ISSN - 2250-0650

TRANSIENT

A Journal of Natural Sciences and Allied Subjects

- a peer reviewed journal

VOLUME V 2016

DON BOSCO COLLEGE

Tura, Meghalaya

ISSN - 2250-0650

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DON BOSCO COLLEGE, TURA
Meghalaya, India

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CONTENTS

STRATEGY PAPER

Emerging Pollutants and their future challenges

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Human activities, such as industrial, transport, agriculture, urbanization, mining and energy generation and consequential increase in living standards and resource consumption have greatly increased the pollution of the air, water and soil in recent decades. Large number of pollutants, for example, CO_2, NOx, SO_2, CH_4 and particulate matter in air; a variety of chemicals, metals, nutrients, leachates, oil, hazardous wastes, pesticides etc. in water and soil have been added in huge quantity and are responsible for causing various human health and environmental problems. These pollutants are referred to as conventional pollutants because they are monitored under existing regulations due to their known harmful effects.

The other area of concern is our modern way of life style increasingly based on man-made products stuffed with a variety of chemicals. We produce and use thousands of different types of chemicals of different purposes. These chemicals are used to make virtually every man-made product and play an important role in the everyday life of people around the world. Our usage of chemicals is increasing day-by-day with economic and industrial development. They have become indispensable to industrial production which greatly facilitates our daily life. Their sale increased by 95% in world between 2001 and 2011 in value terms, which was estimated to be about Euro 2,744 billion in 2011. It has been reported that between 1930 and 2000, global production of anthropogenic chemicals increased from 1 million to 400 million tons per year. It includes basic chemicals and its products, petrochemicals, fertilizers, paints, varnishes, gases, soaps, perfumes and toiletry, pharmaceuticals etc. Statistics published by EUROSTAT in 2013 reveal that, between 2002 and 2011, over 50% of the total production of

chemicals is represented by environmentally harmful compounds. Over 70% of these are chemicals with significant environmental impact.

An estimated over 100,000 chemical substances are used by us in different forms and ways. Many of these chemicals are present in items of our daily use. For instance, when we use toothpaste, shaving cream, tissue paper and napkin, soap and shampoo, moisturizer; eat fruits and vegetable, processed food; take medication; use household items such furniture, curtain, polyvinyl flooring; clean our household items with detergent; burn petrol and LPG as fuel; work with paints, varnish, enamel; protect our crops from pests etc., we come in contact with different types of chemicals, directly or indirectly and expose ourselves in different ways on daily basis. The residues of these chemicals and/or their metabolites ultimately reach to our environment and contaminate water, soil and air. Water bodies are major recipients of residues of these chemicals due to release of the effluents from the sewage treatment plants, leachate from landfill sites, runoff from industrial and agricultural areas.

Every year hundreds of new chemicals are added in our use list. Despite thousands of chemicals being in use, only about 1 percent of them have been toxicologically evaluated. Thus, we have no information or very limited information on majority of chemicals regarding their occurrence and adverse impacts on human health, flora and fauna and environment. Due to this fact only a fraction of it is currently regulated by administrative agencies despite recent research findings, which establish relationship between many of these chemicals and the physiological disorders of human and other biota and also with ecological disturbances.

Due to widespread use of chemicals and their formulations, environment is getting contaminated with numerous types of diverse chemicals of unknown harmful effects or suspected harmful effects. They are being added in low concentration in environment particularly in water. These pollutants or contaminants are called ‘emerging pollutants (EPs)’ or ‘emerging contaminants (ECs)’. Emerging pollutants (EPs) encompass a wide range of man-made chemicals (such as, pharmaceuticals, pesticides, cosmetics, personal and household care products etc.), which are in use worldwide and are indispensable for modern society. Some definitions of EPs include newer classes of compounds, such

as nonomaterial and genetically modified food items. In most cases, they correspond to unregulated contaminants, which may be candidates for future regulation depending on research on their potential health effects and the results of monitoring of their occurrence.

On one hand we do not know much on physiological and ecological effects of many of these chemicals, on the other hand large number of newer chemicals and their metabolites having potential to cause adverse impacts on human health, flora and fauna are being added in environment continuously. In recent years, increasing attention has been paid to the presence of emerging pollutants in wastewater and surface and ground waters. The occurrence of EPs is reported worldwide in a range of aquatic environments, such as lakes, rivers, freshwater catchments, estuaries, reservoirs and marine waters; in soil; in air (indoor and outdoor ambient air); and in biota (plants and animals).

Major sources and pathways of these emerging contaminants can be linked to the wastes and wastewaters resulting from industrial, agricultural, household or municipal activities. The environmental and human health consequences of most of the emerging pollutants are not well understood due to non availability of toxicological data. However, many are known as endocrine disrupters, allergents, asthamagenic, cytotoxic, carcinogenic that affect human health, biodiversity and ecosystem through a complex pathway.

Emerging pollutants reach the environment from various anthropogenic sources and are distributed throughout environmental components. These EPs occur ubiquitously in urban receiving waters and have both point and non-point sources such as house hold products, industrial waste, land fill sites, wastewater /sewage, runoff and infiltration from agricultural or industrial areas, direct discharges from health centers and hospitals. A variety of substances of varying nature used in day-to-day life contribute different types of emerging pollutants in environment (Table 1).

Table. 1: Products which contributed different type of emerging pollutants

Sl. No.	Products/sources of EPs	Emerging pollutants
1.	Pharmaceuticals	Medications including hormones, pain relievers, psychopharmaceuticals, lipid regulators, antibiotics, etc.
2.	Steroid Hormones	Oestradiol, Coprostanol
3.	Surfactants and Detergents	Perfluoro-octane sulphonic acid (PFOS) Nonylphenols, APEs,
4.	Flame retardants	Hexabromochloracyclododecane (HBCD) Tri (2-chloroethyl) phosphate, PBDEs,
5.	Plasticisers	Bisphenol A, Phthalates, Methanone
6.	Personal care products	Antiseptics (triclosan/triclocarban), sunscreen components, cosmetics, etc.
7.	Perfumes and Personal care products	Synthetic musks and other chemical fragrances
8.	Phytoestrogens	Plant products that are similar to vertebrate hormones
9.	Brominated compounds	Include PBDE flame retardants, plastic and insulation compounds
10.	Fluorinated compounds	Perfluorinated compounds (found in surfactants, stain-resistant fabric protectors and non-stick cookware), flame retardants, etc.
11.	Disinfectants and their by products	Alcohols, Aldehydes and oxidizing Agents, Chloroform, Nitrosodimethylamine (NDMA)
12.	Nonhalogenated compounds	Formaldehyde, carboxylic acid, etc.
13.	Solvents	Para-Cresol, DNP
14.	Nanomaterials	Manufactured particulates less than 100 nanometers (nm) in size (Silica, Aluminium fibre, Gypsum, Cellulose)

Some house hold and personal care products include large number of synthetic chemicals. Many of these chemicals are harmful in long run. For example, in shampoos the main ingredient a surfactant is combined with other compounds rendering qualities of pleasing foam, easy ringing, minimal skin/eye irritation and hair damage, thick and creamy feeling, pleasant fragrance, low toxicity, good biodegradability and slightly acidic pH. A typical shampoo is composed of 10 to 30 ingredients (Table 2). After use the surfactants and other ingredients finally reach to soil and water environment and are likely to cause different problems. Many of these chemicals are known to posses toxic, allergic and endocrine disrupting properties.

Table 2. Commonly used Shampoo Ingredients that come under the list of emerging pollutants

Ingredients	Compounds	Functions
Surfactants	Sodium laureth sulfate, Sodium Lauryl SulfateSodium lauroamphoacetate, Ammonium laureth sulfate, Alkyl sodium sulpgate, Sodium oelfin sulfate, TEA-lauryl sulfate	Cleansing
Panthenol and Humectants	Panthenol , Glycerin, Sorbitol, Glycols, Propylene glycol	Add luster and maintains moisture
Silicone	Dimethicone, Cyclomethicone	Conditioner
Proteins	Collagen, Elastin	Act as good conditioner
Foam boosters	Cocamide MEA, Lauramide MEA, Lauric DEA, Lauramine oxide, Cocamidopropyl hydroxysultaine, Polysorbate 20	Form more lather
Citric Acid	Citric acid	Maintains slightly acidic pH/ balanced pH
Preservatives	Methylparaben, Propylparaben, Phenoxyethanol, DMDM hydantoin, 2-bromo-2-nitropropate-1, 3-diol, Imidazolidinyl urea	Protect from spoiling
Anti-microbial agent	Triclosan	Anti-microbial
Quarternary Ammonium Compounds	Guar hyroxypropyltrimonium chloride, Dicetyldimonium chloride, Benqylmonium chloride, Quaternium 18, Stearalkonium chloride.	Help create manageable hair
Thickeners	stearyl alcohol, acetyl alcohol, hydrogenated lanolin, polyethylene glycol, glycol stearate, palmitic acid	Make shampoo thicker
Water	Water	Aqueous medium
Other Ingredients	Extracts of almond, allspice, angelica, arnica, balm mint oil, balsam, basil, bergamot, chamomile, cinnamon, citrus, clove	Added for specific purposes

Similarly, synthetic fragrances are mixtures of various chemicals that produce a desired scent. Although, fragrances seem to made up from flowers and natural fragrance products, but actually 95% of the chemicals in fragrances are synthetic compounds derived from petroleum. Synthetic fragrances are added in commonly used consumer products such as lotion and cream; prescription and nonprescription medications (e.g., inhalers and sports creams); hairspray; soaps and detergents; shampoos and conditioners; talcum

powder; deodorants and antiperspirants; scented oils; shaving creams and aftershave lotions; toothpastes and mouthwash; air fresheners and deodorizers; sunscreen and anti-acne products; other cosmetics; insect repellants; candle and incense sticks; industrial and household chemicals; furniture polish; nail polish and removers; scented pens and pencils; diapers and sanitary napkins; fabric softener; paper (magazines, newsprint, and stationery); some foods (buttered microwave popcorn); building, construction and renovation materials (paint, varnish, urethane finishes) etc. Over 4,000 chemicals are used to make fragrances and hundreds can be used in one product. After application these synthetic fragrances reach in environment. Their presence has been reported in water, sediment, suspended particulate matter (SPM) in air and in biota. Some synthetic fragrances commonly used in Personal Care Products and their probable harmful effects are presented in Table 3.

Table 3. Some synthetic fragrances commonly used in Personal Care Products and their harmful effects

Ingredients	Role	Probable Effects
Alpha-terpineol	A synthetic fragrance giving floral smell	Causes irritation of nasal passages and mucous membranes; affects central nervous system (CNS)
Benzenethanol	A sweet-smelling, floral, rose synthetic fragrance	Causes irritation of eyes, skin, and upper respiratory tract; adversely affects CNS; affects bone marrow and immune system; carcinogenic
Benzenemethanol	Used as a solvent (benzenemethanol) for fragrance chemicals	Causes irritation of eyes, skin, and upper respiratory tract; carcinogenic; adversely affects CNS
Benzyl acetate	A fruity, floral synthetic fragrance	Linked to pancreatic cancer; causes irritation of eyes and respiratory tract
Benzaldehyde, 4-hydroxy-3-methoxy	A synthetic fragrance adds vanilla notes	Aggravates the throat, mouth, lungs, skin, eyes, and gastrointestinal tract; causes abdominal pain, nausea and affects kidney and CNS
Cyclopentadecanolide	One of the artificial musks	Known as a hormone disrupting chemical, a carcinogenic, and irritant
Ethyl linalool; linalool	A synthetic fragrance adds scent of lavender and bergamot.	Known as a narcotic and CNS disrupter
Eugenol	A synthetic fragrance used as a replacement for clove oil	Causes irritation of eyes, skin, and respiratory tract; triggers contact dermatitis
Galaxolide 50	A synthetic musk fragrance	Known as a hormone disrupting chemical, irritant and a carcinogen

Similarly, other personal care products, pharmaceuticals, surfactants and detergents, plasticizers, solvents, pesticides, flame retardants, paints, nanomaterial, etc. contribute numerous chemicals in environment and add to the list of EPs.

Conclusion

Emerging pollutants comprise of personal care products and fragrances, nanomaterials, pesticides, pharmaceuticals, industrial additives and by-products, water treatment by products, flame/fire retardants and surfactants, as well as caffeine and nicotine metabolites and hormones. They also include constituent chemical compounds present and their metabolites. Many of the compounds are relatively small and/or polar molecules which often are not be effectively removed by conventional drinking water treatments. Due to limited information on their occurrence and effects most of these EPs are not monitored and regulated. However, many of these compounds are toxic and known as endocrine disrupters, allergents, asthamagenic, cytotoxic, carcinogenic that affect human health, biodiversity and ecosystem through a complex pathway. Detection, monitoring, toxicological, health and ecological impact analyses and regulation of these compounds are challenging tasks and require much better understanding of their properties, distribution and behaviour in environment. The challenges also include identifying new emerging compounds, setting appropriate standards and developing strategies to reduce the use and inputs to the environment.

REVIEW PAPER

Impedance study of SnO_2: A short review

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ABSTRACT

Tin oxide being a material of extreme importance having application in optoelectronics and gas sensing is discussed in this review work. The electrical representation and output expected is put forward. Also, some important experimental work that has been carried out by difference research group is discussed. The authors also present here some experimental work where the impedance property of SnO2 thin film deposited by spray pyrolysis technique is discussed. The ethanol vapour sensing property of the same is presented to throw light on the application of the synthesized films.

Keywords: SnO_2; sensing; thin film; spray pyrolysis

INTRODUCTION

Tin oxide (SnO_2) is a transparent conducting oxide (TCO) and has application in various fields [1-4]. Because of the transparency and low resistivity optoelectronic devices also cannot do away with the use of the same. SnO_2 is one of the primaries TCO and is chemically stable. The thin films can be synthesized using various chemical and physical methods. Chemical methods are fast and cheaper for the synthesis of thin films and include methods like atomic layer epitaxy, chemical vapor deposition, spin coating, dip coating and spray pyrolysis. Physical methods can synthesize controlled layer of thin films and includes methods like Vacuum evaporation, Laser Ablation, Molecular beam epitaxy and sputtering.

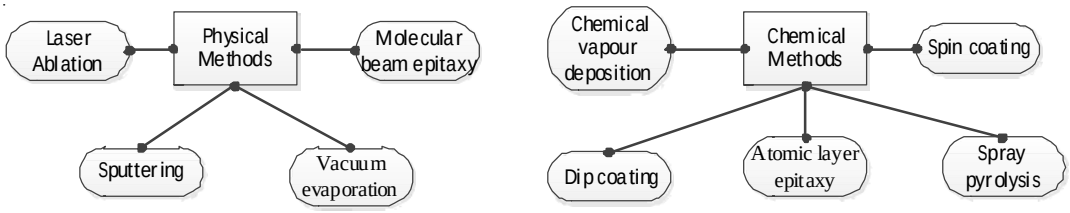

Figure 1: Methods for deposition of thin films

The as-deposited thin films behave differently in terms of electrical properties depending on the morphology, deposition technique, after treatment and thickness of the film. In the present review study, we analyze on the impedance study on SnO_2 thin film.

In electrical studies, the common method is an application of a stimulus or an input signal to the thin film and studying the response as the output. A plot between the components of input and output reveals many important characteristics. The electrical characteristic can be studied by applying an ac or dc input signal. But the output might not give the same result in these cases. In dc characterization mostly IV Characteristic curves reveal the electrical behavior. This is a plot between current and applied voltage. The voltage is given as an input to the terminal and the current response is recorded as the output. In a dc signal, the frequency is zero, hence a circuit consisting of a capacitance in series will offer infinite resistance and the circuit acts as open. On the other hand, an inductance placed in parallel offers zero resistance. So the component which is most effective in the change of properties is resistance and we cannot predict a capacitive or an inductive effect.

But the presence of these components in an electrical system cannot be discarded. In dc characterization capacitance and impedance of the system can be evaluated depending on the applied frequency as an input. In impedance characterization, an input signal like changing frequency can be applied. The output impedance, phase angle, dielectric loss, capacitance and other components can be studied as a function of frequency which can reveal its applicability in the various fields.

A deposited thin film is one such circuit which has are sponse to an ac signal, be it ac or dc. So we can assume it to behave like an electrical circuit and depend on its outputs; the equivalent

circuit thus designed can reveal about its internal behavior. A thin film is composed of bulk and grain boundaries, intergranular contact regions and electrode-sample interface regions. The effect of each of these components can be analyzed by ac impedance measurement. For example cole-cole plot is plotted between the real and imaginary part of impedance can reveal the transport mechanism.

B. Benrabah et al. prepared Sb-doped SnO_2 thin film by sol-gel process. Agilent 4284A LCR meter was used for recording the impedance parameters. The films were deposited on pyrex plates using the dip-coating method. The impedance parameters were extracted at different temperature from 80-250 ^oC and frequency range of 20 Hz to 1 MHz. Semi-circular arcs of Nyquist Plots had no spur and shrank as temperature increased. This showed that the resistance of the grain boundary reduced in size. The work revealed that the grain boundary dominates in the conduction mechanism and the activation energy of conduction was 0.87 eV [5].

M. A. Ponce et al. prepared SnO_2 thick films by painting synthesized paste of SnO_2 onto insulating alumina substrate. Electrodes with an interdigitated shape were deposited on the substrate by sputtering. Impedance parameters were determined at a fixed temperature of 424 ^oC. The impedance plots were analyzed under air and vacuum atmosphere. Equivalent circuit wasestimated and capacitance and resistance variation in air and vacuum were fitted. The results showed that with specific frequency use the response and the sensitivity of the film may be improved [6].

H. J. Schwenn et al. investigated the SnO_2 nanoparticle dispersed in a zeolite matrix. The impedance measurements were done using pressed pellets of diameter 5mm and 0.3-0.4 mm thickness. The frequency range employed was from 10 Hz to 10^7 Hz using HP 4192 An Impedance Analyzer and the temperature is varied from 293 k to 673 K. The conductivity was described by Arrhenius plot and the activation energy was calculated to be 78 kJ/ mol. The change was observed between oxidative and reductive gas environment. This also showed that the sample was efficient for use as sensing materials [7].

A. E. De Souza et al. prepared SnO_2 thin film by dip coating. Nb-doped sample was also prepared at the same time. The effect of doping concentration on the

complex impedance measurements was studied. Cole-cole plot of the samples revealed the presence of ionized carrier trapped on the acceptor level which was localized at the grain or crystallite boundary. For smaller concentration of doping the resistance was more than that of the undoped sample. The resistance thus keeps on decreasing with the increase of dopant concentration [8].

A. Azam et al. investigated Mn-doped tin oxide nanoparticles synthesized by sol-gel method. The doping was varied from 0-15 mol %. The impedance analysis was carried out at room temperature. The grain and boundary contribution to the system was analyzed. Dielectric constant, dielectric loss and ac conductivity were studied as a function of frequency. The dielectric parameters were observed to decrease with the increase of dopant amount. At high frequency, the dielectric loss dropped to zero [9].

R. Muccillo et al. studied CoO doped SnO_2 pellets. Doping was varied from 0.5 to 2 mol %. The impedance spectroscopy was studied from 5 Hz-13 MHz. It was revealed that with higher concentration the resistance of the samples drops at lower temperatures. It was suggested that impedance study can be used to study densification mechanism in ceramics [10].

Varghese et al. prepared ultrafine grained tin oxide thin films by sol-gel method and impedance study was carried out in the frequency range 250 kHz-10 MHz. The impedance values changed at room temperature when interacted with water vapour. The conduction mechanism was attributed to the transfer of protons through layer water molecules. A low-frequency spur was also observed and was suggested to be because of adsorbed ions in the film layer. The spur, however, disappeared on heating the film due to desorption of water molecules. The film was found to display semiconducting behavior at 473 K. At higher temperature spur re-appeared but disappeared when in presence of ethanol due to oxygen ions removal by ethanol molecules [11].

P. R. Bueno et al. SnO_2 varistor system by doping with CoO, Nb_2O and Cr_2O_3 were analyzed by impedance spectroscopyfrom 25 ^oC to 400 ^oC. The Nyquist plot showed two activation energies at the low and at the high frequency. This was attributed to adsorption and reaction of O_2 species at the grain boundary. The barrier formation mechanism was attempted in this work [12].

EXPERIMENTAL

The authors are presently working in the field of impedance characterization. Cole-cole plot revealed many important characteristics. Cole-cole plot can be used to predict the equivalent circuit. The equivalent circuit comprises of resistors, capacitors and debye and non-debye elements. For the characterized sample the equivalent circuit is shown in figure 2. The impedance of the equivalent circuit is given by:

$$\frac{1}{Z} = \frac{1}{Z' + jZ''} = \frac{1}{R} + C(j\omega)^n$$

where $\omega = 2\pi f$

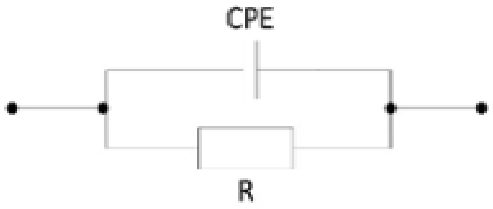

Figure 2: Equivalent circuit SnO_2 thin film

The semi-circles shown in the cole-cole plot is a result of charge transfer process which occurs at high frequency.

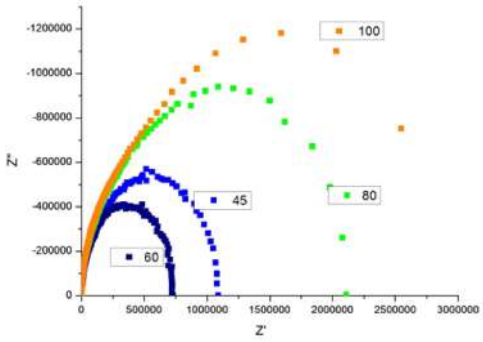

Figure 3: Cole-cole plot of SnO_2 thin film

Figure 3 shows the cole-cole plot (plotted between real and imaginary part of impedance) of SnO_2 thin film synthesized using the spray pyrolysis technique. The temperature was varied and impedance data was collected at 45 ^oC, 60 ^oC, 80 ^oC and 100 ^oC. The single semicircular shape of the plot shows that the effect of grain boundaries. Also the shrinking of the size of the semi-circle shape points towards the decrease of resistance of the grain boundaries. The transport mechanism of the charge carriers can be attributed to the hopping process. The same film was exposed to gasses and it was observed that the impedance (resistance and reactance) of the film dropped which shows that the film has application in the field of gas sensing.

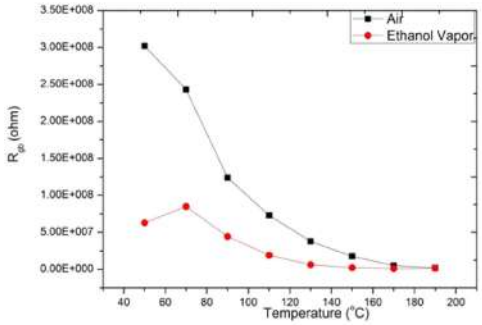

Figure 4: Grain Resistance (R_{gb}) drop when film is exposed to ethanol

CONCLUSION

Tin oxide is one of the most explored transparent conducting oxides. Some of the important work on the synthesis and application of the material is discussed in the present work. Also, in the experimental section the impedance spectroscopy has been highlighted. It can be visualized the immense applicability that impedance spectroscopy holds in exhibiting the electrical properties of SnO_2 thin films The applicability of the same in various applications is explored in terms of electrical properties. Hence impedance spectroscopy plays a vital role in the electrical studies. The equivalent circuit using the cole-cole plot is discussed. The as-synthesised thin film shows that it can have gas sensing application as it was able to show variation in impedance with ethanol vapour present in the environment compared to that of air.

REFERENCES

1. Lee J 2008. Effects of oxygen concentration on the properties of sputtered SnO_2: Sb films deposited at low temperature. *Thin Solid Films*. 516: 1386-1390
2. Ma J, Hao X, Huang S, Huang J, Yang Y, Ma H 2003. Comparison of the electrical and optical properties for SnO_2: Sb films deposited on polyimide and glass substrates. *Appl. Surf. Sci*. 214: 208-213
3. Lehmann HW, Widmer R 1975. Preparation and properties of reactively co-sputtered transparent conducting films. *Thin Solid Films* 27: 359-368
4. Suzuki K, Mizuhashi M 1982. Structural, electrical and optical properties of rf-magnetron-sputtered SnO_2: Sb film. *Thin Solid Films* 97: 119-127
5. Benrabah B, Bouaza A, Kadari A, Maaref MA 2011. Impedance studies of Sb doped SnO_2 thin film prepared by sol gel process. *Superlattices and Microstructures* 50: 591-600\
6. Ponce MA, Bueno PR, Varela J, Castro MS, Aldao CM 2008. Impedance spectroscopy analysis of SnO_2 thick-films gas sensors. *J Mater Sci: Mater Electron* 19: 1169-117

7. Schwenn HJ, Wark M, Schulz-Ekloff G, H. Wiggers H, Simon U 1997. Synthesis of new alkyl maleates ammonium derivatives and their uses in emulsion polymerization. *Colloid & Polymer Science* 275(1): 1-8
8. De Souza AE, Monteiro SH, Santilli CV, Pulcinell SH 1997. Electrical and optical characteristics of SnO_2 thin films prepared by dip coating from aqueous colloidal suspensions. *J Materials Science:Materials in Electronics* 8: 265-270
9. Azam A, Ahmed AS , Chaman M, Naqvi AH 2010. Investigation of electrical properties of Mn doped tin oxide nanoparticles using impedance spectroscopy. *J Applied Physics* 108(9): 094329
10. Muccillo R, Cerri JA, Leite ER, Longo E, Varela JA 1997. Impedance spectroscopy of SnO_2: CoO during sintering. *Materials Letters* 30: 125-130
11. Varghese OK, Malhotra LK 2000. Studies of ambient dependent electrical behaviour of nanocrystalline SnO_2 thin films using impedance spectroscopy. *J Applied Physics* 87: 7457-7465
12. Bueno PR, Pianaro SA, Pereira EC, Bulhões LOS, Longo E, Varela JA 1998. Investigation of the electrical properties of SnO_2 varistor system using impedance spectroscopy. *J Applied Physics* 84: 3700-3705

Tri-phenyltin(IV) carboxylate based Anticancer Drugs: A Short Review

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ABSTRACT

This article reviews the progress on the investigation of tri-phenyltin(IV) anticancer drugs using carboxylate based ligands. The rich diversity of the carboxylate based ligands in the coordination chemistry of tin(IV) provides not only interesting structural chemistry but also exciting therapeutic properties. In specific, these compounds have gained increasing attention in antitumor applications and are hypothesized to exhibit higher therapeutic potential than most of the presently offered drugs.

Keywords: Carboxylate, tri-phenyltin(IV) carboxylate, *in vitro*, anti-cancer

INTRODUCTION

The first inorganic cancer chemotherapeutic agent cisplatin remains a front line in the treatment of cancer [1-4]. In spite of having severe side effects, it is among the most widely used anti-cancer drugs than other platinum (II) complexes, such as carboplatin, oxaliplatin and nedoplatin [5-12]. The success of platinum(II) compounds has encouraged a great deal of attention in other platinum and non-platinum metallodrugs such as Ti, Au, Cu, Ru and Pd etc. and have been well documented in the literature of anticancer drugs [13-23]. Organotin(IV) compounds have also emerged as a widely studied class of metal-based anti-tumour drugs which led to the discovery of compounds with excellent *in vitro* anti-tumour activity [24-30]. In recent research reports the design of improved organotin(IV) antitumor agents occupies a significant place in cancer chemotherapy [31-40]. Amongst organotin(IV) compounds, tri-phenyltin(IV) carboxylate compounds in particular, have evolved as potential anti-cancer agent and demonstrated promising

results in the field of anticancer drugs [31-40]. In general tri-phenyltin(IV) carboxylate compounds displays excellent biological activities than their diorganotin and monoorganotin analogues. Consequently, a large number of tri-phenyltin(IV) carboxylate compounds have been developed and investigated for their anti-tumor activities [31-40]. Some of the promising anti-tumour activity of tri-phenyltin(IV) carboxylates compounds has been achieved with *viz.*, -salicylates [41], -3,6-dioxaheptanoate, -3,6,9-trioxadecanoate [42], -4-carboxybenzo-15-crown-5, -4-carboxybenzo-18-crown-6 [42,43], -steroidcarboxylate [44], -terebate [45-47] and those derived from Schiff bases containing amino acetates, e.g., 2-{[(2Z)-(3-hydroxy-1-methyl-2-butenylidene)] amino}-4-methyl-pentanoate; 2-{[(*E*)-1-(2-hydroxyphenyl) methylidene]amino}-4-methyl-pentanoate; 2-{[(*E*)-1-(2-hydroxyphenyl) ethylidene] amino}-4-methyl-pentanoate [48], 2-{[(2Z)-(3-hydroxy-1-methyl-2-butenylidene)] amino}phenylpropionate; 2-{[(E)-1-(2 hydroxyphenyl) methylidene]-amino} phenylpropionate; 2-{[(*E*)-1-(2-hydroxyphenyl) ethylidene] amino} phenylpropionate [49] and arylazobenzoates [31-32], when screened for *in vitro* studies against human tumour cell lines. Thus it is comprehensible that tri-phenyltin(IV) carboxylate compounds can be developed with high *in vitro* antitumor activity. Therefore, in view of the rapid progress of organotin(IV) carboxylates in the realm of anticancer drugs, an attempt is being made in this review to highlight some of the research findings of recent years about tri-phenyltin(IV) carboxylate compounds as potential anticancer drugs.

In vivo anti-tumour activities of tri-phenyltin(IV) carboxylate compounds

Triorganotin(IV) carboxylates are the subject of notable interest because of both their structural diversity in the crystalline state and their interesting biological activity [31-40]. Basu et al. 2010, reported two tri-phenyltin(IV) compounds using 2-[(*E*)-2-(aryl)-1-diazenyl]benzoates as ligand source (Figure 1). These important classes of compounds accelerate hydrogen bonding interactions through the azo group nitrogen atoms and carbonyl oxygen atoms with various key enzymes leading to the inhibition of cancer as evidenced from the theoretical studies carried out [31]. The cytotoxic potential was evaluated on various cancer tumour cell lines, such as A498 (renal cancer), EVSA-T (mammary cancer), H226 (non-

small-cell lung cancer), IGROV (ovarian cancer), M19-MEL (melanoma), MCF-7 (mammary cancer) and WIDR (colon cancer) (Table 1). The triphenyltin(IV) compounds (**1** and **2**) displayed ID_{50} values in the range 41-109 ng/ml (Table 1), across a panel of human tumour cell lines; these were found to be far superior to some of the standard drugs such as CDDP (cisplatin), 5-FU (5-fluorouracil) and ETO (etoposide), when tested across a panel of same cell lines and the activity of these compounds were even found to be more prominent for the A498 (22 fold) and H226 (33 fold) cell lines compared to CCDP, and A498 (13 fold), H226 (39 fold) and MCF-7 (33 fold) cell lines compared to ETO.

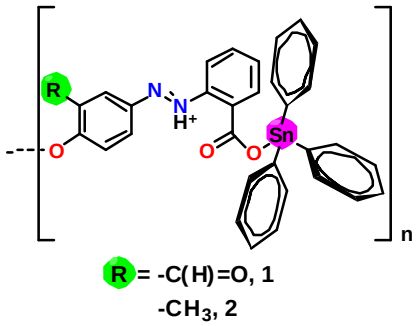


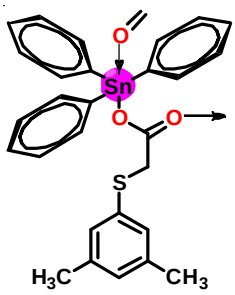
Figure 1: Structure of tri-phenyltin(IV) compounds **1** and **2**.

Table 1: *In vitro* IC_{50} values (ng/ml) of tri-phenyltin(IV) compounds (**1**-**2**) and standard drugs using cell viability tests in seven human tumour cell lines.

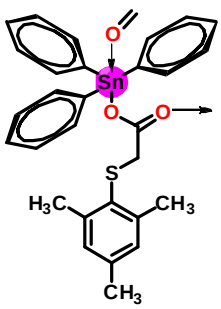
Test compounds	Cell lines						
	A498	**EVSA-T**	**H226**	**IGROV**	**MI19 MEL**	**MCF-7**	**WIDR**
1	103	49	101	101	104	78	95
2	101	41	104	109	103	92	104
CDDP[a]	2253	422	3269	169	558	699	967
5-FU[a]	143	475	340	297	442	750	225
ETO[a]	1314	317	3934	580	505	2594	150

[a]CDDP, cisplatin; 5-FU, 5-fluorouracil; ETO, etoposide.

Gallium and titanium complexes of xylylthioacetato and mesitylthioacetato ligands exhibited potential cytotoxic agents [50, 51]. Thus in the order to know the effect of xylylthioacetato and mesitylthioacetato ligands on the cytotoxicity of organotin(IV) complexes, Gómez-Ruiz et al. 2010, reported two tri-phenyltin(IV) compounds (**3-4,** Figure 2) derived from xylylthioacetato and mesitylthioacetato ligands, respectively and investigated for their *in vitro* cytotoxicity against the human tumor cell lines: 8505C (anaplastic thyroid cancer), A-253 (head and neck tumor), A-549 (lung carcinoma) and DLD-1 (colon carcinoma) [33]. The IC_{50} values of the tri-phenyltin(IV) compounds against the aforesaid cell lines (**3-4**) are presented in Table 2. The cytotoxic activity of both the compounds were found to be 285 and 2520 times greater than their gallium(III) and titanocene(IV) analogues, respectively [51,52]. Further, the cytotoxic activity of these compounds were found to be superior to that of cisplatin.



(**3**)



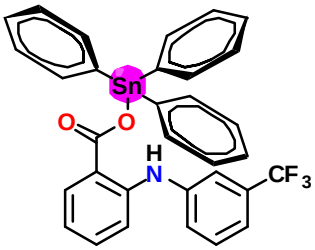
(**4**)

Figure 2: Structure of tri-phenyltin(IV) compounds **3** and **4**.

Table 2: *In vitro* antiproliferative activity results (IC_{50}, μM) of tri-phenyltin(IV) compounds (**3-4**) against different cell lines.

	Cell lines			
Test Compounds	**8505C**	**A-253**	**A-549**	**DLS-1**
3	0.132	0.081	0.094	0.060
4	0.172	0.100	0.129	0.178
Cisplatin	5.0	0.81	1.51	5.1

The chemistry of NSAIDs (Nonsteroidal anti-inflammatory drugs) is well known so as its biological activity. Thus Kovala-Demertzi et al. 2011, reported few tri-phenyltin(VI) compounds (**5-8,** Figure 3) using some of the NSAIDs such as flufenamic acid (Flu), 2-(2,3-dichlorophenylamino)benzoic acid (dcpa), 2-(2,6-dimethylphenylamino)benzoic acid (dmpa) and 2-(2,3-dimethylphenylamino) benzoic acid (mef) in order to improve the biological activity compared to the "parent drugs". These compounds were tested for their *in vitro* antiproliferative activity against a panel of human cancer cell lines: MCF-7 (human breast cancer cell line), T24 (bladder cancer cell line), A-549 (non small cell lung carcinoma). The IC_{50} values of all the tri-phenyltin(IV) compounds are presented in Table 3. One of the compounds (**7**) was found to exhibit highest activity and selectivity against A-549 and MCF-7 cancer cell lines [36].



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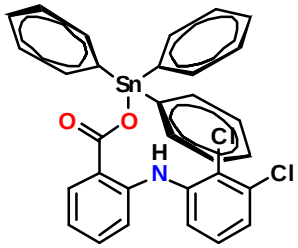

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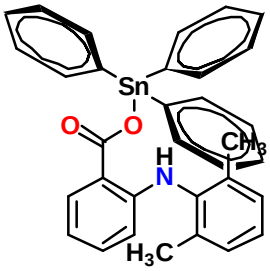
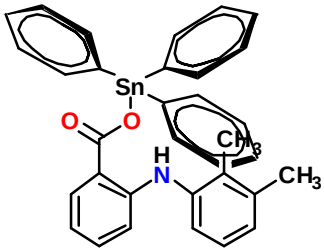


(**7**)



(**8**)

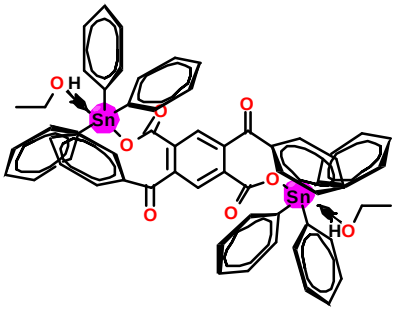
Figure 3: Structure of tri-phenyltin(IV) compounds **5-8**.

Table 3: *In vitro* activity of tri-phenyltin(VI) compounds (**5**-**8**) derived from NASAIDS expressed as IC_{50} (μM)) against various cancer cell lines.

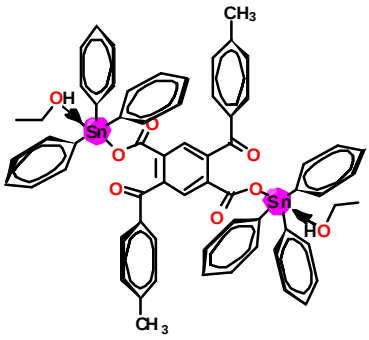
	Cell lines		
Test compounds	**A-549**	**MCF-7**	**T-24**
[Ph_3Sn(flu)] (**5**)	60.44 ± 4.80	1.26 ± 0.05	4.78 ± 0.41
[Ph_3Sn(dcpa)] (**6**)	10.28 ± 0.91	2.01 ± 0.34	3.49 ± 0.22
[Ph_3Sn(dmpa)] (**7**)	0.22±0.01	0.17±0.01	3.27±0.26
[Ph_3Sn(mef)] (**8**)	7.21 ± 0.7	0.68±0.41	0.29±0.02
Cis-platin	0.69 ± 0.03	41.66 ± 2.2	7.99 ± 0.31

Flu, Flufenamic acid; dcpa, [2-(2,3-dichlorophenylamino)benzoic acid]; dmpa, [2-(2,6-dimethylphenylamino)benzoic acid]; mef, [2-(2,3-dimethylphenylamino) benzoic acid.

Some new tri-phenyltin(IV) carboxylates compounds (**9**-**11**, Figure 4), based on 1,3-benzenedicarboxylic acid and 1,4-benzenedicarboxylic acid ligands were synthesized by Xu et al. 2011, and evaluated for antitumor activity against cervical (HeLa), fibrosarcoma (HT1080) and glioma (U87) cell lines [52]. Compound **11**, displayed excellent antitumor activity against HeLa cells and having greater antitumor activity than cisplatin (Table 4). On the other hand, compounds (**9**) and (**10**) were the most efficient antitumor agents for U87 and having greater antitumor activities than cisplatin (Table 4). Further, cisplatin demonstrated no effect on HT1080 cancer cells, however all the compounds displayed noticeable *in vitro* cytoxic activity against HT1080 cancer cells.



(**9**)



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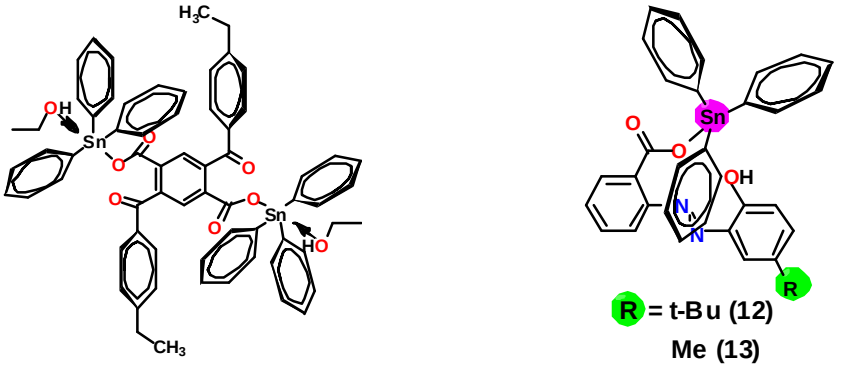


(**11**)

Figure 4: Structure of tri-phenyltin(IV) compounds **9-11**.

Table 4: *In vitro* anticancer results (IC_{50}, µg/ml) of tri-phenyltin(IV) carboxylate compounds (**9-11**) against different cell lines.

	Cell lines		
Test Compounds	**HeLa**	**HT1080**	**U87**
9	25.72	5.00	0.06
10	31.74	6.39	0.60
11	2.68	6.13	74.0
Cisplatin	3.50	-----	2.60

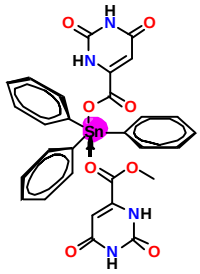
In another study, Basu et al. 2012, reported tri-phenyltin(IV) 2-[(E)-2-(aryl)-1-diazenyl] benzoates (**12-13**) having a triphenyltin(IV) carboxylate group at the ortho position in the diazo-forming moiety (Figure 4) [53]. These compounds were screened for their *in vitro* cytotoxic potential across a panel of human tumor cell lines: A498 (renal cancer), EVSA-T (mammary cancer), H226 (non-small-cell lung cancer), IGROV (ovarian cancer), M19 MEL (melanoma), MCF-7 (mammary cancer) and WIDR (colon cancer) (Table 5). The cytotoxicity results showed that the test compounds are better than standard drug CDDP (cisplatin), 5-FU (5-fluorouracil) and ETO (etoposide) (Table 5).

Table 5: *In vitro* ID_{50} values (ng/ml) of tri-phenyltin(IV) compounds (**12-13**) and standard drugs using cell viability tests in seven human tumour cell lines.

	Cell lines						
Test compounds	**A498**	**EVSA-T**	**H226**	**IGROV**	**MI19 MEL**	**MCF-7**	**WIDR**
12	101	43	102	111	103	79	106
13	162	97	148	214	118	113	106
CDDP[a]	2253	422	3269	169	558	699	967
5-FU[a]	143	475	340	297	442	750	225
ETO[a]	1314	317	3934	580	505	2594	150

[a]CDDP, cisplatin; 5-FU, 5-fluorouracil; ETO, etoposide.

Orotic acid plays a very pivotal role in the living organisms for the 'de-novo' biosynthesis of pyrimidine bases of nucleic acids [54]. Some metal orotates such as Platinum orotates, palladium orotates, and zinc orotates have exhibited interesting anticancer properties [55,56]. Therefore, in order to know the anticancer activity of organotin(IV) orotates, Nath et al. 2013, reported a tri-phenyltin(IV) compound (**14,** Figure 5) of orotic acid and screened for *in vitro* cytotoxic activity against five human cancer cell lines: mammary cancer (MCF-7), kidney cancer (HEK-293), prostate cancer (PC-3), colon cancer (HCT-15) and liver cancer (HepG-2) [57]. It was observed that this compound was active against all the cell lines. However, the compound was found to be less potent in comparison to some of the standard drugs such as cisplatin, 5-fluorouracil and methotrexate.



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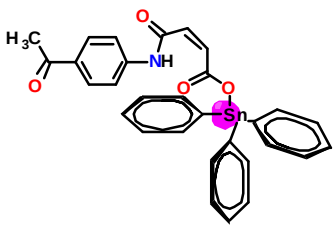

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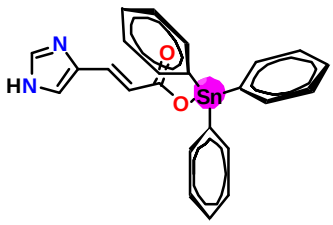


(16)

Figure 5: Structure of triphenyltin(IV) compounds **14-16**.

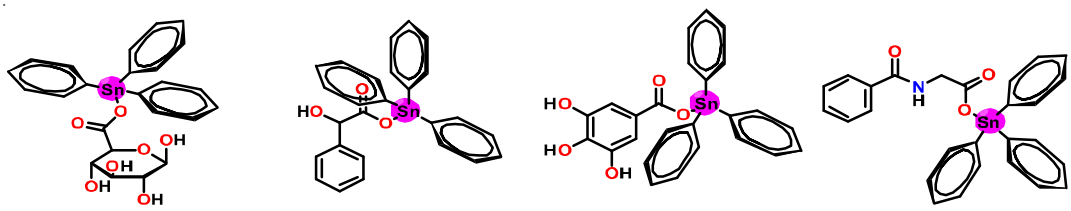
Mirza et al. 2013, reported a tri-phenyltin(IV) compound (**15**) derived from maleic anhydride and p-aminoacetophenone (Figure 5) and screened for antitumor activity by potato disc antitumor assay. The result from this study shows that this compound exhibited very good tumor inhibitory activity [37].

A novel tri-phenyltin(IV) carboxylate compound (**16**) was synthesised by Gaviño et al. 2013, from a biologically active urocanic acid and screened for its *in vitro* antitumour activity against a panel of human cancer cell lines: human glioblastoma (U251), human prostatic adenocarcinoma (PC-3), human chronic myelogenous leukemia (K562), human colorectal adenocarcinoma (HTC-15), human mammary adenocarcinoma (MFC-7) and human lung adenocarcinoma (SKLU-1) (Table 6). On the basis of the IC_{50} values, this compound exhibits higher cytotoxic effects than cisplatin, in specific cell lines [58].

Table 6: IC_{50} values (mM) of compound **16** and cisplatin on human cancer cell lines after a 48 h incubation time.

	Cell lines					
Test compound	**U251**	**PC-3**	**K562**	**HCT-15**	**MCF-7**	**SKLU-1**
16	0.85±0.07	0.67±0.03	0.54±0.04	0.35±0.01	0.38±0.02	0.56±0.04
Cisplatin	12.23 1.20	15.91 1.70	12.9 1.20	13.8 0.70	18.31 0.90	13.3 1.20

Souluibility of organotin(IV) compounds has always been an issue. Glucuronic acid (HGlu), mandelic acid (HMal) and gallic acid (HGal) are highly soluble in water, methanol, ethanol and other organic solvents and possess various medicinal properties. Thus Nath et al. 2014, reported few tri-phenyltin(IV) compounds (**16-18,** Figure 6) using these acids with the assumption to increase the soluibility and studied their *in vitro* cytotoxicity effect against five human cancer cell lines, viz. MCF-7 (mammary cancer), HEK-293 (kidney cancer), PC-3 (prostate cancer), HCT-15 (colon cancer) and HepG-2 (liver cancer) (Table 7). However, IC_{50} values indicated these compounds are moderately cytotoxic in nature [38].



(**17**) (**18**) (**19**) (**20**)

Figure 6: Structure of triphenyltin(IV) compounds **17**-**20**.

Table 7: IC_{50} values (mM) of compounds **16**-**18** and cisplatin on various human cancer cell lines after a 48 h incubation time.

	Cell lines				
Test Compounds	**MCF-7**	**HEK-293**	**PC-3**	**HCT-15**	**HepG-2**
Ph_3Sn(Glu) (**16**)	29.95±0.6	29.93 ± 0.8	26.66 ± 1.1	27.96 ± 0.6	28.46 ± 0.8
Ph_3Sn(Mal) (**17**)	13.36 ± 1.1	16.10 ± 0.8	17.60 ± 1.1	17.02 ± 1.1	23.83 ± 0.3
Ph_3Sn(Gal) (**18**)	9.03 ± 0.9	5.99 ± 0.7	6.45 ± 0.7	12.99 ± 0.3	18.24 ± 1.7
Cis-platin	8.97 ± 0.10	6.72 ± 0.13	5.99 ± 0.05	3.71 ± 0.05	5.97 ± 0.10
5-Fluorouracil	<0.65	1.61 ± 0.05	1.41 ± 0.05	7.17 ± 0.13	<0.65

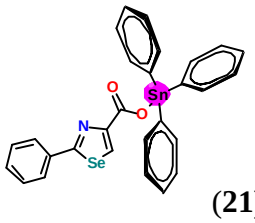
Glucuronic acid (HGlu), mandelic acid (HMal) and gallic acid (HGal)

Further, Nath et al. 2015, synthesised a tripheyltin(IV) compound (**19**, Figure 6) using hippuric acid because of its biological importance and screened for *in vitro* studies against five human tumour cell lines, viz. MCF-7 (mammary cancer), HEK-293 (kidney cancer), PC-3 (prostate cancer), HCT-15 (colon cancer), and HepG-2 (liver cancer) (Table 8). The results from this study indicated that this compound exhibits good anti-cancer activity against MCF-7, HEK-293, and PC-3 cell lines (Table 8) [39].

Table 8: Anti-cancer activity of compound **19** in various cancer cell lines at concentration 5×10^{-5} M.

	Cell lines				
Test compound	**MCF-7**	**HEK-293**	**PC-3**	**HCT-15**	**HepG-2**
19	37	37	24	01	0
Cis-platin (CPT)	60	61	63	73	63
5-Fluorouracil (5-FU)	74	70	69	65	76

Organo selenium compounds have shown great potential for applications in pharmaceutics with a high curative efficacy in cancer prevention and treatment. Based on this principle, very recently a tri-phenyltin(IV) compound (**20**) of carboxylic acid ligand containing selenium (2-thienylselenoacetic acid) was reported by Ma et al. 2016, and investigated for its *in vitro* anti-tumor activity against human cervix (HeLa) and breast cancer (MDA-MB-231) cell lines. The triphenyltin(IV) compound derived from 2-thienylselenoacetic acid exhibited excellent anti-tumour activity against the HeLa (IC_{50}: 0.03 μM) and MDA-MB-231 (IC_{50}: 0.02 μM) cell lines, respectively in comparison to cisplatin [IC_{50}: 16 μM (HeLa); 66 μM (MDA-MB-213)] [40]. In another study, a tri-phenyltin(IV) compound (**21**) was synthesised by Li et al. 2016, using 2-phenyl-4-selenazole carboxylic acid as ligand source and screened for its *in vitro* cytotoxic activity against three different cancer cell lines: human lung carcinoma cell line (A549), human colon carcinoma cell line (HCT-116/HT-29) and human colon adenocarcinoma cell line (Caco-2) (Table 9). It was observed that this compound demonstrated higher *in vitro* cytotoxic activity than cisplatin against all three cancer cell lines and one normal cell line [59].



(**21**)

Table 9: Anti-cancer activity of compound **21** in various cancer cell lines.

	Cell lines			
Test compound	**HCT-116**	**A-549**	**Caco-2**	**BRL**
21	0.08±0.02	0.29±0.16	1.42±0.61	0.15±0.07
Cisplatin	＞100 28.50±4.61	＞100 28.50±4.61	＞100 28.50±4.61	＞100 28.50±4.61

CONCLUSIONS

To summarize, we can state that tri-phenyltin (IV) carboxylate compounds exhibits promising *in vitro* antitumour activities against various human tumour cell lines and some of the compounds have demonstrated greater antitumor activity than some of the standard drugs, indicating that these compounds have

great potential for future use as medicine. Different tri-phenyltin(IV) carboxylate compounds have selectivity for different cell lines. Structural and ligand property may be responsible for this selectivity in antitumor activity against different cancer cells. And, also may be accountable for enhancing the antitumor activity of the resulting tri-phenyltin(IV) carboxylate compounds. More research work should be undertaken in this area to understand the mode of action of these tri-phenyltin(IV) carboxylate compounds with cancer cells.

ACKNOWLEDGEMENT

The financial support of the Foundation for Science and Technology (FCT), Lisbon, Portugal (Grant No. SFRH/BPD/88450/2012) is greatly appreciated for preparing this review article.

REFERENCES

1 Abu-Surrah AS, Kettunen M 2006. Platinum Group Antitumor Chemistry: Design and development of New Anticancer Drugs Complementary to Cisplatin. *Curr Med Chem.*, 13(11):1337-1357

2 Barnes KR, Lippard SJ 2004. Cisplatin and related anticancer drugs: recent advances and insights, *Met Ions Biol Syst.*, 42: 143-177

3 Cepeda V, Fuertes MA, Castilla J, Alonso C, Quevedo C, Perez JM 2007. Biochemical mechanisms of cisplatin cytotoxicity**.** *Anticancer Agents Med Chem.*, 7: 3-18

4 Yang P, Guo M 1999. Interactions of organometallic anticancer agents with nucleotides and DNA. *Coord. Chem. Rev.*, 185-186:189-211

5 Kelland L 2007. The resurgence of platinum-based cancer chemotherapy. *Nat Rev Cancer.*, 7(8):573-584

6 Jung YW, Lippard SJ 2007. Direct Cellular Responses to Platinum-Induced DNA Damage. *Chem. Rev.*, 107(5): 1387-1407

7 Boulikas T, Vougiouka M 2003. Cisplatin and platinum drugs at the molecular level. (Review). *Oncol Rep.*, 10(6):1663-1682

8 Cohen SM, Lippard SJ 2001. Cisplatin: from DNA damage to cancer chemotherapy. *Nucleic Acids Res Mol Biol.*, 67:93-130

9. Wong E, Giandomenico CM 1999. Current status of platinum-based antitumor drugs. *Chem. Rev.*, 99(9):2451-2466

10. Calvert AH, Newell DR, Tilby MJ 1995. Cisplatin Nephrotoxicity, Oxford Textbook of Oncology,

Oxford University Press, Oxford, New York, vol 1, p. 552

11. Kelland LR 1993. New platinum antitumor complexes. *Crit Rev Oncol Hematol.*, 15 (3):191-219
12. Daugaard G, Abildgaard U 1989. Cisplatin nephrotoxicity. *Cancer Chemother. Pharmacol.*, 25(1): 1-9
13. Köpf-Maier P 1994. Complexes of metals other than platinum as antitumour agents. *Eur. J. Clin. Pharmacol.*, 47(1):1-16 and references therein
14. Santini C, Pellei M, Gandin V, Porchia M, Tisato F, Marzano C 2014. Advances in Copper Complexes as Anticancer Agents. *Chem. Rev.*, 114(1):815-862
15. Kate AN, Kumbhar AA,. Khan AA, Joshi PV, Puranik VG 2014. Monitoring cellular uptake and cytotoxicity of copper(II) complex using a fluorescent anthracene thiosemicarbazone ligand. *Bioconjug Chem.*, 25(1):102-114
16. Cater MA, Pearson HB, Wolyniec K, Klaver P, Bilandzic M, Paterson BM, Bush AI, Humbert PO, Fontaine SL, Donnelly PS, Haupt Y 2013. Increasing Intracellular Bioavailable Copper Selectively Targets Prostate Cancer Cells. *ACS Chem. Biol.*, 8 (**7**):1621-1631
17. Gao E, Liu C, Zhu M, Lin H, Wu Q and Liu L 2009. Current development of Pd(II) complexes as potential antitumor agents. *Anticancer Agents Med Chem.*, 9(3):356-368
18. Tardito S, Marchio L 2009. Copper compounds in anticancer strategies. *Curr. Med. Chem.*, 16:1325-1348
19. Zhang X, Bi C, Fan Y, Cui Q, Chen D, Xiao Y, Ping Dou Q 2008. Induction of tumor cell apoptosis by taurine Schiff base copper complex is associated the with inhibition of proteasomal activity. *Int J Mol Med.*, 22(5):677-682
20. Rademaker-Lakhai JM, Van den Bongard D, Pluim D, Beijnen JH, Schellens JH 2004. A Phase I and pharmacological study with imidazolium-trans-DMSO-imidazole-tetrachlororuthenate, a novel ruthenium anticancer agent. *Clin Cancer Res.*, 10(11):3717-3727
21. Theophanides T, Anastassopoulou J 2002. Copper and carcinogenesis. *Crit Rev Oncol Hematol.*, 42 (1) : 57-64
22. Brewer GJ 2001. Copper control as an antiangiogenic anticancer

therapy: lessons from treating Wilson's disease. *Exp Biol Med (Maywood)*, 226(7):665-673

23. Barton JK 1994. Bioinorganic Chemistry, ed. Bertini I, Grey HB, Lippard SJ, Valentine JS, University Science Book, Mill Valley, p. 455
24. Shuaibu MN, Kanbara H, Yanagi T, Ichinose A, Ameh DA, Bonire JJ, Nok AJ 2003. *In vitro* trypanocidal activity of dibutyltin dichloride and its fatty acid derivatives. *Parasitology Research*, 91(1):5-11
25. Jan CR, Jiann BP, Lu YC, Chang HT, Su W, Chen WC, Yu CC, Huang JK 2002. Effect of the organotin compound triethyltin on Ca^{2+} handling in human prostate cancer cells. *Life Sci.*, 70**(**11):1337-1345
26. Samuel MP, de Vos D, Raveendra D, Sarma JARP, Roy S 2002. 3-D QSAR studies on new dibenzyltin(IV) anticancer agents by comparative molecular field analysis (CoMFA). *Bioorg Med Chem. Lett.*, 12(1):61-64
27. Jr Carraher CE, Battin A, Shahi KR, Roner MR 2007. Synthesis, Structural Characterization, and Initial Evaluation as Anticancer Drugs of Dibutyltin Polyamines Derived from Various 4,6-Diaminopyrimidines. *J Inorg Organomet Polym Mat.*, 17 (4):631-639
28. Barot G, Shahi KR, Roner MR, Jr Carraher CE 2007. Synthesis, Structural Characterization, and Ability to Inhibit Cancer Growth of a Series of Organotin Poly(ethylene glycols). *J Inorg Organomet Polym.*, 17:595-603
29. Roner M, Carraher C, Sabir T, Shahi K, Roehr J, Bassett K (2006). Anticancer and antiviral activities of organotin polyether amines derived from the antiviral acyclovir. *Polym Mater Sci Eng.*, 95:525-527
30. Carraher C, Ashida Y, Battin G (2006). Synthesis of organotin polyethers containing diethylstilbestrol. *Polym Mater Sci Eng.*, 95:556-558
31. Basu Baul TS, Paul A, Pellerito L, Scopelliti M, Singh P, Verma P, de Vos D 2010. Triphenyltin(IV) 2-[(*E*)-2-(aryl)-1-diazenyl]benzoates as anticancer drugs: synthesis, structural characterization, in vitro cytotoxicity and study of its influence towards the

mechanistic role of some key enzymes. *Investigational New Drugs*, 28(5):587-599

32. Basu Baul TS, Paul A, Pellerito L, Scopelliti M, Pellerito C, Singh P, Verma P, Duthie A, de Vos D, Verma RP, Englert U 2010. Molecular basis of the interaction of novel tributyltin(IV) 2/4-[(*E*)-2-(aryl)-1-diazenyl]benzoates endowed with an improved cytotoxic profile: Synthesis, structure, biological efficacy and QSAR studies. *J. Inorg. Biochem.*, 104(9):950-966
33. KaluðeroviæGN, Paschke R, Prashar S, Gómez-Ruiz S 2010. Synthesis, characterization and biological studies of 1-D polymeric triphenyltin(IV) carboxylates. *J. Organomet. Chem.* 695(15): 1883-1890
34. Basu Baul TS, Paul A, Pellerito L, Scopelliti M, Singh P, Verma P, de Vos D, Tiekink ERT 2011. Dibutyltin(IV) complexes containing arylazobenzoate ligands: chemistry, in vitro cytotoxic effects on human tumor cell lines and mode of interaction with some enzymes. *Investigational New Drugs*, 29(2): 285-299
35. Liu C, Li W, Du D, Zhu D, Xu L 2011. Synthesis, structural characterization and thermal stabilities of two triphenyltin (IV) carboxylates based on naphthalimide derivatives. *J. Mol. Struct.* 994 (1-3): 263-268
36. Dokorou V, Primikiri A, Kovala-Demertzi D 2011. The triphenyltin(VI) complexes of NSAIDs and derivatives. Synthesis, crystal structure and antiproliferative activity. Potent anticancer agents. *J. Inorg. Biochem.* 105(2): 195-201
37. Arshad N, Farooqi SI, Bhatti MH, Saleem S, Mirza B 2013. Electrochemical and spectroscopic investigations of carboxylic acid ligand and its triorganotin complexes for their binding with ds.DNA: In vitro biological studies. *J. Photochem. PhotoBiol. B: Biol.* 125:70-82
38. Nath M, Vats M, Roy P 2014. Design, spectral characterization, anti-tumor and anti-inflammatory activity of triorganotin(IV) hydroxycarboxylates, apoptosis inducers: In vitro assessment of induction of apoptosis by

enzyme, DNA-fragmentation, acridine orange and comet assays. *Inorg Chim Acta*, 423:70-82

39. Nath M, Vats M, Roy P 2015. Design and microwave-assisted synthesis of tri- and dialkyltin(IV) hippurates, characterization, in vitro anti-cancer and in vivo anti-inflammatory activities. *Med Chem Res.* 24:51-62
40. Zhang YY, Zhang RF, Zhang SL, Cheng S, Lia QL, Ma C-L 2016. Syntheses, structures and anti-tumor activity of four new organotin(IV) carboxylates based on2-thienylselenoacetic acid. *Dalton Trans*., 45, 8412-8421
41. Gielen M, Willem R, Biesemans M, Bouălam M, El Khloufi A, de Vos D 1992. Exceptionally high *in vitro* antitumor activity of substituted triphenyltin benzoates including salicylates against a human mammary tumor, MCF-7, and a colon carcinoma, WiDr. *Appl. Organomet. Chem.*, 6(3): 287-291
42. Kemmer M, Gielen M, Biesemans M, de Vos D, Willem R 1998. Synthesis, Characterization and *In Vitro* Antitumour Activity of Di-n-Butyl, Tri-n-Butyl and Triphenyltin 3,6-Dioxaheptanoates and 3,6,9-Trioxadecanoates. *Metal-Based Drugs*, 5(4): 189-196
43. Kemmer M, Ghys L, Gielen M, Biesemans M, Tiekink ERT, Willem R 1999. Synthesis and characterization of triphenyl-, tri-*n*-butyl and di-*n*-butyltin derivatives of 4-carboxybenzo-18-crown-6 and -15-crown-5. *J. Organomet. Chem.*, 582(2): 195-203
44. Gielen M, Lelieveld P, de Vos D, Pan H, Willem R, Biesemans M, Fiebig HH (1992). In vitro effect of organotin-substituted steroids in human tumor cell lines. *Inorg Chim Acta*, 196: 115-117
45. Bouălam M, Gielen M, El Khloufi A, de Vos D, Willem R, Novel (1993). organo-tin compounds having anti-tumour activity and anti-tumour compositions, Pharmachemie B.V., Eur Pat , Publ 538 517, Appl. 91/202, 746.3-, 22.10.91; *Chem Abstr*., 119, 117548b
46. Gielen M, Tiekink ERT (eds) (2005). Metallotherapeutic drug and metal-based diagnostic agents: ^{50}Sn Tin compounds and their therapeutic potential. Wiley, Chichester, England, pp 421-439 (and references therein)
47. Gielen M, Willem R, Dalil H, de Vos D, Kuiper CM, Peters GJ (1998). Toxicity profiles in vivo in mice and antitumour activity in

tumour-bearing mice of di- and triorganotin compounds. *Met Based Drugs*, 5: 83-90

48. Basu Baul TS, Basu S, de Vos D, Linden A (2009). Amino acetate functionalized Schiff base organotin(IV) complexes as anticancer drugs: synthesis, structural characterization, and in vitro cytotoxicity studies. *Invest New Drugs*, 27: 419-431
49. Basu Baul TS, Masharing C, Ruisi G, Jirásko R, Holčapek M, de Vos D, Wolstenholme D, Linden A (2007). Self-assembly of extended Schiff base amino acetate skeletons, 2-{[(2Z)-(3-hydroxy-1-methyl-2-butenylidene)] amino} phenylpropionate and 2-{[(*E*)-1-(2-hydroxyaryl) alkylidene] amino} phenylpropionate skeletons incorporating organotin(IV) moieties: synthesis, spectroscopic characterization, crystal structures, and in vitro cytotoxic activity. *J Organomet Chem.*, 692: 4849-4862
50. Kaluderović MR, Gómez-Ruiz S, Gallego B, Hey-Hawkins E, Paschke R, Kaluderović GN 2010. Anticancer activity of dinuclear gallium(III) carboxylate complexes. *Eur. J. Med. Chem.*, 45(2): 519-525
51. Gómez-Ruiz S, Gallego B, Žižak Ž, Hey-Hawkins E, Juranić ZD, Kaluderović N 2010. Titanium(IV) carboxylate complexes: Synthesis, structural characterization and cytotoxic activity. *Polyhedron* 29(1): 354-360
52. Du D, Jiang Z, Liu C, Sakho AM, Zhu D, Xu L 2011. Macrocyclic organotin(IV) carboxylates based on benzenedicarboxylic acid derivatives: Syntheses, crystal structures and antitumor activities. *J. Organomet. Chem.*, 696(13): 2549-2558
53. Basu Baul TS, Paul A, Pellerito L, Scopelliti M, de Vos D, Verma RP, Englert U, Duthie A 2012. An *in vitro* comparative assessment with a series of new triphenyltin(IV) 2-/4-[(*E*)-2-(aryl)-1-diazenyl]benzoates endowed with anticancer activities: Structural modifications, analysis of efficacy and cytotoxicity involving human tumor cell lines. *J. Inorg. Biochem.*, 107(1): 119-128
54. Lehninger A, Principles of Biochemistry, Worth Publishers Inc., New York, 1970. p. 661
55. Castan P, Wimmer S, Colacio-Rodriguez E, Beauchamp AL, Cros S 1990. Platinum and palladium complexes of 3-methyl

orotic acid: a route toward palladium complexes with good antitumor activity. *J. Inorg. Biochem.*, 38(1): 225-239

56. Matsumoto K 1998. Antitumor activities of platinum blues containing α-pyrrolidone, 3,3-dimethylglutarimide, orotic acid, succinamic acid and oxamic acid. *Inorg. Chim. Acta*, 151(1): 9-10
57. Nath M, Vats M, Roy P 2013. Tri- and diorganotin(IV) complexes of biologically important orotic acid: synthesis, spectroscopic studies, in vitro anti-cancer, DNA fragmentation, enzyme assays and in vivo anti-inflammatory activities. *Eur. J. Med. Chem.*, 59: 310-321
58. Camacho-Camacho C, Rojas-Oviedo I, Garza-Ortiz A, Cárdenas J, Toscano RA, Gaviño R 2013. Synthesis, structural characterization and in vitro cytotoxic activity of novel polymeric triorganotin(IV) complexes of urocanic acid. *Appl. Organometal. Chem.*, 27: 45-51
59. Hong M, Yang Y, Li C, Xu L, Li D, Li C-Z 2016. Study of the effect of molecular structure and alkyl groups bound with tin(IV) on their cytotoxicity of organotin(IV) 2-phenyl-4-selenazole carboxylates. *RSC Adv.*, 5: 102885-102894.

A Review on Green Biotechnology: An essential approach to tackle future challenges

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ABSTRACT

In this generation, considering the global challenges we are facing today, agriculture is one of the central issue. In a world where famine and diseases related to malnutrition is on high alert and is expected to increase in the future, new technological approaches have to be necessitated as unlike other natural disasters this is the one which we can prepare for and even prevent. While adopting the technique, one should keep in view the future perspective of the crises, i.e., the growing population, environmental damages and also the depletion of natural resources. Traditional techniques alone cannot fulfil the required criteria, alternative measures need to be sorted out and thus Green Biotechnology is in urgent need of action. But in order to adopt the technique, farmers play a crucial role and the awareness for the technology has to be evaluated. So this paper relates Green Biotechnology to cope up with future challenges emphasising on the applications of the techniques and the need for its adoption.

Keywords: Green Biotechnology, Micro propagation, GMO, MAS

INTRODUCTION

Green biotechnology is the discipline that uses natural phenomena and biodiversity for the enhancement of agriculture and food quality. Green Biotechnology is a rapidly expanding field within modern biotechnology and involves the exploitation of plants not only for the sustainable production of food, but also their utilisation as a source of renewable energy as a biofuel, and as a novel means to generate pharmaceuticals and other

novel products. They generate more efficient crop plants, healthy and nutritious food, and other commercially attractive products. **Green biotechnology** is focused on agriculture as working field. Green biotechnological approaches and applications include creating new plant varieties of agricultural interest, producing biofertilizers and biopesticides, using in vitro cultivation and cloning plants. It uses environmentally-friendly solutions alternative to traditional agriculture, horticulture, and animal breeding processes for selection, breeding, and management of crops for more economical production which are accounted as follows (**Vaghasiya et al. 2015)**:

- use of bacteria to facilitate the growth of plants
- development of pest-resistant grains
- engineering of plants to express pesticides tolerance/resistance
- use of bacteria to assure better crop yields instead of pesticides and herbicides
- production of superior plants by stimulating the early development of their root systems
- use of plants to remove heavy metals such as lead, nickel, or silver, which can then be extracted from the plants
- genetic manipulation to allow plant strains to be frost-resistant
- use of genes from soil bacteria to genetically alter plants to promote tolerance to fungal pathogens
- use of bacteria to get plants to grow faster, resist frost and ripen earlier.

The world population is expected to reach over 10 billion in the year 2050, while agricultural production is growing at the slower rate of about 1.8 % annually (Altman 1999). All human beings depend on agriculture that produces food of the appropriate quality at the required quantities. But the traditional agriculture faces several serious limitations such as market limitations, limitations of natural resources and inherent biological genetic limitations. Since the requirements cannot be fulfilled by traditional methods alone, breeding through Green Biotechnology is a necessity. The Green Revolution has helped immensely by increasing the wheat production 10-fold in India and several other countries, thereby feeding triple amount. But this too has its own limits,

and there is a need for alternative solutions to breed improved crops. So by adopting Green Biotechnology, we can convert it to "Evergreen Revolution". To counter balance the predicted increase in the world population in the future generation and the related implications of climate change, new technologies need to be developed to increase yields and productivity in a sustainable way, side by side lowering the demand for fertilizers and pesticides and adapting crops to compete with the changing environment. Our evolving environment requires the prompt and widespread adoption of more efficient and sustainable agriculture practices to improve food security and at the same time reduce the negative effects of intensive agriculture. So, a need for an approach to Green Biotechnology is compelling.

MAJOR CHALLENGES OF AGRICULTURE

- Population growth: More food requirements to meet the needs of the ongoing population.
- Less acreage: Shortage of arable land is a major concern in some regions.
- Less water: Limited water resource for agricultural consumption.
- Environment protection: Agriculture must contribute towards reduction of greenhouse gas emissions, by using biomass from plants for future energy production.
- Abiotic stresses: Agriculture will have to adjust to extreme weather conditions and enhance tolerance to abiotic stresses such as drought, flood, salinity, etc.
- Biotic stresses: Biotic stresses such as weeds, diseases, insects, etc. can have a huge impact on agriculture, so it should find measures to enhance tolerance to these problems.

So in order to cope up with the above challenges new technological solutions need to be employed.

THE NEED TO ADOPT GREEN BIOTECHNOLOGY

It is found that in US, organic farming is the fastest growing food trend. According to the Organic Production Survey conducted by the USDA, organic farms have lower yields than conventional farms. It is said that it takes one and a half times to two times as much land to grow organically than conventionally (Ramez 2013). In developing world which means

slashing and burning forestland into farmland, emits tremendous amount of carbon dioxide into the atmosphere ultimately leading to global warming and harming both the water cycle and species that live in forests. In order to reduce pesticides use and nitrogen runoff, if all of the world's farmland turned to organic farming, then we would need an additional 50% of farmland. Hence half of the forests will need to be chopped off from the remaining forests to grow crops and also graze cattle to meet the manures required to fertilise those crops. Chopping of forests will produce tons of carbon dioxide gases, i.e., far more greenhouse gases which is not at all a viable path. So now the question is, whether there any other alternative for growing more food on the same land with less pesticides and nitrogen runoff without chopping down the rest of the world's forests. Yes, the answer to this is Green Biotechnology as the technology could feed more people with greater nutrition, less fertilizer, less irrigation and less use of pesticides.

APPLICATIONS OF GREEN BIOTECHNOLOGY

Tissue culture and micropropagation: Tissue culture is the cultivation of plant cells, tissues or organs on specially formulated nutrient media under aseptic condition. Using the right condition, an entire plant can be regenerated from a single cell. There are different tissue culture methods which are as follows:

Anther culture, one of the tissue culture method to develop improved varieties in a short time has been employed in the successful development of doubled haploid lines of rice, wheat, sorghum, barley and other field crops. Anther culture also helps genetic improvement of scented *indica* rice by the use of androclonal variation (Roy et al. 2005)

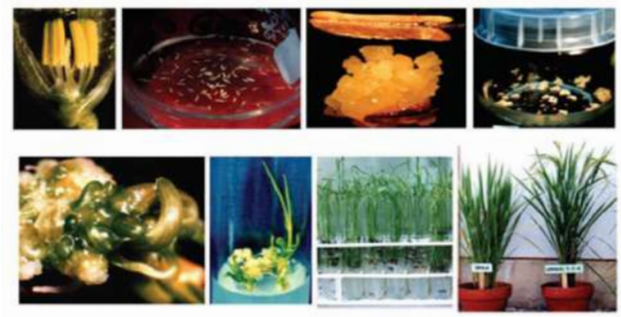

Figure 1: Anther culture of Rice (Anonymous 2014)

Embryo rescue involves the culture of immature embryos of plants in a special medium to prevent abortion of the young embryo and to support its germination. This is used routinely in breeding parental lines having different or incompatible genome such as in introducing traits of wild relatives into cultivated crops. Wild rice is a rich source of traits for resistance to pests and abiotic stresses. The development of a new rice plant type for West Africa had combined yield traits of the Asian *Oryza sativa* parent with local adaptation traits from African rice *Oryza glaberrima* (Anonymous 2014). So embryo rescue technique is utilized for the transfer of resistant gene from the wild type to the cultivated ones. This technique has significant advantages over traditional clonal propagation techniques.

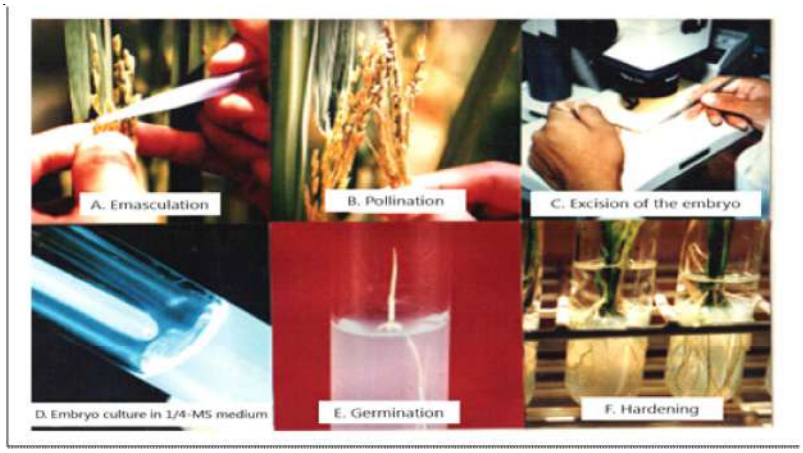

Figure 2: Embryo Rescue of Rice (Anonymous 2014)

Micropropagation, a tissue culture method developed for the production of disease-free, high quality planting material and for the rapid production of many uniform plants is now possible to provide clean and uniform planting materials, in plantations like banana, pine, date, rubber tree, etc., field crops like pineapple tomato, etc., root crops like cassava, yam, sweet potato(a low cost technique is available for this) (Ogero et al. 2012) and ornamental plants like orchids such as *Coelogyne stricta* (through pseudobulb segment culture) (Basker et al. 2006), *Dendrobium crysanthum* (Rao et al. 2014), anthuriums, gerbera (*Gerbera jamesonii*) (Bhargava et al. 2013), and *Begonia rubrovenia* var. *meisneri* which

is a rare and endemic plant of Meghalaya (Mittal et al. 2013). Many medicinal plants can be regenerated through this technique such as *Drymaria cordata* (Tejavathi et al. 2013), *Tylophora indica* (Kaur et al. 2011), *Centella asiatica* (Singh et al. 2010), various *Decalepsis* species (Sharma et al. 2014), *Saraca asoca* (Subbu et al. 2008), *Tagetes erecta* (Deka et al. 2014), and *Gaultheria fragrantissima* (Ranyaphia et al. 2011), the valuable oil yield of which is known to be higher in the north-eastern part of India. Conservation of biodiversity of these important medicinal plants of India through this technique can be seen in a review paper (Sharma et al. 2010). Many important spice crops like turmeric (*Curcuma longa*) (Mittal et al. 2013), ginger, chilli (*Capsicum annuum* L.) (Reddy et al. 2014), garlic (Taskin et al. 2013) also use this technique for improvement of the crops. This technique also offers effective strategy for rapid propagation and mass multiplication of economically important species of various *Dendrocalamus* species (Singh et al. 2014) (Kapruwan et al. 2014) keeping in view of their sustainable development and utilization. Plant which is critically endangered to Meghalaya, *Ilex khasiana* (Dang et al. 2011) and the only pitcher plant in India which is available only in the state of Meghalaya, *Nepenthes khasiana* (Anonymous 2001) also use this technique for its mass multiplication including a giant fern, *Cyathea gigantean* (Das et al. 2013) one of the endangered plant available in the North-Eastern states. Most of the plants mentioned above are endangered and important, so by the adoption of this technique it can be of much achievement. Micropropagated plants are found to establish more quickly, grow more vigorously and taller, have a shorter and more uniform production cycle and produce higher yields than conventional propagules.

Molecular Breeding and Marker-Assisted Selection: For identification of specific genes, a short segment of nucleotide sequence known as molecular markers are used. The markers are located near the DNA sequence of the desired gene. Hence a map of the markers and genes on specific chromosomes can be created by identifying the location of the gene with the help of the marker. This genetic linkage map shows the location of markers and genes and their distance from other known genes. Using a very detailed genetic maps and better knowledge of the genetic structure of a

plant's DNA, researchers can analyse a tiny bit of tissue from a newly germinated seedling and hence can concentrate only on a specific trait. Currently this technique is already in use for crops where gene and the markers for a specific trait are known. It is being used in the efficient introgression of important genes into rice such as bacterial blight resistance, increased beta carotene content, submergence tolerance, etc. There are already more than 2200 simple microsatellite repeats identified for rice. Molecular markers are also used to determine the genetic profile of a line of variety. The information on genetic diversity of the lines is utilized in selecting for extremely unrelated parents useful for hybrid seed technology and also provides details on the parentage of the line, the possible traits and the unique identity of the plant useful for germplasm collection database. This technique has been used for genetic diversity analysis in many plants like soybean (Ghosh et al. 2014), cucurbit species and many more using different markers like SSRs and RAPDs and thus can be utilized for widening the genetic base. Diversity among coconut plants can also be analysed through SCoT marker analysis (Rajesh et al. 2015).

Genetic Engineering and Genetically Modified (GM) Crops: Genetic engineering is the process by which the genetic make-up of an organism can be altered using recombinant DNA technology. The ability to manipulate individual genes and to transfer genes between species that would not readily interbreed is what distinguishes genetic engineering from traditional plant breeding. In contrast to conventional breeding, genetic engineering allows the direct transfer of one or just few genes between either closely related or distantly related organisms.

When to use Genetic Engineering: This technique is only used when all other techniques have been exhausted and when: (Anonymous 2014) 1) the trait to be introduced is not present in the germplasm of the crop; 2) the trait is very difficult to improve by conventional breeding methods; and 3) it will take very long time to introduce or improve such trait in the crop by conventional breeding methods. The length of time in developing transgenic plant depends upon the gene, crop species, available resources and regulatory approval (Choudhary et al. 2014). It varies from 6 to 15 years before a new transgenic plant or hybrid is ready for commercial release. There has been a

consistent increase in the global area planted to transgenic or GM crops or biotech crops from 1996 up to the present. ISAAA's Annual Global Status Report downloadable at the ISAAA website: http://www.isaaa.org presents an up-to-date record of the number of countries planting GM crops, the hectarage planted, the benefits derived from the biotech crops, farmer accounts of planting biotech crops as well as future prospects and directions of the technology. Transgenic crops which are planted commercially are herbicide tolerant soybean, maize, canola, cotton; insect resistant maize and cotton; and virus resistant squash and papaya: in India BT cotton being the only commercially available crop. With the help of genetic engineering, more than one trait can be incorporated into the plant known as stacked trait, such as both insect resistant and herbicide tolerant in combination in corn and cotton crops that are available commercially. Biofertilizers, biopesticides and many biocontrol agents can be introduced by genetic engineering. *Burkholderia cepacia* (Devi et al. 2012), a naturally occurring rhizobacter found in North-East India can be used as a biocontrol agent for the control of many diseases such as wilt and damping off diseases in French beans. *Burkholderia cepacia* has also been reported to promote growth of maize, enhance crop yield and degrade diverse pesticides. *Withania somnifera* (Thilip et al. 2015), an important medicinal plant which yield pharmaceutically active compounds called withanolides can be genetically modified by agrobacterium mediated transformation through sonication and heat treatment for hairy root induction as the hairy root has the ability to synthesize withaferine A and withanolide A, both steroidal lactones of medicinal value. It is found that it is possible to produce transgenic crops which are substantially equivalent to the controlled non-transformed lines (Baudo et al. 2006). There are various future initiatives in genetic engineering which will make more direct contributions to food quality, clean environment, pharmaceutical production and livestock feeds. GM seed tend to be more expensive, but in return it reduces expenses in other areas, such as the cost of pesticides, machines and labour. But above all: yields generally increase considerably because plants' own mechanism protect them from harmful insects and more effective weed management reduces harvest losses which used to be considered inevitable. Farmers have widely adopted GM technology. Between 1996 and 2011, the total surface

area of land cultivated with GM crops had increased by a factor of 94, from1700 sq. kms. (4200000 acres) to 1600000km^2 (395 million acres (160 million hectares) in 29 countries including India. For more researches on GM crops one can also refer to the book of 'A decade of EU-funded GMO research (2001-2010)' (Anonymous 2010).

The above techniques can also be used in combination, as in case of genetic improvement of ginger (Suma et al. 2008), *Dichanthium annulatum* (Vaghasiya et al. 2015), and many other crops as well.

Production of Green Energy: Adoption of biofuels like bioethanol from food crops, biomass and lignocellulosic materials and biodiesel from used vegetable oils and animal fats, and biogas which is generated by fermentation of plant and animal waste is very good source for energy production to combat green house gas emission and environmental pollution which otherwise with other traditional energy products like fossil fuels is damaging to the environment and destined to unavoidable depletion. The first generation biofuels were made from edible sugars and starches which has its limitations such as competition for land and water for food and fibre with increasing demand for animal feeds while the next generation or second and third generation biofuels are being developed from non-edible lignocellulosic materials (Mittal et al. 2013) (Asgher et al. 2014) that include woody biomass and wood wastes, crop residues, switch grass, municipal wastes and algae which do not compete directly with food production and can often be produced on marginal or unused croplands. Plant microbe interactions can also be a promising strategy for bioenergy crop production as these crops are not utilized for human consumption, it is ideal for developing and evaluating novel technologies and applications. Lands unfit for food production can be made into use and planted with low input perennial crops capable of producing high biomass yields annually and these energy crops inoculated with beneficial endophytes can also be employed to phytoremediate land for future crop production. Although these bioenergies can not be a replacement but it can surely supplement our use. The Indian Railways has started to use the oil from the Jatropha plant to power its diesel engines with great success, currently diesel locomotives running fromThanjavur to Nagore section and Tiruchirapalli to Lalgudi, Dendigul and Karur sections (Anonymous 2012).

Numerous researches have been conducted on the field of Biotechnology which can also be referred in Annual Report of Indian Agricultural Research Institute, New Delhi, Biotechnology and Management of Bioresources Division, TERI, New Delhi and many more.

ROLE OF GREEN BIOTECHNOLOGY TO FIGHT AND ADAPT TO CLIMATE CHANGE

Changing meteorological conditions associated with climate change will definitely have an impact on agriculture yields. Green Biotechnology offers a toolbox which can help farmers produce food sustainably through green house gas emission reduction, crop adaptation, crop protection and increased yield from less available arable land.

- Green house gas reduction: Agricultural practices such as deforestation, cattle feedlots and fertilizer use contribute to green house gas emissions. So green biotechnology can help farmers to produce food sustainably through less fuel consumption on farms through a reduced need to spray crops, carbon sequestration and reduced fertilizer use and nitrous oxide emissions. Crops developed with green biotechnology like GM herbicide tolerant and GM insect resistant crops reduce the need for tillage or ploughing allowing farmers to adopt conservation or "no-till" farming practices and less pesticide spraying. This results in less fuel use and less CO_2 emissions. The development of crops that use nitrogen efficiently which requires less nitrogen fertilizer also helps in reduction of NO_2 emissions.
- Crop adaptation: Green Biotechnology can play a vital role in improving yields by using water more sustainably, thus helping to cope with water scarcity which works in two ways, i.e. by reducing water loss and by improving drought tolerance. Water loss can be reduced by developing practices to reduce the amount of ploughing before planting the crops which means the soil surface is not inverted and hence traps the soil moisture. Drought tolerance can be improved by using drought tolerant crops.

- Protected and increased yield with less surfaces: Crops adopted by Green Biotechnology helps farmers to increase yield while also using fewer precious natural resources and being more resistant to pests and disease that are likely to spread in today's changing climate.

CONCLUSION

Green Biotechnology as we can see is changing the plant scene in three major areas, i.e., growth and development control (vegetative, generative and propagation); protecting plants against the ever-increasing threats of biotic and abiotic stress; and expanding the horizons by producing specialty foods, bio chemicals and pharmaceuticals (Altman 1999). To cope up with the problems that we are facing today and the future days to come, it is the need of an hour to adopt Green Biotechnology and find measures to fight with it. The challenges are mainly linked to climate change, food safety and security, limited fossil fuel resources, an ageing population and the fight against diseases, poverty and social exclusion. Crop production will have to cope with rapidly increasing demand while ensuring environmental sustainability. Preservation of natural resources and the need to support livelihood of the farmers and the rural populations around the world are major concerns. Food that are tolerant to different climatic changes, food with higher yield, disease resistant, and development of alternative renewable resources that are environmental friendly, (some of which are just a waste and regarded as unwanted materials can therefore be a useful one) should be the main focus of today's research activities which I must say can be achieved through Green Biotechnology. In India biotech applications to agriculture is still in the nascent stage and its benefits have not reached the majority of the population. Why is it so? The main reason behind this is the lack of awareness among the people. So there should be more of awareness programmes regarding this field. For an agricultural country like India, the adoption of an agriculture technology needs to be done carefully, keeping in mind the interest of farmers. Regarding the 'for' or 'against' the technique, one should be fully aware of the pros and cons and should look into both sides of it scientifically. First of all one should be able to differentiate between a fact and a myth appropriately. Scientific evaluation is the basis of every approval decision and scientific, technical and other information

should be provided to the public promptly and appropriately. People should consider the dimensions of risks and benefits separately. We should make use of the application of all available technologies without prejudice, while respecting fundamental safety and ethical principles. However only a structured dialogue with policy makers, stakeholders and the public based on sound science and empirical evidence will clear the way for a balanced assessments of the benefits and risks of biotechnology. It is necessary to promote awareness and educate the local inhabitants as of the important indigenous crops available in the region and importance towards the conservation strategy and the techniques need to be adopted to combat the crises we are going to face in the near future.

Agricultural scenario of the North-East region is still not encouraging. The region still practices the age old shifting (jhum) cultivation which has many disadvantages and the region, once richly endowed with rich genetic diversity of plants, has been denuded due to human interference by adoption of unscientific land use system. With rapid increase in human and livestock population and the rising demand of food, feed, fuel, fodder, fibre, timber and the other developmental activities, the farmers have been forced to exploit forestland and water resources at sub-optimal level in complete defiance of the inherent potential. This has resulted in progressive decrease in forest cover, loss of biodiversity, serious soil erosion leading to depletion of plant nutrients, gradual degradation and decline in land productivity and its carrying capacity, silting of major river basin causing recurrent floods in the plains, and drying up of perennial steams as well as ecological imbalances. Gradual degradation of these resources is of prime concern and calls for location-specific measure to conserve, utilise and manage these resources for optimising production on sustained basis without adversely affecting its quality. The scientific goal for biotechnology and world agriculture is the improvement of the genetics of our crops. Since the economy of the country is agriculture based with majority of the population being agricultural dependent, it is an alarming situation we need to deal with “GREEN BIOTECHNOLOGY”.

REFERENCES

Altman A 1999. Plant biotechnology in the 21st century: the challenges ahead: Review. *EJB Electronic Journal of Biotechnology*. 2(2): 51-55

Anonymous 2010. A decade of EU-funded GMO research (2001-2010). *European Commission Directorate-General for Research and Innovation Biotechnologies, Agriculture*, Food, Publications Office of the European Union, pp 264

Asgher M, Bashir F, Iqbal HNM 2014. A comprehensive ligninolytic pre-treatment approachfrom lignocellulose green biotechnology to produce bio-ethanol. *Chemical Engineering Research and Design*. 92(8): 1571-1578

Basker S, Bai VN 2006. Micropropagation of *Coelogyne stricta* (D.Don) Schltr. Via Pseudobulb Segment Cultures. *Tropical and Subtropical Agroecosystems*. 6: 31-35.

Baudo MM, Lyons R, Powers S, Pastori GM, Edwards KJ, Holdsworth MJ, Shewry PR 2006. Transgenesis has less impact on the transcriptome of wheat grain than conventional breeding. *Plant Biotechnology Journal*. 4: 369–380

Bhargava B, Dilta BS, Gupta YC, Dhiman SR, Modgil M 2013. Studies on micropropagation of gerbera (*Gerbera jamesonii* Bolus). *Indian Journal of Applied Research*. 3: 8-11

Choudhary B, Gheysen G, Buysse J, Meer M, Burssens S 2014. Regulatory options for genetically modified crops in India: Review. *Plant Biotechnology Journal*. 12: 135 146

Dang JC, Kumaria S, Kumar S, Tandon P 2011 Micropropagation of *Ilex khasiana*, a critically endangered and endemic holly of Northeast India. *AoB Plants*. 1: 1-7

Das S, Choudhary MD, Mazumder PB 2013. Invitro Propagation of *Cyathea gigantean* (wall ex. Hook) - A Tree Fern. *International Journal of Recent Scientific Research*. 4 (3): 221-224.

Deka B, Arjuna A 2014. Effect of Plant Growth Regulators on in vitro propagation of *Tagetes erecta* Linn: Review. *Indian Journal of Basic and Applied Medical Research*. 3(4): 15-23

Devi SI, Somkuwar B, Potshangbam M, Talukdar NC 2012. Genetic characterization of *Burkholderia cepacia* strain from Northeast

India: A potential bio-control agent. *Advances in Bioscience and Biotechnology*. 3: 1179-1188

Ghosh J, Ghosh PD, Choudhury PR 2014. An Assessment of Genetic Relatedness between Soybean [*Glycine max* (L.) Merrill] Cultivars Using SSR Markers. *American Journal of Plant Sciences*. 5: 3089-3096

Gomathy V, Anbazhagan M, Arumugam K 2014. *In vitro* propagation of *Curcuma longa* (Turmeric). *International Journal of Research in Plant Science*. 4(1): 30-33

http://www.isaaa.org/. Agricultural Biotechnology (A Lot More than Just GM Crops) 2014, Retrieved on 20 October 2016

Kaur H, Anand M, Goyal D 2011. Establishment of an efficient protocol for micropropagation of stem explants of *Tylophora indica*, an important medicinal plant. *African Journal of Biotechnology*. 10(36): 6928-6932

Kumar J, Shukla SM, Bhat V, Gupta S, Gupta MG 2005. In Vitro Plant Regeneration and Genetic Transformation of *Dichanthium annulatum*. *DNA and Cell Biology*. 24: 670 679

Kumaria S, Kehie M, Shekhar S, Das M, Singh M, Tandon P 2012. Invitro regeneration of *Begonia rubrovenia* var. *meisneri* C.B. Clarke- A rare and endemic ornamental plant of Meghalaya, India. *Indian Journal of Biotechnology*. 11: 300-303

Martinez VD 2010. The Colours of Biotechnology. https://biotechspain.com/en/article.cfm?iid=colores_biotecnologia. Accessed July 7, 2015.

Mittal A, Decker SR 2013. Special issue: Application of biotechnology for biofuels:transforming biomass to biofuels. *Biotech*. 3: 341–343

Ogero KO, Mburugu GN, Mwangi M, Ngugi MM, Ombori O 2012. Low Cost Tissue Culture Technology in the Regeneration of Sweet Potato (*Ipomoea batatas* (L) Lam). *Research Journal of Biology*. 2(2): 51-58

Rajesh MK, Sabana AA, Rachana KE, Rahman S, Jerard BA, Karun A 2015. Geneticrelationship and diversity among coconut (*Cocos nucifera* L.) accessions revealed through SCoT analysis. *Biotech*. 3:304

Ramez N 2013. Greener than green: Biotech and the future of agriculture (Part I) http://

www.geneticliteracyproject.org/2013/04/22/greener-than-green-biotech-and the future-of-agriculture/. Accessed July 2, 2015

Ranyaphia RA, Maoa AA, Borthakurb SK 2011. Direct organogenesis from leaf and internode explants of in vitro raised wintergreen plant (*Gaultheria fragrantissima*). *Science Asia.* 37: 186–194

Rao S, Barman B 2014. *In Vitro* Micropropagation of *Dendrobium chrysanthum* Wall. Ex Lindl. –A Threatened Orchid. *Scholars Academic Journal of Biosciences*. 2(1): 39-42

Reddy MK, Srivastava A, Kumar S, Kumar R, Chawda N, Ebert AW, Vishwakarma M 2014. Chilli (*Capsicum annuum* L.) Breeding In India: An Overview. *Sabrao Journal of Breeding and Genetics*. 46 (2):160-173

Roy B, Mandal B 2005. Anther culture response in *indica* rice and variations in majoragronomic characters among the androclones of a scented cultivar, Karnal local. *African Journal of Biotechnology*. 4 (3): 235-240

Sharma S, Rathi N, Kamal B, Pundir D, Kaur B, Arya S 2010. Conservation of biodiversityof highly important medicinal plants of India through tissue culture technology- a review. *Agriculture and Biology Journal of North America.* 1(15): 827-833

Sharma S, Shahzad A 2014. An overview on Decalepsis: A Genus of Woody Medicinal Climbers. *Journal of Plant Science and Research*. 1(1): 104

Shatakshi Kapruwan, Meena Bakshi and Manpreet Kaur 2014. Effect of growth regulators on the *in vitro* multiplication of *Dendrocalamus Hamiltonii. International Journal of Engineering Research and Applications*. 4, (11): 83-86

Singh M, Jaiswal VS, Jaiswal U 2014. Thidiazuron-Induced Anatomical Changes and Direct Shoot Morphogenesis In *Dendrocalamus strictus* nees. *Canadian Journal of Pure and Applied Sciences*. 8(2): 2901-2904

Singh S, Gautam A, Sharma A, Batra A 2010. *Centella asiatica* (L.): A Plant with Immense Medicinal Potential but Threatened. *International Journal of*

Pharmaceutical Sciences Review and Research. 4: 9-17

Subbu RR, Chandraprabha A, Sevugaperumal R 2008. Invitro Clonal propagation of vulnerable medicinal plant, *Saraca asoca* (Roxb.) De Wilde. *Natural Product Radiance*. 7(4): 338-341

Suma B, Keshavachandran R, Nybe EV 2008. *Agrobacterium tumefaciens* mediatedtransformation and regeneration of ginger (*Zingiber officinale* Rosc.). *Journal of Tropical Agriculture*. 46 (1-2): 38-44.

Taskin H, Baktemur G, Kurul M, Buyukalaca S 2013. Use of Tissue Culture Techniques for Producing Virus-Free Plant in Garlic and Their Identification through Real-Time PCR. *The Scientific World Journal*. 3: 1-5

Tejavathi DH, Indira MN 2013. Regeneration of Shoots from Leaf Callus Cultures of *Drymaria cordata* (l) willd ex Roem and Schult. *Indian Journal of Fundamental and Applied Life Sciences*. 3(1): 111-115

Thilip C, Raju CS, Varutharaju K, Aslam A, Shajahan AA 2015. Improved *Agrobacteriumrhizogenes*-mediated hairy root culture system of *Withania somnifera* (L.) Dunal using sonication and heat treatment. *Biotech*. 3: 297

Vaghasiya KK, Shiroya AJ 2015. A Review Green biotechnology - a help to the environment. http://www.pharmatutor.org/articles/review-green-biotechnology-help environment. Accessed July 2, 2015.

RESEARCH PAPER

3D Nanostructures: Smart materials for energy harvesting applications

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ABSTRACT

Nanostructures for different tunable 3D properties of homojunction, heterojunction and interface electronic alignment provides specific system for application in energy conversion and storage devices. In comparisons to 0D nanoparticles, 1D nanowires, 3D nanostructures are more productive as they provide high surface to volume ratio, structural hierarchy & direct electron transport route. Therefore 3D nanostructures are in focus of recent research for energy harvesting materials. There are number of ways to harvest energy in form of photovoltaics, photocatalysis, photoelectrochemical (PEC) water splitting for hydrogen generation, supercapacitors and Li ion batteries. In this short review, the synthesis of a wide variety of 3D nanostructures is summarized. The methods cover vapour phase, solution phase, chemical route and their combinations. As the main part of this review, the most up-to-date results on the energy applications of 3D nanostructure mainly focused on photovoltaics application and the benefits of the 3D nanostructures have been discussed.

Keywords: - 3D nanostructures, photovoltaics, energy harvesting, photoelectrochemical

INTRODUCTION

Energy and environmental issues are two major areas in this 21st century to keep the current life and earth sustainable. With global awareness towards the crisis of conventional fossil fuels and their injurious impact on environment, the search for clean and renewable alternative energy solutions has motivated worldwide

attention [1]. Low cost and environment friendly energy sources is one of the most important research area due to increase in pollution and depletion of conventional energy sources. Solar energy, as the clean, greener and unlimited energy source holds the great potential to meet our future energy demand. In this regard, photovoltaics and photocatalysis water splitting are two promising ways towards efficient solar energy utilization [2-4]. In addition to energy generation, with the increasing power consumption, development of advanced energy storage devices such as supercapacitors and batteries are also important for storage of the alternative energy resources. Among the various clean sources of energy, sunlight is the most important as it can fulfil all the requirements of energy needs due to abundant and environment friendly. From last two decades, nanostructured materials have attended a worldwide interest due to their fascinating mechanical, electrical and optical properties capable by dimension confinement of such materials and combination of bulk & surface properties for overall achievements. [5,6] Fig. 1 shows the schematic diagram of energy harvesting and its way of storage in different forms.3D nanostructure improve the light absorption due to enhanced optical path as well as additional light trapping through reduced reflection and multi-scattering in comparison to 1D nanowire arrays, which are beneficial to solar energy harvesting application. The bottom up approach includes vapour phase and solution based routes for variety of 3D nanostructures for solar cell application.

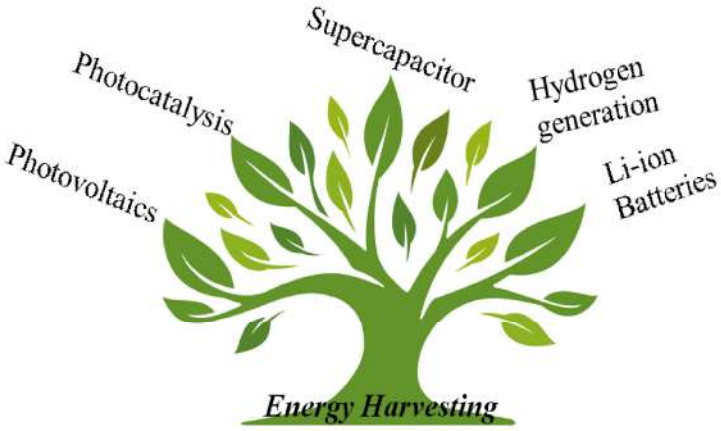

Fig. 1: Schematic diagram of energy harvesting

Solution growth including hydrothermal, solvothermal, chemical bath deposition, electro deposition, SILAR method, simple solution and wet chemical process etc. have been widely employed for growth of 3D nanostructures on substrate. Among different approach for synthesis & fabrication of 3D nanostructures the chemical route is best suitable techniques for growth of good morphology. The growth of 3D nanostructures for photovoltaic devices has been tabulated in Table -1.

Table-1

S. No.	Method	Materials	Advantages	Application	Ref.
1	Phase transition induced branching	CdTe, CdS	Metal catalyst free, high yield, low cost	Solar cells, photocatalyst	7,8
2	Hydrothermal Route	TiO_2	Cost effective and lower temperature	Dye sensitized solar cells (DSSC)	9
3	Chemical Vapour Deposition (CVD)	CdS/ CdTe	Low cost on flexible substrate	Solar cells	10
4	Spray deposition	TiO_2/$CuInS_2$	Low cost	Photovoltaics cells	11
5	Solution processed	Cu_2ZnSnS_4	Earth abundant materials, Non toxic	Photovoltaics cells	12
6	Solution processed	$AgBiS_2$	Low temperature	Photovoltaics cells	13
7	Dip Coating	ZnO	Low cost, Non toxic	DSSC	14
8	Hydrothermal	TiO_2	Low cost, high efficiency	Quantum dot sensitized solar cells	15

The technology for the conversion of solar to electrical energy is called photo-voltaic and thus the solar cells can be termed as photovoltaic devices or it harvests the sunlight directly into electricity which is effective way to approach for clean & sustainable energy supply. Solar cells technologies divided in three generation (1) first generation based on crystalline Si (b) second generation based on amorphous and hybrid Si (c) third generation based on wide band gap metal oxide semiconductors prepared through simple cost effective chemical route. All the various generation solar cells are associated with their own advantages & disadvantages.

The 3D branched nanostructures having large surface areas and additional light trapping effect by light multi-scattering as well as reduced carrier diffusion paths are

believed beneficial to photovoltaic devices. In this section, the recent advance in the application of 3D nanostructures in exciton solar cells are highlighted, including dye sensitized solar cells (DSSC), polymer/inorganic hybrid devices and quantum dots (QDs) sensitized solar cells.

Dye sensitized solar cells

Dye sensitized solar cells in which dye molecular absorbed onto nanostructured semiconductors like TiO_2 or ZnO for light harvesting is the type of most investigated exciton cells [16]. Cheng et al. fabricated branched ZnO nanowires with a two-step hydrothermal route for DSSCs application [17]. The optimized *J*sc and efficiency were 8.78 mA/cm^2 and 2.63%, respectively, nearly five times higher than that of free upstanding ZnO nanowires. The increased surface area enabling for more dye loading, and light harvesting as well as reduced electron—hole recombination through direct conduction path along the ZnO branches arebelieved to account for the efficiency enhancement. Similarly TiO_2 branched nanotrees were also demonstrated for DSSC with improved performance. Improved light harvesting effect has also been demonstrated using optical fibres. The Wang group designed a novel 3D photoanode with optical fibre as backbone to guide and confine the light, and ZnO nanowire branches as the photoactive component for dye loading. This smart design allows remote input of sunlight and more efficient light absorption in the working region.

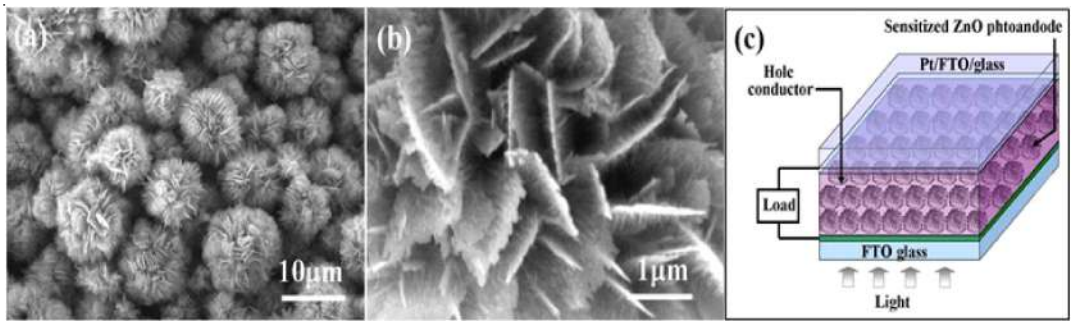

Fig. 2: 3D nanostructures beautifully arranged for solar device [Ref. 18]

Polymer Inorganic Hybrid Solar Cells

Another type of exciton cells is polymer – inorganic hybrid solar cells, in which inorganic crystals serve as the electron acceptor and conjugate polymer as electron donor, and both components contribute to light absorption. For this device 3D nanostructures are proven superior to both nanorods and quantum dots when mixed with polymers. It provides high organic inorganic contact interface area short diffusion length for exciton dissociation and direct pathway for charge transportation and collection. Polymer inorganic hybrid solar cells show a great pathway towards cheap and benign PV devices. Chemical modification is a great prospect to enhance its hybrid solar cell efficiency and improvement 3D nanostructures are of great importance due to higher surface to volume ratio.

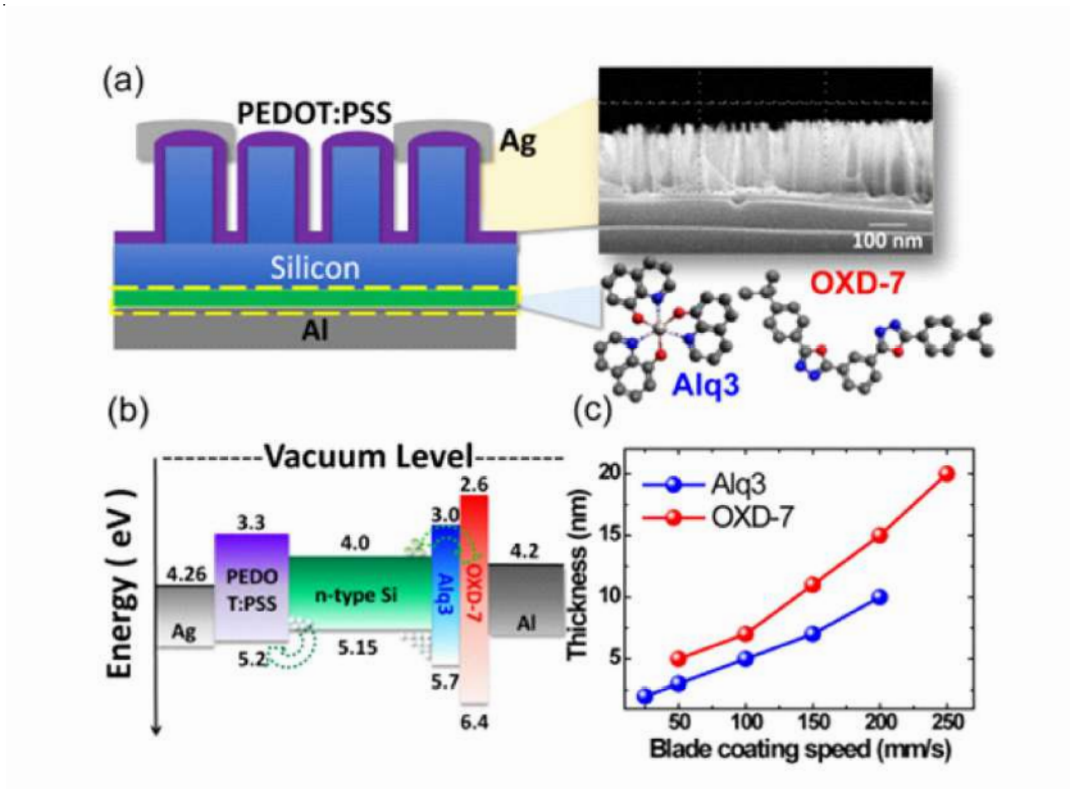

Fig. 3: Polymer – inorganic hybrid solar cells having 3D nanostructures in PV devices [Ref. 19]

Quantum dot solar cells

In this type of solar cells QDs replace the dye molecular for light harvesting due to some unique physical properties and general efficiency than DSSC. The bandgap of QDs can be easily tuned by their sizes enabling wavelength selective light absorption. Semiconductor QDs have higher extinction coefficient than dye molecule. Compared to the widely applied QDs, nanorod-shaped photosensitizers are believed more interesting for sensitized solar cells [20]. The length variation in one-dimensional rods brings in advantages in solar cell performance as compared to just diameter control in zero-dimensional QDs. These advantages include a higher loading of sensitizers due to increased surface area, easier electron—hole charge separation due to more favourable energy band alignment between nanorod/TiO_2 and thus efficient electron injections, and lastly, a larger optical absorption cross section. Research on this particular direction just is started but will most likely progress fast.

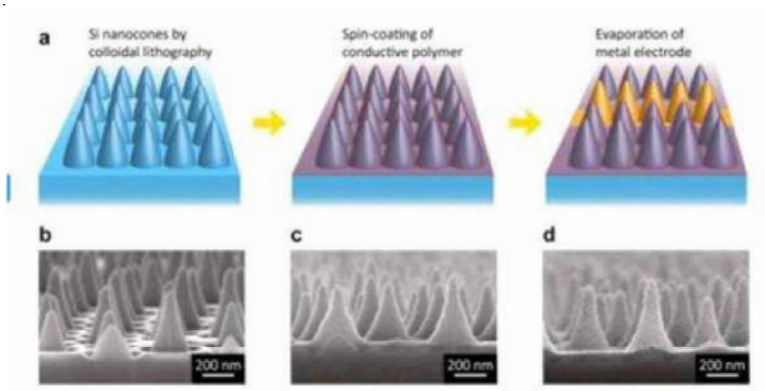

Fig. 4: 3D nanostructures for quantum dot solar cells [Ref. 20]

CONCLUSION

In this short review application of the 3D nanostructures in the emerging energy conversion by photovoltaics device has been highlighted. The potential energy applications of 3D nanostructures are not only limited on these photovoltaics instead of its application in other forms such as fuel cells, thermoelectric devices, piezoelectric devices are also being explored. By using 3D nanostructures to harvest various type of ambient power like thermal, wind, vibration and

electromagnetic energy would also be very much promising which provides a potentially endless source of energy.

Fabrication and application of 3D nanostructures have hanging on far behind. Further development in this research field requires improvement in synthetic methods and novel fabrication processes to provide better control of the structural complexity, composition uniformity, surface chemistry and interface electronics etc. However during fabrication of 3D nanostructures some hazardous and toxic source has been used so for the benign and environmental friendly synthesis method is required to be more focused. The main aim is to focus the energy device towards practical application which needs the development of devices with high efficiency low cost and long durability with great life span. Thus the optimization of 3D nanostructures and the improvement of the energy conversion efficiency will remain the future scope of research in photovoltaics application.

REFERENCES

1. Tarascon J M, Armand M 2001. Issues and challenges facing rechargeable lithium batteries. *Nature* 414(6861): 359–367
2. Walter MG, Warren EL, Mc Kone JR, Boettcher SW, Mi Q, Santori EA, Lewis NS 2010. Solar Water Splitting Cells, *Chem. Rev.* 110(11): 6446–6473
3. Chen X, Mao SS 2007. Titanium Dioxide Nanomaterials: Synthesis, Properties, Modifications, and Applications. *Chem. Rev.* 107 (7): 2891–2959
4. Cheng C, Karuturi SK, Liu L, Liu J, Li H, Su LT, Tok AIY, Fan HJ 2012. Quantum-Dot-Sensitized TiO_2 Inverse Opals for Photoelectrochemical Hydrogen Generation, *Small* 8(1): 37–42
5. Hu JT, Odom TW, Lieber CM 1999. Chemistry and Physics in One Dimension:Synthesis and Properties of Nanowires and Nanotubes. *Acc. Chem. Res.* 32(5): 435-445
6. Xia YN, Yang PD, Sun YG, Wu YY, Mayers B, Gates B, Yin YD, Kim F, Yan YQ 2003. One-Dimensional Nanostructures: Synthesis, Characterization, and Applications. *Adv. Mater*. 15 (5): 353-389
7. Manna L, Scher EC, Alivisatos AP 2000. Synthesis of Soluble and Processable Rod-, Arrow-,

Teardrop-, and Tetrapod-Shaped CdSe Nanocrystals. *J. Am. Chem. Soc*. 122(51): 12700-12706

8. Manna L, Milliron DJ, Meisel A, Scher EC, Alivisatos AP 2003. Controlled growth of tetrapod-branched inorganic nanocrystals. *Nat. Mater*. 2: 382-385
9. Sun Z, Kim J, Zhao Y, Attard DJ, Dou SX 2013. Morphology-controllable 1D–3D nanostructured TiO_2 bilayer photoanodes for dye-sensitized solar cells. *Chemical Communications*. 49 (10): 966-968
10. Fan Z et al. 2009. Three-dimensional nanopillar-array photovoltaics on low-cost and flexible substrates, *Nat. Mater*. 8(8): 648–653
11. Nanu M, Schoonman J, Goossens A 2005. Nanocomposite three-dimensional solar cells obtained by chemical spray deposition. *Nano Letters*. 5(9): 1716–1719
12. Bernechea M et al. 2016. Solution-processed solar cells based on environmentally friendly $AgBiS_2$ nanocrystals. *Nature Photonics*. 10: 521–525
13. Ming-Yang Hsieh et al 2016, Realizing omnidirectional light harvesting by employing hierarchical architecture for dye sensitized solar cells. *Nanoscale*. 8: 5478-5487
14. Buatong N, I-Ming Tang, Pon-On W 2015. Quantum dot-sensitized solar cells having 3D-TiO_2 flower-like structures on the surface of titania nanorods with CuS counter electrode. *Nanoscale Research Letters* 10: 146
15. Zhou S, Liu X, Lin Y, Wang D, Angew 2008. Spontaneous Growth of Highly Conductive Two-Dimensional SingleCrystalline $TiSi_2$ Nanonets. *Chem. Int. Ed*. 47: 7681-7684
16. Cheng HM, Chiu WH, Lee CH, Tsai SY, Hsieh WF 2008. Formation of Branched ZnO Nanowires from Solvothermal Method and Dye-Sensitized Solar Cells Applications. *J. Phys. Chem*. C 112 (42): 16359-16364
17. Yantao Shi et al 2012. Optimizing nanosheet-based ZnO hierarchical structure through ultrasonic-assisted precipitation for remarkable photovoltaic enhancement in quasi-solid dye-sensitized solar cells. J. Materials Chemistry 22(26): 13097-13103

18. Yi-Chun Lai et al. 2016. Rear interface engineering of hybrid organic-silicon nanowire solar cells via blade coating. *Optics Express*. 24 (2): A414-A423
19. Salant A, Shalom M, Tachan Z, Buchbut S, Zaban A, Banin U 2012. Quantum Rod-Sensitized Solar Cell: Nanocrystal Shape Effect on the Photovoltaic Properties. *Nano Lett*. 12 (4): 2095-2100
20. Jeong, et al. 2012. Hybrid Silicon Nanocone–Polymer Solar Cells. *Nano Lett.* 12 (6): 2971–2976.

Identification of fungal pathogens associated with *Solanum tuberosum* L. of South West Garo Hills

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ABSTRACT

Fungal pathogens associated with Solanum tuberosum L. were investigated for a period of one year from October 2014-March 2015 for one crop cycle in Sonamite village under South West Garo Hills District of Meghalaya. A total of 5 fungal pathogens with 80 numbers were isolated and identified from different parts of potato. Higher number of pathogens isolated was from the leaves and the least from roots. Rhizoctonia solani has the highest frequency of occurrence followed by Phytophthora infestans, Sclerotium rolfsii, Alternaria alternata and Fusarium solani.

***Keywords*- Isolation, fungal pathogens, *Solanum tuberosum* L and potato**

INTRODUCTION

Potatoes are widely cultivated and contribute to reduce worldwide food shortages. However, potato plants are susceptible to devastation by various diseases, such as black scurf caused by *Rhizoctonia solani* and dry rot caused by *Fusarium sambucinum* (Agrios, 1997). Black scurf and dry rot diseases have limiting effects on tuber yield. In the same time, *R. solani* infected plantlets may develop crown rot, root rot, or stem canker which often leads to wilting and plant death in the severe cases. Similarly, *Fusarium* dry rot of seed tubers can reduce establishment by killing the developing potato sprouts. Also, both diseases can greatly affect tuber quality, and, therefore, can severely reduce its market value (Grosch *et al.*, 2005).Diseases are one of the most important causes of yield and tuber quality losses in potato production worldwide (Hooker 1981).

In the recent years, an environmentally friendly and sustainable alternative to protect plants against soil borne pathogens is the biological control using antagonistic microorganisms as bioagents (Weller *et al.*, 2002;Grosch *et al*., 2005;). Several researchers have already proved fungal microorganisms to suppress diseases caused by *R. solani* (Lewis and Larkin, 1998; Ahmed *et al*., 2012 and Van den Boogert and Luttikholt,2004). Additionally, antagonistic plant-associated microbes are another important group of beneficial microorganisms for the control of soil-borne plant pathogens (Mao *et. al.*, 1997; Weller *et al*., 2002; Grosch *et al*., 2005). The present study was carried out to isolate and identify fungal pathogens associated with potato in order to employ adequate control measures especially biological measures which are safe and environmentally friendly such as the use of microorganisms that are parasites or antagonistic to the pathogens.

MATERIALS AND METHODS

The present investigation was carried out in South West Garo Hills district of Meghalaya for a period of one year from October 2014-March 2015 for one crop cycle. The potato plants were cut with the help of a sterile digger and brought to the laboratory and placed in sterilized plastic bags and stored at 40ºC until isolation. The fungal pathogens were isolated in Potato Dextrose Agar (PDA) media from the various parts of potato plant such as leaves, stem, roots and tubers by the method of **Suryanarayanan *et.al*. (2003)**.The identification of fungal pathogens was based on the fungal colonies or hyphae, the characteristics of the spores' structures by using standard manuals (**Barnett and Hunter, 1972**, **Domsch *et.al.* 1980).** The pure cultures of the isolates were maintained in Czapex Dox Agar (CDA) media at 4ºC till further used.

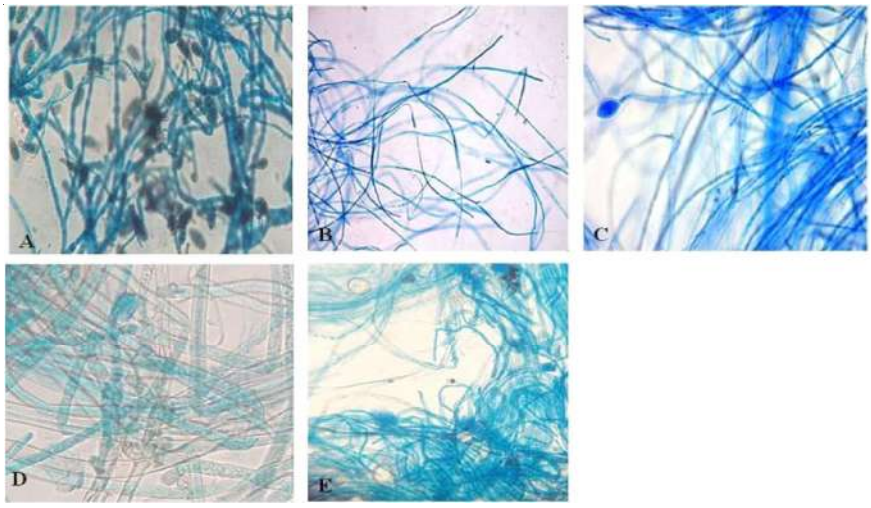
RESULTS AND DISCUSSION

A total of 5 fungal pathogens were isolated with 80 numbers of isolates from different parts of potato plant (Table 1). The highest occurrence of pathogens were observed in leaves (11), followed by tubers (10), stem (7) and the least in roots (2). The pathogens identified were *Alternaria alternata, Fusarium solani, Phytophthora infestans,Rhizoctonia solani* and *Sclerotium rolfsii*. It was observed that *R. solani* showed maximum occurrence with 26 isolates followed by *P. infestans* with 25 isolates, *S. rolfsii* with 12 isolates, *A. alternata* with 9 isolates and *F. solani* showed minimum occurrence of 8 isolates (Figure1).

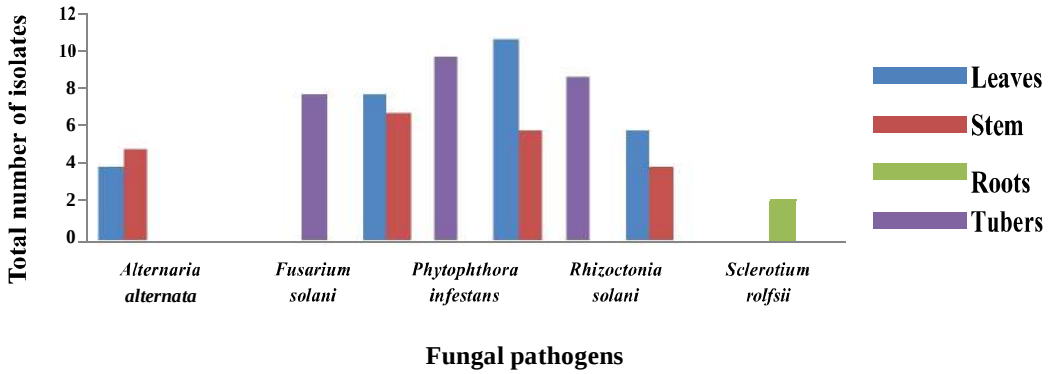
Many fungi are quiescent phytopathogens which may cause infectious symptoms when the host plant is aged and/or stressed. On the other hand, during the long co-evolution of the phytopathogen and its host plant, an endophytic mutant may result from the balanced antagonism and/or gene mutation. The key research areas that arise as a means of better controlling most of these pathogens are the role of intra-specific variation in pathogenesis and ecology, problems of detecting and quantifying inoculums, and the need for improved methods for biological control.

"Table1. Fungal pathogens isolated from different plant parts of Solanum tuberosum L."

Fungal pathogens	Plant parts used				
	Leaves	Stem	Roots	Tubers	Total
A. alternata	04	05	-	-	09
F. solani	-	-	-	08	08
P. infestans	08	07	-	10	25
R. solani	11	06	-	09	26
S. rolfsii	06	04	02	-	12
Total number of fungal pathogens isolated=5	Total number of isolates from different parts of the potato plant=80				



"Figure 1.Fungal pathogens isolated from different parts of potato plant"
A) A.alternata B) F.solani C) P.infestans D) R.solani E) S.rolfsii



"Figure2. Graphical representation showing the number of fungal pathogens isolated and identified from different parts of the potato plant"

CONCLUSION

The maximum occurrence of fungal pathogens in different parts of potato could be attributed to their ability to produce numerous spores and are affected during the production cycle. Agronomic factors including rotation, planting material, cultivar selection, irrigation, pesticide application, crop residues have profound influence on the incidence and severity of diseases.

ACKNOWLEDGEMENT

The support by the UGC Non-Net fellowship, Government of India is gratefully acknowledged. Appreciation is also expressed to the people of Sonamite village for extending help and assistance in the field work.

REFERENCES

Ahmed M, Hussain MD, Kaul S 2012. Isolation of microbial endophytes from some ethnomedicinal plants of Jammu and Kashmir. *Journal of Natural Product and Plant Resources*.2 (2):215-220

Barnett HL, Hunter BB 1972. Burgess Publishing Company. *Illustrated genera of Imperfect Fungi*. Third edition

Domsch KH, Gams W, Anderson TH 1980. *Compendium of soil fungi*. Academic Press

Grosch R, Faltin F, Lottmann J, Kofoet A, Berg G 2005. Effectiveness of 3 antagonistic bacterial isolates to control Rhizoctonia solani Kuhn on lettuce and potato. *Canadian Journal of Microbiology*. 51: 345-353

Hooker WJ 1981.Compendium of Potato Diseases. *American Phytopathological Society*. St. Paul, Minnesota

Lewis JA, Larkin RP. 1998. Formulation of the biocontrol fungus Cladorrhiunum foecundissimum to reduce damping-off diseases caused by Rhizoctonia solani and Pythium ultimum. *Biological Control*. 12: 182-190

Mao W, Lewis JA, Herbber PK, Lumsden RD 1997. Seed treatment with a fungal or a bacterial antagonist for reducing corn damping-off caused by species of Pythium and Fusarium. *Plant Disease*. 81: 450-454

Suryanarayanan TS, Venkatesan G, Murali TS 2012. *Journal of Natural Product and Plant Resources*.2 (2):215-220

Van den Boogert PHJF, Luttikholt, AJG 2004. Compatible biological and chemical control system for Rhizoctonia solani in potato. *European Journal of Plant Pathology*.110: 111-118

Weller DM, Raaijmakers JM, Gardener BBM, Thomashow LS 2002. Microbial populations responsible for specific soil suppressiveness to plant pathogens. *Annual Review of Phytopathology*.40:309–348.

Structure and Function of Algal Assemblages in the Streams of Jaintia Hills District, Meghalaya.

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ABSTRACT

Biodiversity has a low threshold of response to stress, whereas biomass and function are stable or increase under low to moderate stress and decrease only under high stress. Acid mine drainage is causing a major damage to different aquatic system, its flora and fauna in Jaintia Hills district of Meghalaya where "rat hole" method of coal mining has been accomplished for a long time. For the present study, Water parameter analysis showed significant differences in between unimpacted and impacted streams. In unimpacted stream, pH was 6.8 nearing neutral with high dissolved oxygen (11.2mg/l), low level of sulphate (0.16mg/l) iron (0.28ppm), manganese (0.05ppm), lead (0.01ppm) and zinc (0.02ppm) whereas in coal mine areas pH was low, varied from 2.9-4.06 with low dissolved oxygen (1.70-5.32mg/l) and high level of sulphate (51.94-69.43mg/l).we examined the impact of AMD on biomass and productivity of dominant algae in field condition seasonally. Periphytonic algal assemblages attached to different substrates and benthic algal assemblages from sediments were collected from four selected streams of the said area. Periphytonic algal samples were mainly composed of Microspora quadrata and Klebosormedium acidophilum. It contributed almost 98-100% of the algal biomass measured by quadrat method.Other benthic taxa found in the sediments were few diatoms like Navicula cryptocephala , Frustulia rhomboids, pinnularia viridis etc. High biomass (222gm/m^2) was obtained from the mat during spring due to luxuriant growth during that period and biomass was low (50gm/m^2) due to poor growth during monsoon. Chlorophyll a content was maximum in winter and minimum

in monsoon. One way analysis of variance between Periphytonic algal communities showed significant difference between various sites and seasons during the entire study. Two way analysis of variance between benthic algal communities also showed significant difference between various sites and seasons. Analysis of variance between productivity (chlorophyll a content) in periphytonic algal communities, benthic algal communities with different physico-chemical characteristics showed significant differences between various sites and seasons. Mixed metals and productivity showed significant positive relationship in all AMD impacted streams at 0.001 levels which showed with increasing metal content, productivity of the AMD streams increased. In this study, it showed that impacted streams increased their biomass with few tolerant species growing in abundance.

Keywords: Microspora quadrata, chlorophyll, biomass, Jaintia hills, mining

INTRODUCTION

Space and time interact to shape lotic communities, on a continuum from short-term local scales, to evolutionary-global scales (Minshal, 1988). Temporal change affects both the taxonomic composition (Oemke and Burton, 1986), and biomass (Sherwood and Sheath, 1999), of stream periphyton and benthic communities. Most aquatic systems' primary productivity is based solely on measurements of macrophytes and biomass production. Coal is the most exploited mineral of Jaintia hills district of Meghalaya. Most of the water bodies in those areas are affected by "*rat hole*" mining method of active mining and huge storage of coal which has lead to a variety of environmental impacts and a drastic loss in biodiversity (Banks *et al*., 1997). The rivers, streams and springs of this region are mostly characterized by low pH, high conductivity, high concentration of sulphates, iron and many toxic heavy metals, low dissolved oxygen and high BOD (Singh, 2005; Das and Ramanujam, 2011). All these parameters describe the degradation of water quality and weaken the life-supporting function of the water.

In any acid mine drainage (AMD) systems, communities are restricted to few tolerant organisms with their different functional aspects. Disappearance of many sensitive species was compensated by tolerant Periphytonic and benthic algal species which dominate the AMD systems

by increasing their productivity and biomass. These dominant species according to their altered and adverse physico- chemical conditions of the surrounding vary structurally and functionally. Algal communities respond to environmental stressors and may be structured by a combination of pH (Kinross *et al*., 1993) and metal oxide deposition (Niyogi *et al*., 1999) which possibly could decrease algal diversity, biomass and function. Many algal studies in AMD systems have concentrated or have focussed on ecosystem functioning and biomass (Niyogi *et al*., 2002) rather than diversity and composition (Neil *et al.,*2009).

Effects of stress from AMD on ecosystem functions, including primary production, decomposition and nutrient cycling had been studied Howarth (1991). Odum (1985) suggested that ecosystem functions would be stouter to change than diversity or other structural measures in ecosystems under stress. Niyogi *et al., (*2002) proposed a hypothesis where that relates biodiversity, community biomass, and ecosystem function to a gradient of stress. According to this hypothesis, biodiversity has a low threshold of response to stress, whereas biomass and function are stable or increase under low to moderate stress and decrease only under high stress. This hypothesis was tested by examining communities of primary producers in streams under stress from mine drainage in the Rocky Mountains of Colorado, USA.

For the present study, we examined the impact of AMD on biomass and productivity of algal assemblages in gradient of stress in AMD impacted region of Jaintia hills district of Meghalaya.

MATERIALS AND METHODS

A. Present study area

To study the impact of coal mining on productivity and biomass production of dominant algae of the area, four streams were selected for the study in Jaintia hills district of Meghalaya which represents different status of mining effect namely,

1. Stream located in Ummulong far from coal mining areas in Jaintia hills district of Meghalaya and not affected by mining lying between 25^0 31’ 21.06"N to 092^0 08’15.89"E. (referred as unimpacted). Depth: 10-100cm; Width: 2.0-5.0 m.

2. Stream located in Wapung abandoned site (left abandoned for 5-7 years after active coal mining) lying between 25^0 24’30.72"N to 092^0 18’56.46" E.

(Referred as abandoned). Depth: 5.0-15 cm; Width: 2.0-5.0 m.

3. Stream located in Khliehriat receiving wastes from active coal mining areas lying between 25^0 22'27.72"N to 092^0 23'22.86" E. (Referred as active coal mine). Depth: 4.0- 12 cm; Width: 2.0-6.0m.

4. Stream located in Ladrymbai receiving acid water through seepage from huge coal storage (mined coal is stored in on the road side for transportation to different places) lying between 25^0 23'16.26"N to 092^0 19'28.26" E.(Referred as coal storage).Depth: 10- 20 cm; Width: 4.0-5.0m.

B. Water sampling and analysis

Samplings were carried out at all selected sites in the first week of every month from April 2010 to March 2012. Five replicates of surface water samples were collected in 1 liter polyethylene bottles kept in ice and were brought to the laboratory for further analysis. In situ, parameters like Temperature, pH, Dissolved Oxygen (DO), Conductivity and Turbidity were recorded using Deluxe Soil and Water analysis Kit (**Model-191E).** Other water quality parameters which were analysed in the laboratory included Free CO_2, Chloride, Total hardness, Nitrate-Nitrogen (NO_3-N), Nitrite-Nitrogen (NO_2-N), Soluble reactive Phosphorus (SRP), Sulphate (SO_4^{2-}) and Silica (SiO_2). Standard procedures were followed for water samples collection and water sample analysis (APHA, 2005).

C. Estimation of chlorophyll *a* content

Periphytonic algal assemblages attached to different substrates and benthic algal assemblages from sediments were collected from all four streams. For Chlorophyll estimation, samples were collected from 1 sq cm area from different points in a stream and kept in 10ml of 90% acetone and brought to the laboratory in packed ice bags. For extraction of chlorophyll, samples were refrigerated for 24 hours and centrifuged in 3000 rpm for three times. The absorbance of supernatant was measured at different wavelengths (630, 647 and 660nm) using Perkin Elmer Spectrophotometer. The amount of chlorophyll-*a* was calculated following the method given by Strickland and Parsons, 1972.

Chlorophyll *a* (mg/l) =11.85 (OD_{664})-1.54 (OD_{647})-0.08 (OD_{630})

D. Estimation of Biomass production from mat

Five replicate algal mat samples were collected from each site. 5% of the algal sample was preserved in 4% formalin for identification of the species composing the mat. The remaining algal samples were rinsed three times with distilled water to remove the debris. For biomass content, mat samples were collected from AMD streams and was harvested from 50 sq cm area from 5 points in a stream, cleaned thoroughly to remove other taxa attached with the filaments dried at 105ºC for 24 h and weighed.

Analysis of variance (Single factor ANOVA) was calculated for different seasons and sites at 0.05 levels. Relationships between chlorophyll *a* content with different metals were examined by linear regression analysis using XLSTAT 2015.Metals like iron, zinc, lead, managanese etc were examined from different streams using Atomic absorption spectroscopy (Perkin Elmer).

RESULTS

A. Physico-chemical characteristics of stream water

Temperature is one of the most important factors, which influence the development of aquatic micro organisms. Water temperature showed a sharp seasonal fluctuation. In SI (unimpacted stream) average temperature ranged from 18.31 to 18.72ºC, In SII (abandoned mining site) temperature ranged from 20.01 to 23.76ºC. In SIII (Active mining site) and SIV (Coal storage mining site) water temperature ranged from 21.18 to 27.10ºC and 0.01 to 28.0ºC respectively. Water temperature during winter was minimum in SI (18.31ºC) compared to all AMD streams where it was significantly higher than in unimpacted stream .pH, a very important parameter to judge the status of water showed highly acidic water in coal mine impacted streams .PH ranged from 2.88 to 4.28 in coal mine impacted streams whereas in unimpacted stream pH ranged from 6.02 to 6.69. In mining areas, minimum pH was recorded from SIII (active mining stream) i.e. 2.88 during spring followed by SII (abandoned mining stream) where pH was noted to be 3.13. Maximum pH was recorded from SIV (coal storage site) during monsoon. i.e. 4.28 among the impacted streams. In unimpacted stream, maximum pH was recorded during monsoon (6.69) and minimum during spring (6.02). Analysis of variance showed significant variations in pH (p>0.05) between SI and other

three coal mine impacted streams, although there was no clear trend of seasonal variation in water pH in the four study sites.Water conductivity showed higher values in mine impacted streams and ranged from 954.35 µS/cm in SIII during spring to 233.0 µS/cm in SII during monsoon. In SI, conductivity ranged from 79.94 µS/cm during autumn to 19.87 µS/cm during monsoon. Conductivity was high in stream near active mining area (SIII) throughout the study period. Significant temporal and spatial variations at 0.05 level was observed between different sites and seasons. In general, dissolved oxygen was low in coal mine impacted steams than the unimpacted stream in all sampling seasons. Dissolved oxygen ranged from 5.72 to 13.53 mg/l and maximum was recorded during monsoon. In AMD streams, dissolved oxygen ranged from 2.85 to 7.26 mg/l. Very low dissolved oxygen was recorded from active (2.85mg/l) and abandoned (2.89mg/l) coal mining impacted streams during spring. In coal storage impacted stream, dissolved oxygen (3.15mg/l) was recorded during spring. Among the three AMD streams, active mining impacted stream showed the lowest Dissolved oxygen content. Significant temporal and spatial variation at 0.05 levels .Turbidity was higher in AMD streams as compared to unimpacted stream. In unimpacted stream, maximum turbidity was found during winter (4.21NTU) and minimum during monsoon (0.73 NTU). In AMD streams, maximum was recorded during spring (10.77NTU) and minimum during monsoon (1.16NTU). When compared among the AMD streams, in active mining impacted streams, turbidity was maximum throughout the study period .Significant temporal and spatial variation at 0.05 levels was observed between different sites and seasons Silica content was high in in SII (33.07mg/l) and SIII (28.47mg/l) respectively compared to other two sites i.e. SI (3.5mg/l) and SIV (5.74mg/l). High silica content was recorded during winter in SI, SII and SIII. In SIV, silica content was maximum in spring and minimum in monsoon in all the four streams. Significant temporal and spatial variation at 0.05 levels was observed between different sites and seasons. Significant seasonal differences in sulphate content was observed during the study. Chloride ranged from 20.91 to 44.31 mg/l in SI. In other three sites, chloride ranged from 53.63 to 237.58 mg/l. It was maximum in SIV in winter compared to other three streams. Significant temporal and spatial variation at 0.05 levels was observed

between different sites and seasons. Hardness varied from 3.96 mg/l during monsoon to 34.29 mg/l during spring in SI. In AMD streams, hardness varied from 8.86 to 84.87 mg/l, maximum being in spring in SIII and minimum in monsoon. Significant variations in between sites and seasons (p<0.05) were observed during the study period .Maximum sulphate was recorded in SIII (188.12mg/l) during spring and minimum during monsoon (65.67mg/l).sulphate content was also high in other two mine impacted streams. In SIV, 101.23mg/l of sulphate was recorded in spring followed by SII where it ranged from 45.92 to 81.77 mg/l. In unimpacted stream, SI Sulphate content was comparatively lower than impacted ones. It was maximum during winter i.e. 1.12mg/l and minimum during monsoon i.e. 4.60mg/l .Nitrate content in general was low and did not show any specific pattern during the study in four sites. Highest nitrate content was recorded in SI during autumn (0.72mg/l) and the lowest during monsoon (0.16mg/l). From other three coal mine impacted sites, nitrate was maximum during autumn. 0.72mg/l in SII, 0.80 mg/l in SIII and 0.87 mg/l in SIV. Nitrate content was minimum in winter. Significant differences in nitrogen content were observed in different seasons and sites. No particular pattern could be observed throughout the study. Maximum nitrite content was recorded in SIV (0.15mg/l) during spring whereas in SI, SII and SIII it was maximum in autumn. Minimum nitrite content was recorded during monsoon (0.01mg/l) in SIV. Nitrite content varied significantly between seasons but no significant differences was observed between sites .Maximum phosphate was recorded in SI during spring (1.25mg/l) and minimum in monsoon (0.33mg/l) from SI. Other three sites also showed the same trend where phosphate content was maximum in spring ranged from 0.90 to 1.20mg/l and minimum in winter (0.18-0.19mg/l). Among AMD impacted sites, SII showed maximum amount of phosphate content .Phosphate content varied significantly between sites and seasons. (Table 1). Analysis of variance to show significant difference between sites and different seasons were given in Table 2.

B. Productivity of the streams

Productivity of the streams was measured by measuring Chlorophyll *a* content of different algal groups. In SI, chlorophyll *a* content of the Periphytonic algae ranged from 898.30, to 998.30 during spring,

359.84 to 459.84 during monsoon, 705.23 to 805.23 during autumn and 876.7454 to 976.74 mg/m^2 during winter. In SII, chlorophyll *a* content of the Periphytonic algae ranged from 923.46 to 1523.46 during spring, 177.52 to 277.51 during monsoon, 990.06 to 1077.06 during autumn and 1066.61 to 1466.61 mg/m^2 during winter. In SIII, chlorophyll *a* content of the Periphytonic algae ranged from 848.31 to 1348.31 during spring, 487.15 to 587.15 during monsoon, 800.47 to 1098.47 during autumn and 966.65 to 1166.65 mg/m^2 during winter. In SIV, chlorophyll *a* content of the Periphytonic algae ranged from 662.35 to 762.35 during spring, 590.29 to 690.29 during monsoon, and 882.66 to 882.66 during autumn and 900.98 to 984.98 during winter (Fig. 1).

Benthic algal communities in SI showed 100.42 to 106.96 mg/m^2 of chlorophyll a content during spring, 67.41 to 80.97 mg/m^2 of chlorophyll a content during monsoon, 77.74 to 287.53 mg/m^2 of chlorophyll a content during autumn and 100.42 to 121.6 mg/m^2 of chlorophyll *a* content during winter. In SII, it ranged from 50.22 to 99.05 during spring, 43.06 to 44.59 during monsoon, 87.46 to 113.22 during autumn and 100.42 to 154.20 during winter mg/cm^2. In SIII Benthic algal communities showed chlorophyll *a* content of 43.61 to 94.54 mg/cm^2 during spring, 27.86 to 30.52 mg/cm^2 during monsoon, 60.84 to 91.86 mg/cm^2 during autumn and 67.48 to 129.79 mg/cm^2 during winter. In SIV, it ranged from 120.30 to 124.90 mg/cm^2 during spring, 41.47 to, 89.92 mg/cm^2 during monsoon, 48.56 to 118.88 mg/cm^2 during autumn and 74.60 to, 147.33 mg/cm^2 during winter (Fig. 2).

One way analysis of variance between Periphytonic algal communities showed significant difference between various sites and seasons during the entire study (Table 3).Two way analysis of variance between benthic algal communities also showed significant difference between various sites and seasons (Table 4). Mixed metals and productivity showed significant positive relationship in all AMD impacted streams at 0.001 levels which showed with increasing metal content, productivity of the AMD streams increased (Fig 3).

Analysis of variance between productivity (chlorophyll *a* content) in periphytonic algal communities and in benthic algal communities showed significant differences between various sites and seasons. Significant positive correlation

was also observed with N: P ratio, at SI (p=0.000; r^2=0.48), SII (p= 0.002; r^2 =0.19) and SIV (p<0.0001; r^2=0.11). PH, showed significant negative correlation in SII (p< 0.0001; r^2= -0.30) and positive correlation in SIII (p=0.000; r^2=0.25) (Fig 4). Productivity was positively correlated with some other important environmental variables like chloride, dissolved oxygen, silicate, turbidity, total nitrogen, total phosphorus in SI, with conductivity, turbidity and silica in SII, with turbidity and silica in SIII and with conductivity, silica and turbidity in SIV (Table 5). Benthic communities also showed significant difference between sites and seasons. Correlation between benthic productivity and different parameters showed significant correlation with total nitrogen, silica, turbidity in SI, pH, current velocity, conductivity, total phosphorus, turbidity, silica in SII, pH, current velocity, conductivity, total phosphorus, N:P ratio, turbidity in SIII and total nitrogen, total phosphorus, dissolved oxygen, silica in SIV (Table 6).

C. Composition of the mat

Mat samples were mainly composed of *Microspora quadrata* . It contributed almost 98-100% of the algal biomass measured by quadrat method (Fig 5). Another filamentous green alga, a species of *Klebosormedium acidophilum* was also found attached to the mat in small proportion .Other taxa found in the mats were few diatoms like *Navicula cryptocephala, Frustulia rhomboides* etc.

D. Qualitative analysis of the algal mat

The mat started growing after monsoon from the month of September and attained its maximum growth during spring. Mat found in every site is dark green in colour except in SIII where (active mining site) it was little light green to brownish colour during spring. Filaments are long jointed (1-2m) and attached to rock substratum (Fig 6). Slimy layer is present on the upper surface of the filament. The mat covered the whole stream bed and the water body looked greenish in colour.

E. Seasonal variations in biomass content of the mat

Biomass content of the mat ranged from 137.52 to 205.81gm/m^2 during spring which was considered to be the season for highest biomass contribution from mat. Biomass content of the mat from other seasons ranged from 36.68 to 62.31 gm/m^2 during monsoon, 105.56 to 116.68gm/^{2} during autumn and 122.36 to 146.44 gm/m^2 during winter. Among the sites, SII

added the maximum biomass content (Fig 7). Single factor ANOVA confirmed significant variation between different AMD sites and different seasons during the tenure of the study (Table 7). In this study, it showed that impacted streams increased their biomass with few tolerant species growing in abundanc.

DISCUSSION

Appearance of dominant stress tolerant algae like *Microspora quadrata* and *Klebosormedium acidophilum* in coal mine impacted streams of Jaintia hills were also reported by Das and Ramanujam (2011). Many algal studies in AMD systems have concentrated on the most severely affected systems (Brake *et al*., 2001; Sabater *et al*., 2003) or have focussed on ecosystem functioning and biomass (Niyogi *et al*., 2002) rather than diversity and composition.

The algal productivity in the studied streams followed a seasonal pattern i.e. higher productivity in winter and spring seasons and low in monsoon season. This trend had also been observed and reported by many authors from tropical streams (Borduqui *et al.*, 2008). Seasonal variations in algal productivity i.e., high productivity in winter and spring could thus be related to the abundant growth of filamentous green algae during that period where the current velocity was least (Biggs *et al.*, 2005). AMD impacted streams were very productive and showed higher concentration of chlorophyll *a* by increasing their biomass. Phosphorus loading to these streams (above 1mg/l) could increase the biomass of periphyton, macro algae as measured by chlorophyll *a* (Welch *et al*., 1998). Low pH and conductivity in AMD were also some important factors responsible for enhanced productivity (Pena and Barreiro 2009).

In this study, numerous taxa have been shown to be tolerant of conditions within AMD waterways, even at the most highly acidic sites (DeNicola, 2000; Sabater *et al*., 2003; Novis and Harding, 2007). *Microspora quadrata*, the most dominant alga which formed the main component of the mat in this study was also observed in huge abundance in AMD streams of New Zealand (Bray 2007).

Algal biomass was significantly greater in the AMD impacted, low pH streams, which is in accordance with several studies (Verb and Vis, 2001; Sabater *et al*., 2003) but not others (Kinross *et al*., 1993). Verb and Vis, (2005) found an inverse relationship

between biomass and dominance of diatom and macro algal communities in AMD. They suggested that where diatoms dominate, low biomass may be expected, but where other algae dominate, high biomass may be expected. However, in this study, in spite the presence of huge biomass, few tolerant diatoms species were also recorded in huge density which contradicts the mentioned study. Several factors may account for high algal biomass in many low pH streams. Tolerant species may be stimulated where physicochemical conditions such as pH are optimised for that particular species (Novis, 2006). Alternatively, other taxa may be limited by the extreme physicochemical conditions, releasing tolerant species from interspecific competition (Niyogi *et al*., 1999). Furthermore, physicochemical conditions often exclude grazers, thus releasing algae from any top-down control that might normally be occurring (Rosemond *et al*., 1993; Niyogi *et al*., 2002). Other factors such as light, physical disturbance, nutrient concentrations and substrate suitability are also important factors influencing biomass growth and productivity (Dodds, 2007). Season also played an important role in significant biomass variation within sites (Bray, 2008). A hypothesis has been proposed and tested to account for the effects of stress in aquatic ecosystems on diversity, biomass and function of algal communities (Niyogi *et al*., 2002). The hypothesis suggested that biodiversity is very sensitive to change, while biomass and function (where function includes primary production, decomposition and nutrient cycling) may increase under low and moderate levels of stress only decreasing their response at much higher levels. The present study was in accordance with the mentioned hypothesis where biomass increased due to low and moderate stress in AMD streams of the region.

CONCLUSION

Despite the complex pattern of polluted environments generated by the combination of these various agents of stress, periphyton and benthic algal communities grow abundantly and produce huge biomass. High productivity showed different structural and functional attributes of algal assemblages when exposed to stresses environment. *Microspora quadrata and Klebosormedium acidophilum* filament showed better growth in acidic environment which showed the acidophilic nature of the alga and tolerance of the alga in extreme condition. As those algae grow

luxuriantly in coal mining impacted streams, could be suggested as a useful plant material to remove toxic metals from AMD impacted streams of Jaintia hills district.

REFFERENCES

Banks D, Younger PL, Arnesen RT, Iverson ER and Banks SB 1997. Mine water chemistry: the good, the bad and the ugly. *Environmental Geology*. 32:157-174.

Biggs BJF, Nikora VI, Snelder TH 2005.Linking scales of flow variability to lotic ecosystem structure and function: *River Research and Applications*. 21:283–298

Borduqui M, Ferragut C, Bicudo CEM 2008. Chemical composition and taxonomic structure vertical and seasonal variation of periphyton community in a shallow eutrophic reservoir (Garças Reservoir, Sao Paulo). *Acta Limnologica Brasilensia*.20: 381-399

Brake SS, Dannelly HK, Connors KA 2001. Controls on the nature and distribution of an alga in coal mine-waste environments and its potential impact on water quality. *Environmental Geology*. 40:458-469

Bray JP 2007. The ecology of algal assemblages across a gradient of acid mine drainage stress on the West Coast, South Island, New Zealand. M.Sc.Thesis, University of Canterbury, Christchurch.

Das M, Ramanujam P 2011. Metal Content in Water and in Green Filamentous Algae *Microspora quadrata* Hazen from Coal Mine Impacted Streams of Jaintia Hills District, Meghalaya, India. *International Journal of Botany*. 7: 170-176

Dodds WK, Welch EB 2000. Establishing nutrient criteria in streams. *Journal of the North American Benthological Society*. 19: 186-196

Howarth RW 1991. Comparative responses of aquatic ecosystems to toxic chemical stress. In: Cole, J., Lovett, G., Findlay, S., editors. *Comparative analysis of ecosystems*. New York: Springer-Verlag. Pp. 169–95

Kinross JH, Christofi PA, Read PA, Harriman R 1993. Filamentous algal communities related to pH in streams in The Trossachs, Scotland. *Freshwater Biology*. 30: 301-317

Minshall GW 1988. Stream ecosystem theory: a global perspective. *Journal*

of the North American Benthological Society 288.7:263

Neil LC, McCullough CD, Lund MA ,Tsvetnenko Y, Evans L 2009.Toxicity assessment of acid mine drainage pit lake water remediated with limestone and phosphorus. *Ecotoxicological Environmental Safety*. 72: 2046–2057

Niyogi DK, Lewis WM, Jr McKnight DM 2002. Effects of stress from mine drainage on diversity, biomass, and function of primary producers in mountain streams. *Ecosystems*. 5: 554-567

Niyogi DK, McKnight DM, Lewis WM Jr 1999. Influences of water and substrate quality for periphyton in a montane stream affected by acid mine drainage. *Limnology and Oceanography*. 44: 804-809

Niyogi DK, Lewis WM, McKnight DM 2001. Litter breakdown in mountain streams affected by mine drainage: biotic mediation of abiotic controls. *Ecological Applications*. 11: 506-516

Niyogi DK, William ML, Diane M, McKnight M*K Y*, Hassan KY 2002. Effects of Stress from Mine Drainage on Diversity, Biomass, and Function of Primary Producers in Mountain Streams. *Ecosystems*. 5: 554–567

Novis PM, Harding JS 2007. Extreme acidophiles: freshwater algae associated with acid mine drainage. In: *Algae and Cyanobacteria in Extreme Environments* (Eds.), Seckbach J., editor. Heidelberg, Germany: Springer. 443 –463

Novis PM 2006. Taxonomy of Klebsormidium (Klebsormidiales, Charophyceae) in New Zealand streams and the significance of low-pH habitats. *Phycologia*. 45(3): 293-301

Odum EP 1985. Trends expected in stressed ecosystems. *Bio-Science*. 35:419–22

Oemke MP, Burton TM 1986. Diatom colonization dynamics in a lotic system.

Pena SD, Barreiro R 2009. Biomonitoring acidic drainage impact in a complex setting using periphyton. DOI 10.1007/s10661-008-0235-4.*Limnologyand Oceanography*. 40: 938-946

Rosemond AD, Mulholland PJ, Elwood JW 1993. Top-down and bottom-up control of stream periphyton: effects of nutrients and herbivores. *Ecology*. 74: 1264-1280

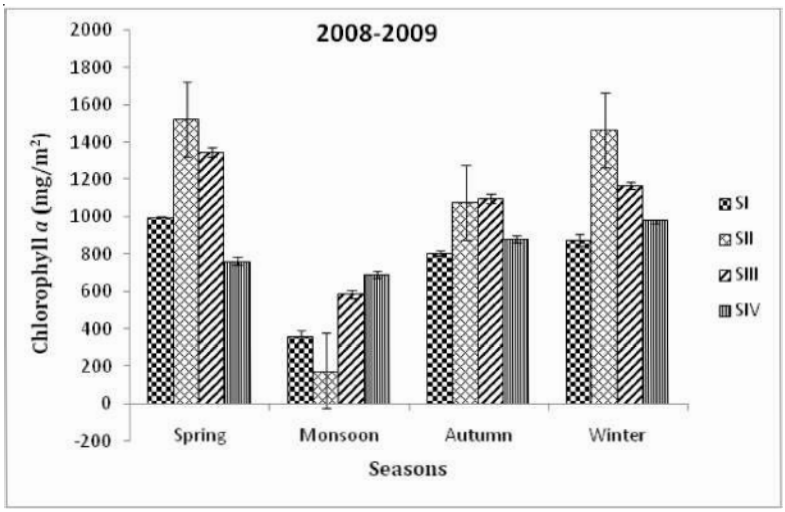
Sabater S, Buchaca T, Cambra J, Catalan Guasch H, Ivorra N, Munoz I, Navarro E, Real M, Romani A 2003. Structure and function of benthic algal communities in an extremely acid river. *Journal of Phycology 39* (3): 481–489

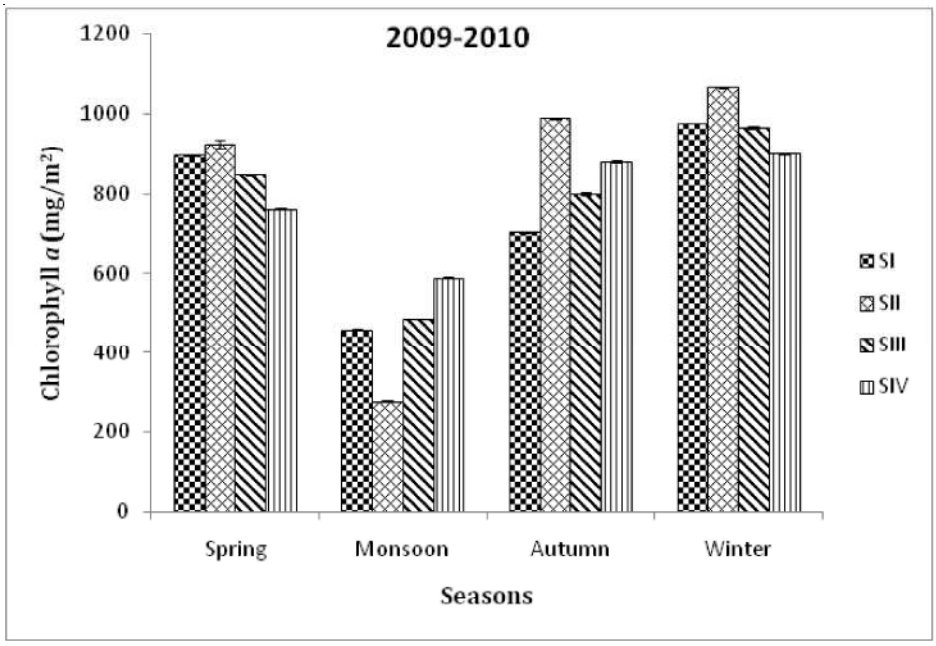
Sherwood AR, Sheath RG 1999. Seasonality of macroalgae and epilithic diatoms in spring-fed streams in Texas, USA. Hydrobiologia. 390: 73-82

Verb RG and Vis ML 2005. Periphyton assemblages as bioindicators of mine-drainage in unglaciated Western Allegheny Plateau lotic systems. *Water Air and Soil Pollution*. 161: 227-265

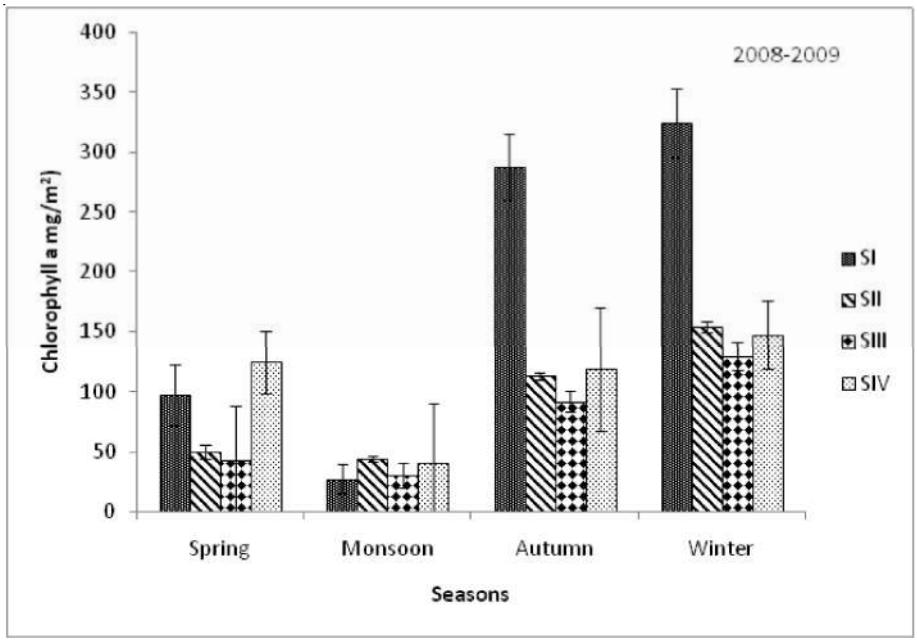
Verb RG and Vis ML 2001. Macroalgal communities from acid mine drainage impacted by watershed. *Aquatic Botany*. 71: 93-107

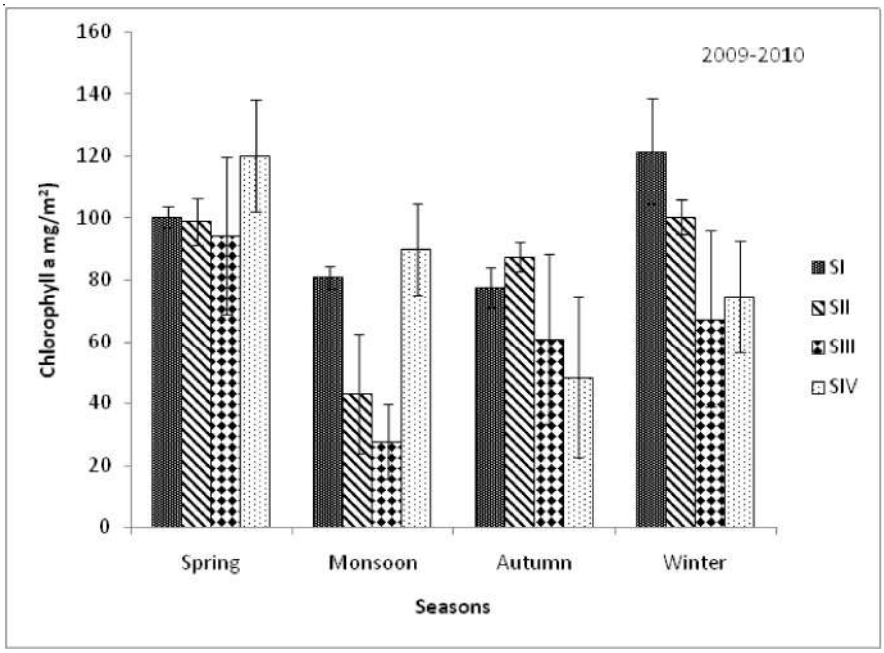
Sing OP 2005. *Mining Environment. Problems and Remedies*. (Eds.), Regency Publications, New Delhi.



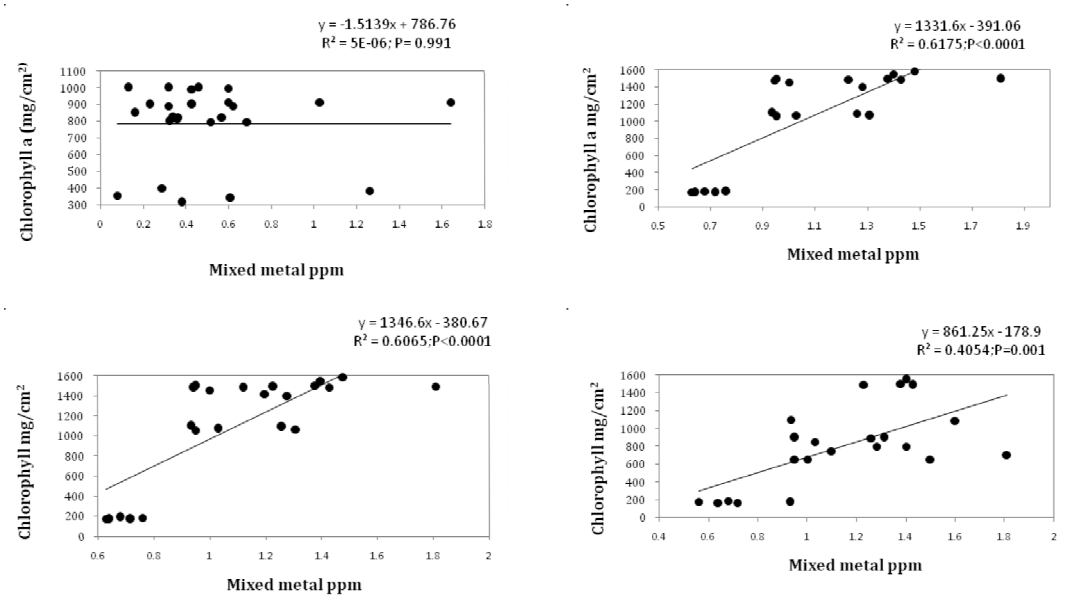


"Figure 1. Seasonal variation in chlorophyll a content contributed by Periphytonic algal communities in different sites"



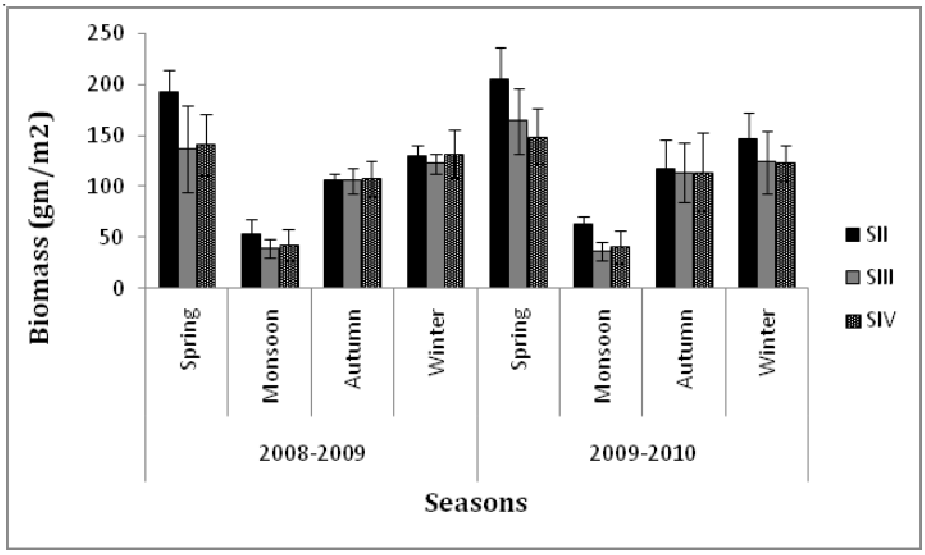


"Figure 2. Seasonal variations in Chlorophyll a content contributed by Benthic algal communities in different sites"



"Figure. 3. Linear regression analysis between Chlorophyll a and toxic metals effect in different streams"

"Figure 4. Mat formation in AMD impacted streams" **"Figure *5. Long jointed filamentous algae in AMD impacted streams"***



"Figure 6. Seasonal variations in the biomass content of the mat"

"Table 1. Physico-chemical characteristics of stream water"

		2008-2009				2009-2010			
		Spring	Monsoon	Autumn	Winter	Spring	Monsoon	Autumn	Winter
TEMPERATURE	SI	22.2	20.3	24.72	18.31	22.4	21.58	21.58	18.63
	SII	21.4	23.76	23.12	20.01	21.6	21.97	21.97	20.06
	SIII	26.9	23.4	23.88	21.36	27.1	24.52	24.52	21.18
	SIV	28	23.7	23.7	20.1	27.5	24.6	24.6	20.01
pH	SI	6.42	6.69	6.26	4.336	6.48	6.31	6.02	6.21
	SII	3.13	3.68	3.464	3.32	3.31	4.28	3.23	3.763
	SIII	2.88	3.870	3.284	3.24	3.09	3.48	3.23	3.61
	SIV	3.51	3.61	3.21	3.5	3.55	3.38	3.11	3.46
CONDUCTIVITY	SI	66	25	22	28.33	70.94	19.87	79.75	55
	SII	488	233	238	258	442.23	361	376.62	287
	SIII	862	695	542	514	954.35	389.87	824	675.62
	SIV	672	257	352	352	562.58	227.37	721	727.75
DO	SI	8.93	13.53	9.86	9.07	5.72	9.44	8.95	8.45
	SII	6.14	6.23	5.13	4.97	2.89	6.84	7.26	6.45
	SIII	4.34	5.36	4.57	4.97	2.85	4.92	4.77	4.61
	SIV	5.02	4.14	6.788	6.36	3.15	4.81	6.59	5.68
TURBIDITY	SI	2.27	1.26	1.62	3.217	1.23	0.738	1.922	4.21
	SII	4.36	2.43	3.208	4.44	4.04	1.7036	4.028	4.38
	SIII	10.45	2.80	6.468	7.9712	10.779	1.16	7.062	8.15
	SIV	3.53	3.93	3.26	3.98	3.83	2.40	3.82	4.18
SILICA	SI	3.11	2.67	3.29	3.593	3.01	2.67	3.25	3.90
	SII	24.64	20.89	18.677	29.66	25.22	21.00	17.93	33.07
	SIII	25.29	20.99	19.44	27.98	26.31	21.00	18.99	28.47
	SIV	4.17	2.83	3.77	3.95	5.38	2.32	3.75	2.96
FREE CO_2	SI	6.54	6.6	7.49	7.25	15.67	8.6	17.49	17.82
	SII	42.76	22.3	40.78	39	58.94	35.6	48.47	94.3
	SIII	45.80	31.94	46.32	53.87	80.190	45.93	133.018	83.55
	SIV	30.04	21.41	32.36	44.12	45.89	60.81	70.90	91.56
ACIDITY	SI	5.63	7.78	7.236	16.24	19.34	6.5	14.4	16.32
	SII	34.17	45.6	31.81	51.09	55.054	37.9	39.4	70.56
	SIII	94.48	47	47.51	61.78	97.89	33.6	56.2	77.29
	SIV	76.9	34.4	34.1	25.89	90.4	24.9	52.2	59.454
CHLORIDE	SI	37.58	31.20	40.42	40.76	35.36	20.91	39.84	44.31
	SII	129.06	74.45	141.75	94.82	60.89	68.790	79.29	89.162
	SIII	112.04	83.87	71.62	75.33	59.92	61.28	53.63	64.58
	SIV	137.57	115.58	154.42	238.49	120.91	87.81	168.64	237.58
	SIII	78.41	29.71	50.36	19.53	55.85	6.67	13.83	17.25
	SIV	77.12	39.01	60.63	40.17	42.26	11.58	31.86	45.79
HARDNESS	SI	34.29	13.2	16.21	27.82	22.15	3.96	33.38	29.47
	SII	67.85	42.8	59.75	32.08	32.05	10.23	30.65	30.47
	SIII	84.47	38.4	57.74	32.66	50.79	8.86	20.83	27.32
	SIV	82.83	45.8	69.41	56.72	62.82	10.62	42.18	60.21
SULPHATE	SI	12.56	4.60	13.23	31.12	21.96	18.96	25.87	30.11

"Table 2. Analysis of variance to show significant variation between sites and seasons"

	First year				Second year			
	Sites		Seasons		Sites		Seasons	
	F-Value	P-Value	F-Value	P-Value	F-Value	P-Value	F-Value	P-Value
pH	4.009044	**2.29E-13**	55.78931	**2.34E-23**	477.6856	**1.01E-102**	0.912858	0.436318
Temperature	7.108987	**0.000216**	26.95975	**1.34E-12**	6.408038	**0.000529**	27.31404	**1.01E-12**
Conductivity	120.2371	**1.4E-37**	5.586915	**0.001336**	89.59459	**1.15E-39**	3.019772	**0.031053**
Turbidity	23.89162	**2.05E-12**	6.761832	**0.000292**	14.40336	**1.61E-07**	11.93566	**1.74E-06**
Silica	572.1764	**2.54E-69**	2.496691	**0.061844**	169.0264	**1.55E-33**	1.333626	**0.002697**
DO	25.83232	**3.28E-12**	4.975006	**0.003526**	14.53377	**2.71E-08**	15.08927	**1.46E-08**
Free CO2	39.29747	**3.44E-19**	5.186262	**0.001871**	34.54261	**1.92E-17**	11.18738	**9.61E-07**
Acidity	50.14963	**9.48E-23**	6.257674	**0.000488**	25.23859	**2.29E-13**	29.49095	**3.68E-15**
Chloride	67.31815	**1.64E-27**	5.744571	**0.00098**	66.94877	**2.56E-28**	4.975006	**0.002525**
Hardness	37.78945	**1.28E-18**	19.09066	**1.35E-10**	5.005461	**0.002411**	55.78931	**2.34E-23**
Sulphate	271.3224	**8.34E-61**	3.148308	**0.027085**	22.09084	**2.18E-10**	8.85721	**4.17E-05**
Phosphate	2.570612	**0.046256**	9.484495	**8.58E-06**	2.128153	**0.010361**	48.28504	**1.42E-17**

"Table 3. One way analysis of variance (ANOVA) showing significant difference of Productivity (mg/m2) between sites and seasons"

Year of stuy	Season								Sites	
	SI		SII		SIII		SIV			
	F- value	P- value	F- value	P- value	F- value	P- value	F- value	P- value	F- value	P- value
2008-2009	879.182	**2.15E-21**	2915.34	**1.41E-26**	1251.016	**6.46E-23**	1093.141	**2.47E-22**	5.05288	**0.00302**
2009-2010	14730.0	**9.83E-28**	28031.8	**5.72E-3**	15051.31	**8.27E-2**	41669.13	**2.4E-3**	20.5413	**7.57E-1**

Values in BOLD are significantly different at 0.05 level

"Table 4. Two ways Analysis of variance (ANOVA) to show significant differences (Chlorophyll a, mg/m^2) between different sites and seasons"

ANOVA: 2008-2009

Source of Variation	SS	df	MS	F	P-value	F crit
Sample	360639.3	3	120213.1	263.4857	**2.35E-41**	2.718785
Columns	194934.4	3	64978.14	142.4206	**5.44E-32**	2.718785
Interaction	178708.1	9	19856.45	43.52182	**3.36E-27**	1.999115
Within	36499.31	80	456.2413			
Total	770781.1	95				

ANOVA:2009-2010

Source of Variation	SS	df	MS	F	P-value	F crit
Sample	40801.84	3	13600.61	44.76625	**4.39E-17**	2.718785
Columns	8271.639	3	2757.213	9.075332	**3.06E-05**	2.718785
Interaction	19359.21	9	2151.023	7.080065	**1.81E-07**	1.999115
Within	24305.12	80	303.814			
Total	92737.81	95				

Values in BOLD are significantly different at 0.05 level

"Table: 5. Pearson Correlation coefficients between periphytons chlorophyll-a and selected environmental variables. P < 0.05. TN = Total Nitrogen, TP= total phosphorus. WC= Water current, DO = Dissolved Oxygen, SO4"

Variables	SI	SII	SIII	SIV
Chlorophyll	1	1	1	1
pH	-0.083	*-0.556	*-0.504	0.171
WC	*-0.409	*-0.470	*-0.414	*-0.629
Conductivity	0.059	*0.598	*0.555	*0.500
TN	*-0.398	-0.167	-0.254	0.000
TP	*0.503	0.288	0.260	0.272
SO4	-0.235	0.051	*-0.415	*-0.327
N:P	*0.408	*0.445	0.016	0.141
Chloride	*0.420	0.026	0.028	0.415
DO	*-0.410	-0.021	0.134	0.099
Silicate	*0.570	*0.426	*0.754	*0.500
Turbidity	*0.549	*0.367	*0.328	*0.146

***Sign indicates significantly different at 0.05 level**

"Table 6. Pearson correlation coffecient between benthic algal productivity mg/cm^2) and environmental variables. TN=Total nitrogen. TP= total phosphorus.SO4= sulphate. DO= dissolved oxygen"

Variables	SI	SII	SIII	SIV
Chlorophyll	1	1	1	1
pH	-0.180	*-0.37	*-0.488	0.004
WC	*-0.536	*-0.603	*-0.334	*-0.463
Conductivity	0.029	*0.436	*0.579	0.083
TN	*-0.528	0.229	0.289	*0.673
TP	0.270	*0.337	*0.434	*0.445
SO4	0.087	0.027	*-0.419	-0.136
N:P	0.264	0.088	0.201	0.000
Chloride	0.240	-0.185	0.031	-0.076
DO	-0.159	-0.249	-0.072	*-0.377
Silicate	*0.642	*0.158	*0.636	*0.511
Turbidity	*0.656	*0.21	0.298	0.126

"Table 7. Single factor ANOVA showing significant variation between AMD sites and seasons"

	SII		SIII		SIV		Sites	
	F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value
2008-2009	164.10	*4.74E-21	34.566	*1.07E-10	39.4477	*1.8E-11	1.805	*0.169

***sign indicates significantly different at 0.05 level**

Diversity of Microbes Associated with *Artocarpus heterophyllus* in Nokrek Biosphere Reserve of Meghalaya.

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ABSTRACT

Plants provide a substantial ecological niche for microorganisms. Microorganisms show specificity with the hosts, tissue and age of the plants. The microorganisms that lead to destructive associations are called 'pathogens'. A wide range of fruit species thrive in the Nokrek Biosphere Reserve out of which Artocarpus heterophyllus (jackfruit) has immense economic potential and is loved by most of the local inhabitants. Ripe fruits are relished as dessert and unripe fruits are used as vegetable or pickled. The jackfruit tree has number of medicinal uses as well. Like any other plant growing in the reserve, jackfruit is also susceptible to a number of diseases. The objective of the study was to identify the pathogenic microbes infecting jackfruit plants in the core zone, buffer zone and transition zone of the Nokrek Biosphere Reserve. From the study it is clear that disease causing pathogens are more in transition zone than in core and buffer zone. The plant seems to be infected by similar types of pathogens in pre monsoon season and post monsoon seasons in all the three zones. The soil microbes were found to be more in the topsoil i.e. 0-15 cm depth than the subsoil i.e. 15-30 cm depth in all the three zones of the biosphere reserve in both the seasons.

Keywords: **Biosphere reserve, microbes, *Artocarpus heterophyllus*, diversity**

INTRODUCTION

Microbial diversity encompasses the spectrum of variability among all types of microorganism's viz. bacteria, fungi, viruses, nematodes and many more in the

natural world. They are found in habitats with extremes of temperature, pH, water and salt stress. Plants provide a substantial ecological niche for microorganisms. Microorganisms show specificity with the hosts, tissue and age of the plants. The microorganisms that lead to destructive associations are called 'pathogens'. Infectious diseases of plants i.e. conditions that disturb or harm their normal growth or development are caused by diverse pathogens. They include an array of multicellular life forms including fungi, fungus like oomycete, nematodes, parasitic plants and protozoa. Among them fungi is the most prevalent and important plant pathogen (Ploetz, 2007). Forest fruit plants are known to be attacked by various pathogens in forest nurseries, plantations and also in natural forests. The survival and performance of most plant pathogens depend on the prevailing conditions of temperature and moisture or on the presence of water in their environment.

Soil harbours a variety of microorganisms both beneficial and harmful. Microorganisms in soil are critical for maintenance of soil function both in natural and managed agricultural soils. The soil microbes decompose the plant and animal residue entering the soil and convert them into soil organic matter which influences the soil physical, chemical and biological reactions and life support in the soil environment. The plant species growing in the soil influences the population and species composition of the soil fungi and bacteria (Garbera, 2004). Soil is the most complex heterogenous environment which serves as a medium for growth of higher plants and a wide array of microorganisms including some soil borne pathogens.

Nokrek Biosphere Reserve located in the Garo Hills District of Meghalaya is considered to be one of the least disturbed forest tracts of the sub-Himalayan ranges. A diverse forest habitat is found in the reserve due to altitudinal variation, like tropical evergreen forest, tropical semi evergreen forest, tropical moist deciduous forest and riverean forest. A wide range of fruit species thrive in the Nokrek Biosphere Reserve out of which *Artocarpus heterophyllus* (jackfruit) has immense economic potential and is loved by most of the local inhabitants. Ripe fruits are relished as dessert and unripe fruits are used as vegetable or pickled. Seeds are boiled or roasted. The jackfruit tree has number of medicinal uses as well. Like any other plant growing in the reserve, jackfruit is also susceptible to a number

of diseases. The objective of the study was to identify the pathogenic microbes (in air and soil) infecting jackfruit plants in the core zone, buffer zone and transition zone of the Nokrek Biosphere Reserve.

MATERIALS AND METHODS

(a)Area of Study: The study was conducted in Nokrek Biosphere Reserve situated in between latitudes 25°25'- 25 °30'N and longitudes 90 °15'- 90 °35'E at an elevation of about 4650 feet above sea level and stretched over an area of 820 sq Km. The reserve consists of the core zone covering an area of 47.48 sq Km, the buffer zone which is an area of land beyond the core zone covering about 227.92 sq Km. and the transition zone covering an area of 544.60 sq Km including the immediate villages surrounding the buffer zone.

(b)Sampling technique: Five jackfruit trees were selected randomly from each zone of the biosphere reserve for collection of diseased plant samples and identification of microbes. The collection was done during pre-monsoon and post monsoon period of years 2014 and 2015. Soil samples were collected from the rhizosphere of each tree from two depths (viz. 0-15 cm and 15-30 cm) and from four directions with the help of a soil auger. The soil samples collected from four directions were mixed to form a composite sample and a representative sample was drawn from the composite sample for culturing and identification of soil microbes. Soil sampling was also done during pre-monsoon and post monsoon period of years 2014 and 2015.

(c) Culture Technique: For isolation of fungal pathogen from diseased plant samples, single spore technique and single hyphal tip technique of culturing were used. The isolated fungal pathogens were then purified by streaking and single spore isolation method. Pathogenicity tests were conducted thereafter by pin prick method (Tomkins and Trout, 1913) and the pathogenicity was confirmed by Koch's postulates. Soil microorganisms were identified by the Direct method and Plate method. Identification of microorganisms was done by studying their macro and micro morphological characters.

RESULTS AND DISCUSSION

The pathogens identified in plants of *Artocarpus heterophyllus* during the pre-monsoon and post-monsoon period of years 2014 and 2015 in the core zone, buffer zone and transition zone are presented in Table 1 and Table 2. Fungus *Phomopsis artocarpina* which causes

brown leaf spot infected the leaves of the plants only in the core zone during the pre-monsoon and post monsoon season of both the years. Fungus *Ustilana zonata* causing charcoal rot was recorded in the core zone and transition zone in the year 2014 during premonsoon season. However, in the post monsoon season this pathogen was present in both the years. Fungus *Phytophthora palmivora* causing fruit rot was identified from fruits of the selected plants in buffer and transition zone in both the seasons in 2014 and 2015. Fungus *Botrytis cineria* was isolated from fruits and shoots of selected plants in the core zone, buffer zone and transition zone in both the years of observation during postmonsoon whereas in premonsoon season it was isolated from plants of buffer and transition zone only. Fungus *Colletotrichum gloeosporoides* causing leaf spot disease was identified from the leaves in all three zones during premonsoon season in both the years of observation. Interestingly, it was observed in buffer and transition zones in 2014 and only in transition zone in 2015 during the post monsoon season. Fungus *Phyllostica artocarpina* causing leaf spot diseases in the leaves were noticed in all the three zones during premonsoon and post monsoon seasons of both the years. The fungus *Rhizopus artocarpii* responsible for the disease Rhizopus rot was found in all the three zones during both years of observation in premonsoon and postmonsoon season . Fungus *Pythium splendens* causing root rot disease was found only in the year 2014 in buffer zone and transition zone during the premonsoon season while it was observed only in transition zone in both the years during post monsoon season. Fungus *Fusarium spp* causing root rot was observed in core zone and transition zone only in both the years during premonsoon season. However, it was found in the core zone, only in year 2014 and in buffer and transition zone in both the years during post monsoon season. Fungus *Uredocarpii spp* which causes rust disease was noticed only in the year 2015 in core zone during the pre monsoon season.

Ten disease causing pathogens were identified in *Artocarpus heterophyllus* from the three zones of Nokrek Biosphere Reserve during pre monsoon season and nine disease causing pathogens were isolated during the post monsoon season. The occurance of disease causing pathogens was apparently more in transition zone compared to other two zones. Shail and Dubey (1997) studied the seasonal changes in microbial community

(bacteria and fungi) and species diversity in fungi in banj-oak and chir-pine forest soil of Kumaon Himalaya in relation to edaphic factors. Maximum number of fungal taxa and average number of bacteria (per gram soil) were recorded in rainy season and minimum in summer season from both the soils.

The soil microbes identified in the rhizosphere of selected plants of *Artocarpus heterophyllus* during the pre-monsoon and post monsoon period of years 2014 and 2015 in the core zone, buffer zone and transition zone are presented in Table 3 and 4. Fungus *Aspergillus flavus* was isolated from 0-15 cm soil depth in all the three zones in 2014 and 2015 during pre monsoon and post monsoon season. However, at 15-30 cm soil depth it was observed only in core zone and buffer zone in both the years during premonsoon and in all the zones in post monsoon season. *Aspergillus niger* was observed in the top soil i.e. 0-15 cm depth in all the three zones of the reserve in 2014 and 2015 in both seasons and in transition zone during postmonsoon season in both the years. *Botrytis spp* was isolated only from 0-15 cm soil depth in core zone and buffer zone in both years of observation during premonsoon season while in post monsoon season it was found only in 15-30 cm soil depth in buffer zone in 2015. *Colletotrichum spp* was identified from the buffer zone and transition zone only from 0-15 cm depth during pre monsoon season of years 2014 and 2015 whereas in post monsoon season it was found in the buffer zone at 15-30 cm depth and in the transition zone at 0-15 cm depth in both the years. *Fusarium spp* was observed in all the three zones from 0-15 cm depth in both the years during pre monsoon season. At 15-30 cm depth it was found in core zone in pre monsoon season of 2015. In post monsoon season, it was isolated from 0-15 cm depth of core zone only in 2015 and from buffer and transition zone in both years. It was isolated from 15-30 cm depth of core zone in both years and 15-30 cm depth of buffer zone only in 2015. *Penicillium spp1* was found in the core zone at both depths of the soil in both the years whereas in buffer zone it was present only at 15-30 cm depth and in transition zone it was observed in both the years at 0-15 cm depth but only in year 2014 at 15-30 cm depth; whereas in post monsoon it was found in both the years at both depths of soil in all the three zones. *Penicillium spp2* was observed only in the buffer zone and transition zone at 0-15 cm depth in both years of observation during pre monsoon season.

However, during post monsoon it was found in core zone and buffer zone at 0-15 cm depth in both years while in transition zone it was observed only in year 2015. At 15-30 cm depth it was isolated from core zone and transition zone in both the years. *Penicillium spp3* was observed from the transition zone at 0-15 cm depth and from the core zone at 15-30 cm depth in both the years during the pre monsoon season only.

Helminthosporium spp was recorded from only one depth i.e. 15-30 cm in the core zone and buffer zone in 2014 and 2015 during pre monsoon season whereas it was observed only at 0-15 cm depth in the buffer zone in both the years in post monsoon season. *Mucor spp* was observed from 0-15 cm depth in core zone in 2015 only whereas at 15-30 cm depth it was found in both the years while in transition zone it was found at both depths of soil in both years of observation during pre monsoon season. However, during post monsoon it was found in both depths of soil in the core zone. In transition zone, it was isolated from 0-15 cm soil depth in both years of observation but only in year 2014 at 15-30 depth. *Phytophthora spp* was found at 0-15 cm depth only in the buffer zone in 2014 while at 15-30 cm depth it was observed in both core zone and transition zone in the year 2014 and 2015 during pre monsoon season only. *Rhizopus spp* was isolated in the core zone from both depths of soil in both years of observation whereas in the buffer zone and transition zone it was found only from 0-15 cm depth in both years of observation. However, it was observed in all the three zones in both the depths in both 2014 and 2015 during post monsoon season. *Trichoderma spp* was isolated from 0-15 cm depth of soil in all the three zones in both the years during pre monsoon season whereas in post monsoon season it was found in core zone and transition zone in 2015 at 0-15 cm depth and in buffer zone in 2014. At 15-30 cm depth, it was isolated only from core zone in year 2014. *Trichosanthes roseum* was identified during the pre monsoon season from the core zone only from 0-15 cm depth in 2015. In the buffer zone it was found only in 0-15 cm depth in both the years of observation whereas in the transition zone it was noted only from 0-15 cm depth in 2014. However, during the post monsoon season, it was observed only at 0-15 cm depth in the core zone and transition zone in year 2014.

Observations of the present study reveal that the soil microbes are less in number at 15-30 cm soil depth in all the

three zones of the Nokrek Biosphere Reserve compared to 0-15 cm (topsoil). Similar findings have been reported by Tangjang *etal*. (2009). Dkhar (1983) suggested that fungi grow slowly in the deeper soil layers due to shortage of mineral nutrients and compaction of soil along depth.

CONCLUSION

From the study it is clear that disease causing pathogens are more in transition zone than in core and buffer zone. The plant seems to be infected by similar types of pathogens in the pre monsoon and post monsoon seasons in all the three zones. The soil microbes isolated from the rhizosphere of *Artocarpus heterophyllus* are more in the topsoil i.e. 0-15 cm depth than the subsoil i.e. 15-30 cm depth in the core zone, buffer zone and transition zone of the biosphere reserve in both the seasons.

REFERENCES

Dkhar M S 1983. Studies on ecology of edaphic microbial populations and their activities in maize fields. Ph.D Thesis, North-Eastern Hill University, Shillong, India

Garbera P, Veen JA and Elsas JD 2004. Microbial Diversity in Soil. *Annu Rev. Phytopathol*. 2004. 42:243-70

Ploetz RC 2007. Diseases of tropical perennial crops. Challenging problems in diverse environments. *Plant Disease* 91: 644-663

Shail S, Dubey RC 1997. Seasonal changes in microbial community in relation to edaphic factors in two forest soils of Kumaon Himalayas. In:*Himalayan Microbial Diversity* (eds S.C. Sati, J.Saxena and R.C.Dubey) pp. 381-391.

Tangjang S, Arunachalam K, Arunachalam, A and Shukla A 2009. Microbial Population Dynamics of Soil under Traditional Agroforestry Systems in northeast India. *Research Journal of Soil Biology*, 1:1-7

Tomkins RG, Trout SA 1931. The use of ammonium salts for the prevention of green moulds in Citrus. *Jour. Pomo. Hort. Sci*., 9:257-264.

Table 1: Pathogenic microbes identified in Artocarpus heterophyllus in different zones of Nokrek Biosphere Reserve during premonsoon season of year 2014 and 2015.

PATHOGEN ISOLATED (Fungi)	DISEASE CAUSED	CORE ZONE		BUFFER ZONE		TRANSITION ZONE	
		2014	2015	2014	2015	2014	2015
Phomopsis artocarpina	Brown leaf spot	+	+	–	–	–	–
Ustilana zonata	Charcoal rot	+	–	–	–	+	–
Phytophthora palmivora	Fruit rot	–	–	+	+	+	+
Botrytis cineria	Gray mold	–	–	+	+	+	+
Colletotrichum gloeosporoides	Leaf spot	+	+	+	+	+	+
Phyllostica artocarpina	Leaf spot	+	+	+	+	+	+
Rhizopus artocarpii	Rhizopus rot	+	+	+	+	+	+
Pythium splendens	Root rot	–	–	+	–	+	–
Fusarium spp	Root rot	+	+	–	–	+	+
Uredocarpii spp	Rust	–	+	–	–	–	–

*** ‘ +’denotes presence, ‘_’ denotes absence of microorganisms.

Table 2: Pathogenic microbes identified in Artocarpus heterophyllus in different zones of Nokrek Biosphere Reserve during postmonsoon season of of year 2014 and 2015.

PATHOGEN ISOLATED (Fungi)	DISEASE CAUSED	CORE ZONE		BUFFER ZONE		TRANSITION ZONE	
		2014	2015	2014	2015	2014	2015
Phomopsis artocarpina	Brown leaf spot	+	+	–	–	–	–
Ustilana zonata	Charcoal rot	+	+	–	–	–	–
Phytophthora palmivora	Fruit rot	–	–	+	+	+	+
Botrytis cineria	Gray mold	+	+	+	+	+	+
Phyllostica artocarpina	Leaf spot	+	+	+	+	+	+
Colletotrichum gloeosporoides	Leaf spot	–	–	+	–	+	+
Rhizopus artocarpii	Rhizopus rot	+	+	+	+	+	+
Pythium splendens	Root rot	–	–	–	–	+	+
Fusarium spp	Root rot	+	–	+	+	+	+

*** ‘ +’denotes presence, ‘_’ denotes absence of microorganisms

Table 3: Microbial diversity in the rhizosphere of Artocarpus heterophyllus in different zones of Nokrek Biosphere Reserve during premonsoon season of 2014 and 2015.

MICRORGANISM ISOLATED (Fungi)	CORE ZONE				BUFFER ZONE				TRANSITION ZONE			
	0-15 cm Soil depth		15-30 cm Soil depth		0-15 cm Soil depth		15-30 cm Soil depth		0-15 cm Soil depth		15-30 cm Soil depth	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Aspergillus flavus	+	+	+	+	+	+	+	+	+	+	_	_
Aspergillus niger	+	+	_	_	+	+	_	_	+	+	_	_
Botrytis spp	+	+	_	_	+	+	_	_	_	_	_	_
Colletotrichum spp	_	_	_	_	+	+	_	_	+	+	_	_
Fusarium spp	+	+	_	+	+	+	_	_	+	+	_	_
Helminthosporium spp	_	_	+	+	_	_	+	+	_	_	_	_
Mucor spp	_	+	+	+	_	_	_	_	+	+	+	+
Penicillium spp1	+	+	+	+	_	_	+	+	+	+	+	_
Penicillium spp2	_	_	_	_	+	+	_	_	+	+	_	_
Penicillium spp3	_	_	+	+	_	_	_	_	+	+	_	_
Phytophthora spp	_	_	+	+	+	_	_	_	_	_	+	+
Rhizopus spp	+	+	+	+	+	+	_	_	+	+	_	_
Trichoderma spp	+	+	_	_	+	+	_	_	+	+	_	_
Trichosanthes roseum	_	+	_	_	+	+	_	_	+	_	_	_

*** ‘ +’denotes presence, ‘_’ denotes absence of microorganisms.

Table 4: Microbial diversity in the rhizosphere of Artocarpus heterophyllus in different zones of Nokrek Biosphere Reserve during postmonsoon season of 2014 and 2015.

MICRORGANISM ISOLATED (Fungi)	CORE ZONE				BUFFER ZONE				TRANSITION ZONE			
	0-15 cm Soil depth		15-30 cm Soil depth		0-15 cm Soil depth		15-30 cm Soil depth		0-15 cm Soil depth		15-30 cm Soil depth	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Acremonium spp	+	+	+	+	–	–	–	–	–	–	–	–
Aspergillus flavus	+	+	+	+	+	+	+	+	+	+	+	+
Aspergillus niger	+	+	–	–	+	+	–	–	+	+	+	+
Botrytis spp	–	–	–	–	–	–	–	+	–	–	–	–
Colletotrichum spp	–	–	–	–	–	–	+	+	+	+	–	–
Fusarium spp	–	+	+	+	+	+	–	+	+	+	–	–
Helminthosporium spp	–	–	–	–	+	+	–	–	–	–	–	–
Mucor spp	+	+	+	+	–	–	–	–	+	+	+	–
Penicillium spp1	+	+	+	+	+	+	+	+	+	+	+	+
Penicillium spps2.	+	+	+	+	+	+	–	–	–	+	+	+
Rhizopus spp	+	+	+	+	+	+	+	+	+	+	+	+
Trichoderma spp	–	+	+	–	+	–	–	–	–	+	–	–
Trichosanthes roseum	+	–	–	–	–	–	–	–	+	–	–	–

*** ‘ +’denotes presence, ‘_’ denotes absence of microorganisms.

Physico-Chemical Characteristics of Urpod Beel of Goalpara

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ABSTRACT

The present study on the physico chemical parameters of one of the important beels in Goalpara district near Goalpara Town portrays the details of the quality of water in the beel. The limnological parameters did not show much abrupt fluctuation with an average value of temperature of water 29.5^{0}C, pH 6.66, Conductivity 0.15 mS, Total Dissolved Solids 150 ppm, Dissolved Oxygen 5mg/l, Turbidity 57.4NTU, Total Hardness 26.4mg/l, Free CO_2 9.4 mg/l, Total Alkalinity 9.3 mg/l and Salinity 1420ppm. Although experimental studies indicate that water quality is conducive(Vass et al., 2009) for pisciculture and the wetland has a fairly high production potential, but the average estimated production of the beel is less as the current method, regulations and system of management are not conducive to sustainable production from the water bodies.

Keywords: **Beel, Urpod, Goalpara, Wetland**.

INTRODUCTION

Wetlands are recognized as one of the most significant natural resources associated with the human settlement since the inception of civilization. Although there is worldwide uncertainty about the definition and categorization of the wetlands, the internationally agreed definition taken during Ramsar Convention in 1971 in Iran describes wetlands very broadly as “areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water which is static or flowing, fresh, brackish or salt, including areas of marine waters, the depth of which at low tide does not exceed six meters” (Clare and Cyrille,

1999). In addition to production of fishes the, wetlands are providing water for drinking as well as raising crops in the agricultural field, helping the mankind in various ways like controlling flood, controlling ground water recharge and discharge, nutrient recycling and improvement of water quality, etc. The wetlands also act as the breeding ground for the large growing riverine fishes along with other ornamental fishes and aquatic birds. But, presently the wetlands are suffering from encroachment as human settlement, for boro-paddy and mustard cultivation, monoculture of fishes, etc in spite of their contribution as unique natural resource. The lower Assam has innumerable fresh water lakes, wetlands, oxbow lakes, marshes, and seasonal flood plains. The perennial floodplain wetlands (beels), a kind of ecotone, constitute the most important fishery resource suitable for culture-based fishery development but some of them are under capture fishery and considered as the most threatened of all natural resources.

Assam is gifted with 3,513 wetlands covering an area of 1, 01,231.8 ha (ARSAC, 1997), around half of national wetland coverage and is capable producing 1000kg/ha/yr of fishes with moderate level of management (CIFRI, 2000). This is close to 4% of the total floodplain area and 1.3% of the total area of the State. Although, there are 3,513 wetlands in Assam, only 1392 are listed floodplain wetlands, of which 423 are registered and remaining 969 are unregistered. The later are under the control of both government (505) and private (464) ownership, (Chandra, 2011). But surprisingly, the present level of fish production from these beel is only $^{1}/_{5}$ of the potential i.e. 173 kg/ha/yr on average (CIFRI, 2000). Urpodbeel is one of the riverine wetlands in the South bank of river Brahmaputra in Goalpara district which provides a large variety of aquatic flora and fauna other than a great diversity of fishes and migratory birds.

UrpodBeelone of the largest beel in lower Assamis situated in Goalpara District near Solmari around 8 km away from the Goalpara town. The Beel is situated at latitude 26°6´38.83´´North and longitude 90°35´30.77´´East and altitude 24 m above msl and covers an area of about 649.38 ha of land (Saud *et al.*, 2012). The wetland is already included in Asian Wetland Directory (Scot, 1989). The eastern side of the beel is surrounded by agricultural and land of surrounding villages. The Urpod Beel is connected with Patakata Beel by a small drain located in

the eastern side of the Beel, enabling exchange of water and other aquatic flora and fauna in both the Beels. The river Jhinari originates from the Garo Hills of Meghalaya in the southern side of the Beel, passes by the side of the Beel to the north and northeast direction before meeting the river Brahmaputra. Maximum depth of the beel is 20 feet during monsoon and minimum is 4 feet during the winter. The Beel is under capture fishery and the local fishermen capture upto2-4 quintals of fishes per day during peak season. Although the beel is registeredunder state Governmentbut not leased.

Very few works done on the beel like Saud *et al*., (2012) recorded 60 species of fishes,Sarma and Dutta (2012) reported 48 speciesof fishes from Urpod and Kumribeel, Choudhury *et al*., (2013) studied the abundance of the exotic carps in the beel. Hence the present study aimed at the assessment of water quality of the beel to understand the health and productivity of the beel.

MATERIALS AND METHODOLOGY

The water samples from the Urpodbeel were collected from seven different stations in the morning with a regular interval of around 6 days in the month of March 2015. Some of the parameters such as air and water temperature etc measured on the field itself with the help of a mercury bulb thermometer (0-100°C). Water samples were collected in the pre-cleaned bottles and immediately brought in to the laboratory for estimation of various physico-chemical parameters like pH, dissolved oxygen (DO), Total Dissolved solid (TDS), Total Hardness, Specific Conductivity, Salinity, Free Carbon di-oxide (FCO_2), Total Alkalinity (TA), Turbidity, etc. pH of the water samples were recorded using pH meter (make: Systronics; model: MK VI). Specific Conductivity, Salinity, TDS and Turbidity of the water sample were recorded using digital portable water analysis kit (make: MAC; model-MSW-551), while the other parameters like Free CO_2, TA, DO, Hardness of the water sample were measured by manual titration method. Some of the information was collected through interviews, group discussion with the leasee, fishermen and local peoples.

OBSERVATION:

Table: Physico-chemical characteristics of the water of UrpodBeel at different study sites.

Date	Spot	Temp. Water (C)	FCO_2 (mg/l)	TA (mg/l)	Total Hardness (mg/l)	pH	TDS (ppm)	Conductivity (ms)	Salinity (ppm)	D.O. (mg/l)	Turbidity (NTU)
2/3/2015	1	27.9	6.0	16.0	30.0	6.20	180	0.19	1700	7.2	41
Do	2	27	8.0	7.0	24.0	6.27	180	0.18	1600	4.2	93
Do	3	27.9	12.0	5.0	20.0	6.55	180	0.16	1700	3.2	61
9/3/2015	4	27.9	10.0	4.0	34.0	6.37	170	0.18	1600	3.2	64
16/3/2015	5	27.9	16.0	5.0	32.0	6.43	170	0.18	1700	3.2	28
23/3/2015	6	34	8.0	16.0	25.0	7.32	80	0.08	700	7.0	70
30/3/2015	7	34	6.0	12.0	20.0	7.50	80	0.09	970	7.0	45
Average		29.5	9.4	9.3	26.4	6.66	150	0.15	1420	5	57.4

RESULT AND DISCUSSION

pH: Hydrogen ion concentration i.e. pH of water is measure of relative acidity and alkalinity. H^+ ion concentration is one of the most important parameter of any aquatic system since all the biochemical activities depend on pH of surrounding water. The variation of pH is often linked with the species composition and life processes of animal and plant communities inhibiting them.The pH level of water of the Urpodbeel was estimated in between the range of 6.2 to 7.5. Dodds(2003) described a secondary source of H^+ ions from periphytic photosynthesis which locally increases pH of the system by upto 1 unit.

Temperature: In aquatic system temperature is one of the most important limiting factors as it controls the metabolic activities and growth rate in organism (Dheer, 1988). It plays a vital role in biochemical and self purification of aquatic system, organic matter that gets oxidized is supposed to be highly influence by the water temperature. Thus self purification (breakdown of organic matter) is more rapid during summer months compared to rainy and winter seasons leading to oxygen consumption in the aquatic environment.According to Welch(2003), no other single factor has such a direct or indirect influence on aquatic water ecosystem than temperature. The temperature in wetland water is largely regulated by solar radiation, air temperature and topography. Temperature in turn regulates the dissolve oxygen concentration of water, primary productivity thatcauses a great variability in plant and animal distribution. In Indian

subcontinent water temperature in various water bodies varies from 7.8°C to 45.5°C. However, in north-eastern region it generally lies between 14°C to 40.5°C.The average water temperature of the beel was recorded to be 29.5^0C.

Dissolved Oxygen (DO): Dissolved oxygen is one of the most important limiting factor of aquatic environment to determine the distribution and abundance of various algal groups. It plays a vital role in metabolism of organisms. The occurrence of DO in water depends mainly on a physical process and biological process. It is significantly influenced by the temperature, salinity, dissolved salts and water movements (Zutshi and Vass, 1978). The average dissolved oxygen of the beel was found to be 5mg/l. Although the DO value is suitable for the growth and development of fishes throughout the year it reduces in the winter due to receding water level with increase in planktons and weeds in the beel.

Free Carbon di-oxide: Aquatic vegetation and phytoplankton require CO_2 for photosynthetic activity. The decomposition of organic matter and respiratory activity of aquatic plant and animals produces CO_2. The level of free carbon di-oxide was recorded to be maximum i.e. 16mg/l and minimum 6mg/l. Many of the previous workers also reported FCO_2 as absent in limonitic water (Ganapati, 1940; George, 1966; Jana and Sarkar, 1971). But it is interesting to note that throughout the period of present investigation $FCO_2$was recordedalthough sometimes, poor proportions.

Total alkalinity: Total alkalinity of water is its buffering capacity or capacity to neutralize acid. It is an aggregate property of water due to presence of carbonate, bicarbonate and hydroxyl compounds of calcium, magnesium, sodium, potassium, etc. Alkalinity is mainly due to bicarbonate present in water (Raid, 1961). The fluctuation in alkalinity may be due to rainfall as observed by Michael (1969) and Jana (1973). The fluctuation in alkalinity values depends upon nature of bottom deposits, rainfall and autotrophs of water. The total alkalinity is directly related to aquatic productivity (Spence, 1967; Alikunhi, 1957). The maximum value of total alkalinity of the beel was recorded to be 16 mg/l in the pre-monsoon period.

Total Hardness: Total hardness normally indicates the total calcium and magnesium salts present in water along with some other polyvalent metals such as iron, aluminium, manganese etc. It determines

the suitability of water for domestic, industrial anddrinking purposes and attributed to presence ofbicarbonates, sulphates, chloride and nitrates ofcalcium and magnesium (Taylor, 1949).The total hardness of the water body was in the range between 20mg/l to 34mg/l in the study period.

Salinity: Salinity is a measure of the amount of dissolved particles and ions in water. The change in the salinity that is salt content of a water body greatly affects the distribution and abundance of fishes (Bailey *et al*., 1954). In the case of fishes the consumption of Oxygen increases along with the increase in salinity (Toepfer and Barton, 1992). Salinity rarely changes in isolation from the other environmental factors such as dissolved oxygen, carbon di-oxide level, pH and temperature etc (Wheatly, 1988). High concentration of salt pose threats for the environment as well as agricultural and infrastructure and therefore the widen economy. High level of salinity in water and soil may cause wetland to become unhealthy and lead to a decline in biodiversity through dominance of salt-resistant species potentially altering ecosystem structure. The salinity of the water body fluctuates between 700ppm -1700ppm.

Turbidity: Turbidity is a function of light dispersing and absorbing properties of water and is a striking characteristic to know the physical status of the rivers. It is caused by the presence of suspended matters like clay, silt, colloidal organic particles and plankton. The turbidity is greatly influenced by surface and drainage run off. Turbidity of water always has a negative effect on the biotic communities. It decreases light penetration in water, checks the process of photosynthesis in aquatic plants and decreases the potability and productivity of water (Pandey *et al.*, 1999; Kaushik and Saksena, 1991). The average turbidity of the water body was recorded as 57.4 NTU during the present study period.

Conductivity: The conductivity is a measure of water's capacity to conduct an electric current. The relationship of the conductivity to ionised matter concentration varies with both quality and quantity of the ions present. The specific conductivity was observed very low during present investigation; however, it shows a well marked seasonal pattern (Gahlawat*etal*., 2007). The specific conductivity was found to increase during the late winter and early spring but with the onset of monsoon a gradual decline was observed. This may be due to dilution

by the rain water and increase in temperature as temperature affects the ionic velocity. The maximum conductivity of the water body was recorded 0.19 mS, while minimum was recorded 0.08 mS.

***Total Dissolved Solid*:** TDS is a measure of all dissolved substances in water,including organic and suspended particles that can pass through a very small filter. Total dissolves solids are naturally present in water or are the result of mining or some industrial treatment of water.Sorensen *et al*., (1977) recorded a precipitous decrease in biomass of organic matter (Phytoplankton) with about 1200ppm TDS. The TDS of the water body ranges from 80ppm to 180ppm.

CONCLUSION

Just like the other wetlands of the state the UrpodBeel experience the most dramatic changes in their trophic status and biota. There is a gradual shrinkage in the size of the wetland due to encroachment, agricultural activities, forest cover change in the adjoining reserved forests and human settlement within the wetland causing an imbalance in the wetland eco-system. The wetlands, in contrast, maintain to a high extent their major biotic and abiotic components, though many fish and bird populations have been directly affected by floods due to climate change and human intervention.

Although the Millennium Ecosystem Assessment (2005) estimates that wetlands cover seven percent of the earth's surface and deliver 45% of the world's natural productivity and ecosystem services. The existence of these unique resources in this region of the country is under threat due to differential developmental activities and population pressure. This calls for a long-term planning for preservation and conservation of these resources(National Wetland Atlas, 2010).

From the present observation it can be concluded that encroachment, siltation, jute retting and surface run-off carrying fertilizer from agricultural field etc affecting the wetland resulting in prolific weed growth, thereby, affecting sustainable food production and potable water for humans and livestock. A large number of people residing in or on the fringe areas of wetlands are partially or entirely dependent upon the aquatic resources of the Beel. The Beel is a habitat of diverse groups of organisms and harbours vast array of aquatic resources.

These include fish and fiber, recreational opportunities, water purification, climate regulation, flood regulation, tourism. Loss of wetlands or degradation of water quality harms them directly. Therefore, restoration of the Beel is very much important for maintaining the bio-diversity.

Fish is an important component in people's diets, providing about 2.9 billion people with almost 20 percent of their average intake of animal protein(FAO, 2014). Fishery sectors are particularly important in developing countries, for providing both food and livelihoods. The Beel offer immense potential for increasing fish production, employment generation and several other additional source of income for the rural population of lower Assam.

Although, there are various agencies like Department of Fisheries, Forestry, Wildlife, Revenue, AFDC, CIFRI, NFDB etc having their individual roles in regulating the wetland resources of the state but in the case of UrpodBeel recently the state Government has taken an initiative in the development of the wetland. Therefore, if we can attract the attention of all the regulating bodies for the better scientific management and maintenance along with the introduction of culture based fishery than the fish production of the beel can be increased 3 fold i.e. upto 668 tonnes of fishes per year.

It is our considered opinion that the fish production of the beel can be augmented if the beel is taken under culture based fishery using proper scientific management framework. This will require support from the Government specially in (i) regulating the flow of flood water from river Brahmaputra, (ii) leasing the beel to the co-operative society with traditional (*Koiborta, Mahimal*) and trained fisher, (iii) strict enforcement of regulations (Indian Fisheries Act, 1897) regarding fishing access, period, time, type, mesh size, gears, encroachment and free riders, (iv) training the fisher about the recent scientific technique.

ACKNOWLEDGEMENT

The authors are thankful to the Principal, GoalparaCollege and Head Department of Zoology, GoalparaCollege, Goalpara for giving permission to conduct the basic survey work and using the laboratory.

REFERENCES

Alikunhi KH 1957. Fish culture in India, Farm Bull. *Indian Coun.Agric.Res.* 20: 1-144

ARSAC 1997. *Report of Wetlands of Assam, Assam Remote Sensing Application Centre*, Guwahati, Assam, India.

Baily R M, WinnHE,Smith C L 1954. Fishes from the Escambia River, Alabama and Florida, with ecologic and taxonomic notes.*Proc. Nat. Sci. Philadelphia*. 106: 109-164

Chandra G 2011. Management Regimes and Institutional Arrangement in Floodplain Wetlands Fisheries of Assam: An Evaluation.*Indian Journal of Extension Education*. 47(1-2): 27-33

Choudhury R, Das P, Goswami U C 2013. Abundance of Four Exotic Fish Species *Cyprinuscarpio*, *Ctenopharyngodonidella*, *Hypophthalmichthys molitrix* and *Aristichthysnobilis* in the UrpodBeel of Goalpara District of Assam.*International Journal of Applied Biology and Pharmaceutical Technology.* 4 (1): 303-307

CIFRI 2000. *Ecology and fisheries in beels of Assam*. Bulletin No. 104, Central Inland Fisheries Research Institute, Barrackpore, India, pp. 48

ClareS, Cyrille de K 1999. *Wetlands, Water and the Law. Using law to advance wetland conservation and wise use*. IUCN, Gland, Switzerland, Cambridge, UK and Bonn, Germany. xvi + 330 pp

DheerJMS 1988. Haematological, haematopoitic and biochemical response to thermal stress in an air-breathing freshwater fish *Channa punctatus* (Bloch, 1793).*J. Fish Biol*. 32: 197-206

DoddsW K2003. The role of periphyton in phosphorus retention in shallow fresh water aquatic system.*J.Phycol.* 39:840–849

Food and Agriculture Organization 2014. *Food and Nutrition in Numbers-2014*. FAO, Rome.

Gahlawat S K, Gupta R K, Yadava N K, Jain K L, Sihag RC,Sabhlok VP 2007. *Manual of Experimental Ichthyology.*Daya Publishing House, New Delhi, pp. 293

Ganapati SV 1940. The ecology of the temple tank containing a permanent bloom of Microcystisaeuruginosa (kuts) Henfry.*J. Bombay. Nat.Hist.Soc.*, 42 (1): 65-77

George MG 1966. Comparative plankton ecology of five fish tanks in Delhi. *Hydrobiologia*, 27 (1-2): 81-108

Jana BB 1973. Seasonal periodicity of plankton in a fresh water pond in West Bengal, Int. Rev. Gen.*Hydrobiologia,* 58 (1): 127-143

Jana BB, SarkarHD 1971. The limnology of Swatganga, a thermal spring of Bakraswar, West Bengal. *Hydrobiologia*, 37 (1): 33-47

Kaushik S, Saksena DN 1991. Physico-chemical limnology of certain waterbodies of central India. In: Vijaykumar, K. (ed.). *Freshwater Ecosystem of India*.Daya Publishing House, New Delhi. pp. 1-58

Michael RG 1969. Seasonal trends in physico-chemical factors and plankton of Fresh water fish pond and their role in fish culture.*Hydrobiologia*, 33 (1): 144-160

Millennium Ecosystem Assessment 2005.Ecosystems and Human Well-Being: Wetlands and Water Synthesis.World Resources Institute, Washington, DC

National Wetland Atlas: Assam 2010. SAC/RESA/AFEG/NWIA/ATLAS/18/2010, Space Applications Centre(ISRO), Ahmedabad, India, pp.174

Pandey BD, Das PKL, Dubey SV and Hussain S 1999. Biomonitoring of water quality of river Ramjan (at Kishanganj) in relation to its impact on biological components. In: Vijaykumar, K. (ed.). Freshwater Ecosystem of India. Daya Publishing House, New Delhi. pp. 310 - 336.

Raid G K 1961. *Ecology of Inland waters and Estuaries*. Reinhold Book Corp., New York

Sarma D,A Dutta 2012. Ecological Studies of two riverine wetlands of Goalpara District of Assam, India.*Nature Environment and Pollution Technology,* 11(2): 297-302

Saud B J, MChetia, V KVerma, D Kumar 2012. Eco-hydrobiology with Special emphasis on Ichthyofaunal Diversity of Urpod Wetland of Goalpara, Assam, India. *International Journal of Plant, Animal and Environmental Sciences,* 2 (3): 103-109

Scott DA1989, *A directory of Asian wetland*, IUCN, Gland, Switzerland and Cambridge

Sorensen D L, McCarthy M,Middlebrooks EJ, PorcellaDB 1977. Suspended and dissolved solids effects on freshwater

biota: A review. *US Environmental Protection Agency*, EPA-600/3-77-042

Spence DHN 1967. Factors controlling the distribution of freshwater macrophytes with particular reference to Scottish lochs. *J.Ecol.* 55: 147-170

Taylor EW 1949. *The examination of water and water supplies*. J. and A Churchill Ltd, London

Toepfer C, Barton M 1992. Influence of salinity on the rates of oxygen consumption in two species of freshwater fishes, *P erythrogaster* (family Cyprinidae), and *F catenatus* (Family Fundulidae), *Hydrobiologica*, 242: 149-154

Vass KK, Shrivastava NP, Katiha P K, Das A K 2009. Enhancing fishery productivity in small reservoir in India. A Technical Manual. WorldFish Center Technical Manual No. 1949. The WorldFishCenter, Penang, Malaysia. pp.19.Welch, P.S.(2003). *Limnological methods*. Narendra Publishing House. New Delhi, India. pp. xviii+381

Wheatly M G 1988. Integrated responses to salinity fluctuation, *Am.Zool*., 28:65-77

Zutshi DP, Vass KK 1978. Limnological studies on Dal Lake Chemical features. *Indian J.Ecol*,

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Economics of Shifting Cultivation in West Garo Hills District of Meghalaya

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ABSTRACT

The present study was undertaken in the West Garo Hills district of Meghalaya covering a total of 80 households under shifting cultivation which were selected through multistage random sampling procedure. The selected farmers were then stratified into two size group's viz. Group I and Group II based on area under shifting cultivation using Cumulative Root Frequency Rule. A total of 7 Crop Mixtures were identified being practiced by the sample farmers in the area. Cost of labour accounted for the highest expenditure in the total cost for all the groups. Across the various sizes of the farm growing different crop mixtures, the highest net return per hectare was found to be CM III (Rice + Maize + Vegetables + Ginger + Tubers + Cucurbits + Millet + Turmeric) at Rs. 63,343.00 in Group I farm and Rs. 57,070.00 for CM V (Rice + Maize + Vegetables + Ginger + Tubers + Cucurbits + Millet + Turmeric + Sesamum) in Group II farm.

Keywords: Shifting Cultivation, Crop Mixtures, Economics, West Garo Hills

INTRODUCTION

Shifting cultivation or *jhum* cultivation as it is more commonly known in India, is an agricultural system and occupies a distinct place in the tribal economy and constitutes a vital part of the life-style and socio-economic set-up of hill and tribal agriculture. This form of cultivation is regarded as a distinct stage in the evolution of agriculture. Essentially it involves clearing and burning of forests on the hill slopes, followed by cultivation of different crops often intermixed on the same plot.

After one or two years of cultivation, the land is abandoned for rest and a new site is selected to repeat the process. Thus, in shifting cultivation, farmers rotate land rather than crops to sustain livelihoods. In the Garo hills, shifting cultivation or *aba.oa*, has historically been the principal mode of agricultural production and a part of culture rather than of commerce. It is practiced in semi-evergreen forest in the upper reaches and moist deciduous forest at lower elevations. The *jhumming* or shifting agriculture in the district is characterized by dependence on rainfall, predominance of seasonal crops and traditional methods of cultivation. Among the seven districts of Meghalaya, the number of *jhumia* families in West Garo Hills district is maximum (18,086) and also the annual area under *jhum* cultivation is also highest at 155.45 sq. km (NIC, Meghalaya State Centre Shillong, 2001).

In the light of the above, a study was conducted to understand the economics of shifting cultivation in West Garo Hills district of Meghalaya to provide a broad basis in understanding the livelihood of the farmers.

MATERIALS AND METHODS

The present study was undertaken in West Garo Hills district of Meghalaya. The study was actually based on primary data of 240 sample households out of which 80 sample households belonged to purely settled cultivators, 80 sample households purely belonging to shifting cultivators and 80 sample households belonging to both settled and shifting cultivators. Multistage random sampling technique was adopted for selection of sample farmers. At the first stage, four C&RD Blocks of the district viz., Rongram, Dadenggre, Selsella and Gambegre were selected randomly. In the second stage, five villages were selected randomly from each C&RD Blocks. Then in the final stage, 4 numbers of farmers for each selected villages of those growing only settled or only shifting or only both type of cultivation was prepared after consulting with the village headman. From the list of farmers, 80 settled cultivators, 80 shifting cultivators and 80 cultivators practicing both types were selected based on random sampling. Thus a total of 240 samples were stratified into three groups viz., Group I (0.00–0.39), Group II (0.40 - 0.92), and Group III (0.93 and above) based on area under settled, shifting and both type of cultivation by using

Cumulative Root Frequency Rule. Data pertained to the year 2012-2013 and were collected from the sample households by interview method using structured schedules.

Accordingly, the 80 sample farmers under shifting cultivation which was stratified into groups are presented in Table 1.

Table 1: Distribution of sample farmers under shifting cultivation

Category of Farmers	Land holding (ha)	Number of selected farmers under shifting cultivation
Group I	0.00-0.39	61
Group II	0.40-0.92	19
Group III	0.93 and above	0
Total		80

RESULTS AND DISCUSSION

In this section, discussions on costs and return of various crop mixtures have been made. However, before evaluating the profitability, the various crop mixtures raised by the farmers under shifting cultivation were identified and presented in Annexure I.

A. Crop mixtures of Group I farmers

Table 2 indicated that cutting, clearing of stumps; fire structure; cleaning; planting material; equipment; sowing; weeding; harvesting; marketing; other cost include milling were the major components of production cost in various crop mixtures under shifting cultivation. Out of these components, weeding accounted more than 25 percent of the total costs in all the crop mixtures. The highest total cost was observed in Crop Mixture VII (Rs. 1,34,197.00) which might be due to larger crop mixtures cultivated by few of the sample farmers. Further, the table revealed that labour cost accounted the highest share in the total cost in all the crop mixtures.

The net return from the various crop mixtures of Group I farms for CM I, CM II, CM III, CM IV, CM V, CM VI, CM VII were estimated at Rs. 36,079.00, Rs. 48,815.00, Rs. 63,343.00, Rs. 54,807.00, Rs. 62,134.00, Rs. 53,941.00

and Rs. 48,638.00 respectively. The highest net return was found in case of CM III. This might be due to higher profitability of vegetable crops in CM III as compared to other crop mixtures.

B. Crop mixtures of Group II farmers

The costs and return of various crop mixtures raised by the sample farmers of Group II farms is presented in Table 3. From the table it is found that the per hectare total costs of various crop mixtures of Group II farms did not have much variation. The highest total cost was found to be in CM III (Rs. 80,266.00) and the least was for CM I (Rs. 79,988.00). This might be due to the fact of growing more number of vegetable crops by the sample farmers in the given particular group which may have resulted in higher cost per farm. Further, the Table revealed that labour cost accounted the highest share in the total cost in all the crop mixtures.

The net return from the various crop mixtures of Group II farms for CM I was Rs. 42,725.00, Rs. 57,439.00 for CM III, and Rs. 57,979.00 for CM V. The highest net return was found in case of CM V which might be due to inclusion of more numbers of crops in the crop mixture as compared to other crop mixtures.

Table 2: Item Wise break-up of Per Hectare Production Cost and Returns (Rs.) in Various Crop Mixtures of Group I Farms under Shifting Cultivation

Item	**CM I**	**CM II**	**CM III**	**CM IV**	**CM V**	**CM VI**	**CM VII**
1. Cutting, clearing of stumps	13774 (13.54)	13746 (14.45)	11896 (12.86)	17500 (13.77)	14488 (12.98)	13359 (12.77)	19737 (14.71)
2. Fire structure	2548 (2.51)	1956 (2.06)	1906 (2.06)	3688 (2.90)	2462 (2.21)	2438 (2.33)	3118 (2.32)
3. Cleaning	6250 (6.15)	5924 (6.23)	4896 (5.29)	6688 (5.26)	6069 (5.44)	5625 (5.38)	9434 (7.03)
4. Planting material	8416 (8.28)	9819 (10.33)	11014 (11.90)	9145 (7.20)	11361 (10.18)	11462 (10.96)	9200 (6.86)
5. Equipment	8228 (8.09)	6903 (7.26)	5555 (6.00)	10513 (8.27)	7179 (6.43)	7341 (7.02)	11321 (8.44)
6. Sowing	12261 (12.06)	11503 (12.10)	13313 (14.39)	18938 (14.90)	16221 (14.53)	14719 (14.08)	16934 (12.62)
7. Weeding	28424 (27.95)	24875 (26.16)	22958 (24.81)	33500 (26.36)	27192 (24.36)	26719 (25.55)	32289 (24.06)
8. Harvesting	17197 (16.91)	15385 (16.18)	14865 (16.06)	22500 (17.70)	18697 (16.75)	16453 (15.73)	24039 (17.91)
9. Marketing	4039 (3.97)	4268 (4.49)	5229 (5.65)	3697 (2.91)	6839 (6.13)	5534 (5.29)	6797 (5.07)
10. Other cost	573 (0.56)	725 (0.76)	906 (0.98)	938 (0.74)	1118 (1.00)	928 (0.89)	1326 (0.99)
11. Total cost	101709 (100)	95104 (100)	92538 (100)	127105 (100)	111626 (100)	104578 (100)	134197 (100)
12. Gross return	137788	143919	155881	181912	173760	158519	182835
13. Net return	36079	48815	63343	54807	62134	53941	48638

Figures in parentheses indicate percentages to total cost

Table 3: Item Wise break-up of Per Hectare Production Cost and Returns (Rs.) in Various Crop Mixtures of Group II Farms under Shifting Cultivation

Item	**CM I**	**CM II**	**CM III**	**CM IV**	**CM V**	**CM VI**	**CM VII**
1. Cutting, clearing of stumps	10250 (12.81)	-	10042 (12.51)	-	10031 (12.54)	-	-
2. Fire structure	1406 (1.76)	-	1661 (2.07)	-	1551 (1.94)	-	-
3. Cleaning	3750 (4.69)	-	3778 (4.71)	-	3635 (4.54)	-	-
4. Planting material	7751 (9.69)	-	10659 (13.28)	-	10023 (12.53)	-	-
5. Equipment	3981 (4.98)	-	3871 (4.82)	-	3541 (4.43)	-	-
6. Sowing	14719 (18.40)	-	13583 (16.92)	-	13356 (16.69)	-	-
7. Weeding	20563 (25.71)	-	18431 (22.96)	-	18707 (23.38)	-	-
8. Harvesting	12625 (15.78)	-	12556 (15.64)	-	13558 (16.95)	-	-
9. Marketing	4268 (5.34)	-	4677 (5.83)	-	4798 (6.00)	-	-
10. Other cost	675 (0.84)	-	1058 (1.32)	-	814 (1.02)	-	-
11. Total cost	79988 (100)	-	80266 (100)	-	80012 (100)	-	-
12. Gross return	122713	-	137705	-	137991	-	-
13. Net return	42725	-	57439	-	57979	-	-

Figures in parentheses indicate percentages to total cost

CONCLUSION

The above discussion highlighted that there are seven crop mixtures raised by the sample farmers. Labour cost accounted the highest share in the total cost per hectare in all the crop mixtures which was similarly reported by Saikia *et al.*, (1971) in hill villages in North East India. Across the various sizes of the farm growing different crop mixtures, the highest net return per hectare was found to be CM III (Rice + Maize + Vegetables + Ginger + Tubers + Cucurbits + Millet + Turmeric) at Rs. 63,343.00 in Group I farm and Rs. 57,070.00 for CM V (Rice + Maize + Vegetables + Ginger + Tubers + Cucurbits + Millet + Turmeric + Sesamum) in Group II farm.

REFERNCES

Chauhan BS 2001. Shifting Cultivation in Perspective. Nagaland University Publication, Kohima, Nagaland. p.4

Choudhury D, Sundriyal R 2003. Issues and Options for improving livelihoods of marginal farmers in Shifting Cultivation areas of Northeast India. *Outlook in Agriculture* 32: 17-28

Mishra BK, Ramakrishna PS 1981. The economic yield and energy efficiency of hill agro-ecosystem at higher elevation of Meghalaya. *Indian Journal of Agricultural Economics*: 40-45

Ninan KN 1992. Economics of Shifting Cultivation in India. *Economic and Political Weekly*. 27 (13): A2-A6

Ramakrishnan PS 1992. Shifting Agriculture and Sustainable Development: an interdisciplinary study from north-eastern India. MAB Series, Vol. 10, UNESCO, Paris

Saikia PD, Bora D 1971. Pattern of crop production under shifting and settled cultivation – a study in Garo hills, Meghalaya. *Indian Journal of Agricultural Economics*, Vol.43

Shah SL 1971. Farming systems in hill areas. *Indian Journal of Agricultural Economics*. 40 (3): 65-70

SHORT COMMUNICATION

Transfer of Technology in Hill Agriculture

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ABSTRACT

Hill agriculture by default is characterized by complex, diverse and risk-prone. The farmers are small and marginal and about 80% of the population depends on agriculture for their livelihood. So, the agricultural productivity needs to be enhanced several fold with the help of appropriate technology development and transfer, for which, there is a need to understand the environment under which the technology has to operate and have some basic information of the agro ecological zone. There are different models of technology transfer which may be used according to the local situation for transfer of technology. Even, there are several factors like agro-ecological, political, cultural, educational, etc. which has to be taken into consideration for effective and successful transfer of technology. Today, KVK has become the best institution for technology transfer in a district. The KVK is the knowledge repository in a district. The KVK has a role of assessment, refinement and demonstration of a technology. So, the KVK, scientists, extension workers and also the government need to join hand for overcoming the constraints taking into account the farmers perspective for effective transfer of technology in the hills.

Keywords: Technology transfer, Hill agriculture, Agro-ecological zone, KVK.

Agriculture is the key sector of Indian economy. The sector contributes 18.6% to the National GDP (IMF, 2006). The growth rate of agriculture sector has been 2% in last few years. Only, this year it has risen to 4.8%. Even though 57% of the total work force of the country is engaged in agriculture and allied activities and today, the Indian agriculture is faced with the challenge of providing adequate and sustained livelihood to over 103 million farm families. Hilly region is characterized by fragility, marginality and inaccessibility

and the hill agriculture is complex, diverse and risk-prone. The farmers are small and marginal and about 80% of the population depends on agriculture for their livelihood. The basic issues facing hill agriculture are small land holdings, low cropping intensity, low productivity, inadequate access to appropriate technologies and other external inputs, irrigation facilities, increased natural calamities etc. Even with these adverse condition, to bring food self sufficiency in the hills and to feed the ever increasing human population, the agricultural productivity needs to be enhanced several fold with the help of appropriate technology development and transfer.

Hill agro-ecological zone

Agro ecological zones are commonly described by a combination of climatic and soil characteristics with special and temporal variability. Hill agro ecological zone includes the following production system and unsustainability issues and indicators.

AEZ	**Prod. Systems/ Commodities**	**Unsustainability Issues**	**Unsustainability Indicators**
Hill agro ecological zone	Potato Maize Barley Medicinal plants Livestock Pasture Horticulture Plantation crops Spices Roots and tubers Horticulture, Rice, wheat Dairy cattle Agroforestry Coffee, tea Ornamental plants Shifting cultivation	Land tenure Accessibility & marketing Fragility Limited technological choice Deforestation	Loss of forest cover Run off/soil erosion Reeduced water retention capacity Soil acidity Loss of biodiversity Downstream flooding and sedimentation Poverty Incidence of shifting cultivation

This un-sustainability issues should be taken into consideration while developing any technology and formulating any strategy to increase the agricultural productivity of the region.

Issues related to Technology generation and transfer

Technology generation consists of planning, administration and implementation of research activities that develop, assess, adapt and test improved agricultural technology for farmers and other users. For development of agricultural technology there is a need to understand the environment under which the technology has to operate and have some basic information of the agro ecological zone (FAO, 1996). They are as follows:

- AEZ (Agro-Ecological Zones)
  - Climate data
    - Rainfall means and distribution
    - Temperature
    - Solar radiation and day length
    - Length of growing period.
  - Topography.
  - Altitude
    - Resource endowment
  - Soil data
    - Soil type
    - Water holding capacity
    - Underground water
    - Fertility: high/low
    - Biodiversity (flora and fauna)
    - Farm enterprise (crops and animals)
    - pecies (indigenous spp.)
    - Socio-economic factors
    - Population, density
    - Type of agriculture practised
    - permanent
    - shifting

- nature of enterprise: commercial, semi-commercial, subsistence
- Infrastructure
- Information system
- Access to land
- Access to credit
- Access to markets
- Access to other support services
- Access to water
- Access to inputs

Technology transfer means a system under which various inter-related components of technology, namely, "hardware" (materials such as a variety), "software" (technique, know-how, information), humanware (human ability), "orgaware" (organizational, management aspects) and the final product (including marketing) are rendered accessible to the end-users (farmers) (FAO, 1996). Technology transfer also includes issues concerning the ultimate acceptance and use of the technology. So, the technology transfer implies that a technology has not been successfully transferred until it has been accepted and used by the end users. Several issues should be considered while transfer of agricultural technology which are as follows:

In its most basic form, the technology transfer triangle includes the transfer item itself, the developer of the technology, various channels to accomplish the transfer, and the technology recipient (Ahmed, 2009).

According to the above conceptual approach to technology transfer, several issues should be considered:

The process used to transfer a technology influences the success of the transfer (Johnson *et al.*, 1999). This process is described as models of transfer.

Regardless of the degree of technology development within any institution, the technology providers must have a linkage policy that defines its degree of commitment to interaction with the end users and transfer agencies (Ahmed, 2005; Eponou, 1996)

The end users should be the principal consideration in the design of technologies. Through early and regular

contact with the end users, technologies can be developed that suit their needs.

This interactive development becomes even more important when differing cultural and social values are involved. Without sensitivity for the needs of the end users and recognition of the environment in which the technology will ultimately be used, the transfer will be a difficult process (Ahmed *et al*., 2003).

Technology does not stand alone, but encompasses political, social, economic, and cultural values that can serve as barriers to the diffusion or transfer of technology. These barriers exist for all innovations, but some transfers are more affected than others.

The appropriateness of technology seems to have a significant impact on its ability to overcome transfer barriers. **Appropriate technology** refers to a technology package which must be technically feasible, economically viable, socially acceptable, environment-friendly, consistent with household endowments, and relevant to the needs of farmers. The concept is a dynamic one and the elements of appropriateness will vary over time and space. Thus technologies are subject to adjustment, change and evolution. The assumption is that the characteristics of a technology underlying a user ecological, socio-economic and institutional context play the central role in the adoption decision and diffusion process (Biggs, 1990; Scoones and Thomson, 1994). Another way to consider the appropriateness of a technology is to examine its characteristics (Ahmed *et al*., 2003; Ahmed, 2003).

Successful technology transfer is not achieved through the simple movement of technology to a new environment; it requires the development of a process and infrastructure that will help the technology break through the different barriers. Communication is a key element in the transfer process. If researchers develop a new technology but the end users are not aware of it, this new technology will never reach its intended end users. Transfer requires human intervention for a technological innovation to become part of a larger system. Transfer agencies are therefore the most important communication channel that supports the transfer process. Linkages between research institutions and transfer agencies are vital.

The availability of funding greatly influences the transfer of technology (Ahmed, 2005a)

The timing of the transfer is critical and an important factor in the success or failure of an innovations ability to progress from the technological activity output phase to beneficial use. The optimum time when the innovation is needed will also help to overcome the transfer barriers.

The process of technology transfer should take place in a continuous progression over time. The stages include: importation of technology and application; compatibility stage, including the adaptation of new technology to the local environment, labour force, raw material, and so on; establishing the supporting technologies by producing some tools internally in order to modify and develop the imported tools and equipment; and finally the production of new technologies by the simple mixing of what is available locally or by the new addition of an independent new technology.

Technology transfer models

There are three major models of technology transfer. The first is the typical top down conventional model. Second is the feedback model which considers the reaction of the farmers. And third is the participatory model which takes into account the farmers participation in technology development and transfer.

Conventional model:

In this model technology generation is done without the involvement of farmers and extension workers. The farmers are seen as only the passive recipient of the technology. The extension workers role is only to motivate the farmers to adopt the technology. No consideration is taken into account to solve the problems of the farmers. This model was evident in green revolution where the aim was only to increase the production of food grain.

Feedback model:

This model considers the farmers orientation in the technology development in the mode of feed back of the farmers toward a technology. It emphasized on the technology development for solving the problems of the farmers. The technology is evaluated both in the research station as well as in the farmer's field. Here the farmer's role is consultative in nature. The initiative, inquisitiveness and wisdom of the farmers are not taken into account.

Farmers' participatory model:

This is the most recent and effective model which take into consideration the active participation of the farmers in development and transfer of technology. It is the joint venture by the researchers

and the farmers to solve the problems of the farmers with the help of farmer's wisdom. Here the farmer's role is collaborative in nature. It is farmers oriented and non-perspective. Participatory technology development is the best example of this model.

The role shifting model: A New Model of Technology Transfer

A country's competitive advantages increasingly lie in its capabilities to generate further innovations and to use effectively new technology, which is generally a function of the capacity of its population to absorb new technologies and incorporate them into the production process (Kolfer & Meshkati, 1987). This implies that a successful transfer of technology has a large impact on the advancement of a nation and it significantly depends on the capacity of people to assimilate, adapt, modify, and generate new technology. Consequently, educational infrastructure to develop "human capital" is the basic component for a successful technology transfer. After accumulating a high quality of human capital, a recipient of technology should develop an elaborate plan to increase the willingness of both the recipient and the donor of technology transfer. This plan could facilitate the transfer of technology by strengthening the collaboration between the donor and the recipient. Lastly, the recipient should be able to generate new innovations based on the successful transfer of technology. This model can be shaped as shown in Figure 1.

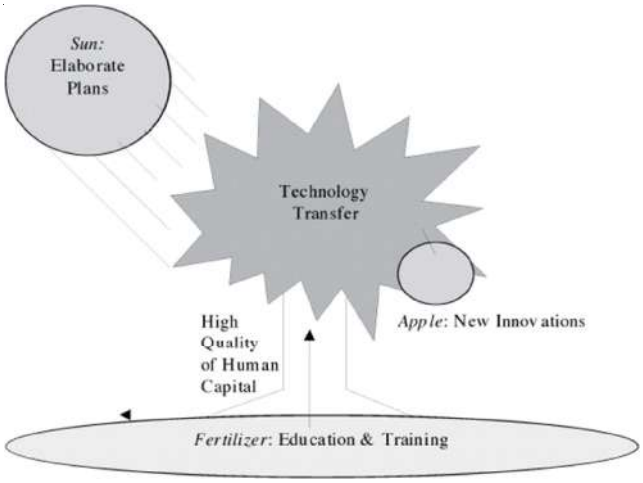

Figure 1. The role shifting model of technology transfer (*Choi, 2009)*

This figure is titled "the role shifting model of technology transfer" because its ultimate goal is to generate new innovations. This model depicts how recipients of technology in 2009 can be tomorrow's donors of technology: It shows the conditions that enable fruit to ripen or in other words, new innovations. Thus, a high level of continuing education and training results in the role of fertilizing or helping an apple tree (technology transfer) grow well. In addition, elaborate plans for collaboration between recipients and donors help achieve successful technology transfer as either sun or rain is helpful for the growth of a tree. Consequently, farmers who are recipients of technology will be able to produce a plenty of fruit (new innovations) based on a high level of continuing education and training (fertilizer) and elaborate plans that play a role of sun and rain.

Factors for successful transfer of technology in hill agriculture

Agro-ecological: As much as the agro ecological situation of mountain ecosystem is taken into consideration while developing and transferring the technology much faster will be the rate of transfer and adoption. The technology needs to suit to the specific agro climatic condition of the hill region.

Political: The political change in the national and state level leads to the change in policy related to technology transfer which slower the rate of technology transfers.

Cultural: Hill regions are mainly inhabited by different group of tribals who have their own culture. The culture of each tribal community has to be considered for effective transfer of technology.

Education: Most of the farmers in hills are illiterate or semi-illiterate. So, the technology should be presented to them so that they can easily understand every tits and bits of technology.

Gender: Hill agriculture is dominated by women farmers. So for effective transfer, the technology should be women friendly.

Farm size and risk taking ability of the farmers: The land holding and farm size is small or marginal in hilly areas. So, the risk taking ability of the farmer is low, which impedes the rate of technology transfer.

Access to credit and quality inputs: Availability of critical inputs as well as credit facilities is not available near the farmers door step. Moreover, the farmers in the hills are not economically sound. So, the technology should be low input intensive for effective transfer.

Transportation: Remote areas in the hilly region cannot be reached by the extension workers due to no or poor road condition. This will not only impede the transfer of technology but also supply of critical inputs and marketing of technological products.

Land tenure system: The jhum land in many parts of the hilly region is owned by the village heads. So, before convincing the farmers, the village heads should be convinced for effective transfer of technology.

Communication: Tribal farmers of the hilly region speak different languages. More over their access to mass media may be limited thus reducing the options for the extension workers for the transfer of agricultural technology.

Unorganized marketing: Non availability of regulated market in hilly areas distress sells of the technology products. This makes the farmers sceptical in adopting new technology in future.

KVKs and technology transfer: Some thoughts

Today, KVK has become the best institution for technology transfer in a district. The KVK is the knowledge repository in a district. The KVK has a role of assessment, refinement and demonstration of a technology.

KVK is conducting On farm trials (OFT) to assess the location specificity of the technology. But most of us are confused about the OFTs. OFT is multidisciplinary in nature but we assign a particular discipline to it. For, example, OFT on assessment of a new paddy variety is assigned to the discipline of agronomy. But, in reality for effective OFT, the planning and designing is to be done by agricultural extension personnel right from identification of the problem, preference of the farmers regarding the new paddy variety, collection of feedback from the farmers regarding the varieties under OFT. Moreover, during any disease or pest infestation, the plant pathology or plant entomology personnel have to take part in the trial. So, OFT should be multi disciplinary and the steps of conducting OFT should be adhered to, for effective transfer of technology. Further, we are afraid of reporting the negative result of a trial. But, it may serve as a basis for some new research, if the critical analysis is done to find out the cause of the failure of the technology.

Frontline demonstration (FLD) is conducted by the KVKs to show the

production potential of the technology. New technology not more than 5 years old can only be taken up in FLD. But if there is no proper substitute of an older technology suitable for a particular micro agro climatic situation, the older technology but new to that area may be taken up for effective transfer and adoption of the technology. Moreover, after conducting FLD, the availability of the critical inputs should be ensured for continuous use of the technology by the farmers, may be by producing the technology products in KVK farm and supply to the farmers and also creating a linkage between the farmers, input dealers and market.

In any OFT or FLD we calculate the B: C ratio on the basis of the total production and expected market price of the product. We do not consider the actual price the farmer is getting by selling the products and the total amount of the product sold. This leads to the wrong interpretation of the actual condition.

KVK is supposed to impart skill training to the farmers. But most of the trainings are for one day and remains to be of awareness type, which hampers the adoption of a technology. For example, training on grafting of mango is imparted for one day with some audio-visual presentation and some practical session to show the method of grafting to the farmers. But, the farmers need to do the grafting by them several times so that they gain self confidence and the training is not completed until that time. Moreover, the training need assessment, design and content are very important for an effective training.

It may be concluded that technology transfer in hill agriculture is a difficult task for the scientists and extension worker due to several biophysical and socio-economic constraints. Considering the above constraints, ICT can play a vital role in quick and effective transfer of agricultural technology in the hilly areas. The scientist, extension workers and also the government need to join hand for overcoming the constraints taking into account the farmers perspective for effective transfer of technology in the hills.

REFERENCES

Ahmed A 2003. Technology Management in the Sudan: Strategic and Policy Challenges, *Management Decision* 41(3):267-73 Emerald, Bradford: UK

Ahmed A 2005. Sustainable Development and Technology Transfer Opportunities in the Sudan,

International Journal of Technology Transfer and Commercialization, 4(4): 421-438. Inderscience, Geneva: Switzerland

Ahmed A 2005a. The Impact of Finance and Funding on Technology Adoption in Africa, *Journal of African Development*, 7(1):20-41. New York University, John Hopkins, NY: USA

Ahmed A 2009. Understanding the concept of technology transfer and sustainable development in Sudan: An overview. Presented in "The role of diaspora in technology transfer and achieving sustainable development in Sudan", Brighton, UK, 24-25th January, 2009

Ahmed A, Adams J and Newton J 2003. Designing Appropriate Technology in Rural Sudan - End User Considerations and Strategic Change. *In Dimensions of African Business and Development*, edited by S. Nwankwo *et al*. Sheffield Hallam University Press, Sheffield: UK, pp. 375-97

Biggs SD 1990. A multiple source of innovation model of agricultural research and technology promotion, *World Development*, no. 18, pp. 1481–99

Choi HJ 2009. Technology Transfer Issues and a New Technology Transfer Model. *The Journal of Technology Studies*. Retrieved from http://scholar.lib.vt.edu/ejournals/JOTS/v35/v35n1/pdf/choi.pdf

Eponou T 1996. Linkages between research and technology users in Africa: The situation and how to improve it, briefing paper no. 31, *ISNAR*

FAO 1996. Technology assessment and transfer for sustainable agriculture and rural development in the Asia-Pacific Region. Retrieved from http://www.fao.org/sd/rtdirect/rtre0019.htm

Johnson S Gatz EF and Hicks D 1999. Expanding the Content Base of Technology Education: Technology Transfer as a Topic of Study. University of Illinois

Kolfer VL and Meshkati N 1987. Transfer of technology: Factors for success. *In M. J. Marquardt (Ed.), Corporate culture: International HRD perspectives* (pp. 70-85). Alexandria, VA: American Society for Training and Development

Scoones I and Thomson J 1994. Knowledge, power and agriculture – towards a theoretical understanding in Scoones, I. and Thomson, J. (eds) *Beyond Farmer First: Rural Peoples' Knowledge and Extension Practice*, Intermediate Technology Publications, pp. 16–32.

Traditional Knowledge on Ethnomedicines-A potential area of Research among Garo Tribe

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ABSTRACT

Traditional medicines play a vital role in the discovery of novel therapeutic agents from plants. In ancient India, almost all medicines were derived from biological resources. Indigenous knowledge of plants forms the bulk of ethnomedicine which is being practiced in India and other parts of the world since time immemorial. This traditional knowledge, which is mostly not documented, is transmitted orally from generation to generation. Tribal societies all over the world use an enormous range of wild plants for food, fiber, medicine etc. The Garo traditional healthcare practitioners locally known as 'Ojhas' use various ethnomedicinal plants for preparation of indigenous medicines. Medicinal plants which were once easily collected from forests are facing an increased risk of extinction due to unscrupulous deforestation, rapid urbanization, climate change etc. Extinction of plant species could result in eradication of invaluable information regarding centuries old traditional methods of healthcare. Thus conservation of plant species and the traditional knowledge on ethnomedicinal plants in particular has become imperative. Although few researchers have documented the use of medicinal plants from various parts of the country and abroad, systematic investigation and documentation of the medicinal plants used by the Garo tribe is still in its infancy. Therefore, detailed research and documentation on ethnomedicines and their traditional usage among the Garo tribe needs adequate attention.

Keywords: Traditional Knowledge, Ethnomedicine, Garo tribe

Ethnomedicine is a set of empirical local practices rooted in the indigenous knowledge of a social group often passed on from generation to generation with intent to understand social, cultural, and economic factors influencing health problems and to overcome such problems.Ethnomedicine is an area of research that deals with medicines derived from plants, animals, minerals, etc. and used in the treatment of various diseases and ailments, based on indigenous pharmacopoeia, folklore and herbal charms (Weiner, 1971). It is a suitable source of information regarding useful medicinal plants. Ethnomedicine consists of those beliefs and practices relating to disease which are products of indigenous cultural development. Ethnomedicine is the mother of all modern drugs and recently the importance of these traditional knowledge based medicines are being recognized throughout the world.Traditional knowledge is the knowledge that has been developed based on certain tradition of certain tribal groups i.e. culturally rooted or culturally oriented. The World Health Organization (WHO) defined traditional medicine as "the sum total of the knowledge, skills, and practices based on the theories, beliefs, and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health as well as in the prevention, diagnosis, improvement or treatment of physical and mental illness"(WHO, 2000).Information from ethnic groups on indigenous traditional medicines had always played a vital role in the discovery of novel therapeutic agents from plants. Traditional medicines or ethnomedicines have recently been receiving lot of attention world over. In ancient India; nearly all medicines were derived from biological resources. Even in modern India as much as 67-70% of medicines are derived from natural resources (Anon., 2001).

The use of plants as a source of medicine against various ailments is perhaps, as old as human existence on this planet earth. Initially, indigenous knowledge of plants formed the bulk of folk-medicine or ethnomedicine which is being practiced in India and other parts of the world. Later, a part of this indigenous knowledge were studied, documented and eventually passed into the organized systems of medicine, such as Ayurveda, Unani and Sidha (Singh *et al*., 2013). Several ethnic groups, more precisely the tribal communities are using the botanical treasure of mother earth not only for food and sustenance, but also for treating

various kinds of ailments and diseases. Similarly tribal communities of the north-eastern states of India, Chhattisgarh, Jharkhand, Orissa and Andaman have their own knowledge of medicinal plants and trees and use them to utmost effectiveness in treating various diseases and ailments. Changes in lifestyle brought about by globalization have led to abandonment of traditional practices with a simultaneous loss of related traditional knowledge. Up to 70% of the rural population still depends on traditional medicine as a primary healthcare source (Guptaand Vairale, 2010).

Garo Hills is a rich reserve of natural flora and fauna. These hills are home to Nokrek Biosphere Reserve, Balpakram Wildlife Sanctuary, Siju Wildlife Sanctuary and Baghmara Pitcher Plant Sanctuary. The abundant natural flora of Garo Hills have led to the adoption of traditional methods of treatment of diseases by the Garo tribe with the use of roots, leaves and stems of certain plants.They use many plant species for healthcare practices and have enormous knowledge about their medicinal usage. More than 80 plant species have been identified as popular medicinal plants used by the Garo tribe of the West Garo Hills district (Singh, 2014). Traditional knowledge, which is mostly not documented, is transmitted orally from generation to generation. The utilization of plants by Garo tribe for a variety of purposes from food to medicine is area specific and culture specific. Since rural areas inhabited by the Garo tribe remained underdeveloped due to poor communication system, they have been closer to nature deriving most of their basic needs from nature. Like many other tribal population, the Garo tribe too have intimate association with nature and knowledge of plants and their uses (Singh *et al.*, 2016). Local herbalists or traditional health practitioners or traditional medicine men,who are highly learned in the knowledge, skill and practices of traditional medicine are known as 'Ojhas' among the Garo tribe. The faith of large number of people in the herbal medicines prepared by the Ojhas is unshakable and most of them believe that they produce more results than chemical treatments given in modern hospitals. In Garo hills the traditional health care system was functioning individually till 1989 when Meghalaya Sam Achik Association came into existence with around 300 Ojhas registered as members. During the year 2011, a traditional health care clinic was established in Tura in the name of Sam

Achik Sikram. The registered Ojhas attend to patients in this clinic. Although the rich indigenous knowledge on medicinal use of plants has been relatively well documented in other ethnic groups, very little work has been done among the Garo tribe.

The tribal societies and cultures are themselves disappearing and with them, their indigenous knowledge on ethnomedicines. Thus conservation of plant resources in general and ethnomedicinal plants in particular has become imperative. In order to avoid a catastrophic loss of knowledge we should conserve what we have now. India enjoys a rich collection of plant medicine industry in Asia, but key species have declined due to over-collection from the natural habitat to meet the ever increasing demand of the domestic and foreign medicinal markets. Medicinal plants which were easily obtained from forests during ancient times now face an increased risk of extinction due to unscrupulous deforestation, rapid urbanization etc. Therefore, extinction of endangered species could result in eradication of information regarding centuries old traditional methods of curing diseases from medicinal plant species.

In every ethnic group there exists a traditional health care system, which is culturally patterned and it is their faith that holds them to continue herbal treatment. Tribal societies all over the world use an enormous range of wild plants for food, fiber, medicine etc. However, very little attention is paid towards the conservation of those plants that they harvest every day. Little do they realize that the plants that they need for their livelihood is on the verge of extinction. Therefore, suitable measures need to be taken in the direction of conservation and sustainable management of natural resources. Although various researchers have documented about the medicinal plants from various regions of the world, systematic investigation among the Garo tribe on application of medicinal plants against different ailments is still in its infancy. Detailed research and documentation on ethnomedicines and their traditional usage among the Garo tribe needs adequate attention.

REFERENCES

Anonymous 2001. *State Forest Report*, West Bengal, Directorate of Forests, Government of West Bengal, Kolkata.

Gupta R and Vairale MG 2010.Ethnomedicinal uses of some plants used by Gond tribe of

Bhandara district, Maharashtra.*Indian Journal of Traditional Knowledge.* 9(4):713-717

Singh KD 2014.An ethnobotanical study of wild edible plants among Meitei and Garo people of North East India. Ph.D. thesis submitted to the North Eastern Hill University, Meghalaya.

Singh, KD, Mathew B and Mohan R 2016.Nutraceutical usage of wild edible plants among the Garo tribe of Meghalaya, India.*International Journal of Science, Environment and Technology*. 5(5):2959-2965.

Singh MP, Srivastava JL and Pandey SN 2013.*Indigenous Medicinal Plants, Social Forestry and Tribals*.Daya Publishing House, DRYA Ganj, New Delhi- 110002.

Weiner, MA 1971. Ethnomedicine in Tonga. *Economic Botany.* 25:423-450.

WHO 2000.*General guidelines for methodologies on research and evaluation of traditional medicine*. World Health Organization, Geneva.

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