vitro* rooted plantlets at room temperature (30 ± 2 °C) for 1 week, and roots were washed with tap water, followed by transferred to plastic tray that contained a mixture of sand and rice shell ash (1:1), and grown in a tent where proper moisture content was maintained and the plantlets were kept for 21 days. Then, the plantlets were transferred into the greenhouse conditions for 7 days. The plants were then transferred to a plastic pot (6-inch) containing soil for 2 months and the survival rate was 86%. In another experiment, after removal from the culture vessels, the plantlets were washed with tap water and transferred to plastic pot containing a mixture of soil, sand, farmyard manure (1:1:1) (Das *et al.*, 2008). The plantlets were covered by polythene to maintain humid conditions. After proper acclimatization, the plantlets were then transplanted to the field, where 80% plants were survived. From all the studies it is clear that during acclimatization soil mixture played an important role.

Direct organogenesis:

Shoot regeneration was found when cultured on MS medium with NAA (0.1 mg dm^{-3}) and BAP (1.0 - 5.0 mg dm^{-3}) (Banerjee *et al.*, 1999). Direct shoot regeneration was highly variable, depending on the genotype and explant. For petiole explants, the mean maximum regeneration frequency (42 %) on medium supplemented with 2.0 mg dm^{-3} BAP and for petiole explants of another genotype, cultured on 0.1 mg dm^{-3} IBA, found maximum regeneration frequency (44 %) (Banerjee *et al.*, 1999). However, in other hand, for leaf explants, in one experiment, maximum regeneration frequency (30%) occurred with 3.0 mg dm^{-3} BAP and 0.1 mg dm^{-3} NAA, 25 % regeneration for leaf explants of occurred on medium containing 5.0 mg dm^{-3} BAP and 0.1 mg dm^{-3} NAA (Aziz *et al.*, 2007).

Indirect organogenesis:

In *C. asiatica* there are many reports which indicate rapid regeneration and multiplication through organogenesis. Callusing was observed at optimum level in MS + BAP (0.5 mg/l) + NAA (0.3 mg/l) using stem and leaf explants and the frequency of callus induction was 75% and

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83.33% respectively. For shoot induction from leaf callus, MS medium supplemented with BAP (0.5 mg/l) and MS medium supplemented with BAP (0.75 mg/l) when applied in the callus derived from stem explant were regarded as the most potent. Indole-3-butyric acid (IBA, 0.5 – 2.0 mg/l) showed the best response for root induction when used on MS media (full strength). Regeneration of multiple shoots was observed from callus derived from nodal explant when cultured on MS medium supplemented with Kn and IBA. Further when callus was subcultured on MS medium with IBA and different concentrations of Kn, optimum shoot growth was observed. Maximum callus production was observed on MS basal medium supplemented with IBA (3 mg/l) and Kn (3 mg/l) and maximum number of shoots were formed on MS medium with IBA (1 mg/l) and Kn (3 mg/l).

Somatic embryogenesis-

In *C. asiatica* there are many reports on somatic embryogenesis. By the process of somatic embryogenesis, ample numbers of plantlets to be produced within a short time. Somatic embryogenesis has been reported for many medicinal plants of Apiaceae, namely *Trachyspermum ammi* (Sehgal and Abbas, 1994), *Heracleum candicans* (Wakhlu and Sharma, 1998), *Eryngium foetidum* (Ignacimuthu *et al.,* 1999), *Daucus spp.* (Imani *et al.,* 2001), and *Cuminum cyminum* (Tawfik and Noga, 2002). Different stages of somatic embryogenesis are-globular, heart-shaped, torpedo, bipolar stage and from bipolar to plantlet formation. High-frequency of somatic embryo development and subsequently plantlet formation were achieved on callus derived from leaf, internode and stolon tip explants. PGRs significantly influenced process of somatic embryogenesis and subsequent plant regeneration. In one experiment by Martin (2004) callus developement was achieved on MS medium fortified with 4.52 mM 2,4-D or 5.37 mM α-naphthaleneacetic acid (NAA), both with 2.32 mM kinetin (Kn), were superior for somatic embryogenesis. Induction of embryo followed by maturation was much earlier when subcultured on medium fortified with NAA and Kn in comparison to that subcultured on Kn and 2,4-D. In another experiment, within 3 to 4 weeks of culture induction of somatic embryos occurred in the dark on medium supplemented with 2,4-dichlorophenoxy acetic acid (2,4-D). Leaves produced embryogenic calli at 2.26 and 4.52 mM 2,4-D, whereas stolon tips were responsive only in the 9.04 mM 2,4-D treatment. Embryogenic callus cultured on medium with NAA and Kn were transferred to liquid cultures of MS medium (half strength) supplemented with 2.69 mM NAA and 1.16 mM Kn, 204.3 somatic embryos developed/ 100 mg callus. While embryogenic callus cultured on 2,4-D and Kn and subsequently transferred to liquid cultures of MS medium (half strength) fortified with 0.45 mM 2,4-D and 1.16 mM Kn, 303.1 embryos developed/per 100 mg callus. 88% of the embryos underwent maturation and conversion to plantlets upon transfer to half-strength MS semisolid medium having 0.054 mM NAA with either

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0.044 mM BAP or 0.046 mM Kn. Plantlets derived from embryoids established in field showed morphological similarity. The effectiveness of 2,4-D and Kn for somatic embryogenesis induction has also been well established among the other Apiacean members, for e.g., *Apium graveolens* (Williams and Collin, 1976), and *Cuminum cyminum* (Tawfik and Noga, 2002). The success of somatic embryogenesis depends on induction and maturation of embryos. In the study of Martin (2004) embryos from the callus developed on medium containing Kn and NAA exhibited early maturation and conversion as compared to the callus developed on Kn and 2,4-D. According to Joshee *et al.* (2007) withdrawal of 2,4-D resulted in maturation of somatic embryos and further development of plantlet from embryos. Peeters *et al.*, (1991) suggested that uptake as well as utilization of NAA is faster, so early maturation followed by conversion of embryoids may be due to the faster uptake as well as utilization of NAA. The delay in maturation and conversion of somatic embryos from 2,4-D induced callus may be due to its persistence in subsequent cultures. Zimmermann (1993) and Martin (2003) have also emphasized the persistence and inhibitory effect of 2,4-D in the maturation of embryos during consecutive cultures. Several factors control somatic embryogenesis such as Thidiazuron (TDZ) has cytokinin-like activity in different plants (Mok *et al.*, 1987; Visser *et al.*, 1992; Huetteman and Preece, 1993) and thus it is used in tissue culture. It is found that application of TDZ induce different responses such as callus induction, somatic embryo formation in many plants (Mok *et al.*, 1987; Visser *et al.*, 1992; Huetteman and Preece 1993; Zhang *et al.*, 2001; Ipekci and Gozukirmizi 2003). Somatic embryogenesis induced in presence of TDZ on the lower surfaces of cotton cotyledons was less genotype-dependent than when BA was used (Zhang *et al.*, 2001). Subsequent removal of TDZ from the callus induction media, showed embryo maturation and subsequent growth of the embryo that led to formation of plantlets on MS basal medium (Ipekci and Gozukirmizi, 2003). Friable callus developed on NAA, IAA, or 2,4-D alone and a combination of NAA or 2,4-D with BAP was inferior to NAA or 2,4-D with Kn-supplemented medium-derived callus in the efficacy of somatic embryogenesis. The callus developed on NAA or 2,4-D alone and in combination with BAP started to induce embryos 160 days after explant establishment and there was a reduction in frequency of somatic embryo development. Cream-colored friable callus developed on MS media supplemented with 4.52 mM 2,4-D and 2.32 mM Kn, upon transfer to suspension and solid cultures of MS medium (full strength) with reduced levels of 2,4-D (1.13 mM) and 2.32 mM Kn, exhibited proliferation of embryogenic callus only. Transfer of the embryogenic callus (90 d old) to liquid culture of MS medium (half strength) with reduced concentrations of 2,4-D (0.45 mM) along with Kn (1.16 mM) facilitated proliferation of embryogenic callus and development of embryos at 303.1 embryos/ 100 mg of callus. Embryonic callus cultured on MS agar medium (half strength) with 2,4-D and Kn at the same concentration under light was less competent for somatic embryo induction. Solid medium

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cultures incubated in the dark, formed fewer embryos than light-incubated calluses. White or ash-colored friable callus developed on MS medium with 5.37 mM NAA and 2.32 or 4.65 mM Kn was transferred to liquid culture with reduced level of growth regulators (2.69 Mm NAA and1.16 mM Kn) for somatic embryo induction. Somatic embryo induction was observed on subculture between 80 and 90 days after inoculation of explants and subsequent transfer induced development of somatic embryos in large number. During the period of subculture, nearly 204.3 embryos/ 100 mg callus were obtained in liquid of MS medium (half strength) with 2.69 mM NAA and 1.16 mM Kn. However, few embryos progressed to cotyledonary stage. Agar gelled medium with the same PGRs was less efficient in somatic embryos induction. Proliferation of the embryogenic callus was also observed and was more frequent on solid medium.

Low cost methods of micropropagation:

Low cost options were potent in lowering cost without changing the quality of plantlets (Raghu *et al.,* 2007). For establishing commercially feasible microprogation method, two combinations such as half strength MS and quarter strength MS medium were applied. For reduction of cost of agar, liquid medium, house hold cane sugar as carbon source, jam bottles and, tap water were used as it is less expensive (Raghu *et al.,* 2007).

Applications:

Synthetic seed:

Synthetic seed (= synseed) technology, based on the use of different micropropagules like somatic embryos, axillary shoot buds, apical shoot tips, embryogenic masses and protocorms, provides methods for production of seed analogues. It can be an alternative to traditional micropropagation for production of cloned plantlets in the future although it still has limitations for wider commercial uses. Artificially encapsulated micropropagules are able to convert into plantlets under controlled conditions and can be used as a seed after proper storage. For embryo encapsulation, 1%, 2%, and 3% sodium alginate (w/v) were dissolved in basal MS medium with sucrose (3%). Embryoids of 1.0 to 2.0 mm long heart shaped stage and bipolar stage were subcultured on MS basal medium without any PGRs, were used for encapsulation of embryo. Embryoids were transferred to alginate mixture (0.15 to 0.20 mL). After encapsulation with alginate, calcium chloride solution (50 mM and 80 mM) was added drop wise. Every drop with one embryo was nursed in calcium chloride solution for different times like 10 min, 30 min or 60 min. After incubation period, calcium chloride solution was decanted and followed by recovery of beads. Beads were washed thrice with MS basal solution. Somatic embryos encapsulated with sodium alginate (2%) prepared in MS salt solution and submerged 30 to 60 min in 80 mM calcium chloride for hardening, produced seeds with a coat firm enough for handling and

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allowing synseeds to develop into plantlets. It was observed that 30 minutes exposure in calcium chloride solution (80 mM) was good enough for production of firm synthetic seeds. The germination was influenced by sodium alginate concentration, same type of observation was found in many other plants also (Rao and Singh, 1991; Castillo *et al.*, 1998; Malabadi and van Staden, 2005). Synseeds with sodium alginate coating (2%) showed the best results (60% survival) for germination than the other treatments. Storage at low temperature was important for conservation purpose. Further study using cryoprotectants and different types of soluble and insoluble sugars in the encapsulation matrix may be helpful for longer storage and better germination and survival. In another report, encapsulation with sodium alginate (3%) in *Paulownia elongata*, showed 73.7% survival rate and 53.3% germination frequency. These results are promising and suggest that synseed technology offers great potential both in micropropagation and in germplasm conservation, although further research is needed to increase the rate of conversion and to develop steps towards automatization.

Production of bioactive compounds:

In the liquid-culture the production of asiaticoside was higher amount [494.62 mg g^{-1} (d.m.)] than that of callus and leaf [190.48 and 125.0 mg g^{-1} (d.m.)] tissues. So, using suspension culture, large amount of callus was obtained within a short time and the alkaloid content increased too. Thus, by suspension culture it is possible to achieve higher growth and production of compound (Nath and Buragohain, 2005).

Biomass (30 g) was collected from shake culture and then was transferred into a bioreactor (5 L). Proper agitation was maintained at the rate of 120 rotations per min for 30 days. Aeration (2 L/min) was achieved that helps better production. The culture was maintained at 25°C temperature. At agitation speeds of 170- 200 r/ min reached asiaticoside content was low, while asiaticoside content reached highest value of 59.43 mg/g dry weight at 150 r/ min.

Genetic transformation through hairy root cultures:

For overcoming conventional, sexual hybridization systems, the use of genetic transformation is essential in the genetic improvement. Genetic engineering plays crucial role in the efficient transfer of horticulturally important features like resistance to bacteria, insects, fungi and herbicides, rooting ability, or dwarfism of rootstocks, environmental stress resistance or modified metabolism, from various genera. Successful application of genetic transformation is based on the development and existence of tissue culture techniques. Hairy root culture is very good approach for secondary metabolites production. It is reported that by hairy root cultures using *Agrobacterium rhizogenes* strain R1000 asiaticoside and madecassoside production were increased. It is also seen that hairy roots were formed from a tissue junction between the leaf and petiole (14.1%). Co-cultivation for 7 days with *A. rhizogenes* resulted 36.1% production of hairy roots. When elicited with MJ treatment asiaticoside production was enhanced (Kim *et al.*, 2007).

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Asiaticoside biosynthesis shown to be tissue specific, produced mainly in the leaf of *C. asiatica* (Kim *et al.*, 2004). In addition to these, the CabAS transcripts (putative b-amyrin synthase) gene, associated with asiaticoside biosynthesis, was detected in leaf tissues only (Kim *et al.*, 2005). Nath and Buragohin (2005) reported the interesting fact that sizeable quantities of asiaticosides are biosynthesized in suspension-cultured cells and undifferentiated calli of *C. asaitica*. Application of elicitor to hairy root cultures of *C. asiatica* resulted into better asiaticoside production. An observation similar to this result has shown that in *in vitro*-cultured roots of whole plants treated with MJ, asiaticoside contents were about five times than that of the controls. On the basis of these results, it is found that there is a positive correlation between high levels of CabAS mRNA and asiaticoside production.

Conclusion:

In vitro regeneration of *Centella asiatica* indicates that it is feasible for rapid propagation, faster introduction of new cultivars with desirable traits and for rapid multiplication of disease-free, healthy propagation material. The studies carried out during the last several years on different stages involved in micropropagation of *C. asiatica* has led to considerable improvement of protocols and methods. Use of liquid medium shows cost efficiency in micropropagation using bioreactors. Results reviewed on propagation of *C. asiatica* in bioreactors indicate that it can be the most promising way for production at large-scale in the future. However, some new challenges are faced day by day by the tissue culture industry that includes cost efficiency, automation, control and optimization of the microenvironment etc. *In vitro* regeneration of *C. asiatica* via somatic embryogenesis, direct regeneration and indirect regeneration offers a great potential for rapid propagation and improvement.

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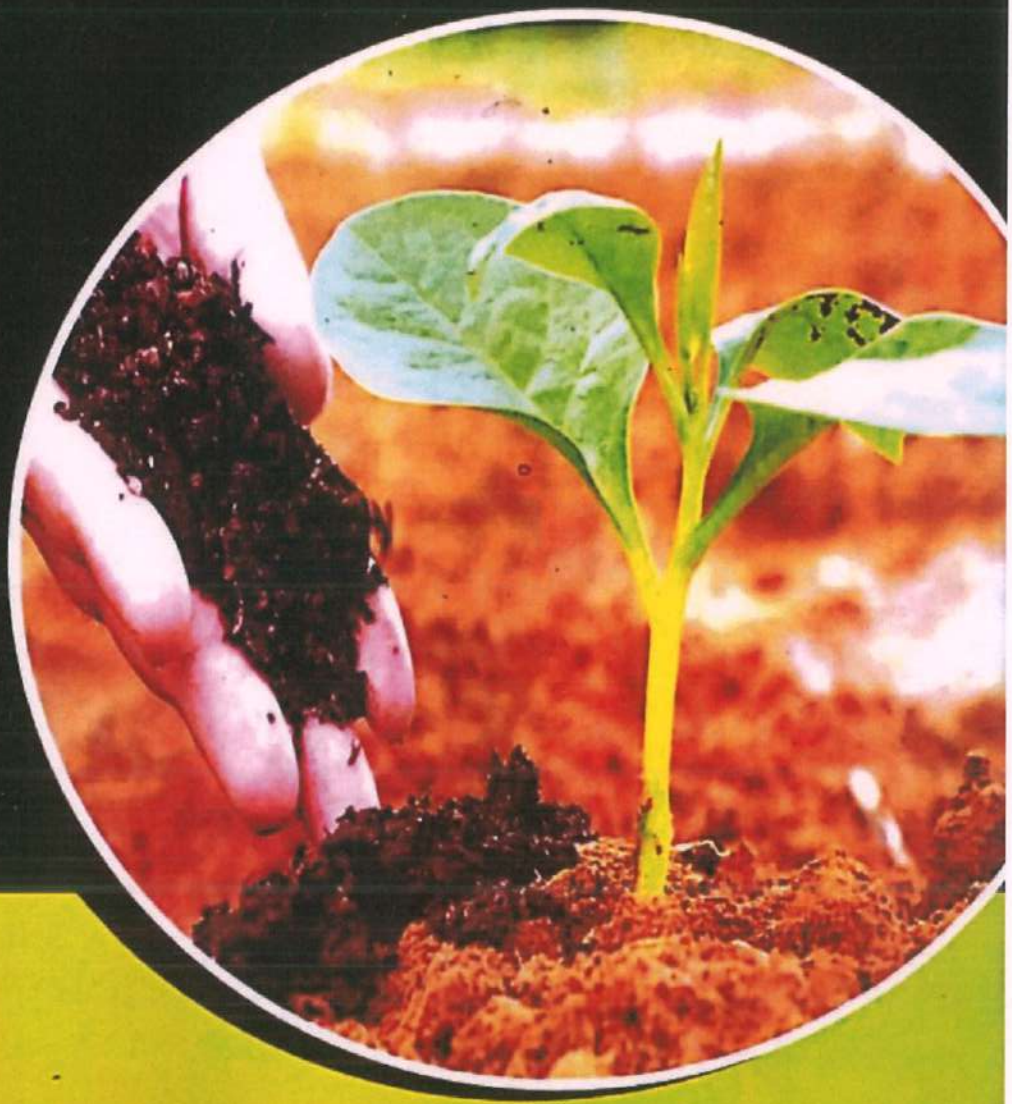

Fundamentals on Plant and Soil Microbial Interactions

(Theory and Practice)

Dr. Pampi Ghosh

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Chapter

8 A Review on Organic Farming

Dipu Samanta

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ABSTRACT

Organic farming is a kind of agricultural process in which using of synthetic fertilizers and pesticides are not used at all. This process depends on organic materials and microbial fertilizers. Products from organic farming are better in quality, and quantity, and also eco-friendly.Organic foods are healthy andsafe for human health, and rich in nutrients. It is the way of sustainable development. Organic farming follows four principles. These are health, care, ecology, and fairness. It reduces the harmful chemical effect of pesticides on the environment. Organic farming is practiced all over the world. India is one of the leading nations of organic farming and obtains the first rank in the number of organic farming farmers. No genetically modified crops are cultivated by this process.

Keywords: Agriculture, Environment,, Ecosystem, Organic farming, Organic products, Pesticides, Sustainable development, Soil fertility.

INTRODUCTION

Organic farming is an agricultural approach in which pesticides and synthetic fertilizers are not used. In ancient times this type of agricultural system was used by humans. After Green Revolution, modern agricultural systems began to use synthetic fertilizers, pesticides, excessive synthetic plant hormones for high yields. But several negative impacts on the environment raised such as

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destruction of soil structure, reduction of soil fertility and nutrients, damage of flora and fauna of the soil, reduction in productivity, an increase of toxic substances in soil, and also in products (Behera et al., 2011). This leads to spread detrimental effects on the environment and the health of living organisms including human beings. So there was a need to follow a new way in agricultural farming systems for protecting nature. Organic farming is the best alternative process to the common farming system (Sharma, 2006). The International Federation of Organic Agriculture Movements (France, 1972) lead to promote organic agriculture all over the nations because the process was eco-friendly and the way of sustainable development (Hammas et al., 2017). About 120 countries including India are members of IFOAM. The fundamental purpose of organic farming is to decrease the use of chemicals and to increase organic products without damaging the environment. It plays a significant role in protecting the environment and concentrates on the use of organic fertilizers, improvement of soil fertility in a natural way, promoting various cultural techniques such as crop rotation, biological pests and weeds control, green manure, and compost, cover cropping, and livestock management.

PRINCIPLES, ADVANTAGES AND DISADVANTAGES OFORGANIC FARMING

Principles of Organic Farming

Organic farming follows four principles. These are health, care, ecology, and fairness.

- **Principle of health:** This principle highlights the health of the ecosystem and its living individuals. The health of an ecosystem and its living individuals are interconnected. Healthy soil is the producer of healthy crops which nourish the health of living individuals of that ecosystem.
- **Principle of care:**MPrecaution and responsibilities are the main objectives of the development, management, and technologies of this system to protect the health of the environment and individuals in the future.
- **Principle of ecology:** Recycling and the use of ecological processes for healthy and high production are the main objectives.
- **Principle of fairness:** This principle points up the certainty of fairness for those who are involved in this system. It aims to produce a sufficient amount of good quality foods and other products and ensure equality, reduction of poverty, and good quality of life of farmers, processors, traders, distributors.

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Advantages of Organic Farming

- Organic farming increases employment opportunities and farmer's income. (Zeynab et al., 2017). It can reduce the poverty of small scales farmers (Jouzi et al., 2017).
- It gives food and ecosystem security in the future (Wachter & Reganold, 2014).
- This type of farming improves soil fertility and soil nitrogen cycle (Cidòn et al., 2021).
- Improved farm management and technologies can enhance the use of natural resources and increase the number of yields (Lin et al., 2016).
- Crop rotation such as legume rotations with cereal rotation increase soil fertility (Feiziene et al., 2015). Use of green manure and Legume based catch crop increase the amount of production (Canali et al., 2017, Silva et al., 2017).
- It enhances soil health and biodiversity by avoiding agrochemicals (Gomiero, 2018).
- Healthy and tasty foods are produced by this system. These products are safe and secure for all living beings.

Disadvantages of Organic Farming

- Organic farming is time-consuming and products are sometimes expensive for poor people.
- No preservatives and waxes are used in organic foods. As a result, organic fruits and vegetables spoil faster than conventional ones.
- Skilled farmers are required for organic farming. They should know every step of farming, correct choice, and uses of organic manure, ability to catch the symptoms of diseases of plants.
- In many cases organic farming is not suitable for high yield.

DISCUSSION

Organic farming leads to sustainable development in the future. It has a positive impact on the environment and living individuals. India produces 30% of total organic products in the world (Elayaraja & Vijai, 2020). Government launches some projects or yojana to promote organic farming such as Rashtriya Krishi Vikash Yojana, Paramparagat Krishi Vikash Yojana, and so on. Organic farming action program 2017-2020 provides Biobonus, a bonus for organic products for investment, marketing, education, sales, and processing (Elayaraja & Vijai, 2020). India has the highest number of organic farmers. Sikkim, a small state of India is the first 100% organic state in the world according to UN Food and Agriculture (FAO). But in many cases, organic farming is

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not suitable for some reason. One of the most important reasons is the huge population. Once scientist Nina Fedoroff said, " If everybody switched to organic farming, we couldn't support the earth's current population- maybe half". We need to support organic farmers by buying their products. Improvement of infrastructure for farming, arrangement of training programs for farmers, choosing the right methods for organic farming, and government support are the main requirements for high-yielding organic farming.

Conclusion

Organic farming system is essential fora sustainablefuture. It gives us a healthy lifestyle and a pollution-free habitat.More research is needed to solve problems associated with this system.

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(Basic to Research)

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2 Ecological Significance of Estuarine Molluscs

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Abstract

In detritus based coastal ecosystem, mangroves and associated vegetations are main driving source of nutrients and harbour to a variety of molluscan fauna, which plays various functional attributes like decomposer, nutrient recycling, create microbiome and invites several other organisms of higher trophic levels to establish a better ecology in the coastal region. Molluscs also have special pharmaceuticals, ornamental values while cascading interest as bioindicators for its special ability to accumulate various types of toxic substances, purifying water etc. Distribution of mangrove molluscs species are high and therefore uncontrolled collection, least conservation strategies coupled with loss of mangrove diversity, climate change imposed potential threat to decline on molluscan abundance and distribution.

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18 Indian Sundarbans: A harbour of Molluscs in Association with Mangroves

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Abstract

The world most diversified Sundarbans mangrove forest is changing in terms of species composition, density under various natural and anthropogenic stress factors which threatening ecological services. Phylum mollusc is one the most dominant faunal group, occupying several ecological niches in the mangrove ecosystem with wide range of tolerance. In Sundarbans and other mangrove zones of India, mangrove associate mollusc species are being overexploited for commercial, ornamental, aesthetic, food and medical values for centuries. As this group of fauna distributed over wide geographical limit, the conservation approach for molluscan fauna is highly overlooked. Studies showed that Indian Sundarbans is harbour of large number of molluscs; few of them are only reported from this pristine ecosystem. This group is least concerned but has gained importance as bio-monitoring tool globally. Their distribution and dynamic activities helps to assess perturbed ecosystem health and decline in mangrove mollusc species vis-a vis affect their functional attributes to the mangrove ecosystem.

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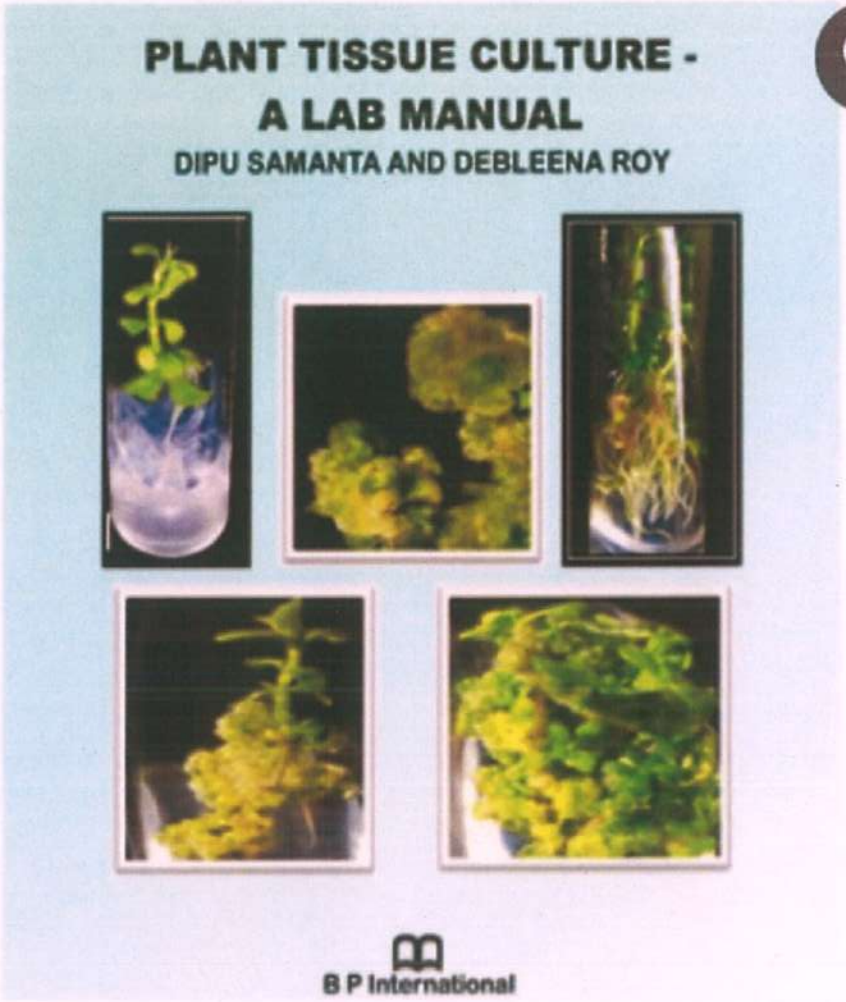

Plant Tissue Culture- A Lab Manual

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A Manifestation on the Phytoplankton Dynamics of Sundarbans Ecoregion

Renia Mullick [a], Suchita Sinha [a], Debleena Roy [a] and Dipu Samanta [b*]

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ABSTRACT

Sundarbans is recognized as highly productive ecosystems providing large quantities of organic matter to adjacent coastal waters in the form of detritus and live animals. With each passing year, Sundarbans is facing serious threats and hence need to be conserved. Phytoplanktons are the major contributors to primary productivity in this region. However, for broader economic benefit, employment and restoration of balance in the ecosystem, phytoplankton estimation is essential. This requires, proper knowledge of phytoplankton diversity and primary productivity which will help in future management and planning issues of the Sundarbans. This review conglomerates information from different phytoplankton-based studies that have been carried out from the Sundarbans mangrove ecoregion emphasizing on seasonal variation, hydrobiological parameters and molecular approach. It can be seen that among the diverse group of phytoplanktons, Diatoms are the most dominant entities in this region. Although the timespan is too short for predicting the impact of aquatic climate change, still variation in the phytoplankton community in the past few years indicates them to be potential aquatic bioindicators of climate change.

Keywords: Diatoms; phytoplankton; rbcL; Sundarbans.

1. INTRODUCTION

Sundarbans, the world's largest contiguous deltaic mangrove ecosystem located at the apex of Bay of Bengal is the largest halophytic mangrove block in the world (covering an area of about 10,000 km^2) formed by the geological precipitation of the sediment load brought by the Ganges, Brahmaputra and the Meghna River systems across India and Bangladesh being tidally influenced by coastal water from the Bay of Bengal [1]. It spans from West Bengal's Hooghly River (extending over 4,260 km^2 along North and South 24 Parganas) to the Baleswar River of Bangladesh's Khulna division (extending over 6,017 km^2) thus constituting about 5% of the world total mangrove vegetation [3]. Due to the unique floral and faunal assemblage of Sundarbans Mangrove region, it has been recognized as a world heritage site by both International Union for Conservation of Nature (1989) and United Nations Educational, Scientific and Cultural Organization (1974) [2].

Cyclones are routine in the Sundarbans. The mangrove vegetation of this region serves as a natural barrier against these prevalent cyclonic storms, which in turn causes immense damage to this ecosystem altogether resulting in consistent climate changes. Recently two super Cyclonic storms, Amphan (2020) followed by Yaas (2021) made their landfall in the Sundarbans which caused breaching of the river embankments resulting in an increase in the water level. Such phenomena may not only result in increasing turbidity, pH, nutrient content etc. on adjacent aquatic systems but can also damage local economies. This would cause dissolution of land masses which may eventually lead to an increase in suspended particulate matter load in the water further delimiting the photic zone ratio and affecting the structure and productivity of phytoplankton populations [3]. This review focuses on phytoplanktons because of their indispensable role as autotrophs in the mangrove ecosystem.

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Phytoplanktons are minute free-floating plants that drift in water, and are the primary biological producers as they form the base line of many food webs in the aquatic environment from where energy is transferred to higher trophic levels. In natural aquatic ecosystems, they contribute to about 98% of aquatic productivity and about 40% of global productivity [3]. Phytoplanktons have been used as indicators of water quality as they strongly influence certain non-biological aspects of water such as pH, color, taste, and odor [4]. Blooming of phytoplankton plays a large role in climate control due to the production of dimethyl sulfide, carbamyl sulfide, and isoprene that produce aerosol particles when exposed to oxygen in the atmosphere. These aerosol particles are in turn responsible for forming low lying clouds that reflect the sun rays mitigating global warming [5]. The biovolume and abundance of phytoplanktons varies with changing abiotic factors such as salinity, surface water temperature etc. Diversified phytoplankton assemblages have great significance in the food web of mangroves. This review explores the relationship between mangroves and phytoplankton production which may vary on a seasonal basis. Molecular and statistical analysis [6] revealed some novel small sized phytoplanktons which are impossible to trace under a microscope thus indicating a source of thought for future research in this arena.

2. REVIEW OF METHODS PURSUED

2.1 Sampling Sites

This review focuses on 6 sampling sites all along Sundarbans. Some of the plots are highlighted in Fig. 1.

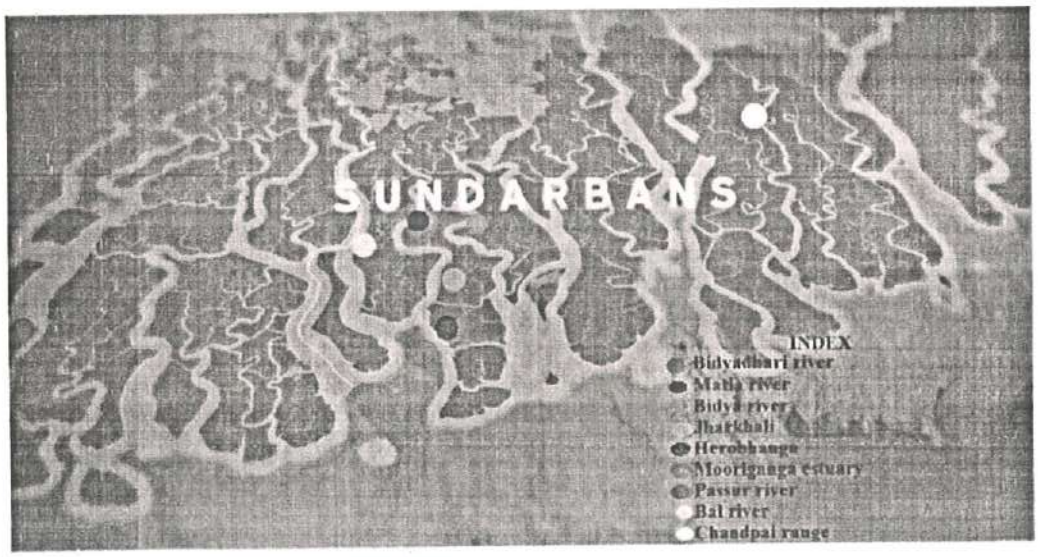

Fig. 1. Map of Sundarbans showing the sampling sites

Site 1- Jaigopalpur, Bhagabatpur, Jharkhali island, Lothian island, Matla river, Bidya river, Bakkhali sea beach, Kala jangal, Suryamoni island, Basanti, Morahero, Nrayanitala island, Cheramatla, Sushni island [7].

Site 2- Chemaguri creek located in Sagar Island of the Sundarbans near Mooriganga estuary [1].

Site 3- Baro Herobhanga Khal along with Matla River in the west and Bidya River in the east [6].

Site 4- Baleswar-Supati river system, Passure-Sibsa river system, Arpangasia-Batla river system, Jamuna-Malancha river system [4].

Site 5- Confluence of Chemaguri creek and the Mooriganga estuary [3].

Site 6- Passur river, Sela river, Harmal river, Betmara river, Conjoint of Hansharaj and Mardat river, Near conjoint of Bal and Arpangasia river, Bisindri Khal, Shipsa river, Kalabogi river [8].

2.2 Phytoplankton Collection

For phytoplankton collection, specialized scientific equipment called a phytoplankton net is required. This net is made of fine mesh that has holes allowing only water to pass through and not the planktons. Readymade phytoplankton nets (with a finer mesh size) can be used for collection or one can construct their own phytoplankton net. At the time of plankton collection, scientists usually tow a plankton net behind a boat. This generates a water current which collects planktons from the water and concentrates it in the collecting bottle attached to the phytoplankton net [9]. The collecting bottle containing phytoplankton now needs to be preserved in the lab with Lugol's solution [4] and buffered formaldehyde [6] for further experimental purposes. The preserved samples can be kept in the refrigerator until analysis [9].

Megaplanktons (above 20 cm), Macroplanktons (diatoms and dinoflagellates, within 2 to 20 cm), Mesoplanktons (between 0.2 to 20mm) and Microplanktons (20 to 200 µm) can be collected using phytoplankton net whereas Nanoplanktons (2 to 20 µm) and Picoplanktons (usually bacteria, 0.2 to 2 µm) cannot be captured using these nets because of their extremely small size. Thus they are obtained by centrifuging the seawater or by using other modern methods (Odyssey-Sundarbans-Mangrove Biodiversity-Phytoplankton. Kriyetic.com).

2.3 Identification and Counting

For phytoplankton enumeration, Sedgewick-Rafter counting chamber can be used which is 50 mm long, 20mm wide and 1 mm deep. Prior to counting, they can be enumerated (Table 1) with the help of a compound microscope [4]. Also, Zeiss binocular microscope equipped with phase contrast optics can be used as it reveals the lightly silicified cells of diatoms. Shannon-Weiner diversity index (H1), species richness (d) and species evenness (J) were also calculated by Manna et al. [6].

Geographic Information System (GIS) software can be used for viewing the statistical results and map of Sundarbans mangrove forest [4].

2.4 Biochemical Analysis

For biochemical analysis, water sample from the plankton net needs to be sieved, filtered, and refiltered on a glass microfiber filter GF/F. The samples are next transferred to the laboratory in ice tanks for determination of several biochemical parameters such as Protein using Biuret method [24] or Folin-CioCalteu reagent [12]; Carbohydrate using Phenol-sulphuric acid hydrolysis method; Lipid using Sulphophosphovanillin (SPV) procedure [13] and Chlorophyll a by extracting it overnight in 90% acetone and calculating applying trichromatic equation [14].

2.5 Hydrological Parameters

Conductivity, Turbidity [6], Transparency, Salinity, Surface water temperature (SWT), pH, Secchi depth, Dissolved oxygen and orthophosphate concentration along with several nutrient concentration like inorganic nitrogen, soluble phosphate and reactive silicate (Table 2) were measured by Bhattacharjee et al. [1].

2.6 Molecular Analysis

2.6.1 Genomic DNA extraction

Bhattacharjee et al. [1] collected surface water samples from mouth of Chemaguri creek in early summer, winter and spring for studying the phytoplankton assemblage pattern based on molecular approach. They filtered the water sample through a 0.22m sterivex filter (Millipore) using a peristaltic pump. Genomic DNA was extracted from the sterivex filters following standard protocols [1

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2.6.2 rbcL Gene Fragment Amplification, Clone Library, DNA Sequencing and Molecular Phylogeny

The rbcL gene (Ribulose bisphosphate carboxylase large chain) is a part of DNA which is located in the chloroplast DNA and can be used as a DNA barcode because of its ease in amplifying and analyzing [15]. Bhattacharjee et al. [1] amplified rbcL gene fragments from environmental DNA isolated from sterivex filters for the months of March, April and December. They used previously published PCR primers to amplify rbcL fragments. Polymerase Chain Reaction (PCR) reactions for each DNA sample were performed in triplicates followed by pooling and subsequently purified using Qiagen Gel Purification Kit. Purified PCR products were cloned by Bhattacharjee et al. [1] using the pGEM-T Easy vector system (Promega). Plasmid DNA containing the inserts was sequenced with SP6 primer in an ABI3130 Genetic Analyzer. Chromatograms were checked by Bhattacharjee et al., [1] in BioEdit v7.0 for any ambiguity or error before downstream analyses. The generated DNA sequences were translated into amino acid sequences using Transeq and subsequently compared with published rbcL sequences from GenBank, EMBL, PDB, DDBJ and blastp tools. Alignment using ClustalX, phylogenetic tree and bootstrap tests were further performed. The sequences generated were then submitted to GenBank [1].

2.7 Statistical Analysis

In order to compare microscopic data with rbcL clone library data, the sequences generated should be grouped into operational taxonomic units (OTUs, phylotypes) based on a 3% cut off at the amino acid level using the program DOTUR. Also STATISTICA software can be used for different statistical analysis and correlation regression analysis. Total expected number of OTUs in each clone library was calculated by Bhattacharjee et al. [1] using nonparametric richness estimator Chaol. Phylotype (or OTUs) frequency curves were then prepared to determine the OTUs frequency across the clone libraries followed by rarefaction analysis to compare the diversity of rbcL clone libraries [1].

3. DISCUSSION

3.1 Molecular and Statistical Analysis

In Site 2, 52 rbcL clones were sequenced by Bhattacharjee et al. [1]. Blastp results indicated that all the clones showed 92–100% identity with published cultured and uncultured eukaryotic rbcL amino acid sequences of chromophytic algal groups. When the GC content that ranged from 37%-44% was analyzed, it was found that non-diatom rbcL clones had higher GC content than diatom rbcL clones. Majority of the generated sequences were clustered with published rbcL sequences belonging to diatoms of orders Thalassiosirales, Bacillariales, Lithodesmiales, Surirellales and of classes Haptophyta, Cryptophyta and Pelagophyta. These Haptophyte and Pelagophyte-like rbcL sequences were first found from Sundarbans and they indicated the importance of small sized algal cells in primary production. Hence alike microscopy, rbcL gene clusters also indicated the dominance of diatoms. Small sized diatoms like *Thalassiosira minima* and *Campylodiscus clypeus* which are usually difficult to identify under a microscope were detected in the rbcL clone libraries indicating the importance of this methodology for studying phytoplankton assemblages [1].

20 OTUs (12 of which represented diatoms) based on a 3% cutoff value at the amino acid sequence level were detected from the pooled rbcL clone libraries of Mooriganga estuary. Expected number of OTUs richness was calculated using a nonparametric Chaol estimator. The highest Chaol value was recorded from April whereas the lowest from March, it also showed the presence of smaller diatoms that were untraceable in microscopy. Thus, it clearly indicates that an integrated approach based on microscopy and molecular techniques can significantly improve our knowledge regarding phytoplankton community structure [1].

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Table 1. Phytoplankton abundance of Sundarbans based on seasonal variation

Sampling sites	Phytoplanktons of sundarbans			Comments
	Summer	Monsoon	Winter	
Site 1 [7]	Ulvophyceae- 50% Chlorophyceae- 15% Zygnematophyceae - 25% Trebouxiophyceae- 10%	Ulvophyceae- 77.14% Chlorophyceae- 27.14% Zygnematophyceae- 7.14%	Ulvophyceae- 48.4% Chlorophyceae- 27.5% Zygnematophyceae- 17.4% Trebouxiophyceae- 6.8%	Maximum abundance of algal species took place during the winter season, followed by summer and the least in monsoon (Fig. 2).
Site 2 [1]	Dinophyceae-7.31% Bacillariophyceae-58.5% Chlorophyceae-7.31% Coscinodiscophyceae-9.75% Fragilariophyceae-4.8% Cyanophyceae-7.3% Mediophyceae-4.8%	Coscinodiscophyceae- 16.6% Bacillariophyceae-55.55% Dinophyceae-16.6% Fragilariophyceae-5.5% Chlorophyceae- 5.5%	Coscinodiscophyceae- 31.8% Bacillariophyceae- 50% Dinophyceae-4.5% Chlorophyceae-4.5% Mediophyceae-4.5% Noctiluciphyceae- 4.5%	Centric and pennate diatoms dominated the area. The centric ones dominated in Chemaguri creek, however post winter pennate diatoms dominate across all the stations because of their lower settling rates than the centric ones.
Site 3 [6]	Bacillariophyceae- 59% Chlorophyceae- 26.2% Cyanophyceae- 8.1% Euglenophyceae- 3.2% Chrysophyceae- 3.2%	Sample collection was not performed during the monsoon season	Bacillariophycea e- 67.6% Chlorophyceae- 19% Cyanophyceae- 7.3% Euglenophyceae- 3% Chrysophyceae- 3%	Centric diatoms predominate in winter while Pennates in summer.
Site 4 [4]	Myxophyceae- 56.6% Bacillariophyceae- 20.4% Chlorophyceae- 22%	Myxophyceae- 53% Bacillariophyceae- 27.8% Chlorophyceae- 18.6%	Myxophyceae- 52.5% Bacillariophyceae- 29% Chlorophyceae- 18%	The abundance of phytoplankton varied from one river system to the other. The species composition shows Myxophyceae>Bacillariophyceae> Chlorophyceae. The study data showed an indication of low diversity of phytoplankton.
Site 5 [3]	Coscinodiscophyceae- 23.5% Bacillariophyceae- 64.7% Fragilariophyceae- 11.7%			Members of Bacillariophyceae dominated the population, followed by dinoflagellates and chlorophytes (Fig. 3).
Site 6 [8]	Chlorophyceae- 15% Bacillariophyceae- 82.45% Xanthophyceae- 0.8% Euglenophyceae- 1.6%			A couple of centric diatoms, pinnate diatoms and a green algae *Oocystis pusilla* were dominant. *Coscindiscus lineatus* was distributed in all the nine sites irrespective of both high and low tides indicating its capacity to tolerate high fluctuations in

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Sampling sites	Phytoplanktons of sundarbans			Comments
	Summer	Monsoon	Winter	
				water chemistry. In the Buragauranga river estuary of Patuakhali district Ahmed et al. (2010) reported the species diversity value which was 80% dominated by the members of Bacillariophyceae.

Table 2. Estimation of hydrobiological parameters along with statistical and molecular analysis of phytoplanktons

Sampling sites	Hydrological and biochemical parameters	Comments
Site 1 [7]	• pH between 2-8 • Phosphate and nitrate levels fluctuated throughout the year. • Variation in salinity was observed due to diurnal tidal cycle.	• Due to upstream rivers and monsoon rain, huge amount of saline water are carried inside by the tidal cycle. This site has three hydrological zones based on water salinity level- brackish, moderately saline and saline that greatly influences the flora. Hence, freshwater, marine and estuarine algae grow luxuriantly in this ecosystem.
Site 2 [1]	• Highest salinity in Mooriganga estuary. • Secchi depth values highest. • Chemaguri creek with highest Surface Water Temperature. • Dissolved orthophosphate highest post-monsoon. Major peaks in dissolved silicate concentration recorded during winter. • Two minor peaks of Chlorophyll-a detected during the winter and summer. Fucoxanthin, showed temporal shifts during winter and summer that corresponded with changes in hydrological parameters in the water column.	• Centric diatoms collected from spring were shorter in size than their winter counterparts that correlated with fluctuating nutrient conditions (nitrate and orthophosphate) which in turn as a whole indicated the presence of smaller size phytoplanktons under limiting nutrient conditions. • Higher abundances of phytoplanktons were found during winter and lower during the monsoon (Fig. 2). This corresponded with lower salinity following heavy precipitation during monsoons. • Post- precipitation in spring, Cyanophyta were documented in high abundance. During February after the Gangasagar event, higher abundance of Dinophyta pointed towards the poor water quality in creek and adjoining estuary. • Fucoxanthin showed higher values over chlorophyll-a which may have resulted due to changed irradiances and photoadaptation. Chl a concentration was highest during pre-monsoon when light attenuation coefficients were minimum. However, seasonally pigment concentrations decreased from pre-monsoon to post-monsoon. This would suggest that the total chlorophyll a concentrations were not only planktonic but were contributed by other autotrophic components, along with detrital chlorophyll a from leaf litter of adjacent deciduous mangrove vegetation [10].

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Sampling sites	Hydrological and biochemical parameters	Comments
		• In winter, Shannon-Wiener diversity indices were highest for Mooriganga estuary and lowest during summer which may have been due to limited sequencing efforts.
Site 3 [6]	• Lowest Surface Water Temperature in winter while highest in summer. • pH- weakly alkaline. • Salinity gradually increased from post to pre-monsoon. • Dissolved oxygen moderate to high with its maximum in winter. • Turbidity increased from post monsoon to pre-monsoon. • Nitrite, ammonia, phosphate and silicate showed higher concentration in winter. Concentration of Silicate and Nitrite were always greater than Phosphate and Ammonia. • Chlorophyll-a concentration average in summer, winter and maximum in February. Similar result was observed in case of phytoplankton cell count whereas in contrast fluorescence count was maximum in summer than winter.	• The higher presence of Dinoflagellates post- monsoon indicated high pollution levels in the water which may be due to high nutrient input in coastal estuary water. Chlorophyceae and Cyanophyceae have higher abundance of salinity tolerance. • Biomass production increased with increasing salinity indicating that the salinity regime was within the tolerance level of planktonic biomass. • During winter, chlorophyll a concentrations were very high which indicated that the estuary was in eutrophic condition. Chlorophyll a levels dropped rapidly at the onset of summer and became even lower in May resulting in mesotrophic-eutrophic estuary which correlated with the presence of Dinoflagellates at that time. • Species richness and species diversity showed more or less higher values indicating a healthy phytoplankton community in the estuary. It was observed that during post monsoon when species diversity increased simultaneously the phytoplankton biomass also increased and the estuary was in a eutrophic state. Similarly, during premonsoons when species diversity declined, phytoplankton biomass also declined.
Site 5 [10]	• Habitat- weakly alkaline with a mesohaline to hypersaline transition from monsoon to post monsoon periods.	• Mitra et al. collected phytoplankton from Sundarbans and divided them as representations from central and western regions. It was reported that cell volume in the western sector is higher than the central counterpart. Some of the species recorded showed positive or negative correlation with salinity suggesting that some of the phytoplankton taxa can be indicative of aquatic salinity. This further testifies that cell biovolume is not a constant feature, but it might vary on the basis of abiotic factors. Thus, regular observations of the temporal and spatial shifts of the cellular biovolume of individual phytoplankton taxa can actually act as a suitable descriptor of the impact of abiotic stress on phytoplankton populations [11].

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Sampling sites	Hydrological and biochemical parameters	Comments
Site 6 [8]	• Salinity- Mesohaline –Polyhaline • pH- slightly to moderately alkaline	• The water of Hangsha river where maximum species diversity was found was characterized by higher values of conductivity, salinity and TDS with low alkalinity whereas that of Chandpai range had the lowest. • In the Passure river, the Shannon-Weiner diversity index was very high. The lowest was found in Bisandri Khal and Kalabogi river.
Sundarbans Biosphere Reserve [5]	Over a span of 25 years (1990-2015) • Surface Water Temperature increased • pH decreased • Transparency decreased • Nutrient load increased	• The Surface Water Temperature alterations became significantly prominent since 2005. Rapid industrialization and urbanization of Kolkata, Howrah and Haldia complex might be a possible reason behind the increase in air temperature which has reflected on surface water. • The decreasing trend in pH may be correlated to more absorption of atmospheric CO_2 and increased rate of sewage discharge. • Reduction in transparency of the aquatic phase is due to increased erosion of the adjacent landmasses which in turn may be a direct consequence of sea level rise and subsequent tidal amplitude. • The nutrient load except silicate has increased along with time which may be due to hike up in the sewage discharge from the adjacent areas or unplanned mushrooming of shrimp farms in and around the Sundarbans Biosphere Reserve that generates nitrate, phosphate etc. • Phytoplankton species diversity showed significant variation since 1990 with more numbers of stenohaline species in the upstream areas.

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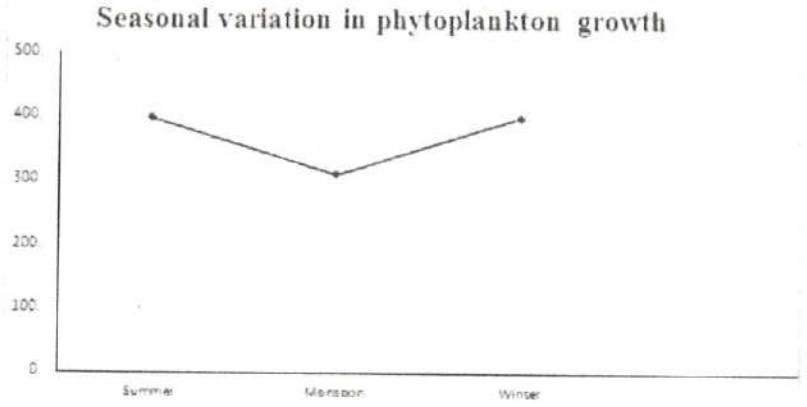

Fig. 2. Growth of phytoplankton showing seasonal variation

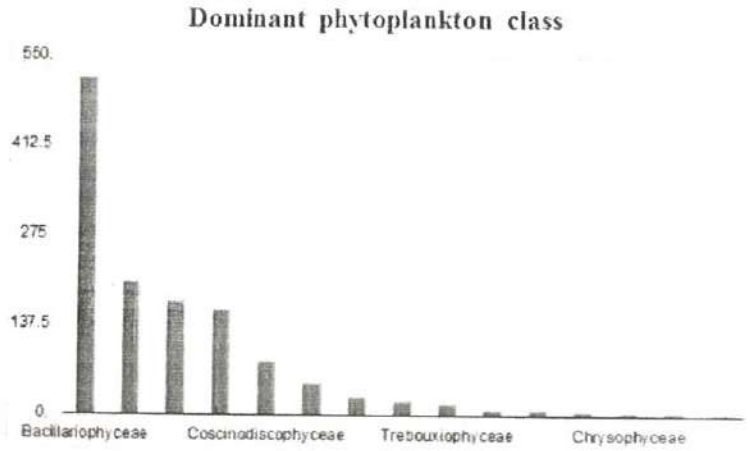

Fig. 3. Comparative analysis of different class belonging to phytoplanktons

3.2 Environmental Impact of Phytoplanktons

Phytoplanktons play some of the most important roles in oxygen supply, climate control, and food production. They contribute to half of the photosynthesis on the planet, making themselves one of the world's most important producers of oxygen [16]. They use up carbon dioxide, which helps in regulating atmospheric CO_2 levels and produces oxygen for other organisms to live. Phytoplanktons are generally consumed by zooplanktons and other small marine organisms like krill following consumption by larger marine organisms like fish. This chain continues up to apex predators such as polar bears, sharks, and humans. Along with providing food and oxygen for nearly all life forms on Earth, phytoplankton helps to regulate inorganic carbon in the atmosphere. CO_2 taken by phytoplanktons from the water is replaced by CO_2 from the atmosphere. Phytoplankton as a biological carbon pump removes approximately 10 trillion kilograms of carbon from the atmosphere every year transferring it to ocean depths. Without this, atmospheric CO_2 would have risen to approximately 400 ppm. This consumption helps to keep CO_2 levels in check thus reducing its risk as a greenhouse gas. Even small changes in phytoplankton populations could have an effect on the atmosphere and world climate. An imbalance in the levels of phytoplankton can cause major problems. If too many nutrients become available, it can trigger an algal bloom. If a phytoplankton concentration remains steady even after the initial bloom, it may become a red tide. Red tides and the toxins they release can have a direct or indirect effect on human health and other organisms. This can suffocate fish during a bloom by clogging or irritating their gills thus preventing them from intaking oxygen [17]. Nearly all marine predators feed on phytoplanktons as their primary food source, so if ever the phytop

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disappeared then the small predators wouldn't be far behind. With all the small predators gone, there would be nothing left for the large creatures of the ocean to eat, so animals like dolphins, sharks, and whales would soon perish too and this devastating chain reaction would quickly extend its reach out of the ocean. Sea birds, seals, and polar bears would starve to death due to the unavailability of food. Planktons also help to make the air we breathe. They produce half of the world's oxygen through photosynthesis, and in turn absorb CO_2 from the atmosphere, taking it with them to the bottom of the ocean when they die. Thus, in the absence of phytoplanktons the levels of carbon in the atmosphere would increase, which would not only accelerate climate change but will also make it difficult for humans to breathe [18]. Hence, in order to maintain a balanced ecosystem, phytoplankton levels in marine environment should be kept on a count.

4. CONCLUSION

The woody halophytes-dominated ecosystem situated at the confluence of land and sea is the mangroves which occupy a harsh environment, being daily subjected to tidal changes in temperature, water, salinity and varying degrees of anoxia [6]. Phytoplankton populations and their photosynthetic productivity fluctuate due to a number of factors, most of which are part of seasonal changes. The largest influence on phytoplankton levels is nutrient scarcity. While sunlight levels affect productivity, nutrient levels affect phytoplankton growth and populations. This review clearly highlights the abundance of centric diatoms (winter) and pennate diatoms (summer) in the Sundarbans ecoregion. In terms of abundance, Coscinodiscophyceae exhibited prominence and in terms of diversity, Bacillariophyceae was predominant [19]. Low nutrient conditions cause the abundance of small sized phytoplanktons. The biomass of phytoplanktons including algae are found to be maximum during winter and minimum during the monsoon period. They have a positive correlation with levels of salinity. The abundance of Dinoflagellates in the tidal creek of Sundarbans estuary indicated high pollution levels, thus phytoplanktons can be used as a parameter to assess water quality. Chlorophyll-a concentration decreases in winter and increases in summer which corresponds with levels of phytoplankton abundance. Higher the diversity index and species richness, higher is the biomass of phytoplanktons indicating a healthy ecosystem. Accordingly, with increasing concern over global climate changes, biovolume estimation will be a more logical representative of the actual phytoplankton population of different aquatic ecosystems around the world. However, more research should be conducted to develop basic knowledge of the ecosystem that may help to balance the ecology of mangroves through proper management and conservation of the Sundarbans. The rbcL clone library approach highlights the presence of several cosmopolitan and novel phytoplankton lineages which were not found through microscopy. Thus a combination of microscopy and molecular tools can help in better understanding of phytoplankton assemblages in mangrove environments which will help researchers' in conserving this world heritage site.

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We are sincerely thankful to the Principal, Lady Brabourne College for providing the necessary facilities and The Department of Science & Technology (DST) for financial assistance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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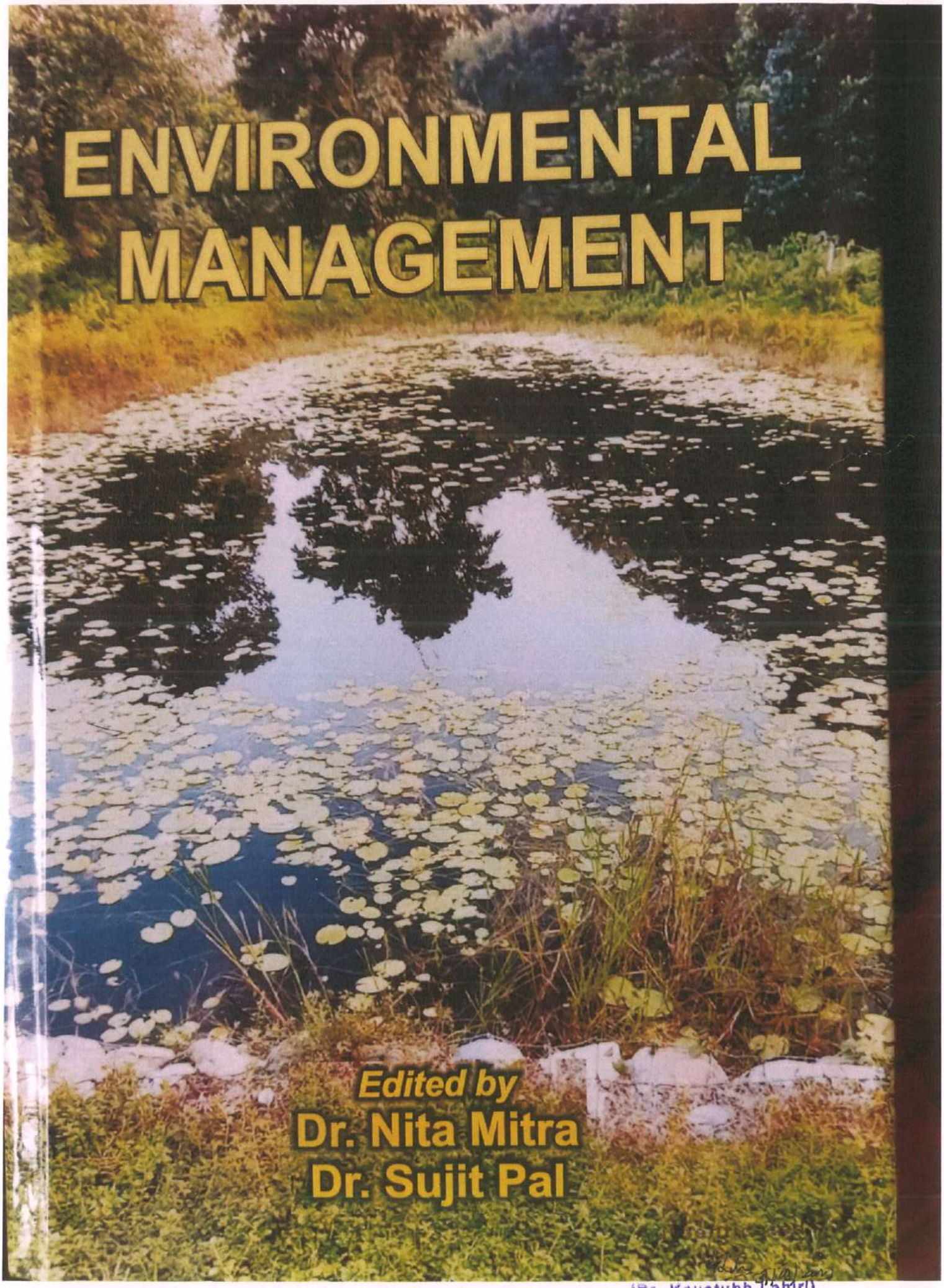

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CHAPTER

12

Environmental Degradation: Causes, its impact on Living Organisms and Mitigation

Dr. Dipu Samanta & Samadrita Deb

Abstract:

The rapid deterioration of natural environment is mainly caused by the most of the anthropogenic activities. Natural disasters are also degraded environment but not so serious issues. Nature heals itself. But human activities such as deforestation, urbanization, industrialization, pollution, overpopulation gradually making the earth unsuitable for living in. Global warming, climate change, biodiversity loss, scarcity of drinking water, poverty, lack of foods, health problems – these problems are increasing day by day. So, it is the high time to focus on the protection of our environment from the destruction and leaving a livable place for future generations.

Keywords: *Environment, Global warming, Human activities, Mitigation, Natural disasters, Pollution*

Introduction:

Environmental degradation is the rapid deterioration of the of the natural environment. Several natural phenomena such as storms (typhoon, cyclone, tornado, hurricane), droughts, volcanic activity, landslides, forest fire cause environmental degradation. Although direct or indirect human activities are the major cause of environmental degradation and its effect is dangerous for all living beings. Deforestation, modern urbanization, industrialization, over population, use of unsustainable resources, including biotic and abiotic elements, arbitrary use of fossil fuels and plastics, use of chemicals

such as pesticides, insecticides are responsible for degradation of the environment. Biodiversity, ecosystems, climate, natural resources, habitat and economical balance among people can be completely destroyed due to the long-term effects of environmental degradation. In order to reduce environmental degradation, it is needed for environmental awareness among the people. Moreover, it is required to establish national and international laws and act to protect the environment from degradation. Sustainable development is mandatory for conservation and habitat regeneration.

Causes of environmental degradation: Environmental degradation is a concept whose long-term effects include deforestation, depletion of biodiversity, desertification, global warming, extinction of animals, pollution, change of climate, global warming, and more. The environment is degraded more by activities of human than natural phenomena (Shrinkhal, 2019). Natural disasters cause environmental degradation. These are of three types- land based, air based and water based. Land based disasters such as earthquake, landslides, volcanic eruption, forest fire cause disturbances on surface of earth (Kamboj et al., 2020). Volcanic eruption is one of the reasons of climate change. Forest fire destroys organic matters of the forest and as well as its eco-system. Air based disasters include storms, tornado, hurricane, thunderstorms and cyclones. In 2020, super cyclone Amphan uprooted several thousand trees and killed at least 72 people in India during covid-19 pandemic situation. Mangrove forest Sundarbans acted as a wall of defense against Amphan cyclone and protected coastal ecosystem of West Bengal. In the United States, every year, tornadoes took the lives of about 2000 people (Edward et al., 2013). Water based disasters are floods, tsunami, and drought. These natural hazards lead to degraded environment which in turn can cause damage in society socially and economically. Water scarcity or overflow affects badly in the agricultural system and makes people's life upside down. So, nature itself is one of the reasons for environmental degradation. Although human activities which received less attention, is the main aspect of affecting earth's environment which in turn degrade the environment (Kafka et al., 2009). Human mediated degradations are carbon dioxide (CO_2) emissions, nitrogen oxide (NOx) emissions, deforestation for urbanization and industrialization, water pollution, and degradation of land (Li & Reuveny, 2006). Human made inequality is another cause of environmental degradation (James K. Boyce,1994). Overpopulation, environmental pollution, industrialization, economical imbalance all

these made by anthropogenic activities which are not good enough for the future.

Consequences of environmental degradation: Effects of environmental degradation are a global and serious issue. Carbon dioxide and other greenhouse gas emissions from human activities are the primary reason of global warming and as well as climate change (Ritchie & Roser, 2020). Deforestation is another reason for global warming (Venkataramanan & Smitha, 2011). Burning of fossil fuels such as petroleum, oil, natural gas increases the amount of carbon dioxide level, which is the main contributor of the greenhouse effect and global warming (Venkataramanan & Smitha, 2011). Global warming is the main reason for climate change which in turn accelerates disasters such as storms, heatwaves, floods, and droughts (Venkataramanan & Smitha, 2011). In the last 100 years, the average temperature on the surface of earth has increased by about 10. Celsius (Venkataramanan & Smitha, 2011). Another worst consequence of environmental degradation is glacier melting and rise of sea level. Wildlife in arctic regions such as polar bear, walrus is losing their home. Acid rain makes acidic soil, which affects soil fertility and soil structure and as a result production rate of crops decreases and food security faces a big question. Acid rain influences the heart disease and lung problems such as asthma, bronchitis of human beings (Bhargava & Bhargava, 2013). Acidification effects on bird population through making an error in calcium rich eggshells (Graveland, 1998). Fresh water acidification due to acid rain effects on fish reproduction, destroy aquatic ecosystem. It has toxic effects on fish, vegetation and other animals of the habitat (Burns et al., 2016). Biodiversity is the wealth and health of nature that supports to build a healthy environment (Roe, 2019). But loss of biodiversity effects on health and hunger of all living beings because it includes decline of diversity of fish species, loss of crop genetic diversity, unable to maintain diversity in cropping systems, crop yielding, and animal breeding system (Roe, 2019). Human health directly depends on food quality and quantity. A large number of human populations depends on herbal medicines for health purpose but due to biodiversity loss availability of source of herbal medicines is rapidly declining. As a result, health problems among the poor people is increased for not being able to afford expensive drugs (Roe, 2019). Another big problem of environmental degradation is pollution. Due to air pollution, suspended particles in the air crossed their safety level in Delhi, India (Chopra, 2016). A number of children under age 3 in Delhi and

Mumbai show the sign of exposure of harmful lead on their bodies (Chopra, 2016). Tuberculosis, a serious respiratory problem and blindness caused by using biomass fuel for cooking, are the effects of air pollution (Mishra et al., 1999). Heavy metals from polluted water and soil are consumed by living beings through eating and drinking foods and water respectively. Heavy metals such as Cu, Pb, Zn, Se and Hg in the blood cause neurodegenerative diseases (Giacoppo et al., 2014). Arsenic induced vascular, skin and kidney diseases are the major worldwide health problems. Seven districts of West Bengal, India are badly affected by arsenic toxicity and more than two lakh people are suffering from arsenic related diseases (Mandal et al., 1996). The shortage of safe drinking water in coastal areas is increasing day by day due to the effect of salinity, drought and mixing of heavy metals in the water. Overpopulation is the reasons of unemployment, poverty, starvation, illiteracy, socio-economical imbalance, diseases and pollutions.

Mitigation of Environmental Degradation:

The biggest way to mitigate the environmental degradation is the plantation. Trees absorb dust and radioactive elements and clean the air. Plant modifies the soil structure through their root system (Angers & Caron, 1998). Leguminous plants increase soil fertility through rhizobium bacteria in their roots. Using bio fertilizers instead of using pesticides, artificial fertilizer is the way of the agricultural sustainability. Promoting organic farming, saving water and energy, conservation of wildlife and biodiversity, habitat regeneration, waste management, energy and resource management, approaching reuse, reduce, recycle method, birth control campaign, people awareness, human development, following environmental laws and acts are the primary steps of sustainable development which is the pillar of mitigating environmental degradation. We must need to focus on and take action against those human activities which lead to degraded environment.

Conclusion:

Environmental degradation is the serious issues for all living beings. This type of depletion of natural environment cannot be allowed to continue. People awareness is not enough to prevent the degradation. For mitigating environmental degradation, it is necessary to establish strict laws and acts. In 2002, Indian parliament proposed Biological Diversity Act; which included wildlife

conservation, sustainable development, and preservation of biodiversity. In 1992, the Convention on Biological Diversity also known as "Rio Earth Summit" was held to Focus on environmental Problems and development of socio economy at global level. Another act enacted by the Indian parliament is The Wildlife (Protection) Act ,1972 to protect wildlife from poaching and to conserve them. Indian 'Air (Prevention and Control of Pollution) Act, 1981' is the act to control and prevention of air pollution. In 1974, 'The Water (Prevention and Control of Pollution) Act' was enacted also for water maintenance and restoration purpose. Pollution Control Board of India publish statistical and technical data of all types of pollution and organize several training programs to engage people for control, prevention, and reduction of Pollution. In 2019, Indian Government in Rajya Sabha proposed. The Population Control Bill to stop overpopulation which is the main reason for poverty, starvation, unemployment, and pollution. Now if we can stop environmental degradation, the future is going to be face a terrible situation. This is why it is so important to discuss and aware about the environmental degradation.

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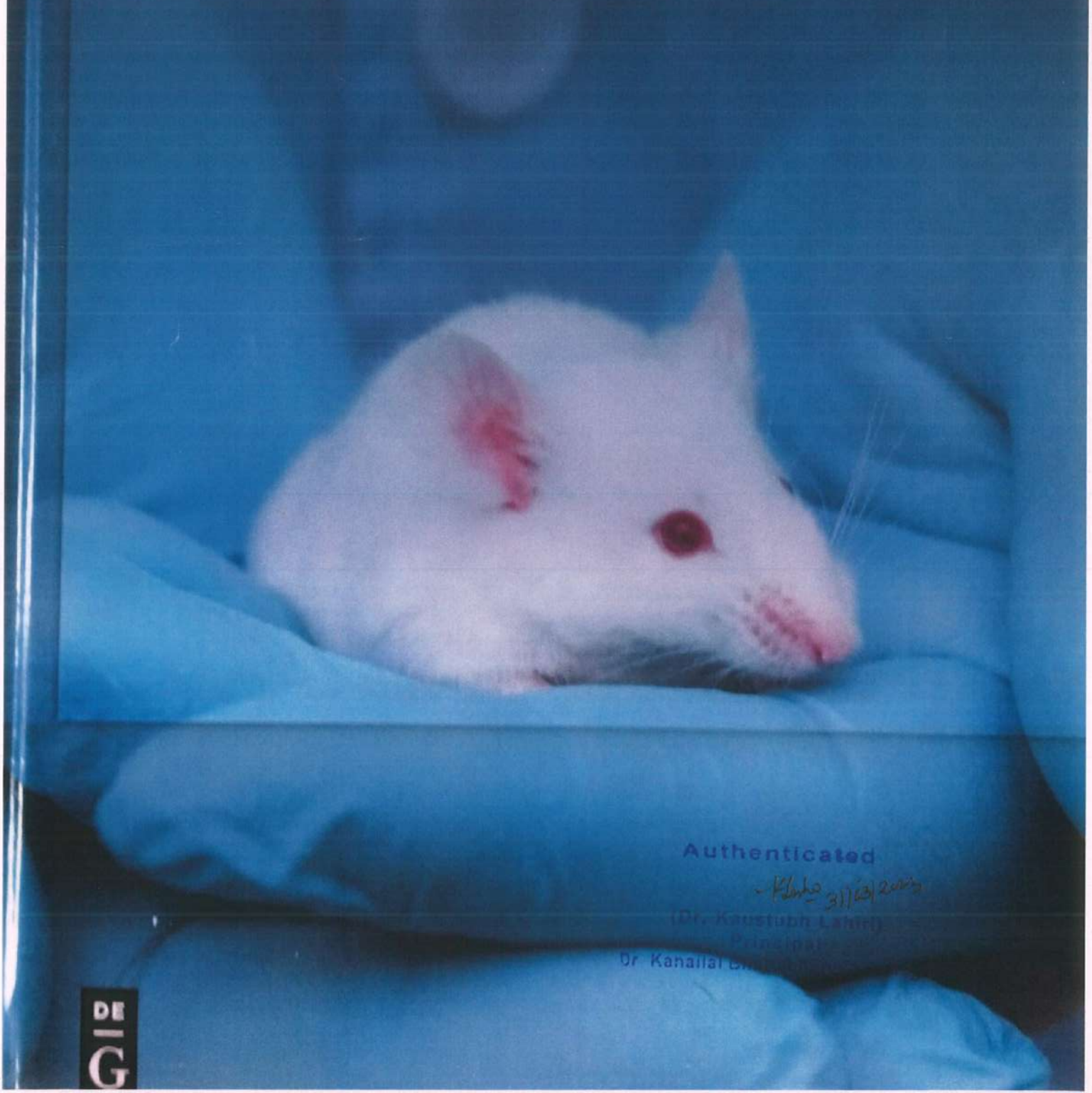
NANOPARTICLES AND THE IMMUNE SYSTEM

VOLUME 2: IMMUNE SYSTEM OF ANIMALS



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2 Cnidaria immune system and nanoparticles

Garima Hore, Shyamasree Ghosh, Dhriti Banerjee

Abstract: The phylum Cnidaria of invertebrates, although primitive in its organization, reveals an innate immune system. Diseases are caused when exposed to pathogens. The body is capable to show reactions while exposing to the environmental stress factors. Different aspects such as Cnidarian immunity, molecules and pathways involved, symbiosis, regeneration, and healing process of wound and cellular immune process are discussed in this chapter. Nanoparticles have been reported to induce toxic effects on the Cnidarians affecting their physiological and cellular processes. They have found their applications in trapping nanoparticle waste and model nanoparticle-mediated environmental toxicity. We discuss in this chapter nanoparticle-mediated toxicity and its impact on Cnidarians.

Keywords: Cnidaria, nanoparticles, immune system

Abbreviations

A. aureta	*Aurelia aurita*
A. digitifera	*Acropora digitifera*
A. millepora	*Acropora millepora*
A. pallida	*Aptasia pallida*
AMP	Antimicrobial peptides
C. werneri	*Corumbella werneri*
CASP-3	Caspase-3
CTLs	C-type lectins
ERK	Extracellular signal-regulated kinases
G. ventalina	*Gorgonia ventalina*
H. magnipapillata	*Hydra magnipapillata*
H. vulgaris	*Hydra vulgaris*
MACPF	Membrane-attack complex/perforin
MAPK	Mitogen-activated protein kinases
Myd88	Myeloid differentiation primary response 88
N. vectensis	*Nematostella vectensis*
N	Nitrogen

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