

**ALGAL STUDIES ON THE DIVERSITY AND
DISTRIBUTION OF BLUE GREEN ALGAE (BGA) FROM
SELECTED PADDY FIELD HABITATS OF GOA**

**Thesis submitted to
Goa University
for the Award of Degree of**

**DOCTOR OF PHILOSOPHY
IN
BOTANY**

**by
Ms ANNIE F. D'SOUZA E GOMES. M. Sc.**

Research Guide

**Dr. A. V. VEERESH, M. Sc., Ph. D.
Associate Professor, Department of Botany,
Smt. Parvatibai Chowgule College of Art's & Science
Margao- Goa.**

Co- Guide

**Dr. B. F. RODRIGUES, M.Sc., Ph. D.
Professor, Department of Botany,
Goa University.**

**UGC-SAP DEPARTMENT OF BOTANY
GOA UNIVERSITY**

2012

DECLARATION

I hereby declare that the thesis entitled “**ALGAL STUDIES ON THE DIVERSITY AND DISTRIBUTION OF BLUE GREEN ALGAE (BGA) FROM SELECTED PADDY FIELD HABITATS OF GOA**” submitted to Goa University, for the award of **DOCTOR OF PHILOSOPHY IN BOTANY** is a record of original work carried out by me in the Department of Botany, Smt. Parvatibai Chowgule College of Arts & Science, Margao under the supervision of **Dr A. V. VEERESH**, Associate Professor, Department of Botany, Smt. Parvatibai Chowgule College of Arts & Science, Margao and **Dr. B. F. RODRIGUES**, Professor, Department of Botany, Goa University and that the thesis has not previously formed the basis for the award of any Degree, Diploma, Associate-ship or fellowship or any other similar title to any candidate of this or any other University.

Signature of the student
(Ms Annie F. D’Souza e Gomes)

Signature of the Guide
(Dr. A. V. Veeresh)

Signature of the Co-guide
(Dr. B. F. Rodrigues)

CERTIFICATE

We certify that the thesis entitled “**ALGAL STUDIES ON THE DIVERSITY AND DISTRIBUTION OF BLUE GREEN ALGAE (BGA) FROM SELECTED PADDY FIELD HABITATS OF GOA**” submitted to Goa University, for the award of **DOCTOR OF PHILOSOPHY IN BOTANY** is a record of original work carried out by **MS ANNIE F. D’SOUZA E GOMES** in the Department of Botany, Smt. Parvatibai Chowgule College of Arts & Science, Margao during the period of May 2006 to April 2012 under our supervision and that the thesis has not previously formed the basis for the award of any Degree, Diploma, Associate-ship or Fellowship or any other similar title to any candidate of this or any other University.

Signature of the Guide

(Dr. A. V. Veeresh)

Associate Professor,

Department of Botany,

Smt. Parvatibai Chowgule College of Art’s & Science

Margao- Goa.

Signature of the Co-guide

(Dr. B. F. Rodrigues)

Professor,

Department of Botany,

Goa University.

Countersigned:

Dedicated to my...
....Late parents



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CONTENTS

1	INTRODUCTION	1-20
2	REVIEW OF LITERATURE	21-25
3	METEOROLOGICAL DATA AND PHYSICO-CHEMICAL ANALYSIS OF SOIL AND WATER FROM THE STUDY SITES	26-66
4	BLUE GREEN ALGAE (BGA) FROM PADDY FIELDS OF GOA	67-130
5	DENSITY AND DIVERSITY OF BLUE GREEN ALGAE (BGA) IN PADDY FIELDS OF GOA	131-168
6	EFFECT OF ALGAL BIOFERTILIZERS ON GROWTH AND YIELD OF <i>ORYZA SATIVA</i> L. (VAR. JAYA)	169-193
7	EFFECT OF LOCALLY USED COMMERCIAL FERTILIZERS ON BGA	194-239
8	EFFECT OF PESTICIDES ON BLUE GREEN ALGAE	240-282
9	SUMMARY	283-289
10	CONCLUSION	290-291
	REFERENCES	292-325
	SYNOPOSIS	326-338
	APPENDIX	339

LIST OF TABLES

Sr. No.	TITLE	Page No.
3.1	Monthly meteorological data for the year 2006	39
3.2	Monthly meteorological data for the year 2007	40
3.3	Monthly meteorological data for the year 2008	41
3.4	Monthly meteorological data for the year 2009	42
3.5	Physico-chemical parameters of water and soil samples from hinterlands of Quepem for kharif and rabi season of 2006-2007	46
3.6	Physico-chemical parameters of water and soil samples of paddy fields from hinterlands of Quepem for kharif and rabi season of 2007-2008.	47
3.7	Physico-chemical parameters of water and soil samples of paddy fields from hinterlands of Quepem for kharif and rabi season of 2008-2009	48
3.8	Physico-chemical parameters of water and soil samples of paddy fields from coastal area of Utorda for kharif and rabi seasons of 2006-2007	51
3.9	Physico-chemical parameters of water and soil samples of paddy fields from coastal area of Utorda for kharif and rabi seasons of 2007-2008	52
3.10	Physico-Chemical parameters of water and soil samples of paddy fields from coastal area of Utorda for kharif and rabi seasons of 2008-2009.	53
3.11	Physico-chemical parameters of water and soil samples of paddy fields from khazan area of Quelossim for kharif and rabi seasons of 2006-2007	56
3.12	Physico-chemical parameters of water and soil samples of paddy fields from khazan area of Quelossim for kharif and rabi seasons of 2007-2008	57
3.13	Physico-chemical parameters of water and soil samples of paddy fields from khazan area of Quelossim for kharif and rabi	58

	seasons of 2008-2009	
Sr. No.	TITLE	Page No.
3.14	Physico-chemical parameters of water and soil samples of paddy fields from mining area of Velguem for kharif and rabi seasons of 2006-2007	61
3.15	Physico-chemical parameters of water and soil samples of paddy fields from mining area of Velguem for kharif and rabi seasons of 2007-2008	62
3.16	Physico-chemical parameters of water and soil samples of paddy fields from mining area of Velguem for kharif and rabi seasons of 2008-2009	63
4.1	Distribution of BGA from different rice field habitats for the year 2006 -2007	74-77
4.2	Distribution of BGA from different rice field habitats for the year 2007 -2008	78-81
4.3	Distribution of BGA from different rice field habitats for the year 2008 -2009	82-85
5.1	Distribution of BGA from different rice field habitats for the year 2006 -2007	132-137
5.2	Distribution of BGA from different rice field habitats for the year 2007 -2008	138-141
5.3	Distribution of BGA from different rice field habitats for the year 2008 -2009	142-145
5.4	Cyanobacterial density of hinterlands fields of Quepem during the study period of 2006-2009	148
5.5	Diversity indices of different seasons in the three groups of cyanobacteria in the hinterlands of Quepem	150
5.6	Cyanobacterial density of coastal fields of Utorda during the study period of 2006-2009	153
5.7	Diversity indices of different seasons in the three groups of cyanobacteria in coastal paddy fields of Utorda	154
5.8	Cyanobacterial density of khazan fields of Quelossim during	157

	the study period of 2006-2009.	
Sr. No.	TITLE	Page No.
5.9	Diversity indices of different seasons in the three groups of cyanobacteria in Khazan paddy fields of Quelossim.	158
5.10	Cyanobacterial density of mining area fields during the study period of 2006-2009	161
5.11	Diversity indices of different seasons in the three groups of cyanobacteria in mining area paddy fields of Velguem	162
5.12	Comparative diversity indices of BGA from different habitats	168
6.1	Effect of BGA inoculation on growth and grain yield in <i>Oryza</i> (var. jaya).	187
6.2	Correlation analysis between various plant characters and grain yield/plant.	188
6.3	Effect of BGA inoculation on carbohydrate and protein content of grains and chlorophyll content of leaves in <i>Oryza sativa</i> L. (var. jaya)	189
7.1	Chemical formulations of fertilizers.	196
7.2	Effect of fertilizers (Samarth and Samrat) on biomass content of <i>A. oryzae</i> .	226
7.3	Effect of fertilizers (Samarth and Samrat) on chlorophyll a content of <i>A. oryzae</i> .	227
7.4	Effect of fertilizers (Samarth and Samrat) on total protein content and total carbohydrate content of <i>A. oryzae</i> .	228
7.5	Effect of fertilizers (Samarth and Samrat) on biomass content of <i>C. membranacea</i> .	230
7.6	Effect of fertilizers (Samarth and Samrat) on chlorophyll a content of <i>C. membranacea</i> .	231
7.7	Effect of fertilizers (Samarth and Samrat) on total protein and total carbohydrate content of <i>C. membranacea</i> .	232
7.8	Effect of fertilizers (Samarth and Samrat) on biomass content of <i>N. rivulare</i> .	233
7.9	Effect of fertilizers (Samarth and Samrat) on chlorophyll a	234

	content of <i>N. rivulare</i> .	
Sr. No.	TITLE	Page No.
7.10	Effect of fertilizers (Samarth and Samrat) on total protein and total carbohydrate content of <i>N. rivulare</i> .	235
8.1	Chemical formulations of pesticides.	242
8.2	Effect of Rogar 30 , Monocrotophos, Butachlor and Phorate on biomass in <i>A. oryzae</i> .	271
8.3	Effect of Rogar 30, Monocrotophos, Butachlor and Phorate on chlorophyll a content of <i>A. oryzae</i> .	272
8.4	Effect of Rogar 30, Monocrotophos, Butachlor and Phorate on total protein and total carbohydrate content of <i>A. oryzae</i> .	273
8.5	Effect of Rogar 30, Monocrotophos, Butachlor and Phorate on biomass of <i>C. membranacea</i>	274
8.6	Effect of Rogar 30 , Monocrotophos, Butachlor and Phorate on chlorophyll a content of <i>C. membranacea</i>	275
8.7	Effect of Rogar 30 , Monocrotophos, Butachlor and Phorate on total protein and total carbohydrate content of <i>C. membranacea</i> .	276
8.8	Effect of Rogar 30, Monocrotophos, Butachlor and Phorate on biomass of <i>N. rivulare</i> .	277
8.9	Effect of Rogar 30, Monocrotophos, Butachlor and Phorate on chlorophyll a content of <i>N. rivulare</i> .	278
8.10	Effect of Rogar 30 , Monocrotophos, Butachlor and Phorate on total protein and total carbohydrate content of <i>N. rivulare</i>	279

LIST OF FIGURES

Sr. No.	TITLE	Page No.
3.1	Map of Goa showing location of study sites.	30
6.1	Effect of BGA isolates on various growth characteristics of <i>Oryza sativa</i> L. (var. jaya).	180
6.2	Effect of BGA isolates on various yield characteristics of <i>Oryza sativa</i> L. (var. jaya).	181
6.3	Effect of BGA inoculation on carbohydrate content of grains in <i>Oryza sativa</i> L. (var. jaya).	183
6.4	Effect of BGA inoculation on protein content of grains in <i>Oryza sativa</i> L. (var. jaya).	184
6.5	Effect of BGA inoculation on leaf chlorophyll content in <i>Oryza sativa</i> L. (var. jaya)	185
7.1	Effect of fertilizer (Samarth) on biomass of <i>A. oryzae</i> .	202
7.2	Effect of fertilizer (Samrat) on biomass of <i>A. oryzae</i> .	202
7.3	Effect of fertilizer (Samarth) on biomass of <i>C. membranacea</i>	205
7.4	Effect of fertilizer (Samrat) on biomass of <i>C. membranacea</i> .	205
7.5	Effect of fertilizer (Samarth) on biomass of <i>N. rivulare</i> .	208
7.6	Effect of fertilizer (Samrat) on biomass of <i>N. rivulare</i> .	208
7.7	Effect of fertilizer (Samarth) on chlorophyll a content of <i>A. oryzae</i> .	210
7.8	Effect of fertilizer (Samrat) on chlorophyll a content of <i>A. oryzae</i>	210
7.9	Effect of fertilizers (Samarth) on chlorophyll a content of <i>C. membranacea</i>	212
7.10	Effect of fertilizer (Samrat) chlorophyll a content of <i>C. membranacea</i> .	212
7.11	Effect of fertilizer (Samarth) on chlorophyll a content of <i>N. rivulare</i>	215
7.12	Effect of fertilizer (Samrat) on chlorophyll a content of <i>N. rivulare</i>	215
7.13	Effect of fertilizer (Samrath) on total protein and total carbohydrate content of <i>A. oryzae</i> .	217
7.14	Effect of fertilizer (Samrat) on total protein and total	217

	carbohydrate contents of <i>A. oryzae</i> .	
Sr. No.	TITLE	Page No.
7.15	Effect of fertilizer (Samarth) on total protein and total carbohydrate content of <i>C. membranacea</i> .	219
7.16	Effect of fertilizer (Samrat) on total protein and total carbohydrate content of <i>C. membranacea</i> .	219
7.17	Effect of fertilizer (Samarth) on total protein and total carbohydrate content of <i>N. rivulare</i> .	221
7.18	Effect of fertilizer (Samrat) on total protein and total carbohydrate content of <i>N. rivulare</i> .	221
8.1	Effect of Rogar 30 on biomass of <i>A. oryzae</i> .	247
8.2	Effect of Monocrotophos on biomass of <i>A. oryzae</i>	247
8.3	Effect of Butachlor on biomass of <i>A. oryzae</i> .	248
8.4	Effect of Phorate on biomass of <i>A. oryzae</i> .	248
8.5	Effect of Rogar 30 on biomass of <i>C. membranacea</i> .	249
8.6	Effect of Monocrotophos on biomass of <i>C. membranacea</i> .	249
8.7	Effect of Butachlor on biomass of <i>C. membranacea</i> .	250
8.8	Effect of Phorate on biomass of <i>C. membranacea</i> .	250
8.9	Effect of Rogar 30 on biomass of <i>N. rivulare</i> .	251
8.10	Effect of Monocrotophos on biomass of <i>N. rivulare</i> .	251
8.11	Effect of Butachlor on biomass of <i>N. rivulare</i> .	252
8.12	Effect of Phorate on biomass of <i>N. rivulare</i> .	252
8.13	Effect of Rogar 30 on chlorophyll a content of <i>A. oryzae</i> .	255
8.14	Effect of Monocrotophos on chlorophyll a content of <i>A. oryzae</i> .	255
8.15	Effect of Butachlor on chlorophyll a content of <i>A. oryzae</i> .	256
8.16	Effect of Phorate on chlorophyll a content of <i>A. oryzae</i> .	256
8.17	Effect of Rogar 30 on chlorophyll a content of <i>C. membranacea</i> .	257
8.18	Effect of Monocrotophos on chlorophyll a content of <i>C. membranacea</i> .	257
8.19	Effect of Butachlor on chlorophyll a content of <i>C. membranacea</i> .	258
8.20	Effect of Phorate on chlorophyll a content of <i>C. membranacea</i> .	258
8.21	Effect of Rogar 30 on chlorophyll a content of <i>N. rivulare</i> .	259
8.22	Effect of Monocrotophos on chlorophyll a content of <i>N. rivulare</i> .	259

8.23	Effect of Butachlor on chlorophyll a content of <i>N. rivulare</i> .	260
Sr. No.	TITLE	Page No.
8.24	Effect of Phorate on chlorophyll a content of <i>N. rivulare</i> .	260
8.25	Effect of Rogar 30 on total protein and total carbohydrate content in <i>A. oryzae</i> .	264
8.26	Effect of Monocrotophos on total protein and total carbohydrate content of <i>A. oryzae</i> .	264
8.27	Effect of Butachlor on total protein and total carbohydrate content of <i>A. oryzae</i> .	265
8.28	Effect of Phorate on total protein and total carbohydrate content of <i>A. oryzae</i> .	25
8.29	Effect of Rogar 30 on total protein and total carbohydrate content of <i>C. membranacea</i> .	266
8.30	Effect of Monocrotophos on total protein and total carbohydrate content of <i>C. membranacea</i> .	266
8.31	Effect of Butachlor on total protein and total carbohydrate content of <i>C. membranacea</i> .	267
8.32	Effect of Phorate on total protein and total carbohydrate content of <i>C. membranacea</i> .	267
8.33	Effect of Rogar 30 on total protein and total carbohydrate content of <i>N. rivulare</i> .	268
8.34	Effect of Monocrotophos on total protein and total carbohydrate content of <i>N. rivulare</i> .	268
8.35	Effect of Butachlor on total protein and total carbohydrate content of <i>N. rivulare</i> .	269
8.36	Effect of Phorate on total protein and total carbohydrate content of <i>N. rivulare</i> .	269

LIST OF PLATES

Sr. No	TITLE	Page No.
1	Plate I and Plate II	104
2	Plate III, IV and V	113
3	Plate VI, VII and VIII	120
4	Plate IX, X	123
5	Plate XI, XII	127

INTRODUCTION:

Cyanobacteria (also known as blue-green algae, blue-green bacteria, and Cyanophyta) is a phylum of bacteria that are photosynthetic. The name "cyanobacteria" comes from their colour (Greek: (kyanós)=blue). The photosynthetic ability of cyanobacteria is thought to have converted the early reducing atmosphere into an oxidizing one, which has changed the composition of life forms on earth by stimulating biodiversity and leading to the near-extinction of oxygen-intolerant organisms. According to endosymbiotic theory, chloroplasts in plants and eukaryotic algae have evolved from cyanobacteria through endosymbiosis.

Cyanobacteria occur in almost every type of environment ranging from oceans to fresh water to bare rocks to soil. They can occur as floating planktonic cells or form phototrophic biofilms in fresh water and marine environments, they occur in damp soil, or even on temporarily moistened rocks in deserts. A few forms occur as endosymbionts in lichens, plants, various protists, or sponges and provide energy for the host. Some live in the fur of sloths, providing a form of camouflage. Aquatic cyanobacteria are well known for the extensive blooms that are formed in both freshwater and the marine environment and gives a blue-green appearance for the scum. The association of toxicity with such blooms has frequently led to the closure of recreational waters when blooms are observed (Schultz, 2009).

Cyanobacteria are unicellular and colonial species. Colonies consists of filaments, sheets or even hollow balls. Some filamentous colonies have the ability to differentiate into different types of cells like the vegetative cells which are the normal photosynthetic

cells that are formed under favourable growing conditions, akinetes which are the climate-resistant spores that are formed when environmental conditions become unfavourable (Anand, 1989) and thick-walled heterocysts, which contain the enzyme nitrogenase, key enzyme for nitrogen fixation (Fleming and Haselkorn, 1973). Heterocysts are sometimes also formed under anoxic environmental conditions during scarcity of fixed nitrogen. Heterocystous species are specialized for nitrogen fixation and are able to fix nitrogen gas into ammonia (NH_3), nitrites (NO^{-2}) or nitrates (NO^{-3}) which is made available to plants and converted to proteins and nucleic acids as plants cannot directly fix atmospheric nitrogen. The paddy fields of Asia, which produce about 75% of the world's rice can do so well due to the luxuriant growth of nitrogen-fixing cyanobacteria in the paddy fields. (United Nations Conference on Trade and Development, 2010)

Many cyanobacteria also form hormogonia which are motile filaments that detach from the main filament to form new colonies. The cells in a hormogonium are often thinner than in the vegetative state and the cells on either end of the motile chain may be tapered. In certain species hormogone development is initiated by the formation of separation disc called the necridium. The cells of the necridium undergo lyses and dehydration to serve as breaking points for hormogone detachment. Each individual cell of a cyanobacterium typically has a thick, gelatinous cell wall. They differ from other gram-negative bacteria, in that the quorum sensing molecules autoinducer-2 (Sun, *et al.*, 2004) and acyl-homoserine lactones (Dittmann, *et al.*, 2001) are absent. They lack flagella, but hormogonia and some species may move about by gliding along surfaces. Many of the multicellular filamentous forms of *Oscillatoria* spp are capable of a

oscillating motion; the filament oscillates back and forth. In water columns some cyanobacteria float by forming gas vesicles. These vesicles are not organelles as such and are not bound by lipid membranes but by a protein sheath. Some of these organisms contribute significantly to global ecology and the oxygen cycle. The tiny marine cyanobacterium *Prochlorococcus* was discovered in 1986 and accounts for more than half of the photosynthesis of the open ocean (Nadis, 2003).

Cyanobacteria have been reported from a wide range of soils, thriving both on and below the surface. They are often also characteristic features of other types of sub-aerial environment, intermittently wet ones such as paddy fields. Most paddy fields have an indigenous population of cyanobacteria which provides a potential source of nitrogen fixation. Like in many other biological systems, nitrogen fixation in cyanobacteria is brought about by a high molecular weight, oxygen labile metalloprotein enzyme known as nitrogenase. Ammonia can be taken up by cyanobacteria through passive diffusion or as ammonium (NH_4) by a specific uptake system. The amino acids arginine, asparagine and glutamine have also been reported to serve as nitrogen sources. Nitrate and nitrite are important sources, which later reduce into ammonia. Many cyanobacteria are also capable of using atmospheric dinitrogen (N_2) as the source of nitrogen, and this is what is most commonly termed nitrogen fixation. A considerable amount of research on heterocystous forms (Stewart, 1980) proved that heterocysts are the sites of enzyme nitrogenase (Flemming and Haselkorn, 1973).

Nitrogenase reduces molecular nitrogen to ammonia in presence of hydrogen. Due to this important characteristic of nitrogen fixation, cyanobacteria are used in

agriculture to enhance production. Many studies have been reported on the use of dried cyanobacteria to inoculate soils as a means of aiding fertility, and the effect of adding cyanobacteria to soil on paddy yield was first studied in the 1950s in Japan. The term 'Algalization' is now applied to the use of a defined mixture of cyanobacterial species to inoculate soil and research on algalization is going on in all major rice producing countries (Upassana and Pabbi, 2004).

Oryza sativa L. (rice) is the staple food of over 40% of the world's population and thus a most important food crop currently produced (Yadav *et al.*, 2000). Amongst many others, the nutritional requirements of the crop are considered to be the most important factor affecting yield and they go far beyond the natural capacity of any soil type (Ahlawat *et al.*, 1998). Here, in order to get good yield a huge amount of chemical fertilizers must be added to the soil. Excessive application of nitrogen fertilizers can result in a high soil nitrate concentration after crop harvest (Jokela and Randall, 1989; Roth and Fox, 1992; Gordon *et al.*, 1993). This situation can lead to an increase in the level of nitrate concentration of portable water because nitrate remaining in the soil profile may leach to ground water (Singh *et al.*, 1995).

Plant Growth Promoting Rhizo bacteria (PGPR) are bacteria which are associated with the roots of crop plants and can induce beneficial effect on their hosts (Vermeiren *et al.*, 1999). The biological fixation of nitrogen carried out by these organisms can constitute a significant and ecologically favourable contribution to soil fertility. However, the low efficiency of the use of this fixed nitrogen by its host in the formation of grain protein could be a limitation (Vlassak *et al.*, 1992). Therefore, emphasis must be laid on the use of biofertilizers and hence several workers have been working on the effect of

biofertilizers on rice growth and development (Yanni, 1992; Hammad, 1994; Nayak *et al.*, 1996) and have reported an increase in growth and yield. Similar findings were reported by Singh *et al.*, (1992) and Wang (1986) who showed that increased biomass of *Azolla* in the soil increased rice stem height by 7.5 cm and the number of spikes/hills by 2.0 over the control.

Cyanobacteria are a morphologically diverse organization. Generally they can be grouped into unicellular, colonial, unbranched, filamentous, pseudoparenchymatous, heterotrichous, heterocystous forms (Desikachary, 1959). Fogg (1949) demonstrated experimentally that heterocysts are the specialized cells that contain the nitrogen fixing mechanism.

In addition to increasing grain yield, cyanobacteria also secrete growth promoting substances like cytokinins (Chauhan and Gupta, 1984). Cyanobacterial cultures used to pre-soak rice seeds showed enhanced germination, promotion of growth of roots and shoots, and an increase in weight and protein content of grains (Jacq and Roger, 1977). Several other workers have attributed such effects to growth regulating substances like hormones and vitamins. However, cyanobacterial regulators have not yet been isolated and characterized. Hormone and vitamin forming potential of cyanobacteria need to be critically studied, substantiated with their well proved roles in improving soil organic content, water holding capacity, nitrogen enrichment, formation of extracellular polysaccharides leading to improved soil aggregation and solubilization of phosphates (Roger and Kulasooriya, 1980). It was demonstrated that cyanobacterial population influenced changes in the upper 0.7cms of experimental columns of brown earth silt loam, increasing the cyanobacterial counts thereby significantly improving the soil

aggregation properties, increase in dehydrogenase, urease and phosphatase activities (Rao and Burns, 1990). The increase in rice grain yield suggests that cyanobacterial inoculation produces both cumulative and residual effects on buildup of both organic content and number of cyanobacterial propagules in the soil, facilitating the re-establishment of cyanobacterial biomass (Ghosh and Saha, 1997). Several workers have reported an increase in organic matter and nitrogen content of soils inoculated with cyanobacteria in pot and field conditions (Singh and Singh, 1989; Venkataraman, 1993; Vaishampayan, 1998). Singh (1961) indicated the role of cyanobacteria in reclaiming usar soils. Subhashini and Kaushik (1981) reported that cyanobacterial inoculation in combination with gypsum had an appreciable reclamation property applicable to sodic soils. In a soil rendered saline due to bad farm management, a 25-30% decrease in salinity was observed through the repeated cultivation of *Anabaena torulosa*. Cyanobacteria from saline paddy fields reported a halotolerant *Anabaena* spp. to be a good nitrogen fixer (Thomas and Apte, 1984). The addition of nitrogen by cyanobacterial inoculation increased in the presence of phosphate fertilizers, and both total and organic nitrogen were maintained beyond the tilling stage (Chopra and Dube, 1971).

Kleiner and Harper (1977) reported more extractable P in soils with cyanobacterial cover than in soils without cover, thus proving cyanobacterial ability to mobilize insoluble forms of inorganic P. Bose *et al.*, (1971) showed that out of 18 strains tested, 17 strains solubilized tricalcium phosphate. The cyanobacterial P-solubilizing activity also acts on hydroxyapatite (Cameron and Julian, 1988) and Mussorie rock phosphate (Roychoudhary and Kaushik, 1989). Whitton *et al.*, (1991) tested 50 cyanobacterial strains for their ability to grow with organic P as their P source and found

that all strains used monoesters, that almost all used diesters, and that just a few used phytic acid. A proper scientific interpretation is still awaited in some evidences about cyanobacterial effectiveness at increasing P availability in saline soils (Kaushik and Subhashini, 1985). Sankaran (1971) showed in a long term study that the organic carbon increases gradually due to cyanobacterial inoculation, but later the amount remains steady at the end of three years. It was also reported that the influence of cyanobacterial inoculation on soil properties was not significant in the first and second cropping seasons but responded well in the third cropping season, showing 2-11% increase in soil organic carbon as a result of cyanobacterial inoculation (Bisoyi, 1982). Cyanobacterial growth has been noted to cause an initial increase in soil pH that later decline to the original value (Saha and Mandal, 1979). It was also observed in these experiments that P content decreased up to 90 days of cyanobacterial growth and began to increase toward the later period of incubation.

In flooded paddy fields, cyanobacteria influences the forms in which Fe, Mn and also possibly Zn occurs (Das *et al.*, 1991). These changes are considered to be due to release of oxygen and the addition of organic matter, especially the extracellular material and also due to the decomposition of cyanobacterial biomass. This decomposition is ascribed to the development of reducing conditions and formation of organic acids. A decreased content of readily available Fe may help to minimize Zn deficiency in rice. In many cyanobacterial species, the gelatinous sheath was able to chelate Fe, Cu, Mo, Zn, Mn and other elements essential for their growth (Lange, 1976). The sheath was also known to influence the availability to other organisms (Belnap and Harper, 1995). A cyanobacterial sheath reduces particle erosion and may adsorb charged nutrient cations

(Whitton, 2000). The higher plants also stimulate or inhibit cyanobacterial growth in soil (Parks and Rice, 1969). Intracellularly occurring cyanobacteria have also been reported in rice (Kozyrovskaya, 1990), Wheat (Gantar *et al.*, 1991a, 1991b, 1993; Dodds *et al.*, 1995), and maize, beans, sugar beets and rice (Svireev *et al.*, 1997). One of the major concerns for the use of cyanobacteria as effective biofertilizers is the choice of suitable strains that will survive adverse and extreme ecological conditions in paddy fields and also be a good nitrogen fixer. Several workers have worked towards these concerns, especially on the selections of beneficial isolates of nitrogen fixing cyanobacteria and genetic improvement of these species.

The cyanobacteria have been critically examined to form the nitrogen fixing heterocysts and synthesize active nitrogenase specifically in the absence of or least combined nitrogen supplied condition in the laboratory (Stewart and Rowell, 1975; Singh *et al.*, 1978a, 1978b; Vaishampayan and Singh, 1981a, 1981b; Vaishampayan, 1982b) and in fields (Mikheeva *et al.*, 1990; Singh, 1990; Singh *et al.*, 1990), except in *Anabaena* strain CA (ATCC 33047), in which a covalent modification mechanism of nitrogenase during inhibition by combined nitrogen is non-operative (Bottomley *et al.*, 1979). *Nostoc muscorum* a nitrate reductase deficient mutant is also an exception (Singh and Sonic, 1977; Vaishampayan and Prasad, 1982).

Cyanobacterial nitrogen available to paddy crops:

Cyanobacteria release the fixed nitrogen mainly in the form of polypeptides, with lesser amount of free amino acids, vitamins and auxin like substances (Venkataraman, 1993), either by exudation or by microbial degradation after cell death (Subramanian and

Shanmugasundaram, 1986a, 1986b). Under field conditions, part of the fixed nitrogen is made available to the paddy plants, and the rest is reincorporated into the soil (Singh and Singh, 1989). The uptake of free nitrogen from cyanobacteria to the crop and other organisms has been investigated using ^{15}N tracer techniques (Mayland and McIntosh, 1966; Stewart, 1967, 1970). The ^{15}N labeled *Aulosira* species spread on the soil and incorporated in the soil recorded 37% and 51% respectively of labeled ^{15}N in the rice (Wilson *et al.*, 1980). Using tracer technique $^{15}\text{N}/^{14}\text{N}$, it has been reported that 40% of cyanobacterial nitrogen was recovered by the rice plants and addition of ammonium chloride equivalent to 100 kg N ha^{-1} had no adverse effect on the recovery of cyanobacterial nitrogen (Venkataraman, 1981; Mian and Stewart, 1985; Ladha *et al.*, 1987). The relative amount of cyanobacterial nitrogen available to rice plants depends on the strain and its physiological state (Wilson *et al.*, 1980; Tirol *et al.*, 1982). Cyanobacteria are sometimes seen on the surface of aquatic roots of deepwater rice plants (Whitton *et al.*, 1988c), and evident from ^{15}N studies (Kulasooriya, 1998), that cyanobacterial nitrogen reaches rice plants either by release of extracellular combined nitrogen or indirectly by grazing and parasitism.

Rice-fields: an aquatic ecosystem

Paddy fields are the most extensive freshwater aquatic ecosystem on earth with more than 1.5 million km^2 . Whitton *et al.*, (1988a; 1988b; 1988c) described in a series of 5 papers the ecology of deep water rice fields from Bangladesh. More recently Roger (1996) published a comprehensive monograph about the paddy fields, from an agronomical point of view, but considering as well the ecology of this ecosystem. The paddy fields are a peculiar aquatic ecosystem in which the water layer is very shallow,

but relatively constant during a fraction of the year, because of that, the interaction of sediment water is very important and likely plays a major role on the biological activities. Moreover, the paddy plant growth triggers severe shifts, making paddy fields a highly dynamic ecosystem because of the changes in the physical and chemical characteristics of water and sediments that take place during the cultivation cycle. Land management and agricultural practices also have an important influence over the ecological characteristics of the paddy fields, because of the physical disruption of sediments, as well as the input of nutrients or pesticides which impair the natural community structure and stability, favoring the dominance of rice (Valient and Quesada, 2004).

Micro environments in rice fields:

Flooding and the presence of paddy plants lead to the differentiation of microenvironments in the paddy field ecosystem: floodwater, surface-oxidized soil, reduced soil, paddy plants (submerged plants and rhizosphere), plow layer and subsoil. These environments differ in their physical, chemical and trophic characteristics (Roger *et al.*, 1993). The most pertinent microenvironments are the floodwater, the oxidized soil and the paddy plants. The floodwater is a photic, aerobic environment where aquatic communities of primary producers and consumers recycle nutrients and provide organic matter to the soil. Major activities in the floodwater include photosynthesis and respiration, and photo dependent biological N₂ fixation by free-living and symbiotic cyanobacteria. The floodwater is subjected to large variations in irradiance, temperature, pH, O₂ concentration and nutrient status (Whitton *et al.*, 1988c; Quesada *et al.*, 1995). The light screening effect of the rice canopy induces a rapid decrease of light reaching the floodwater. Light penetration is also decreased by floating macrophytes, plankton and

the turbidity resulting from agronomical practices and the activity of benthic invertebrates. Light reaching the floodwater have a major influence on other variables such as temperature, O₂ concentration and pH.

The oxidized soil layer is a photic aerobic environment, a few millimeters thick, with a positive redox potential. A continuous exchange takes place between floodwater and the oxidized soil. Major activities include: aerobic decomposition of organic matter by aerobic bacteria, photosynthesis by cyanobacteria and algae, photodependent N₂ fixation by free-living cyanobacteria and photosynthetic bacteria; nitrification by ammonium and nitrite oxidizers and methane oxidation. The depth of the oxidized layer, which is usually between 2 and 20 mm, depends on the concentration of O₂ dissolved in the floodwater, the reducing capacity of soil, the water percolation and the activity of soil fauna (Neue, 1988). After land preparation, algae develop at the soil surface and support grazing populations. Later in the crop cycle, organic matter accumulates at the soil surface and supports populations of invertebrates that recycle the nutrients (Roger, 1996). As stated above, the rice plant affects the floodwater and surface soil environments by its shading effect. The submerged parts of paddy plants provide photic and aerobic environment that can be colonized by epiphytic bacteria and algae, and where populations of pulmonate mollusks can also find mechanical support (Roger, 1996).

Benthic, planktonic and epiphytic cyanobacteria are widespread in rice fields, and typically about 50% of the cyanobacterial genera are heterocystous (Whitton, 2000). Cyanobacterial flora includes unicellular (*Microcystis*, *Chroococcus*), filamentous (*Oscillatoria*, *Lyngbya*, *Phormidium*) and filamentous with heterocysts (*Anabaena*, *Nostoc*, *Gloeotrichia* species). Studies on cyanobacterial and algal successions have been

performed in different rice fields all over the world (Gupta, 1966; Roger and Reynaud, 1976; Grant *et al.*, 1986). In spite of the differences found among paddy fields, a general trend can be proposed from these studies. Phytoplankton (mainly chlorophyceans and diatoms) develops early in the cultivation cycle until the tillering phase. From tillering to the initiation of panicle the photosynthetic aquatic biomass reaches its highest values. During this period filamentous green algae and non-nitrogen fixing cyanobacteria are dominant, although in some places also nitrogen-fixing cyanobacteria become abundant. Also during this period submerged macrophytes develop dense populations. From panicle initiation to harvest, the total biomass decreases and nitrogen-fixing cyanobacteria become dominant.

THE STATE OF GOA

Location and Boundaries:

The state of Goa has an area of 3.701 square kilometers and a population of 14,57,723 as per the Census of 2011, and its geographical position is marked by 15°45'00"N and 14°53'54" N Latitude and 74°20'13"E and 73°40'33" E Longitude. The boundaries of the state partly confirm to geographical features. In the North, Goa shares its boundary with Sawantwadi taluka of Ratnagiri district and Kolhapur district of Maharashtra state; the mouth of the Tiracol river lies within Goa and includes the Tiracol fort, across the south.

Physical Features

Goa, being a part of the West Coast region of India, has many physical features that are common to the neighbouring regions of Maharashtra and Karnataka States.

Broadly, there are three main physical divisions of Goa : mountainous region of the Sahayadries in the east which serves over the major part as a watershed between the Arabian Sea and Bay of Bengal drainage and demarcates the administrative boundary with a part of Kolhapur district of Maharashtra, Belgaum and North Kanara districts of Karnataka, middle level plateaus in the centre with their detached elements abutting in several places into the sea, and the low-lying river basins and the coastal plains.

Physical Geology

The present landforms of Goa, when explained geologically, contribute substantially by the basaltic outflows of the Deccan Lavas, and has accordingly the typical landforms consisting of flat topped summit levels with terraced flanks, and wide opening valley courses with sides rising more as a succession of steps than as smooth slopes; the Sahayadrian scarp, steep and in many places bold, has been regarded as due to major faulting which created the western flank of the Sahayadri as a whole. The topography of the basalts in its details is due to weathering and intense water erosion though highly on seasonal scale resulting in residual hill features with rounded summits like the Chandranath hill, and minor knolls, which are common in the mountain tracts of Goa. Extensive laterisation, attributed to the tropical moist climate with vast seasonal changes, is another interesting and significant feature of this landscape. There are extensive laterite caps both in the high Sahayadries and in the medium and low level plateaus below, associated with Fe and Mn deposits of Goa. There are limited outcrops of older rocks, metamorphic schists, mostly belonging to the Dharwar series of stratification. More important are the recent alluvial spreads along the courses of rivers

and the coastal plains. These and the sandy deposits along the coastline are the most recent formations.

Agricultural seasons

Most of the crops in the state are dependent on monsoons. The monsoon crops are called the *kharif* or *sorod* crops and the winter crops are called *rabi* or *vaingan* crops. *Sorod* crops are raised in rains from the south-west monsoon while *vaingan* crops are grown with the help of irrigation and occasional fair weather showers occurring in September-October and occasional rains from pre-monsoon showers in May. *Sorod* crops are sown during the period from the first week of June to early July and harvesting is done in September-October. *Vaingan* crops are sown during the period from the first week of November to the second week of December and are reaped in March.

Crops grown in the *kharif* (*sorod*) season include *Oryza sativa* L. (paddy), *Eleusine coracana* (nachani), etc., while the crops grown in the *rabi* season include paddy, pulses like *Macrotyloma uniflorum* (kulith) (horse gram), *Phaseolus mungo* (udid) (black gram), *Cajanus cajan* (tur) (pigeon pea) and a variety of beans.

As has been stated earlier, an area of 1,33,797 hectares is under food crops. Of this, an area to the extent of 66-88% of the total under food crops excluding that under horticultural crops in the state is under rice cultivation.

In the state of Goa, generally two crops are grown depending on the availability of water after October. Presently, two crops are grown on about 5,600 hectares of land which is of the category of *ker* and *khajan*. The following table gives the area under rice fields taluka-wise for the year 2009-10:

Table 1.1: Taluka-wise estimated area under rice cultivation in Goa for the year 2009-2010.

State/ Taluka	Rice fields (hecters)		
	Kharif	Rabi	Total
State of Goa	31166	15938	47104
North Goa	18201	8688	26889
Tiswadi	4914	620	5534
Bardez	5605	1820	7425
Pernem	2860	1208	4068
Bicholim	1650	1750	3400
Sattari	452	650	1102
Ponda	2720	2640	5360
South Goa	12965	7250	20215
Sanguem	850	2200	3050
Canacona	2255	750	3015
Quepem	3100	2200	5300
Salcete	6350	1635	7985
Mormugao	400	465	865

The practice of *rabbing* for preparing seed beds to raise seedlings is very common. Seed bed area is covered by a layer of dry leaves about three inches thick, dry cattle dung and other dry refuse and burnt to in April-May on the eastern end of the area, preferably in the evening to allow for the slow burning which is accomplished easily

because the evening sea breeze blows from west to east and as such it takes some time for the fire, set on the eastern side, to reach the western side. This process of burning the seed bed area is locally known as “*rab*” and is still followed probably with a view to destroying the weeds, weed seeds, harmful micro-organisms and insects. It also adds some manure through the ash formed, for the young seedlings. Since rains are due in the first week of June, the seed beds, after some operation with hand tools, are sown with paddy seeds early in June, either in anticipation of rains or immediately after rains. After a month when seedlings grow to a suitable height, they are transplanted. The preparatory tillage of paddy lands consists of – (a) *Ukhalani* or light ploughing; (b) *Chikhalani* or puddling and (c) *Guta phiravine* or planking or leveling. *Ukhalani* is done after first monsoon showers to break the hard crust of surface soil so that penetration in the earth becomes easier for subsequent ploughings. Puddling is done by means of a light plough to prepare fine soft mud-beds for transplanting the seedlings. Puddling has to be done in all kinds of rice soils. A well-puddled field holds water longer and keeps the plants green. After puddling, a wooden plank is dragged by bullocks over the field to level the land.

As soon as the mud-beds get ready, seedlings are carefully uprooted from the seed bed, tied in small bundles and carried to *Khachars* where they are finally transplanted. Transplanting is done by hand. Generally eight to ten persons are required for transplanting an acre of land. Ten to fifteen seedlings held in a bunch are simply pressed in the mud with a spacing of nine or twelve inches both ways.

In the case of *Kuryat* lands, transplanting is replaced by broadcasting of sprouted seeds in puddled fields. This method is locally known as ‘*rahu*’ method. Paddy seeds are put in an oval shaped vessel in which they are submerged in water. The lighter seeds,

which float on water surface, are removed and the heavy seeds are retained. After about 12 to 24h, water is allowed to drain away and the soaked seeds are filled in bamboo *karandahs* (baskets) which are lined by rice straw on inner side. Lukewarm water is then poured on the seed; the top of *karandahs* or baskets is then covered by teak leaves and rice straw and loaded with stones and pieces of logs so as to create warmth inside, required for sprouting. On each of the two consecutive days, water is sprinkled over the paddy straw to keep the seed moist. The seeds sprout in three days. The quantity of seeds required for sowing an acre of land under this method is about 60 to 80lbs, as against 40 to 60lbs. under transplanting.

In salt lands, early coarse varieties of paddy are generally sown. Sprouted seeds of two or three days old are broadcast in the field when the area becomes inaccessible after heavy rains. These get very hard on drying and get very soft and sticky when wet. Farmers find it almost impossible to enter the field when it is wet and hence the implements cannot be used in such fields. This method of broadcasting sprouted seedlings is also followed in some parts where, after ploughing, the field remains inaccessible for sowing due to continuous torrential rains.

Dry sowing, which is known as *dhul-waf* sowing, is also done in some places, in the months of May and June just before rains. This method of sowing facilitates an early start for the seedlings.

In southern talukas, in the low-lying and retentive soils known as *shel-soils*, seed is sown during March and April. Hand digging of seed beds precedes ploughing. Seeds are sown by broadcasting. No *rabbing* (seed bed preparation) is done. The seed germinate

and the seedlings remain on the ground till monsoon starts. These seedlings are known as *Top-tarava* and survive on dew and on the moisture retained by the soil. They are supposed to resist pest incidence, especially of the stemborers.

The introduction of the Japanese method of paddy cultivation marks an important development in the process of paddy cultivation. The main features of this method are:

- (i) Raised nurseries for seedlings;
- (ii) Low seed rate for nurseries;
- (iii) Heavy manuring of the crop, both in nurseries and in fields;
- (iv) Transplantation of few seedlings per bunch;
- (v) Transplanting in rows; and
- (vi) Adequate interculturing and proper weeding

In some parts, bold grain varieties like *bhadas*, etc. are grown for obtaining par-boiled rice which is mainly eaten here. Paddy is boiled in plain water for about half an hour till the husk slightly splits. Grain is then dried in shade for three to four days, de-husked and consumed in the form of boiled rice (*bhat*) or thick gruel (*ambil* or *pej*).

Vaingan paddy is grown on high-lying or upland soil locally known as *kuryat* soils and low-lying, more retentive soils known as *mal* soils in the proximity of water facilities. During January and February months, the paddy fields become compact and are artificially irrigated and immediately ploughed both lengthwise and breadthwise so that

clods do not come up. Clods are then crushed by *gutephali* on the third day and land is again ploughed both lengthwise and breadthwise after irrigation, followed by clod crushing. Bunds are then prepared in the rice fields at suitable places to divide the field into compartments (*dala* or *choudas*) for compounding water and are plastered with mud not to allow any growth of weeds. Land is then puddled by a plough; Puddling is best achieved by the use of *gutephali* fater puddling by plough. Where *vaingan* paddy is grown on interior well terraced and banded lands, as many as six ploughings are given both lengthwise and breadthwise, so as to bring land into good puddle condition so essential for (i) standing water and (ii) for preventing drainage of water in the hot season (Gazetteer of Goa, 1969 reprinted in 2010).

Rice (*Oryza sativa L*), the staple food of Goans is being cultivated over an area of 47,104 hectares both in Kharif (31,166ha) and Rabi (15,938ha). This cereal crop accounts for 31% of the total cropped area and 86% of the food grain production. It is cultivated on three different land types *viz.*, Kher lands (rainfed lowlands), Morod lands (rain fed uplands) and Khazan lands (coastal saline lands). The average productivity of rice is about 2.2t/ha Kharif and 2.8t/ha in Rabi.

Small and fragmented land holdings, lack of ownership titles, ever increasing cost of labor and their unavailability in time and lack of technical knowledge about its profitable cultivation are some of the major constraints faced by our farmers. One of the ways to make rice cultivation profitable in Goa is to bring down the cost of its production per unit area. This can be achieved by adopting proper agronomic practices like selection and seed treatment of suitable high yielding variety, maintaining adequate plant population (particularly in direct sown rice), optimum use of agrochemicals, efficient

use of water, timely harvesting and adopting proper storage methods. Use of biofertilizers by developing blue green algal inocula of indigenous species and minimizing use of agrochemicals will also go a long way in reducing the cost on investment, thereby increasing the profit margin.

The objectives of the present study are:

1. Survey and distribution of BGA in the selected study sites.
2. Seasonal variations in Blue Green Algae.
3. Effect of selected species of Blue Green Algae on yield of *Oryza sativa*.
4. Effect of inorganic fertilizers on BGA.
5. Effect of pesticides on BGA.

REVIEW OF LITERATURE:

Cyanobacteria are prokaryotic micro-organisms that resemble gram negative bacteria in structure but possess oxygen evolving photosynthetic system similar to that of eukaryotic algae and higher plants (Fogg *et al.*, 1973). They belong to ambient group of organisms that are recorded even from pre-cambrian microfossils (Schopf, 1970) and dominate a wide range of diverse environments characterized by extremes of temperature, desiccation, pH, Salinity, light intensity and nutrients (Whitton, 2000). The majority of cyanobacteria are capable of fixing the atmospheric nitrogen, and their presence in paddy fields is known to maintain nitrogen levels in the soil (Venkataraman, 1993). From the time, the importance of cyanobacteria was recognized; a considerable amount of research has been carried out to evolve methods and means to effectively utilize these organisms as biofertilizers (Brouers *et al.*, 1987; Shi *et al.*, 1987, 1991; Shi and Hall, 1988; Anand, 1998b; Vaishampayan *et al.*, 2000c).

Most cyanobacteria inoculated in soil fail to dominate over the indigenous flora of the soil receiving the inoculation and inoculated species are able to dominate only when the indigenous flora is sparse. Thus, 'Algalization' seems likely to be most useful where there are marked seasonal changes in land such as when ground is ploughed frequently before planting so that the indigenous soil cyanobacteria is much reduced by the time the new paddy season begins. A number of studies have also been carried out on the selection of natural or mutant strains with an aim to maximize the nitrogen fixing ability. These strains either show high levels of nitrogenase activity in laboratory studies or in pot experiments are therefore important to check whether they can also compete effectively with other native soil strains under field conditions (Upassana and Pabbi, 2004).

The abundance of cyanobacteria in rice fields was first observed by Fritsch (1907). The relative occurrence of cyanobacteria in rice fields varies within wide limits (Singh and Singh, 1989). Studies on paddy fields in several countries *viz.*, Japan, Thailand, China, the Philippines, Bangladesh and India have reported the dominance presence of cyanobacteria (Venkataraman, 1981; Roger and Kulasooriya, 1989). Cyanobacteria constitute 86% of the total algal flora in southern Iraq (AL-Kaisi, 1976), 75% in Indian rice fields (Pandey, 1965) and 70% in Italian soils (Materasi and Balloni, 1965). It is important to note that cyanobacteria are scarce in Australian rice fields, possibly due to higher levels of copper sulphate and combined nitrogen present in irrigation water (Bunt, 1961). Taxonomic and floristic accounts of soil cyanobacteria from several other countries is also available, *viz.*, Argentina (Eldridge and Greene, 1994), Bangladesh (Khan *et al.*, 1994), Czech Republic and Russia (Desertova, 1974), Greece, (Economou *et al.*, 1984), India (Gupta, 1966; Prasad and Srivastava, 1968; Tiwari, 1975; Tiwari and Pandey, 1976; Jha *et al.*, 1986; Anand and Hopper, 1987; Anand, 1989; Singh *et al.*, 1997a, Singh *et al.*, 1997b), the United Kingdom (Bristol, 1920), and the United States (Anderson and Rushforth, 1976; Ashley *et al.*, 1985; Johansen, 1993).

The most relevant factors for the occurrence of cyanobacteria in addition to light are soil moisture, pH, mineral nutrients, and combined nitrogen (Granhall, 1975). Cyanobacteria are more abundant in the tropical soils due to their higher temperature optima (Castenholtz and Waterbury, 1989). The filaments of *Anabaena* and *Nostoc* species are most commonly found nitrogen fixing organisms in rice fields, occurring as free floating water blooms, forming a microbial mat. Many other rice field cyanobacteria

include: *Nostoc commune* forming balls like structures of mucilage, *Scytonema* species showing characteristic false branching and heterocysts, *Calothrix* species showing characteristic terminal heterocysts; *Nodularia* species with vegetative cells and heterocysts; *Gloeotrichia* species showing characteristic ball like circular assembly of filaments; and *Lyngbya* species having characteristic yellow–brown colouration of the mucilage sheath due to the presence of scytonemin, an UV absorbing compound (Vaishampayan *et al.*, 2001). More than 100 strains of heterocystous cyanobacteria that belong to the genera of *Anabaena*, *Nostoc*, *Nodularia*, *Cylindrospermum*, *Scytonema*, *Calothrix*, *Anabaenopsis*, *Mastigocladus*, *Fischerella*, *Tolypothrix*, *Aulosira*, *Stigonema*, *Haplosiphon*, *Chlorogloeopsis*, *Camptylonema*, *Gloeotrichia*, *Nostochopsis*, *Rivularia*, *Schytonematopsis*, *Westiellopsis*, *Wollea* and *Chlorogloea* genera have been found to be efficient nitrogen fixers (Venkataraman, 1993). They are more prevalent in tropical and sub-tropical regions, as compared with the temperature belts (Vaishampayan *et al.*, 2001).

Rice fields in India, being situated in the tropical belt, are quite rich in cyanobacterial flora as seen from the surveys of conducted in the states of Karnataka (Bongale and Bharti, 1980), Kerela (Aiyer, 1965; Amma *et al.*, 1966), Madhya Pradesh (Agarkar, 1967), Maharashtra (Sinha and Pandey, 1972; Tamil Nadu (Chacko, 1972; Kamat and Patel, 1973; Sardeshpande, 1981.), Uttar Pradesh (Pandey, 1965; Bendre and Kumar, 1975), Orissa (Sankaran, 1971; Singh. 1975), West Bengal (Banerji, 1939). Singh (1978) reported the dominance of *Aphanothece*, *Anabaena*, *Aulosira*, *Cylindrospermum*, *Gloeotrichia* and *Nostoc*. The cyanobacterial species are mostly found to be area specific as cyanobacterial inocula brought from larger distance i.e. more than 1500 km could not

be established in the Cuttack area due to dominance of indigenous species (Bisoyi, 1982). In an all India survey out of 2213 soil samples from rice fields, 33% were found to harbour nitrogen fixing cyanobacteria (Venkataraman, 1975). Upland soils in arid climates are very inhospitable to many micro-organisms because of high temperature and limited water, yet cyanobacteria are especially resistant to such adverse conditions and form the dominant component of the micro-flora in many cases (Fogg *et al.*, 1973). Through a quantitative study of algal flora of dried soil samples from upland fields (pH 7.8-8.3) at the Indian Agricultural Research Institute (IARI), New Delhi cyanobacteria were found to dominate in all soil samples (Dutta & Venkataraman, 1968). 62 algal species were recorded from 120 soil samples collected from the Gulf of Mexico and areas of Ecuador and Colombia, of these 46 species were cyanobacteria with 23 nitrogen fixers that included population of *Nostoc muscurum* (21%), *Nostoc paludosum* (13%) and other nitrogen fixing cyanophytes (4%) (Durrell, 1964).

More than half of the populations of cyanobacterial heterocystous forms are found growing at or floating above the surface which is particularly evident in wetland rice fields, which supply 86% of the world's rice requirements (Ladha and Reddy, 1995). The periodicity of cyanobacteria in rice fields in Uttar Pradesh and Bihar was investigated by Singh (1961) and found three prominent filamentous and heterocystous forms *i.e.* *Aulosira fertilissima*, *Anabaena ambigua* and *Cylindrospermum ghorakpurease*.

Several cyanobacterial strains have shown wide pH tolerance, as rice fields in India vary from acidic to highly alkaline. Sardeshpande and Goyal (1982) identified many strains that could adapt to a wide range of pH, grow well and also fix nitrogen efficiently. A study showed that *Nostoc calcicola* could shift the pH from acidic or highly

alkaline of an external medium to support its maximum growth within six days (Anand *et al.*, 1990). Anand and Revathi (1992) showed that *N. calcicola* could metabolically adapt to wide pH regimes to fix nitrogen efficiently. A survey of 102 soil samples from four countries has shown an abundance of heterocystous forms, positively correlated with pH and available P content of the soils (Roger *et al.*, 1993). The abundance of heterocystous species was significantly correlated with available P in paddy fields of Bangladesh (Mandal *et al.*, 1993). It is difficult to assess the impact of P fertilization on cyanobacteria in paddy fields, since other fertilizers, particularly K, are added at the same time. The highly significant increase in cyanobacterial biomass of the cyanobacterial genera i.e. *Aulosira*, *Aphanothece* and *Gloeotrichia* was shown specifically to be due to addition of phosphate (Bisoyi and Singh, 1988a, 1988b).

Light is another factor that decides the relative abundance of dominant cyanobacterial genera, as shown with studies in rice fields near Valencia, Spain. Quesada *et al* (1998) found that non-heterocystous forms occurred three times more abundantly at higher incident radiation than at lower incident radiations and that the three main heterocystous forms *viz.*, *Anabaena*, *Nostoc* and *Calothrix* species responded differently to different levels of irradiation. Most of the cyanobacteria appeared to be different in rain moistened and flooded rice fields of Bangladesh, though mats of *Scytonema mirabilis* were common under both conditions (Rother and Whitton, 1989; Whitton *et al.*, 1989).

INTRODUCTION:

The state of Goa, which is situated well within the tropics and flanked by the Arabian Sea to the west and the Western Ghats (Sahayadris) rising to an average height of one kilometer to the east, has tropical-maritime and monsoon type of climate, with profound topographic influence. Accordingly, the climate is equable and moist throughout the year. Other features of the climate are the regular and sufficient rainfall during the southwest monsoon season, mainly from June to September and temperate weather during the rest of the year with little or no clear cut demarcation between what is generally termed as the winter period (January-February) and the hot weather period (March-May). The climate is generally pleasant. Discomfort may be felt in the absence of wind particularly during pre-monsoon and post-monsoon months.

Rainfall

The monsoon bursts over the state in the beginning of June and withdraws from it by early October. The annual rainfall is of the order of 350cm. As a result of the orographic influence, rainfall increases rapidly towards the Western Ghats from 250-300cm along the coast to over 400cm nearer the Ghats. Over 90% of the annual rainfall occurs during the monsoon months of June to September. July is the rainiest month when about 36% of the annual rainfall is recorded.

Temperature

Temperature variations through the seasons are slight. May is relatively the warmest month when the mean daily temperature is around 30°C and January the coolest with the mean daily temperature of about 25°C.

It is interesting to note that the day temperatures are lowest in the monsoon months of July and August and not in the 'cool weather' months of December and January. Maximum temperatures are at their highest (33°C being mean) in the pre-monsoon months of April and May and again in the post-monsoon months of November and December. Lowest night temperatures of the order of 20°C are experienced in December and January. During the winter season, cold and dry continental air from the north is prevented by the Western Ghats from exerting its full influence over the state with the result that temperatures do not fall appreciably in the same way as they do inland to the east of the Ghats or even along the coast in the north. Along the coast, the maximum temperature rarely goes beyond 37°C.

Humidity

Due to proximity of the sea, the climate is generally humid, with a further rise in humidity during the monsoon weather. Even during the summer months the relative humidity is generally above 60%.

Cloudiness

Skies are clear to lightly clouded from November to March, with gradual increases thereafter till May after which there is a sharp increase in cloudiness with the onset and advance of monsoon. Skies remain mostly clouded to overcast till September and Cloudiness decreases sharply after October.

Winds

Winds in the morning are easterly to north-easterly during October to April backing to north or north-east in May, while in the afternoon they tend to blow towards west or north-west, due to the sea breeze effect. During the monsoon months

the winds are generally westerly throughout the day. Winds are fairly strong during the monsoon period. Otherwise they are generally moderate in strength.

Soils

Soils of Goa can be classified as laterite, alluvial and sandy. The major portions of soils are lateritic. It is highly acidic in nature, sandy loam to silt in texture and well drained. They are good in organic matter and nitrogen. Alluvial soils of khazans are subject to inundation by saline water of land with a high water table which can be exploited for irrigation and multiple cropping. These soils are also acidic, sandy to sandy loam, fairly rich in organic matter.

The local population distinguishes different types of fields according to soil and rainfall conditions and nearness to the riverside. *Khazans* or *Cantar* lands are marshy, but very fertile. Invariably these are situated near the creeks and riversides. Though these lands are very fertile, ill-distributed rainfall, or a breach in the river embankment destroys the crop. As such, cultivation is very risky and unless co-operative efforts are made to guard the embankments, farmers are unwilling to cultivate these fields. The area under *khazan* is estimated at 18,000 hectares distributed in Bardez, Bicholim, Ponda, Ilhas, Pernem, Salcete and Quepem talukas. Most of the *khazans* lands are in coastal talukas and on the border lands of the interior talukas. The average yield varies between 20 to 25 candies (one candie is equal to one quintal), paddy per hectare. These are saline lands and require salt-resistant varieties. There are further distinctions in the *khazan* lands depending on the type of seed used (*shitto, korgut, etc.*).

The *ker* lands are the best paddy lands in Goa and if properly cultivated would give a yield as high as 80 candies per hectare. Water conditions are optimum,

drainage is good and soils are of the alluvial type. Normally these lands are situated between *khazans* and *morods* (high land paddy fields). A second crop of vegetables, onion, sweet potatoes can as well be grown here if irrigation facilities are available. Approximately 17,000 hectares of paddy fields are of the *ker* type. However, the present position of lands is far from satisfactory. There is much population pressure in these areas and the result is that there are too many small holdings. Presently, the average yield varies from 20 to 25 candies per hectare.

The rest of the paddy lands are termed as *Morod*. These are the plots situated on the high lands, with very good soils. The pressure of population has led to their cultivation. As these areas are rainfed, only the kharif crop is cultivable. Yields are very low (in the vicinity of 7 to 8 candies per hectare) in the absence of manures and fertilizers and better cultivation methods. Certain *Morod* lands do yield as high as 15 to 20 candies per hectare, if manured with riverside silt and fertilizers. Use of silt is, however, possible only in the coastal tract.

Besides these three main types of paddy lands, there is one more, viz., the *Kulne* lands. However, as these are high lands mostly located in the midst of forest areas, their hectareage is limited. Here *rabbing* (manuring with the ashes of dry wood and foliage) is generally practiced and yields are also very low.

In the present study paddy field habitats influenced by different soil conditions were selected. These include the hinterland paddy fields of Quepem, coastal area paddy fields of Utorda, khazan paddy fields of Quelossim and mining affected paddy fields of Velguem. All the four paddy field habitats were analyzed for their physico-chemical parameters (**Table 2.5 -2.15**). In the paddy fields growth of BGA and algal succession are governed by climatic and physico-chemical parameters (Roger, 1985).

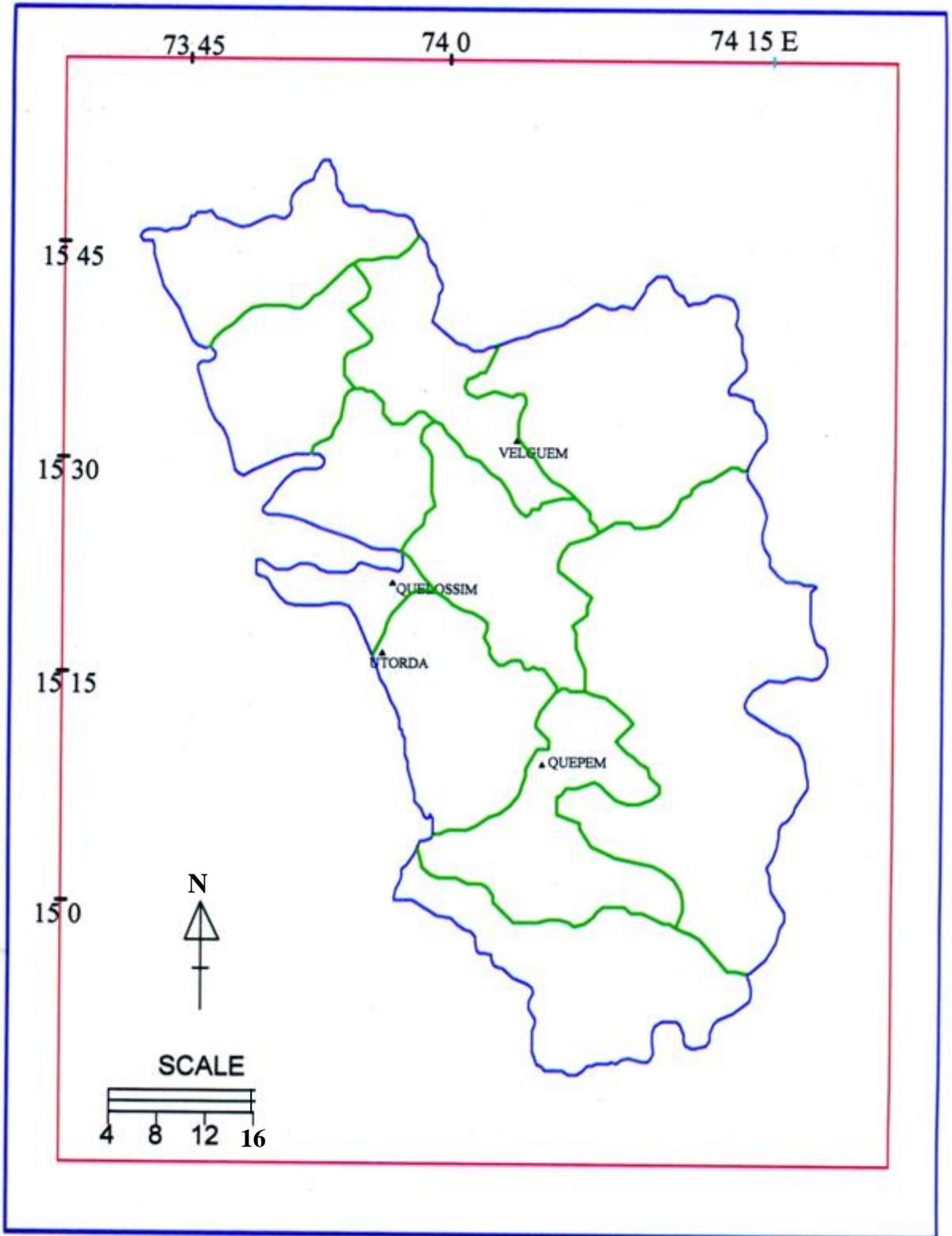


Figure 3.1: Map of Goa showing location of study sites.

MATERIALS AND METHODS:

Collection of water samples for physico-chemical parameters: Water and soil samples were collected for analyzing physico-chemical parameters from the four selected paddy field habitats every month from June, 2006 to June, 2009.

A. Analyses of water samples

Analyses of water samples were carried out using the methods given in 'Standard Methods' (APHA, 1995) and 'Chemical and Biological Methods for Water Pollution Studies' (Trivedy and Goel, 1989).

- 1. Temperature** of the water in degree Celsius was checked every month with the help of a thermometer.
- 2. pH** of water was determined using a digital pH meter (pocket pH meter-Elico model).
- 3. Dissolved Oxygen** in the water was determined by Winkler's Method, the details of which are described below:

Water sample was collected at the site in a 300ml glass stoppered (BOD) bottle avoiding any kind of bubbling and trapping of the air bubbles in the bottle after placing the stopper. 1ml of each of the filtered MnSO_4 (100g of MnSO_4 in 200ml of pre-boiled water) and alkaline KI (100g of KOH and 50g of KI in 200ml of pre-boiled distilled water) were added well below the surface. A brown precipitate appeared indicating the presence of oxygen. The contents were well shaken by repeatedly inverting the bottle and the precipitate was allowed to settle. 2ml of Conc. H_2SO_4 was added and shaken well to dissolve the precipitate. About 100ml of the contents were transferred to a conical flask and titrated against 0.025 N Sodium thiosulphate

solution using starch (1g of starch in 100ml of distilled water) as an indicator. The initial dark blue-black colour changes to colourless. Calculations were done as follows:

$$\text{Dissolved Oxygen in mg/l} = \frac{(\text{ml xN}) \text{ of Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O} \times 8 \times 100}{V_2 (V_1 - V) / V_1}$$

Where V_1 – Volume of sample bottle

V_2 – Volume of contents titrated

V – Volume of MnSO_4 and KI added (2ml)

4. Calcium in mg/l was determined using titrimetric method as described below:

To 50ml of water sample, 20ml of 1 N NaOH solution and 100mg of Murexide indicator were added. It was titrated with 0.01M EDTA till pink colour changes to dark purple. Calcium in mg/ l was calculated as follows:

$$\text{Calcium in mg/ l} = \frac{\text{ml of EDTA used} \times 400.8}{\text{ml of sample}}$$

5. Magnesium content of the water was determined by titrimetric method as described below:

Magnesium was expressed as a difference between Ca + Mg titration and the titration alone for calcium. It was calculated as follows:-

$$\text{Mg. in mg/l} = \frac{(Y-X) \times 400.8}{\text{ml of sample}}$$

Where 'X' – EDTA used for calcium determination in ml.

'Y' – EDTA used for hardness (calcium + magnesium) determination using the same volume of sample as used for calcium.

6. Chloride contents of the water was estimated by titrating 50ml of the water samples against 0.02 N AgNO₃ solution using 2ml of 5% potassium chromate as an indicator until a persistent reddish-brown tinge appears. It was calculated as follows:

$$\text{Chloride in mg/l} = \frac{(\text{ml} \times \text{N}) \text{ of Ag NO}_3 \times 1000 \times 35.5}{\text{ml of sample}}$$

7. Phosphate present in the water was estimated with stannous chloride method. To 50ml of water 2ml of ammonium molybdate (25g of ammonium molybdate dissolved in 175ml of distilled water and 280ml of conc. H₂SO₄ in 400ml of distilled water, cooled and both mixed and volume made to 1l) and 5 drops of stannous chloride (2.5g

in 100ml glycerol by heating on water bath) were added due to which blue colour was developed. After five minutes and before 12 minutes its OD was taken at 690nm using a spectrophotometer. The concentration of phosphate was determined as mg/l using a standard curve. Standard phosphate solution was prepared by dissolving 4.388g of pre- dried anhydrous K_3HPO_4 in distilled water and volume made to one litre. This solution was diluted 100 times and contents were reduced to 10mg/l of phosphate, which is considered as standard phosphate solution for the purpose.

8. Electrical Conductivity of the water sample was measured using an Elico (CM180) Conductivity meter.

B. Analysis of the soil samples

The soil samples for analysis were collected monthly from each paddy field habitat with the help of a trowel. Soon after collection they were transported to the laboratory and spread for air drying. After proper drying, the soil was ground to break up aggregates and crumbs. It was then analyzed for various parameters. The procedures for water sample were carried out by dissolving the soil sample as mentioned in the 'Standard Methods' (APHA, 1995) and 'Chemical and Biological Methods for Water Pollution Studies' (Trivedy and Goel, 1989).

1. pH was determined using a digital pH meter (pocket pH meter-Elico model). Soil suspension (1:5) was prepared taking 20g of soil in 100ml of distilled water and stirred for about an hour at regular intervals.

2. Calcium and Magnesium: 50g of air dried soil was taken in 500ml beaker and 100ml of 1 N ammonium acetate solution (57ml glacial acetic acid diluted to 800ml with distilled water and then neutralized to pH 7 with concentrated NH_4OH making

the final volume to 1l), the suspension stirred, kept overnight, supernatant filtered through Whatman No. 42 filter paper. Soil leached 4 to 5 times more with portions of ammonium acetate and volume made up to 500ml in a volumetric flask. Concentration of calcium and magnesium was determined following the EDTA method as for the analysis of water. Calcium and magnesium were calculated as follows:

$$\text{Ca in mg/100g} = \frac{A \times 400.8 \times V}{V \times 10 \times S}$$

$$\text{Mg in mg/100g} = \frac{(B - A) \times 400.8 \times V}{v \times 1.645 \times 10 \times S}$$

Where 'A' is the volume of EDTA used for Ca in ml.

'B' is the volume of EDTA used for Ca + Mg in ml.

'V' is total volume of soil extract prepared

'S' is the weight of soil taken

'v' is volume of soil extract titrated in ml.

3. Chlorides: 1:5 soil suspension was prepared by dissolving 20g of soil in 100ml of distilled water for about 1h and filtering the suspension through Whatman No. 50

filter paper using Buchner funnel and vacuum pump. The chloride content in 50ml of soil solution was then determined by

$$\text{Chloride in mg/100g} = \frac{(\text{ml} \times \text{N}) \text{ of AgNO}_3 \times 35.5 \times 1000}{\text{ml of soil sample} \times 2}$$

Where 'N' is the Normality of AgNO₃.

4. Phosphate: Soil P was estimated with stannous chloride method. 1:5 soil suspension was prepared by dissolving 20g of soil in 100ml of distilled water for about 1h and filtering the suspension through Whatman No. 50 filter paper. To 50ml of soil suspension 2ml of ammonium molybdate (25g of ammonium molybdate dissolved in 175ml of distilled water and 280ml of conc. H₂SO₄ in 400ml of distilled water, cooled and both mixed and volume made to 1l) and 5 drops of stannous chloride (2.5g in 100ml glycerol by heating on water bath) were added due to which blue colour was developed. After five minutes and before 12 minutes its OD was taken at 690nm on a spectrophotometer. The concentration of phosphate was determined as mg/l using a standard curve. Standard phosphate solution was prepared by dissolving 4.388g of pre-dried anhydrous K₃HPO₄ in distilled water and volume made to one litre. This solution was diluted 100 times and contents were reduced to 10mg/l of phosphate, which is considered as standard phosphate solution for the purpose.

5. Potassium: 50g of air dried soil was taken in 500ml beaker and 100ml of 1 N ammonium acetate solution (57ml glacial acetic acid diluted to 800ml with distilled water and then neutralized to pH 7 with concentrated NH₄OH making the final volume to 1l), the suspension stirred, kept overnight, supernatant filtered through

Whatman No. 42 filter paper. Soil leached 4 to 5 times more with portions of ammonium acetate and volume made up to 500ml in a volumetric flask. Concentration of potassium was determined by Flame Photometric method as described for the water analysis using Elico CL 361 flame photometer.

$$\text{K in mg/100g} = \frac{\text{mg /l of soil extract} \times V}{S \times 10}$$

Where 'V' is total volume of soil extract

'S' is the weight of soil taken

6. Analysis of micro-nutrients: micro nutrients such as Zn, Cu, Fe, Mn and B were analyzed by Atomic absorption spectrophotometer (AAS 4139).

RESULTS:

According to the meteorological data, during the year 2006-2007 kharif season, average daily sunshine recorded was 146.04h, average rainfall recorded was 149.2mm, and average relative humidity recorded was 81.3% at 8.30am and 83.6% at 5.30pm. The average temperature of the season varied from maximum 30⁰C to minimum 24⁰C. During the rabi season of the same year, average daily sunshine recorded was 277.62h, no rainfall, and average relative humidity recorded was 82.4% at 8.30am and 61.8% at 5.30pm. The average temperature of the rabi season varied from maximum 33⁰C to minimum 22⁰C (**Table 3.1 and 3.2**).

During the year 2007-2008 kharif season, average daily sunshine recorded was 102.18h, average rainfall recorded was 699.54mm, and average relative humidity recorded was 92.8% at 8.30am and 86% at 5.30pm. The average temperature of kharif season varied from maximum 30⁰C to minimum 24⁰C. During the rabi season of the same year, average daily sunshine recorded was 271.86h, average rainfall recorded was 11.86mm, and average relative humidity recorded was 82.6% at 8.30am and 62.4% at 5.30pm. The average temperature of the season varied from maximum 33⁰C to minimum 21⁰C (**Table 3.3**).

The meteorological data of 2008-2009 shows that during kharif season, the average daily sunshine recorded was 139.244h, average rainfall recorded was 551.42mm, and average relative humidity recorded was 90.04% at 8.30am and 82.4% at 5.30pm. The average temperature of the season varied from maximum 31⁰C to minimum 24⁰C. During the rabi season of the same year, average daily sunshine recorded was 270.56h, average rainfall recorded was 1.5mm, and average relative

humidity recorded was 83.6% at 8.30am and 62.6% at 5.30pm. The average temperature of the season varied from maximum 32⁰C to minimum 23⁰C (Table 3.4).

Table 3.1: Monthly meteorological data for the year 2006

Station : Goa (Panjim) Year: 2006						
Month	Total Sunshine (hours)	Total Rainfall (mm)	Monthly Mean Relative Humidity (RH)		Monthly Mean Temperature (°C)	
			at 8.30 am (%)	at 5.30 pm (%)	Max	Min
January	295.2	000.0	77	54	34.0	19.6
February	273.2	000.0	80	59	34.1	20.6
March	285.3	044.3	83	62	32.2	22.8
April	276.4	000.0	77	69	32.7	24.8
May	230.7	416.7	81	74	32.9	26.0
June	135.3	734.6	91	85	30.6	24.6
July	096.8	371.1	87	85	30.0	24.0
August	121.2	576.4	91	86	29.4	24.1
September	160.1	422.5	92	85	30.1	23.8
October	217.0	391.5	88	77	32.3	23.1
November	228.9	006.2	83	70	34.0	23.6
December	283.3	000.0	76	55	34.0	20.1

Table 3.2: Monthly meteorological data for the year 2007

Station : Goa (Panjim) Year: 2007						
Month	Total Sunshine	Total Rainfall	Monthly Mean Relative Humidity (RH)		Monthly Mean Temperature (°C)	
			at 8.30 am (%)	at 5.30 pm (%)	Max	Min
January	293.0	000.0	86	59	33.4	20.2
February	278.9	000.0	87	60	32.7	20.6
March	267.2	000.0	84	66	32.6	23.6
April	265.7	Trace	79	69	33.8	26.3
May	270.8	093.8	75	67	34.1	26.2
June	082.4	1077.3	92	86	30.4	24.8
July	058.3	688.6	93	88	29.5	24.5
August	092.6	887.0	93	89	29.1	24.1
September	107.8	763.2	95	87	29.5	24.0
October	169.8	081.9	91	80	31.6	24.1
November	273.1	075.6	85	65	33.4	21.2
December	258.2	000.7	83	62	33.4	20.9

Table 3.3: Monthly meteorological data for the year 2008

Station : Goa (Panjim) Year: 2008						
Month	Total Sunshine	Total Rainfall	Monthly Mean Relative Humidity (RH)		Monthly Mean Temperature (°C)	
			At 8.30 am (%)	At 5.30 pm (%)	Max	Min
January	300.9	000.0	84	55	32.9	18.8
February	277.5	Trace	85	60	31.4	19.3
March	245.3	043.1	85	69	32.9	22.8
April	277.4	015.5	76	66	33.5	24.9
May	288.1	010.2	75	69	34.3	25.9
June	077.0	782.6	88	83	30.8	24.5
July	126.0	562.6	91	84	30.1	24.2
August	120.6	841.9	94	87	29.2	23.5
September	143.5	559.2	94	85	30.2	23.3
October	229.1	010.8	85	73	33.8	23.8
November	239.2	005.9	80	63	34.4	22.6
December	277.5	007.5	81	58	24.7	21.2

Table 3.4: Monthly meteorological data for the year 2009

Station : Goa (Panjim) Year: 2009						
Month	Total Sunshine	Total Rainfall	Monthly Mean Relative Humidity (RH)		Monthly Mean Temperature (°C)	
			at 8.30 am (%)	at 5.30 pm (%)	Max	Min
January	293.0	000.0	86	59	33.8	20.3
February	266.1	000.0	88	63	33.1	21.2
March	266.0	Trace	85	66	33.6	24.0
April	250.2	000.0	78	67	34.3	26.2
May	260.3	009.7	79	67	43.4	26.4
June	127.0	743.3	91	82	32.2	24.0
July	066.0	2279.8	92	90	29.2	24.3
August	161.8	263.9	91	85	30.3	24.7
September	138.0	366.7	93	87	30.1	24.1
October	217.8	383.7	88	78	31.5	23.6
November	227.0	157.4	83	71	32.7	23.1
December	243.2	000.0	81	61	32.9	22.1

The physico-chemical analyses of water and soil in the four different habitats is described below.

a. Hinterlands of Quepem: During the study period from 2006 – 2009, water temperature ranged between 26⁰C to 29.5⁰C with a minimum temperature of 26⁰C recorded in the months of January 2006, December 2007 and February 2009 and a maximum temperature of 29.5⁰C recorded in the month of June 2008.

The pH of water ranged from 6.4 to 7.8. The least pH recorded was 6.4 in the months July 2006, September 2007 and highest pH recorded was 7.8 in the month of February 2009. pH of soil ranged from 6.5 to 7.9, the lowest pH value recorded was 6.5 in the month of February 2007 and the highest value recorded was 7.9 in the month of October 2008.

Electrical conductivity of water varied widely from 7.45-9.43mmhos/cm. The minimum EC of 7.45mmhos/cm was recorded in the month of August 2006 and highest EC recorded was 9.43mmhos/cm in the month of July 2006 whereas EC of soil ranged from 7.28 to 9.02mmhos/cm. The lowest EC recorded was 7.28mmhos/cm in the month of September 2006 and the highest EC recorded was 9.02mmhos/cm in the month of August 2006.

Dissolved oxygen (DO) varied from 5.6 to 8.5mg/l during the study period. The least DO recorded was 5.6mg/l in the month of October 2006 and the highest DO recorded was 8.5 mg/l in the month of June 2006.

Calcium content of water varied from 1.8 to 3.6mg/l. The lowest Ca of 1.8mg/l was recorded in the month of August 2006 and the highest Ca of 3.6mg/l was recorded in the months of June 2007, February 2008. Ca content of soil varied from

0.4 to 7.56mg/l with the lowest value of 0.4mg/l recorded in the month of March 2008 and highest value of 7.56mg/l recorded in the month of June 2008.

Magnesium content of water varied from 1 to 2.6mg/l with the least of 1mg/l recorded in the month of June 2006 and highest value of 2.6mg/l in the month of January 2009, both in the same year. Mg content of soil ranged from 0.04 to 5.01mg/l which is comparatively lower than water. The least Mg content of 0.04mg/l was recorded in the month of October 2007 and highest was 5.01mg/l in the month of June 2008.

Chloride content of water ranged from 4.5 to 8.2mg/l with the least value of 4.5mg/l recorded in the month of October 2006 and the highest value of 8.2mg/l recorded in the month of January 2007. The Cl content of soil ranged from 6.02 to 10.2mg/l. The lowest Cl content of 6.02mg/l soil was recorded in the month of June 2007. The highest Cl content 10.2mg/l was recorded in the months of March 2008, February 2009.

Phosphorus content of water ranged from 0.02-0.31mg/l with the lowest value of 0.02 mg/l recorded in the month of October 2006 and highest value of 0.31mg/l was recorded in the month of June 2008. P content of soil fluctuated widely from 26.82 to 83.44kg/ha. The lowest value of 26.82kg/ha was recorded in the month of February 2006 and highest value of 83.44kg/ha was recorded in the month of October 2006.

Nitrogen content of soil ranged from 0.51 to 2.92kg/ha with the least value of 0.51 kg/ha recorded in the month of February 2009 and the highest value of 2.92kg/ha recorded in the month of January 2009.

Potassium content of paddy fields fluctuated from 672.2 to 1153kg/ha during the study period with the least value of 672.2kg/ha recorded in the month of February 2007 and the highest value of 1153 kg/ha recorded in the month of October 2006.

The soil samples were analyzed for microelements Zn, Fe, Mn, Cu, and B. Zn varied from 1 to 5ppm, Fe ranged from 40 to 90ppm, Mn ranged from 15 to 33ppm, Cu ranged from 3 to 6ppm and B ranged from 0 to 4ppm in the soil samples **(Tables 3.5-3.7)**.

Table 3.5: Physico-chemical parameters of water and soil samples from hinterlands of Quepem for kharif and rabi season of 2006-2007

Water Sample									Soil Sample													
Parameters	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	EC mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm	
Months																						
June	6.90	8.23	27.90	8.50	3.20	1.00	0.25	6.00	7.40	8.20	1.97	68.54	1129.00	4.10	0.20	6.50	4.59	73.99	19.70	4.46	2.71	
July	6.40	9.43	27.00	7.60	3.30	1.90	0.13	5.00	6.80	8.22	2.51	71.52	1130.00	2.30	0.20	7.00	3.33	55.04	16.15	4.98	2.91	
Aug	6.90	7.45	28.00	6.40	1.80	2.00	0.08	5.20	7.50	9.02	1.67	71.52	1125.00	1.90	0.14	8.30	2.02	66.50	20.20	3.53	3.31	
Sept	6.70	8.46	27.10	5.90	3.30	2.00	0.05	4.60	7.20	7.28	1.96	83.44	1127.00	1.90	0.14	9.10	3.01	62.71	17.19	4.32	3.00	
Oct	7.50	7.86	27.00	5.60	3.10	2.00	0.02	4.50	6.90	8.45	1.05	65.56	1153.00	1.60	0.18	9.10	2.45	66.86	23.38	4.20	3.12	
Dec	7.20	8.22	26.10	6.80	3.10	2.30	0.20	8.10	6.80	8.21	2.21	77.48	1123.00	1.60	0.19	9.20	4.18	74.99	17.68	4.56	2.92	
Jan	6.60	7.69	26.00	7.10	3.10	2.10	0.30	8.20	6.80	7.82	1.05	26.82	1125.00	1.70	0.19	9.40	2.67	66.95	21.40	4.82	2.86	
Feb	6.90	8.29	26.20	6.60	3.10	2.30	0.20	6.00	6.50	7.99	1.23	38.74	672.20	2.10	0.20	8.30	1.80	74.42	26.20	4.15	0.53	
March	6.70	7.77	27.10	5.80	3.10	2.10	0.10	5.00	6.70	7.80	1.99	59.60	1120.00	1.80	0.19	9.10	3.21	68.68	32.54	2.12	3.20	
April	7.10	7.59	28.50	6.70	3.20	2.10	0.10	5.10	6.80	7.53	1.56	56.62	1126.00	1.70	0.19	9.90	2.94	63.34	26.83	4.31	3.20	
Average	6.89	8.10	27.09	6.70	3.03	1.98	0.14	5.77	6.94	8.05	1.72	61.98	1083.02	2.07	0.18	8.59	3.02	67.35	22.13	4.15	2.78	
SD ±	0.32	0.58	0.85	0.88	0.44	0.37	0.09	1.35	0.32	0.49	0.50	17.48	144.63	0.75	0.02	1.08	0.87	6.19	5.15	0.81	0.81	

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

Table 3.6: Physico-chemical parameters of water and soil samples of paddy fields from hinterlands of Quepem for kharif and rabi season of 2007-2008.

Water Sample									Soil Sample												
Parameters	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	EC mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm
Months																					
June	6.70	8.54	29.20	7.20	3.60	1.80	0.30	6.50	7.30	9.02	1.95	66.82	1127.00	7.23	4.40	6.02	4.60	74.90	20.13	5.21	2.99
July	7.60	9.20	28.20	7.00	3.20	1.90	0.14	5.80	7.40	8.45	1.49	68.52	1120.00	6.21	4.10	7.02	3.36	55.60	17.21	5.00	2.82
Aug	7.20	8.23	27.20	6.80	2.50	2.10	0.11	5.10	7.20	8.54	1.12	70.62	1136.00	1.40	1.60	8.20	2.29	68.50	20.46	3.59	3.42
Sept	6.40	8.47	27.10	5.80	2.50	2.10	0.05	5.30	7.80	7.98	1.88	71.32	1132.00	1.20	1.00	8.10	3.32	67.68	18.19	4.38	3.25
Oct	6.60	7.82	27.50	6.30	3.10	2.00	0.04	4.90	6.90	8.25	1.03	62.58	1130.00	1.60	0.04	9.20	2.46	68.23	24.38	4.50	3.16
Dec	6.80	8.10	26.00	6.90	2.80	2.30	0.20	6.70	6.80	8.30	1.23	72.89	1130.00	2.20	0.22	9.20	4.28	72.23	18.69	4.60	2.89
Jan	7.60	7.54	26.30	7.00	3.00	2.50	0.20	7.00	6.80	7.70	0.98	30.28	1128.00	2.20	0.26	9.90	3.00	71.18	22.50	4.71	2.72
Feb	6.80	8.13	26.50	7.00	3.60	2.30	0.30	6.90	7.40	7.89	1.52	32.35	1118.00	1.60	0.33	9.90	2.26	68.23	25.10	4.21	0.62
March	6.90	7.79	27.00	6.30	3.30	2.10	0.10	6.80	6.60	7.97	0.58	42.68	1120.00	0.40	0.40	10.20	3.10	62.14	31.26	3.26	2.60
April	6.90	7.55	28.00	6.00	2.90	2.30	0.10	6.90	6.80	7.52	0.55	49.82	1119.00	2.50	0.43	9.30	2.82	65.26	27.82	4.12	2.90
Average	6.95	8.14	27.30	6.63	3.05	2.14	0.15	6.19	7.10	8.16	1.23	56.79	1126.00	2.65	1.28	8.70	3.15	67.40	22.57	4.36	2.74
SD ±	0.40	0.51	0.97	0.49	0.39	0.21	0.09	0.83	0.38	0.44	0.48	16.60	6.31	2.24	1.63	1.36	0.79	5.46	4.55	0.60	0.78

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

Table 3.7: Physico-chemical parameters of water and soil samples of paddy fields from hinterlands of Quepem for kharif and rabi season of 2008-2009

Water Sample									Soil Sample												
Parameters	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	EC mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm
Months																					
June	6.90	8.00	29.50	7.60	3.60	1.80	0.31	6.60	7.10	9.02	1.96	69.52	1129.00	7.56	5.10	6.20	4.61	75.12	20.22	5.26	2.98
July	7.50	8.66	28.50	7.20	3.30	1.90	0.15	5.80	7.00	8.45	1.45	70.61	1130.00	7.20	4.20	7.20	3.38	60.20	18.32	4.98	2.78
Aug	7.20	9.28	27.20	6.80	2.80	2.20	0.12	5.20	7.20	8.54	1.62	71.56	1128.00	4.60	2.10	8.20	2.30	66.20	20.22	4.20	3.36
Sept	6.70	8.23	27.50	5.90	2.70	2.10	0.06	5.10	7.80	7.98	1.82	80.44	1126.00	3.20	1.20	8.10	3.31	68.20	18.29	4.38	3.15
Oct	6.80	8.56	27.20	6.20	3.20	2.00	0.05	4.80	7.90	8.23	2.05	56.56	1121.00	1.80	0.06	8.00	2.72	67.10	24.52	4.52	3.12
Dec	6.80	7.82	26.70	7.20	2.80	2.30	0.22	6.60	7.80	8.29	2.23	78.50	1130.00	2.50	0.23	9.20	4.12	68.25	18.23	4.80	2.99
Jan	7.10	8.12	26.50	7.00	3.10	2.60	0.21	7.10	6.90	7.69	2.92	36.80	1128.00	2.80	0.31	9.10	2.98	71.25	20.55	4.72	2.82
Feb	7.80	7.68	26.00	7.10	3.50	2.30	0.30	6.90	6.50	7.89	0.51	40.12	1127.00	1.90	0.39	10.20	2.52	71.28	21.22	4.32	2.76
March	6.90	8.39	27.00	6.50	3.40	2.10	0.10	6.70	6.60	7.95	0.56	68.60	1120.00	0.50	0.46	10.00	3.26	67.25	24.36	3.25	1.72
April	6.90	7.82	28.50	6.20	2.80	2.30	0.20	6.90	6.90	7.52	0.56	53.60	1118.00	2.10	0.42	9.10	2.81	62.25	27.66	4.28	1.10
Average	7.06	8.26	27.46	6.77	3.12	2.16	0.17	6.17	7.17	8.16	1.57	62.63	1125.70	3.42	1.45	8.53	3.20	67.71	21.36	4.47	2.68
SD ±	0.35	0.49	1.07	0.55	0.33	0.23	0.09	0.86	0.50	0.44	0.81	15.23	4.40	2.34	1.80	1.24	0.71	4.34	3.17	0.55	0.71

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

b. Coastal Paddy Fields of Utorda: During the study period from 2006-2009, water temperature ranged between 25⁰C to 28⁰C with a minimum temperature of 25⁰C recorded in the months of January, February of 2006 and 2009 and a maximum temperature of 28⁰C recorded in the months of October of 2006, 2008 and April 2008.

The pH of water ranged from 5.1 to 6.5. The least pH recorded was 5.1 in the month of February 2007 and highest pH recorded was 6.5 in the month of June 2007. pH of soil ranged from 5.2 to 7.1, the lowest value recorded was 5.2 in the month of April 2007 and the highest value recorded was 7.1 in the month of August 2008.

Electrical conductivity of water varied widely from 1.26-5.65mmhos/cm. The minimum EC recorded was 1.26mmhos/cm in the month of February 2009 and highest EC recorded was 5.65mmhos/cm in the month of August 2007 whereas EC of soil ranged from 4.7 to 6.5mmhos/cm. The lowest EC recorded was 4.7mmhos/cm in the month of February 2007 and the highest EC recorded was 6.5mmhos/cm in the months of June 2007 and January 2009.

Dissolved oxygen (DO) varied from 2.1 to 8mg/l during the study period. The least DO recorded was 2.1mg/l in the month of February 2008 and the highest DO of 8mg/l was recorded in the month of June 2008.

Calcium content of water varied from 1.56 to 4.96mg/l. The lowest Ca content recorded was 1.56mg/l in the month of October 2007 and highest Ca recorded was 4.96mg/l in the month of June 2007. Ca content of soil varied from 1.8 to 4.1mg/l with the lowest value of 1.8mg/l recorded in the month of October 2008 and highest value of 4.1mg/l recorded in the month of April 2008.

Magnesium content of water varied from 1 to 3.7mg/l with the least value recorded was 1mg/l in the month of October 2006 and highest value recorded was 3.7mg/l in the month of February 2006 both in the same year. Mg content of soil

ranged from 0.17 to 1.5mg/l which is comparatively lower than that of water. The least Mg content recorded was 0.17mg/l in the month of January 2009 and highest was 1.5mg/l in the month of September 2007.

Chloride content of water ranged from 5.3 to 8.2mg/l with the least value of 5.3mg/l recorded in the month of August 2006 and the highest value of 8.2mg/l recorded in the months of December 2006, January 2008 and March 2008. The Cl content of soil ranged from 6 to 10mg/l. The lowest chloride content of 6mg/l soil was recorded in the months of August 2006, 2008 and September 2007. The highest chloride content of 10mg/l was recorded in the month of December 2006.

Phosphorus content of water ranged from 0.01 to 0.32mg/l with the lowest value 0.01mg/l recorded in the months of December 2006, 2007 and October 2008 and highest value of 0.32mg/l recorded in the month of February 2009. P content of soil fluctuated widely from 5.96 to 72.62kg/ha. The lowest value of 5.96kg/ha was recorded in the month of September 2006 and 2008 and highest value of 72.62kg/ha was recorded in the month of March 2009.

Nitrogen content of soil ranged from 0.26 to 1.47kg/ha with the least value of 0.26kg/ha recorded in the month of March 2008 and the highest value of 1.47kg/ha recorded in the month of March 2009.

Potassium content of paddy fields fluctuated from 85.3 to 224kg/ha during the study period with the least value of 85.3kg/ha recorded in the month of April 2009 and the highest value of 224kg/ha recorded in the month of October 2006.

The soil samples were analyzed for microelements Zn, Fe, Mn, Cu, and B. Zn varied from 1 to 4ppm, Fe ranged from 5 to 85ppm, Mn ranged from 0 to 2ppm, Cu ranged from 1 to 2ppm and B ranged from 0 to 1ppm in the soil samples **(Tables 3.8-3.10)**.

Table 3.8: Physico-chemical parameters of water and soil samples of paddy fields from coastal area of Utorda for kharif and rabi seasons of 2006-2007

Parameters	Water Sample									Soil Sample												
	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	EC mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm	
Months																						
June	6.10	5.58	27.00	7.80	4.82	2.20	0.24	5.80	6.80	6.20	0.45	17.88	179.20	2.20	0.23	6.20	3.32	82.3	2.14	1.69	0.80	
July	6.30	5.18	26.00	7.40	1.72	2.00	0.12	5.70	6.50	5.80	0.42	23.84	156.80	2.50	0.20	6.10	2.77	79.52	0.28	1.39	0.44	
Aug	6.20	5.63	25.50	6.20	1.63	2.00	0.01	5.30	6.60	5.50	0.40	8.94	134.40	2.00	0.32	6.00	3.82	69.80	1.17	1.61	0.47	
Sept	6.00	5.39	27.20	6.50	1.58	2.00	0.02	6.20	6.20	5.40	0.33	5.96	156.80	2.00	1.20	7.80	1.62	74.43	1.14	1.54	0.22	
Oct	5.30	5.02	28.00	6.80	4.52	1.00	0.02	7.10	5.80	5.30	0.32	5.96	224.00	1.98	0.20	9.00	2.92	59.58	1.04	1.72	0.58	
Dec	5.60	5.34	26.00	6.20	3.70	1.20	0.01	8.20	5.60	5.10	0.52	17.88	112.00	2.80	0.19	10.2	3.38	43.14	0.53	1.39	0.73	
Jan	5.40	4.53	25.00	6.80	3.60	3.10	0.25	7.10	5.70	4.80	0.56	8.94	145.60	3.80	0.18	10.0	3.14	51.88	0.78	1.69	0.58	
Feb	5.10	1.29	25.00	5.80	3.50	3.70	0.3	6.50	5.40	4.70	1.37	26.82	89.60	3.40	0.26	9.20	1.72	80.84	1.51	1.46	0.33	
March	5.40	4.91	26.50	6.60	3.20	2.80	0.28	8.10	5.30	5.20	0.35	8.94	89.60	3.50	0.23	6.50	3.16	62.02	1.31	1.88	0.65	
April	5.30	4.65	27.50	5.70	4.20	2.00	0.3	5.40	5.20	5.10	0.57	71.52	89.60	4.00	0.25	6.20	3.06	59.24	1.05	1.5	0.73	
Average	5.67	4.75	26.37	6.58	3.25	2.20	0.16	6.54	5.91	5.31	0.53	19.67	137.76	2.82	0.33	7.72	2.89	66.28	1.10	1.59	0.55	
SD ±	0.44	1.27	1.04	0.66	1.21	0.82	0.13	1.06	0.58	0.45	0.31	19.68	44.19	0.80	0.31	1.73	0.70	13.24	0.52	0.16	0.19	

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

Table 3.9: Physico-chemical parameters of water and soil samples of paddy fields from coastal area of Utorda for kharif and rabi seasons of 2007-2008

Parameters	Water Sample								Soil Sample												
	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	E.C mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm
Months																					
June	6.50	5.58	27.00	7.90	4.96	2.30	0.25	6.70	6.80	6.50	0.48	18.88	176.50	2.80	0.24	6.30	3.50	83.56	2.20	1.70	0.81
July	6.30	5.28	26.00	7.90	4.85	2.20	0.16	5.60	6.60	6.20	0.46	20.62	162.30	2.60	0.19	6.20	2.80	82.31	0.30	1.68	0.52
Aug	6.30	5.65	25.60	7.80	3.20	2.20	0.12	5.60	6.50	5.80	0.43	19.22	128.50	2.20	0.31	6.10	3.20	60.20	1.18	1.61	0.46
Sept	6.20	5.40	26.50	7.00	1.80	2.00	0.02	5.20	6.60	5.50	0.38	8.85	132.50	2.20	1.50	6.00	1.80	75.30	1.15	1.56	0.35
Oct	6.10	5.20	27.00	5.30	1.56	1.80	0.03	5.30	5.60	5.40	0.35	6.83	133.50	2.00	1.30	7.20	2.60	58.50	1.06	1.75	0.45
Dec	5.80	5.34	27.50	5.40	4.20	1.50	0.01	7.50	5.60	5.30	0.51	18.26	126.80	2.50	1.20	8.50	3.35	46.15	0.65	1.40	0.72
Jan	5.70	4.65	27.00	4.60	3.70	3.60	0.12	8.20	5.70	4.90	0.57	13.26	139.00	3.60	0.20	9.20	3.16	50.00	0.72	1.70	0.60
Feb	5.60	2.10	26.50	2.10	3.60	3.60	0.23	7.50	5.30	4.80	1.40	9.83	152.60	3.50	0.23	9.50	1.83	72.83	1.62	1.52	0.45
March	5.10	4.90	26.00	4.50	3.20	2.90	0.25	8.20	5.30	5.30	0.26	25.20	162.80	3.40	0.19	6.80	3.27	65.50	1.51	1.78	0.53
April	5.20	4.50	28.00	4.70	3.80	2.30	0.23	6.80	5.30	5.20	0.55	10.12	161.80	4.10	0.20	6.00	3.05	56.20	1.08	1.46	0.76
Average	5.88	4.86	26.71	5.72	3.49	2.44	0.14	6.66	5.93	5.49	0.54	15.11	147.63	2.89	0.56	7.18	2.86	65.06	1.15	1.62	0.57
SD ±	0.48	1.04	0.74	1.90	1.13	0.71	0.10	1.17	0.62	0.54	0.32	6.12	17.66	0.71	0.54	1.38	0.61	13.06	0.54	0.13	0.15

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

Table 3.10: Physico-Chemical parameters of water and soil samples of paddy fields from coastal area of Utorda for kharif and rabi seasons of 2008-2009.

Parameters	Water Sample									Soil Sample											
	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	EC mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm
Months																					
June	6.20	5.56	27.00	8.00	4.82	2.30	0.26	5.90	6.80	6.50	0.46	17.62	178.50	2.30	0.23	6.10	3.33	80.33	2.28	1.70	0.82
July	6.30	5.52	26.00	7.80	2.70	2.00	0.25	5.80	7.00	6.20	0.43	22.35	153.80	2.60	0.19	6.20	2.85	76.50	0.35	1.50	0.52
Aug	6.40	5.61	26.00	7.50	1.85	2.00	0.24	5.50	7.10	5.90	0.42	8.83	135.20	2.20	0.30	6.00	3.38	68.20	1.02	1.60	0.48
Sept	6.20	5.40	27.00	6.50	1.62	2.00	0.03	6.10	6.70	5.80	0.35	6.24	152.80	2.20	1.20	7.20	1.82	72.50	1.09	1.50	0.31
Oct	5.60	5.10	28.00	6.60	4.60	1.20	0.01	6.50	5.90	5.40	0.33	5.96	217.00	1.80	0.19	8.80	2.95	56.30	1.10	1.80	0.56
Dec	5.70	5.30	26.00	6.50	3.80	1.20	0.20	7.50	5.80	5.60	0.46	16.88	109.00	2.30	0.19	9.50	3.36	48.50	0.56	1.40	0.65
Jan	5.30	4.80	25.00	6.90	3.90	3.10	0.26	7.20	5.80	4.90	0.48	8.25	122.60	2.80	0.17	10.00	3.18	50.22	0.82	1.71	0.72
Feb	5.20	1.26	25.00	5.80	4.20	3.20	0.32	6.80	5.70	4.80	0.57	26.22	90.20	3.20	0.25	9.20	1.83	80.15	1.62	1.52	0.56
March	5.30	4.90	26.50	6.30	4.30	3.10	0.29	7.20	5.60	5.30	1.47	8.23	86.20	3.50	0.24	7.80	3.55	60.02	1.39	1.92	0.33
April	5.30	4.50	27.00	6.00	4.00	2.00	0.31	6.50	5.50	5.20	0.56	72.62	85.30	3.80	0.24	6.70	2.90	58.62	1.02	1.60	0.62
Average	5.75	4.80	26.35	6.79	3.58	2.21	0.22	6.50	6.19	5.56	0.55	19.32	133.06	2.67	0.32	7.75	2.92	65.13	1.13	1.63	0.56
SD ±	0.48	1.29	0.94	0.75	1.13	0.73	0.11	0.67	0.63	0.55	0.33	20.03	43.38	0.64	0.31	1.52	0.62	12.00	0.55	0.16	0.16

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

c. Khazan paddy fields of Quelossim: During the study period from 2006-2009, water temperature ranged between 25⁰C to 30⁰C with a minimum temperature of 25⁰C recorded in the month of January 2007 and a maximum temperature of 30⁰C recorded in the month of June 2006.

The pH of water ranged from 5.6 to 6.5. The least pH recorded was 5.6 in the month of April 2009 and highest pH recorded was 6.5 in the months of February and October 2008. pH of soil ranged from 6.1 to 6.7, the lowest value of 6.1 was recorded in the month of June 2006 and the highest value of 6.7 was recorded in the month of April 2009.

Electrical conductivity of water varied widely from 6.95 to 12.83mmhos/cm. The minimum EC recorded was 6.95mmhos/cm in the month of September 2006 and highest EC recorded was 12.83mmhos/cm in the month of August 2006 whereas EC of soil ranged from 7.33 to 12.63mmhos/cm. The lowest EC recorded was 7.33mmhos/cm in the month of December 2008 and the highest EC recorded was 12.63mmhos/cm in the month of September 2006.

Dissolved oxygen (DO) varied from 6.5 to 8.6mg/l during the study period. The least DO of 6.5mg/l was recorded in the month of October 2006 and the highest DO recorded was 8.6mg/l in the month of June 2008.

Calcium content of water varied from 1.5 to 3.3mg/l. The lowest Ca recorded was 1.5mg/l in the months of February 2007 and March 2009 and the highest Ca of 3.3mg/l was recorded in the month of February 2008. Ca content of soil varied from 0.28 to 8.8mg/l with the lowest value of 0.28mg/l recorded in the month of April 2009 and highest value of 8.8mg/l recorded in the month of June 2009.

Magnesium content of water varied from 0.7 to 2.1mg/l with the least content of 0.7mg/l recorded in the month of October 2008 and highest content of 2.1mg/l in

the month of July 2008 both in the same year. Mg content of soil also ranged from 0.26 to 3.33mg/l. The least Mg content of soil recorded was 0.26mg/l in the month of February 2007 and highest was 3.33mg/l recorded in the months of April 2007 and 2009.

Chloride content of water ranged from 4.2 to 9mg/l with the least value of 4.2mg/l recorded in the month of October 2008 and the highest value of 9.0mg/l recorded in the month of June 2008. The Cl content of soil ranged from 3.2 to 9.2mg/l. The lowest Cl content of 3.2mg/l soil was recorded in the month of February 2007. The highest Cl content 9.2mg/l was recorded in the month of October 2008.

Phosphorus content of water ranged from 0.01 to 0.9mg/l with the lowest value 0.01mg/l recorded in the months of September 2006, September 2007, September and October 2008 and highest value of 0.9mg/l was recorded in the month of February 2009. P content of soil fluctuated widely from 2.6 to 8.94kg/ha. The lowest value of 2.6kg/ha was recorded in the month of March 2009 and highest value of 8.94kg/ha was recorded in the month of April 2007.

Nitrogen content of soil ranged from 0.31 to 1.46kg/ha with the least value of 0.31kg/ha recorded in the month of March 2008 and the highest value of 1.46kg/ha recorded in the months of February 2007 and December 2008.

Potassium content of paddy fields fluctuated from 672 to 940.8kg/ha during the study period with the least value of 672kg/ha recorded in the month of December 2006 and the highest value of 940.80kg/ha recorded in the month of June 2006.

The soil samples were analyzed for microelements Zn, Fe, Mn, Cu, and B. Zinc varied from 1 to 4ppm, Iron ranged from 50 to 75ppm, Manganese ranged from 0 to 2ppm, Copper ranged from 1 to 3ppm and Boron ranged from 0 to 1ppm in the soil samples (**Tables 3.11-3.13**).

Table 3.11: Physico-chemical parameters of water and soil samples of paddy fields from khazan area of Quelossim for kharif and rabi seasons of 2006-2007

Parameters	Water Sample									Soil Sample											
	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	EC mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm
Months																					
June	6.60	9.35	30.00	8.30	1.70	1.50	0.04	8.20	6.10	9.05	0.97	6.02	896.00	8.20	1.20	7.60	2.62	56.95	0.20	2.82	
July	6.30	11.30	28.50	8.20	1.60	2.00	0.03	6.10	6.50	10.32	0.57	6.01	940.80	7.80	1.20	7.40	3.32	60.32	0.18	1.92	0.80
Aug	6.40	12.83	26.30	7.20	1.60	1.50	0.04	5.40	6.20	11.30	1.23	6.00	828.80	6.50	3.20	9.80	2.26	71.32	0.16	1.85	0.40
Sept	6.40	6.95	26.00	7.50	2.80	1.60	0.01	4.60	6.40	12.63	1.05	5.98	784.00	1.60	1.50	9.80	3.52	69.35	0.12	1.92	0.81
Oct	6.50	6.97	27.00	6.50	3.20	0.80	0.02	4.50	6.60	7.82	1.23	5.96	716.80	1.30	1.30	9.00	2.82	58.25	0.10	1.86	0.88
Dec	6.20	12.14	27.50	7.80	3.20	1.10	0.02	7.80	6.30	6.98	1.37	5.96	672.00	1.20	1.30	9.00	1.28	57.62	0.19	2.10	0.82
Jan	6.30	9.18	25.50	8.20	1.80	1.00	0.03	7.90	6.40	11.15	1.46	3.00	828.80	1.20	1.30	9.00	1.16	65.20	0.20	2.80	0.75
Feb	6.40	10.54	25.00	7.90	1.50	1.00	0.03	5.80	6.40	9.83	0.48	2.98	761.80	1.20	0.26	3.20	2.26	58.20	0.21	2.60	0.64
March	6.40	10.43	26.00	7.20	2.90	1.20	0.03	5.20	6.50	10.22	0.32	8.94	784.00	0.26	0.28	4.54	1.98	59.20	0.19	2.50	0.53
April	6.40	10.66	28.00	6.80	3.10	1.90	0.03	5.20	6.70	10.56	0.67	3.20	828.80	0.25	3.33	6.02	3.20	55.32	0.18	2.30	0.82
Average	6.39	10.04	26.98	7.56	2.34	1.36	0.03	6.07	6.41	9.99	0.94	5.41	804.18	2.95	1.49	7.54	2.44	61.17	0.17	2.27	0.72
SD ±	0.11	1.97	1.54	0.62	0.75	0.40	0.01	1.40	0.18	1.67	0.40	1.86	79.32	3.20	1.03	2.28	0.81	5.51	0.04	0.39	0.16

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

Table 3.12: Physico-chemical parameters of water and soil samples of paddy fields from khazan area of Quelossim for kharif and rabi seasons of 2007-2008

Water Sample									Soil Sample												
Parameters	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	E.C mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm
Months																					
June	6.50	8.15	29.50	8.20	1.80	1.20	0.03	8.60	6.30	10.85	0.98	6.10	918.00	8.30	1.60	7.80	2.65	57.80	0.19	2.86	0.89
July	6.20	10.30	29.00	8.30	2.70	1.30	0.03	7.80	6.40	10.25	0.45	6.01	910.20	6.70	1.20	7.50	3.52	61.30	0.18	1.98	0.81
Aug	6.30	9.35	27.20	7.50	2.80	0.90	0.04	5.80	6.30	11.82	1.34	6.00	909.00	6.80	1.20	7.40	2.28	62.50	0.17	1.87	0.51
Sept	6.30	7.25	26.50	7.70	1.70	0.80	0.01	4.60	6.50	12.60	1.09	5.96	893.00	7.30	2.20	9.20	3.83	60.90	0.12	1.92	0.42
Oct	6.40	6.83	26.00	6.80	2.60	1.10	0.02	5.20	6.80	8.90	1.28	5.95	894.00	2.10	1.80	9.30	2.92	58.32	0.11	1.85	0.81
Dec	6.20	9.20	26.00	7.30	2.80	1.80	0.02	4.50	6.50	11.53	1.42	5.95	716.00	1.80	1.50	9.00	2.78	56.52	1.20	2.20	0.82
Jan	6.30	8.70	26.00	7.60	3.20	1.10	0.12	7.20	6.60	10.28	1.45	3.02	772.00	1.70	1.50	9.10	1.12	62.33	1.28	2.60	0.72
Feb	6.50	7.20	26.50	7.90	3.30	1.00	0.15	7.30	6.60	9.83	0.56	2.88	767.00	1.70	1.50	9.30	1.13	64.35	1.30	2.70	0.65
March	6.40	7.90	27.00	7.80	3.10	1.20	0.08	4.90	6.70	10.13	0.31	3.25	758.00	1.70	0.28	5.20	2.10	56.28	0.17	2.50	0.49
April	6.10	7.40	27.50	7.20	3.00	1.80	0.09	4.80	6.70	10.56	0.58	3.30	812.00	0.30	0.28	4.60	2.00	52.38	0.18	2.30	0.79
Average	6.32	8.23	27.12	7.63	2.70	1.22	0.06	6.07	6.54	10.68	0.95	4.84	834.92	3.84	1.31	7.84	2.43	59.27	0.49	2.28	0.69
SD ±	0.13	1.13	1.24	0.46	0.55	0.34	0.05	1.51	0.17	1.07	0.43	1.49	77.51	3.02	0.61	1.73	0.90	3.64	0.53	0.37	0.16

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

Table 3.13: Physico-chemical parameters of water and soil samples of paddy fields from khazan area of Quelossim for kharif and rabi seasons of 2008-2009

Water Sample									Soil Sample												
Parameters	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	EC mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm
Months																					
June	6.30	9.22	29.00	8.60	2.10	1.60	0.05	9.00	6.50	9.20	0.96	6.50	798.00	8.80	1.40	7.80	3.03	57.93	0.22	2.96	0.90
July	6.20	10.86	29.50	7.50	1.80	2.10	0.02	8.60	6.30	9.50	0.56	6.20	812.00	8.20	1.40	7.50	2.82	62.83	0.16	1.98	0.82
Aug	6.10	11.23	27.50	7.30	7.10	1.40	0.02	7.30	6.20	9.05	1.13	6.02	809.00	8.00	2.80	8.80	3.62	72.35	0.15	1.88	0.45
Sept	6.30	12.24	27.50	7.60	1.80	1.50	0.01	4.50	6.30	8.32	1.08	5.96	818.00	1.80	1.60	8.80	3.52	66.35	0.11	1.95	0.81
Oct	6.20	6.82	27.50	6.60	1.60	0.70	0.01	4.20	6.50	7.52	1.33	5.85	806.00	4.50	1.50	9.20	2.86	55.28	0.10	1.88	0.88
Dec	6.50	8.82	27.00	7.30	2.30	1.00	0.05	6.50	6.20	7.33	1.46	5.82	828.00	1.80	1.50	9.00	1.88	58.29	0.18	2.20	0.83
Jan	6.40	9.28	27.00	7.30	3.20	0.90	1.30	6.60	6.30	9.25	0.54	3.50	792.00	1.70	1.50	9.00	1.29	60.12	0.21	2.80	0.78
Feb	6.40	10.20	26.50	7.50	1.80	0.90	0.90	6.80	6.40	10.27	0.53	2.60	784.00	1.70	0.32	3.50	1.18	58.12	0.22	2.58	0.75
March	5.80	9.26	27.00	7.50	1.50	1.10	0.07	5.30	6.50	9.83	0.68	7.30	728.00	0.36	0.30	4.54	2.26	58.00	0.19	2.50	0.56
April	5.60	9.35	28.00	7.20	2.60	1.60	0.05	5.10	6.70	9.66	0.71	2.80	760.00	0.28	3.30	6.02	1.98	57.16	0.17	2.30	0.62
Average	6.18	9.73	27.65	7.44	2.58	1.28	0.25	6.39	6.39	8.99	0.90	5.26	793.50	3.71	1.56	7.42	2.44	60.64	0.17	2.30	0.74
SD ±	0.28	1.50	0.94	0.49	1.67	0.43	0.46	1.63	0.16	0.97	0.34	1.65	29.92	3.39	0.93	2.05	0.86	5.18	0.04	0.39	0.15

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

d. Paddy fields from mining affected areas of Velguem: During the study period from 2006- 2009, water temperature ranged between 27⁰C to 31⁰C with a minimum temperature of 27⁰C recorded in the month of December 2006 and a maximum temperature of 31⁰C recorded in the month of June 2008.

The pH of water ranged from 4.4 to 5.8. The least pH recorded was 4.4 in the month of October 2006 and highest pH recorded was 5.8 in the months of August 2006 and June 2008. pH of soil ranged from 4.7 to 6, the lowest value of 4.7 was recorded in the month of March 2006 and the highest value recorded was 6 in the month of June 2008.

Electrical conductivity of water varied from 1.63 to 7.82mmhos/cm. The minimum EC recorded was 1.63mmhos/cm in the month of April 2006 and highest EC recorded was 7.82mmhos/cm in the month of October 2006 whereas EC of soil ranged from 1.83 to 4.7mmhos/cm. The lowest EC recorded was 1.83mmhos/cm in the month of October 2007 and the highest EC recorded was 4.7mmhos/cm in the month of January 2009.

Dissolved oxygen (DO) varied from 5.2 to 6.6mg/l during the study period. The least DO recorded was 5.2mg/l in the months of August 2006, March 2007 and April 2007 and the highest DO recorded was 6.6mg/l in the month of June 2008.

Calcium content of water varied from 0.5 to 2.2mg/l. The lowest Ca content recorded was 0.5mg/l in the month of October 2008 and the highest Ca content of 2.2mg/l was recorded in June 2008. Ca content of soil was slightly higher than that of water and ranged from 0.73 to 2.5mg/l with the lowest value of 0.73mg/l recorded in the month of December 2006 and highest value of 2.5mg/l recorded in the months of June 2008, January 2009.

Magnesium content of water ranged from 0.01 to 0.98mg/l with the least content of 0.01mg/l recorded in the months of October and December 2006,

September 2007 and 2008 and highest value of 0.98mg/l in the month of June 2008. Mg content of soil ranged from 0.04 to 0.95mg/l which is comparatively higher than that of water. The least Mg content of 0.04mg/l was recorded in the month of October 2007 and highest was 0.95mg/l in March 2009.

Chloride content of water ranged from 4.8 to 6.2mg/l with the least value of 4.8mg/l recorded in the month of October 2006 and the highest value of 6.2mg/l recorded in the months of January 2006 and February 2009. The chloride content of soil ranged from 4.3 to 6.5mg/l. The lowest chloride content of 4.3mg/l soil was recorded in the months of September 2006, February 2008. The highest chloride content 6.5mg/l was recorded in the month of January 2008.

Phosphorus content of water ranged from 0.01 to 0.16mg/l with the lowest value 0.01mg/l recorded in the months of August, September, October 2006 and September 2008 and highest value of 0.16mg/l was recorded in the month of March 2009. P content of soil fluctuated from 2.72 to 6.02kg/ha. The lowest value of 2.72kg/ha was recorded in the month of March 2009 and highest value of 6.02kg/ha was recorded in the months of October 2007 and October 2008.

Nitrogen content of soil ranged from 0.29 to 0.72kg/ha with the least value of 0.29kg/ha recorded in the month of August 2006 and the highest value of 0.72kg/ha recorded in the month of December 2007.

Potassium content of paddy fields fluctuated from 22.4 to 98.2kg/ha during the study period with the least value of 22.4kg/ha recorded in the months of January and April 2007 and the highest value of 98.2kg/ha recorded in the month of June 2006.

The soil samples were analyzed for microelements Zn, Fe, Mn, Cu, and B. Zinc varied from 1 to 2ppm, Iron ranged from 70 to 90ppm, Manganese ranged from 0 to 2ppm, Copper ranged from 0 to 2ppm and Boron ranged from 0 to 1ppm (**Tables 3.14-3.16**).

Table 3.14: Physico-chemical parameters of water and soil samples of paddy fields from mining area of Velguem for kharif and rabi seasons of 2006-2007

Parameters	Water Sample								Soil Sample												
	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	EC mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm
Months																					
June	5.50	2.00	30.00	6.20	1.80	0.96	0.04	5.40	5.60	2.10	0.32	2.98	95.6	2.00	0.76	5.80	1.82	86.98	1.15	1.65	0.50
July	5.00	1.96	28.50	5.30	1.70	0.07	0.02	5.30	5.30	1.98	0.32	2.97	85.3	1.80	0.08	5.70	1.76	75.96	0.18	1.32	0.49
Aug	5.80	2.00	28.00	5.20	1.80	0.05	0.01	5.80	5.40	1.98	0.52	2.98	46.3	1.70	0.05	5.40	1.55	83.28	0.20	1.29	0.42
Sept	5.70	3.16	28.00	5.40	0.62	0.02	0.01	5.40	5.80	2.10	0.42	5.96	45.3	1.50	0.04	4.30	1.62	80.32	0.22	1.52	0.32
Oct	4.40	7.82	27.50	5.60	0.75	0.01	0.01	4.80	4.90	3.20	0.67	6.00	44.8	0.75	0.80	4.80	1.32	85.63	0.56	1.56	0.27
Dec	5.70	2.30	27.00	5.80	1.90	0.01	0.03	6.00	5.00	4.10	0.35	5.97	44.8	0.73	1.00	5.20	1.22	85.55	0.72	1.72	0.58
Jan	4.80	4.54	27.50	5.50	1.80	0.02	0.10	6.10	5.10	4.20	0.32	2.95	22.4	0.65	1.10	5.40	1.18	80.32	0.62	1.62	0.49
Feb	4.80	2.26	27.50	5.30	0.90	0.21	0.12	5.40	4.80	3.30	0.35	2.96	34.8	1.20	0.98	5.30	1.85	80.44	0.65	1.61	0.46
March	5.10	2.56	28.00	5.20	0.85	0.22	0.04	5.30	4.70	3.20	0.36	2.95	44.8	1.50	0.96	5.20	1.78	81.32	0.60	1.60	0.30
April	5.00	1.63	29.50	5.20	1.00	0.30	0.03	5.30	4.80	2.20	0.35	2.97	22.4	1.80	0.85	5.60	1.77	82.45	0.64	1.61	0.32
Average	5.18	3.02	28.15	5.47	1.31	0.19	0.04	5.48	5.14	2.84	0.40	3.87	48.65	1.36	0.66	5.27	1.59	82.23	0.55	1.55	0.42
SD ±	0.47	1.88	0.94	0.32	0.53	0.29	0.04	0.39	0.37	0.88	0.11	1.45	23.99	0.50	0.43	0.44	0.26	3.28	0.29	0.14	0.11

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

Table 3.15: Physico-chemical parameters of water and soil samples of paddy fields from mining area of Velguem for kharif and rabi seasons of 2007-2008

Parameters	Water Sample								Soil Sample												
	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	EC mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm
Months																					
June	5.40	2.10	30.00	6.10	1.60	0.83	0.04	5.60	5.50	2.30	0.39	2.93	98.20	2.10	0.82	5.60	1.83	85.28	1.18	1.85	0.40
July	4.90	2.00	28.60	5.40	1.50	0.08	0.03	5.40	5.40	2.20	0.31	3.01	84.10	1.90	0.09	5.50	1.76	80.16	0.16	1.55	0.40
Aug	5.00	1.96	28.50	5.30	1.50	0.06	0.02	5.10	5.40	2.10	0.29	3.05	65.20	1.80	0.08	5.50	1.58	78.20	0.21	1.32	0.30
Sept	5.60	1.97	28.20	5.50	1.40	0.01	0.02	5.10	5.70	1.86	0.36	5.98	52.10	1.60	0.05	5.30	1.63	95.30	0.23	1.52	0.30
Oct	5.70	3.80	27.50	5.60	0.82	0.02	0.02	5.00	4.80	1.83	0.41	6.02	45.80	0.82	0.04	5.70	1.33	78.60	0.48	1.48	0.28
Dec	4.80	2.50	27.00	5.90	1.60	0.02	0.04	5.20	5.10	2.20	0.72	5.95	44.60	0.85	0.80	6.10	1.28	80.12	0.67	1.68	0.56
Jan	5.60	4.30	27.50	5.40	1.70	0.04	0.12	6.20	5.10	4.00	0.42	2.99	32.60	0.75	1.20	6.50	1.20	82.38	0.62	1.66	0.44
Feb	4.90	2.29	27.50	5.40	1.80	0.23	0.11	6.00	4.90	4.10	0.39	2.77	33.60	1.80	1.10	4.30	1.62	83.56	0.66	1.63	0.42
March	4.80	2.12	28.50	5.30	0.80	0.21	0.03	5.80	4.80	3.80	0.36	2.89	45.00	1.30	1.00	4.50	1.65	82.38	0.61	1.65	0.35
April	5.00	1.72	29.50	5.30	0.82	0.09	0.03	5.70	4.80	3.10	0.36	2.97	28.20	1.50	0.82	5.20	1.70	82.46	0.63	1.61	0.36
Average	5.17	2.48	28.28	5.52	1.35	0.16	0.05	5.51	5.15	2.75	0.40	3.86	52.94	1.44	0.60	5.42	1.56	82.84	0.55	1.60	0.38
SD ±	0.36	0.86	0.95	0.27	0.39	0.25	0.04	0.41	0.33	0.91	0.12	1.47	22.98	0.49	0.48	0.66	0.21	4.90	0.30	0.14	0.08

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

Table 3.16: Physico-chemical parameters of water and soil samples of paddy fields from mining area of Velguem for kharif and rabi seasons of 2008-2009

Water Sample									Soil Sample												
Parameters	pH	EC mmhos/cm	Temp °C	DO mg/l	Ca mg/l	Mg mg/l	P mg/l	Cl mg/l	pH	EC mmhos/cm	N kg/ha	P kg/ha	K kg/ha	Ca mg/l	Mg mg/l	Cl mg/l	Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm
Months																					
June	5.80	1.98	31.00	6.60	2.20	0.98	0.06	5.60	6.00	2.20	0.33	2.94	96.20	2.50	0.82	6.20	1.89	86.99	1.18	1.68	0.58
July	5.30	1.96	29.00	6.20	1.70	0.08	0.05	5.50	5.60	1.98	0.32	3.02	86.20	2.20	0.79	6.00	1.88	79.83	0.16	1.65	0.42
Aug	5.70	2.00	28.50	6.00	2.00	0.04	0.03	5.70	5.80	2.00	0.50	3.06	49.30	1.90	0.62	6.10	1.82	85.26	0.23	1.32	0.49
Sept	5.60	2.35	28.00	5.90	1.80	0.05	0.01	5.50	5.90	2.10	0.48	5.98	46.50	1.80	0.28	5.80	1.56	81.35	0.25	1.28	0.35
Oct	4.50	3.20	28.00	5.80	0.56	0.03	0.02	5.00	5.10	3.30	0.56	6.02	46.20	0.80	0.27	5.50	1.63	85.32	0.63	1.53	0.28
Dec	5.60	4.50	27.50	6.20	1.50	0.08	0.02	4.90	5.20	4.50	0.45	5.95	45.00	0.85	0.10	5.80	1.56	85.56	0.76	1.65	0.62
Jan	4.90	2.80	27.50	6.00	1.80	0.06	0.05	5.80	5.10	4.70	0.39	2.97	28.00	0.73	1.29	5.90	1.53	81.32	0.73	1.63	0.53
Feb	5.00	3.90	27.00	6.20	0.98	0.32	0.11	6.20	5.20	3.50	0.37	2.76	32.00	2.10	1.28	5.60	1.57	80.55	0.70	1.65	0.48
March	5.10	4.00	27.50	5.80	0.82	0.56	0.16	6.10	5.30	3.60	0.35	2.81	45.20	1.80	0.95	5.60	1.73	83.52	0.62	1.62	0.33
April	5.00	3.20	28.00	5.50	2.60	0.32	0.06	5.20	5.10	3.30	0.33	2.72	22.80	1.50	0.76	5.60	1.75	82356.00	0.62	1.60	0.35
Average	5.25	2.99	28.20	6.02	1.60	0.25	0.06	5.55	5.43	3.12	0.41	3.82	49.74	1.62	0.72	5.81	1.69	8310.57	0.59	1.56	0.44
SD ±	0.42	0.93	1.14	0.30	0.64	0.31	0.05	0.43	0.36	1.02	0.08	1.49	23.73	0.63	0.41	0.24	0.14	26016.91	0.31	0.14	0.11

Legend: EC = Electrical Conductivity; DO = Dissolved oxygen

All values are mean of three readings.

Thus it is seen in the above study that the highest pH is seen in the hinterlands of Quepem, followed by coastal fields of Utorda and khazans of Quelossim. The least pH is seen in the mining area fields of Velguem. Among the other physico-chemical parameters analyzed higher readings are observed in Quepem followed by Utorda and Quelossim. The least values of parameters are observed in mining fields of Velguem. The nutrients *viz.*, the P content, dissolved Oxygen, Calcium, Magnesium, N, K and micronutrients were in higher amounts in Quepem followed by Utorda and Quelossim while they were least in Velguem.

DISCUSSION:

In the paddy fields growth of BGA and algal succession are governed by climatic and physico-chemical factors. Among the soil properties, pH is the most important factor determining the algal flora composition. Under natural conditions BGA grow preferentially in environments that are neutral to alkaline pH (Roger, 1985). This is the reason why positive correlation occurs in the paddy fields between: water pH and BGA number, soil pH and N₂ fixing algal biomass (Roger and Reynaud, 1982; Pereira *et al.*, 2005; Ghadai *et al.*, 2010).

In the present study, water pH ranged from 6.4-7.8 and soil pH also ranged from 6.5-7.9 in the hinterland fields, in coastal fields water pH ranged from 5.1-6.5 and soil pH ranged from 5.2-7.1, in khazan fields water pH ranged from 5.6-6.5 and soil pH ranged from 6.1-6.7 while in the mining affected paddy fields the water pH ranged from 4.4-5.8 and soil pH ranged from 4.7-6. The study revealed that although the pH showed acidic nature in certain habitats it supported growth of BGA. Presence of certain strains of BGA in soils with pH values between 5 and 6 has also been reported (Durell, 1964; Aiyer, 1965).

In the present study, temperature in all the study sites ranged from 25⁰C to 31⁰C during study period. Temperature is known to influence the composition of algal biomass and productivity. Low temperature decreases productivity while higher temperatures are known to favour BGA and increase algal productivity, with optimal temperature for luxuriant growth of BGA range from 30⁰C-35⁰C (Roger and Kulasooriya, 1980).

In the present study amount of P varies in different habitats. P content of soil ranges from 26.82 to 83.4kg/ha in hinterlands, 5.96 to 72.62kg/ha in coastal fields, 2.6 to 8.94kg/ha in khazan fields and from 2.72 to 6.02 kg/ha in paddy fields affected by

mining. Since hinterlands shows maximum P content, it can support luxuriant growth of BGA. Availability of P plays an important role in determining BGA growth which has been substantiated by various workers (Okuda and Yamaguchi, 1952; Quesada and Valiente, 1996; Begum *et al.*, 2008).

The study revealed a variation in Ca contents in different habitats. Ca content ranges from 1.8-3.6mg/l in water and 0.4-7.56mg/l in hinterland soils, 1.56-4.96mg/l in water and 1.8-4.1mg/l in soils of coastal fields, 1.5 to 3.3mg/l in water and 0.28 to 8.8 mg/l in khazans and 0.5-2.2mg/l in water and 0.73-2.5mg/l in mining affected fields. Since the hinterlands shows maximum Ca content, it can favour luxuriant growth of BGA. Previous studies suggested better growth of BGA in soils with optimum Ca levels (Healey, 1973; Roger and Reynaud, 1985).

Among the study areas, mining affected fields showed acidic pH with low P and Ca content and this may affect the growth of BGA. The growth of nitrogen fixing cyanobacteria is affected by acidic pH, low content of P and Ca (Roger and Reynaud, 1985; Healey, 1973) as observed in mining affected fields of Velguem. The study suggests that hinterlands are most suitable for the growth of BGA while the mining affected fields are least suitable although there are reports that indicate BGA growth in pH range of 5 to 6 (Durell, 1964; Aiyer, 1965).

Various physico-chemical factors viz., light, temperature, pH, humidity, water and nutrient availability are known to favour the growth of cyanobacteria in paddy fields (Mitra, 1951). Therefore, the understanding of physico-chemical parameters and documentation of cyanobacteria can be applied for sustainable agricultural practices by reducing the application of chemical fertilizers to obtain indigenous inocula for algalization of fields.

INTRODUCTION:

According to Fritsch (1935), algae include all halophytic organisms that fail to reach the level of differentiation characteristic of archegoniate plants. Algae grow in a variety of habitats such as fresh water or marine system, soil, paddy fields and tree trunks. Algal growth in these habitats significantly influences the ecosystem. It is therefore essential to study algal distribution in nature for their better exploitation. These algae may range from tiny microscopic forms to giant seaweeds or kelps several meters in length. In the five kingdom classification, the word alga refers to organisms in any three kingdoms: in Monera, blue green algae (Cyanobacteria); in Protista several types of unicellular, phytoplanktonic organisms; and in the plant kingdom – green, red algae and brown algae.

The gram negative photosynthetic cyanobacteria (blue green algae) are one of the most successful groups of organisms on earth. They even inhabit the steaming hot springs and the undersides of icebergs. They have survived successfully for almost three billion years. Blue green algae form the potential source of nitrogen in paddy fields that remain flooded during most of the crop growth cycle. Cyanobacteria may be single celled, colonial or filamentous. Some cells may be specialized for performing a special function, like the heterocysts. Many are non-motile, few have flagella. Some show gliding movement whereas some filaments show a pendulum like oscillation motion. Gas vacuoles are often present which help it to regulate buoyancy in water. Blue green algae are self contained autotrophs which explain their global success and release nitrogenous compounds into their environment, enriching it. Cyanobacteria are abundantly found in paddy fields because of alkaline pH, flooded conditions, shade provided by the crop canopy. Certain species are able to fix atmospheric nitrogen by the virtue of the enzyme nitrogenase. The dual capacity of fixing atmospheric carbon and nitrogen makes them attractive source of nitrogenous

biofertilizers in paddy cultivation. Their growth not only adds nitrogen to the soil but helps in reducing soil erosion, decreasing soil compaction, adding organic matter and liberating growth regulators. It is therefore necessary to undertake extensive survey of paddy fields to explore the status of cyanobacterial flora which would help in preparing algal map and nutrient budgeting of the area under investigation.

Paddy is one of the important crops in the world. Paddy cultivation requires waterlogged conditions in which various types of algae occur. The paddy fields provide an ideal environment for the growth of blue green algae. The waterlogged conditions are good homes for blue green algae, which play a beneficial role in paddy cultivation. Blue green algae constitute about 15% of the total paddy field algal flora in the tropics and about 2% in the temperate climate. The distribution of nitrogen fixing blue green algae in the paddy soil varies from 4% to 80%.

Paddy is successfully grown on land, which provides sufficient water for 3-6 months during the cultivation period. The principle biological consequences of water logging are the suppression of changes of mesophytic vegetation in soil microflora and the growth of several forms of algae. It is known that paddy fields provide all necessary requirements like light, and water and nutrients for the growth of algae. The growth and activity of algae in submerged soil is of great importance, especially of blue green algae, which are favoured by paddy field ecosystem. Blue green algae are known for their worldwide distribution. Importance of nitrogen fixing blue-green algae in improving soil fertility for sustainable agriculture in submerged and irrigated paddy cultivation in the tropical and subtropical regions is well recognized. It is also known that the endemic strains have an establishment advantage over the introduced strains. Bristol and Roach (1927) carried out the earliest detailed studies on soil algae. According to them the blue-green algal flora varies from habitat to habitat and even within different areas of same habitat with marked seasonal fluctuations in the flora.

Paddy field ecology has been studied less than that of heterotrophic microorganisms and that is why in the recent years interest is found predominantly in paddy fields.

Certain paddy field algae serve as soil conditioners and supply growth substance, which are beneficial for paddy plants. The biological properties of nitrogen fixing blue green algae are of considerable importance in tropical soil such as India. Based on the extended study of De (1939) and Singh (1942), they have recommended certain blue-green algae as biofertilizers. The potentiality of these biofertilizers in increasing paddy yield has been well documented. The recent studies on nitrogen fixation by blue-green algae in paddy fields have been carried out by various workers from different parts of the country (Singh & Bisoyi, 1989; Verma *et al.*, 1990; Anand & Hopper, 1995; Nayak *et al.*, 1996; Singh *et al.*, 1997;).

Cyanophycean algae or blue green algae are considered to be one of the remarkable groups of photosynthetic plant forms (Hellebust, 1974). The cellular organization of this form of algae is prokaryotic which is characterized by lack of membrane bound organelles like nucleus, chloroplast or mitochondria. Thus they are very much identical to photosynthetic bacterial forms and it is very often called cyanobacteria or photosynthetic bacteria or blue green algae. Though cyanobacteria are referred to as blue green algae but they are not necessarily blue green but can be blackish green, blue green, brown or reddish.

In view of the World's food crisis greater attention has been turned to traditional farming practices. But the prospects of increased food grains production are aggregated by the ever-increasing cost of the fuel and chemical fertilizer. Utilization of biological nitrogen fertilizers in the agricultural field has greater significance. Many tropical paddy fields receive neither chemical fertilizer nor natural manure, yet they remain productive and capable of supporting large population with

basic food. Here the fertility of paddy soil is maintained by the activities of blue green algae which grow spontaneously and often luxuriantly in the water logged field. They provide fixed nitrogen to paddy plants through both secretion of nitrogenous substances and on their decay and subsequent mineralization of organic substances in the soil.

De (1939) attributed the inherent fertility of the tropical paddy field soils to the activity of nitrogen-fixing blue green algae; considerable interest has been generated in exploiting the potential of these biological systems. Although blue greens normally prefer warmer habits they have been shown to play a major role as nitrogen fixers in temperate, polar and sub polar regions also. The distribution and role of nitrogen fixing blue green in temperate regions have been investigated in Russia (Gollerbach and Shitina, 1969), Northern and Western Europe (Henriksson *et al.*, 1972; Granhall, 1975) and Northern America (Shields and Durrell, 1964; Jungenoen and Davey, 1968).

Recent advances in methodology have helped a great deal in our understanding of blue green algal nitrogen fixation. Nitrogenase is oxygen sensitive and blue green algae have evolved special devices such as heterocyst for the protection of their nitrogenase enzyme, against oxygen damage. The mapping of 'nif' genes was also made in several nitrogen fixing blue green algae.

In the present study survey of the BGA from the paddy fields of Goa, was carried out. This would enable to know the indigenous cyanobacterial flora of the region and help to understand and document the same from the paddy fields in Goa. Besides, it would assist in identifying the dominant species and heterocystous nitrogen fixers which in turn would help in the production of area specific inocula of indigenous cyanobacterial nitrogen fixers.

MATERIAL AND METHODS:

The study constituted mainly the collection of soil samples containing blue green algae from the paddy fields of four different habitats of Goa, *viz.*, coastal, mining, khazans and hinterlands. Collection of the soil samples containing blue greens was initiated during the study period (2006-09), at regular intervals from the growing, till the harvesting of the paddy. Care was taken to collect algal samples from the surface of the soil, from the surface of submerged parts of the paddy plants and from the water surface. Camera lucida drawings were made and the identification of the blue green algae isolated from various sites was carried out by using standard keys (Desikachary, 1959; Anand, 1989; Prasad and Srivastava, 1992; Santra, 1993).

RESULTS:

The study revealed 84 species belonging to 16 genera from four different habitats of Goa. The study was carried out for three consecutive years from June 2006 to June 2009. The distribution of BGA during the study period is depicted in the **Tables 4.1, 4.2 and 4.3**. The three year study revealed that in all the four habitats variations in the distribution of genera and species for the two growing seasons of paddy *i.e.* kharif and rabi were observed. The kharif season of the year 2006-2007 recorded 63 species belonging to 15 genera in hinterlands, 61 species belonging to 15 genera in coastal fields, 43 species belonging to 13 genera in khazans and 31 species belonging to 10 genera in mining affected fields. The rabi season of the same year 2006-2007, recorded 63 species belonging to 14 genera in hinterlands, 62 species belonging to 15 genera in coastal fields, 33 species belonging to 13 genera in khazans and 29 species belonging to 9 genera in mining affected fields (**Table 4.1**).

The kharif season of the year 2007-2008 recorded 65 species belonging to 16 genera in hinterlands, 61 species belonging to 15 genera in coastal fields, 44 species belonging to 15 genera in khazans and 33 species belonging to 13 genera in mining affected fields. The rabi season of the same year 2007-2008, recorded 63 species belonging to 15 genera in hinterlands, 60 species belonging to 15 genera in coastal fields, 34 species belonging to 11 genera in khazans and 30 species belonging to 11 genera in mining affected fields (**Table 4.2**).

The kharif season of the year 2008-2009 recorded 66 species belonging to 16 genera in hinterlands, 61 species belonging to 14 genera in coastal fields, 44 species belonging to 15 genera in khazans and 34 species belonging to 12 genera in mining affected fields. The rabi season of the the same year 2008-2009, recorded 63 species belonging to 14 genera in hinterlands, 60 species belonging to 15 genera in coastal

fields, 36 species belonging to 13 genera in khazans and 31 species belonging to 12 genera in mining affected fields (**Table 4.3**).

The study also revealed that the BGA documented belonged to the three different groups viz., unicellular, heterocystous and non-heterocystous forms. All the 13 species of unicellular forms belonging to 5 genera were members of family Chroococcaceae of order Chroococcales. *Microcystis* is represented by two species viz., *M. aeruginosa* and *M. elabens*, *Chroococcus* is represented by *C. turgidus*, *C. minutes*, *C. pallidus* and *C. cohaerens*, *Gloecapsa* is represented by *G. punctata*, *G. aeruginosa* and *G. kuetzingiana*, *Aphanocapsa* is represented *A. banaresensis*; while *Aphanothece* is represented by *A. stagnina*, *A. saxicola* and *A. castegnei*.

The non-heterocystous BGA belonged to family Oscillatoriaceae of order Nostocales. The study recorded 30 species belonging to 4 genera of non-heterocystous forms. *Lyngbya* is represented by *L. spiralis*, *L. bergei*, *L. dendrobia*, *L. confervoides* and *L. martensiana*; *Oscillatoria* is represented by 19 species viz., *O. ornata*, *O. limosa*, *O. subbrevis*, *O. curviceps*, *O. princeps*, *O. anguina*, *O. proboscidea*, *O. chlorina*, *O. martini*, *O. chalybea*, *O. tenuis*, *O. simplissima*, *O. limnetica*, *O. pseudogeminata*, *O. clarycentrosa*, *O. formosa*, *O. salina*, *O. acuminata*, *O. brevis*; *Spirulina* is represented by *S. meneghiniana*, *S. princeps*; while *Phormidium* is represented by *P. jadinianum*, *P. microtomum*, *P. purpurascens* and *P. mucosum*.

The heterocystous BGA identified belonged to three families viz., Nostocaceae, Scytonemataceae and Rivulariaceae. A total of 41 species belonging to 7 genera of heterocystous forms were recorded during the study period. Family Nostocaceae was represented by genera *Cylindrospermum*, *Nostoc* and *Anabaena*. *Cylindrospermum* is represented by *C. stagnale* and *C. Musicola*; *Nostoc* is represented by 14 species viz.,

Table 4.1: Distribution of BGA from different rice field habitats for the year 2006 -2007

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	species↓								
1	<i>Microcystis aeruginosa</i>	+	-	-	+	+	-	-	+
2	<i>M. elabens</i>	-	-	-	+	-	+	-	+
3	<i>Chroococcus turgidus</i>	+	+	-	+	+	+	-	+
4	<i>C. minutus</i>	-	-	+	+	-	-	+	+
5	<i>C. pallidus</i>	+	-	+	-	+	-	+	+
6	<i>C. cohaerens</i>	-	-	+	+	-	-	+	+
7	<i>Gleocapsa punctate</i>	+	+	+	+	+	+	+	+
8	<i>G. aeruginosa</i>	+	+	-	+	-	+	-	+
9	<i>G. kuetzingiana</i>	-	-	-	-	-	+	-	-
10	<i>Aphanocapsa banaresensis</i>	-	+	-	+	+	+	-	-
11	<i>A. stagnina</i>	+	+	+	+	+	+	+	+
12	<i>A. saxicola</i>	-	+	-	+	-	+	-	+
13	<i>A. castagnei</i>	+	+	-	+	-	+	+	+
14	<i>Lyngbya spiralis</i>	+	-	+	-	+	+	-	-
15	<i>L. bergei</i>	-	+	-	+	-	+	-	+
16	<i>L. dendrobia</i>	+	+	+	+	-	+	-	+
17	<i>L. confervoides</i>	+	-	-	+	+	+	-	+
18	<i>L. martensiana</i>	+	+	-	+	-	+	-	+
19	<i>Oscillatoria ornata</i>	-	-	+	-	-	-	-	+
20	<i>O. limosa</i>	+	+	-	+	+	+	-	+
21	<i>O. subbrevis</i>	+	+	+	+	+	+	+	+
22	<i>O. curviceps</i>	-	+	-	+	-	+	-	+
23	<i>O. princeps</i>	+	+	-	+	-	+	-	+
24	<i>O. proboscidea</i>	+	+	+	+	+	+	+	+

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae↓								
25	<i>Oscillatoria anguina</i>	+	+	-	+	-	+	+	+
26	<i>O. formosa</i>	+	+	-	+	+	+	-	+
27	<i>O. chlorina</i>	-	+	-	-	-	+	-	+
28	<i>O. martini</i>	+	+	+	-	-	-	+	-
29	<i>O. chalybea</i>	+	+	-	+	-	+	-	-
30	<i>O. tenuis</i>	+	+	+	+	+	+	+	+
31	<i>O. simplissima</i>	+	+	+	+	+	+	+	+
32	<i>O. limnetica</i>	-	+	-	+	-	-	+	+
33	<i>O. pseudogeminata</i>	-	+	-	+	-	-	-	+
34	<i>O. claricentrosa</i>	-	+	-	+	-	+	-	+
35	<i>O. salina</i>	+	+	-	-	+	+	-	-
36	<i>O. acuminata</i>	+	+	+	+	+	+	+	+
37	<i>O. brevis</i>	+	+	+	+	+	+	+	+
38	<i>Spirulina meneghiniana</i>	-	+	-	+	+	+	-	+
39	<i>S. princeps</i>	+	+	+	+	-	+	-	+
40	<i>Phormidium jadinianum</i>	-	-	-	+	-	-	-	-
41	<i>P. microtomum</i>	-	+	-	-	-	+	-	-
42	<i>P. purpurascens</i>	-	+	-	-	-	-	-	-
43	<i>P. mucosum</i>	-	+	-	+	-	-	+	-
44	<i>Cylindrospermum stagnale</i>	-	+	-	+	+	+	-	+
45	<i>C. muscicola</i>	+	+	+	+	-	+	-	+
46	<i>Nostoc punctiforme</i>	+	+	+	+	+	+	+	+
47	<i>N. entophytum</i>	-	+	-	+	+	+	+	+
48	<i>N. paludosum</i>	+	+	-	+	-	+	-	-

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae ↓								
49	<i>Nostoc linckia</i>	+	+	+	+	+	+	+	+
50	<i>N. rivulare</i>	+	+	+	+	+	+	+	+
51	<i>N. carneum</i>	-	+	-	+	-	+	-	+
52	<i>N. ellipso sporum</i>	-	+	+	+	-	+	-	+
53	<i>N. calcicola</i>	+	+	+	+	-	-	-	+
54	<i>N. passerinianum</i>	-	+	-	-	-	+	-	-
55	<i>N. muscorum</i>	+	+	+	+	+	+	+	+
56	<i>N. commune</i>	+	+	+	+	+	+	+	+
57	<i>N. microscopium</i>	+	+	+	+	+	+	+	+
58	<i>N. hatei</i>	-	+	-	+	+	+	+	+
59	<i>N. sphaericum</i>	+	+	-	+	+	+	-	+
60	<i>Anabaena sphaerica</i>	+	+	+	+	+	-	-	+
61	<i>A. oryzae</i>	+	+	+	+	+	+	+	+
62	<i>A. fertilissima</i>	+	+	-	+	+	-	-	+
63	<i>A. naviculoides</i>	+	+	+	-	+	+	-	+
64	<i>A. variabilis</i>	-	+	-	+	-	+	-	-
65	<i>A. torulosa</i>	+	-	-	+	-	+	-	+
66	<i>Scytonema simplex</i>	+	+	-	-	-	+	-	+
67	<i>S. coactile</i>	-	-	+	-	-	-	+	-
68	<i>S. bohneri</i>	-	+	+	-	-	+	+	-
69	<i>S. schmidtii</i>	-	-	-	-	-	-	-	+
70	<i>S. freyui</i>	+	-	-	-	-	-	-	-
71	<i>Tolypothrix nodosa</i>	-	-	-	+	-	-	-	+
72	<i>T. tenuis</i>	-	-	-	+	-	+	-	-

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae↓								
73	<i>Tolypothrix fragilis</i>	-	-	-	+	-	-	-	+
74	<i>T. byssoidea</i>	-	-	-	+	-	+	-	-
75	<i>T. conglutinata</i>	-	+	-	-	-	-	-	-
76	<i>Calothrix castellii</i>	-	-	-	+	-	+	-	+
77	<i>C. elenkinii</i>	-	-	+	-	-	-	+	-
78	<i>C. braunii</i>	-	+	-	-	-	+	-	-
79	<i>C. parietina</i>	+	-	-	+	-	+	-	+
80	<i>C. weberi</i>	-	-	-	+	-	-	-	+
81	<i>C. membranacea</i>	+	+	+	+	+	+	+	+
82	<i>C. marchica</i>	-	+	-	-	-	+	-	+
83	<i>Rivularia aquatica</i>	-	+	-	-	-	+	-	+
84	<i>R. globiceps</i>	-	-	-	+	-	+	-	+

Table 4.2: Distribution of BGA from different rice field habitats for the year 2007 -2008

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae↓								
1	<i>Microcystis aeruginosa</i>	+	-	-	+	+	-	-	+
2	<i>M. elabens</i>	-	-	-	+	-	+	-	+
3	<i>C .turgidus</i>	+	+	-	+	+	+	-	+
4	<i>C. minutus</i>	-	-	+	+	-	-	+	+
5	<i>C. pallidus</i>	+	-	+	-	+	-	+	+
6	<i>C. cohaerens</i>	-	-	+	+	-	-	+	+
7	<i>Gleocapsa punctate</i>	+	+	+	+	+	+	+	+
8	<i>G. aeruginosa</i>	+	+	-	+	-	+	-	+
9	<i>G. kuetzingiana</i>	-	-	-	-	-	+	-	-
10	<i>Aphanocapsa banaresensis</i>	-	+	-	+	+	+	-	-
11	<i>A. stagnina</i>	+	+	+	+	+	+	+	+
12	<i>A. saxicola</i>	-	+	-	+	-	+	-	+
13	<i>A .castagnei</i>	+	+	-	+	-	+	+	+
14	<i>Lyngbya spiralis</i>	-	+	-	+	+	+	-	+
15	<i>L. bergei</i>	+	+	+	+	-	+	-	+
16	<i>L. dendrobia</i>	-	-	+	-	-	-	-	+
17	<i>L. confervoides</i>	+	+	-	+	+	+	-	+
18	<i>L. martensiana</i>	+	+	+	+	+	+	+	+
19	<i>Oscillatoria ornata</i>	-	+	-	+	-	+	-	+
20	<i>O. limosa</i>	+	+	-	+	-	+	+	+
21	<i>O. subbrevis</i>	+	+	+	+	+	+	+	+
22	<i>O. curviceps</i>	-	+	-	-	-	+	-	+
23	<i>O. princeps</i>	+	+	+	-	-	-	+	-
24	<i>O. proboscidea</i>	+	+	-	+	-	+	-	-

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae ↓								
25	<i>Oscillatoriaanguina</i>	+	+	+	+	+	+	+	+
26	<i>O. formosa</i>	-	+	-	+	-	-	+	+
27	<i>O. chlorina</i>	-	+	-	+	-	-	-	+
28	<i>O. martini</i>	-	+	-	+	-	+	-	+
29	<i>O. chalybea</i>	+	+	-	+	+	+	-	+
30	<i>O. tenuis</i>	+	+	-	-	+	+	-	-
31	<i>O. simplissima</i>	+	+	+	+	+	+	+	+
32	<i>O. limnetica</i>	+	+	+	+	+	+	+	+
33	<i>O. pseudogeminata</i>	+	+	+	+	+	+	+	+
34	<i>O. claricentrosa</i>	-	-	-	+	-	-	-	-
35	<i>O. salina</i>	-	+	-	-	-	+	-	-
36	<i>O. acuminata</i>	-	+	-	-	-	-	-	-
37	<i>O. brevis</i>	-	+	-	+	-	-	+	-
38	<i>Spirulina meneghiniana</i>	+	-	+	-	+	+	-	-
39	<i>S. princeps</i>	-	+	-	+	-	+	-	+
40	<i>Phormidium jadinianum</i>	+	+	+	+	-	+	-	+
41	<i>P. microtomum</i>	+	-	-	+	+	+	-	+
42	<i>P. purpurascens</i>	+	+	-	+	-	+	-	+
43	<i>P. mucosum</i>	-	+	-	+	+	+	-	+
44	<i>Cylindrospermum stagnale</i>	-	+	-	+	-	+	-	+
45	<i>C. muscicola</i>	+	+	+	+	-	+	+	+
46	<i>Nostoc punctiforme</i>	+	+	+	+	-	+	-	+
47	<i>N. entophytum</i>	-	+	-	+	+	+	-	+
48	<i>N. paludosum</i>	+	+	+	+	+	+	+	+

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae↓								
49	<i>Nostoc linckia</i>	-	+	-	+	+	+	+	+
50	<i>N. rivulare</i>	+	+	-	+	-	+	-	-
51	<i>N. carneum</i>	+	+	+	+	+	+	+	+
52	<i>N. ellipso sporum</i>	+	+	+	+	+	+	+	+
53	<i>N. calcicola</i>	-	+	-	+	-	+	-	+
54	<i>N. passerinianum</i>	+	+	+	+	-	-	-	+
55	<i>N. muscorum</i>	-	+	-	-	-	+	-	-
56	<i>N. commune</i>	+	+	+	+	+	+	+	+
57	<i>N. microscopium</i>	+	+	+	+	+	+	+	+
58	<i>N. hatei</i>	-	+	-	+	+	+	+	+
59	<i>N. sphaericum</i>	+	+	-	+	+	+	-	+
60	<i>Anabaena sphaerica</i>	-	+	+	+	-	+	-	+
61	<i>A. oryzae</i>	+	+	+	+	+	+	+	+
62	<i>A. fertilissima</i>	+	+	+	+	+	-	-	+
63	<i>A. naviculoides</i>	+	+	+	+	+	+	+	+
64	<i>A. variabilis</i>	+	+	-	+	+	-	-	+
65	<i>A. torulosa</i>	+	+	+	-	+	+	-	+
66	<i>Scytonema simplex</i>	-	+	-	+	-	+	-	-
67	<i>S. coactile</i>	+	-	-	+	-	+	-	+
68	<i>S. bohneri</i>	-	-	-	+	-	-	-	-
69	<i>S. schmidtii</i>	+	+	-	-	-	+	-	+
70	<i>S. freyiii</i>	-	-	+	-	-	-	+	-
71	<i>Tolypothrix nodosa</i>	-	+	+	-	-	+	+	-
72	<i>T. tenuis</i>	-	-	-	-	-	-	-	+

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae↓								
73	<i>Tolypothrix fragilis</i>	+	-	-	-	-	-	-	-
74	<i>T. byssoidea</i>	-	-	-	+	-	-	-	+
75	<i>T. conglutinata</i>	-	-	-	+	-	+	-	-
76	<i>Calothrix castellii</i>	-	-	-	+	-	-	-	+
77	<i>C. elenkinii</i>	-	-	-	+	-	+	-	-
78	<i>C. braunii</i>	-	+	-	-	-	-	-	-
79	<i>C. parietina</i>	-	-	-	+	-	+	-	+
80	<i>C. weberi</i>	-	-	+	-	-	-	+	-
81	<i>C. membranacea</i>	+	+	+	+	+	+	+	+
82	<i>C. marchica</i>	+	-	-	+	-	+	-	+
83	<i>Rivularia aquatica</i>	-	-	-	+	-	-	-	+
84	<i>R. globiceps</i>	+	+	+	+	-	-	-	+

Table 4.3: Distribution of BGA from different rice field habitats for the year 2008 -2009

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae↓								
1	<i>Microcystis aeruginosa</i>	+	-	-	+	+	-	-	+
2	<i>M. elabens</i>	-	-	-	+	-	+	-	+
3	<i>Chroococcus turgidus</i>	+	+	-	+	+	+	-	+
4	<i>C. minutus</i>	-	-	+	+	-	-	+	+
5	<i>C. pallidus</i>	+	-	+	-	+	-	+	+
6	<i>C. cohaerens</i>	-	-	+	+	-	-	+	+
7	<i>Gleocapsa punctate</i>	+	+	+	+	+	+	+	+
8	<i>G. aeruginosa</i>	+	+	-	+	-	+	-	+
9	<i>G. kuetzingiana</i>	-	-	-	-	-	+	-	-
10	<i>Aphanocapsa banaresensis</i>	-	+	-	+	+	+	-	-
11	<i>A. stagnina</i>	+	+	+	+	+	+	+	+
12	<i>A. saxicola</i>	-	+	-	+	-	+	-	+
13	<i>A. castagnei</i>	+	+	-	+	-	+	+	+
14	<i>Lyngbya spiralis</i>	-	+	-	+	+	+	-	+
15	<i>L. bergei</i>	+	+	+	+	-	+	-	+
16	<i>L. dendrobia</i>	-	-	+	-	-	-	-	+
17	<i>L. confervoides</i>	+	+	-	+	+	+	-	+
18	<i>L. martensiana</i>	+	+	+	+	+	+	+	+
19	<i>Oscillatoria ornata</i>	-	+	-	+	-	+	-	+
20	<i>O. limosa</i>	+	+	-	+	-	+	+	+
21	<i>O. subbrevis</i>	+	+	+	+	+	+	+	+
22	<i>O. curviceps</i>	-	+	-	-	-	+	-	+
23	<i>O. princeps</i>	+	+	+	-	-	-	+	-
24	<i>O. proboscidea</i>	+	+	-	+	-	+	-	-

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae ↓								
25	<i>Oscillatoria anguina</i>	+	+	+	+	+	+	+	+
26	<i>O. formosa</i>	-	+	-	+	-	-	+	+
27	<i>O. chlorina</i>	-	+	-	+	-	-	-	+
28	<i>O. martini</i>	-	+	-	+	-	+	-	+
29	<i>O. chalybea</i>	+	+	-	+	+	+	-	+
30	<i>O. tenuis</i>	+	+	-	-	+	+	-	-
31	<i>O. simplissima</i>	+	+	+	+	+	+	+	+
32	<i>O. limnetica</i>	+	+	+	+	+	+	+	+
33	<i>O. pseudogeminata</i>	+	+	+	+	+	+	+	+
34	<i>O. claricentrosa</i>	-	-	-	+	-	-	-	-
35	<i>O. salina</i>	-	+	-	-	-	+	-	-
36	<i>O. acuminata</i>	-	+	-	-	-	-	-	-
37	<i>O. brevis</i>	-	+	-	+	-	-	+	-
38	<i>Spirulina meneghiniana</i>	+	-	+	-	+	+	-	-
39	<i>S. princeps</i>	-	+	-	+	-	+	-	+
40	<i>Phormidium jadinianum</i>	+	+	+	+	-	+	-	+
41	<i>P. microtomum</i>	+	-	-	+	+	+	-	+
42	<i>P. purpurascens</i>	+	+	-	+	-	+	-	+
43	<i>P. mucosum</i>	-	+	-	+	+	+	-	+
44	<i>Cylindrospermum stagnale</i>	-	+	-	+	-	+	-	+
45	<i>C. muscicola</i>	+	+	+	+	+	-	+	+
46	<i>Nostoc punctiforme</i>	+	+	+	+	-	+	-	+
47	<i>N. entophytum</i>	-	+	-	+	+	+	-	+
48	<i>N. paludosum</i>	+	+	+	+	+	+	+	+

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae ↓								
49	<i>Nostoc linckia</i>	-	+	-	+	+	+	+	+
50	<i>N. rivulare</i>	+	+	-	+	-	+	-	-
51	<i>N. carneum</i>	+	+	+	+	+	+	+	+
52	<i>N. ellipso sporum</i>	+	+	+	+	+	+	+	+
53	<i>N. calcicola</i>	-	+	-	+	-	+	-	+
54	<i>N. passerinianum</i>	+	+	+	+	-	-	-	+
55	<i>N. muscorum</i>	-	+	-	-	-	+	-	-
56	<i>N. commune</i>	+	+	+	+	+	+	+	+
57	<i>N. microscopium</i>	+	+	+	+	+	+	+	+
58	<i>N. hatei</i>	-	+	-	+	+	+	+	+
59	<i>N. sphaericum</i>	+	+	-	+	+	+	-	+
60	<i>Anabaena sphaerica</i>	-	+	+	+	-	+	-	+
61	<i>A. oryzae</i>	+	+	+	+	+	+	+	+
62	<i>A. fertilissima</i>	+	+	+	+	+	-	-	+
63	<i>A. naviculoides</i>	+	+	+	+	+	+	+	+
64	<i>A. variabilis</i>	+	+	-	+	+	-	-	+
65	<i>A. torulosa</i>	+	+	+	-	+	+	-	+
66	<i>Scytonema simplex</i>	-	+	-	+	-	+	-	-
67	<i>S. coactile</i>	+	-	-	+	-	+	-	+
68	<i>S. bohneri</i>	-	-	-	+	-	-	-	-
69	<i>S. schmidtii</i>	+	+	-	-	-	+	-	+
70	<i>S. fremyii</i>	-	-	+	-	-	-	+	-
71	<i>Tolypothrix nodosa</i>	-	+	+	-	-	+	+	-
72	<i>T. tenuis</i>	-	-	-	-	-	-	-	+

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae ↓								
73	<i>Tolypothrix fragilis</i>	+	-	-	-	-	-	-	-
74	<i>T. byssoidea</i>	-	-	-	+	-	-	-	+
75	<i>T. conglutinata</i>	-	-	-	+	-	+	-	-
76	<i>Calothrix castellii</i>	-	-	-	+	-	-	-	+
77	<i>C. elenkinii</i>	-	-	-	+	-	+	-	-
78	<i>C. braunii</i>	-	+	-	-	-	-	-	-
79	<i>C. parietina</i>	-	-	-	+	-	+	-	+
80	<i>C. weberi</i>	-	-	+	-	-	-	+	-
81	<i>C. membranacea</i>	+	+	+	+	+	+	+	+
82	<i>C. marchica</i>	+	-	-	+	-	+	-	+
83	<i>Rivularia aquatica</i>	-	-	-	+	-	-	-	+
84	<i>R. globiceps</i>	+	+	+	+	+	+	+	+

N. punctiforme, *N. entophytum*, *N. paludosum*, *N. linkia*, *N. rivulare*, *N. carneum*, *N. ellipsosporum*, *N. calcicola*, *N. passerinianum*, *N. muscorum*, *N. commune*, *N. microscopium*, *N. hatei* and *N. sphaericum*; *Anabaena* is represented by 6 species viz., *A. sphaerica*, *A. oryzae*, *A. fertilissima*, *A. naviculoides*, *A. variabilis* and *A. torulosa*. Family *Scytonemataceae* is represented by two genera viz., *Scytonema* and *Tolypothrix*. *Scytonema* is represented by five species, viz., *S. simplex*, *S. coactile*, *S. bohneri*, *S. schmidtii* and *S. fremyii* while *Tolypothrix* is represented by five species viz., *T. nodosa*, *T. tenuis*, *T. fragilis*, *T. byssoidea* and *T. conglutinata*. Family *Rivulariaceae* recorded 9 species belonging to 2 genera. *Calothrix* is represented by *C. castellii*, *C. elenkinii*, *C. braunii*, *C. parietina*, *C. weberi*, *C. membranacea* and *C. marchica*. *Rivularia* is represented by only two species viz., *R. aquatica* and *R. globiceps*. The forms showed variations in their occurrence during both kharif and rabi seasons. Maximum diversity of the BGA forms was observed in the hinterlands, followed by coastal fields and khazans, while the least diversity was recorded in mining affected fields.

CLASSIFICATION OF BLUE GREEN ALGAE

DIVISION: CYANOPHYTA

CLASS: CYANOPHYCEAE

ORDER: CHROOCOCCALES

FAMILY: CHROOCOCACEAE

GENUS: **MICROCYSTIS**

SPECIES: *M. aeruginosa*, *M. elabens*

GENUS: **CHROOCOCCUS**

SPECIES: *C. turgidus*, *C. minutus*, *C. pallidus*,
C. cohaerens

GENUS: **GLOECAPSA**

SPECIES: *G. punctata*, *G. aeruginosa*,
G. kuetzingiana

GENUS: **APHANOCAPSA**

SPECIES: *A. banaresensis*

GENUS: **APHANOTHECE**

SPECIES: *A. stagnina*, *A. saxicola*, *A. castegnei*

ORDER: NOSTOCALES

FAMILY: OSCILLATORIACEAE

GENUS: *LYNGBYA*

SPECIES: *L. spiralis*, *L. bergei*, *L. dendrobia*,

L. confervoides, *L. martensiana*

GENUS: *OSCILLATORIA*

SPECIES: *O. ornata*, *O. limosa*, *O. subbrevis*,

O. curviceps, *O. princeps*,

O. anguina, *O. proboscidea*,

O. chlorina, *O. martini*,

O. chalybea, *O. tenuis*,

O. simplissima, *O. limnetica*,

O. pseudogeminata, *O. clarycentrosa*,

O. formosa, *O. salina*, *O. acuminata*,

O. brevis.

GENUS: *SPIRULINA*

SPECIES: *S. meneghniana*, *S. princeps*

GENUS: *PHORMIDIUM*

SPECIES: *P. jadinianum*, *P. microtomum*, *P.*

purpurascens, *P. mucosum*

FAMILY: NOSTOCACEAE

GENUS: **CYLINDROSPERMUM**

SPECIES: *C. stagnale*, *C. musicola*

GENUS: **NOSTOC**

SPECIES: *N. punctiforme*, *N. entophytum*,

N. paludosum, *N. linkia*, *N. rivulare*,

N. carneum, *N. elliposporum*,

N. calcicola, *N. passerinianum*,

N. muscorum, *N. commune*,

N. microscopium, *N. hatei*,

N. sphaericum

GENUS: **ANABAENA**

SPECIES: *A. sphaerica*, *A. oryzae*,

A. fertilissima, *A. naviculoides*,

A. variabilis, *A. torulosa*

FAMILY: SCYTONEMATACEAE

GENUS: **SCYTONEMA**

SPECIES: *S. simplex*, *S. coactile*, *S. bohneri*,

S. schmidtii, *S. fremyii*

GENUS: **TOLYPOTHRIX**

SPECIES: *T. nodosa*, *T. tenuis*, *T. fragilis*,

T. byssoidea,

T. conglutinata

FAMILY: RIVULARIACEAE

GENUS: **CALOTHRIX**

SPECIES: *C. castellii*, *C. elenkinii*, *C. braunii*,

C. parietina, *C. weberi*,

C. membranacea, *C. marchica*

GENUS: **RIVULARIA**

SPECIES: *R. aquatica*, *R. globiceps*

KEYS OF ORDERS, FAMILIES, GENERA AND SPECIES

Class: Cyanophyceae Sachs.....Blue Green Algae, prokaryotic with no well defined nucleus. Fresh water and marine forms, heterocysts present, some have hormogones, akinetes mostly nitrogen fixers.

Key to orders

1. Cells unicellular, single or colonial forms, without differentiation into trichomes and filaments, no hormogones, no heterocysts, embedded in mucilaginous mass.....Chroococales Wettstein
1. Plants filamentous with trichome and filaments, organized in "hormogonales organization". Homogones present, often with heterocyst, akinetes without true branching, unbranched or with false branching.....Nostocales Geitler

Key to families

Order: Chroococales Wettstein

1. Cells unicellular, or colonial forms,
not forming filament like growth.....Chroococcaceae
1. Cells of thallus arranged in linear series forming
forming pseudofilamentous growth.....Entophysalidaceae

Key to families

Order: Nostocales Geitler

1. Trichome without heterocysts, spores absent.....Oscillatoriaceae
1. Trichome with heterocysts and akinetes.....2
2. Trichomes not showing branching and
not attenuated.....Nostocaceae

3. Trichomes showing branching and not attenuated
to hair like point.....Scytonemataceae
2. Trichomes showing branching and attenuated
to hair like point.....Rivulariaceae

Family: Chroococcaceae Nageli

Key to the Genera

1. Cells arranged in regular tranverse and longitudinal rows*Merismopedia*
1. Cells not so arranged2
2. Cells without individual envelop or sheath, mostly planktonic....*Microcystis*
2. Cells with or without individual envelopes
or sheath, may be subaerial,or planktonic.....3
3. Cells spherical.....4
3. Cells elongate or ellipsoidal6
4. Sheath vesicular..... *Gloecapsa*
4. Sheath not vesicular.....5
5. Thallus mostly microscopic, sheath of individual cells
distinct.....*Choroococcus*
5. Thallus mostly macroscopic, sheath of individual
cells generally in distinct...*Aphanocapsa*
6. Colonial, mucilage not homogenous,
individual sheath vesicular.....*Gloeothece*
6. Colonial, generally homogeneous, individual sheath not
vesicular.....*Aphanothece*

Genus: *Microcystis* Kützing

Key to species

1. Colony many times longer than broad3
1. Colony round or slightly longer than broad2
2. Colony clathrate, colonial, mucilage distinct, hyaline..... *M. aeruginosa*
2. Cells free swimming, clathrate, about 2-4.5 μ broad*M. elabens*

Genus: *Choococcus* Nägeli

Key to the species

1. Cells with sheath less than 32 μ broad, lamellae of sheath distinct*C. turgidus*
1. Cells without sheath, 4-10 μ broad*C. minutus*
2. Cells without sheath, 4.5-6 μ diam*C. pallidus*
2. Cells without sheath, 2-3.5 μ diam.....*C. coharens*

Genus: *Gloeocapsa* Kützing

Key to the species

1. Cells without sheath upto 3 μ broad, thallus blackish*G. punctata*
1. Cells without sheath upto 3 μ broad, thallus Blue green ...*G. aeruginosa*
1. Cells without sheath 3-5 μ broad*G. kuetzingiana*

Genus: *Aphanocapsa* Nägeli

Key to species

1. Cells planktonic 2
1. Cells attached..... 3

- 2. Colonies small, colourless, cells 4-6.2 μ in diam *A. banaresensis*
- 2. Colonies large, coloured4

Genus: *Aphanothece* Nägeli

Key to species

- 1. Thallus firm, gelatinous, spherical or hemispherical,
3-6.5 μ diam.*A. stagnina*
- 1. Thallus mucilaginous, cells 1.5-2 μ broad*A. saxicola*
- 2. Cells without individual sheaths3
- 2. Cells with individual sheath4
- 3. Cells 2-5.5 μ broad.*A. castagnei*

Order: Nostocales Geitler

Family: Oscillatoriaceae Kirchner

Key to genera

- 1. Filaments not in bundles..... *Lyngbya*
- 1. Filament mostly in erect bundles *Symploca*
- 2. Trichomes more or less straight not
regularly spirally coiled..... 3
- 2. Trichomes regularly spirally coiled. 4
- 3. In free swimming bundles..... 6
- 3. Not in bundles..... *Oscillatoria*
- 4. Cells of trichome not visible or unicellular*Spirulina*
- 4. Cells of trichome clearly visible 7
- 5. Filaments single 8

5. Filaments forming a thallus with
more or less confluent sheath.....*Phormidium*

Genus: *Lyngbya* Ag

Key to species

1. Filaments less narrow than 10 μ 2
1. Filaments 20-24 μ broad*L. birgei*
2. Trichome 4.5 - 5 μ broad*L. spiralis*
2. Trichomes 9-10 μ broad*L. dendrobia*
3. Trichomes 9-25 μ broad without calyptra*L. confervoides*
3. Trichomes 6-10 μ broad, cells 1.7 – 3.3 μ long*L. martensiana*

Genus: *Spirulina*

Key to species

1. Spirals regular*S. meneghiniana*
1. Spirals irregular.....2
2. Trichomes 4.5-5 μ broad*S. princeps*
2. Trichomes narrower3

Genus: *Phormidium* kützing

Key to species

1. Trichomes 4-6 μ broad, cells shorter than broad or quadrate.....*P. jadinianum*
1. Trichomes 1.5 -2.5 μ broad, thallus purple to viole.....*P. purpurascens*
2. End cells of trichome with calyptras.....*P. microtomum*

2. End cells of Trichome without calyptras,
trichome 2.5 -3 μ broad..... *P. mucosum*

Genus: *Oscillatoria* Vaucher

Key to species

1. Trichomes 9-11 μ broad, not attenuated..... *O. ornata*
1. Trichomes straight, end cell with thickened outer wall *O. limosa*
1. End cell without outer thickened wall, trichomes about 4 μ
broad*O. subbrevis*
2. Trichome broader than 4 μ , end cells rounded*O. curviceps*
2. Trichome broader than 4 μ , end cells slightly capitate.....*O. princeps*
3. Trichomes 7.5 - 8 μ broad, capitate*O. proboscidea*
3. Trichomes 6-8 μ broad, capitate*O. anguina*
3. Trichomes 4-6 μ broad*O. formosa*
4. Trichomes with cells 4-8 μ long*O. chlorina*
4. Trichomes with cells 2.5 -8 times long as broad*O. limentica*
5. Cells shorter, septa not granulated*O. martinii*
5. Cells longer septa not granulated,
Trichome 1-2.2 μ broad.....*O. pseudogeminata*
5. Cells longer, septa granulated, trichomes 0.8-1.2 μ broad.....*O. angusta*
6. Trichomes constricted, 8-13 μ broad*O. chalybea*
6. Trichomes constricted, 4-10 μ broad apical cell
with thickened outer wall *O. tenuis*
7. Trichomes 5.2 –6 μ broad without thickened
outer membrane..... *O. simplissima*

- 8. Cells longer 3-5 times as long as broad,
end cells not capitate *O. claricentrosa*
- 7. Cells shorter8
- 9. Trichomes 3-6 μ broad, apex bent with hyaline pointed cell *O. salina*
- 9. Trichomes 3-4 μ broad, end cell pointed, rarely quadrate..... *O. acuminata*
- 9. End cell tapering hooked or flexuous.....*O. brevis*

Family: Nostocaceae kützing

Key to Genera

- 1. Heterocysts present commonly terminally
with a single large spore adjoining.....*Cylindrospermum*
- 1. Heterocysts rarely terminal generally intercalary2
- 2. Filaments single or in a formless gelatinous mass *Anabaena*
- 2. Filaments in a definite colony.....3
- 3. Thallus finger shaped, attached at first..... 4
- 4. Thallus otherwise *Nostoc*

Genus: *Cylindrospermum* kützing

Key to species

- 1. Spores spherical 2
- 1. Spores not spherical3
- 3. Spores cylindrical, 10-16 μ broad..... *C. stagnale*
- 3. Spores narrow, 9-12 μ broad, 10-20 μ long.....*C.musicola*

Genus: *Nostoc* Vaucher

Key to species

1. Trichomes very densely coiled, 2.4 – 4.4 μ broad *N. punctiforme*
1. Trichomes densely coiled, aquatic *N. linckia*
2. Trichome 2.5 - 3 μ broad, relatively thickly arranged *N. entophytum*
2. Trichome 3.3 - 5 μ broad loosely arranged *N. paludosum*
3. Cells cylindrical *N. clipposponum*
3. Cells little longer than broad *N. rivulare*
3. Cells little longer than broad, heterocysts 6 μ broad *N. carneum*
4. Spores spherical. *N. calcicola*
4. Spores not spherical 5
5. Trichomes parallel, spores 6x8 μ *N. passernianum*
5. Trichomes with definite node *N. muscorum*
6. Thallus subaerial, very large, flat, membranous *N. commune*
6. Thallus small, spherical, 5 - 8 μ broad *N. microscopium*
7. Thallus upto 7cm broad, trichome 4 - 5 μ broad..... *N. sphaericum*
7. Colonies upto 2cm in diameter *N. hatei*.

Genus: *Anabaena* Bory

Key to species.

1. Akinetes contiguous to heterocyst, 8 -12 μ broad *A. sphaerica*
1. Akinetes not contiguous to heterocyst *A. oryzae*
2. Trichomes 5 - 5.6 μ broad, end cell rounded akinete *A. fertilissima*
2. Trichome 6 - 7.5 μ broad, end cell pointed 3

3. Akinetes with pointed protruding ends surrounded
by spherical mucilagenous sheath *A. naviculoidis*
3. Akinetes barrel - shaped with flattened ends.....*A. variabilis*
4. Akinetes with end cells conical*A. torulosa*

Family: Scytonemataceae Raben

Key to Genera

1. False branches, single or geminate *Scytonema*
1. False branches. usually single and
arise next to heterocyst *Tolypothrix*

Genus: *Scytonema* Ag

Key to species

1. Trichomes upto 10 μ broad3
1. Trichomes broader than 10 μ 2
2. Filament 14-15.7 μ broad, trichome 9-10 μ broad*S. simplex*
2. Filament 17-20 μ broad, trichome 9.4-11.7 μ broad*S. coactile*
3. Filaments 10-12 μ broad, trichomes 5-8 μ broad*S. bohneri*
3. Filaments 9 μ broad, tichome 5 μ broad*S. fremyii*
4. Trichome constricted 6.5 - 9 μ broad, cells subquadrate.....*S. schmidtii*
4. Trichome not constricted6

Genus: *Tolypothrix* kützing

Key to species

1. Trichomes 4.2 - 5.2 μ broad*T. nodosa*

1. Trichomes 5 - 8 μ broad*T. tenuis*
2. Filaments united*T. byssoidea*
2. Filaments free3
3. Sheath lamellated filament 14-16 μ broad*T. conglutinata*
3. Sheath lamellatedm Trichomes unconstructed*T. fragilis*

Family: Rivulariaceae

Key to Genera

1. Trichomes single in a sheath, spore present or absent*Calothrix*
1. Trichomes many in a sheath, spores not known*Rivularia*

Genus: *Calothrix* Ag

Key to species

1. Trichomes 4.5 - 5 μ broad, terminating into hair*C. braunii*
1. Trichomes not terminating into hair*C. elenkinii*
2. Trichomes very short5
2. Trichomes very long4
3. Heterocysts subspherical, trichomes 3.5 - 4.5 μ broad,
thallus membranous*C. membranacea*
3. Trichomes 4 - 4.5 μ broad, not membranous thallus.....*C. marchica*
4. Trichome 8 - 10 μ broad*C. castellii*
4. Trichome 5 - 10 μ broad*C. parietina*
5. Cells larger than broad*C. weberi*
5. Cells shorter than long6

Genus: *Rivularia* (Roth) Ag

Key to species

1. Thallus soft, filamentous, trichome 7-9 μ broad*R. aquatica*
1. Trichomes narrower about 4.8-6 μ broad,
sheath not lamellated*R. globiceps*

DESCRIPTION OF SPECIES

***MICROCYSTIS* Kützing**

Cells spherical or elongated, many in spherical, ellipsoidal or irregularly overlapping or net-like colony, free-swimming, often with attached daughter colonies; cells in homogenous colourless, often diffluent, mucilage, individual envelopes absent; cells mostly very densely arranged, cell-division in all directions, generally transverse in elongate cells; gas-vacuoles often present.

***Microcystis aeruginosa* Kütz.**

Colonies when young round or slightly longer than broad, solid when old becoming clathrate, with distinct hyaline colonial mucilage, cells 3-7 μ in diam., spherical, generally with gas-vacuoles (**Pl. 1, Fig.1a & b**).

***Microcystis elabens* (Breb.) Kütz.**

Colony spherical, or flat and expanding, blue-green or olive-green, when old together with a number of daughter colonies; cells oblong, 2-4.5 μ broad, (-3) 4-8.5 μ long, with gas vacuoles (**Pl. 1, Fig. 2a & b**).

***CHROOCOCCUS* Nag.**

Cells spherical or sub spherical, hemispherical, after division in small groups of 2-4 individuals, sometimes 8-16, rarely single, in a gelatinous or mucous of 2-4 individuals, sometimes 8-16, rarely single, in a gelatinous or mucous matrix; sheath of individual cells distinct, firm, generally lamellated, in some homogeneous, persistently or irregularly broken; reproduction by cell division and fragmentation of colonies; division of cells in three directions. Nannocytes occasionally seen.

***Chroococcus turgidus* (Kütz.) Nag.**

Cell spherical or ellipsoidal single, or in groups of mostly 2-4, very seldom many, blue-green, olive green or yellowish, without sheath 8-32 μ , with sheath 13-25 μ diam. rarely 40 μ ; sheath colourless, not distinctly lamellated (**Pl. 1, Fig. 3a & b**).

***Chroococcus minutus* (Kütz.) Nag.**

Cell spherical or oblong, single or in group of 2-4, light blue-green, with sheath 6-15 μ diam., and without sheath 4-10 μ diam., colonies 10-13x15-20 μ ; sheath not lamellated, colourless (**Pl. 1, Fig. 4a & b**).

***Chroococcus pallidus* Nag.**

Thallus gelatinous, yellowish or colourless; cells single or 2-4, seldom up to 8 in elliptic oblong colonies, without sheath 5-8 μ , with sheath 7-11.5 (13) μ broad, blue-green or yellow; sheath colourless, unlamellated (**Pl. 1, Fig. 5a & b**).

***Chroococcus cohaerens* (Breb.) Nag.**

Thallus slimy, or gelatinous, blue or dark-green; cells single or up to 2-8 in groups, without envelop 2-5 (-7) μ diam., and with sheath 2.5-7 μ diam., colony 7-15 μ ; sheath thin, colourless, unlamellated (**Pl. 1, Fig. 6a, b, c & d**).

***GLOEOCAPSA* Kützing**

Cells spherical, 2-8 in colonies, seldom many, with a number of concentric special envelopes; colonies single or many together forming an expanded mass, individual sheaths lamellated or unlamellated, cell division very regularly in three directions, cells in large colonies often secondary colonies, arranged irregularly; occasionally with nannocytes, resembling *Aphanocapsa* stage; spores with thick firm walls often formed in a number of spores.

Gloeocapsa punctata

Thallus gelatinous, light blue green; cells without sheath 0.7-1.5(-2.8) μ diam., with sheath 3.5-7 μ broad, blue-green; sheath thick, colourless, unlamellated or scarcely lamellated; cells 2-16 in groups or colonies, about 25 μ in diam. (**Pl. 2, Fig.1**).

***Gloeocapsa aeruginosa* (carm.) Kütz**

Thallus crustaceous, granulose or cartilaginous, mucilaginous; cells 2-3 μ broad, with sheath 4.8 μ broad, in colonies; colonies spherical, 16-50 μ diam., sheath indistinctly lamellated (**Pl. 2, Fig. 2**).

***Gloeocapsa kuetzingiana* Nag.**

Thallus thin soft, brownish or blackish; cells densely aggregated in colonies up to 150 μ diam; cell without sheath 3-4 μ diam, with sheath 4-7.5 μ diam, blue-green; sheath yellow to brown, not lamellated (**Pl. 2, Fig. 3**).

***APHANOCAPSA* Nag.**

Cells spherical or nearly so, many loosely arranged without an order, forming a formless gelatinous mass, often a few cms, in diam., mucilage homogeneous, colourless, cells often with a thin more or less gelatinized individual sheaths; often two, four and sometimes many within a common mucilaginous envelope of the parent cell; nannocytes present in some species, formed by repeated division.

***Aphanocapsa banaresensis* Bharadwaja**

Plant mass soft, spherical, hollow, irregularly hyaline or cream coloured, up to 1.5cm. in diam., cells oval or almost spherical, 4-6.2 μ in diam.; sheath thick, unstratified, hyaline, closely adpressed to the cells, up to 1 μ thick (**Pl. 2, Fig. 4**).

***APHANOTHECE* Nag.**

Cells ellipsoidal to cylindrical, straight, or slightly bent, many in a more or less shapeless expanded thallus, mucilage homogeneous, occasionally with lamellated individual envelopes, often gelatinizing; division transverse.

***Aphanothece stagnina* (Spreng.) A. Br.**

Thallus gelatinous, spherical, ellipsoidal, up to many cm. in diam., pale blue-green, dull brown or brownish, in the inside often with calcareous crystals; cells oblong, more or less ovoid or cylindrical, 3-6 μ broad, 4.5-11 μ long, more or less more or less blue-green, densely or sparsely arranged, generally densely in the peripheral region of the colony and sparsely in the inside of the colony, without individual envelopes, homogeneous mucilage (**Pl. 2, Fig. 5**).

***Aphanothece saxicola* Nag.**

Thallus mucilaginous, colourless or yellowish; cells cylindrical, 1-2 μ broad and 2-3 times as long, single or in pairs, seldom many in a common, mucilaginous envelope, pale blue-green (**Pl. 2, Fig. 6**).

***Aphanothece castagnei* (bréb.) Rabenth**

Thallus gelatinous, without any definite shape, slimy, blue-green or brown; cells ellipsoidal to cylindrical, 2-3.6 μ broad, 4-8 μ long, mostly densely arranged, blue-green; sheath diffluent, colourless or yellowish (**Pl. 2, Fig. 7a & b**).

***SPRIULINA* Turpin em. Gardner**

Trichomes unicellular or multicellular cylindrical, sheath absent; loosely or tightly coiled into a more or less regular spiral; apex of trichome usually not attenuated; cross-walls if present obscured; terminal cell rounded, without calyptras.

***Spirulina meneghiniana* Zanard. Ex Gomont**

Trichome 1.2-1.8 μ broad, flexible, irregularly spirally coiled, bright blue-green, forming a thick blue-green thallus; spirals 3.2-5 μ broad and 3-5 μ distant from other (**Pl. 5, Fig. 1a & b**).

***Spirulina princeps* W. et G. S. West**

Trichome 4.5-5 μ broad, short, blue-green, regularly spirally coiled spirals 11-12 μ broad and 9.5-11 μ distant (**Pl. 5, Fig. 2a & b**).

OSCILLATORIA Vaucher

Trichome single or forming a flat or spongy free-swimming thallus, sheath absent, rarely with a more or less very delicate sheath, motile, mostly by a creeping movement causing rotation on the longitudinal axis; end of trichome distinctly marked, pointed, bent like a sickle or coiled.

***Oscillatoria ornata* Kütz. Ex Gomont**

Thallus dark blue-green; trichome spirally coiled at the ends, constricted at the cross- 9-11 μ broad, dull blue-green, cells 1/2-1/6 as long as broad, 2-5 μ long, cross-walls granulated; apices slightly attenuated; end-cells rounded, not capitate, without thickened membrane (**Pl. 4 Fig. 1 & 2**).

***Oscillatoria limosa* Ag. Ex Gomont**

Thallus dark blue-green to brown; trichome more or less straight, dull blue-green, brown or olive-green, not constricted at the cross-walls, or only slightly constricted, 11-20(-22) μ , commonly 13-16 μ broad; cells 1/3-1/6 as long as broad, 2-5 μ long, cross-walls frequently granulated; end-cell flatly rounded with slightly thickened membrane (**Pl. 4 Fig. 3a, b & c**).

***Oscillatoria subbrevis* Schmidle**

Trichomes single, 5-6 μ broad, nearly straight, not attenuated at the apices; cells 1-2 μ long, not granulated at the cross-walls; end cell rounded, calyptras absent (Pl. 4 Fig. 4).

***Oscillatoria curviceps* Ag. Ex Gomont**

Thallus light or dark blue-green; trichomes more or less straight, bent at the end or spirally coiled, not attenuated or very little attenuated, not constricted at the cross-walls, 10-17 μ broad, cells 1/3-1/6 as long as broad, 2-5 μ long, cross-walls sometimes granulated; end-cells flat rounded, not capitates (Pl. 4 Fig. 5).

***Oscillatoria princeps* Vaucher ex Gomont**

Trichomes blue-green, more or less brownish, violet or reddish, mostly forming a thallus, mostly straight, not constricted at the cross-walls, 16-60 μ broad, commonly 25-50 μ , blue-green to dirty green, slightly or briefly attenuated at the apices and bent; cells 1/11-1/4 as long as broad, 3.5-7 μ long; end cells flatly rounded, slightly capital without or with slightly thickened membrane (Pl. 4 Fig. 6).

***Oscillatoria anguina* (Bory) Gomont**

Thallus dark blue-green; trichome straight, at the ends spirally coiled and distinctly attenuated, not constricted at the cross-walls, 6-8 μ broad, cross-walls sometimes granulated; cells 1/3-1/6 as long as broad, 1.5-2.5 μ long, end cell capitates, with a slightly thickened membrane (Pl. 4 Fig. 7).

***Oscillatoria proboscidea* Gomont**

Thallus dull green to dark blue-green; trichome more or less straight, not constricted at the cross-walls, 12-15 μ broad, at the ends distinctly attenuated, slightly

curved or sometimes spirally coiled, brightly blue-green; cells 1/3-1/6 times as long as broad, 2-4 μ long, not granulated at the cross-walls; end-cells flatly rounded capitate, with slightly thickened membrane (**Pl. 4 Fig. 8**).

***Oscillatoria chlorina* Kütz. Ex Gomont**

Thallus very thin, yellowish green; trichome straight or curved, unstricted or slightly constricted at the cross-walls; 3.5-4 μ broad, sometimes up to 6 μ broad, gas-vacuoles absent; cells somewhat longer or shorter than broad, 3.7-8 μ long, cross-walls not granulated; calyptras absent (**Pl. 4 Fig. 9**).

***Oscillatoria martini* Frémy**

Trichome single amidst other algae, sparse, loosely and irregularly spirally coiled throughout its length, unstricted at the cross-walls, 6 μ broad, at the ends short and clearly attenuated, ends straight or slightly curved, capitates; cells 1/3 as long as broad, 2-3 (-6) μ long, not granulated at the cross-walls; end cells with flat convex distinctly thick and broad outer membrane (**Pl. 4 Fig. 10**).

***Oscillatoria chalybea* (Mertens) Gomont**

Thallus dark blue-green; trichome straight or slightly or irregularly spirally coiled, slightly constricted at the cross-walls, attenuated at the apex, and somewhat bent, 8-13 μ broad, blue-green; cells 1/2-1/3 times as long as broad, rarely as long as broad, 3.6-8 μ long, septa not granulated, end cell obtuse, not capitate, without calyptras (**Pl. 4 Fig. 11a & b**).

***Oscillatoria tenuis* Ag. ex Gomont**

Thallus thin blue-green or olive-green, slimy; trichome straight, fragile slightly constricted at the cross-walls, 4-10 μ broad, blue-green, sometimes bent at the

ends, not attenuated at the apices, not capitates; cells up to 1/3 as long as broad, 2.6-5 μ long, at the septa mostly granulated; end cell more or less hemispherical with thickened outer membrane (**Pl. 4 Fig. 12**).

***Oscillatoria simplicissima* Gomont**

Thallus dark blue-green; trichome straight, not constricted at the cross-walls yellowish blue-green, 8-9 μ broad, not attenuated at the apices, not capitates; cells 1/4 -1/2 as long as broad, not attenuated at the apices, not cells hemispherical, with or without a slightly thickened membrane (**Pl. 4 Fig. 13**).

***Oscillatoria limnetica* Lemm.**

Trichome straight or slightly bent, distinctly constricted at the cross-walls, pale blue-green, 1.5 μ broad, not attenuated, not capitates; cells 2.5 - 6 times as long as broad, 4-12 μ long; end cells rounded, calyptras absent (**Pl. 4 Fig. 14**).

***Oscillatoria pseudogeminata* G. Schmid**

Thallus pale or dirty blue-green, trichomes coiled, pale blue-green, ends not attenuated, 1.3-2.2 μ broad; cells as long as broad or somewhat longer or shorter than broad, about 2.6 μ long, not constricted at the cross-walls, cross-walls, thick, not granulated, end cell rounded, calyptras absent (**Pl. 4 Fig. 15**).

***Oscillatoria claricentrosa* Gardner**

Trichome nearly straight, 2.3-2.5 μ broad, attenuated at the ends, pointed slightly constricted at the joints, cells 3-5 times longer than broad, up to 11 μ mostly 6-8 μ long (**Pl. 4 Fig. 16**).

***Oscillatoria formosa* Bory ex Gomont**

Thallus blue-green; trichome straight, slightly constricted at the cross-walls, 4-6 μ broad, bright blue-green attenuated at the ends and bent; cells nearly quadrate, up to half as long as broad, 2.5-5 μ long, septa sometimes slightly granulated; end-cells nearly obtuse, calyptras absent, not capitates (**Pl. 4 Fig. 17**).

***Oscillatoria salina* Biswas**

Plant mass forming a deep blue-green thin membrane extending over the muddy soil and finally after being separated floating on the surface of the water; filaments lying side by side in the stratum, straight, elongate, erect, scarcely curved, fragile, rapidly moving, not at all constricted at the joints, 3-5 μ diam., apices of trichome straight, briefly tapering ending acuminate in a sharp point, hooked or twisted, not capitates; apical cell mucronate hyaline, may be interrupted by inflated refringent cells; transverse septa indistinct, not granulated, cell contents finely uniformly granular, almost homogeneous, blue-green (**Pl. 4 Fig. 18**).

***Oscillatoria acuminata* Gomont**

Thallus blue-green; trichome more or less straight, not constricted or slightly constricted at the cross-walls, 3-5 μ broad, at the ends briefly tapering, sharply pointed, bent; cells longer than broad, rarely subquadrate, 5.5-8 μ long, sometimes granulated at the cross-walls; end cell mucronate, without calyptras (**Pl. 4 Fig. 19**).

***Oscillatoria brevis* (Kütz.) Gomont**

Thallus expanded, olivaceous; trichome blue-green, straight, not constricted at the cross-walls, ends briefly attenuated, more or less bent, not capitate, 4-6.5 μ broad, blue-green; cells 1/2 -1/3 times as long as broad, 1.5-3 μ long, not granulated at the septa; end-cell rounded, conical, calyptras absent.

***PHORMIDIUM* Kütz.**

Filaments many forming a gelatinous or leathery stratum, thallus attached by the lower, side, or floating in water with torn margins; sheath present, more or less firm, sometimes agglutinated, sometimes partly diffuents, thin, colourless; trichomes cylindrical, in some constricted at the joints, apices often attenuated, straight or bent, never regularly spirally coiled, capitate or non-capitate, apical cells in many species with a calyptras.

***Phormidium Jadinianum* Gomont**

Thallus dark-green to olive-green, thin, amorphous; filaments more or less parallel; sheath thin, diffluent and agglutinated, not coloured violet by chlor-zinc-iodide; trichome olive-green, distinctly constricted at the cross-walls, with straight long acuminate ends, 4-6 μ broad,; cells shorter than broad to nearly quadrate, 2-3.5 μ long, contents granulated with a hyaline central area, septa not granulated; end cell acute conical calyptras absent (**Pl. 5, Fig. 3a, b & c**).

***Phormidium microtomum* Skuja**

Thallus expanded, coriaceous, lamellose, dark greyish-green or light-bluish; filaments more or less straight, 6.5-8 μ broad; sheath thin, colourless, later diffluent; trichome ends briefly or prominently attenuated, 6-7 μ broad, long, contents blue-green to olivaceous, septa not granulated or indistinct, and finely granulated; apical cell rounded with a hyaline calyptras (**Pl. 5, Fig. 4a & b**).

***Phormidium purpurascens* (Kütz.) Gomont**

Thallus compact, leathery, purple to brownish violet; trichome strongly bent, entangled, not constricted at the cross-walls, ends not attenuated, 1.5-2.5 μ broad, dark violet; sheath more or less diffluent not coloured violet by chlor-zinc-iodide; cells

nearly quadrate or up to nearly two times longer than broad, 2-4.5 μ long, cross-walls marked by two granules on either side, end-cell rounded, calyptras absent (**Pl. 5, Fig. 5a & b**).

***Phormidium mucosum* Gardner**

Filaments 7.2-7.8 μ broad long, straight or curved; trichome 2.5-3.4 μ broad, not constricted at the cross-walls ends; sheath apparently thick, more or less gelatinous, colourless, unlamellated; cells 2-2 1/3 times as long as broad, pale blue-green; end cell rounded (**Pl. 5, Fig. 6a & b**).

***LYNGBYA* Ag.**

Trichome single or free in a thin or very massive thick, firm sheath; sheath mostly colourless, seldom coloured yellow to brown or red, blue to purple red; filaments sometimes spirally coiled or attached at the base or in the middle or the entire filament attached, mostly without such attachment or free-swimming or forming free thallus.

***Lyngbya spiralis* Geitler**

Filaments forming a thin leathery thallus blue-green or bluish black, 5-6 μ broad, entirely major part or at the ends spirally coiled; sheath not coloured violet by chlor-zinc-iodide, smooth, firm, not lamellated, colourless; trichome in living and dried condition, pale blue-green not attenuated, not capitates, 4.5-5 μ broad, cells mostly 1/3 seldom up to half as long as broad, 1.5-2.5 μ long; end cell broadly rounded, without a thickened outer wall, calyptras absent (**Pl. 3, Fig. 1a & b**).

***Lyngbya birgei* Smith, G. M.**

Filaments straight, seldom coiled, free-floating, 20-24 μ broad; sheath firm, colourless, mostly unlamellated, seldom lamellated, 0.5-4 μ thick; trichome not constricted at the cross-walls, 18-23 μ broad, ends rounded, not attenuated, not capitate; cells shorter than broad, 2-2.5 μ long, sometimes with gas-vacuoles (**Pl. 3, Fig. 2a & b**).

***Lyngbya dendrobia* Bruhl et Biswas**

Stratum more or less expanded, compact, thin, minutely and densely tomentose; filaments long and flexible; closely interwoven, with sheath 1-11 μ thick, smooth hyaline, usually colourless more rarely when old brownish and very moderately stratified; trichomes 9-10 μ broad, scarcely or not at all constricted at the cross-walls; cells 1.7-2.5 times as broad as long, 4-6 μ long; contents of various shades of brown, uniformly and densely granular; dissepiments conspicuous, not marked by granules (**Pl. 3, Fig. 3a & b**).

***Lyngbya confervoides* C. Ag. ex Gomont**

Sheath colourless, when old lamellated, upto 5 μ thick, trichome olive green or blue green, not constricted at cross walls, cross walls not granulated, not attenuated at apices, 9-22 μ mostly 10-16 μ broad; cells 2-4 μ long, end cell rotund, calyptra absent (**Pl. 3, Fig. 4a, b & c**).

***Lyngbya martensiana* Menegh. ex Gomont**

Thallus caespitose, blue-green, when dried violet, filaments long more or less flexible; sheath colourless, thick, not coloured violet with chlor-zinc-iodide outside rough; trichome 6-10 μ broad (rarely 13 μ), not constricted at the cross-walls, cross-wall sometimes granulated, apices not attenuated, pale blue-green; cells 1/2-1/4 times

a s long as broad, 1.75-3.3 μ in length; end cell rotund, without calyptras (**Pl. 3, Fig. 5a & b**).

***CYLINDROSPERMUM* Kütz.**

Thallus mucilaginous, mostly dull blue-green; trichome uniformly broad, short without, but sheath, but in a common mostly very delicate and often imperceptible, mucilage of thin consistency; cells cylindrical, constricted at the cross-walls; heterocysts terminal, at both ends or at one end only, sometimes intercalary; spores single rarely in series, next to the heterocyst on one side much bigger than the vegetative cells.

***Cylindrospermum stagnale* (Kütz.) Born. et Flah.**

Thallus floccose, expanded, attached or free-floating, blue-green; trichomes 3.8-4.5 μ broad, constricted at the cross-walls; cells nearly quadrate, or cylindrical, and often 3-4 times as long; heterocysts subspherical or oblong, 6-7 μ broad, 7-16 μ long; spores cylindrical with rounded ends, 10-16 μ broad and 32-40 μ long, with smooth yellowish brown outer layer (**Pl. 6, Fig. 1**).

***Cylindrospermum musicola* (Kütz.) ex Born. et Flah.**

Thallus expanded, mucilaginous, blackish-green; trichomes 3-4.7 μ broad, considered at the cross-walls, light blue-green; cells 4 (-5) μ long, cylindrical, or nearly quadrate; heterocysts oblong, 4 (-5) μ broad, 5-7 μ long; spores oval, 9-12 μ broad, 10-20 μ long, epispore smooth, yellowish brown (**Pl. 6, Fig. 2**).

***NOSTOC* Vaucher**

Thallus mucilaginous gelatinous or coriaceous. First globose to oblong, later globose, foliose, filiform, bullose, solid or hollow, free or attached, the periphery

dense and darkly coloured; filaments flexuous, curved or entangled; sheath sometimes distinct, generally diffluent; trichome torulose; cells depressed, spherical, barrel-shaped or cylindrical; heterocysts intercalary, and in young conditions terminal; spores spherical, or oblong, formed centrifugally in series in between the heterocysts.

***Nostoc punctiforme* (Kütz.) Hariot**

Thallus sub-globose up to 2 mm diam., scattered or confluent, attached; filaments flexuous, densely entangled; sheath delicate, hyaline, mucous; trichome 3-4 μ broad, cells short barrel-shaped or ellipsoidal, blue-green; heterocysts 4-6.5 μ broad; subspherical, or oblong, 5-6 μ broad and 5-8 μ long, episore thick and smooth (Pl. 6, Fig. 3a, b, c, d & e).

***Nostoc entophytum* Born. et Flah.**

Thallus small macroscopic inconspicuous, blue-green or yellowish growing on aquatic plants, also in the cells or lacuna of plants; filaments densely entangled; sheaths generally distinct, hyaline later brownish; trichomes 2.5-3 μ broad, torulose; cells short barrel-shaped; heterocysts broader than the vegetative cells; spores spherical or slightly compressed, 5-6 μ broad, rarely oblong, 5-8 μ long, with brown smooth episore (Pl. 6, Fig. 5).

***Nostoc paludosum* Kützing ex Born. et Flah.**

Thallus microscopically not visible, punctiform, gelatinous; sheath broad, colourless or yellowish brown; trichomes 3-3.5 μ broad, cells as long as broad, barrel-shaped, pale blue-green; heterocysts broader than the vegetative cells; spores oval, 4-4.5 μ broad, 6-8 μ long, with smooth colourless memberane (Pl. 6, Fig. 4).

***Nostoc linkia* (Roth) Bornet ex Born. et Flah.**

Thallus varying in size, sometimes punctiform, sometimes tuberculate, at first globose later irregularly expanding, torn, gelatinous, blue-green to violet, or blackish green or brown; filaments densely entangled, flexuous or highly coiled; sheath diffluent and colourless inside, distinct only in the peripheral portion; trichomes 3.5-4 μ broad, pale blue-green; cells short barrelshaped; heterocysts subspherical; spores subspherical, 6-7 μ broad, 7-8 μ long, episore smooth (Pl. 6, Fig. 6).

***Nostoc rivulare* Kützing ex Born. et Flah.**

Thallus at first globose, size variable, up to 2-3 mm diam., later bullose-tuberculate, hollow irregularly torn and perforate, lobed, fragile, young ones light pale green, older ones yellowish or variously coloured, filaments loosely entangled, flexuous; sheath distinct at the periphery of the thallus, yellowish at the surface, inside hyaline and diffluent; trichome 4-4.2 μ broad; cells spherical to oblong, longer than broad; heterocysts oblong, 5-6 μ broad; spores oblong or barrel-shaped, 6-8 μ broad, 7-10 μ long, contiguous when mature, episore smooth hyaline or brownish (Pl. 6, Fig. 7).

***Nostoc carneum* Ag. ex Born. et Flah.**

Thallus at first globose, later bullose-tuberculate, leathery and irregularly expanded, gelatinous, flesh-coloured, reddish brown, violet, rose, or blue to olive green; filaments loosely contorted, flexuous; sheath indistinct, colourless; trichome (-)3.5-4 μ broad; cells oblong-cylindrical, up to twice as long as 5-10 μ long, episore smooth and hyaline (Pl. 6, Fig. 8).

***Nostoc elliposporum* (Desm.) Rabenth. ex Born. et Flah.**

Thallus gelatinous, irregularly expanded, attached by the lower surface reddish brown; filaments flexuous, loosely entangled; trichome about 4 μ broad, light blue-green or olivaceous; cells cylindrical, 6-14 μ long; heterocysts sub-spherical, or oblong, 6-7 μ broad, 6-14 μ long, spores ellipsoidal to oblong cylindrical, 6-8 μ broad, 14-19 μ long, epispore smooth, hyaline or brownish (Pl. 6, Fig. 9).

***Nostoc calcicola* Brébisson ex Born. et Flah.**

Thallus mucilaginous slightly diffluent, expands, olive, grey or blue green, often up to 5 cm in diam, filaments loosely entangled, sheath mostly indistinct or distinct only at the periphery of the thallus, colourless or yellowish brown; trichome 2.5 μ broad, pale blue-green; cells barrel-shaped, subspherical, rarely longer than broad; heterocysts subspherical, 4 (-5) μ broad; spores subspherical, 4-5 μ broad, with smooth yellowish membrane (Pl. 7, Fig. 1).

***Nostoc passerinianum* (De Not.) Bornet ex Born. et Flah.**

Thallus crustaceous, expanded, orbicular, gelatinous, membranous attached by the lower surface, olive green, olive yellow or brown, 1-2 cm diam; filaments densely entangled, flexuous, mostly parallel; trichome 5 μ broad torulose; cells short barrel-shaped, or ellipsoidal, 5-7 μ long; hetero-cysts 5 μ broad, subspherical or oblong; spores oval, 6 μ broad, 8 μ long, epispore smooth, yellowish.

***Nostoc muscorum* Ag. ex Born. et Flah.**

Thallus gelatinous membranous, irregularly expanded, attached by the lower surface, tuberculate, dull olive or brown, 2-5cm diam.; filaments densely entangled; sheath distinct only at the periphery of the thallus, yellowish brown; trichome 3-4(-5) μ broad; cells short barrel-shaped to cylindrical up to twice as long as broad;

heterocysts nearly spherical, 6-7 μ broad; spores oblong, many in series, 4-8 μ broad, (7-) 8-12 μ long, epispore smooth and yellowish(**Pl. 7, Fig. 2**) .

***Nostoc commune* voucher ex Born. et Flah.**

Thallus firm, gelatinous, at first globose, later flattened, expanding undulated, membranous or leathery, sometimes irregularly torn, often perforated, many centimetres diam., blue-green, olivaceous or brown; filaments flexuous, entangled; sheath mostly distinct only at the periphery, thick, yellowish brown, often lamellated, inside the thallus more or less distinct, but hyaline; trichome 4.5-6 μ broad, cells short barrel-shaped or nearly spherical, mostly shorter or a little longer than broad, 5 μ long; heterocysts nearly spherical, about 7 μ broad; spore only once observed, as big as the vegetative cells, epispore smooth colourless (**Pl. 7, Fig. 3a, b & c**).

***Nostoc microscopium* Carm. ex Born. et Flah.**

Thallus spherical or ellipsoidal, about 1 cm diam., or only very seldom larger, soft, but with a firm outer surface, first glistening later olivaceous or brown; filaments loosely entangled; sheath more or less distinct, yellowish; trichome 5-8 μ broad, blue-green, or olive-green; cells subspherical or barrelshaped heterocysts nearly spherical, 7 μ broad; spores oval, 6-7 μ broad, 9-15 μ long, olivaceous, epispore smooth (**Pl. 7, Fig. 4**).

***Nostoc hatei* Dixit**

Thallus almost spherical, at first attached, later free-floating, up to 2 cm diam., trichomes 3.7-6 μ broad, irregularly curved and densely entangled; cells spherical or ellipsoidal; heterocysts single, or in short chains of 2-5, almost, spherical rarely slightly barrel-shaped, sometimes flattened, 3.6-5 μ broad, and 5 μ long, spores not observed (**Pl. 7, Fig. 5**).

***Nostoc sphaericum* Vaucher ex Born. et Flah.**

Thallus free, globose, 1-15mm diam, later irregularly plicate-tuberculate, thick, sometimes 6-7 cm in diam, olive-green, yellow or violet brown, with firm outer layer; filaments flexuous, densely entangled; trichome 4 rarely 5 μ broad, cells compressed spherical or barrel-shaped; heterocysts (4-) 6 μ broad, sub-spherical; spores oval 5 (4-6) μ broad, 7 (6-8) μ long, episporium thick and brownish.

***ANABAENA* Bory.**

Trichomes uniformly broad throughout or apices alone somewhat, attenuated, sheath absent or more or less diffluent, forming a free, torn or floccose or soft mucilaginous thallus; heterocysts generally intercalary; spores single or in long series, formed near the heterocysts or in between the heterocysts.

***Anabaena sphaerica* Born. et Flah.**

Thallus floccose, blue-green; trichomes moniliform, straight, arranged parallel, 5-6 μ broad, with an indistinct mucilaginous sheath cells spherical to short barrel-shaped; end cells rounded; heterocysts sub-spherical, 6-7 μ broad; spores on one or both sides of the heterocysts sub-spherical to oval, 8-12 μ broad, 12-18 μ long, one to few together, episporium smooth, yellowish brown (**Pl. 8, Fig. 1a & b**).

***Anabaena oryzae* Fritsch**

Thallus soft, green, gelatinous, membranous, trichomes short, straight densely aggregated, generally parallel cells 2.5-3 μ broad, more or less barrel-shaped, 1.5 - 2 times as long as broad; heterocysts terminal and intercalary broader than the vegetative cells, 3-3.5 μ broad, terminal and intercalary, broad, intercalary ones, single, or 2-3 in series, generally barrel-shaped, sometimes spherical, single; spores rarely single next to the terminal heterocyst, commonly away from the intercalary

heterocysts, single or 2-7 in series subspherical or short ellipsoidal, exospores yellowish brown (**Pl. 8, Fig. 2a, b, c, d & e**).

***Anabaena fertilissima* Rao, C.B.**

Trichome single, straight or bent, with almost rounded end cells, up to 350 μ long, 5-5.6 μ broad, at the apex 4 μ broad; cells barrel-shaped, 4-8-8 μ long; heterocysts almost spherical, 6.4-4 μ broad; spores in long chains, often making the whole trichome sporogenous, adjoining the heterocysts but formed centrifugally, almost spherical, with a smooth hyaline outer wall, 4.8-8 μ broad and 3.2-8.8 μ long (**Pl. 8, Fig. 3**).

***Anabaena naviculoides* Fritsch.**

Thallus thin, gelatinous, blue-green; trichome elongate, more or less coiled, moniliform, apices acuminate; cells 3.5-5 μ broad, as long as or shorter than broad (developing akinetes), apical cell obtuse conical, or acute, sometimes retuse; heterocysts rare, intercalary, single, barrel-shaped, 5-6 μ broad, as long as or slightly longer than broad; spores in long series, irregularly disposed, ellipsoidal, ends acute and protracted, exospores thin and hyaline. (**Pl. 8, Fig. 4a, b & c**).

***Anabaena variabilis* Kützing ex Born. et Flah.**

Thallus gelatinous, dark-green, trichome without any sheath, flexuous, 4-6 μ broad, more often 4.2-5 μ broad slightly constricted at the cross-walls, end-cells conical, obtuse; cells barrel-shaped, sometimes with gas vacuoles, 2.5-6 μ long; heterocysts spherical or oval, 6 μ broad, up to 8 μ long; spores formed centrifugally, not contiguous with the heterocysts, barrel-shaped, in series, 7-9 (-11) μ broad, 8-14 μ long, episore smooth or with fine needles, colourless or yellowish brown (**Pl. 8, Fig. 5**).

***Anabaena torulosa* (Carm.) Lagerh. ex Born, et Flah.**

Thallus mucilaginous, thin, blue-green; trichome 4.2-5 μ broad, apical cell acutely conical; cells barrel-shaped, as long as or somewhat shorter than broad, heterocysts or ovoid, 6 broad, and 6-10 μ long; spores on both sides of the heterocysts, developed centripetally, single or many, subcylindrical with rounded ends, sometimes constricted in the middle, 7-12 μ broad, up to twice as long as broad, epispore smooth and pale brown in colour (**Pl. 8, Fig. 6a, b & c**).

***SCYTONEMA* Ag.**

Filaments false branched, false branches single or geminate, formed laterally generally in between heterocysts; trichomes single in each sheath, straight; hormogones terminal, solitary; pseudo-hormogonia present; spores known only in a few species, spherical or ovate, exospores thin and smooth.

***Scytonema simplex* Bharadwaja**

Thallus thick, dirty blue-green or pale blue-green; filaments 14-15.7 μ broad, irregularly bent and loosely entangled; false branches long, geminate and single in equal numbers; sheath firm up to 2.1 μ thick, hyaline, unstratified; trichomes sometimes with indistinct septa and occasionally with slight constrictions at the joints, 9.4-11.5 μ broad; cells usually elongate cylindrical up to four times as long as broad, sometimes quadrate, at the growing region flattened and barrel-shaped; heterocysts single, sometimes in pairs, usually elongate, cylindrical, rarely more or less quadratic, with convex end walls thicker than the longitudinal ones, as broad as the trichomes, 9.4-11.5 μ broad and 11.5-46.2 μ long (**Pl. 9, Fig. 1a, b, c, d & e**).

***Scytonema coactile* Montagne ex Born. et Flah.**

Thallus radially expanded, woolly, caespitose, green or blue-green, up to 15 cm broad; filament 18-24 μ broad, 4cm or more long; false branches long, erect; sheath firm, membranaceous hyaline or yellowish; trichome 12-18 μ broad, cells subquadrate or longer than broad; heterocysts sparse, subquadrate (**Pl. 9, Fig. 2**).

***Scytonema bohneri* Schmidle**

Stratum filamentous, blackish green; filaments partly creeping, partly ascending, filaments 10-12 μ broad, flash branched, branched mostly single, generally narrow 8-19 (-11) μ diam., 200-300 μ long, narrower at the apex, 6-7 μ diam.; sheath colourless, 1-1.8 μ thick, homogeneous, sometimes divergent; trichome bluish green, 5-8 μ broad; cells rectangular, short at the apices, 0.5 to 1.5 times as long as broad in the rest; heterocysts compressed, ellipsoidal to rectangular, longer than broad, wall hyaline (**Pl. 9, Fig. 3a, b & c**).

***Scytonema schmidtii* Gom.**

Thallus extensive, brownish black, crustaceous, tomentose, about 1 mm diam., with wrinkled surface; filaments extremely and irregularly undulated, crisp, intricate, 10-12 μ diam., lower down about 16 μ broad, primarily prostrate, stolon-like, abundantly and repeatedly false branched; sheath yellowish brown, lower down broad and rugose, not coloured blue by chlor-zinc-iodide; trichomes extremely torulose, bluish, 9-12 μ broad; cells compressed, subquadrate 2-6 μ long; heterocysts quadrate to compressed, colourless (**Pl. 9, Fig. 4**).

***Scytonema frémyi* nom. nov**

Thallus on soil, expanded, greenish black; filaments long, about 9 μ broad, sparsely false branched; false branches geminate, free at the base, long sheath

yellowish at the apices, hyaline, homogeneous, not lamellate, not dilated, and 5 μ thick; trichome constricted at the cross-walls; cells 2-4 times longer than broad, rarely shorter than long; heterocysts rectangular 4-5 times longer than broad (**Pl. 10, Fig. 1**).

***TOLYPOTHRIX* Kützing**

Filaments with a generally firm, thin or thick sheath with a single trichome in each sheath; false branched, mostly free, prostrate or erect; false branches single mostly subtending a heterocyst, occasionally geminate as in *Scytonema*; hormogonia formed from the tips; trichome with apical growth, apices often broader with shorter cells; spores known in some species

***Tolypothrix nodosa* Bharadwaja**

Stratum thick, mucilaginous, blue-green to yellow-brown; filaments irregularly bent, densely entangled, 5.2-7.3 (-8.4) μ broad; false branches few, geminate and single, single branched by the side of dead cells, one pored heterocysts or dead- cells adjoining such heterocysts; sheath firm, thin, occasionally, slightly thickened opposite the septa, hyaline, often bulged out at the point of branching; trichomes constricted at the septa, hyaline, often bulged out at the point of branching; trichomes constricted at the joints, septa indistinct; cells cylindrical, up to 5 times as long as broad sometimes quadratic; heterocysts intercalary and terminal (basal), single, ellipsoidal, rarely cylindrical with convex walls, when mature much wider than the trichome, 4.2-9.4 μ broad and 7.3-16.8 (-23) μ long (**Pl. 10, Fig. 2**).

***Tolypothrix tenuis* (Kütz.) Johs. Schmidt em.**

Thallus caespitose or cushion- like, blue-green or brown; filaments (4) 6-17 (-18) μ broad, up to 2cm long, repeatedly branched; sheath thin, close to the trichome, at first colourless, later yellowish brown, often lamellated; cells (4-) 5-13 μ broad,

quadrate or longer than broad, blue-green, slightly or not constricted at the cross-walls; heterocysts cylindrical, rounded or discoid 6-14 μ and 2.3-6 μ long colourless or yellowish, solitary or 2 to 5 in a row (**Pl. 10, Fig. 3a, b**).

***Tolypothrix fragilis* (Gardner) Geitler**

Filaments 5.5-7 μ broad, short, straight, forming a thin thallus: sheath thin colourless, not lamellated, sometimes gelatinized at the bottom of the branch; trichome 4-5.5 μ broad, not constricted at the cross-walls; cells in the older parts of the trichome as long as broad, at the ends half as long as broad; heterocysts spherical or compressed (**Pl. 10, Fig. 4**).

***Tolypothrix byssoidea* (Berk.) Kirchner**

Thallus woolly, cushion-like, brownish or blackish; filaments up to 1 mm long, 10-15 μ rarely up to 17 μ) in diam., irregularly false branched; false branches short, erect, curved; sheath thin, close to the trichome yellowish to brownish, fragile, tubular, sometimes somewhat coreaceous; trichome 9-11 μ broad, torulose; cells barrel-shaped, 0.3-0.5 times as long as broad; heterocysts basal, rarely intercalary, single or in pairs; spores seen once, in series, ellipsoidal, longer than the vegetative cells, yellowish green (**Pl. 10, Fig. 5a & b**).

***Tolypothrix conglutinate* Borzi ex Born et Flah.**

Filaments densely entangled, irregularly flexuous, forming a blue-green or a brownish slimy crustaceous thallus, 14-18 μ broad; sheath thick, irregularly broadened, colourless and homogenous; cells 8-10 μ broad, shorter than long, not constricted at the cross-walls; heterocysts spherical, single (**Pl. 10, Fig. 6a & b**).

***CALOTHRIX* Ag.**

Filaments single or in small bundles, caespitose, tomentose, pulvinate, or penicillate; filaments arranged more or less parallel, mostly erect, unbranched or seldom false- branched; sheath mostly firm, sometimes seen only at the base; heterocysts mostly basal, seldom intercalary; spores when formed single or in series, next to the basal heterocyst.

***Calothrix castellii* (Massal.) Born. et Flah.**

Thallus spongy, cushion shaped, widely expanded, dull blue green, surface pubescent by projecting ends of filaments; filaments bent, erect, densely aggregated, 12-13 μ broad, swollen at the base and prostrate, 4-8 mm long sheath thin close to the trichome, firm, uniform, hyaline, or yellowish; trichome 8-10 μ broad, attenuated into a long hair; cells 0.5 -1.5 as long as broad; heterocysts basal (**Pl. 11 Fig. 1a & b**).

***Calothrix elenkinii* Kossinskaja**

Filaments 80-250 μ long, united in tufts, bent at the base, interlaced with each other, swollen at the base, and 6-9 μ broad, in the middle 4.5-6 μ broad; sheath close to the trichome, thin, not lamellated, colourless, open at the ends; trichomes blue or olive green, at the base 5-7 μ broad, in the middle 3.5-4.5 μ broad, not constricted at the base, apical hair not formed; cells quadrate or somewhat shorter than; heterocysts basal, single 4.5-7 μ broad (**Pl. 11 Fig. 2a & b**).

***Calothrix braunii* (A. Br.) Bornet et Flahault**

Thallus caespitose, blue green or brownish; filaments straight, parallel 500 μ long, 9-10 μ broad, swollen at the base slightly bent; sheath thin, close to the trichome, colourless; trichome 6-7 μ broad, ending in a long hair, con-basal, hemispherical (**Pl. 11 Fig. 3a, b & c**).

***Calothrix parietina* Thuret ex Born. et Flah.**

Filaments single or forming an expanded crustaceous thallus, thallus brownish to dark black in colour, sometimes somewhat with calcium incrustation; filaments 0.25 mm to 1 mm high, mostly branched, closely adpressed, erect or seldom horizontal, 10-12 (seldom up to 18 μ); sheath very close, generally lamellate, sometimes homogeneous; trichomes 5-10 μ broad, produced into a hair, 1 μ broad, cells at the base shorter than broad, mostly 1.5 -3 times along as broad, than the cells; hormogones about 3 times as long as , single or a few one behind the other (**Pl. 11 Fig. 4a, b, c, d & e**).

***Calothrix weberi* Schmidle**

Filaments single, free floating or attached, unbranched, very much bent, often irregularly spirally coiled, rarely straight; about 8 μ broad at the base, ending in a hair, 2-2.5 μ broad; sheath diffluent, hyaline, thin close to the blue-green; trichome 5.1 μ broad; cells cylindrical, a little longer than broad, blue-green; heterocysts basal.

***Calothrix membranacea* Schmidle**

Thallus papery, blue green; filaments long, horizontal mostly curved irregularly floccose, rarely branched, gradually attenuated; sheath thin, hyaline, not lamellated; trichomes torulose, only seldom trichome produced into a hair; cells half as long as broad to subquadrate, in the apex and the hair more or less hyaline and elongate; hormogones with a few cells, formed in series; heterocysts present, basal (**Pl. 11 Fig. 5a & b**).

***Calothrix marchica* Lemmermann**

Filaments straight, or slightly bent, single, at the base 5-6 μ broad, with a close thin colourless sheath; sheath not coloured blue by chlor-zinc-iodide; trichome blue

green, gradually attenuated into a hair, distinctly constricted at the cross-walls, at the base 4-5.5 μ broad; cells nearly as long as broad, or 0.5 to 1.4 times as long as broad, end cell conical, somewhat pointed; heterocyst single basal nearly spherical or hemispherical, 4-5.5 μ broad (**Pl. 12 Fig. 1a, b& c**).

***RIVULARIA* (Roth) Ag.**

Trichomes unbranched, more or less irregularly false branched; filaments more or less radial or parallel in a hemispherical or spherical mucilaginous colony, hollow or solid; sheath more or less gelatinizing; trichomes ending in a hair, often with distinct trichothallic growth; heterocysts basal or inter-gradually progressing towards the base from the meristematic zone; spores absent.

***Rivularia aquatica* De Wilde**

Thallus spherical up to 2 mm diam., without calcium incrustation; filaments slightly pressed together; sheath thin, colourless, unlamellated, regularly attenuated at the ends; trichome 7-9 μ broad, ending in a long thin hair; cells at the base longer than broad, near the apex longer (**Pl. 12 Fig. 2a, b & c**).

***Rivularia globiceps* West, G.S.**

Thallus small, soft, 1.5-3 mm, hemispherical to spherical without calcium incrustation; filaments highly adpressed; sheath colourless thick, unlamellated, trichome ending a long hair, 4.8-6 μ broad, constricted at the cross-walls; cells cylindrical, at the base 1.5 - 4 times as long as broad, above as long or twice as long as broad, heterocysts spherical, 10-12 μ broad, single seldom two together.

DISCUSSION:

In the present investigation, the three year study (2006-09) revealed 84 species belonging to 16 genera from four different habitats of Goa. The paddy fields of Goa are rich in indigenous cyanobacterial population consisting of unicellular, non-heterocystous and heterocystous forms. Maximum occurrence of all forms of BGA was recorded in hinterlands both during kharif and rabi seasons.

The study also indicated that the pH in hinterlands was neither highly acidic nor alkaline (6.5 to 7.9) and the P content of the soil was higher compared to other sites undertaken for the study. Begum *et al.*, (2008) reported significant variation in cyanobacterial population from the paddy field soils of 11 districts of Bangladesh, where the highest number of indigenous cyanobacterial population was reported from paddy field soils with pH range of 6.8 to 7.5 and available P (12.42 to 28.50 μ g/g soil) which is in conformity with the results obtained in the present study.

Our study reports the presence of BGA belonging to two orders *viz.*, Chroococcales and Nostocales and families Chroococcaceae, Oscillatoriaceae, Nostocaceae, Scytonemataceae and Rivulariaceae. Singh (1978) conducted a survey in the farms of the Central Rice Research Institute, Cuttack, India and reported the dominance *Aphanothece*, *Anabaena*, *Aulosira*, *Cylindrospermum*, *Gloetrichia* and *Nostoc*. Similarly, Ghadai *et al.*, (2010) reported seven major groups that include Chroococcaceae, Pleurocapsaceae, Oscillatoriaceae, Nostocaceae, Rivulariaceae, Scytonemataceae and Stigonemataceae from paddy fields of Gunpur, Orissa.

In the present study, the khazan fields recorded appreciable number of BGA which was however less than found in hinterlands and coastal fields. Such variations in cyanobacterial population were recorded earlier in paddy field soils of India (Roger

et al., 1986). However, Aiyer, (1965) and Amma *et al.*, 1966 reported rich cyanobacterial flora from the coastal and saline paddy fields of Kerala.

Among the study areas, mining affected fields showed acidic pH with low P and Ca content possibly affecting the growth of BGA. The growth of nitrogen fixing cyanobacteria is known to be affected by acidic pH, low content of P and Ca (Roger and Reynaud, 1985; Healey, 1973).

All the four habitats showed dominance of heterocystous forms like *Nostoc*, *Anabaena* and *Calothrix*. Among the non-heterocystous forms, *Oscillatoria* showed maximum (19) species with species number given in parenthesis. Dominance of Oscillatoriaceae and Nostocaceae in paddy fields have been reported earlier (Ghadai *et al.*, 2010).

Unicellular genera like *Microcystis* (2), *Chroococcus* (4), *Gloecapsa* (3), *Aphanocapsa* (1) and *Aphanothece* (3) were recorded in all four habitats with species number given in parenthesis. Choudhary, (2009) reported 28 species of BGA from paddy fields of North Bihar belonging to nine genera of Chroococcaceae including *Aphanocapsa*, *Aphanothece*, *Chroococcus*, *Gloecapsa*, *Gloethece*, *Merismopedia*, *Microcystis*, *Synechococcus* and *Synechocystis*.

The non-heterocystous genera recoded in the present study include *Lyngbya* (5), *Spirulina* (2), *Oscillatoria* (19) and *Phormidium* (4) while the heterocystous genera include *Cylindrospermum* (2), *Nostoc* (14), *Anabaena* (6), *Scytonema* (5), *Tolypothrix* (5), *Calothrix* (7) and *Rivularia* (2) with species number in parenthesis. The most dominant heterocystous species in all the habitats include *Nostoc rivulare* kiitzing, ex Born. et Flah, *Anabeana oryzae* Fritisch and *Calothrix membranacea* Schmidle. The nitrogen fixing heterocystous BGA were dominant in all the study

sites. In an all India survey, Venkataraman, (1975) observed that out of 2213 soil samples from paddy fields, 33% harboured nitrogen fixing cyanobacteria.

Through a quantitative study of algal flora of dried soil samples from upland fields (pH 7.8-8.3) at the Indian Agricultural Research Institute (IARI), New Delhi, cyanobacteria were dominant in all the soil samples (Dutta and Venkataraman, 1968). Out of 62 algal species reported from Gulf of Mexico, Ecuador and Colombia, 46 species were cyanobacteria from which 23 were nitrogen fixing (Durell, 1964). Singh (1961) investigated the periodicity of cyanobacteria in paddy fields of Uttar Pradesh and Bihar and found three prominent filamentous and heterocystous forms viz., *Aulosira fertilissima*, *Anabaena ambigua* and *cylindrospermum ghorakhpurease*. Quesada *et al.*, (1998) found that the three main heterocystous forms viz., *Anabaena*, *Nostoc* and *Calothrix* formed the dominant genera of paddy fields. Similar observations have been recorded in the present study.

The information generated on the dominant indigenous cyanobacterial population could be applied for sustainable agricultural practices by reducing the application of chemical fertilizers. The information could avoid the appearance of non-nitrogen fixers in soil that might compete with nitrogen fixers for nutrients. Finally, it may be concluded that the documentation on cyanobacteria may enhance the understanding of the nutrient status of the field and also knowledge about the indigenous nitrogen fixers.

INTRODUCTION:

Blue green algae (BGA) possess an autotrophic mode of growth like eukaryotic plant cells, metabolic system like bacteria and occupy a unique position. They possess chlorophyll a and are gram negative which carry out oxygenic photosynthesis. They exhibit a great morphological diversity and their broad spectrum of physiological properties reflects their widespread distribution and tolerance to environmental stress (Tandeau de Marsac and Howard, 1993). Interesting results are obtained from detailed studies carried out on the distribution and periodicity of BGA from various parts of India (Venkataraman, 1975; Kolte and Goyal, 1985; Singh, 1985). Several reports have indicated a widespread distribution of forms like *Oscillatoria*, *Nostoc*, *Anabaena*, *Phormidium* and *Aphanothece* (Gupta, 1975; Sinha and Mukherjee, 1975; Paul and Santra, 1982). Singh (1950) and Talpasayi (1962) made a systematic enumeration of cyanobacteria collected from moist soils and rocks. Research has also shown the occurrence of mostly heterocystous forms due to their competitive ability in comparison to non-heterocystous forms (Garcia-Pichel and Belnap 1996). The dominating heterocystous nitrogen fixing blue green algal species of *Aluosira*, *Cylindrospermum*, *Nostoc*, *Anabaena*, *Tolypothrix* and *Calothrix* were reported from soils of Cuttack and Orissa (Singh, 1961). Distributional profiles of cyanobacterial isolates from soils of Bhubaneswar, Cuttack and Howrah indicated the predominance of heterocystous strains (Saxena *et al.*, 2007). Paddy field ecosystem provides a unique aquatic-terrestrial habitat for the favourable growth and nitrogen fixation by cyanobacteria meeting their requirements for light, water and higher temperature thus maintaining the stable yield of paddy under flooded conditions and also the productivity of soils (Roger *et al.*, 1993).

The present study was directed towards evaluating the density and diversity of BGA in four different paddy grown habitats influenced by different soil conditions.

MATERIALS AND METHODS:

The physico-chemical analyses of the study sites were carried out. The investigation on the density and diversity of cyanobacteria from the four different study sites was carried out for a period of three years (June 2006-09). Collection was done from the study sites at fixed spots both in kharif and rabi seasons of paddy cultivation in one litre capacity wide mouthed bottles. The sample was immediately preserved in 1% Lugols iodine which sedimented the BGA. After all the BGA settled the supernatant was siphoned out and the remaining sample was concentrated by centrifugation at 1500rpm. The total concentrated volume was made to 100ml.

For quantitative analysis, the sample was analyzed by Lackey's drop method (1938) as mentioned in APHA (1995). The density was calculated as follows:

$$\text{Phytoplankton unit per litre} = \frac{n \times c}{V} \times 1000$$

Where n = number of phytoplanktons counted in 0.1ml. (1 drop of concentrate)

c = total volume of concentrate in ml.

V = total volume of water filtered in litres.

A colony is considered as one individual. Filament more than three fourth is considered as one individual.

STATISTICAL ANALYSES:

The data collected during the three years of study period was statistically analyzed using PAST statistical package. Shannon (H), Simpson (1-D) and Margalef diversity indices were analyzed for the three types of cyanobacteria namely heterocystous, non-heterocystous and unicellular during kharif and rabi seasons of paddy cultivation in the four different habitats.

RESULTS:

A total of 84 species belonging to 16 genera from the four different study sites of Goa were identified. The study was carried out for three consecutive years from June 2006 to June 2009. The distribution of BGA during the study period is depicted in the **Tables 5.1 to 5.3**. The study revealed that the four habitats showed variations in the distribution of genera and species in the two growing seasons of paddy *i.e.* kharif and rabi. The kharif season of the year 2006-07 recorded 63 species belonging to 15 genera in hinterlands, 61 species belonging to 15 genera in coastal fields, 43 species belonging to 13 genera in khazans and 31 species belonging to 10 genera in mining affected fields. The rabi season of the year 2006-07 recorded 63 species belonging to 14 genera in hinterlands, 62 species belonging to 15 genera in coastal fields, 33 species belonging to 13 genera in khazans and 29 species belonging to 9 genera in mining affected fields (**Table 5.1**).

In 2007-08 the kharif season of the year recorded 65 species belonging to 16 genera in hinterlands, 61 species belonging to 15 genera in coastal fields, 44 species belonging to 15 genera in khazans, 33 species belonging to 13 genera in mining affected fields. The rabi season of the year 2007-08, recorded 63 species belonging to 15 genera in hinterlands, 60 species belonging to 15 genera in coastal fields, 34 species belonging to 11 genera in khazans, 30 species belonging to 11 genera in mining affected fields (**Table 5.2**).

In 2008-09 the kharif season recorded 66 species belonging to 16 genera in hinterlands, 61 species belonging to 14 genera in coastal fields, 44 species belonging to 15 genera in khazans, 34 species belonging to 12 genera in mining affected fields. The rabi season of the year 2008-09, recorded 63 species belonging to 14 genera in hinterlands, 60 species belonging to 15 genera in coastal fields, 36 species belonging

Table 5.1: Distribution of BGA from different rice field habitats for the year 2006 -2007

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	species↓								
1	<i>Microcystis aeruginosa</i>	+	-	-	+	+	-	-	+
2	<i>M. elabens</i>	-	-	-	+	-	+	-	+
3	<i>Chroococcus turgidus</i>	+	+	-	+	+	+	-	+
4	<i>C. minutus</i>	-	-	+	+	-	-	+	+
5	<i>C. pallidus</i>	+	-	+	-	+	-	+	+
6	<i>C. cohaerens</i>	-	-	+	+	-	-	+	+
7	<i>Gleocapsa punctate</i>	+	+	+	+	+	+	+	+
8	<i>G. aeruginosa</i>	+	+	-	+	-	+	-	+
9	<i>G. kuetzingiana</i>	-	-	-	-	-	+	-	-
10	<i>Aphanocapsa banaresensis</i>	-	+	-	+	+	+	-	-
11	<i>A. stagnina</i>	+	+	+	+	+	+	+	+
12	<i>A. saxicola</i>	-	+	-	+	-	+	-	+
13	<i>A. castagnei</i>	+	+	-	+	-	+	+	+
14	<i>Lyngbya spiralis</i>	+	-	+	-	+	+	-	-
15	<i>L. bergei</i>	-	+	-	+	-	+	-	+
16	<i>L. dendrobia</i>	+	+	+	+	-	+	-	+
17	<i>L. confervoides</i>	+	-	-	+	+	+	-	+
18	<i>L. martensiana</i>	+	+	-	+	-	+	-	+
19	<i>Oscillatoria ornata</i>	-	-	+	-	-	-	-	+
20	<i>O. limosa</i>	+	+	-	+	+	+	-	+
21	<i>O. subbrevis</i>	+	+	+	+	+	+	+	+
22	<i>O. curviceps</i>	-	+	-	+	-	+	-	+
23	<i>O. princeps</i>	+	+	-	+	-	+	-	+
24	<i>O. proboscidea</i>	+	+	+	+	+	+	+	+

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae↓								
25	<i>Oscillatoria anguina</i>	+	+	-	+	-	+	+	+
26	<i>O. formosa</i>	+	+	-	+	+	+	-	+
27	<i>O. chlorina</i>	-	+	-	-	-	+	-	+
28	<i>O. martini</i>	+	+	+	-	-	-	+	-
29	<i>O. chalybea</i>	+	+	-	+	-	+	-	-
30	<i>O. tenuis</i>	+	+	+	+	+	+	+	+
31	<i>O. simplissima</i>	+	+	+	+	+	+	+	+
32	<i>O. limnetica</i>	-	+	-	+	-	-	+	+
33	<i>O. pseudogeminata</i>	-	+	-	+	-	-	-	+
34	<i>O. claricentrosa</i>	-	+	-	+	-	+	-	+
35	<i>O. salina</i>	+	+	-	-	+	+	-	-
36	<i>O. acuminata</i>	+	+	+	+	+	+	+	+
37	<i>O. brevis</i>	+	+	+	+	+	+	+	+
38	<i>Spirulina meneghiniana</i>	-	+	-	+	+	+	-	+
39	<i>S. princeps</i>	+	+	+	+	-	+	-	+
40	<i>Phormidium jadinianum</i>	-	-	-	+	-	-	-	-
41	<i>P. microtomum</i>	-	+	-	-	-	+	-	-
42	<i>P. purpurascens</i>	-	+	-	-	-	-	-	-
43	<i>P. mucosum</i>	-	+	-	+	-	-	+	-
44	<i>Cylindrospermum stagnale</i>	-	+	-	+	+	+	-	+
45	<i>C. muscicola</i>	+	+	+	+	-	+	-	+
46	<i>Nostoc punctiforme</i>	+	+	+	+	+	+	+	+
47	<i>N. entophyllum</i>	-	+	-	+	+	+	+	+
48	<i>N. paludosum</i>	+	+	-	+	-	+	-	-

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Alge ↓								
49	<i>Nostoc linckia</i>	+	+	+	+	+	+	+	+
50	<i>N. rivulare</i>	+	+	+	+	+	+	+	+
51	<i>N. carneum</i>	-	+	-	+	-	+	-	+
52	<i>N. elliposporum</i>	-	+	+	+	-	+	-	+
53	<i>N. calcicola</i>	+	+	+	+	-	-	-	+
54	<i>N. passerinianum</i>	-	+	-	-	-	+	-	-
55	<i>N. muscorum</i>	+	+	+	+	+	+	+	+
56	<i>N. commune</i>	+	+	+	+	+	+	+	+
57	<i>N. microscopium</i>	+	+	+	+	+	+	+	+
58	<i>N. hatei</i>	-	+	-	+	+	+	+	+
59	<i>N. sphaericum</i>	+	+	-	+	+	+	-	+
60	<i>Anabaena sphaerica</i>	+	+	+	+	+	-	-	+
61	<i>A. oryzae</i>	+	+	+	+	+	+	+	+
62	<i>A. fertilissima</i>	+	+	-	+	+	-	-	+
63	<i>A. naviculoides</i>	+	+	+	-	+	+	-	+
64	<i>A. variabilis</i>	-	+	-	+	-	+	-	-
65	<i>A. torulosa</i>	+	-	-	+	-	+	-	+
66	<i>Scytonema simplex</i>	+	+	-	-	-	+	-	+
67	<i>S. coactile</i>	-	-	+	-	-	-	+	-
68	<i>S. bohneri</i>	-	+	+	-	-	+	+	-
69	<i>S. schmidtii</i>	-	-	-	-	-	-	-	+
70	<i>S. freyui</i>	+	-	-	-	-	-	-	-
71	<i>Tolypothrix nodosa</i>	-	-	-	+	-	-	-	+
72	<i>T. tenuis</i>	-	-	-	+	-	+	-	-

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae↓								
73	<i>Tolypothrix fragilis</i>	-	-	-	+	-	-	-	+
74	<i>T. byssoidea</i>	-	-	-	+	-	+	-	-
75	<i>T. conglutinata</i>	-	+	-	-	-	-	-	-
76	<i>Calothrix castellii</i>	-	-	-	+	-	+	-	+
77	<i>C. elenkinii</i>	-	-	+	-	-	-	+	-
78	<i>C. braunii</i>	-	+	-	-	-	+	-	-
79	<i>C. parietina</i>	+	-	-	+	-	+	-	+
80	<i>C. weberi</i>	-	-	-	+	-	-	-	+
81	<i>C. membranacea</i>	+	+	+	+	+	+	+	+
82	<i>C. marchica</i>	-	+	-	-	-	+	-	+
83	<i>Rivularia aquatica</i>	-	+	-	-	-	+	-	+
84	<i>R. globiceps</i>	-	-	-	+	-	+	-	+

Table 5.2: Distribution of BGA from different rice field habitats for the year 2007 -2008

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae↓								
1	<i>Microcystis aeruginosa</i>	+	-	-	+	+	-	-	+
2	<i>M. elabens</i>	-	-	-	+	-	+	-	+
3	<i>C. turgidus</i>	+	+	-	+	+	+	-	+
4	<i>C. minutus</i>	-	-	+	+	-	-	+	+
5	<i>C. pallidus</i>	+	-	+	-	+	-	+	+
6	<i>C. cohaerens</i>	-	-	+	+	-	-	+	+
7	<i>Gleocapsa punctate</i>	+	+	+	+	+	+	+	+
8	<i>G. aeruginosa</i>	+	+	-	+	-	+	-	+
9	<i>G. kuetzingiana</i>	-	-	-	-	-	+	-	-
10	<i>Aphanocapsa banaresensis</i>	-	+	-	+	+	+	-	-
11	<i>A. stagnina</i>	+	+	+	+	+	+	+	+
12	<i>A. saxicola</i>	-	+	-	+	-	+	-	+
13	<i>A. castagnei</i>	+	+	-	+	-	+	+	+
14	<i>Lyngbya spiralis</i>	-	+	-	+	+	+	-	+
15	<i>L. bergei</i>	+	+	+	+	-	+	-	+
16	<i>L. dendrobia</i>	-	-	+	-	-	-	-	+
17	<i>L. confervoides</i>	+	+	-	+	+	+	-	+
18	<i>L. martensiana</i>	+	+	+	+	+	+	+	+
19	<i>Oscillatoria ornata</i>	-	+	-	+	-	+	-	+
20	<i>O. limosa</i>	+	+	-	+	-	+	+	+
21	<i>O. subbrevis</i>	+	+	+	+	+	+	+	+
22	<i>O. curviceps</i>	-	+	-	-	-	+	-	+
23	<i>O. princeps</i>	+	+	+	-	-	-	+	-
24	<i>O. proboscidea</i>	+	+	-	+	-	+	-	-

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae↓								
25	<i>Oscillatoria anguina</i>	+	+	+	+	+	+	+	+
26	<i>O. formosa</i>	-	+	-	+	-	-	+	+
27	<i>O. chlorina</i>	-	+	-	+	-	-	-	+
28	<i>O. martini</i>	-	+	-	+	-	+	-	+
29	<i>O. chalybea</i>	+	+	-	+	+	+	-	+
30	<i>O. tenuis</i>	+	+	-	-	+	+	-	-
31	<i>O. simplissima</i>	+	+	+	+	+	+	+	+
32	<i>O. limnetica</i>	+	+	+	+	+	+	+	+
33	<i>O. pseudogeminata</i>	+	+	+	+	+	+	+	+
34	<i>O. claricentrosa</i>	-	-	-	+	-	-	-	-
35	<i>O. salina</i>	-	+	-	-	-	+	-	-
36	<i>O. acuminata</i>	-	+	-	-	-	-	-	-
37	<i>O. brevis</i>	-	+	-	+	-	-	+	-
38	<i>Spirulina meneghiniana</i>	+	-	+	-	+	+	-	-
39	<i>S. princeps</i>	-	+	-	+	-	+	-	+
40	<i>Phormidium jadinianum</i>	+	+	+	+	-	+	-	+
41	<i>P. microtomum</i>	+	-	-	+	+	+	-	+
42	<i>P. purpurascens</i>	+	+	-	+	-	+	-	+
43	<i>P. mucosum</i>	-	+	-	+	+	+	-	+
44	<i>Cylindrospermum stagnale</i>	-	+	-	+	-	+	-	+
45	<i>C. muscicola</i>	+	+	+	+	-	+	+	+
46	<i>Nostoc punctiforme</i>	+	+	+	+	-	+	-	+
47	<i>N. entophytum</i>	-	+	-	+	+	+	-	+
48	<i>N. paludosum</i>	+	+	+	+	+	+	+	+

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae ↓								
49	<i>Nostoc linckia</i>	-	+	-	+	+	+	+	+
50	<i>N. rivulare</i>	+	+	-	+	-	+	-	-
51	<i>N. carneum</i>	+	+	+	+	+	+	+	+
52	<i>N. ellipso sporum</i>	+	+	+	+	+	+	+	+
53	<i>N. calcicola</i>	-	+	-	+	-	+	-	+
54	<i>N. passerinianum</i>	+	+	+	+	-	-	-	+
55	<i>N. muscorum</i>	-	+	-	-	-	+	-	-
56	<i>N. commune</i>	+	+	+	+	+	+	+	+
57	<i>N. microscopium</i>	+	+	+	+	+	+	+	+
58	<i>N. hatei</i>	-	+	-	+	+	+	+	+
59	<i>N. sphaericum</i>	+	+	-	+	+	+	-	+
60	<i>Anabaena sphaerica</i>	-	+	+	+	-	+	-	+
61	<i>A. oryzae</i>	+	+	+	+	+	+	+	+
62	<i>A. fertilissima</i>	+	+	+	+	+	-	-	+
63	<i>A. naviculoides</i>	+	+	+	+	+	+	+	+
64	<i>A. variabilis</i>	+	+	-	+	+	-	-	+
65	<i>A. torulosa</i>	+	+	+	-	+	+	-	+
66	<i>Scytonema simplex</i>	-	+	-	+	-	+	-	-
67	<i>S. coactile</i>	+	-	-	+	-	+	-	+
68	<i>S. bohneri</i>	-	-	-	+	-	-	-	-
69	<i>S. schmidtii</i>	+	+	-	-	-	+	-	+
70	<i>S. fremyii</i>	-	-	+	-	-	-	+	-
71	<i>Tolypothrix nodosa</i>	-	+	+	-	-	+	+	-
72	<i>T. tenuis</i>	-	-	-	-	-	-	-	+

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae ↓								
73	<i>Tolypothrix fragilis</i>	+	-	-	-	-	-	-	-
74	<i>T. byssoidea</i>	-	-	-	+	-	-	-	+
75	<i>T. conglutinata</i>	-	-	-	+	-	+	-	-
76	<i>Calothrix castellii</i>	-	-	-	+	-	-	-	+
77	<i>C. elenkinii</i>	-	-	-	+	-	+	-	-
78	<i>C. braunii</i>	-	+	-	-	-	-	-	-
79	<i>C. parietina</i>	-	-	-	+	-	+	-	+
80	<i>C. weberi</i>	-	-	+	-	-	-	+	-
81	<i>C. membranacea</i>	+	+	+	+	+	+	+	+
82	<i>C. marchica</i>	+	-	-	+	-	+	-	+
83	<i>Rivularia aquatica</i>	-	-	-	+	-	-	-	+
84	<i>R. globiceps</i>	+	+	+	+	-	-	-	+

Table 5.3: Distribution of BGA from different rice field habitats for the year 2008 -2009

Sr. No.	Seasons & Year →	Kharif season (June2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae ↓								
1	<i>Microcystis aeruginosa</i>	+	-	-	+	+	-	-	+
2	<i>M. elabens</i>	-	-	-	+	-	+	-	+
3	<i>Chroococcus turgidus</i>	+	+	-	+	+	+	-	+
4	<i>C. minutus</i>	-	-	+	+	-	-	+	+
5	<i>C. pallidus</i>	+	-	+	-	+	-	+	+
6	<i>C. cohaerens</i>	-	-	+	+	-	-	+	+
7	<i>Gleocapsa punctate</i>	+	+	+	+	+	+	+	+
8	<i>G. aeruginosa</i>	+	+	-	+	-	+	-	+
9	<i>G. kuetzingiana</i>	-	-	-	-	-	+	-	-
10	<i>Aphanocapsa banaresensis</i>	-	+	-	+	+	+	-	-
11	<i>A. stagnina</i>	+	+	+	+	+	+	+	+
12	<i>A. saxicola</i>	-	+	-	+	-	+	-	+
13	<i>A. castagnei</i>	+	+	-	+	-	+	+	+
14	<i>Lyngbya spiralis</i>	-	+	-	+	+	+	-	+
15	<i>L. bergei</i>	+	+	+	+	-	+	-	+
16	<i>L. dendrobia</i>	-	-	+	-	-	-	-	+
17	<i>L. confervoides</i>	+	+	-	+	+	+	-	+
18	<i>L. martensiana</i>	+	+	+	+	+	+	+	+
19	<i>Oscillatoria ornata</i>	-	+	-	+	-	+	-	+
20	<i>O. limosa</i>	+	+	-	+	-	+	+	+
21	<i>O. subbrevis</i>	+	+	+	+	+	+	+	+
22	<i>O. curviceps</i>	-	+	-	-	-	+	-	+
23	<i>O. princeps</i>	+	+	+	-	-	-	+	-
24	<i>O. proboscidea</i>	+	+	-	+	-	+	-	-

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006 to April 2007)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae ↓								
25	<i>Oscillatoria anguina</i>	+	+	+	+	+	+	+	+
26	<i>O. formosa</i>	-	+	-	+	-	-	+	+
27	<i>O. chlorina</i>	-	+	-	+	-	-	-	+
28	<i>O. martini</i>	-	+	-	+	-	+	-	+
29	<i>O. chalybea</i>	+	+	-	+	+	+	-	+
30	<i>O. tenuis</i>	+	+	-	-	+	+	-	-
31	<i>O. simplissima</i>	+	+	+	+	+	+	+	+
32	<i>O. limnetica</i>	+	+	+	+	+	+	+	+
33	<i>O. pseudogeminata</i>	+	+	+	+	+	+	+	+
34	<i>O. claricentrosa</i>	-	-	-	+	-	-	-	-
35	<i>O. salina</i>	-	+	-	-	-	+	-	-
36	<i>O. acuminata</i>	-	+	-	-	-	-	-	-
37	<i>O. brevis</i>	-	+	-	+	-	-	+	-
38	<i>Spirulina meneghiniana</i>	+	-	+	-	+	+	-	-
39	<i>S. princeps</i>	-	+	-	+	-	+	-	+
40	<i>Phormidium jadinianum</i>	+	+	+	+	-	+	-	+
41	<i>P. microtomum</i>	+	-	-	+	+	+	-	+
42	<i>P. purpurascens</i>	+	+	-	+	-	+	-	+
43	<i>P. mucosum</i>	-	+	-	+	+	+	-	+
44	<i>Cylindrospermum stagnale</i>	-	+	-	+	-	+	-	+
45	<i>C. muscicola</i>	+	+	+	+	+	-	+	+
46	<i>Nostoc punctiforme</i>	+	+	+	+	-	+	-	+
47	<i>N. entophytum</i>	-	+	-	+	+	+	-	+
48	<i>N. paludosum</i>	+	+	+	+	+	+	+	+

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mi fields (Velguem)	fields (Quepem)
	Name of Algae ↓								
49	<i>Nostoc linckia</i>	-	+	-	+	+	+	+	+
50	<i>N. rivulare</i>	+	+	-	+	-	+	-	-
51	<i>N. carneum</i>	+	+	+	+	+	+	+	+
52	<i>N. ellipso sporum</i>	+	+	+	+	+	+	+	+
53	<i>N. calcicola</i>	-	+	-	+	-	+	-	+
54	<i>N. passerinianum</i>	+	+	+	+	-	-	-	+
55	<i>N. muscorum</i>	-	+	-	-	-	+	-	-
56	<i>N. commune</i>	+	+	+	+	+	+	+	+
57	<i>N. microscopium</i>	+	+	+	+	+	+	+	+
58	<i>N. hatei</i>	-	+	-	+	+	+	+	+
59	<i>N. sphaericum</i>	+	+	-	+	+	+	-	+
60	<i>Anabaena sphaerica</i>	-	+	+	+	-	+	-	+
61	<i>A. oryzae</i>	+	+	+	+	+	+	+	+
62	<i>A. fertilissima</i>	+	+	+	+	+	-	-	+
63	<i>A. naviculoides</i>	+	+	+	+	+	+	+	+
64	<i>A. variabilis</i>	+	+	-	+	+	-	-	+
65	<i>A. torulosa</i>	+	+	+	-	+	+	-	+
66	<i>Scytonema simplex</i>	-	+	-	+	-	+	-	-
67	<i>S. coactile</i>	+	-	-	+	-	+	-	+
68	<i>S. bohneri</i>	-	-	-	+	-	-	-	-
69	<i>S. schmidtii</i>	+	+	-	-	-	+	-	+
70	<i>S. fremyii</i>	-	-	+	-	-	-	+	-
71	<i>Tolypothrix nodosa</i>	-	+	+	-	-	+	+	-
72	<i>T. tenuis</i>	-	-	-	-	-	-	-	+

Contd.....

Sr. No.	Seasons & Year →	Kharif season (June 2006 to October 2006)				Rabi season (December 2006)			
	Study sites →	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)	Khazan fields (Quelossim)	Coastal fields (Utorda)	Mining fields (Velguem)	Hinterland fields (Quepem)
	Name of Algae ↓								
73	<i>Tolypothrix fragilis</i>	+	-	-	-	-	-	-	-
74	<i>T. byssoidea</i>	-	-	-	+	-	-	-	+
75	<i>T. conglutinata</i>	-	-	-	+	-	+	-	-
76	<i>Calothrix castellii</i>	-	-	-	+	-	-	-	+
77	<i>C. elenkinii</i>	-	-	-	+	-	+	-	-
78	<i>C. braunii</i>	-	+	-	-	-	-	-	-
79	<i>C. parietina</i>	-	-	-	+	-	+	-	+
80	<i>C. weberi</i>	-	-	+	-	-	-	+	-
81	<i>C. membranacea</i>	+	+	+	+	+	+	+	+
82	<i>C. marchica</i>	+	-	-	+	-	+	-	+
83	<i>Rivularia aquatica</i>	-	-	-	+	-	-	-	+
84	<i>R. globiceps</i>	+	+	+	+	+	+	+	+

to 13 genera in khazans and 31 species belonging to 12 genera in mining affected fields **(Table 5.3)**.

The analysis of the cyanobacterial diversity and density in diverse paddy soil ecologies of Goa during the two growing seasons *i.e.* kharif and rabi were evaluated. The physico-chemical environment of the sampling sites also showed variations.

The highest density of 64×10^3 BGA/ml in kharif season of heterocystous forms in the hinterlands in the year 2006-07 followed by coastal fields which recorded 54×10^3 BGA/ml, khazan lands with 50×10^3 BGA/ml. and the least was recorded in mining affected fields 32×10^3 BGA/ml. Rabi season recorded 61×10^3 BGA/ml in hinterlands, 56×10^3 BGA/ml in coastal fields, khazan lands 47×10^3 BGA /ml and 34×10^3 in the mining fields.

Thus the study revealed highest density of BGA in the hinterlands followed by coastal fields which in turn is followed by khazan paddy fields. The least density is recorded in mining affected paddy fields **(Table 5.4, 5.6, 5.8, 5.10)**. The slightly alkaline pH in the range of 6.4 - 7.8 for water and 6.5 - 7.9 for soil was recorded in the hinterlands whereas coastal region recorded a pH in the range of 5.1 to 6.5 for water and 5.2 to 7.1 for soil. The other two sampling sites, khazans and mining affected fields recorded acidic pH in the range of 4 to 6.

The physico-chemical parameters of hinterlands also recorded higher electrical conductivity of 7.45 to 9.43 mmhos/cm for water and 7.28 to 9.02 for soil, temperature of water in the range of 26°C to 29.5°C , and P content in the range of 26.82 to 83.44 kg/ha during the study period **(Table 3.14 to 3.16)**, whereas the coastal fields showed EC in the range of 1.26 to 5.65 for water and 4.7 to 6.5 mmhos/cm for soil, temperature of water in

the range of 25⁰C to 28⁰C, and P content in the range of 5.96 to 72.62 kg/ha during study period (**Table 3.5 to 3.7**).

The khazan fields recorded EC in the range of 6.95 to 12.83mmhos/cm for water and 7.33 to 12.63mmhos/cm for soil, temperature of water in the range of 25⁰C to 30⁰C, and P content in the range of 2.6 to 8.94kg/ha during study period (**Table 3.11 to 3.13**). The mining affected fields showed very low EC in the range of 1.63 to 7.82mmhos/cm for water and 1.83 to 4.7mmhos/cm, temperature of water was in the range of 27⁰C to 31⁰C, and P content in the range of 2.72 to 6.02kg/ha during the study period (**Tables 3.8 to 3.10**).

a. Hinterlands: Among the heterocystous forms, hinterlands recorded the highest density of 64x10³ BGA/ml in kharif season of 2006-07 and the least density of 51x10³ BGA/ml in rabi season of 2008-09. The non-heterocystous forms recorded the highest density of 48x10³ BGA/ml in the rabi season of 2008-09 and lowest density of 40x10³ BGA/ml in the rabi season of 2006-07. Among the unicellular forms, the highest density of 51x10³ BGA/ml was recorded in the rabi season of 2006-07 and the least density of 44x10³ BGA/ml in kharif and rabi season of 2008-09 (**Table 5.4**).

Table 5.4: Cyanobacterial density of hinterlands fields of Quepem during the study period of 2006-2009

Group	2006-2007				2007-2008				2008-2009			
	Kharif	BGA/ml x 10 ³	Rabi	BGA/ml x 10 ³	Kharif	BGA/ml x 10 ³	Rabi	BGA/ml x 10 ³	Kharif	BGA/ml x 10 ³	Rabi	BGA/ml x 10 ³
	JUNE	16	DEC	12	JUNE	11	DEC	14	JUNE	12	DEC	13
Heterocystous	JULY	12	JAN	13	JULY	13	JAN	13	JULY	10	JAN	12
	AUG	10	FEB	12	AUG	12	FEB	10	AUG	11	FEB	10
	SEPT	14	MAR	13	SEPT	14	MAR	12	SEPT	8	MAR	11
	OCT	12	APR	11	OCT	12	APR	11	OCT	10	APR	10
	TOTAL	64	Total	61	Total	62	Total	60	Total	51	Total	56
Non-Heterocystous	JUNE	8	DEC	9	JUNE	10	DEC	10	JUNE	9	DEC	10
	JULY	9	JAN	8	JULY	8	JAN	8	JULY	8	JAN	9
	AUG	10	FEB	8	AUG	8	FEB	10	AUG	10	FEB	10
	SEPT	10	MAR	9	SEPT	9	MAR	8	SEPT	9	MAR	10
	OCT	10	APR	6	OCT	8	APR	8	OCT	8	APR	9
	TOTAL	47	Total	40	Total	43	Total	44	Total	44	Total	48
Unicellular	JUNE	9	DEC	12	JUNE	9	DEC	9	JUNE	8	DEC	9
	JULY	10	JAN	10	JULY	10	JAN	10	JULY	8	JAN	8
	AUG	11	FEB	9	AUG	12	FEB	10	AUG	9	FEB	10
	SEPT	9	MAR	9	SEPT	11	MAR	9	SEPT	10	MAR	9
	OCT	9	APR	10	OCT	9	APR	10	OCT	9	APR	8
	TOTAL	48	Total	50	Total	51	Total	48	Total	44	Total	44

Shannon's diversity indices for heterocystous forms ranged from 1.5 to 1.608 in the hinterlands with a minimum of 1.597 recorded in the kharif season of the year 2006-07. Whereas the non-heterocystous and unicellular forms recorded Shannons diversity indices of more than 1.6 in both kharif as well as rabi season indicating considerable diversity. Simpson's diversity indices for heterocystous forms ranged from 0.7949 to 0.7992 with the least diversity of 0.7949 in the kharif season for the year 2006-07. Non-heterocystous forms recorded the highest Simpsons diversity index of 0.8 in the rabi season of 2008-09. Simpsons diversity indices ranged from 0.7976 to 0.7995 for unicellular forms. Margaleff's diversity indices ranged from 0.9618 to 1.017 for heterocystous forms with the highest of 1.017 recorded in the rabi season for the year 2008-09. Whereas non-heterocystous and unicellular forms recorded in the range of 1.017 to 1.063. The highest value of Margaleff's diversity index of 1.603 was recorded for non-heterocystous forms in the kharif season of the year 2007-08. Unicellular forms recorded the lowest Margaleff's index of 1.017 in the kharif season of the year 2007-08. And the highest value of 1.057 was recorded in the kharif as well as rabi season of 2008-09 (**Table 5.5**).

Table 5.5: Diversity indices of different seasons in the three groups of cyanobacteria in the hinterlands of Quepem

Year / Index	Heterocystous		Non-heterocystous		Unicellular	
	kharif	rabi	kharif	rabi	kharif	rabi
2006-2007						
Dominance_D	0.2051	0.2008	0.2014	0.2038	0.2014	0.2024
Shannon_H	1.597	1.608	1.606	1.6	1.606	1.604
Simpson 1-D	0.7949	0.7992	0.7986	0.7962	0.7986	0.7976
Evenness e[^]H/S	0.9875	0.9981	0.9966	0.9902	0.9966	0.9942
Margalef	0.9618	0.973	1.033	1.084	1.033	1.022
2007-2008						
Dominance_D	0.2014	0.2028	0.2017	0.2025	0.2026	0.2005
Shannon_H	1.606	1.602	1.605	1.603	1.603	1.608
Simpson 1-D	0.7986	0.7972	0.7983	0.7975	0.7974	0.7995
Evenness e[^]H/S	0.9966	0.9931	0.9958	0.9939	0.9936	0.9987
Margalef	1.033	0.977	1.063	1.057	1.017	1.033
2008-2009						
Dominance_D	0.2034	0.2022	0.2014	0.2005	0.2014	0.2014
Shannon_H	1.601	1.604	1.606	1.608	1.606	1.606
Simpson 1-D	0.7966	0.7978	0.7986	0.7995	0.7986	0.7986
Evenness e[^]H/S	0.9914	0.9946	0.9964	0.9987	0.9964	0.9964
Margalef	1.017	0.9937	1.057	1.033	1.057	1.057

b. Coastal paddy fields: Among the heterocystous forms, coastal fields recorded the highest density of 60×10^3 BGA/ml in kharif season of 2008-09 and the least density of 53×10^3 BGA/ml in kharif season of 2007-08. The non-heterocystous forms recorded the highest density of 54×10^3 BGA/ml in the kharif and rabi season of 2006-07 and rabi season of 2008-09 and lowest density of 50×10^3 BGA/ml in the rabi season of 2007-08. Among the unicellular forms, the highest density of 54×10^3 BGA/ml was recorded in the rabi season of 2008-09 and the least density of 44×10^3 BGA/ml in kharif season of 2006-07 (**Table 5.6**). Shannon's diversity indices for heterocystous forms in coastal fields ranged from 1.593 to 1.608. The lowest Shannon's diversity index of 1.593 for heterocystous forms was recorded in the rabi season of the year 2008-09 followed by 1.596 in the rabi season of the year 2007-08. The non-heterocystous forms recorded 1.598 in the rabi season of 2006-07 and the unicellular forms in coastal fields recorded above 1.6 in all seasons during the study period. Simpsons diversity indices for heterocystous forms ranged from 0.7966 to 0.799, the lowest of 0.7966 being recorded in the rabi season of the year 2006-07 and the highest of 0.799 being recorded in the kharif season of both 2007-08 and 2008-09. Simpson's diversity indices for non-heterocystous forms ranged from 0.7956 to 0.7992, the least of 0.7956 being recorded in the rabi season of the year 2006-07 and the highest of 0.7992 was recorded in the rabi season of the year 2007-08. Simpson's diversity indices for unicellular forms ranged from 0.796 to 0.7992, the lowest of 0.796 being recorded in the rabi season of the year 2008-09 and the highest was recorded in the rabi season of the year 2007-08.

Margaleff's diversity indices ranged from 0.9937 to 1.007 for heterocystous forms with highest 1.007 recorded in the kharif season of the year 2007-08 followed by 1.003 recorded in the kharif season of 2006-07. Whereas non-heterocystous forms

all recorded above 1 in the range of 1.003 to 1.022. The highest value of Margaleff's diversity index of 1.022 for non-heterocystous forms was recorded in the rabi season of the year 2007-08. Unicellular forms recorded the Margaleff's indices ranging from 1.003 to 1.057. The lowest value of 1.003 was recorded in the rabi season of the year 2008-09 and highest value of 1.057 was recorded in the kharif season of the year 2006-07 (**Table 5.7**).

Table 5.6: Cyanobacterial density of coastal fields of Utorda during the study period of 2006-2009

Group	2006-2007				2007-2008				2008-2009			
	kharif	BGA/ml x 10 ³	rabi	BGA/ml x 10 ³	kharif	BGA/ml x 10 ³	rabi	BGA/ml x 10 ³	kharif	BGA/ml x 10 ³	rabi	BGA/ml x 10 ³
Heterocystous	JUNE	12	DEC	13	JUNE	11	DEC	12	JUNE	11	DEC	11
	JULY	10	JAN	12	JULY	12	JAN	13	JULY	12	JAN	14
	AUG	12	FEB	12	AUG	10	FEB	12	AUG	12	FEB	12
	SEPT	10	MAR	10	SEPT	10	MAR	10	SEPT	13	MAR	10
	OCT	10	APR	9	OCT	10	APR	8	OCT	12	APR	8
	TOTAL	54	Total	56	Total	53	Total	55	Total	60	Total	55
Non-Heterocystous	JUNE	12	DEC	12	JUNE	11	DEC	10	JUNE	12	DEC	13
	JULY	12	JAN	12	JULY	10	JAN	10	JULY	10	JAN	10
	AUG	10	FEB	12	AUG	12	FEB	11	AUG	12	FEB	10
	SEPT	10	MAR	10	SEPT	11	MAR	10	SEPT	10	MAR	12
	OCT	10	APR	8	OCT	9	APR	9	OCT	9	APR	9
	TOTAL	54	Total	54	Total	53	Total	50	Total	53	Total	54
Unicellular	JUNE	8	DEC	9	JUNE	9	DEC	10	JUNE	12	DEC	13
	JULY	9	JAN	10	JULY	8	JAN	10	JULY	10	JAN	10
	AUG	10	FEB	10	AUG	10	FEB	11	AUG	12	FEB	10
	SEPT	9	MAR	10	SEPT	10	MAR	10	SEPT	10	MAR	12
	OCT	8	APR	8	OCT	9	APR	9	OCT	9	APR	9
	TOTAL	44	Total	47	Total	46	Total	50	Total	53	Total	54

Table 5.7: Diversity indices of different seasons in the three groups of cyanobacteria in coastal paddy fields of Utorda

Year / Index	Heterocystous		Non-heterocystous		Unicellular	
	kharif	rabi	kharif	rabi	kharif	rabi
2006-2007						
Dominance_D	0.2016	0.2034	0.2016	0.2044	0.2014	0.2014
Shannon_H	1.605	1.601	1.605	1.598	1.606	1.606
Simpson 1-D	0.7984	0.7966	0.7984	0.7956	0.7986	0.7986
Evenness e[^]H/S	0.9959	0.9913	0.9959	0.9885	0.9964	0.9963
Margalef	1.003	0.9937	1.003	1.003	1.057	1.039
2007-2008						
Dominance_D	0.2011	0.2053	0.2019	0.2025	0.2013	0.2008
Shannon_H	1.607	1.596	1.605	1.603	1.606	1.607
Simpson 1-D	0.7989	0.7947	0.7983	0.7981	0.7987	0.7992
Evenness e[^]H/S	0.9972	0.9863	0.9958	0.9953	0.9967	0.998
Margalef	1.007	0.9982	1.063	1.007	1.045	1.022
2008-2009						
Dominance_D	0.2006	0.2066	0.2026	0.2037	0.2026	0.2037
Shannon_H	1.608	1.593	1.603	1.6	1.603	1.6
Simpson 1-D	0.7994	0.7934	0.7974	0.7963	0.7974	0.7963
Evenness e[^]H/S	0.9986	0.9834	0.9936	0.9909	0.6868	0.9909
Margalef	0.977	0.9982	1.007	1.003	1.007	1.003

c. Khazan paddy fields: Among the heterocystous forms, khazan fields recorded the highest density of 50×10^3 BGA/ml in kharif season of 2006-07 and the least density of 39×10^3 BGA/ml in rabi season of 2008-09. The non-heterocystous forms recorded the highest density of 47×10^3 BGA/ml in the rabi season of 2008-09 and lowest density of 43×10^3 BGA/ml in the kharif season of 2006-07. Among the unicellular forms, the highest density of 40×10^3 BGA/ml was recorded in the rabi season of 2008-09 and the least density of 34×10^3 BGA/ml in kharif season of 2008-09 (**Table 5.8**).

Shannon's diversity indices for heterocystous forms in khazan lands ranged from 1.604 to 1.608 during the study period. The lowest Shannon's diversity index of 1.604 for heterocystous forms was recorded in the kharif season of the year 2006-07 followed by 1.605 in the rabi season of the year 2008-09 and the highest of 1.608 was recorded in the kharif season of both 2006-07 and 2008-09. The non-heterocystous forms recorded the lowest Shannon's diversity index of 1.593 in the kharif season of 2006-07 and the higher of 1.606 in the kharif seasons of both 2006-07 and 2008-09. Unicellular forms in khazan paddy fields recorded in the range of 1.601 to 1.606 and hence showed values above 1.6 in all seasons during the study period indicating a moderately high and uniform diversity. Simpson's diversity indices for heterocystous forms range from 0.7976 to 0.7995 whereas non-heterocystous forms range from 0.7939 to 0.799 and unicellular forms range from 0.7986 to 0.799 during the study period. Margaleff's diversity indices ranged from 1.022 to 1.092 for heterocystous forms with highest 1.092 recorded in the rabi season of the year 2008-09 followed by 1.07 recorded in the kharif season of 2008-09. The lowest value of Margaleff's diversity index of 1.022 was recorded in the kharif season of the year 2006-07. Whereas non-heterocystous forms recorded in the range of 1.039 to 1.063. The highest value of Margaleff's diversity index of 1.063 for non-heterocystous forms was

recorded in the kharif season of the year 2006-07 and the lowest value of Margaleff's diversity index of 1.039 was recorded in the rabi season of 2008-09. Unicellular forms recorded the Margaleff's indices ranging from 1.1 to 1.134. The lowest value of 1.1 was recorded in the rabi season of the year 2006-07 and highest value of 1.134 was recorded in the kharif season of the year 2008-09 (**Table 5.9**).

Table 5.8: Cyanobacterial density of khazan fields of Quelossim during the study period of 2006-2009.

Group	2006-2007				2007-2008				2008-2009			
	kharif	BGA/ml x 10 ³	rabi	BGA/ml x 10 ³	Kharif	BGA/ml x 10 ³	rabi	BGA/ml x 10 ³	kharif	BGA/ml x 10 ³	rabi	BGA/ml x 10 ³
	JUNE	10	DEC	9	JUNE	9	DEC	8	JUNE	8	DEC	8
	JULY	12	JAN	10	JULY	10	JAN	9	JULY	8	JAN	7
Heterocystous	AUG	9	FEB	9	AUG	9	FEB	10	AUG	9	FEB	7
	SEPT	10	MAR	10	SEPT	9	MAR	10	SEPT	9	MAR	8
	OCT	9	APR	9	OCT	8	APR	9	OCT	8	APR	9
	TOTAL	50	Total	47	Total	45	Total	46	Total	42	Total	39
Non-Heterocystous	JUNE	9	DEC	10	JUNE	8	DEC	7	JUNE	9	DEC	9
	JULY	8	JAN	9	JULY	10	JAN	9	JULY	10	JAN	9
	AUG	6	FEB	7	AUG	9	FEB	8	AUG	10	FEB	10
	SEPT	10	MAR	9	SEPT	9	MAR	10	SEPT	9	MAR	11
	OCT	10	APR	10	OCT	8	APR	10	OCT	8	APR	8
	TOTAL	43		45	Total	44		44	Total	46	Total	47
Unicellular	JUNE	7	DEC	8	JUNE	6	DEC	7	JUNE	7	DEC	8
	JULY	6	JAN	7	JULY	7	JAN	8	JULY	7	JAN	8
	AUG	8	FEB	8	AUG	7	FEB	7	AUG	6	FEB	9
	SEPT	8	MAR	8	SEPT	8	MAR	8	SEPT	6	MAR	7
	OCT	6	APR	7	OCT	8	APR	9	OCT	8	APR	8
	TOTAL	35	Total	38	Total	36		39	Total	34	Total	40

Table 5.9: Diversity indices of different seasons in the three groups of cyanobacteria in Khazan paddy fields of Quelossim.

Year / Index	Heterocystous		Non-heterocystous		Unicellular	
	kharif	rabi	kharif	rabi	kharif	rabi
2006-2007						
Dominance_D	0.2024	0.2005	0.2061	0.203	0.2033	0.2008
Shannon_H	1.604	1.608	1.593	1.602	1.601	1.607
Simpson 1-D	0.7976	0.7995	0.7939	0.797	0.7967	0.7992
Evenness e[^]H/S	0.9942	0.9987	0.9841	0.9923	0.9918	0.9979
Margalef	1.022	1.039	1.063	1.051	1.125	1.1
2007-2008						
Dominance_D	0.201	0.2013	0.2014	0.2035	0.2022	0.2018
Shannon_H	1.607	1.606	1.606	1.6	1.604	1.605
Simpson 1-D	0.799	0.7987	0.7986	0.7965	0.7978	0.7982
Evenness e[^]H/S	0.9975	0.9967	0.9964	0.9911	0.9945	0.9954
Margalef	1.051	1.045	1.057	1.057	1.116	1.092
2008-2009						
Dominance_D	0.2007	0.2018	0.2013	0.2024	0.2024	0.2013
Shannon_H	1.608	1.605	1.606	1.604	1.603	1.606
Simpson 1-D	0.7993	0.7982	0.7987	0.7976	0.7976	0.7987
Evenness e[^]H/S	0.9983	0.9954	0.9967	0.9942	0.994	0.9969
Margalef	1.07	1.092	1.045	1.039	1.134	1.084

d. Mining affected paddy fields of Velguem-Pale: Among the heterocystous forms, mining affected fields recorded the highest density of 34×10^3 BGA/ml in rabi season of 2006-07 and kharif season of 2007-08 and the least density of 31×10^3 BGA/ml in rabi season of 2008-09. The non-heterocystous forms recorded the highest density of 34×10^3 BGA/ml in the kharif season of 2007-08 and lowest density of 29×10^3 BGA/ml in the rabi season of 2006-07 and kharif season of 2007-08. Among the unicellular forms, the highest density of 29×10^3 BGA/ml was recorded in the rabi season of 2007-08 and the least density of 22×10^3 BGA/ml in kharif season of 2007-08 and rabi season of 2008-09 (**Table 5.10**).

Shannon's diversity indices for heterocystous forms in mining area paddy fields ranged from 1.601 to 1.607 during the study period. The lowest Shannon's diversity index of 1.601 for heterocystous forms was recorded in the kharif season of the year 2008-2009 followed by 1.602 in the rabi season of the year 2008-2009 and the highest of 1.607 was recorded in the kharif season of both 2006-2007 and rabi season of 2007-2008. Whereas the non- heterocystous forms recorded values ranging from 1.597 to 1.608, the lowest Shannon's diversity index of 1.597 was recorded in the rabi season of 2007-2008 and the highest of 1.608 in the kharif seasons of both 2007-2008. Unicellular forms in mining affected fields recorded in the range of 1.597 to 1.603 showing least diversity of 1.597 in the kharif season of 2008-2009 and maximum diversity of 1.603 in the kharif season for the year 2007-2008. Simpson's diversity indices for heterocystous forms ranged from 0.7976 to 0.7988 whereas non-heterocystous forms ranged between 0.7967 to 0.799 and unicellular forms ranged from 0.7929 to 0.798 during the study period. Margaleff's diversity indices ranged from 1.125 to 1.165 for heterocystous forms with highest being 1.165 and the least 1.125 both recorded in the rabi season and the kharif seasons respectively of the year

2008-09. Whereas non-heterocystous forms recorded Margaleff's diversity indices in the range of 1.134 to 1.188. The highest value of Margaleff's diversity index of 1.188 was recorded in the rabi season of 2007-08 for non-heterocystous forms and the lowest value of Margaleff's diversity index of 1.134 was recorded in the kharif season of 2007-08. Unicellular forms recorded the Margaleff's indices ranging from 1.188 to 1.294. The lowest value of 1.188 was recorded in the rabi season of the year 2007-08 and highest value of 1.294 was recorded in the rabi season of the year 2008-2009 **(Table 5.11)**.

Table 5.10: Cyanobacterial density of mining area fields during the study period of 2006-2009

Group	2006-2007				2007-2008				2008-2009			
	kharif	BGA/ml x 10 ³	rabi	BGA/ml x 10 ³	kharif	BGA/ml x 10 ³	rabi	BGA/ml x 10 ³	kharif	BGA/ml x 10 ³	rabi	BGA/ml x 10 ³
Heterocystous	JUNE	6	DEC	7	JUNE	7	DEC	6	JUNE	8	DEC	7
	JULY	7	JAN	6	JULY	8	JAN	7	JULY	8	JAN	7
	AUG	6	FEB	8	AUG	6	FEB	7	AUG	7	FEB	6
	SEPT	6	MAR	7	SEPT	6	MAR	6	SEPT	6	MAR	6
	OCT	7	APR	6	OCT	7	APR	6	OCT	6	APR	5
	TOTAL	32	Total	34	Total	34	Total	32	Total	35	Total	31
Non-Heterocystous	JUNE	5	DEC	7	JUNE	6	DEC	7	JUNE	7	DEC	7
	JULY	6	JAN	6	JULY	7	JAN	7	JULY	7	JAN	7
	AUG	6	FEB	6	AUG	6	FEB	7	AUG	7	FEB	7
	SEPT	7	MAR	5	SEPT	5	MAR	5	SEPT	7	MAR	6
	OCT	7	APR	5	OCT	5	APR	5	OCT	6	APR	6
	TOTAL	31	Total	29	Total	29	Total	31	Total	34	Total	33
Unicellular	JUNE	5	DEC	5	JUNE	4	DEC	5	JUNE	7	DEC	5
	JULY	6	JAN	6	JULY	5	JAN	6	JULY	5	JAN	4
	AUG	6	FEB	7	AUG	5	FEB	7	AUG	5	FEB	5
	SEPT	4	MAR	5	SEPT	4	MAR	6	SEPT	4	MAR	4
	OCT	5	APR	4	OCT	4	APR	5	OCT	4	APR	4
	TOTAL	26	Total	27	Total	22	Total	29	Total	25	Total	22

Table 5.11: Diversity indices of different seasons in the three groups of cyanobacteria in mining area paddy fields of Velguem

Year / Index	Heterocystous		Non-heterocystous		Unicellular	
	kharif	rabi	kharif	rabi	kharif	rabi
2006-2007						
Dominance_D	0.2012	0.2024	0.2029	0.2033	0.2041	0.2071
Shannon_H	1.607	1.603	1.602	1.601	1.599	1.592
Simpson 1-D	0.7988	0.7976	0.7971	0.7967	0.7959	0.7929
Evenness e[^]H/S	0.9971	0.994	0.9926	0.9918	0.9895	0.9824
Margalef	1.154	1.134	1.165	1.188	1.228	1.214
2007-2008						
Dominance_D	0.2024	0.2012	0.2033	0.205	0.2025	0.2033
Shannon_H	1.603	1.607	1.601	1.597	1.603	1.601
Simpson 1-D	0.7976	0.7988	0.7976	0.795	0.7975	0.7967
Evenness e[^]H/S	0.994	0.9971	0.9918	0.9873	0.9938	0.9918
Margalef	1.134	1.154	1.188	1.165	1.294	1.188
2008-2009						
Dominance_D	0.2033	0.2029	0.2007	0.2011	0.2096	0.2025
Shannon_H	1.601	1.602	1.608	1.607	1.587	1.603
Simpson 1-D	0.7967	0.7971	0.7993	0.7989	0.7904	0.7975
Evenness e[^]H/S	0.9918	0.9926	0.9982	0.9972	0.9775	0.9939
Margalef	1.125	1.165	1.134	1.144	1.243	1.294

DISCUSSION:

Paddy fields are temporary wetland ecosystems, with variable biodiversity and cyanobacteria are known to be an integral component of waterlogged paddy fields. The paddy field ecosystem with its optimum levels of light, water, temperature, humidity and nutrient availability provide a favourable environment for the luxuriant growth of cyanobacteria. The present study reports the evaluation of cyanobacterial diversity and density in diverse paddy soil ecologies of Goa during the two growing seasons of kharif and rabi.

The physico-chemical environment of the sampling sites showed variations (**Tables 3.5 to 3.16**). Physico-chemical parameters quiet often change during various seasons (Basavarajappa *et al.*, 2010). Therefore it is rather difficult to correlate the physico-chemical parameters of paddy field soils with their algal composition. Paddy field algae are basically in aquatic condition and their terrestrial nature is secondary and hence these algae are able to grow in prolonged changed and severe drought conditions.

pH is an important factor that affects the distribution of paddy field algae. Although cyanobacteria are ubiquitous in their distribution, it is well established that they prefer neutral to slightly alkaline pH. The hinterland fields recorded slightly alkaline pH in the range of 6.4 to 7.8 for water and 6.5 to 7.9 for soil whereas coastal fields recorded pH in the range of 5.1 to 6.5 for water and 5.2 to 7.1 for soil. The other two sampling sites, khazans and mining affected fields recorded acidic pH in the range of 4 to 6 due to which the density of BGA was comparatively lower than in the other study sites (**Tables 5.4, 5.6, 5.8, 5.10**). According to Lund (1945 and 1947), most of the cyanophycean algae prefer neutral to alkaline soils but certain species preponderate in

highly acidic soils. Pandey (1965) have reported more number of BGA in soils of Ballia with a pH range of 6.2 to 6.9. Similarly, Sardeshpande and Goyal (1981) recorded the abundance of BGA (19 genera) in acidic soils of Ratnagiri district of Maharashtra.

The study recorded 84 species belonging to 16 genera from the four different habitats of Goa. Ghadai *et al.*, (2010) reported seven major groups that include Chroococcaceae, Pleurocapsaceae, Oscillatoriaceae, Nostocaceae, Rivulariaceae, Scytonemataceae and Stigonemataceae from paddy field soils of Gunpur, Orissa.

According to Fogg *et al* (1973), the more hospitable the habitat the more likely it is that BGA will be the important constituent of the soil. The most important factors that govern the growth and distribution of algae are water requirements, soil type, depth in the soil and pH (Lund, 1962; Shield and Durell, 1964; Fogg *et al.*, 1973). The relationship between soil algal flora with various inorganic nutrients is poorly understood (Peterson, 1935; Lund, 1945).

The physico-chemical parameters of hinterlands also recorded higher EC for water and soil, optimum temperature of water and optimum P content while the mining affected fields showed very low EC for water and soil, slightly higher temperature of water and lower P content during the study period. Electrical conductivity is known to limit the BGA number (Yashovarma, 1985). Pereira *et al.*, (2005) reported that the temperature of most of the paddy fields sampled in Chile, ranged between 20⁰C to 25⁰C and pH ranged from 5.5 to 7.0 with a total of 12 filamentous heterocystous cyanobacterial population. The P content was known to vary in different habitats undertaken for the study. It is suggested that the luxuriant growth of BGA in the hinterlands is due to optimum P content. Availability of P

plays an important role in determining BGA growth which has been substantiated by various workers (Okuda and Yamaguchi, 1952; Quesada and Valiente, 1996). Begum *et al.*, (2008) reported significant variation in cyanobacterial population from the paddy field soils of 11 districts of Bangladesh, where the highest number of indigenous cyanobacterial population was reported from fields with pH range of 6.8 to 7.5 and available P (12.42 to 28.50 $\mu\text{g/g}$ soil), which is in conformity to the data obtained in the present study.

The study revealed a variation in Ca contents in different habitats. The luxuriant growth of BGA in the hinterlands can be attributed to higher Ca content. The mining affected fields showed acidic pH with low P and Ca content which is known to affect the growth of BGA. The growth of nitrogen fixing cyanobacteria is affected by acidic pH, low P and Ca content (Roger and Reynaud, 1985; Healey, 1973).

Overall the data indicates the predominance of heterocystous forms in all the four habitats followed by non-heterocystous and unicellular forms. Similar results were obtained in a study where 166 cyanobacterial isolates were purified which included maximum heterocystous genera followed by non-heterocystous forms in diverse paddy soil ecologies (Prassanna and Saswati, 2007). A study on diversity and seasonal variation of cyanobacterial strains in paddy fields in Fujian China showed that cyanobacterial diversity was the highest in the middle of growth season of paddy and the lowest after harvest (Song *et al.*, 2005). Earlier studies on cyanobacterial diversity of paddy fields at the Indian Agricultural Research Institute have shown the predominance of heterocystous forms irrespective of chemical/biofertilizers treatments and stage of crop growth (Nayak *et al.* 2001, 2004).

Shannon's diversity indices in all the habitats of all groups of BGA were in the range 1.5-1.6. The highest Shannon's diversity index for heterocystous forms was recorded in hinterlands during the kharif season while lowest Shannon's diversity index for unicellular forms was recorded in mining affected paddy fields during the kharif season. Simpson diversity indices in all the habitats of all groups of BGA range from 0.79-0.80. The highest Simpson diversity index was recorded for non-heterocystous forms was recorded in hinterlands during the rabi season while lowest Simpsons diversity index for unicellular forms was recorded in mining affected paddy fields during the kharif season. In a similar study Shannon's diversity index was indicative of extensive diversity of cyanobacteria within the rhizosphere of paddy cultivars. Simpson's diversity index (1-D) which takes into accounts both richness and evenness also indicated good diversity (Prassanna *et al.*, 2006; Prassanna and Nayak, 2006; Prassanna *et al.*, 2009; Nayak *et al.*, 2001).

The Margalef's diversity indices in all the habitats of all three groups of BGA were in the range of 0.9-1.2. The highest Margalef's diversity index was recorded in mining affected fields for unicellular forms during both kharif and rabi season whereas lowest was recorded in hinterlands for heterocystous during kharif season. The present study indicates that, the overall density and diversity of BGA is highest in the hinterlands fields followed by coastal fields, followed by khazan fields and the least in mining affected fields.

It is clear from the present study that paddy field soils of Goa recorded pH in the range of 4.4 to 7.9 which fulfils the pH conditions required for the growth of BGA.

The study revealed higher density of BGA in the hinterland followed by coastal fields and khazans while least density was recorded in mining affected fields. This is because of the favourable conditions available for their growth in the hinterlands. The most important parameters *viz.*, P content, dissolved Oxygen, Calcium, Magnesium, N, K and micronutrients also recorded highest amounts in hinterland fields followed by coastal fields, khazan fields and least from the mining affected fields. Thus the study suggests that hinterlands support better growth showing higher density and diversity of BGA than the mining affected fields. Similar studies have been reported in the hinterlands of Karnataka (Venkataraman, 1972; Nayak *et al.*, 2001; Nayak *et al.*, 2004; Bongale and Bharati, 1980 and 1985; Giryappannaver, 1988). In the present study, the khazan fields recorded appreciable number of BGA which was however less than found in hinterlands and coastal fields. Similarly, Aiyer, (1965) and Amma *et al.*, (1966) reported rich cyanobacterial flora from the coastal and saline paddy fields of Kerala. The mining paddy fields are unique to Goa and have least density and diversity of BGA perhaps due to unfavorable physico-chemical parameters which is be due to the influx of mining rejects into the field. Such variations in cyanobacterial population were recorded earlier in paddy field soils of India (Roger *et al.*, 1986). Thus the present investigation throws light on the density and diversities of BGA in paddy fields of Goa especially with regard to the indigenous species which could help in development of niche specific inocula for paddy fields of Goa.

Table 5.12: Comparative diversity indices of BGA from different habitats

Year of study	2006-2007						2007-2008						2008-2009					
	Kharif			rabi			Kharif			rabi			Kharif			rabi		
Diversity indices	Shannon	Simpson	Margalef	Shannon	Simpson	Margalef	Shannon	Simpson	Margalef	Shannon	Simpson	Margalef	Shannon	Simpson	Margalef	Shannon	Simpson	Margalef
Heterocystous																		
Hinterlands	1.597	0.7949	0.9618	1.608	0.7992	0.973	1.606	0.799	0.9692	1.602	0.7972	0.977	1.601	0.797	1.017	1.604	0.798	0.9937
Coastal	1.605	0.7984	1.003	1.601	0.7966	0.9937	1.607	0.799	1.007	1.596	0.7947	0.9982	1.608	0.799	0.977	1.593	0.793	0.9982
Khazans	1.604	0.7976	1.022	1.608	0.7995	1.039	1.607	0.799	1.051	1.606	0.7987	1.045	1.608	0.799	1.07	1.605	0.798	1.092
Mining	1.607	0.7988	1.154	1.603	0.7976	1.134	1.603	0.798	1.134	1.607	0.7988	1.154	1.601	0.797	1.125	1.602	0.797	1.165
Non-heterocystous																		
Hinterlands	1.606	0.7986	1.039	1.6	0.7962	1.084	1.605	0.798	1.063	1.603	0.7975	1.057	1.606	0.799	1.057	1.608	0.8	1.033
Coastal	1.605	0.7984	1.003	1.598	0.7956	1.003	1.605	0.798	1.007	1.607	0.7992	1.022	1.603	0.797	1.007	1.6	0.796	1.003
Khazans	1.593	0.7939	1.063	1.602	0.797	1.051	1.606	0.799	1.057	1.6	0.7965	1.057	1.606	0.799	1.045	1.604	0.798	1.039
Mining	1.602	0.7971	1.165	1.601	0.7967	1.188	1.601	0.797	1.188	1.597	0.795	1.165	1.608	0.799	1.134	1.607	0.799	1.144
Unicellular																		
Hinterlands	1.606	0.7986	1.033	1.604	0.7976	1.022	1.603	0.797	1.017	1.608	0.7995	1.033	1.606	0.799	1.057	1.606	0.799	1.057
Coastal	1.606	0.7986	1.057	1.606	0.7986	1.039	1.606	0.799	1.045	1.607	0.7992	1.022	1.603	0.797	1.007	1.6	0.796	1.003
Khazans	1.601	0.7967	1.125	1.607	0.7992	1.1	1.604	0.798	1.116	1.605	0.7982	1.092	1.603	0.798	1.134	1.606	0.799	1.084
Mining	1.599	0.7959	1.228	1.592	0.7929	1.214	1.603	0.798	1.294	1.601	0.7967	1.188	1.587	0.79	1.243	1.603	0.798	1.294

INTRODUCTION:

Blue green algae (BGA) are a group of prokaryotes that have existed almost from the origin of life on earth and have been recorded as Precambrian microfossils (Schopf, 1970) and tolerant to desiccation, extremes of temperatures, pH, salinity, light intensity and nutrients (Whitton, 2000). The group is known to occur abundantly in paddy fields of several countries *viz.*, Japan, Thailand, China, Philippines, Bangladesh and India (Roger and Kulasooriya, 1980; Venkataraman, 1981). Fritsch (1907) for the first time observed the role of BGA in increasing fertility of paddy fields, De (1939) emphasized the importance in maintaining the fertility of paddy fields through biological nitrogen fixation which was later confirmed by Singh (1950, 1961), Holm-Hanson (1968) and Alexander (1975).

Most BGA are known to fix atmospheric nitrogen, their occurrence in paddy fields is known to maintain nitrogen levels in the soil (Venkataraman, 1993). Heterocysts have been demonstrated experimentally to be specialized cells capable of fixing nitrogen (Fogg, 1949). Considerable amount of research on heterocystous forms has become a major attraction (Stewart, 1980; Adams and Duggan, 1999), with immunolabelling studies proving heterocysts as sites of nitrogenase activity (Flemming and Haselkorn, 1973). The prospects of BGA as biofertilizers has triggered a considerable amount of research in evolving methods and means to effectively utilize these organisms (Brouers *et al.*, 1987; Shi *et al.*, 1987; Shi and Hall, 1988; Prasanna and Kaushik, 1994; Anand, 1998; Vaishampayan *et al.*, 2000). BGA are more prevalent in Tropical and Sub-tropical regions as compared to Temperate belts (Vaishampayan *et al.*, 2001). They find a highly favourable environment in the water-logged conditions of paddy fields where they

provide nitrogen to plants, improving crop yields by making soil fertile, vital and productive. BGA inoculation popularly known as “Algalization” helps to provide an environmentally safe agro-ecosystem contributing to economic viability in paddy cultivation, reducing cost and energy inputs (Pabbi, 2008).

Paddy is the staple food of over 40% of the World’s population and the most important food crop (Yadav *et al.*, 2000). The cultivated area of paddy in Asia is about 90% of the global total and supports more than 60% of the World’s population. In developing countries, though the use of nitrogenous fertilizers is much less, nitrogen fixing BGA contribute significantly to the nutritional requirements of paddy (Roger and Kulasoorya, 1980). The nitrogen requirement is a factor which determines the yield of the crop far beyond the natural capacity of any soil type (Ahlawat *et al.*, 1998), insisting the use of large amounts of chemical fertilizers to the paddy fields to improve yield. The excessive use of nitrogenous fertilizers can lead to high soil nitrate concentration after crop harvest (Jokela and Randall, 1989; Roth and Fox, 1992; Gordon *et al.*, 1993), a situation which can lead to increased nitrate contamination of potable water (Singh *et al.*, 1995). Nitrogen fixation carried out by rhizosphere bacteria contributes significantly to soil fertility (Vlassak *et al.*, 1992), but the less efficient use of this fixed nitrogen by plants in incorporating it into grain protein could be a limiting factor (Vlassak *et al.*, 1992). Thus studies could be oriented more towards an alternative source of nitrogenous fertilizers, such as BGA, which act as biofertilizers.

The present study was carried out to assess the effect of biofertilization by BGA on paddy crop in Goa. With increasing population and risk of contamination of ground water by excess leaching of nitrates from the surrounding fields, the application of

dominant nitrogen fixing cyanobacteria found in local paddy fields would help improve yield of paddy and be cost effective. Since the local ecological conditions differ with different agro climatic regions, it becomes very difficult for general BGA formulations to establish itself. Thus, there is a need to develop algal inoculants suitable for different agro climatic regions by isolating the indigenous strains from that particular area which can grow fast and efficiently fix nitrogen. Hence the present study was carried out to identify the efficient heterocystous nitrogen fixing cyanobacteria that are part of the indigenous algal flora in paddy fields of Goa.

MATERIALS AND METHODS:

Algal samples collected from paddy fields were screened to obtain dominant heterocystous forms of BGA and were identified using standard keys (Desikachary, 1959).

Anabaena oryzae Fritsch, *Calothrix membranacea* Schmidle and *Nostoc rivulare* Kützing ex Born et Flah, were isolated from paddy field soils of Goa. Clonal cultures were obtained from a single filament grown in BG-11 medium (Stainer *et al.*, 1971). The cultures were maintained by repeated sub culturing. Pure cultures of the algal species were employed for mass culture and algalization studies. Isolated strains were mass cultured in 2l flasks with simple liquid nutrient medium composed of sterilized tap water supplemented with super phosphate and ash (Bongale, 1986). These flasks were maintained at 27⁰-30⁰C. Flasks were manually shaken twice a day. Soil collected from local paddy field was sterilized in an autoclave for 1 hour at 121⁰C (15psi) for three continuous days. Seeds of *Oryza sativa* L. (var. jaya) were obtained from the local Agriculture Department. Six paddy seedlings (10 days old) transplanted in each pot were thinned to four per pot in the later stages (before flowering). 15 day old seedlings were inoculated using 10 ml of exponentially growing fresh culture per pot. There were three replicates for each treatment. The following algal treatments were prepared and administered.

1. Un-inoculated control
2. *Anabaena oryzae* (Ao)
3. *Calothrix membranacea* (Cm)

4. *Nostoc rivulare* (Nr)
5. *Anabaena oryzae* + *Calothrix membranacea* (Ao + Cm)
6. *Anabaena oryzae* + *Nostoc rivulare* (Ao+ Nr)
7. *Calothrix membranacea* + *Nostoc rivulare* (Cm + Nr)
8. *Anabaena oryzae* + *Calothrix membranacea* + *Nostoc rivulare* (Ao + Cm + Nr)

The experiment was conducted in the rabi season (December-March 2009) and harvested after 120 days after transplanting. Various growth parameters viz., plant height, plant weight (fresh weight), leaf length, spike length, total root length; number of tillers per hill and leaf area index was recorded at regular intervals until flowering stage. Yield parameters, the number of panicles per hill, length of panicles, number of spikelets per panicles, straw yield per plant and grain yield per plant were recorded at harvesting. Biochemical aspects such as total carbohydrate content of grains was estimated according to procedures given by Dubois *et al.*, (1956) and total protein content of grains was estimated by method given by Lowry *et al.*, (1951) at harvesting. The chlorophyll content of paddy seedlings was estimated every fortnight after treatment with BGA, according to procedure described by Arnon, (1949).

BGA were cultured using BG-11 medium (Stainer *et al.*, 1971). The composition of nutrient media is as follows:

BG-11 medium (Stainer *et al.*, 1971)

NaNO ₃	1.5 g
K ₂ HPO ₄	0.04 g
MgSO ₄ .7H ₂ O	0.075 g
CaCl ₂ .2H ₂ O	0.036 g
Citric acid	0.006 g
Ferric ammonium citrate	0.006 g
EDTA (disodium magnesium salt)	0.001 g
Na ₂ CO ₃	0.02 g
Trace metal mix	1.0 ml

A₅ – Micro nutrient solution

H ₃ BO ₃	2.86 g
MnCl ₂ .4H ₂ O	1.81 g
ZnSO ₄ .7H ₂ O	0.222 g
Na ₂ MoO ₄ .2H ₂ O	0.39 g
CuSO ₄ .5H ₂ O	0.079 g

Trace metal mix for BG-11 medium

Add CO (NO₃)₂.6H₂O 0.0494 g/l in A₅ – Solution.

Estimation of total carbohydrates (Dubois *et al.*, 1956)

Weigh 100mg of the sample; hydrolyze it by keeping it in a boiling water bath for three hours with 5ml of 2.5N HCl. After cooling to room temperature neutralize it with solid sodium carbonate until the effervescence ceases. Make up the volume to 100ml and centrifuge. Prepare working standard series. Take 0.1ml of the sample solution and make up the volume to 1ml. Set a blank with 1ml of distilled water. Add 1ml of 5% phenol solution to each tube and then add 5ml of 96% sulphuric acid to each tube and shake well. After 10 min. shake the contents in the tubes and place in a water bath at 25-30°C for 20 min. Cool and read at 490nm. Calculate the amount of total carbohydrates in the sample using standard graph.

Estimation of total chlorophyll (Arnon, 1949)

Chlorophyll was estimated by the method of Arnon, (1949) as given below:

Weigh 1g of finely cut leaf tissue and grind in a clean pestle and mortar with 20ml of 80% acetone. Centrifuge for 5 minutes at 5000rpm and transfer the supernatant to 100ml volumetric flask. Grind the residue again with 20ml of 80%, centrifuge and transfer the supernatant to the same volumetric flask. Repeat the procedure till the residue becomes colourless. Wash the mortar and pestle and transfer the washings into the volumetric flask. Make up the volume to 100ml with 80% acetone. Read the absorbance at 645nm and 663nm against 80% acetone as blank using Spectrophotometer Systronics (117 model) Chlorophyll content was calculated using the formula given below.

$$\text{mg total chlorophyll/g tissue} = 20.2 (A_{645}) + 8.02(A_{663}) \times V/1000 \times W$$

Extraction of protein from sample (Lowry *et al.*, 1951)

Extraction is usually carried out with buffers used for the enzyme assay. Weigh 500mg of the sample and grind well with a pestle and mortar in 5-10ml of the buffer. Centrifuge and use the supernatant for protein estimation.

Chemicals used:

Reagent A: 2% sodium carbonate in 0.1N sodium hydroxide.

Reagent B: 0.5% copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) IN 1% potassium sodium tartarate.

Reagent C: Alkaline copper solution: Mix 50ml of A and 1ml of B prior to use.

Reagent D: Folin –Ciocalteau reagent

Protein solution (stock standard): Weigh accurately 50mg of bovine serum albumin and dissolve in distilled water and make the volume to 50ml in a standard flask.

Estimation of Protein

Prepare working standards into a series of test tubes. Pipette out 0.1ml and 0.2ml of the sample extract in two other test tubes. Make up the volume to 1ml in all the test tubes. 1ml of water serves as blank. Add 5ml of reagent C to each tube including the blank. Mix well and allow to stand for 10 min. Then add 0.5ml of reagent D, mix well and incubate at room temp in the dark for 30 min. Blue colour is developed. Take the readings at 660nm. Draw a standard graph and calculate the amount of protein in the sample.

Statistical analysis:

The data was statistically analyzed by SPSS version 16 statistical package and MINITA B version 13. A p-value of 0.05 or less was considered statistically significant. One way ANOVA was used for multiple group comparisons. Pearsons correlation coefficient (r) analysis was performed to assess the interrelationships and predictions of the effects.

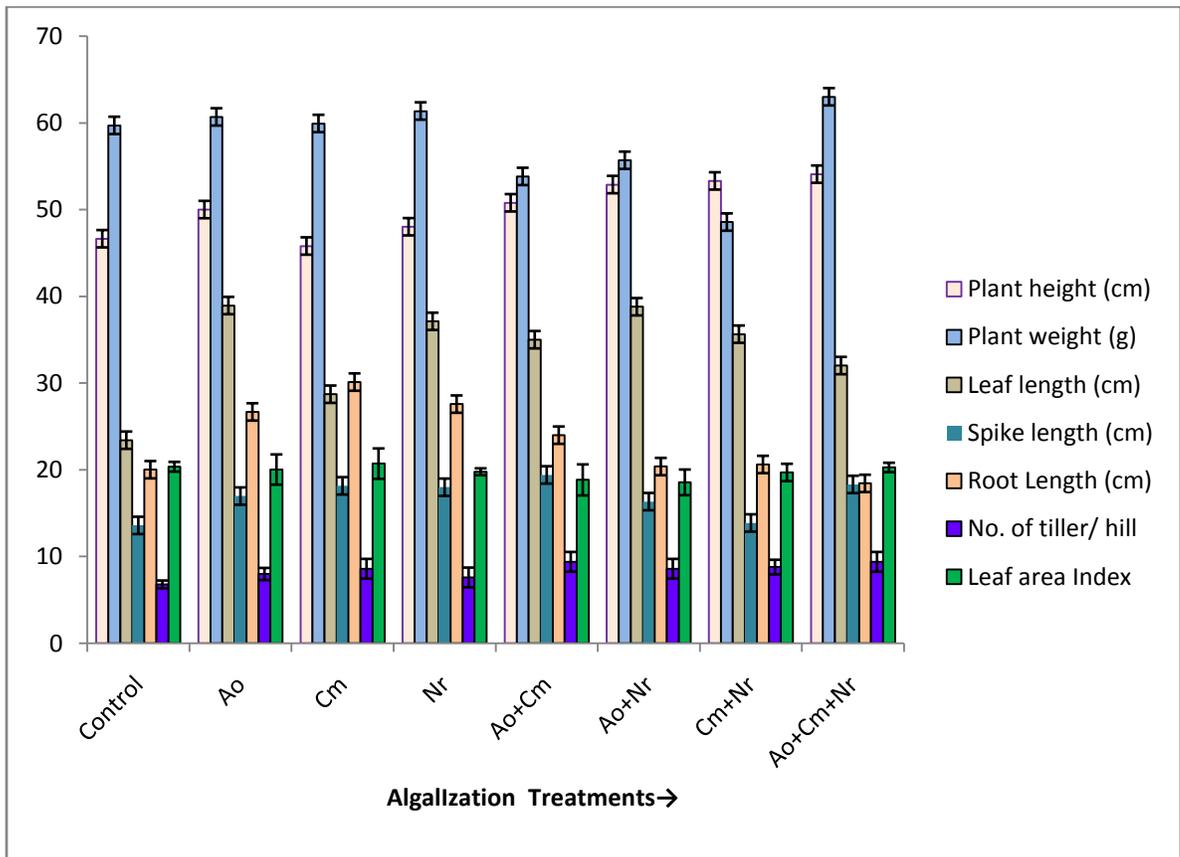
RESULTS:

The results of BGA inoculation on growth, yield and biochemical characteristics in *Oryza sativa* L. (var. jaya) are depicted in **Table 6.1** and **Fig. 6.1- 6.5**. It was observed that the BGA inoculation had significant effects on growth, yield and biochemical characteristics of *Oryza sativa* L. (var. jaya). The combination treatment of local BGA (*Ao* + *Cm* + *Nr*) comprising of the three BGA species viz., *Anabaena oryzae* Fritsch, *Calothrix membranacea* Schmidle and *Nostoc rivulare* Kützing ex Born et Flah., resulted in maximum increase in plant height, plant weight(fresh), spike length, number of tillers per hill, length of panicle and grain yield compared to control.

The study revealed that BGA either singly or in combination with other blue greens produce better results in most of the growth, yield and biochemical parameters (**Table 6.1**). In plants treated with combination treatments viz., *Ao+Nr*, *Cm+Nr*, *Ao+Cm+Nr*, plant height showed an increase of 13, 14 and 16% respectively over control. Plant weight showed little increase in all treatments except *Ao+Cm+Nr* with 5% increase over control. A marked increase in spike length was recorded over control ranging from 19% to 42%. *A.oryzae* recorded 25% increase, *C.membranacea* showed 33% and *N. rivulare* showed 32% respectively. Among the combination treatments, *Ao+Cm* recorded 42% increase, *Ao+Nr* recorded 19% increase and *Ao+Cm+Nr* recorded 34% over control. Increase in number of tillers per hill ranged from 26 to 38% over control. Plants treated with *Cm* and *Ao+Cm* showed an increase of 26% over control and plants treated with a combination treatment *Cm+Nr* showed 29% increase. Maximum increase of 38% was recorded in combination treatment *Ao+Cm+Nr* and *Ao+Cm*. Similarly, panicle length recorded a marked increase in individual treatments and

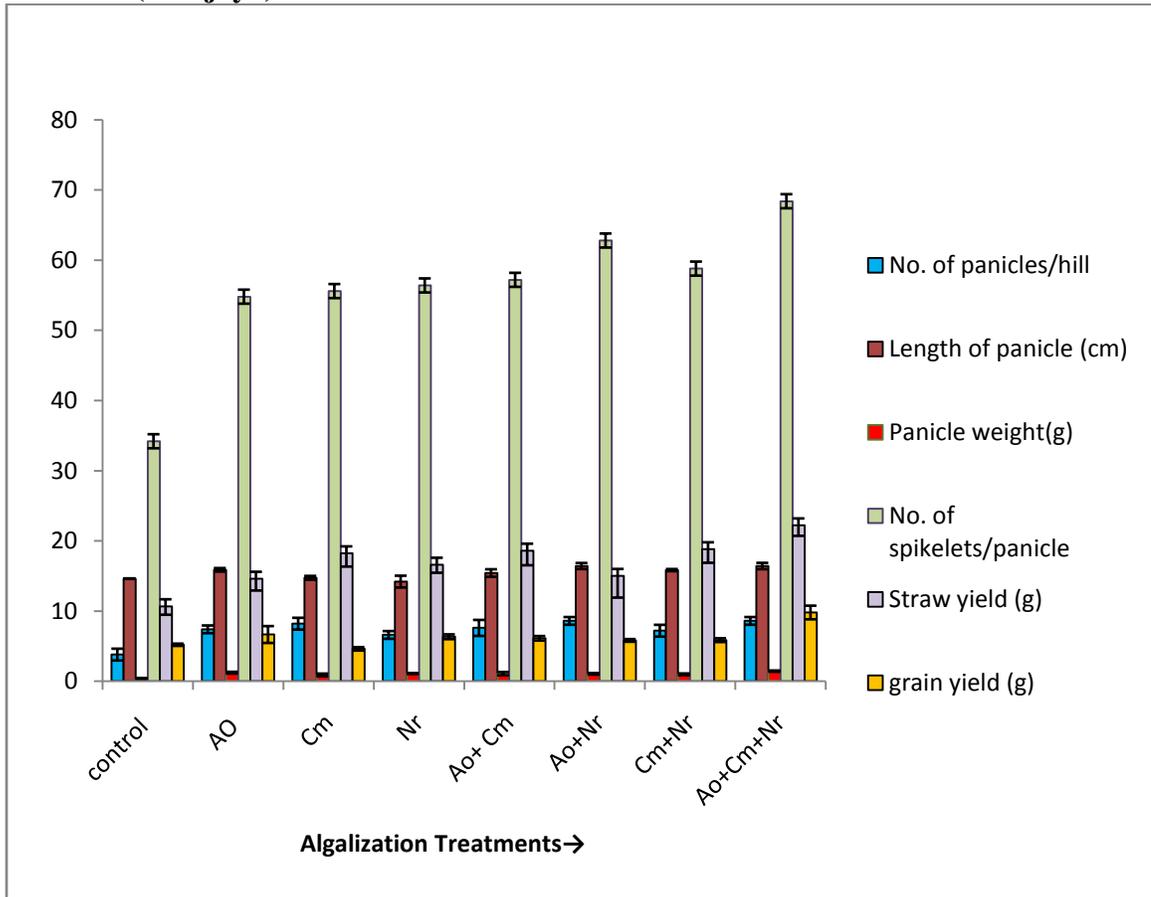
combination treatments. Individual treatment *Ao* and combination treatment *Cm+Nr* both showed 8% increase over control, *Ao+Nr* recorded 10% increase and a maximum 12% increase was recorded by plants treated with the triple combination of BGA. Number of spikelets per panicle showed a considerable increase in all single as well as combinations, ranging from 60% to 100% increase over control, the effect being more in combination algal treatments. Grain yield showed significantly higher yield in the majority of the singular biofertilization treatments and combinations compared to control. Only *Cm* treatment showed reduced grain yield. The percentage increase over control in single treatments *viz.*, *Ao* and *Nr* was 28% and 21% respectively and combination *Ao+Cm+Nr* showed maximum increase of 88% (**Fig. 6.1 and 6.2**).

Fig. 6.1: Effect of BGA isolates on various growth characteristics of *Oryza sativa* L. (var. jaya).



Legend: Ao - *Anabaena oryzae*; Cm - *Calothrix membranacea*; Nr - *Nostoc rivulare*

Fig. 6.2: Effect of BGA isolates on various yield characteristics of *Oryza sativa* L. (var. jaya).



Legend: *Ao* - *Anabaena oryzae*; *Cm* - *Calothrix membranacea*; *Nr* - *Nostoc rivulare*

Biochemical parameters showed variable results. The carbohydrate content showed slight decrease over control in single treatments *viz.*, *Ao*, *Cm* and *Nr* and, a slight increase in combination treatments *Ao+Cm*, *Ao+Nr* and *Cm+Nr*. Highest increase (2.06%) was seen in combination treatment *Ao+Cm+Nr* (**Fig.6.3**). Protein content showed an increase over control in all single as well as combination treatments except in *Ao+Nr* where 3.49% decrease over control was recorded. Highest increase (7%) over control was recorded in combination treatment of *Ao+Cm+Nr*, followed by 5.38% increase in *Nr*. Least increase (0.806%) in protein content was recorded in *Cm*. The combination treatments *Ao+Cm*, *Ao+Nr*, *Cm+Nr* showed 2.06%, 3.49% and 4.8% increase in protein content respectively (**Fig. 6.4**).

The chlorophyll content of treated plants was monitored for four fortnights after inoculation with BGA. It is observed that the leaf chlorophyll content of control as well as treated plants decreased with age of the plants. Highest chlorophyll content was recorded in control plants of first fortnight which decreased progressively till the fourth fortnight. In the first fortnight the percent increase in leaf chlorophyll content of treated plants over control is marked. Increase in leaf chlorophyll content with either single or combination treatment of BGA ranges from 1% to 21%. *Ao* showed 1% increase while *Cm* showed 8% increase. A decrease of 7% in leaf chlorophyll content was observed in *Nr* treatment over control. Highest percent increase (21%), which is seen in combination treatment *Ao+Cm* followed by *Ao+Cm+Nr* (20%) increase over control. The combination treatments *Ao+Nr* and *Cm+Nr* showed 17% and 10% increase respectively over control (**Fig.6.5**).

Fig. 6.3: Effect of BGA inoculation on carbohydrate content of grains in *Oryza sativa* L. (var. jaya).

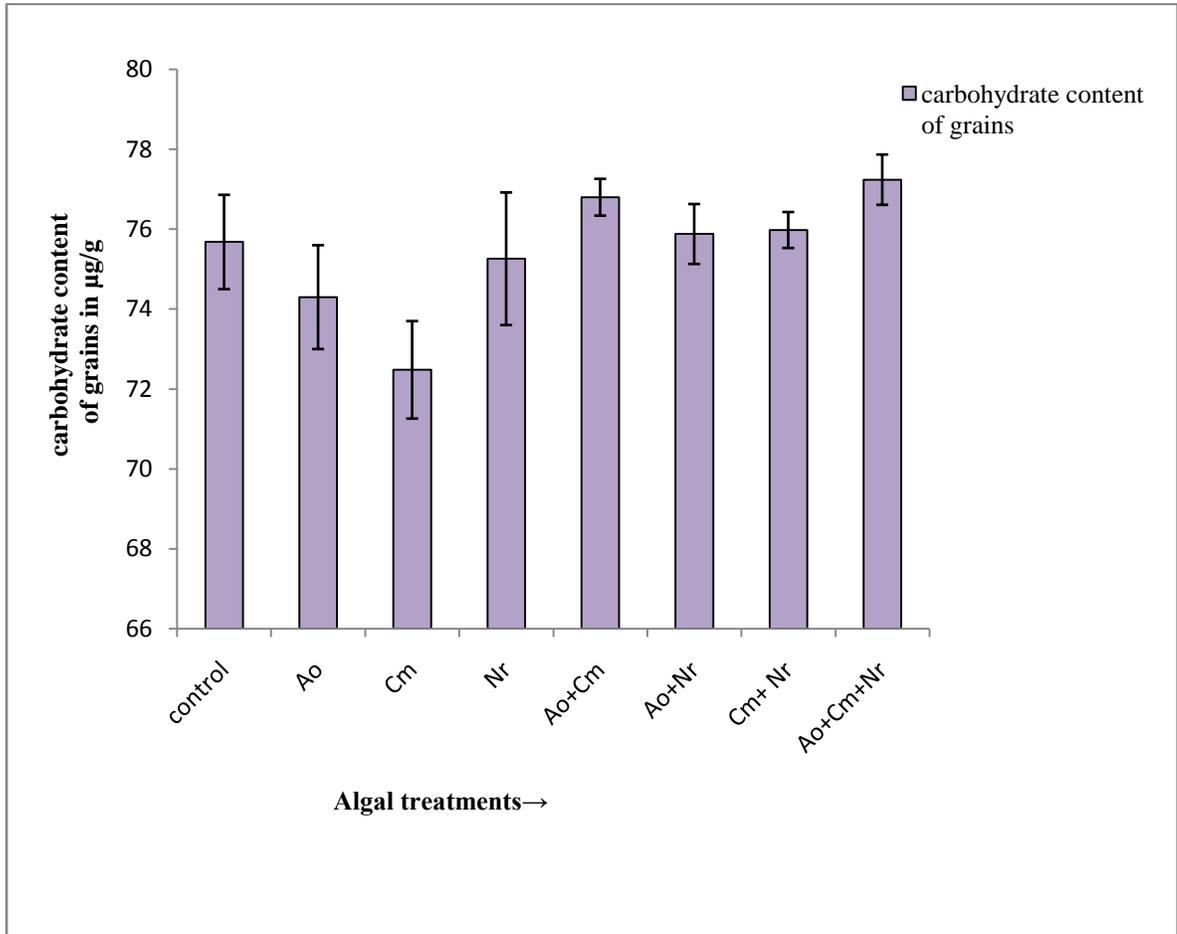


Fig. 6.4: Effect of BGA inoculation on protein content of grains in *Oryza sativa* L. (var. jaya).

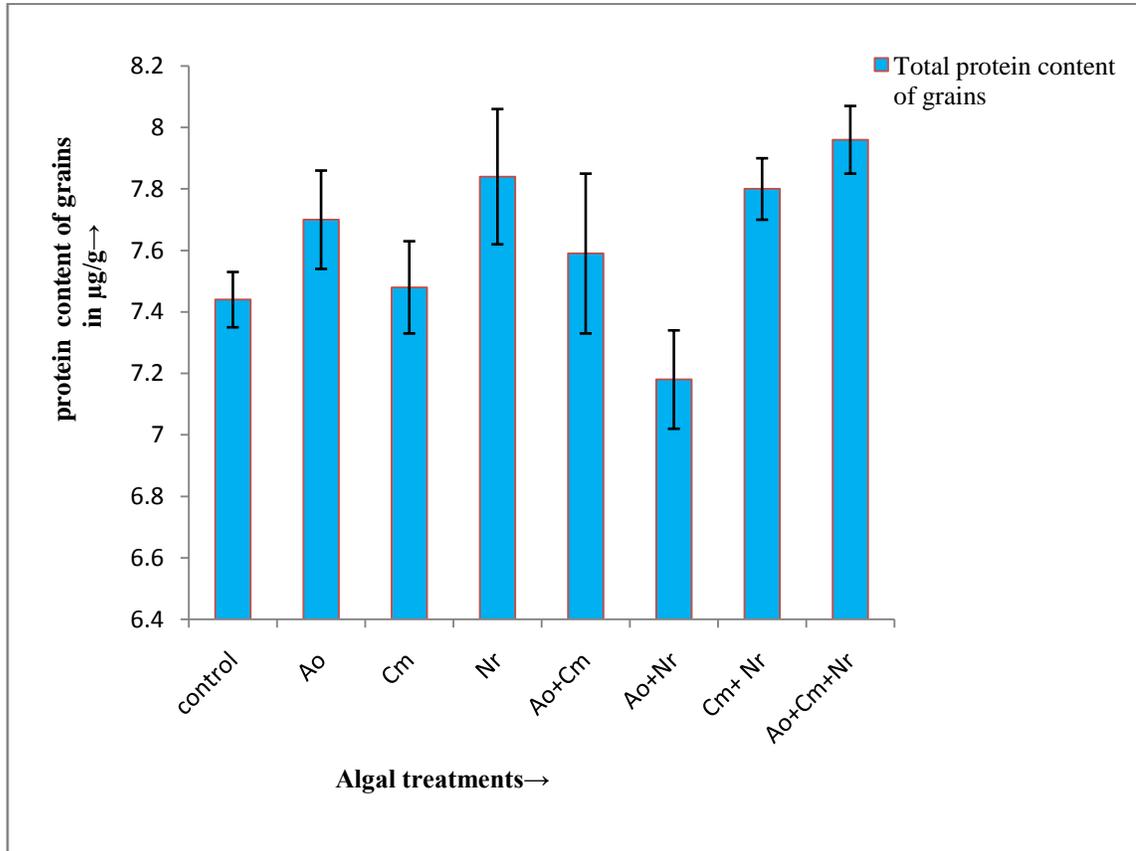
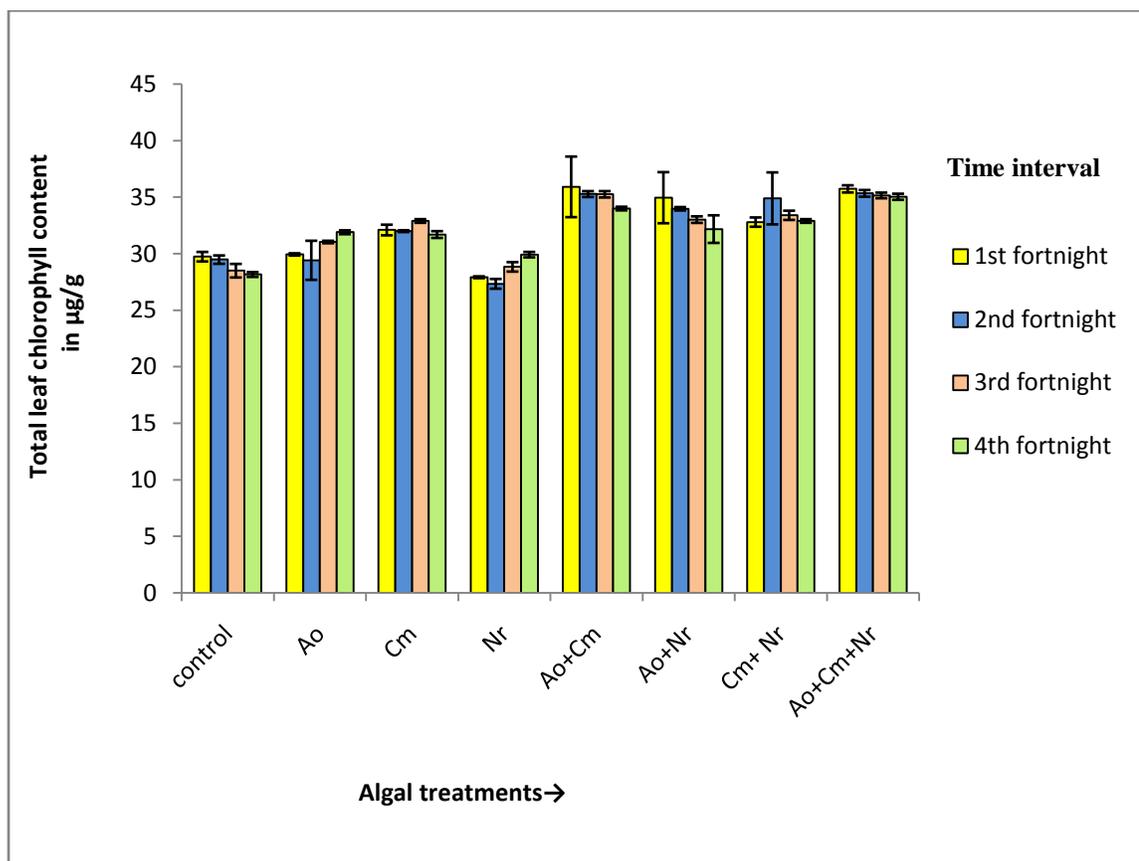


Fig. 6.5: Effect of BGA inoculation on leaf chlorophyll content in *Oryza sativa* L. (var. jaya)



Effects of different BGA combinations on plant growth parameters and grain yield were studied and their comparative results analyzed by one way ANOVA (**Table 6.1**). Correlation analysis (**Table 6.2**) showed that plant height is significantly correlated to plant weight, number of tillers per hill, length of panicle and number of spikelets per panicle, but grain yield did not show any relationship with plant height. Plant weight showed positive correlation with spike length but is negatively correlated with number of tillers per hill, length of panicle and number of spikelets per panicle. Grain yield did not show significant correlation to plant weight. Spike length is significantly correlated with number of tillers per hill and number of spikelets per panicle but not correlated with grain yield. Number of tillers per hill shows significant correlation with length of panicle, number of spikelets per panicle and shows a negative correlation with grain yield. Length of panicle is significantly correlated with number of spikelets per panicle and shows a negative correlation to grain yield. Number of spikelets per panicle is positively correlated with grain yield. Grain yield shows a positive correlation with plant height, plant weight, spike length and number of spikelets per panicle and a negative correlation with number of tillers per hill and length of panicle.

One way ANOVA analysis (**Table 6.3**) of carbohydrates, proteins and chlorophyll content shows that the increase in the combinations of BGA in inoculated plants is statistically significant. Carbohydrate content of grains showed significant increase in combinations $Ao+Nr$, $Cm+Nr$, $Ao+Cm+Nr$ and protein content of grains was significant in combinations Nr , $Ao+Cm$, $Ao+Nr$, $Ao+Cm +Nr$. In both cases higher significance level was in the combination with maximum number of BGA.

Table 6.1: Effect of BGA inoculation on growth and grain yield in *Oryza sativa* L. (var. jaya).

Treatments	Plant height (cm)	Plant weight (g)	Spike length (cm)	No. of tillers/hill	Length of panicle (cm)	No. of spikelets/ panicle	Grain yield/plant (g)
Control	46.6±0.2	59.7±0.4	13.6±0.2	6.8±0.5	14.6±0.1	34.2±0.8	5.20±0.16
<i>Ao</i>	50.0±3.5	60.7±0.4	17.0*±0.1	8.0±0.7	15.9*±0.3	54.8*±3.6	6.66*±0.20
<i>Cm</i>	45.8±5.0	59.9±0.3	18.2*± 0.1	8.6*±1.1	14.7±0.3	55.6*±7.6	4.62±0.24
<i>Nr</i>	48.0±0.4	61.4±0.3	18.0*±0.1	7.6±1.1	14.2±0.8	56.4*±2.1	6.34*±0.34
<i>Ao + Cm</i>	50.8±1.1	53.8*±1.1	19.4*±0.3	9.4*±1.1	15.4±0.5	57.2*±1.9	6.12±0.32
<i>Ao + Nr</i>	52.9*±1.7	55.7*±1.1	16.3*±0.1	8.6*±1.2	16.2*±0.4	62.8*±2.3	5.82±0.19
<i>Cm + Nr</i>	53.3*±0.7	48.6*±3.7	13.9±0.2	8.8*±0.8	15.8*±0.2	58.8*±0.8	5.86±0.27
<i>Ao+Cm+Nr</i>	54.1*±1.0	63.0*±0.1	18.3*±0.1	9.4*±1.2	16.4*±0.5	68.4*±1.5	9.80*±0.97
ANOVA F	9.16	54.7	752.2	4.05	18.51	44.36	34.55
P	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.01

Significance=(P<0.05 and P<0.01)

Legend: *Ao* - *Anabaena oryzae*; *Cm* - *Calothrix membranacea*; *Nr* - *Nostoc rivulare*

Table 6.2: Correlation analysis between various plant characters and grain yield/plant .

	Characters	1	2	3	4	5	6	7
1	Plant height	-	-0.32 *	0.01	0.36 *	0.63 **	0.44 **	0.02
2	Plant weight	-	-	0.36 *	-0.21	-0.18	-0.07	0.24
3	Spike length	-	-	-	0.38 *	0.01	0.51 **	0.27
4	No. of tillers/hill	-	-	-	-	0.43 **	0.58 **	-0.16
5	Length of panicle	-	-	-	-	-	0.59 **	-0.25
6	No. of spikelets	-	-	-	-	-	-	0.18
7	Grain yield/plant (g)	-	-	-	-	-	-	-

Pearson's correlation coefficient * P<0.05 ** P<0.01

Legend: *Ao* - *Anabaena oryzae*; *Cm* - *Calothrix membranacea*; *Nr* - *Nostoc rivulare*

Table 6.3: Effect of BGA inoculation on carbohydrate and protein content of grains and chlorophyll content of leaves in *Oryza sativa* L. (var. jaya)

Treatments		Carbohydrate content of grain ($\mu\text{g/g}$)	Protein content of grain ($\mu\text{g/g}$)	Chlorophyll ($\mu\text{g/g}$)
		Mean	Mean	Mean
1	Control	75.68 \pm 1.18	7.44 \pm 0.09	27.94 \pm 4.01
2	<i>Ao</i>	74.32 \pm 1.30	7.70 \pm 0.16	29.94* \pm 0.09
3	<i>Cm</i>	72.48 \pm 1.22	7.48 \pm 0.15	32.10* \pm 0.47
4	<i>Nr</i>	75.26 \pm 1.66	7.84* \pm 0.22	27.92 \pm 0.08
5	<i>Ao + Cm</i>	76.80* \pm 0.46	7.58* \pm 0.26	35.92* \pm 2.68
6	<i>Ao + Nr</i>	75.88 \pm 0.75	7.18 \pm 0.16	33.96* \pm 0.09
7	<i>Cm + Nr</i>	75.98* \pm 0.46	7.80* \pm 0.10	32.92* \pm 0.16
8	<i>Ao + Cm + Nr</i>	77.24* \pm 0.63	7.96* \pm 0.11	35.74* \pm 0.32
ANOVA *	F value	10.32	11.69	17.26
	P value	< 0.01	< 0.01	< 0.01

Significance=(P<0.01)

Legend: *Ao* - *Anabaena oryzae*; *Cm* - *Calothrix membranacea*; *Nr* - *Nostoc rivulare*

DISCUSSION:

The present study revealed that 'Algalization' with BGA singly and in combinations improved the growth, yield and biochemical characters of *Oryza sativa* L. (var. jaya). The study also revealed that the effect was better when the combinations of BGA were maximum. The study revealed that BGA treatment lead to increase in plant height, plant weight, leaf length, panicle length and grain yield. Our studies recorded an average increase of 45% in paddy yield over control while an average increase of 14% was reported due to BGA inoculation by Roger and Kulasooriya, (1980). Similar observation was recorded earlier in *Oryza sativa* L. (var. jaya) by Giriyaappanaver, (1989) from North Karnataka wherein a combination treatment of BGA biofertilizer consisting of indigenous species of *Anabaena oryzae*, *Nostoc rivulare* and *Nostoc entophyllum* were used. Earlier studies have reported increase in plant height, tiller number and grain weight in paddy due to algalization with BGA (Jagannathan and Kannaiyan, 1977; Pantastico and Gonzalves, 1976; Kannaiyan, 1978b; Kannaiyan, 1979). Experimental evidences using these organisms resulting in enhanced grain yield and straw yield were provided by De and Mandel (1956). Pot experiments with unialgal and composite cultures of BGA increased paddy yield considerably (Dhaliwal *et al.*, 1995). In the present study the combination treatment of *Anabaena oryzae*, *Calothrix membrancea* and *Nostoc rivulare* has resulted in 88% increase in grain yield and was also statistically significant.

The present study also showed increase in protein and carbohydrate content in grains of treated plants. In a similar study, presoaking paddy seeds with BGA cultures or extracts enhanced germination, promoted growth of roots and shoots and increased the

weight and protein content of grain (Roger and Kulasooriya, 1980, Roger, 1984, Yanni *et al.*, 1990, Tiwari *et al.*, 2001, Firoza *et al.*, 2001).

The present study also showed that leaf chlorophyll content increased with algalization. Biofertilization with BGA increased chlorophyll content in paddy leading to overall increase in grain yield (Shariff *et al.*, 2006). Similar conclusions were reported by Shariff *et al.*, 1998, Caestro *et al.*, 2002, Manivannan, 2004, Ibrahim *et al.*, 2004 and Mady, 2004.

The increase in growth, yield and biochemical characters with biofertilization could be attributed to increased availability of Nitrogen. Earlier studies have indicated that application of BGA biofertilizers increased the availability of N resulting in increased leaf area, light intercepting photosynthesis and greater accumulation of dry matter (Rekhi *et al.*, 2000). Aziz and Hashem, (2004) reported cyanobacterial inoculation increased the yield and supplemented more than 20% nitrogen. It resulted in significant increase in plant height, number of grains/panicle, panicle length and straw yield, but did not show significant increase in weight of 1000 grain and number of tillers/hill. The inoculation studies of soils with BGA or algalization carried out in India and abroad have shown beneficial effects on grain yield and nitrogen savings (Venkataraman, 1972; Singh, 1978). Studies on the indigenous BGA from Chilean paddy field soils has proved to be good option for the formulation of a biofertilizer, allowing 50% decrease in the use of synthetic nitrogen fertilizers with similar results with respect to grain yield in comparison with control (Pereira *et al.*, 2009). A multani-mitti (fullers earth) based carrier BGA biofertilizer was shown to increase the grain yield of 'PNR 381' variety of paddy by 48.83 q/ha upon combination with low amounts of chemical fertilizers (Dhar *et*

al., 2007). Paddy variety Pathumthani 1 when grown in two crops at different times of the year and inoculated with vegetative cells and akinetes of *Nostoc* species separately, showed an increase in grain yield by 7.29% and 6.25% respectively (Innok *et al.*, 2009). An increase in grain yield of 15-23% by BGA inoculation was also reported by Singh and Singh, (1987). The better results obtained through algalization could be also attributed to the indigenous BGA used in the study. Indigenous cyanobacteria establish themselves faster than other introduced inocula. Cyanobacteria introduced as a result of algalization can establish themselves permanently if inoculation is done consecutively for three to four cropping seasons (Upassana and Pabbi, 2004). The results of the present study are in accordance with earlier studies showing enhancement in grain yield due to algalization in paddy fields (Venkataraman and Goyal, 1968; Singh, 1985, 1988; Kannaiyan, 1985). In a study conducted in Madhya Pradesh, India, 56 trials showed an increase of 15-20% in grain yield of paddy through algal application alone without any nitrogenous fertilizers.

In pot culture treatments of cyanobacteria to paddy showed 53% increase in plant height, 66% increase in plant roots length and 69% increase in plant fresh weight. Paddy inoculation with heterocystous cyanobacteria isolated from paddy fields in Iran showed that algae had positive effects on paddy planted *in vitro* and they modify physical and biological population of soils in ways which are beneficial to paddy and soil (Sadatnia *et al.*, 2009).

The other attributes of BGA to enhanced performance could be also due to secretion of growth promoting substances and vitamins. There are a number of reports claiming that in addition to nitrogen fixation, BGA secretes a number of plant growth regulators

such as gibberelins, cytokinins, vitamins B₁₂, and amino acids benefiting paddy crop by having a positive effect on crop growth and yield (Venkataraman and Neelkantan, 1967; Roger and Kulasooriya, 1980; Chauhan and Gupta, 1984; Mishra and Kaushik, 1989a, 1989b). They are also known to add a substantial amount of organic matter to the soil (Goyal, 2002).

In the present study, a significant response to indigenous cyanobacterial strains was encouraging and proved to be an efficient biofertilizer for soils. It may be thus concluded that algalization of jaya variety of paddy by these selected combination of indigenous cyanobacterial strains showed significant results in its growth, yield and biochemical parameters proving to be an efficient biofertilizer.

INTRODUCTION:

Soil is a dynamic system in which abiotic and biotic components are in a state of equilibrium. Without considering this equilibrium chemical fertilizers are indiscriminately used to raise a crop product that disturbs the beneficial microorganisms thereby decreasing the soil productivity. Several microorganisms are important components of soil ecosystem which help in better crop nutrient management and maintenance of soil productivity (Goyal, 1993). Water logged rice fields is one among the various soil ecosystems in which cyanobacteria maintain soil fertility and sustain crop yield even in the absence of added nitrogenous fertilizers (Venkataraman, 1981). Tropical conditions of high humidity and temperature coupled with shade of crop canopy favour luxuriant growth of cyanobacteria in tropical paddy fields (Roger and Reynand, 1979). In addition to providing biologically fixed nitrogen, cyanobacteria increase the availability of fertilizers like nitrogen to the rice plants preventing denitrification (Goyal, 1993).

The modern technology of rice cultivation required a high input of synthetic fertilizers, besides the accumulating load of pesticides and insecticides in the field (French and Gay, 1963). With global population estimated to reach 11 billion in 2050 (Tisdale *et al.*, 1995), it is obvious that large and sustained increases in food production will be needed. Since cultivated land areas are expected to expand by only about 20% (Tisdale *et al.*, 1995), the only way out is to intensify the agricultural production by adopting improved cultural practices and use of high yielding crop varieties with agrochemicalization of fields, wherein intense use of fertilizers is required. This agrochemicalization alters the soil-microbe-nutrient environment depending upon the type of fertilizer and quantity used.

The fertilizer needs of the crop may be reduced by controlling weeds with herbicides, which is more perfect than physical methods. Since the herbicides are either photosynthetic inhibitors or uncouplers, they damage the oxygen-evolving photosynthetic apparatus of the cyanobacteria which are the non-target organisms (Vaishampayan and Prasad, 1984b; Prasad and Vaishampayan, 1994a; Vaishampayan, 1998; Vaishampayan *et al.*, 1998d). Thus, in a pesticide treated modern agricultural fields, photosynthesis becomes disadvantageous for the viability of the N₂-fixing cyanobacteria. In this paradoxical situation, it becomes essential to use large doses of synthetic nitrogen fertilizers (Singh *et al.*, 1988).

Effect of commercial fertilizers on nitrogen fixing cyanobacteria in agricultural soils used for cultivating paddy has not been investigated earlier in the State. The effect of different concentrations of locally used commercial fertilizers in Goa *viz.*, Samarth and Samrat was studied on the most abundant indigenous BGA *viz.*, *Anabaena oryzae*, *Calothrix membranacea* and *Nostoc rivulare* from the paddy fields of Goa. The parameters studied include their effect on biomass, Chlorophyll content, total proteins and carbohydrates content of the three selected indigenous cyanobacterial species.

MATERIAL AND METHODS:

Source of chemicals: The fertilizers used by farmers in Goa were purchased from local dealer. The chemical formulation and details of manufacturer are given in

Table 7.1.

Table 7.1: Chemical formulations of fertilizers.

Fertilizer Samarth (10:26:26)	N-10% P ₂ O ₅ (t-26%, cs-26% ws-22.1%) K ₂ O-26% N:P:K – 10:26:26	M/s Zuari Industries Ltd, Jai Kissan Bhawan, Zuarinagar - Goa.
Fertilizer Samrat (DAP) (18:46:0)	DAP N-18% P ₂ O ₅ (t-46%, cs-46%, ws-41%) K ₂ O-0% N:P:K – 18:46:0	M/s Zuari Industries Ltd, Jai Kissan Bhawan, Zuarinagar - Goa.

The stock solution of each fertilizer was freshly prepared before being added to the culture medium. From the stock solution graded concentrations (10, 50, 100, 200 and 300µg/ml) for the treatment were prepared. Algal cultures were maintained in BG-11 medium (Stainer *et al.*, 1973) at 28⁰C ± 2⁰C under fluorescent light (tube) at an intensity of 36 µmol m⁻²s⁻¹/2000 Lux. The experimental cultures were first grown in 250ml flasks containing 100ml of medium with 0.5 million to million cells per millilitre under the same condition described above. The cultures were shaken manually for 30 minutes three times a day. At the exponential growth phase of the algal cultures different concentration of each fertilizer (10ml) were added to the culture. Distilled water was added to cultures maintained as controls. Each treatment was carried out in triplicate. Samples were collected every 7th day after fertilizer treatment for analysis. For each treatment three flasks were maintained. Growth of algae was measured in terms of biomass (Richmond and Grobbelaar, 1986), total

carbohydrate content (Dubois *et al.*, 1956), protein content (Lowry *et al.*, 1951) and chlorophyll a content (Mackinney, 1941).

Biomass determination

Sample containing 10ml of homogenized algal suspension was filtered through a Whatman filter paper, which was weighed prior to filtration. The algal mat along with paper was dried in the oven at 60⁰C until constant weight was obtained (Richmond and Grobbelaar, 1986).

$$\text{Biomass yield (mg ml}^{-1}\text{)} = \frac{\text{Final weight of filter paper with dried culture (mg)} - \text{Initial weight of the filter paper without culture (mg)}}{10}$$

Estimation of chlorophyll a

Chlorophyll a was estimated by the method of Mackinney (1941) as given below.

The homogenized culture suspension of 10ml was centrifuged at 5000rpm for 10 min. and the pellet was washed twice with distilled water. For extraction of chlorophyll, 10ml of 95% methanol was used. The tubes were covered with aluminium foil and incubated at 60⁰C in water bath for 30 min. The sample was cooled and volume was made up to 10ml using methanol and centrifuged at 5000rpm for 10 min. The absorbance of the supernatant was measured in at 650nm and 665nm in Spectrophotometer Systronics (117 model) using 85% methanol as blank. Chlorophyll content was calculated using the formula given below.

$$\text{Chlorophyll a (}\mu\text{g/ml)} = (0.0255 \times E_{650}) + E_{665}$$

Estimation of total carbohydrates (Dubois *et al.*, 1956).

Homogenise 100ml of sample and from that take 1ml and hydrolyze it by keeping on a boiling water bath for three hours with 5ml of 2.5N HCl. After cooling to room temperature neutralize it with solid sodium carbonate until the effervescence ceases. Make up the volume to 100ml and centrifuge. Prepare a series of working standards. Take 0.2ml of the sample solution and make up the volume to 1ml. Prepare a blank with 1ml of distilled water. Add 1ml of 5% phenol solution to each tube and then add 5ml of 96% sulphuric acid to each tube and shake well. After 10min. shake the contents in the tubes and place in a water bath at 25-30⁰C for 20 min. Cool and read at 490nm. Calculate the amount of total carbohydrates in the sample using standard graph.

Extraction of Protein from Sample (Lowry *et al.*, 1951)

Homogenize 100ml of sample and from that take 0.5ml algal suspension in a test tube. Add to it 0.5ml of reagent A. The tube was heated in a boiling water bath for 10min. and cooled in running tap water. Subsequently, 2.5ml of reagent (C) was added and the tube was incubated at room temperature for 10 min. This was followed by addition of 0.5ml of reagent (D). After 15 minutes of incubation at room temperature, the intensity of blue colour was read at 650nm against an appropriate blank. The protein content was estimated using standard calibration curve prepared from bovine serum albumin (BSA) and expressed as µg of protein per ml of culture.

Chemicals used:

Reagent A: 1N sodium hydroxide solution.

Reagent B: i) 5% sodium carbonate

ii) 0.5% copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) solution in 1% potassium tartarate.

Reagent C: Two ml of Reagent B (ii) was mixed with 50ml of freshly prepared Reagent B (i) 5% sodium carbonate.

Reagent D: 1N Folin–Ciocalteu reagent

STATISTICAL ANALYSIS:

Statistical analysis was performed by SPSS version 16 statistical package and MINITA B version 13. A p-value of 0.05 or less was considered statistically significant. Correlation and regression analysis were performed to assess the interrelationships and predictions of the effects (Pearsons).

RESULTS:

It was observed that increased fertilizer concentration does not have a negative effect on growth of BGA as seen by its increased biomass, chlorophyll a content, total protein and total carbohydrate content. It was observed that growth of BGA was stimulated by increasing concentrations of fertilizers as seen from the 7th day till the 28th day after treatment with fertilizers. It was also observed that maximum growth occurred on 14th, 21st and 28th day after treatment with both the fertilizers used separately. The study also revealed gradual increase in algal growth with increasing concentrations of the fertilizers from 10µg/ml to 300µg/ml, with maximum growth at 300µg/ml of fertilizer treatment.

Biomass: The effect of the two fertilizers on the biomass of *Anabaena oryzae* (Ao), *Calothrix membranaceae* (Cm) and *Nostoc rivulare* (Nr) showed increase in biomass with increasing concentration of fertilizers.

When *Anabaena oryzae* (Ao) was treated with Samarth, on the 7th day, with 10, 50 and 100µg/ml, Ao did not show any increase in biomass but with 200 and 300µg/ml there was an increase in biomass by 7.6% as compared to control. On 14th day, the concentrations 10 and 50µg/ml showed no increase over control but with 100, 200 and 300µg/ml showed an increase of 2%, 5.7% and 9% respectively as compared to control. On the 21st day, the concentrations 10 and 50µg/ml showed 2% and 4% increase respectively whereas concentrations 100, 200 and 300µg/ml showed 6%, 10%, and 12% increase over control. On the 28th day, the concentrations 10 and 50 µg/ml showed 4.6% and 22% increase respectively whereas concentrations 100, 200 and 300µg/ml showed 45%, 62%, and 80% increase over control. Thus considerable

increase in biomass of *Ao* is observed with 300µg/ml of Samarth on 14th, 21st and 28th day, highest recorded on 28th day.

When *Ao* was treated with Samrat on the 7th day, with 300µg/ml, 76% increase in biomass was recorded as compared to control. On 14th day, the concentrations 10 and 50µg/ml did not record increase over control but with 100, 200 and 300µg/ml recorded an increase of 5.7%, 9%, and 12% respectively as compared to control. On the 21st day, the concentrations 10 and 50µg/ml recorded 3% and 5.5% increase respectively whereas concentrations of 100, 200 and 300µg/ml recorded 8.8%, 7.7%, and 12% increase over control. On the 28th day, the concentrations of 10 and 50µg/ml recorded 45% and 91% increase respectively whereas concentrations 100, 200 and 300µg/ml recorded more than 100% increase over control. Thus considerable increase in biomass of *Ao* was observed with 300µg/ml of Samrat on 14th, 21st and 28th day, highest being on 28th day (**Fig. 7.1 and 7.2**). It was observed that Samrat showed more better growth response compared to Samarth in *A. oryzae*.

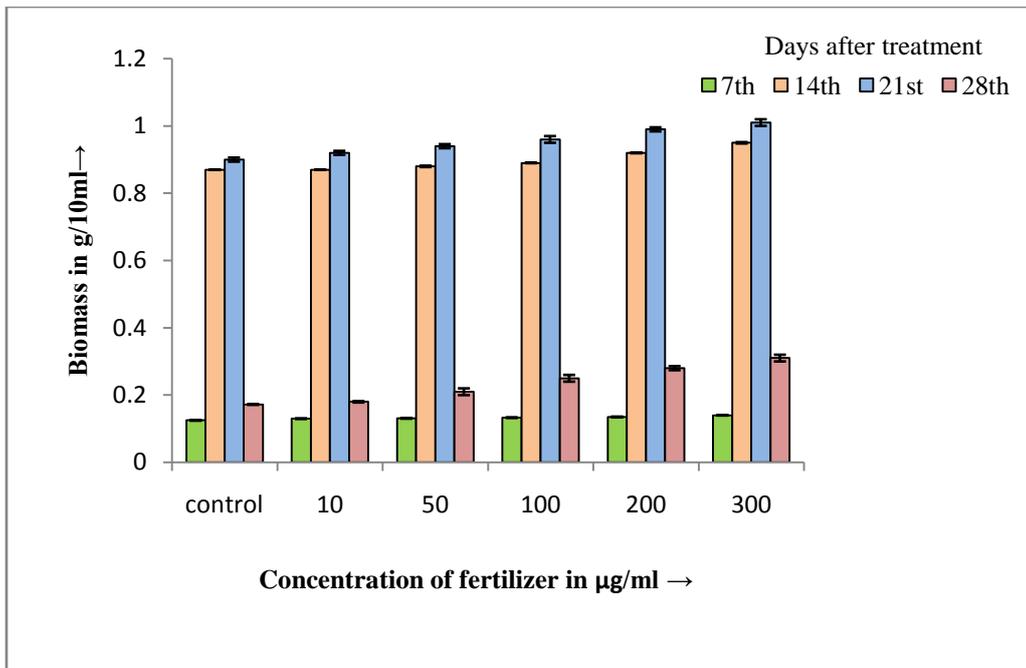


Fig. 7.1: Effect of fertilizer (Samarth) on biomass of *A. oryzae*.

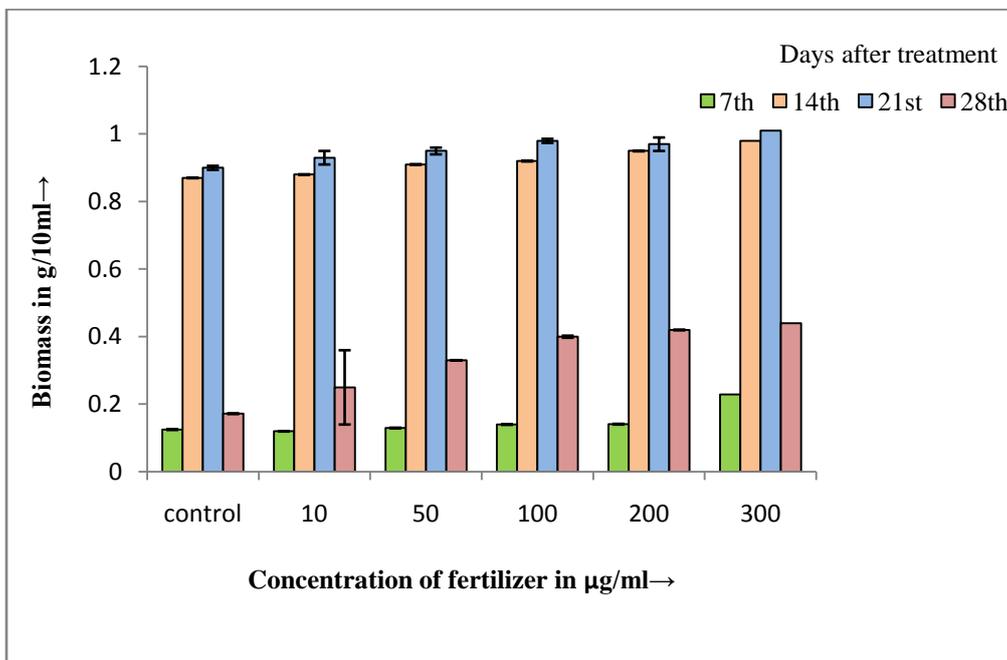


Fig.7.2: Effect of fertilizer (Samrat) on biomass of *A. oryzae*.

When *Calothrix membranaceae* (*Cm*) was treated with Samarth, on the 7th day, with 10 and 50µg/ml, *Cm* recorded an increase of 2.7% but with 100, 200 and 300µg/ml there was an increase in biomass by 12%, 21% and 26% respectively as compared to control. On 14th day, the concentrations 10 and 50µg/ml showed an increase of only 1% and 4% over control but with 100, 200 and 300µg/ml recorded an increase of 5.6%, 7.8% and 4% respectively as compared to control. On the 21st day, the concentrations 10 and 50µg/ml recorded 3% and 5% increase respectively whereas concentrations 100, 200 and 300µg/ml recorded 9.5%, 5%, and 5% respectively increase over control. On the 28th day, the concentrations 10µg/ml did not show any increase but 50µg/ml recorded an increase of 50% over control whereas concentrations 100, 200 and 300µg/ml recorded an enormous increase of 207%, 292% and 271% increase over control. Thus considerable increase in biomass of *Cm* was observed at 100, 200 and 300µg/ml of Samarth on 28th day, maximum being at 200µg/ml.

When *Cm* was treated with Samrat on the 7th day, did not show any increase with 10µg/ml but with 50 and 100µg/ml there was increase in biomass by 17.8% and 21% respectively and with 200 and 300µg/ml it recorded an increase of 25% as compared to control. On 14th day, the concentrations 10 and 50µg/ml did not record increase over control but with 100, 200 and 300µg/ml recorded an increase of 3%, 4% and 7.8%, respectively as compared to control. On the 21st day, the concentrations 10, 50 and 100µg/ml did not record increase in biomass whereas concentrations 200 and 300µg/ml recorded 4% and 5%, increase over control. On the 28th day however, the concentrations 10µg/ml recorded 71% increase in biomass and 50µg/ml recorded 192% increase whereas concentrations 100, 200 and 300µg/ml all recorded an

enormous increase of 221%, 307% and 461% increase over control. Thus considerable increase in biomass of *Cm* is seen at 300µg/ml of Samrat on 28th day, highest being on at 300µg/ml (**Fig. 7.3 and 7.4**). Fertilizer Samrat showed better growth response than Samarth in *Calothrix membranaceae*.

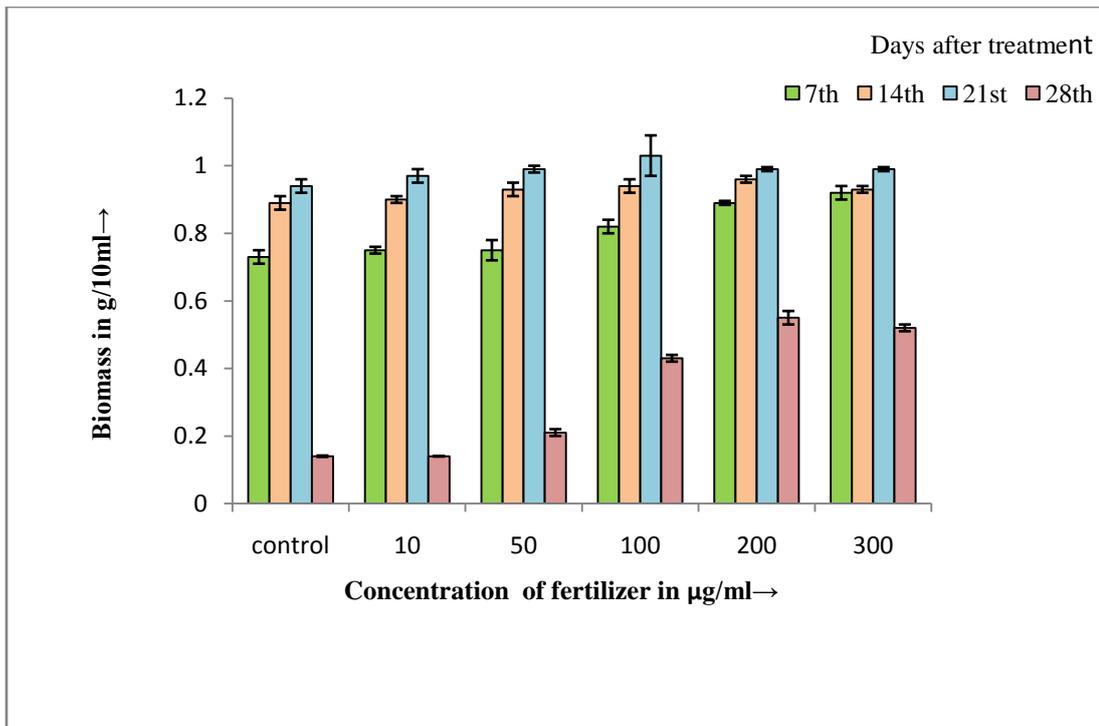


Fig. 7.3: Effect of fertilizer (Samarth) on biomass of *C. membranacea*.

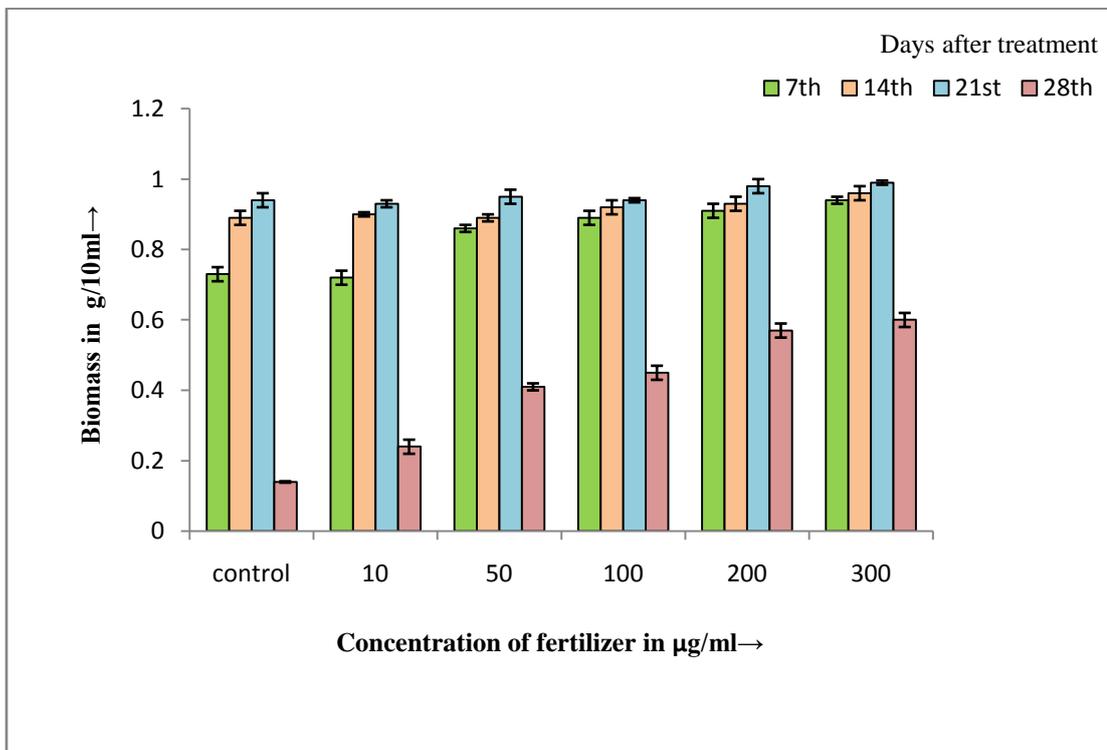


Fig. 7.4: Effect of fertilizer (Samrat) on biomass of *C. membranacea*.

When *Nostoc rivulare* (*Nr*) was treated with Samarth, on the 7th day, with 10, 50 and 100µg/ml, *Nr* did not record increase in biomass but with 200 and 300µg/ml there was increase in biomass by 9% as compared to control. On 14th day, the concentrations 10 and 50µg/ml recorded an increase of only 1% over control but with 100, 200 and 300µg/ml recorded an increase of 2%, 3% and 4% respectively as compared to control. On the 21st day, the concentration 10µg/ml recorded did not show increase in biomass over control but 50 and 100µg/ml recorded an increase of 3% and 4% respectively whereas concentrations 200 and 300µg/ml recorded an increase of 7%, 10% respectively over control. On the 28th day however a steady rise in biomass was observed. With 10µg/ml, an increase of 17% was seen, but 50 and 100µg/ml both recorded an increase of 26% over control whereas concentrations 300µg/ml recorded an increase of 30% over control. Thus considerable increase in biomass of *Nr* was observed at 100, 200 and 300µg/ml of Samarth on 28th day, maximum increase was with 300µg/ml.

When *Nr* was treated with Samrat on the 7th day, no increase was seen with 10 and 50µg/ml, but with 100, 200 and 300µg/ml there was increase in biomass by 9%, 18% and 27% respectively as compared to control. On 14th day, the concentrations 10 and 50µg/ml recorded only 1% increase over control but with 100, 200 and 300µg/ml recorded an increase of 2%, 3% and 4%, respectively as compared to control. On the 21st day, the concentrations 10 and 50µg/ml recorded no considerable increase in biomass whereas concentrations 100, 200 and 300µg/ml recorded 3%, 5% and 8.8% increase over control. On the 28th day however, the concentrations 10, 50 and 100µg/ml recorded 39%, 43% and 30% increase in biomass whereas concentrations 200 and 300µg/ml both recorded an increase of 43% over control. Thus considerable

increase in biomass of *Nr* is seen with 50, 100, 200 and 300µg/ml of Samrat on 28th day (**Fig. 7.5 and 7.6**). Thus in *N. rivulare*, both the fertilizers viz., Samarth and Samrat were responsive and resulted in increased biomass. The positive response in biomass content of the three BGA to the fertilizers studied, is of the order, *Calothrix membranaceae* (*Cm*)>*Anabaena oryzae* (*Ao*)>*Nostoc rivulare* (*Nr*).

Also it was observed that with aging, there was a decrease in the biomass in all the treatments on 28th day when compared to 14th and 21st day of treatment including control.

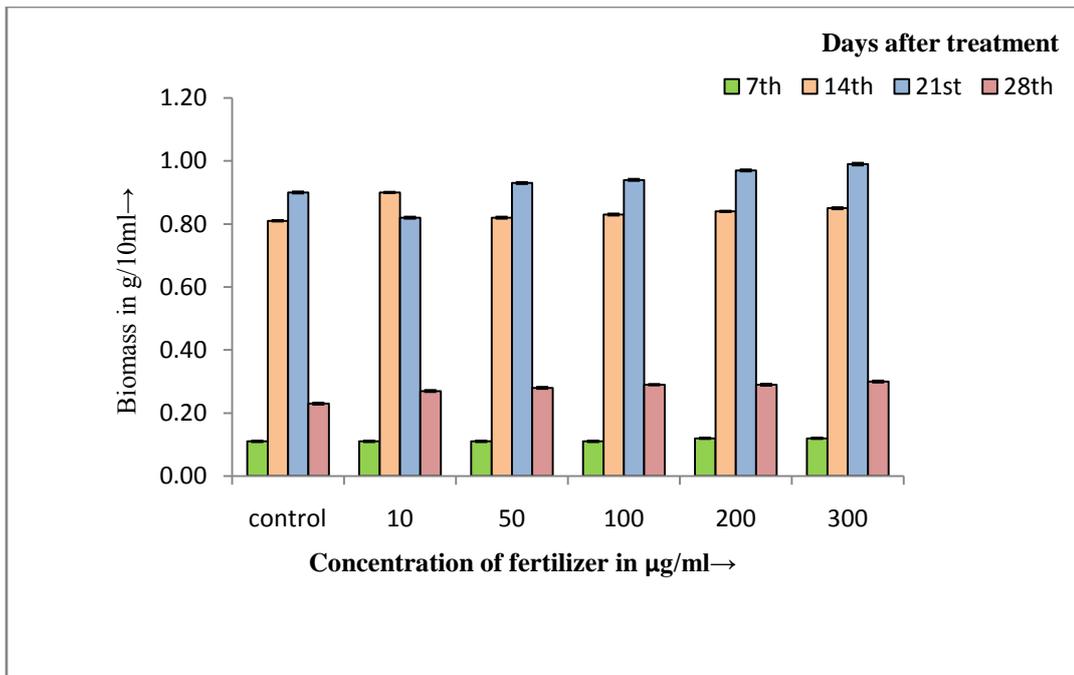


Fig. 7.5: Effect of fertilizer (Samarth) on biomass of *N. rivulare*.

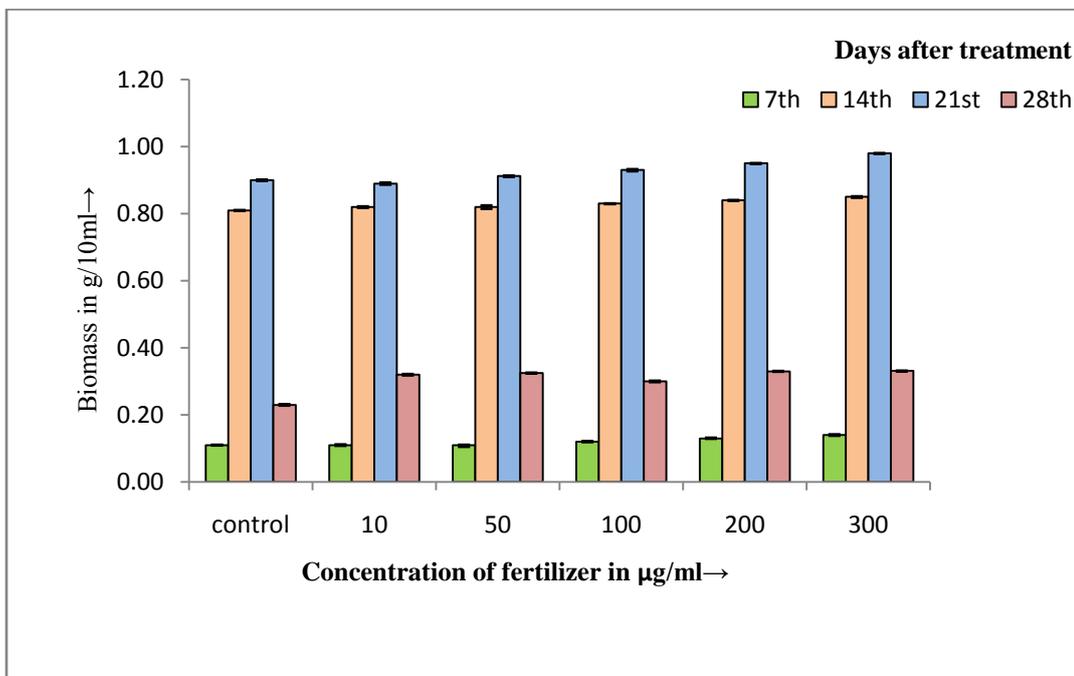


Fig.7.6: Effect of fertilizer (Samrat) on biomass of *N. rivulare*.

Chlorophyll a content: Chlorophyll a content of the three algae when monitored from 7th day to 28th day after treatment with fertilizers showed an increase from 10 to 300µg/ml. There was gradual increase in chlorophyll a content till 28th day with a maximum increase at 300µg/ml on 28th day in treated cultures.

Anabaena oryzae (Ao) after treatment with Samarth recorded very little increase in chlorophyll a content with 10 and 50µg/ml, whereas 100, 200 and 300µg/ml recorded an increase of 4%, 6% and 6.6% respectively, on 14th day recorded an increase in chlorophyll a content of 7.2%, 7%, 11% and 16% with 50, 100, 200, and 300µg/ml respectively of Samarth. On 21st day, concentrations 10 and 50µg/ml did not show considerable increase in chlorophyll a whereas 100, 200 and 300µg/ml recorded an increase of 8%, 6% and 9.6% respectively as compared to control. On 28th day, 10 and 50µg/ml concentrations did not show considerable increase whereas 100, 200 and 300µg/ml recorded an increase of 3.5%, 10% and 8% respectively in chlorophyll a content compared to control. After treatment with Samrat, Ao did not record increase in the first four concentrations. However increase in chlorophyll a content with 300µg/ml was 4% on the 7th day. On 14th day similar results were observed and with concentrations 200 and 300ug/ml an increase in chlorophyll a content of 4% and 8.6% was observed. On the 21st and 28th day Ao did not show increase in chlorophyll a content except with 300µg/ml which recorded an increase of 1.5% on 21st day and 2% on 28th day compared to control. Thus increase in chlorophyll a content of Ao was observed with 300µg/ml of fertilizer treatment on all the days (**Fig. 7.7 and 7.8**). Chlorophyll a content of *A. oryzae* showed better response to Samarth compared to Samrat.

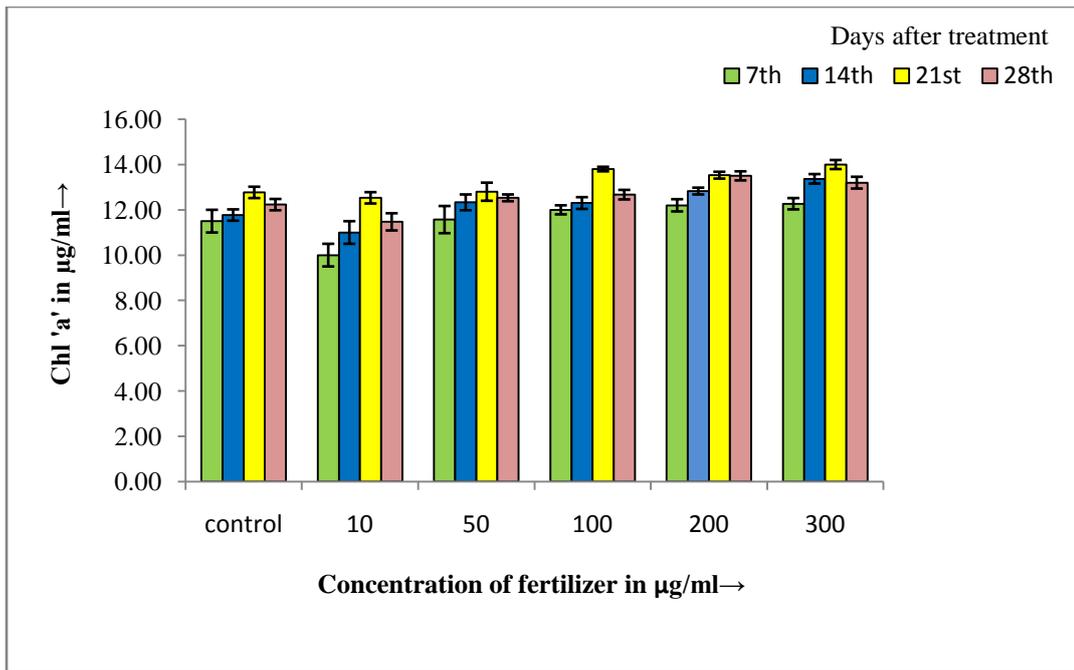


Fig. 7.7: Effect of fertilizer (Samarth) on chlorophyll a content of *A. oryzae*.

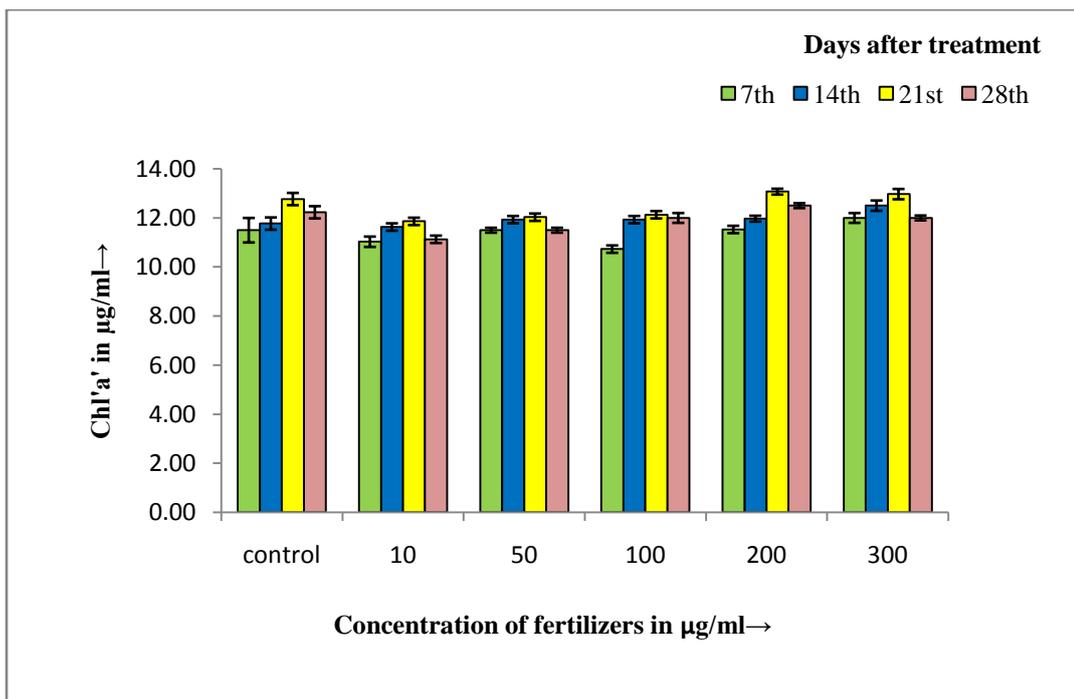


Fig. 7.8: Effect of fertilizer (Samrat) on chlorophyll a content of *A. oryzae*

Calothrix membranaceae (*Cm*), when treated with Samarth, on 7th day recorded an increase of 16% and 37% respectively with 10 and 50µg/ml whereas a highest increase of 56% in chlorophyll a content was observed with 100µg/ml which declined to 54% and 37% respectively with 200 and 300µg/ml. On the 14th day after treatment with Samarth, a highest increase of 46% in chlorophyll a content was observed with 200µg/ml compared to control. On the 21st day after treatment with Samarth, a highest increase of 14% in chlorophyll a content was observed with 200µg/ml as compared to control. On the 28th day after treatment with Samarth, a highest increase of 26% in chlorophyll a content was observed with 100µg/ml as compared to control. Thus increase in chlorophyll a content of *Cm*, with respect to control was observed at 100 and 200µg/ml of fertilizer Samarth treatment on all days of analyses.

After treatment with Samrat, *Cm* recorded no considerable increase in the first two concentrations but however increase in chlorophyll a content with 100, 200 and 300µg/ml was 46%, 65% and 44% respectively. On 14th day also similar results were observed and with concentrations 200µg/ml of Samrat, highest increase of 48% was observed in chlorophyll a content with respect to control. On the 21st and 28th day, *Cm* show considerable increase in chlorophyll a content with 100 and 200µg/ml respectively. This records an increase of 17% on 21st day and 23% on 28th day with respect to control. Thus increase in chlorophyll a content of *Cm*, with respect to control was observed at 100µg/ml and 200µg/ml of Samrat treatment on all the days (**Fig. 7.9 and 7.10**). Chlorophyll a content of *C. membranaceae* showed more positive response to Samarth than Samrat.

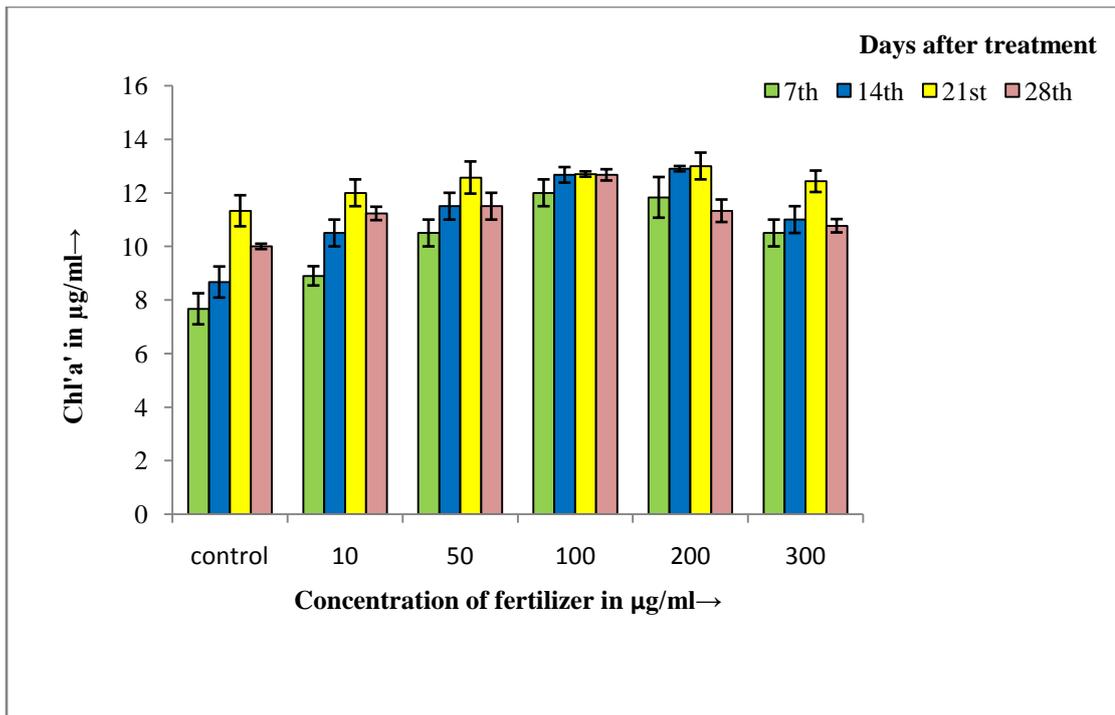


Fig. 7.9: Effect of fertilizers (Samarth) on chlorophyll a content of *C. membranacea*

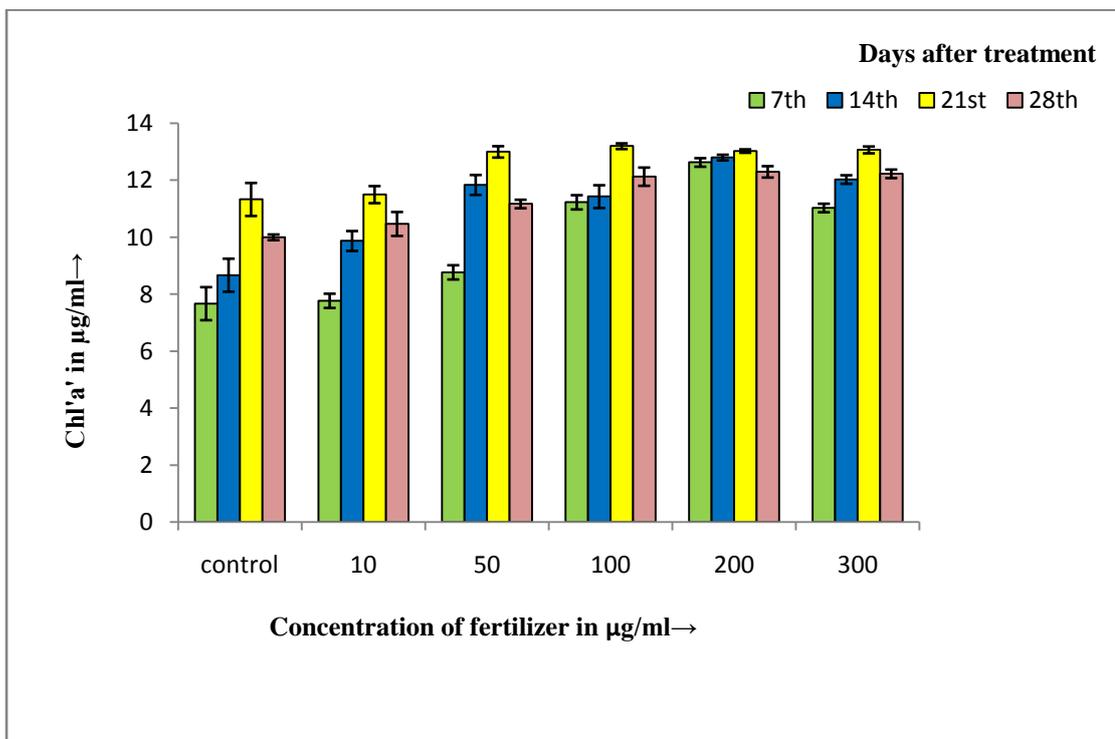


Fig. 7.10: Effect of fertilizer (Samrat) chlorophyll a content of *C. membranacea*.

Nostoc rivulare (*Nr*) when treated with Samarth, on 7th day recorded very little increase in chlorophyll a content with 10 and 50µg/ml, whereas 100, 200 and 300µg/ml recorded an increase of 22%, 25% and 31% respectively in chlorophyll a content with respect to control. On the 14th day after treatment with Samarth, considerable increase in chlorophyll a content was not observed except 0.5% with 300µg/ml with respect to control. On the 21st day after treatment with Samarth, 5% increase in chlorophyll a content was observed with 50µg/ml as compared to control. On the 28th day after treatment with Samarth, an increase of 7% in chlorophyll a content was observed with 50µg/ml with respect to control. Thus considerable increase in chlorophyll a content of *Nr*, with respect to control was observed with 50, 100, 200 and 300µg/ml of fertilizer Samarth treatment on different days of analyses.

After treatment with Samrat, *Nr* did not show considerable increase with concentrations 10 and 50µg/ml but however with 100, 200 and 300µg/ml increase in chlorophyll a content was 8%, 20% and 32% with respect to control. On 14th day no considerable increase was observed except with concentration 300µg/ml of Samrat which recorded 7% increase in chlorophyll a content with respect to control. On the 21st day *Nr* recorded similar results with 6% increase in chlorophyll a content with 300µg/ml with respect to control. On 28th day 3% increase in chlorophyll a content was observed with 300µg/ml with respect to control. Thus maximum increase in chlorophyll a content of *Nr*, with respect to control was observed with 300µg/ml of Samrat treatment on all the days (**Fig. 7.11 and 7.12**). Thus Chlorophyll a content of *N. rivulare* showed more positive response to Samarth than Samrat.

The positive response in chlorophyll a content of the three BGA to the fertilizers studied, was of the order, *Calothrix membranaceae*(Cm)>*Anabaena oryzae* (Ao)>*Nostoc rivulare*(Nr). Further it was observed that maximum chlorophyll a content was on the 21st day in all the BGA with both fertilizers, showing maximum metabolic activity and declines with age on 28th day.

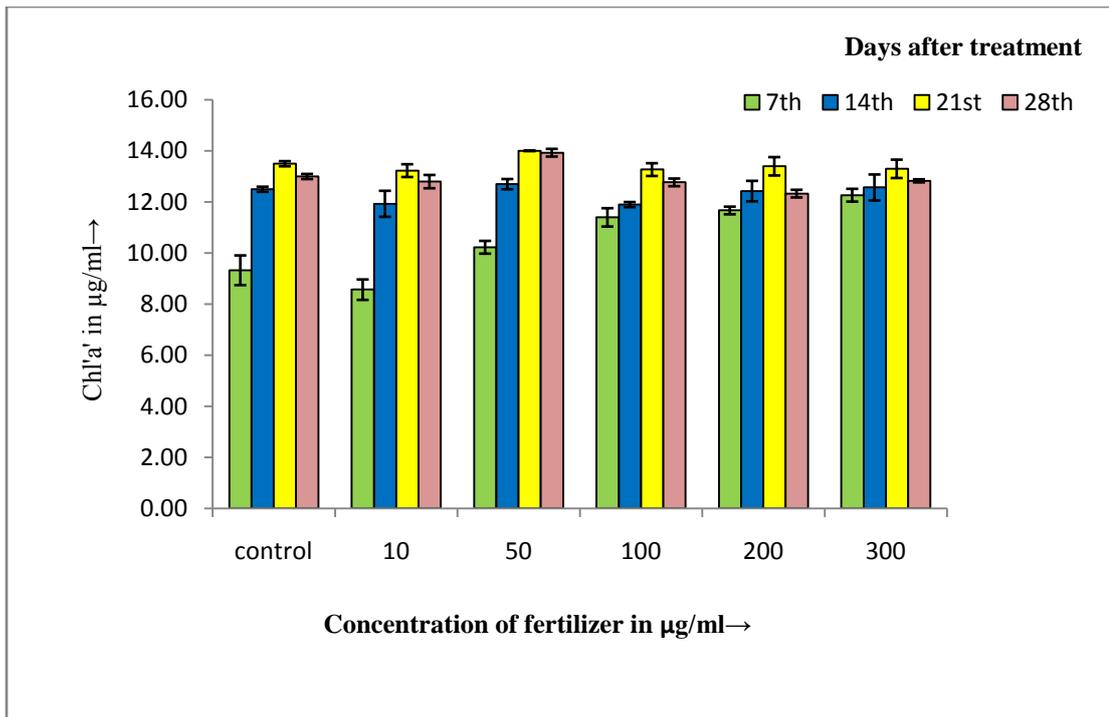


Fig. 7.11: Effect of fertilizer (Samarth) on chlorophyll a content of *N. rivulare*

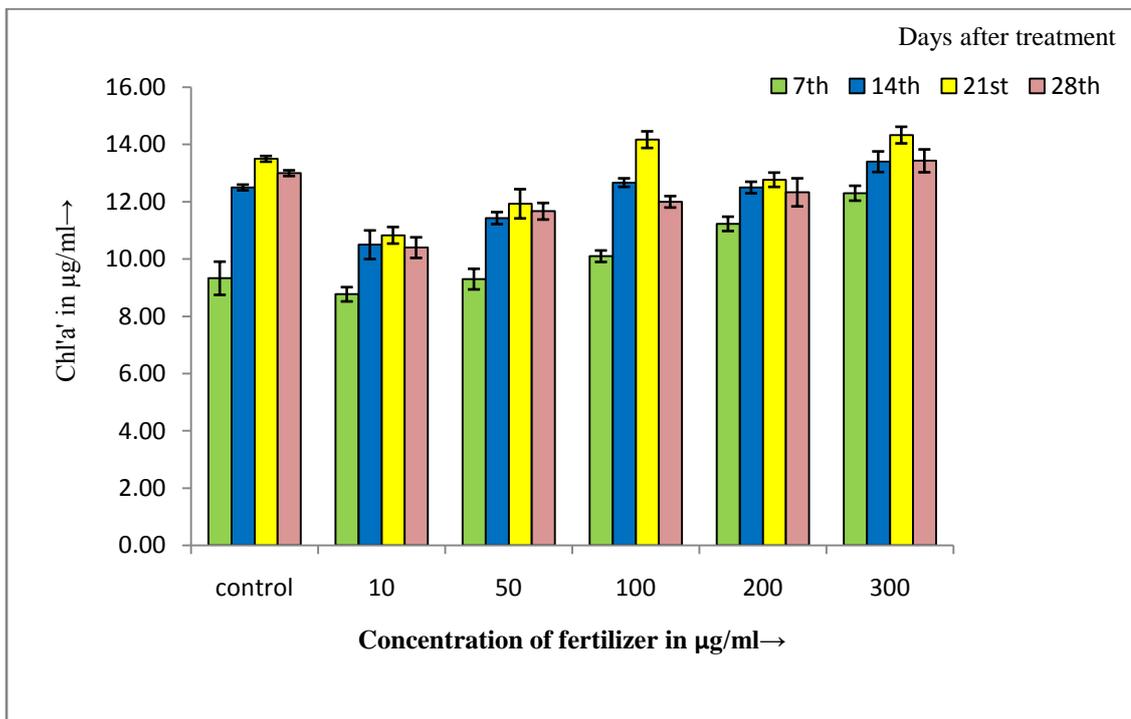


Fig. 7.12: Effect of fertilizer (Samrat) on chlorophyll a content of *N. rivulare*

c. Total protein content: Total protein content of the three algae when monitored from 7th day to 28th day after treatment with fertilizers, showed an increase in total protein content with concentration upto 300µg/ml. Total protein content go on increasing from 7th day till 28th day showing maximum increase with 300µg/ml on 28th day after treatment with fertilizers.

Anabaena oryzae (*Ao*) when treated with Samarth recorded 1.8% and 3.6% increase in total protein content with 10 and 50µg/ml respectively, whereas 100, 200 and 300µg/ml recorded an increase of 5%, 6% and 8% respectively. On 14th day, *Ao* recorded an increase of 4% with 300µg/ml of Samarth. On 21st day, concentrations 10, 50, 100 and 200µg/ml did not show considerable increase in total protein content whereas 300µg/ml recorded an increase of 4.7% as compared to control. On 28th day, concentrations 10, 50 and 100µg/ml does not show considerable increase in total protein content whereas 200 and 300µg/ml recorded an increase of 5% and 7% respectively in total proteins content with respect to control. After treatment with Samrat, *Ao* showed no increase in the first two concentrations but however increase in total protein content with 100, 200 and 300µg/100ml was 5%, 7% and 7.6% respectively. On 14th day however with concentrations 10, 50, 100 and 200µg/ml very little increase was reported but with 300µg/ml an increase in protein content of 2% was observed. On the 21st and 28th day, *Ao* recorded increase in total protein content of 6% and 6.3% each with 300µg/ml respectively with respect to control. Thus considerable increase in total protein content of *Ao*, with respect to control was observed with 300µg/ml of fertilizer treatment on all the days (**Fig. 7.13 and 7.14**). Total protein content of *A. oryzae* showed more positive response to Samarth than Samrat.

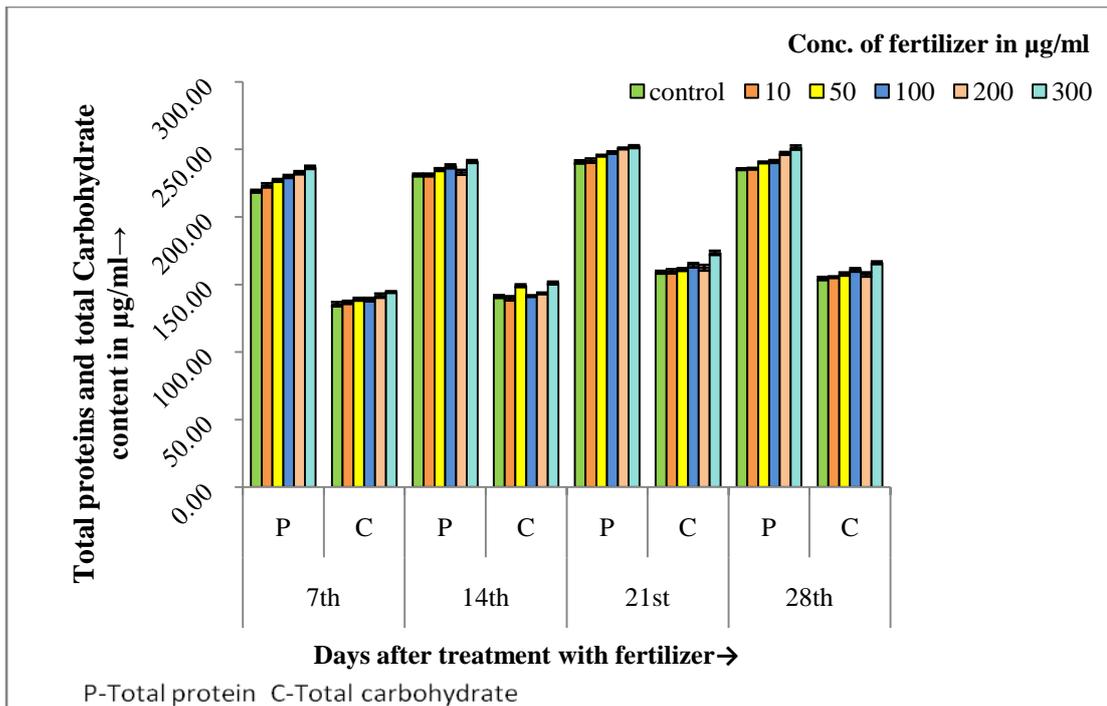


Fig. 7.13: Effect of fertilizer (Samrath) on total protein and total carbohydrate content of *A. oryzae*.

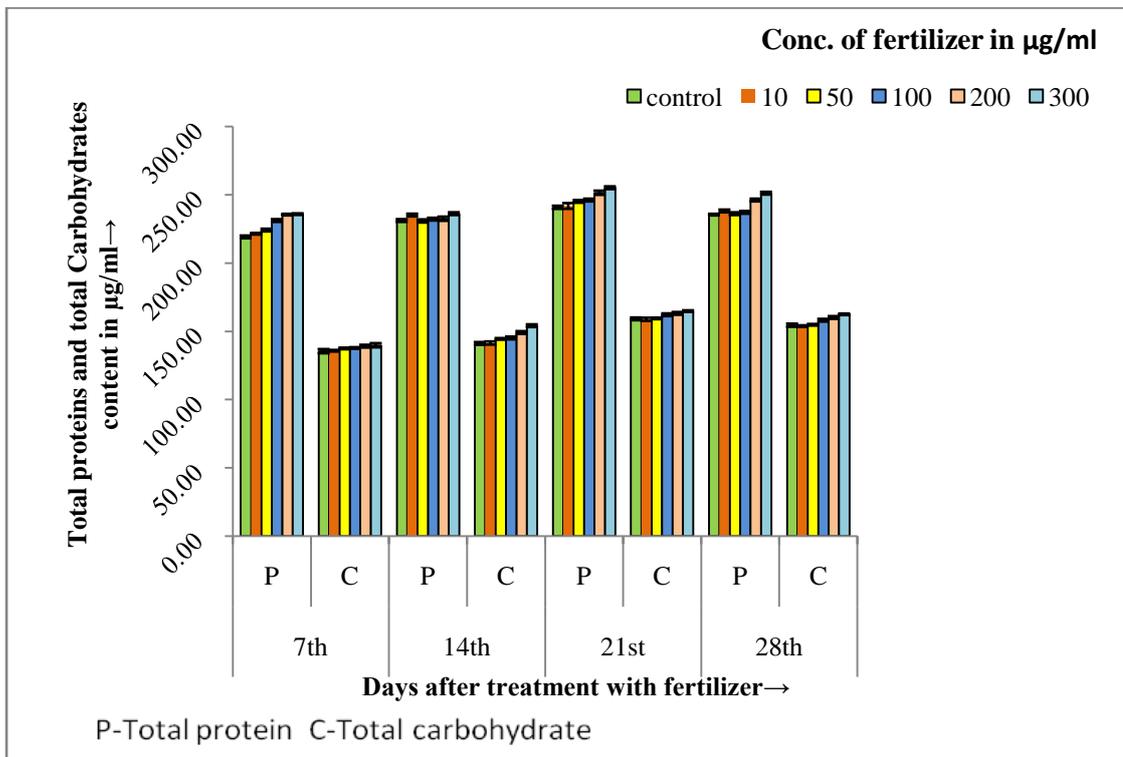


Fig. 7.14: Effect of fertilizer (Samrat) on total protein and total carbohydrate contents of *A. oryzae*.

Calothrix membranaceae (*Cm*), when treated with Samarth recorded 0.5% and 1% increase in total protein content with 10 and 50µg/ml respectively, whereas 100 and 200µg/ml both recorded 2% increase while 300µg/ml recorded an increase of 3%. On 14th day, *Cm* recorded an increase of 3% with 300µg/ml of Samarth. On 21st day, concentrations 10 and 50, 100 and 200µg/ml did not show considerable increase in total protein content whereas 300µg/ml recorded an increase of 4% as compared to control. On 28th day, concentrations 10, 50, 100 and 200µg/ml did not show considerable increase in total protein content whereas 300µg/ml recorded an increase of 5% in total proteins content with respect to control. After treatment with Samrat, *Cm* did not show considerable increase in the first four concentrations but however increase total protein content with 300µg/100ml was 2%. On 14th day however with concentrations 10, 50, 100 and 200µg/ml very little increase was reported but with 300µg/ml an increase in protein content of 3% was observed. On the 21st and 28th day, *Cm* recorded an increase of 5.6% and 4% in total protein content each with 300µg/ml respectively with respect to control. Thus considerable increase in total protein content of *Cm*, with respect to control was observed at 300µg/ml of fertilizer treatment on all the days (**Fig. 7.15 and 7.16**). Thus total protein content of *C. membranaceae* showed a better response to Samarth than Samrat.

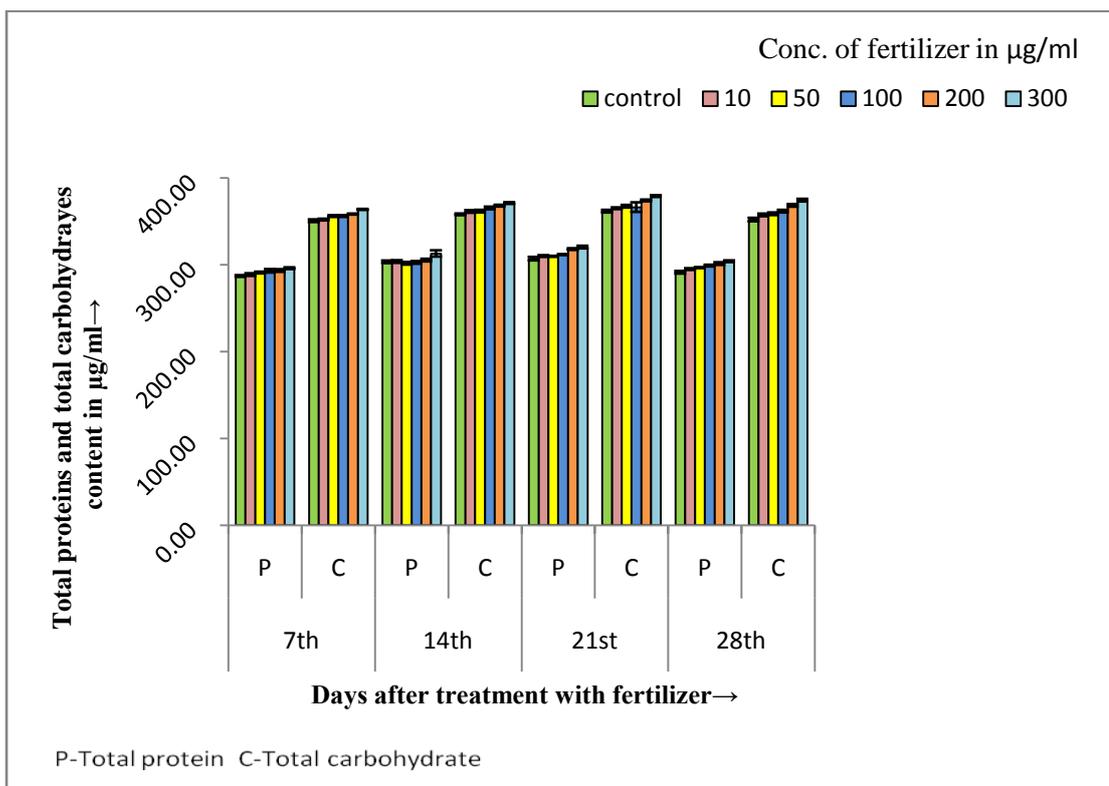


Fig. 7.15: Effect of fertilizer (Samarth) on total protein and total carbohydrate content of *C. membranacea*.

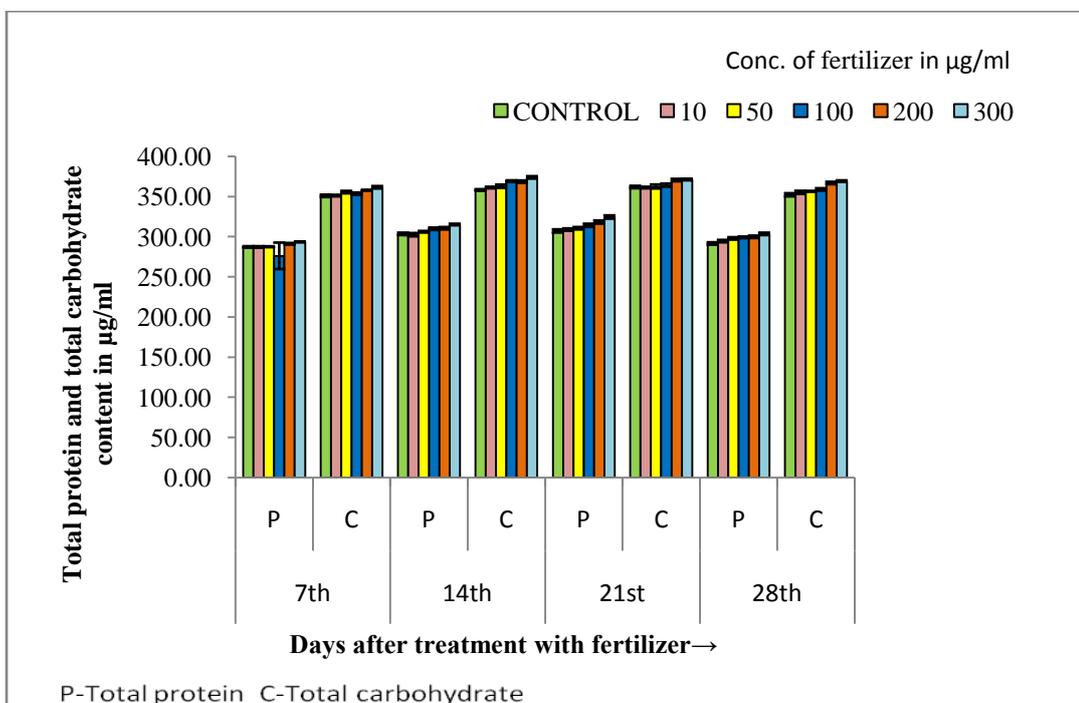


Fig. 7.16: Effect of fertilizer (Samrat) on total protein and total carbohydrate content of *C. membranacea*.

Nostoc rivulare (*Nr*), when treated with Samarth showed, 0.5% and 1.4% increase in total protein content with 10 and 50µg/ml respectively, whereas 100 and 200µg/ml recorded 2.4% and 2.8% increase and with 300µg/ml recorded an increase of 4% in total proteins with respect to control, on 14th day recorded an increase of 3.5% with 300µg/ml of Samarth. On 21st day, concentrations *Nr* recorded an increase in total protein content of 5% with 300µg/ml as compared to control. On 28th day, concentrations 10, 50, 100 and 200µg/ml does not show considerable increase in total protein content whereas 300µg/ml recorded an increase of 5% in total proteins content with respect to control. After treatment with Samrat, *Nr* recorded no considerable increase in the first two concentrations but however increase in total protein content with 100, 200 and 300µg/100ml was 5%, 7% and 7.6% respectively as compared to control. On 14th day however with concentrations 10, 50 and 100µg/ml showed very little increase but with 200 and 300µg/ml, increase was 6.3% and 6% respectively. On the 21st and 28th day *Nr* recorded an increase of 6.7% and 6.3% each with 300µg/ml respectively. Thus considerable increase in total protein content of *Nr*, with respect to control was observed with 300µg/ml of fertilizer treatment on all the days (**Fig. 7.17 and 7.18**). The positive response in total protein content of the three BGA to the fertilizers studied, is of the order, *Anabaena oryzae*(*Ao*)>*Nostoc rivulare*(*Nr*)>*Calothrix membranaceae*(*Cm*). Thus total protein content of *N. rivulare* showed more positive response to Samrat than Samarth. The positive response in total protein content of the three BGA to the fertilizers studied, is of the order, *Anabaena oryzae*(*Ao*)>*Nostoc rivulare*(*Nr*)>*Calothrix membranaceae*(*Cm*).

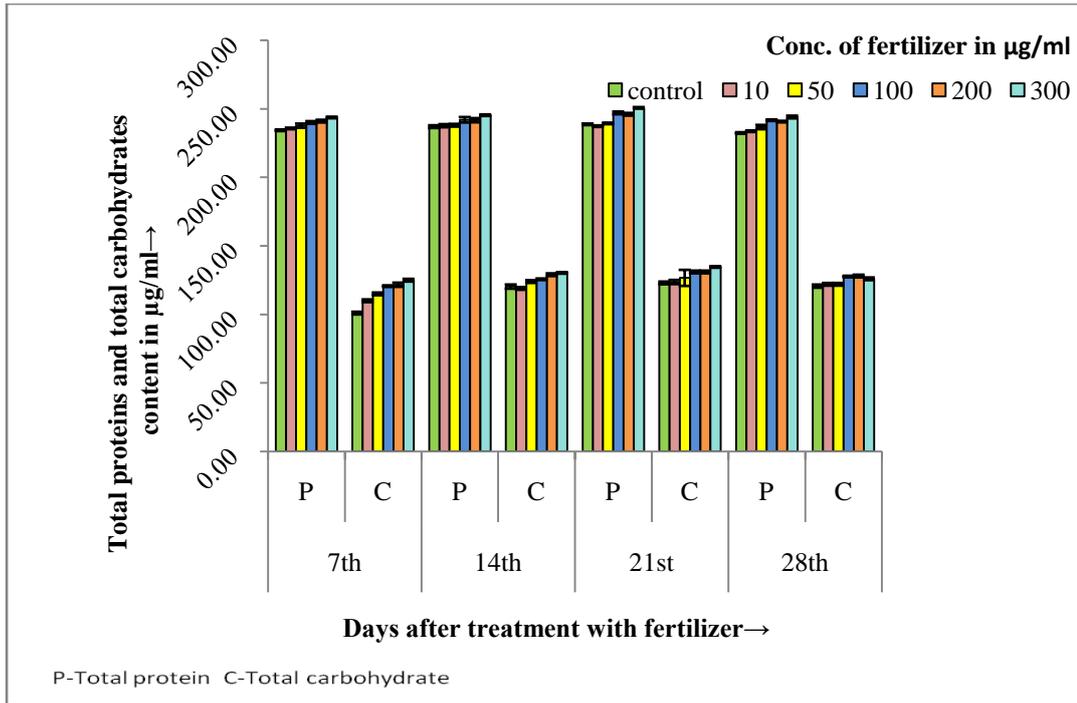


Fig. 7.17: Effect of fertilizer (Samarth) on total protein and total carbohydrate content of *N. rivulare*.

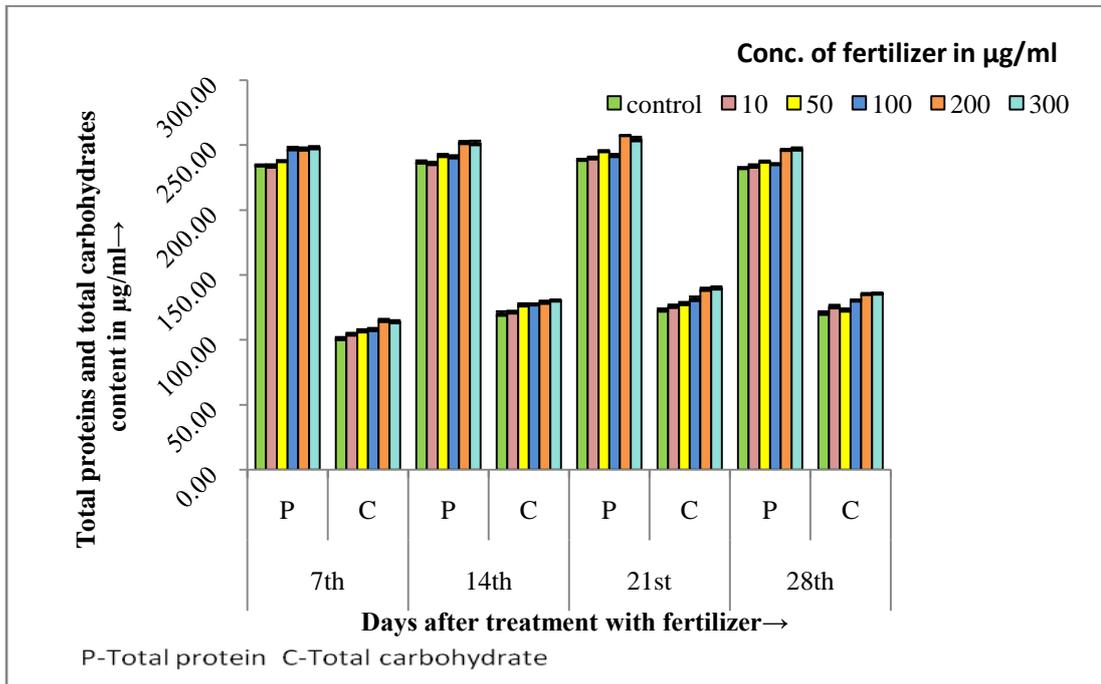


Fig. 7.18: Effect of fertilizer (Samrat) on total protein and total carbohydrate content of *N. rivulare*.

d. Total carbohydrate content:

Anabaena oryzae (*Ao*) when treated with Samarth recorded an increase in total carbohydrates content by 6.6% with 300µg/ml with respect to control, on 14th day recorded an increase of 7% with 300µg/ml of Samarth. On 21st day, *Ao* recorded an increase of 9% in total carbohydrates content with 300µg/ml. On 28th day, concentrations 10, 50, 100 and 200µg/ml did not show considerable increase in total carbohydrates content whereas 300µg/ml recorded an increase of 7.5% in total carbohydrates content with respect to control. After treatment with Samrat, *Ao* recorded no considerable increase in the first four concentrations but however increase in total carbohydrates content with 300µg/ml was 3.2% as compared to control. On 14th day however with concentrations 10, 50 and 100µg/ml showed very little increase but with 200 and 300µg/ml an increase in total carbohydrates content observed was 5.6% and 9.2% respectively. On the 21st and 28th day *Ao* recorded increase in total protein content 3.5% and 5% each with 300ug/ml respectively with respect to control. Thus considerable increase in total protein content of *Ao*, with respect to control was observed with 300µg/ml of fertilizer treatment on all the days (**Fig. 7.13 and 7.14**). Thus total carbohydrate content of *A. oryzae* showed more positive response to Samarth than Samrat

Calothrix membranaceae (*Cm*), when treated with Samarth recorded an increase in total carbohydrates content by 3.7% with 300µg/ml with respect to control, on 14th day recorded an increase of 3.6% with 300µg/ml of Samarth. On 21st day, recorded *Cm* recorded an increase of 4.8% in total carbohydrates content with 300µg/ml as compared to control. On 28th day, concentrations 10, 50, 100 and 200µg/ml did not show considerable increase in total carbohydrates content whereas

300µg/ml recorded an increase of 7.5% in total carbohydrates content with respect to control. After treatment with Samrat, *Cm* did not show considerable increase in the first four concentrations but however increase in total carbohydrates content with 300µg/ml was 3% as compared to control. On 14th day however with concentrations 10, 50, 100 and 200µg/ml show very little increase but with 300µg/ml an increase in total carbohydrates content observed was 4.3%. On the 21st and 28th day *Cm* recorded increase in total carbohydrates content was 2.6% and 4.8% respectively with 300µg/ml with respect to control. Thus considerable increase in total carbohydrates content of *Cm*, with respect to control was observed with 300µg/ml of fertilizer treatment on all the days (**Fig. 7.15 and 7.16**). Thus total carbohydrate content of *C. membranacea* showed more positive response to Samarth than Samrat.

Nostoc rivulare (*Nr*), when treated with Samarth recorded an increase in total carbohydrates content by 8.9% and 13% with 10 and 50µg/ml respectively whereas with 100, 200 and 300µg/ml recorded an increase by 19%, 20% and 23% respectively with respect to control, on 14th day *Nr* recorded an increase of 8.3% with 300µg/ml of Samarth. On 21st day, recorded *Nr* recorded an increase of 9.5% in total carbohydrates content with 300µg/ml as compared to control. On 28th day, concentrations 10 and 50µg/ml did not show considerable increase in total carbohydrates content whereas 100 and 200µg/ml and 300µg/ml recorded an increase of 5.8%, 6% and 4.4% in total carbohydrates content with respect to control. After treatment with Samrat, *Nr* did not record considerable increase in the first four concentrations but however increase in total carbohydrates content with 300µg/ml was 3.2% as compared to control. On 14th day however at concentrations 10, 50 and 100µg/ml show very little increase but at 200 and 300µg/ml an increase in total carbohydrates content observed was 7.2% and

8.3% respectively as compared to control. On the 21st and 28th day *Nr* recorded increase in total carbohydrates content was 14% and 12.4% respectively with 300µg/ml with respect to control. Thus considerable increase in total carbohydrates content of *Nr*, with respect to control was observed with 300µg/ml of fertilizer treatment on all days of analyses (**Fig. 7.17 and 7.18**). Thus total carbohydrate content of *N. rivulare* showed more positive response to Samrat than Samarth.

The positive response in total carbohydrate content of the three BGA to the fertilizers studied, is of the order, *Nostoc rivulare*(*Nr*)>*Anabaena oryzae*(*Ao*)>*Calothrix membranaceae*(*Cm*).

In order to study the effect of different concentrations of fertilizers Samarth and Samrat on biomass, chlorophyll a content, total proteins and total carbohydrate content for each blue green algae viz., *Anabaena oryzae*, *Calothrix membranacea* and *Nostoc rivulare*, correlation and regression analysis was performed. Pearsons correlation co-efficient (r-values) were determined and its significance was tested by t-test to determine P-value (significance level). Whenever significant correlation was found, it was used to estimate the effect on biomass, chlorophyll a content, total protein and total carbohydrate content for a given concentration of the fertilizers. This was done by regression analysis. From this the desired correlation is estimated for required biomass, chlorophyll a content, total protein content and total carbohydrate content. The correlation as well the prediction of biomass, chlorophyll a content, total protein and carbohydrate content is done for each time intervals of 7th, 14th, 21st and 28th day.

A significant positive correlation was found in *A. oryzae* between increasing concentration of fertilizers with increase in biomass on 7th and 14th day of treatment

which are statistically significant ($p < 0.05$) however on 21st and 28th day the correlation was not significant (**Table 7.2**). Chlorophyll a content showed positive correlation on all days with both the fertilizers however significant correlations were seen on 14th, 21st and 28th day for Samarth and on 14th day for Samrat (**Table 7.3**). Total protein content and total carbohydrate content showed significant positive correlations on all days except on the 14th day for proteins and carbohydrates with Samarth and 14th day for proteins with Samrat, though the correlation was positive but not significant (**Table 7.4**).

Table 7.2: Effect of fertilizers (Samarth and Samrat) on biomass content of *A. oryzae*.

Treatment	Day after treatment	Correlation Coefficient		Regression Coefficient	Regression Equation*
		r	p	(b)	(y=a+bx)
Samarth	7 th	0.92	0.01	0.0004	y=0.13 + 0.0004x
	14 th	0.99	0.01	0.003	y=0.87 + 0.003x
	21 st	-0.74	0.09, ns	-0.02	y=1.05 - 0.02x
	28 th	-0.44	0.38, ns	-0.004	y=0.22 - 0.004x
Samrat	7 th	0.87	0.05	0.003	y=0.12 + 0.003x
	14 th	0.98	0.01	0.004	y=0.88 + 0.004x
	21 st	0.91	0.05	0.003	y=0.93 + 0.003x
	28 th	0.85	0.05	0.008	y=0.25 + 0.008x

ns=not significant; (significance p<0.05)

*y and x stand for effect and concentration respectively.

Table 7.3 : Effect of fertilizers (Samarth and Samrat) on chlorophyll a content of *A. oryzae*.

Treatment	Day after treatment	Correlation coefficient		Regression coefficient	Regression Equation*
		r	p	(b)	(y=a+bx)
Samarth	7 th	0.70	0.12, ns	0.05	y=11.0 + 0.05x
	14 th	0.89	0.05	0.06	y=11.6 + 0.06x
	21 st	0.86	0.05	0.04	y=12.7 + 0.04x
	28 th	0.83	0.05	0.05	y=12.0 + 0.05x
Samrat	7 th	0.58	0.23, ns	0.02	y=11.1 + 0.02x
	14 th	0.91	0.05	0.02	y=11.7 + 0.02x
	21 st	0.67	0.15, ns	0.03	y=12.1 + 0.03x
	28 th	0.46	0.36, ns	0.02	y=11.7 + 0.02x

ns=not significant; (significance p<0.05)

*y and x stand for effect and concentration respectively.

Table 7.4: Effect of fertilizers (Samarth and Samrat) on total protein content and total carbohydrate content of *A. oryzae*.

Treatment		Day after treatment	Correlation coefficient		Regression Coefficient	Regression Equation*
			r	p	(b)	(y=a+bx)
Samarth	P	7 th	0.94	0.01	0.51	y=223 + 0.51x
		14 th	0.75	0.08 ns	0.25	y=232 + 0.25x
		21 st	0.95	0.01	0.36	y=240 + 0.36x
		28 th	0.88	0.05	0.54	y=238 + 0.54x
	C	7 th	0.97	0.01	0.27	y=136 + 0.27x
		14 th	0.64	0.17 ns	0.25	y=141 + 0.25x
		21 st	0.89	0.05	0.40	y=159 + 0.40x
		28 th	0.84	0.05	0.30	y=155 + 0.30x
Samrat	P	7 th	0.93	0.01	0.57	y=221 + 0.57x
		14 th	0.53	0.28 ns	0.10	y=232 + 0.10x
		21 st	0.99	0.01	0.47	y=241 + 0.47x
		28 th	0.95	0.01	0.52	y=235 + 0.52x
	C	7 th	0.95	0.01	0.14	y=136 + 0.14x
		14 th	0.99	0.01	0.42	y=141 + 0.42x
		21 st	0.97	0.01	0.20	y=159 + 0.20x
		28 th	0.98	0.01	0.29	y=154 + 0.29x

P – Total proteins; C–Total carbohydrates.

ns=not significant; (significance p<0.05).

*y and x stand for effect and concentration respectively.

A significant positive correlation was found in *C. membranacea* between increasing concentration of fertilizers with increase in biomass (**Table 7.5**). Chlorophyll a content also showed positive correlation but it was not statistically significant except on 28th day for Samrat where it was statistically significant (**Table 7.6**). Total protein content and total carbohydrate content showed positive correlations on all days of treatment but statistically significant results were obtained for total proteins on 7th and 28th day with Samrat (**Table 7.7**).

Table 7.5: Effect of fertilizers (Samarth and Samrat) on biomass content of *C. membranacea*.

Treatment	Day after treatment	Correlation coefficient		Regression coefficient	Regression Equation*
		r	p	(b)	(y=a+bx)
Samarth	7 th	0.98	0.01	0.007	y=0.74 + 0.007x
	14 th	0.66	0.16 ns	0.002	y=0.91 + 0.002x
	21 st	0.40	0.43 ns	0.001	y=0.97 + 0.001x
	28 th	0.91	0.05	0.015	y=0.17 + 0.015x
Samrat	7 th	0.86	0.05	0.007	y=0.77 + 0.007x
	14 th	0.95	0.01	0.002	y=0.89 + 0.002x
	21 st	0.93	0.01	0.002	y=0.93 + 0.002x
	28 th	0.90	0.05	0.014	y=0.25 + 0.014x

ns=not significant; (significance p<0.05)

*y and x stand for stand for effect and concentration respectively.

Table 7.6: Effect of fertilizers (Samarth and Samrat) on chlorophyll a content of *C. membranacea*.

Treatment	Day after treatment	Correlation coefficient		Regression coefficient	Regression Equation*
		r	p	(b)	(y=a+bx)
Samarth	7 th	0.58	0.23 ns	0.08	y=9.33 + 0.08x
	14 th	0.47	0.35 ns	0.06	y=10.5 + 0.06x
	21 st	0.58	0.22 ns	0.03	y=12.0 + 0.03x
	28 th	0.05	0.93 ns	0.004	y=11.2 + 0.004x
Samrat	7 th	0.79	0.06 ns	0.14	y=8.32 + 0.14x
	14 th	0.74	0.09 ns	0.10	y=10.0 + 0.10x
	21 st	0.68	0.14 ns	0.05	y=12.0 + 0.03x
	28 th	0.84	0.05 s	0.07	y=10.6 + 0.07x

ns=not significant; (significance p<0.05)

*y and x stand for stand for effect and concentration respectively.

Table 7.7: Effect of fertilizers (Samarth and Samrat) on total protein and total carbohydrate content of *C. membranacea*.

Treatment		Day after treatment	Correlation coefficient		Regression coefficient	Regression Equation*
			r	p	(b)	(y=a+bx)
Samarth	P	7 th	0.93	ns	0.26	y=289 + 0.26x
		14 th	0.86	ns	0.26	y=302 + 0.26x
		21 st	0.98	ns	0.43	y=308 + 0.43x
		28 th	0.95	ns	0.36	y=294 + 0.36x
	C	7 th	0.96	ns	0.38	y=352 + 0.38x
		14 th	0.97	ns	0.39	y=360 + 0.39x
		21 st	0.98	ns	0.52	y=364 + 0.52x
		28 th	0.98	ns	0.647	y=355 + 0.67x
Samrat	P	7 th	0.91	0.05	0.22	y=286 + 0.22x
		14 th	0.96	ns	0.39	y=303 + 0.39x
		21 st	0.99	ns	0.55	y=308 + 0.55x
		28 th	0.91	0.05	0.32	y=294 + 0.32x
	C	7 th	0.95	ns	0.33	y=351 + 0.33x
		14 th	0.93	ns	0.46	y=360 + 0.46x
		21 st	0.97	ns	0.36	y=361 + 0.36x
		28 th	0.98	ns	0.56	y=353 + 0.56x

P – Total proteins; C–Total carbohydrates; ns=not significant; (significance p<0.05).

*y and x stand for effect and concentration respectively.

Table 7.8: Effect of fertilizers (Samarth and Samrat) on biomass content of *N. rivulare*.

Treatment	Day after treatment	Correlation coefficient		Regression coefficient	Regression Equation*
		r	p	(b)	(y=a+bx)
Samarth	7 th	0.98	0.01	0.001	y=0.11 + 0.001x
	14 th	-0.05	0.93 ns	0.0001	y=0.84 + 0.0001x
	21 st	0.84	0.05	0.004	y=0.88 + 0.004x
	28 th	0.79	0.06 ns	0.002	y=0.26 + 0.002x
Samrat	7 th	0.98	0.01	0.001	y=0.11 + 0.001x
	14 th	0.97	0.01	0.001	y=0.82 + 0.001x
	21 st	0.99	0.01	0.003	y=0.90 + 0.003x
	28 th	0.55	0.26 ns	0.002	y=0.29 + 0.002x

ns=not significant; (significance p<0.05)

*y and x stand for effect and concentration respectively.

Table 7.9: Effect of fertilizers (Samarth and Samrat) on chlorophyll a content of *N. rivulare*.

Treatment	Day after treatment	Correlation coefficient		Regression coefficient	Regression Equation*
		r	p	(b)	(y=a+bx)
Samarth	7 th	0.90	0.05	0.11	y=9.37 + 0.11x
	14 th	0.29	0.58 ns	0.01	y=12.2 + 0.01x
	21 st	-0.28	0.59 ns	-0.01	y=13.5 - 0.01x
	28 th	-0.40	0.44 ns	-0.02	y=13.1 - 0.02x
Samrat	7 th	0.98	0.01	0.11	y=8.94 + 0.11x
	14 th	0.71	0.11	0.06	y=11.5 + 0.06x
	21 st	0.56	0.25 ns	0.06	y=12.2 + 0.06x
	28 th	0.59	0.22 ns	0.05	y=11.6 + 0.05x

ns=not significant; (significance p<0.05)

*y and x stand for effect and concentration respectively.

Table 7.10: Effect of fertilizers (Samarth and Samrat) on total protein and total carbohydrate content of *N. rivulare*.

Treatment		Day after treatment	Correlation coefficient		Regression coefficient	Regression Equation*
			r	p	(b)	(y=a+bx)
Samarth	P	7 th	0.96	0.01	0.28	y=236 + 0.28x
		14 th	0.94	0.01	0.26	y=237 + 0.26x
		21 st	0.91	0.05	0.42	y=239 + 0.42x
		28 th	0.89	0.05	0.35	y=234 + 0.35x
	C	7 th	0.85	0.05	0.64	y=109 + 0.64x
		14 th	0.95	0.01	0.36	y=121 + 0.36x
		21 st	0.94	0.01	0.37	y=124 + 0.37x
		28 th	0.73	0.09 ns	0.20	y=122 + 0.20x
Samrat	P	7 th	0.97	ns	0.50	y=235 + 0.50x
		14 th	0.94	ns	0.56	y=237 + 0.56x
		21 st	0.94	ns	0.53	y=240 + 0.53x
		28 th	0.94	ns	0.51	y=233 + 0.51x
	C	7 th	0.92	ns	0.42	y=104 + 0.42x
		14 th	0.87	0.05	0.30	y=123 + 0.30x
		21 st	0.97	ns	0.57	y=125 + 0.57x
		28 th	0.94	ns	0.49	y=123 + 0.49x

P – Total protein; C – Total carbohydrates; ns=not significant; (significance p<0.05)

*y and x stand for effect and concentration respectively.

A significant positive correlation was found in *N. rivulare* between increasing concentration of fertilizers with increase in biomass except on 14th and 28th day with Samarth where the correlation was not significant (**Table 7.8**). Chlorophyll content also showed significant positive correlation on all days of treatment except on 14th, 21st, 28th day with Samarth (**Table 7.9**). Total protein and total carbohydrate content showed significant positive correlations on all days of treatment with Samarth while with Samrat non significant results were observed for total proteins whereas total carbohydrate showed significant positive correlation with Samrat on 14th day (**Table 7.10**).

DISSCUSSION:

The present investigation on indigenous cyanobacterial species indicate that they are not affected at recommended levels of commercial fertilizers used in paddy fields of Goa. As observed from the results, there was an increase in biomass, chlorophyll a, total carbohydrate and total proteins contents. This could be attributed to increased nitrogen fixation due to addition of P in either soluble or insoluble form. Similar reports are available from previous studies. A study with different soil samples from Bengal and Assam states of India with $\text{Ca}_3(\text{PO}_4)_2$, revealed that the nutrients stimulate algal growth in paddy fields (De and Sulaiman, 1950). Combined application of N and P stimulated the growth of some cyanobacterial species (Mahapatra *et al.*, 1971). Cyanobacterial species could not thrive well in soils treated with higher dose of ammonium sulphate (80kg/ha) alone, but however recorded enhanced growth with P at all levels of application. Anand and Karuppusamy (1987) reported that lower concentration of fertilizers supported all morphological types of cyanobacteria. Anand (1992) reported that certain cyanophycean members continue to fix nitrogen even in the presence of commercial nitrogen fertilizers.

The fertilizers used in the study *viz.*, Samarth and Samrat are chemically different (NPK and DAP) and this could be attributed to differential growth response of BGA. Anand (1992) reported that 50 $\mu\text{g/ml}$ of urea, DAP and 100 $\mu\text{g/ml}$ of potash stimulated growth of *Anabaena sp.* whereas *Cylindrospermum* recorded enhanced growth from 10 to 20 $\mu\text{g/ml}$ DAP and 10 $\mu\text{g/ml}$ NPK. Nitrate nitrogen being favourable to these organisms, shows only marginal reduction in growth. Suseela and Goyal (1995) have screened several strains of cyanobacteria for their capacity to fix nitrogen in the presence of ammonium nitrogen and found that nitrogenase was active even at 100 mg ammonium ml^{-1} . When *Nostoc entophyllum* and *Calothrix*

scopulorum were treated *in vivo* with ammonium chloride and sodium nitrate recorded that growth of *N. entophytum* was stimulated up to 500µg/ml of sodium nitrate maintaining the blue green colour of the cultures. *Calothrix scopulorum* however flourished in all nitrate-nitrogen series. In ammonium nitrogen however growth accelerated like that of nitrate-nitrogen series up to 50µg/ml but decreased considerably beyond 250µg/ml (Stewart, 1964). Similarly 16 cyanobacterial species isolated from paddy fields soils of Vidharba region of Maharashtra state when treated with ammonium-nitrogen stimulated the growth up to 75µg/ml except *Anabaena khannae* which exhibited a retardation of growth at 50µg/ml (Kolte and Goyal, 1989). Fifteen cyanobacterial species isolated from paddy fields of Andhra Pradesh when grown in a medium supplemented with ammonium chloride up to 100µg/ml recorded an accelerated growth and chlorophyll a content with up to 75µg/ml of ammonium chloride. The present study confirms that lower levels of commercial fertilizers stimulate the growth of BGA.

The present study also showed that BGA respond differently to different fertilizers depending on the fertilizer-BGA interaction. Biomass and chlorophyll content of *C. membranacea* was higher followed by *A. oryzae* and *N. rivulare* in response to fertilizer treatments. The carbohydrate content of *Nr* was higher followed by *Ao* and *Cm* whereas protein content of *Ao* showed higher content followed by *Nr* and *Cm*. Stewart (1964) and Venkataraman (1979) reported that in certain cyanobacteria, nitrogen fixation continued even at 50µg/ml of ammonium nitrogen under field conditions and grow faster in the presence of higher levels of fertilizer nitrogen and fix comparatively less nitrogen. However, when the combined nitrogen was removed due to progressive utilization and/or natural loss, their nitrogen fixing capacity was regained. Thus the various studies suggest that recommended doses of

commercial fertilizers used by farmers for paddy cultivation do not adversely affect the indigenous cyanobacterial species. Singh, (1975) showed that all 12 cyanobacterial strains tested for their tolerance to nitrogen and non-nitrogen commercial fertilizers, showed retarded growth at higher concentrations of fertilizers (500µg/ml).

This study on the indigenous cyanobacterial species from paddy fields of Goa revealed important facts about BGA-fertilizer responses. Therefore it is important to refine techniques for qualitative and quantitative examination of soil cyanobacteria and to evaluate their activity and importance to soil fertility. It is also imperative to evaluate the relative chemical fertilizer sensitivities of different cyanobacterial species. Most of the diazotrophic cyanobacterial forms are known to play dual role of being able to fix elemental nitrogen and also utilize various types of nitrogenous fertilizers for their growth which are made available to the crop later. Selection of such cyanobacterial strains to develop niche specific inocula of indigenous cyanobacterial species will be highly beneficial.

INTRODUCTION:

The inoculation of chemical pest control measures has brought into use many powerful pesticides and insecticides. Some of which are even added to irrigation water (Venkataraman, 1975). Generally pesticides may be inhibitory, stimulating or neutral to the growth of algae depending on the nature of the chemical, its concentration and the algal strain (Roger and Kulasoorya, 1980). Since blue green algae are increasingly used as biofertilizer in paddy fields (Venkataraman, 1981), it is imperative that the influence of various agrochemicals on these organisms be thoroughly understood. Attempts to study the effects of different chemicals on different organisms have been made by many workers (Tomisck *et al.*, 1957; Pillay and Tochan, 1970; Inger, 1970; Venkataraman and Rajyalakshmi, 1971; Singh, 1973; Hendrich *et al.*, 1976; Bharati and Giriappanavar, 1986; Subramanian and Shanmugasundram, 1986). The effect of pesticides methyl parathion, malathion, thiodon kalux on primary productivity of fresh water phytoplanktons have been also reported (Alaguchamy and Chandran, 2008).

Organophosphorus (OP) insecticides were introduced as replacement for the persistent organochlorine insecticides such as DDT (Ma *et al.*, 2005). The increased use of OP's originally seen as less of a threat to the environment due to their low persistence has led to a different range of ecotoxicological problems associated with their high acute toxicity (Galloway and Handy, 2003). However, their use may allow them to enter fresh water ecosystems by spray drift, leaching, run-off or accidental spills and present potential risk for aquatic flora (Van der Brink and Ter Braak, 1999). Alterations of the species composition of an aquatic community as a result of toxic stress may affect the structure and the functioning of the whole ecosystem (Verdisson

et al., 2001). Green algae and cyanobacteria are known to be comparatively sensitive to many chemicals (Real *et al.*, 2003). Their ecological position at the base of most aquatic food webs and the essential roles in the nutrient and phosphorus cycling are critical to ecosystems (Sebater and Carrasco, 2001).

Tests on a certain species of algae are of limited applicability in assessing the effects of environmental contaminants on algal communities, which are composed of an array of species with different sensitivities (Ma *et al.*, 2004 b, c). A lot of work has been carried out on the comparative sensitivity of pesticides towards various green algae (Abou-Waly *et al.*, 1991, Junghans *et al.*, 2003; Ma *et al.*, 2003 and 2004a), also there are reports showing the differential response of various cyanobacteria and green algae (Bhaskar *et al.*, 2004) to pesticides. The discovery of sulfonylurea herbicides capable of suppressing weeds at extremely low application rates are viewed as an important advancement in chemical weed control (Pillmoor, 1989; Saari *et al.*, 1994).

The effect of pesticides (insecticides and herbicides) on nitrogen fixing cyanobacteria capable of enhancing the fertility of agricultural soils (paddy fields) in Goa has not been investigated. The commonly used pesticides in for paddy cultivations in Goa were Rogar 30, Monocrotophos, Butachlor and Phorate.

The objective of this study was to determine the effect of different concentrations of four pesticides *viz.*, Rogar 30, Monocrotophos, Butachlor and Phorate on the selected parameters *viz.*, Biomass, Chlorophyll a content, total proteins and total carbohydrates content of selected indigenous BGA.

MATERIAL AND METHODS:

Source of chemicals: The information regarding the usage of various pesticides was collected from the State Agricultural department and from the local farmers. The chemical formulation and details of manufacturer are given in Table 8.1.

Table 8.1: Chemical formulations of pesticides.

Pesticide	Chemical formulation	Manufacturer
Rogar 30 (rogarin)	Dimethoate 30% EC	M/s Insecticide (India) Ltd, Riico Industrial area, Chopanki (Bhiwadi) Rajasthan.
Monocrotophossaan (monosaan)	Monocrotophos 36% SL	M/s Zuari Industries ltd, Jai Kissan Bhawan, Zuarinagar, Goa.
Butachlor (butasaan)	Butachlor 50% EC	M/s Zuari Industries Ltd, Jai Kissan Bhawan, Zuarinagar, Goa.
Phorate (phorasaan)	Phorate 10% CG	M/s Zuari Industries Ltd, Jai Kissan Bhawan, Zuarinagar, Goa.

The stock solution of each pesticide was freshly prepared before being added to the culture medium. From the stock solution graded concentrations for the treatment were prepared.

Algal cultures were maintained in BG-11 medium (Stainer *et al.*, 1973) at $28^{\circ}\text{C} \pm 2^{\circ}\text{C}$ under fluorescent light (tube) at an intensity of $36 \mu\text{mol m}^{-2}\text{s}^{-1}/2000 \text{ Lux}$. The experimental cultures were first grown in 250 ml flasks containing 100 ml of medium with 0.5 million cells to million cells per millilitre under the same condition described above. The cultures were shaken manually for 30 minutes three times a day. At the exponential growth phase of the algal cultures, different concentration (1, 5,

10, 20 and 30µg/ml) of each pesticide (10ml) were added to the culture flasks and studied at intervals of 7 days i.e. 7th, 14th, 21st and 28th day after treatment.

Distilled water was added to cultures maintained as controls. Each treatment was carried out in triplicate. Samples were collected every 7th day after pesticide treatment for growth, analysis of total proteins and total carbohydrates content and chlorophyll a content. Growth of algae was measured in terms of biomass (Richmond and Grobbelaar, 1986), total carbohydrate content (Dubois *et al.*, 1956), proteins content (Lowry *et al.*, 1951) and chlorophyll a content (Mackinney, 1941) as given in the previous chapter.

RESULTS:

Effect of pesticides Rogar 30, Monocrotophos, Butachlor and Phorate on biomass, chlorophyll 'a' content, total proteins and total carbohydrate content on *Anabaena oryzae*, *Calothrix membranaceae*, *Nostoc rivulare*, showed that at low concentration of 1 and 5 µg/ml of the pesticides, growth is stimulated as seen by increasing biomass, chlorophyll a content, total protein and total carbohydrates content but at higher concentration starting from 10, 20 and 30 µg/ml of the pesticides, growth is retarded showing a decline in biomass, chlorophyll a content, total protein and total carbohydrate content (**Fig. 8.1 to Fig. 8.36**). As the algae ages, the biomass, chlorophyll a content, total protein and total carbohydrate content of control plants increases from the 7th day and is maximum on 14th and 21st day which reduces considerably on the 28th day after treatment indicating the lag phase of growth.

a. Biomass:

The effect of the four pesticides on the biomass of BGA viz., *Anabaena oryzae*, *Calothrix membranaceae*, *Nostoc rivulare* showed an initial stimulatory increase which reduces as the concentration of pesticides increases. On the 7th day, with 1 and 5 µg/ml of Rogar 30, *Anabaena oryzae* (Ao) showed stimulatory increase in biomass by 30% and 46% respectively, but at concentrations 10, 20 and 30 µg/ml there was decrease in biomass by 15.4%, 23% and 46% respectively as compared to control. On 14th day, the concentrations 1 and 5 µg/ml showed 2.35% increase over control but at 10, 20 and 30 µg/ml showed a decrease of 28%, 29.4%, and 38.8% respectively as compared to control. There was a marked decrease in biomass at 30 µg/ml of Rogar 30. On the 21st day BGA treated with 1 and 5 µg/ml of pesticides

showed an increase by 8% and 10% respectively but at higher concentration 10, 20 and 30µg/ml of pesticides showed an abrupt decrease of 52%, 72%, and 90.7% respectively over control. Thus maximum decrease is seen at 30µg/ml of Rogar 30. Monocrotophos also affected *A. oryzae* similarly showing stimulatory growth in the lower concentration and retarded growth at higher concentration of 30µg/ml of pesticides. On the 7th day *A. oryzae* showed 50% decrease in biomass over control at 30µg/ml of pesticides. On 14th day 49.4% decrease over control at 30µg/ml of pesticides and 21st day it showed 90.46% decrease over control at 30µg/ml of Monocrotophos. When *A. oryzae* was treated with Butachlor, on the 7th day biomass decreased by 53.85% over control at 30µg/ml, on 14th day it decreased by 69.41% and on the 21st day it decreased by 91.51% at 30µg/ml of Butachlor. When treated with Phorate, on 7th day *A. oryzae* showed a decrease of 53% at 30µg/ml of Phorate, on 14th day 51.76% and on 21st day 79% decrease in biomass at 30µg/ml of phorate.

Calothrix membranacea (*Cm*) also showed an initial increase in biomass at lower concentration of 1 and 5µg/ml of different pesticides but at higher concentration of 10, 20 and 30µg/ml showed a gradual decrease starting from 1µg/ml of pesticides till 30 µg/ml, which showed the maximum decrease. With 30µg/ml of Rogar 30, *Cm* showed on the 7th day after treatment a decrease of 61.64%, on 14th day it showed a decrease of 73.86% and on 21st day a decrease of 77% with respect to control. After treatment with 30µg/ml of Monocrotophos, *Cm* showed on 7th day a decrease of 69%, on 14th day a decrease of 64.7% and on 21st day a decrease of 67% with respect to control. After treatment with Butachlor with 30µg/ml, *Cm* showed on 7th day a decrease of 68%, on 14th day a decrease of 74%, on 21st day a decrease of 79.78% with respect to control. After treatment with Phorate at 30µg/ml, on 7th day *Cm*

showed a decrease of 96%, on 14th day it showed a decrease of 77% and on 21st day it showed a decrease of 81% with respect to control.

Nostoc rivulare (Nr) also showed an initial stimulatory rise in biomass content at lower concentration of pesticides but at higher concentration of 30µg/ml of pesticides showed maximum retardation of biomass. After treatment with 30µg/ml of Rogar 30, *N. rivulare* showed a decrease in biomass by 32.7% on 7th day, 35.37% on 14th day and 77% on 21st day as compared to control. After treatment with 30µg/ml of Monocrotophos, *N. rivulare* showed a decrease in biomass of 68.75% on 7th day, 35.37% on 14th day and 77.17% on 21st day with respect to control. After treating with 30µg/ml of Butachlor, *N. rivulare* showed a decrease of 33.63% on 7th day, 80% on 14th day and 89% on 21st day with respect to control. After treating with 30µg/ml of Phorate, *N. rivulare* showed a decrease of 33.63% in biomass on 7th day, 80% on 14th day and 89.23% on 21st day with respect to control. After treatment with 30µg/ml Phorate, *N. rivulare* showed a decrease in 47.27% on 7th day, 85.89% on 14th day, and 89.23% on 21st day with respect to control.

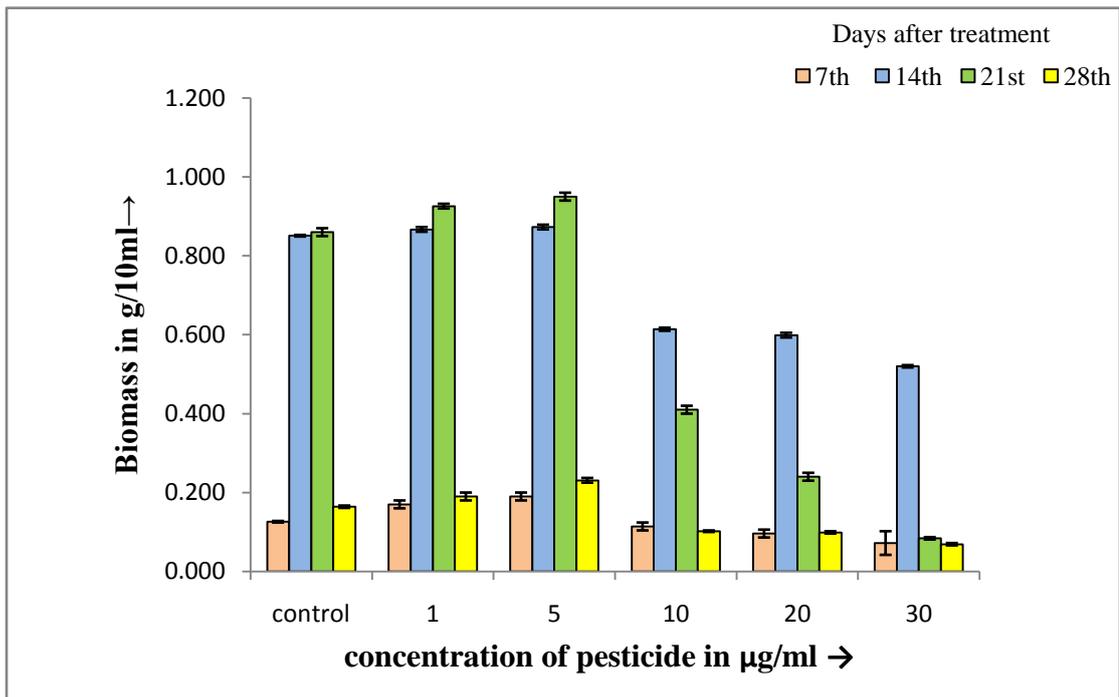


Fig 8.1: Effect of Rogar 30 on biomass of *A. oryzae*.

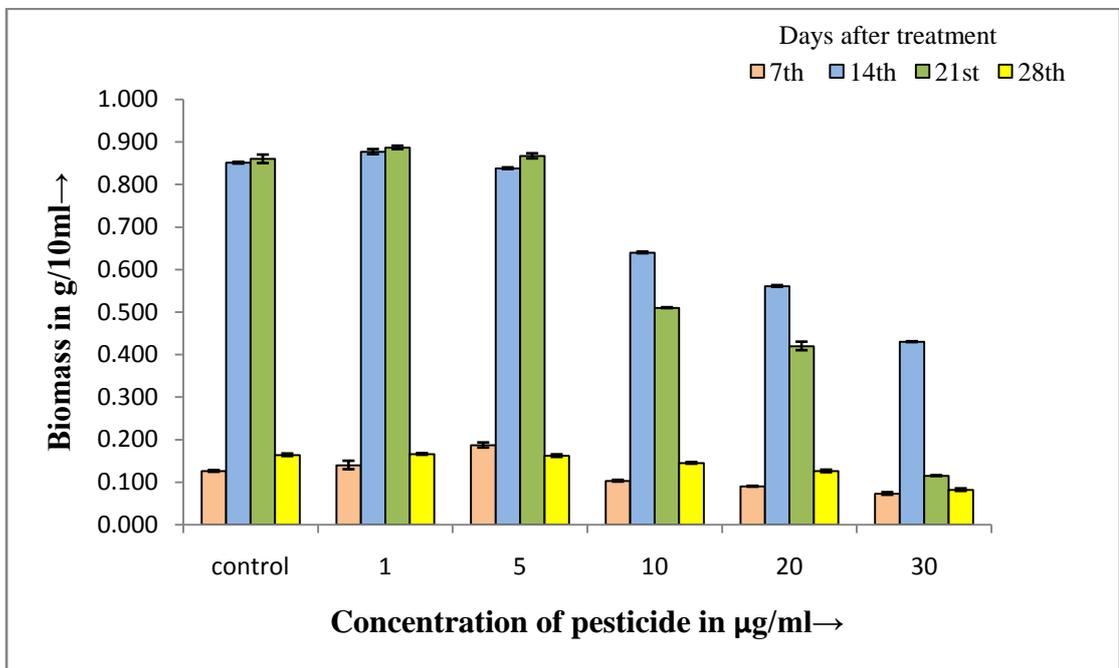


Fig. 8.2: Effect of Monocrotophos on biomass of *A. oryzae*

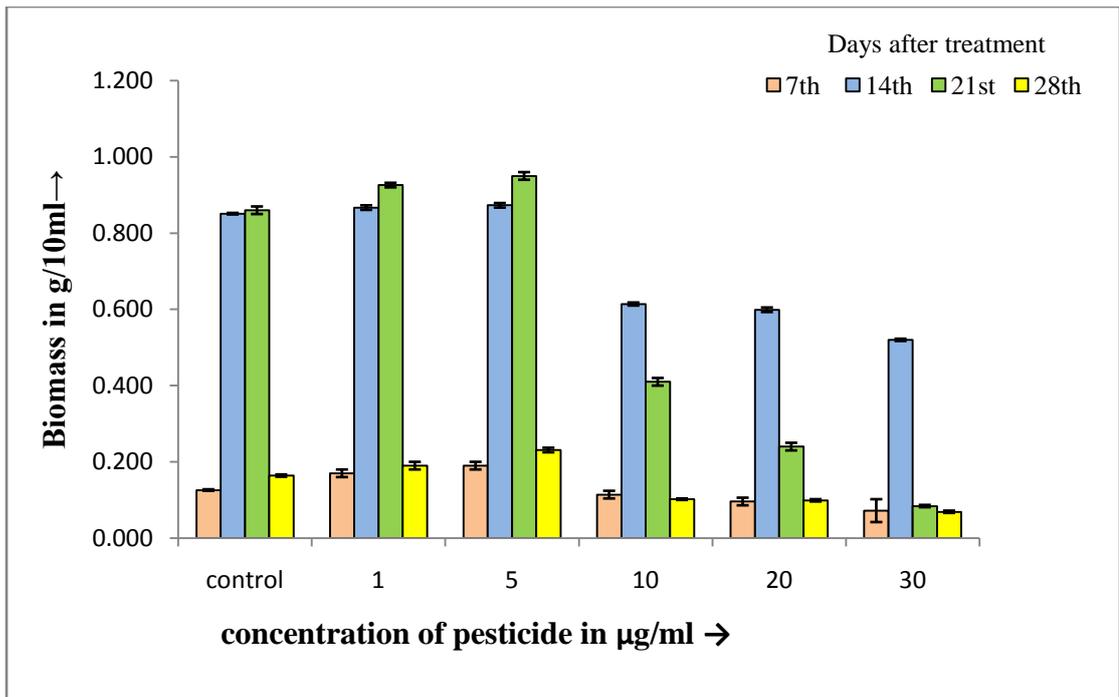


Fig. 8.3: Effect of Butachlor on biomass of *A. oryzae*.

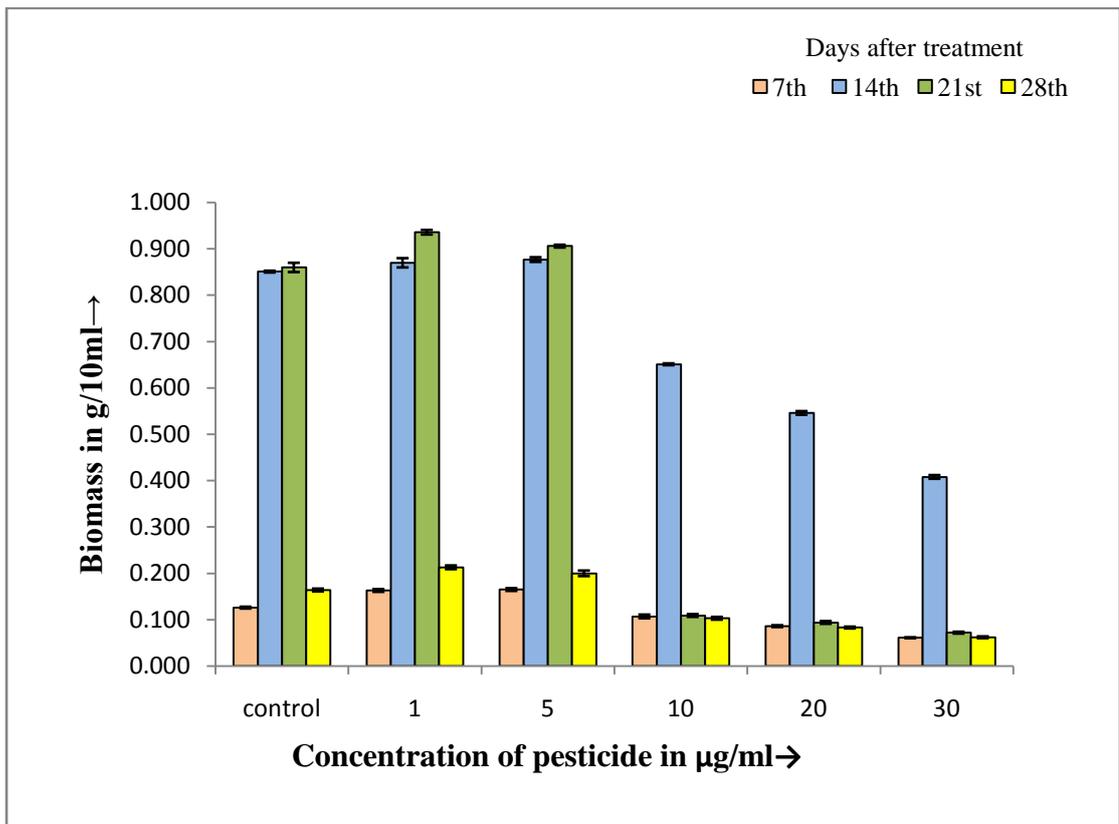


Fig. 8.4: Effect of Phorate on biomass of *A. oryzae*.

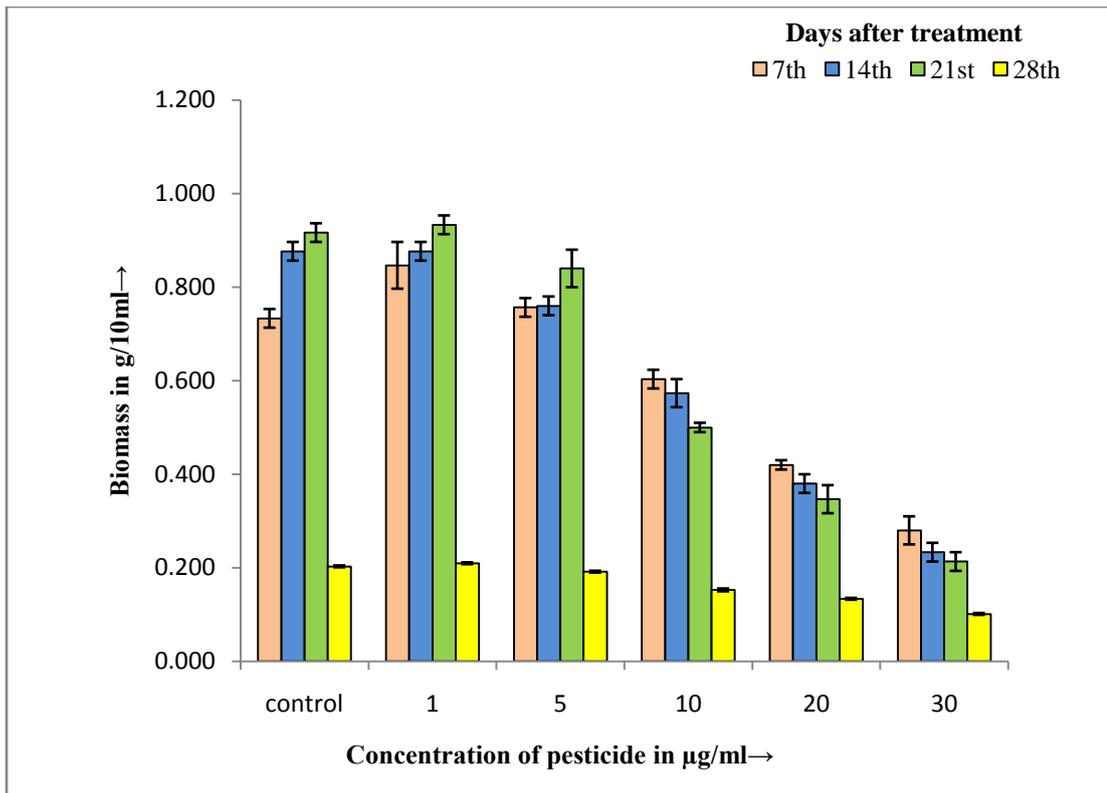


Fig. 8.5: Effect of Rogar 30 on biomass of *C. membranacea*.

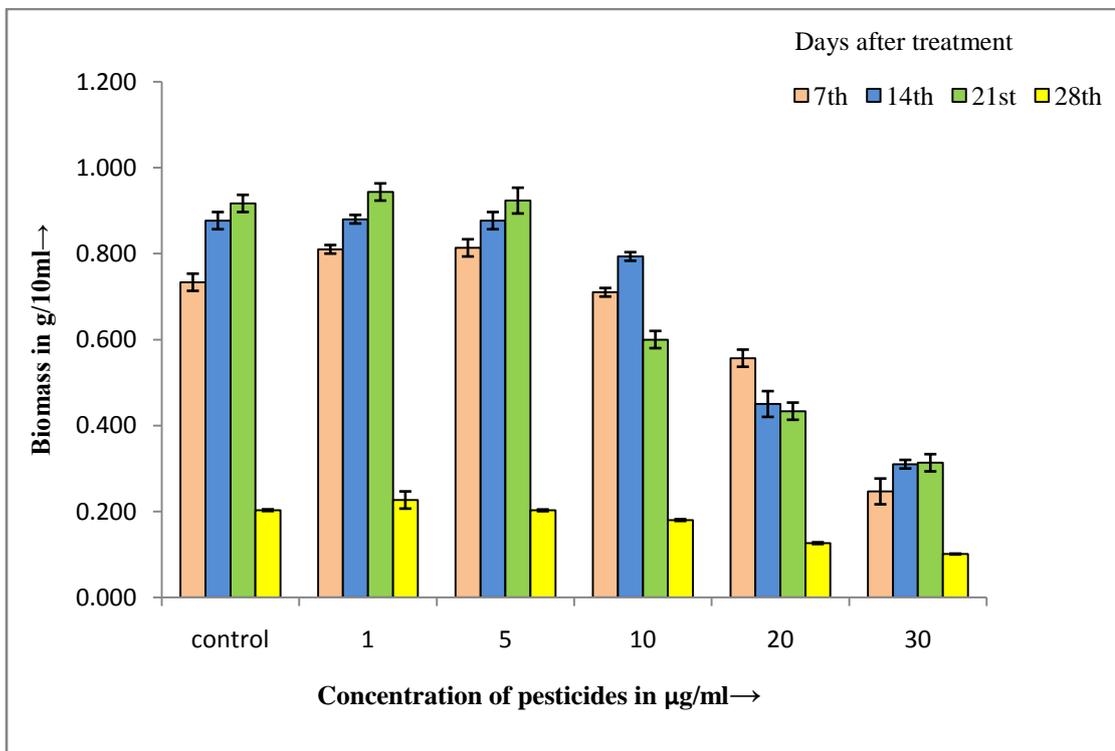


Fig.8.6: Effect of Monocrotophos on biomass of *C. membranacea*.

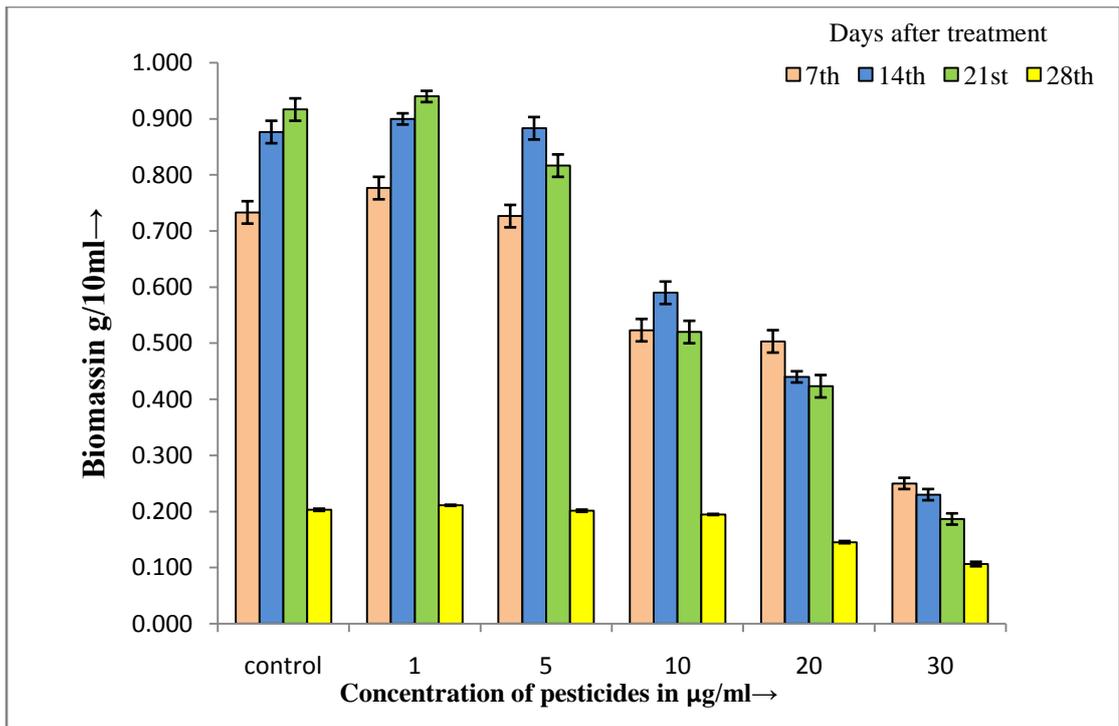


Fig. 8.7: Effect of Butachlor on biomass of *C. membranacea*.

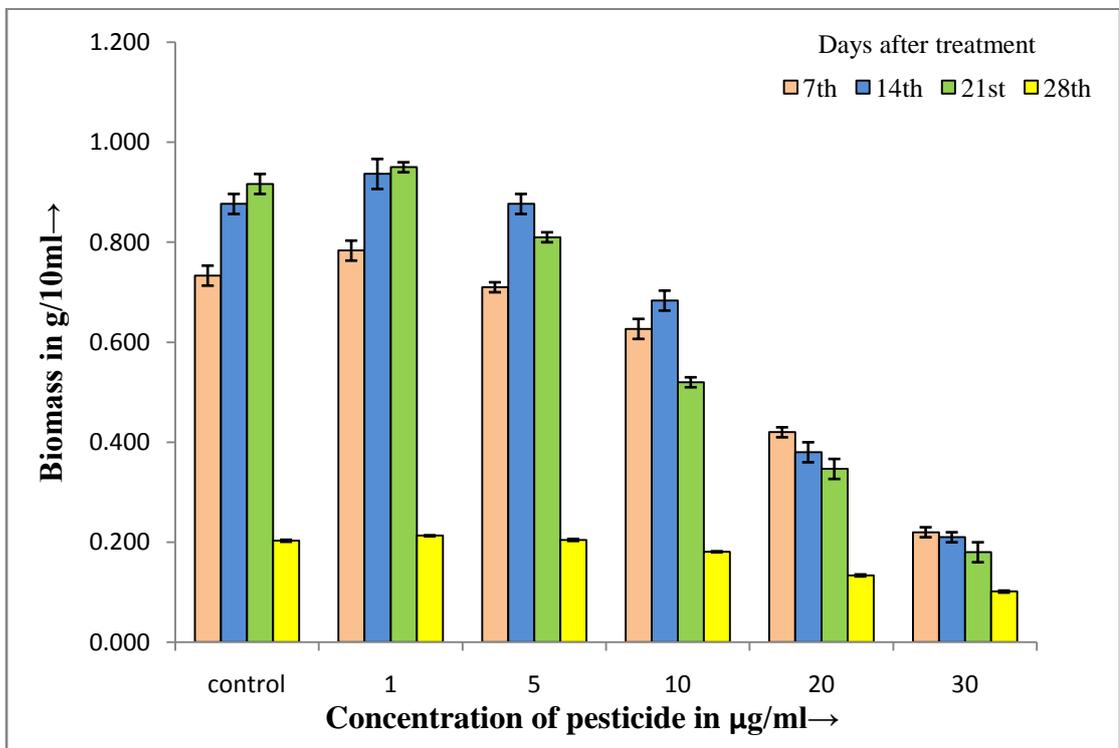


Fig. 8.8: Effect of Phorate on biomass of *C. membranacea*.

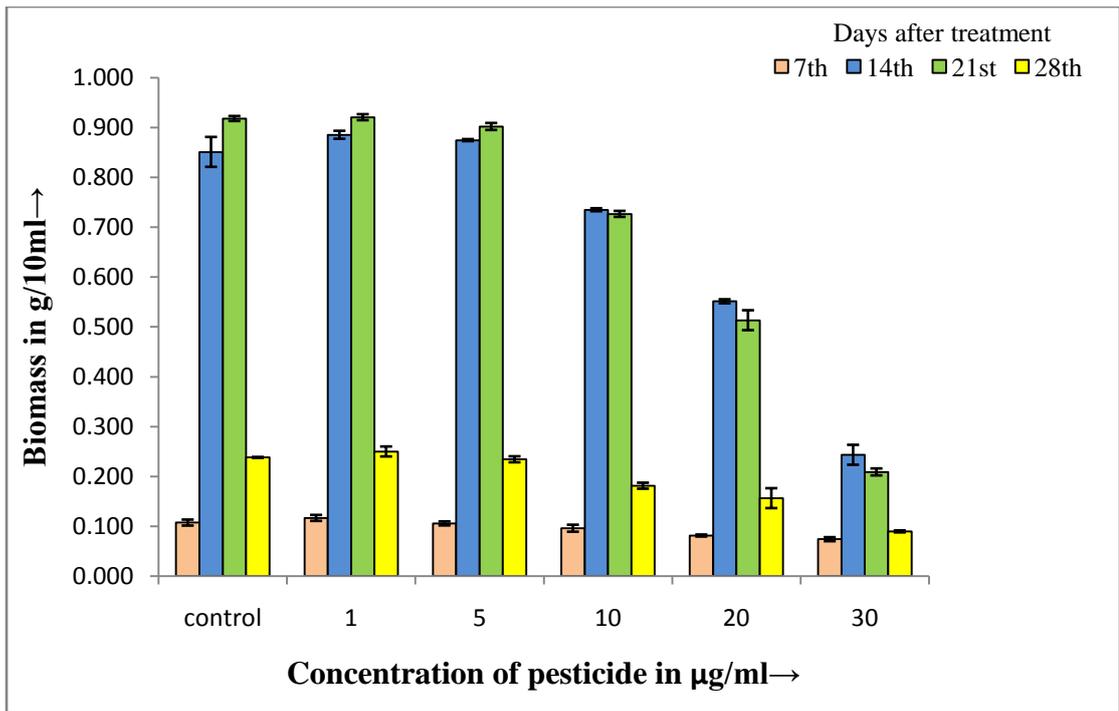


Fig. 8.9: Effect of Rogar 30 on biomass of *N. rivulare*.

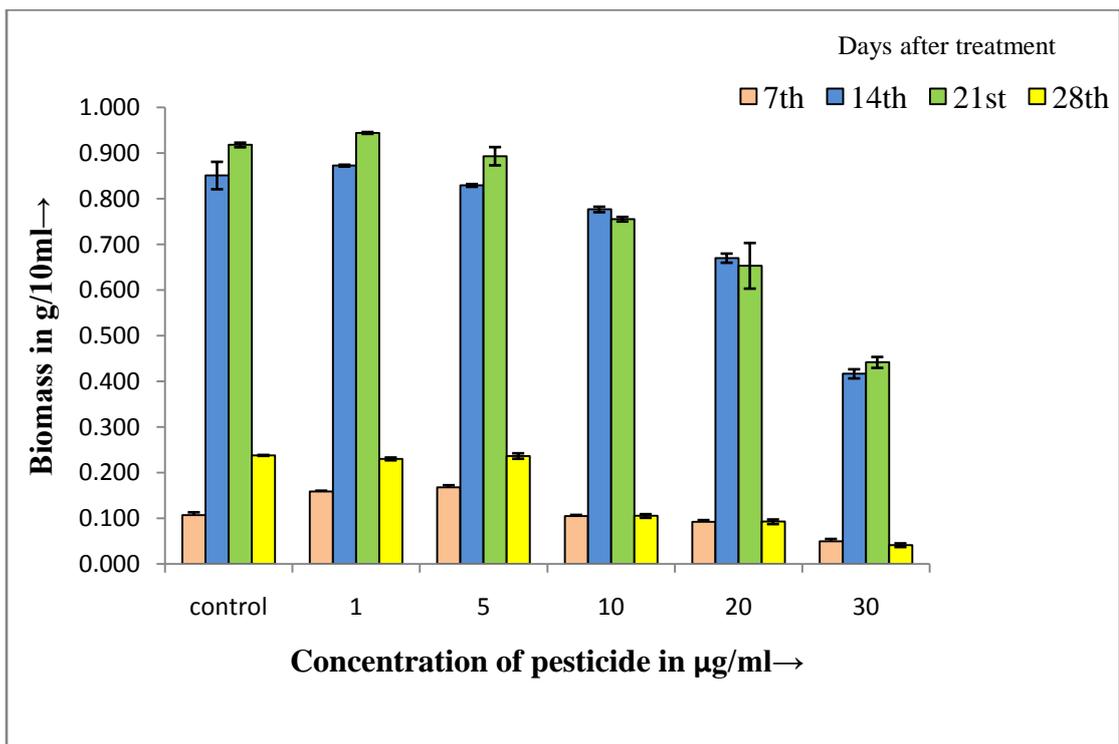


Fig. 8.10: Effect of Monocrotophos on biomass of *N. rivulare*.

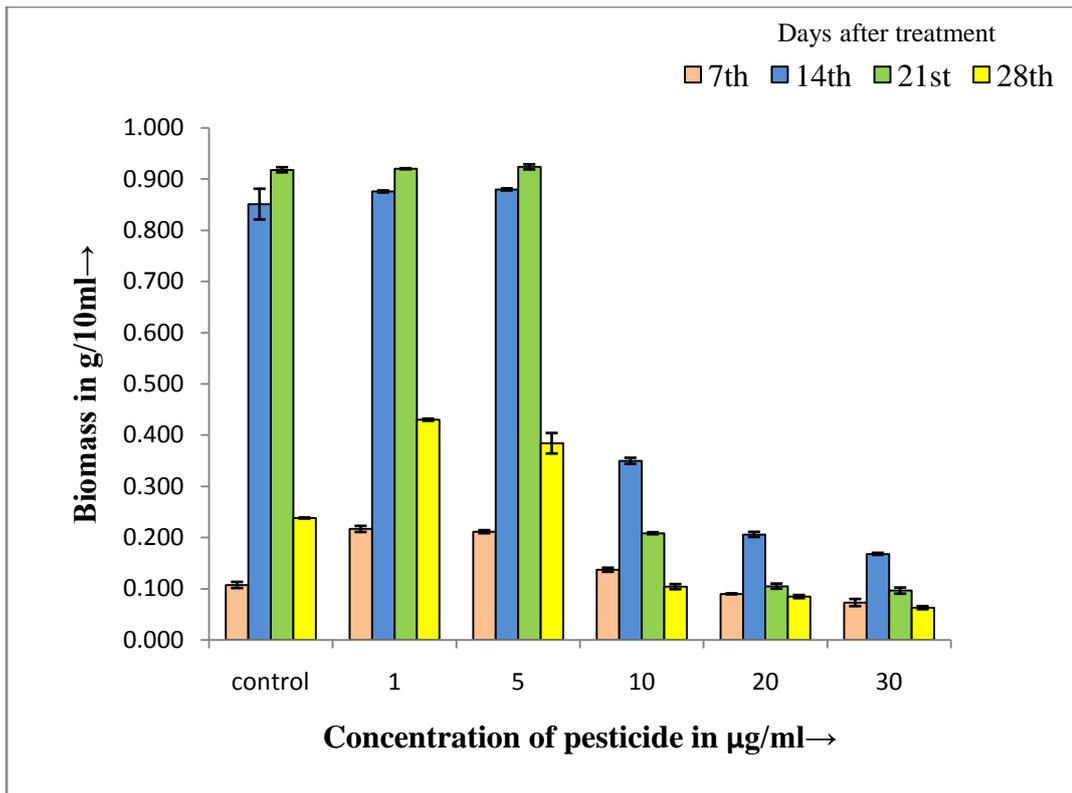


Fig. 8.11: Effect of Butachlor on biomass of *N. rivulare*.

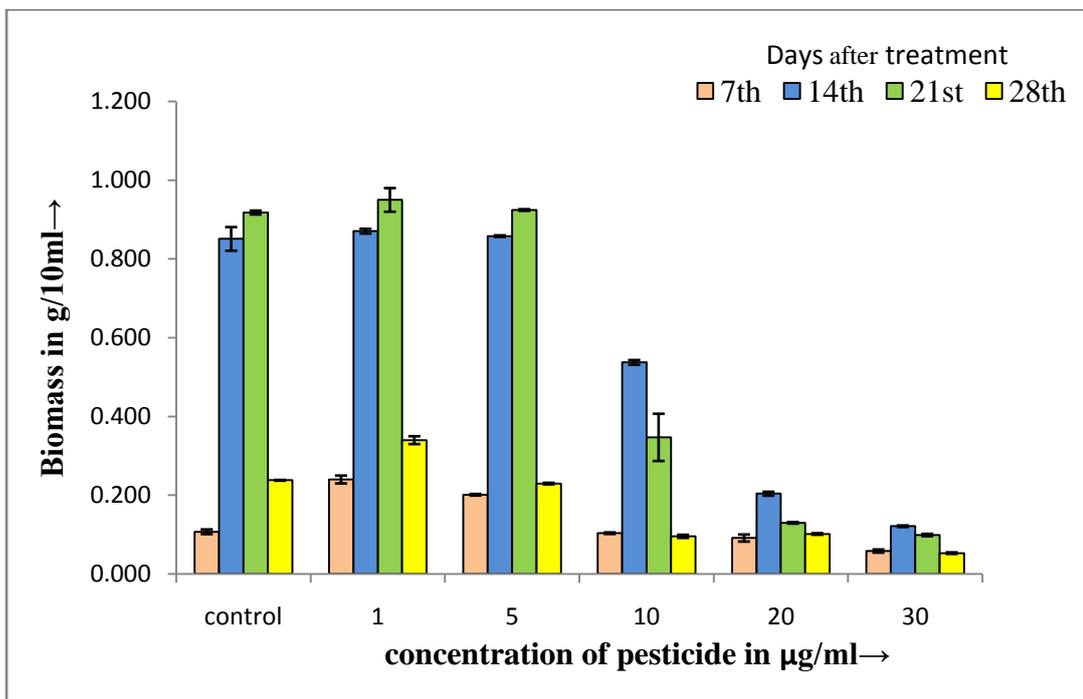


Fig. 8.12: Effect of Phorate on biomass of *N. rivulare*.

b. Chlorophyll a content:

Chlorophyll a content of the three algae when monitored from 7th day to 28th day after treatment with pesticides showed a stimulatory increase in chlorophyll a content at lower concentration of pesticides (1 and 5 µg/ml), but as the concentration of pesticides increased from 10 to 30 µg/ml, the chlorophyll a content goes on decreasing with a maximum decrease at 3 mg/100ml of pesticides.

Anabaena oryzae after treatment with 30 µg/ml of Rogar 30, on the 7th day showed a decrease of 53.7%, on 14th day showed 44% decrease and on 21st day showed 53.7% decrease in chlorophyll a content with respect to control. After treatment with 30 µg/ml Monocrotophos, *A. oryzae* on 7th day showed a decrease of 45%, on 14th day 48% decrease and on 21st day 54.74% decrease in chlorophyll a is observed with respect to control. When treated with 30 µg/ml of Butachlor, on the 7th day showed a decrease of 45.3%, on 14th day showed 73.54% decrease and on 21st day showed 76.86% decrease with respect to control. When treated with 30 µg/ml Phorate, *A. oryzae* showed 54% decrease on 7th day, 61% decrease on 14th day and 66.84% decrease on 21st day with respect to control.

Calothrix membranacea (*Cm*), after treatment with Rogar 30 on the 7th day showed a decrease in Chlorophyll a by 58.73%, on 14th day by 47% and on 21st day by 53.78% with respect to control. When treated with 30 µg/ml Monocrotophos, *Cm* showed a decrease of 34% on 7th day, 51% on 14th day and 61.2% decrease in chlorophyll a on 21st day. After treatment with 30 µg/ml of Butachlor, chlorophyll a of *Cm* decrease by 13% on 7th day, 35.7% on 14th day and 46.2% on 21st day. When treated with 30 µg/ml of phorate, Chlorophyll a of *Cm* decreased by 11.64% on 7th day, 30% on 14th day and 37.83% on 21st day after treatment with respect to control.

Nostoc rivulare (Nr) after treatment with 30µg/ml of Rogar 30 showed a decrease in chlorophyll a by 40.37% on 7th day, 58.68% on 14th day and 67.47% on 21st day. When treated with 30µg/ml of Monocrotophos, *N. rivulare* showed a decrease of 20.76% on 7th day, 45% on 14th day and 62% decrease on 21st day. After treatment with 30µg/ml of Butachlor chlorophyll a of *N. rivulare* reduces by 40% on 7th day, 58.68% on 14th day and 49.74% on 21st day with respect to control. After treatment with 30µg/ml of Phorate chlorophyll a of *N. rivulare* reduces by 20.76% on 7th day, 45% on 14th day and 62% on 21st day with respect to control.

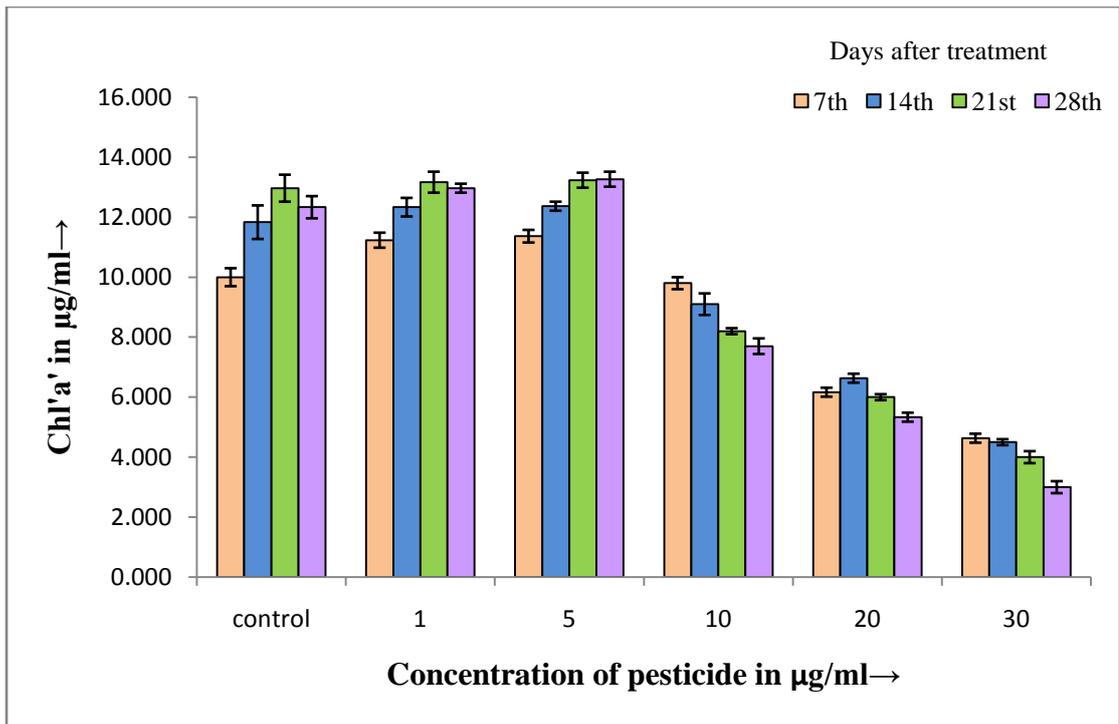


Fig.8.13: Effect of Rogar 30 on chlorophyll a content of *A. oryzae*.

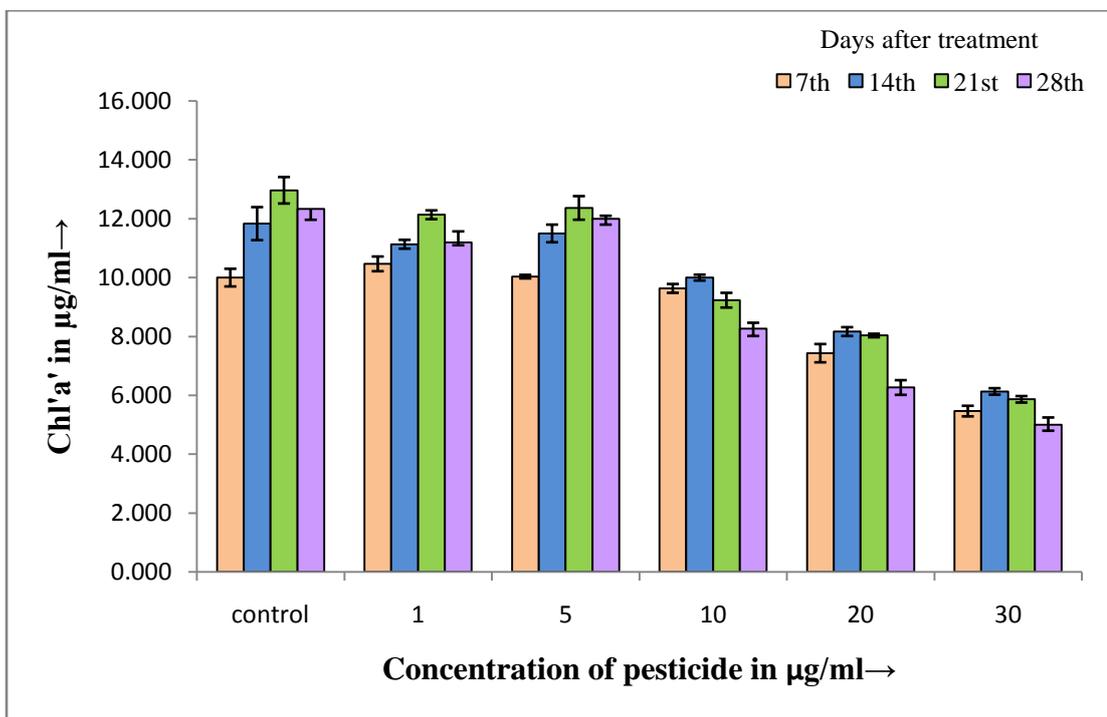


Fig. 8.14: Effect of Monocrotophos on chlorophyll a content of *A. oryzae*.

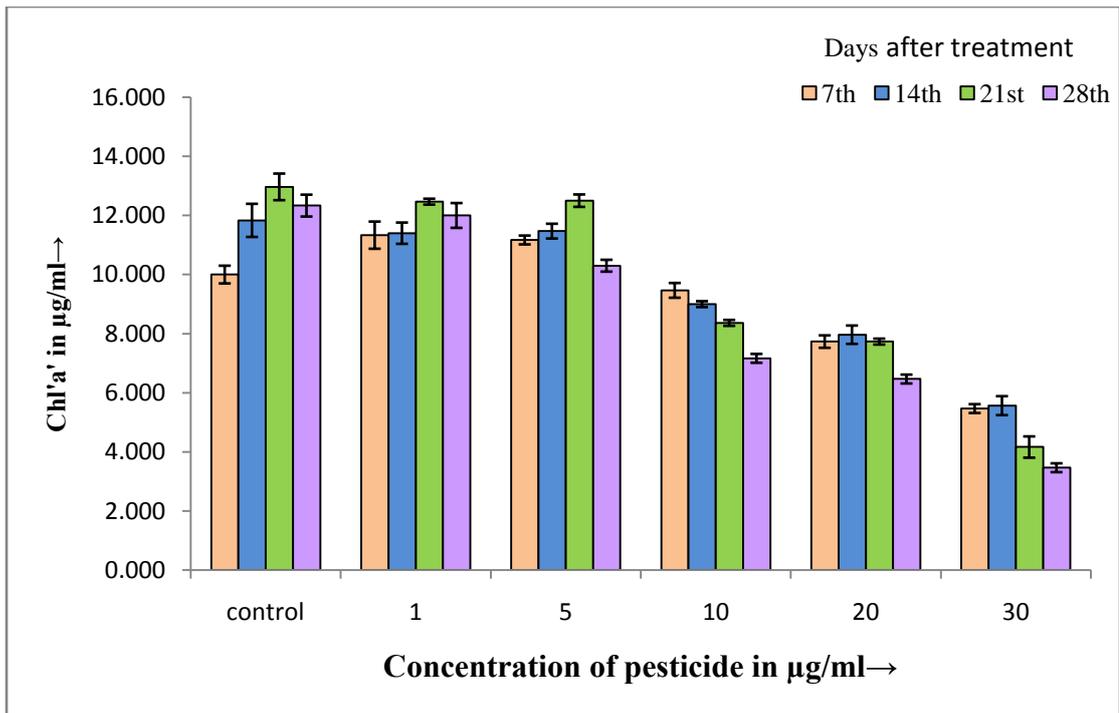


Fig. 8.15: Effect of Butachlor on chlorophyll a content of *A. oryzae*.

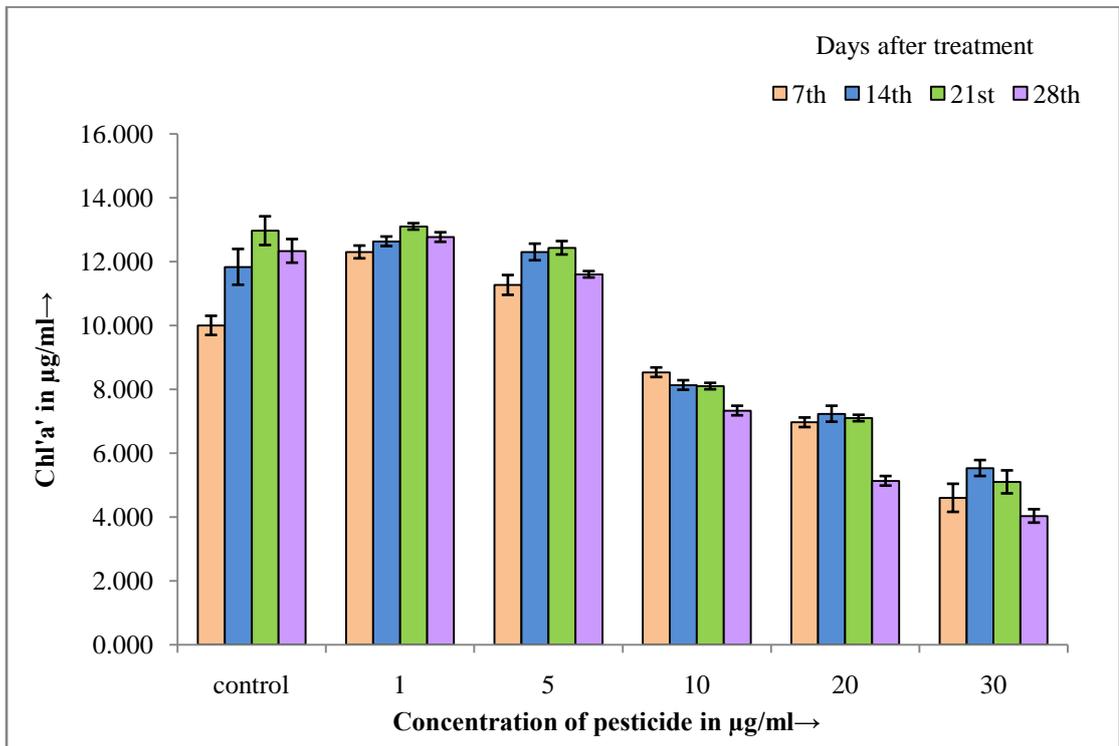


Fig. 8.16: Effect of Phorate on chlorophyll a content of *A. oryzae*.

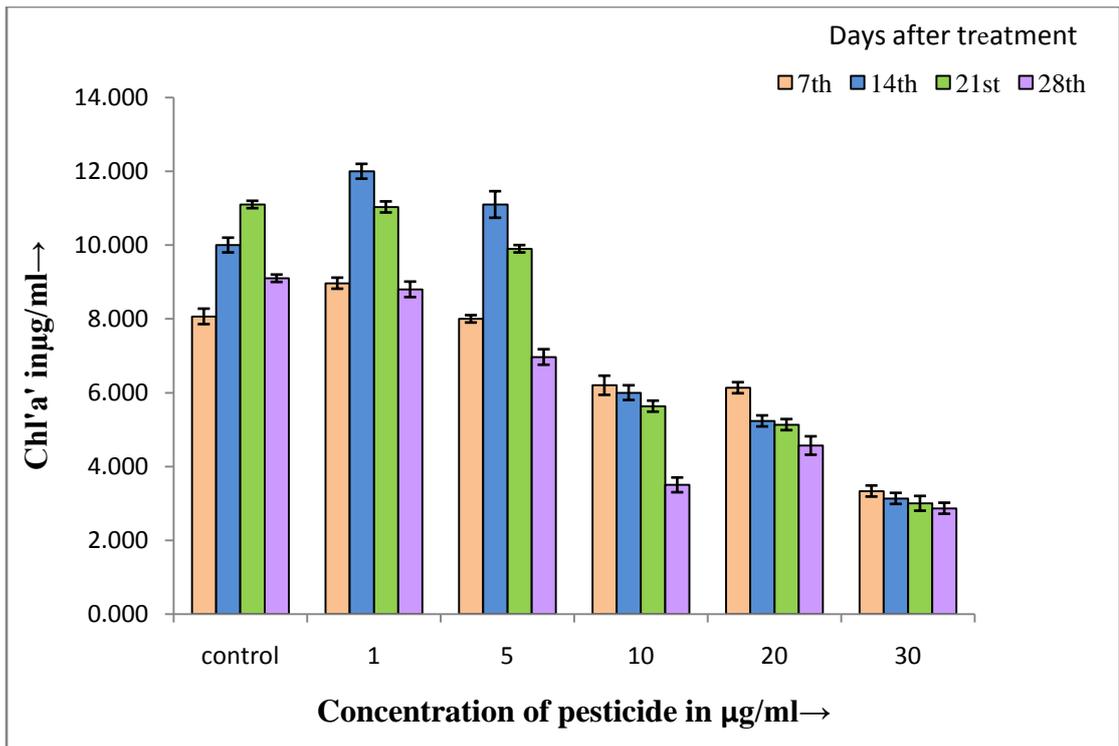


Fig. 8.17: Effect of Rogar 30 on chlorophyll a content of *C. membranacea*.

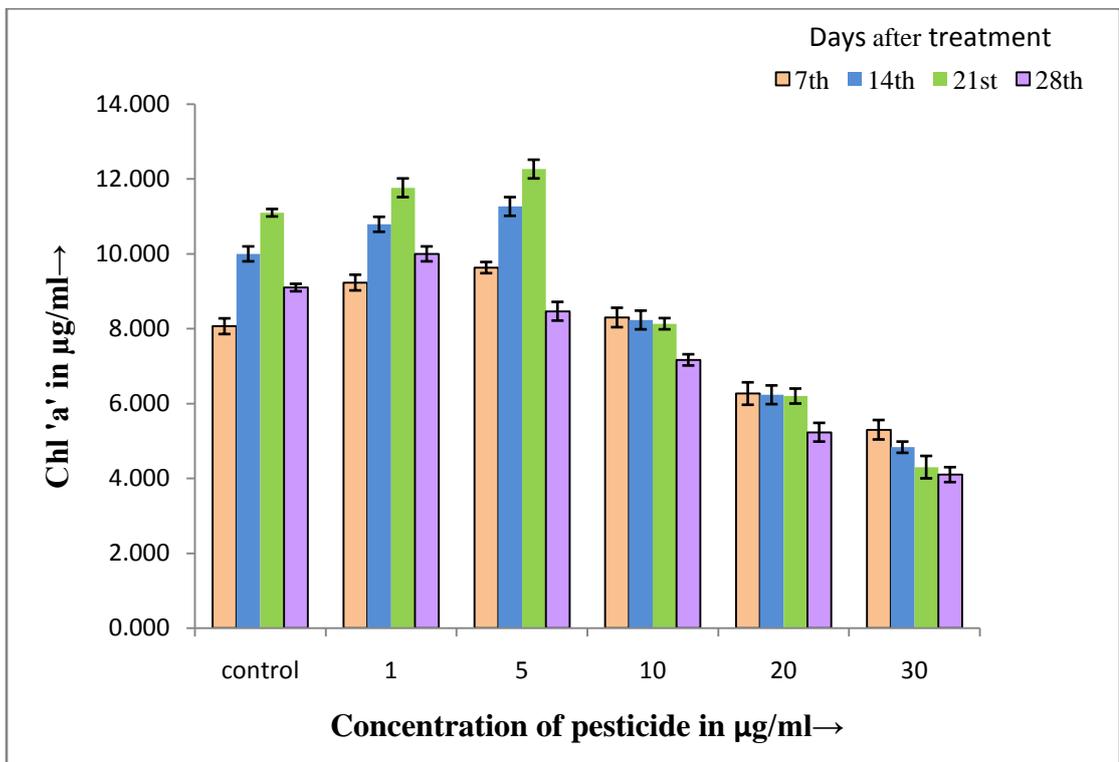


Fig.8.18: Effect of Monocrotophos on chlorophyll a content of *C. membranacea*.

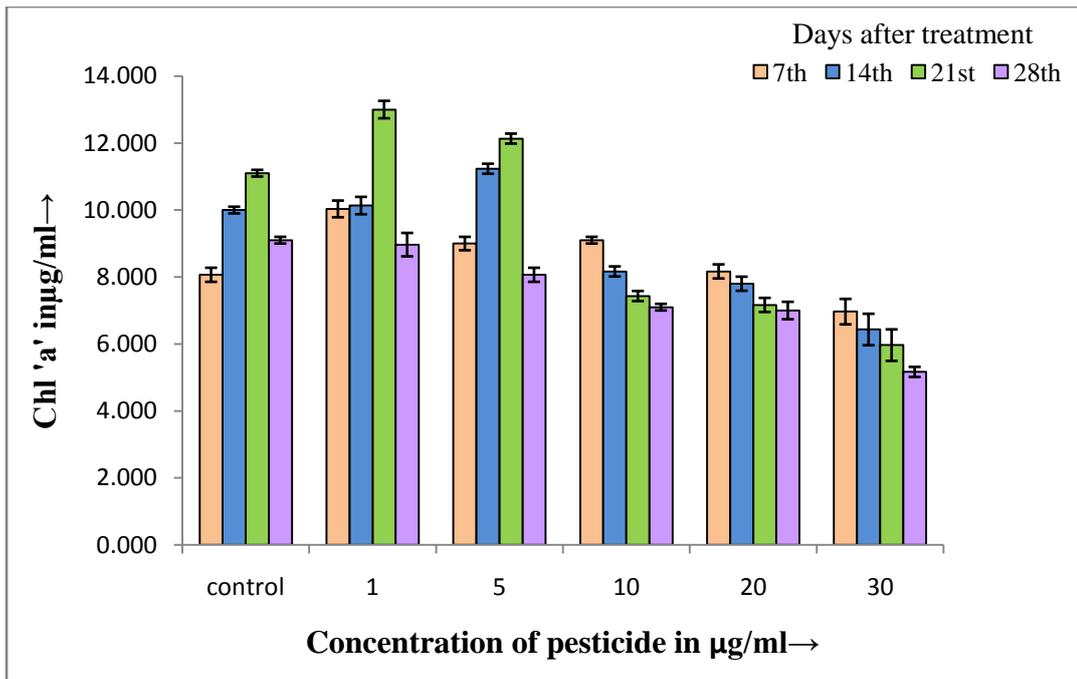


Fig. 8.19: Effect of Butachlor on chlorophyll a content of *C. membranacea*.

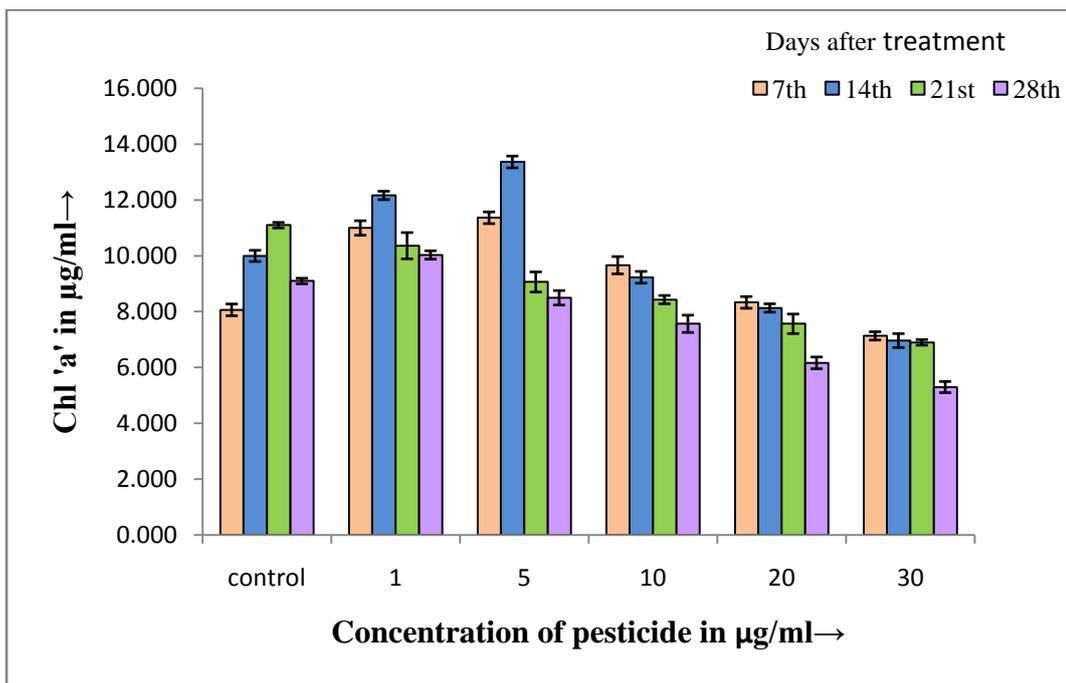


Fig. 8.20: Effect of Phorate on chlorophyll a content of *C. membranacea*.

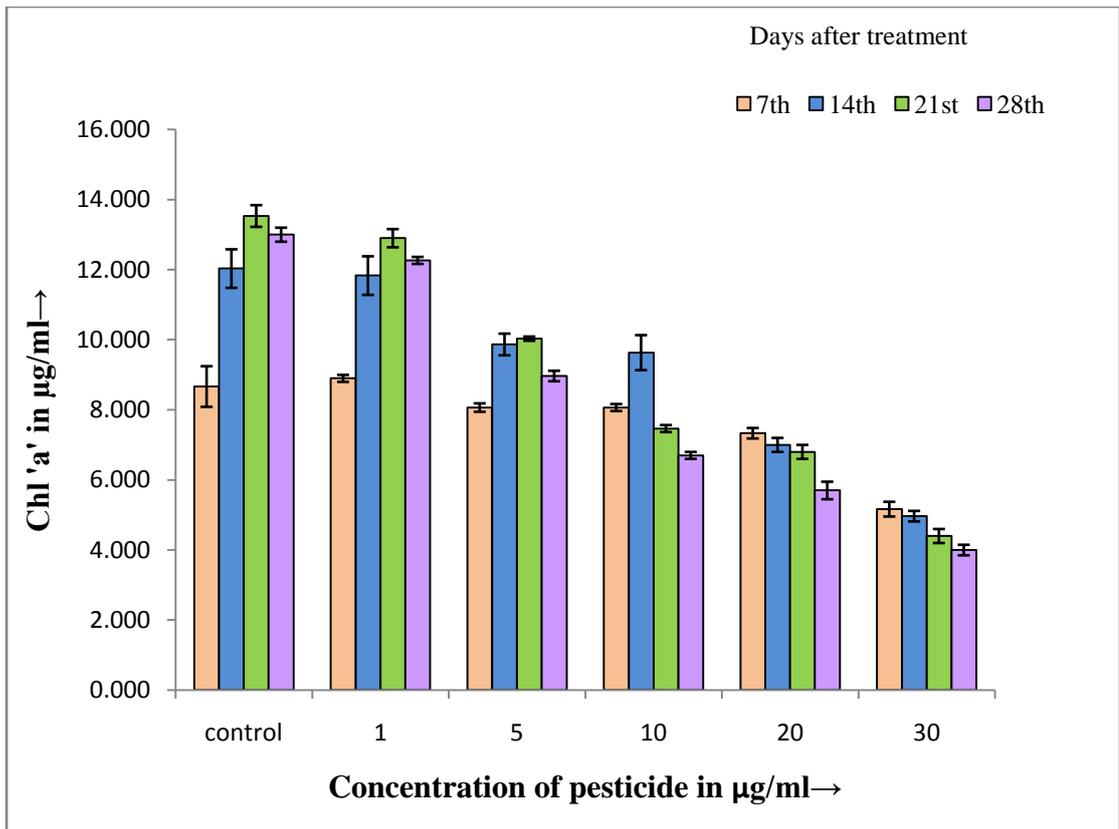


Fig. 8.21: Effect of Rogar 30 on chlorophyll a content of *N. rivulare*.

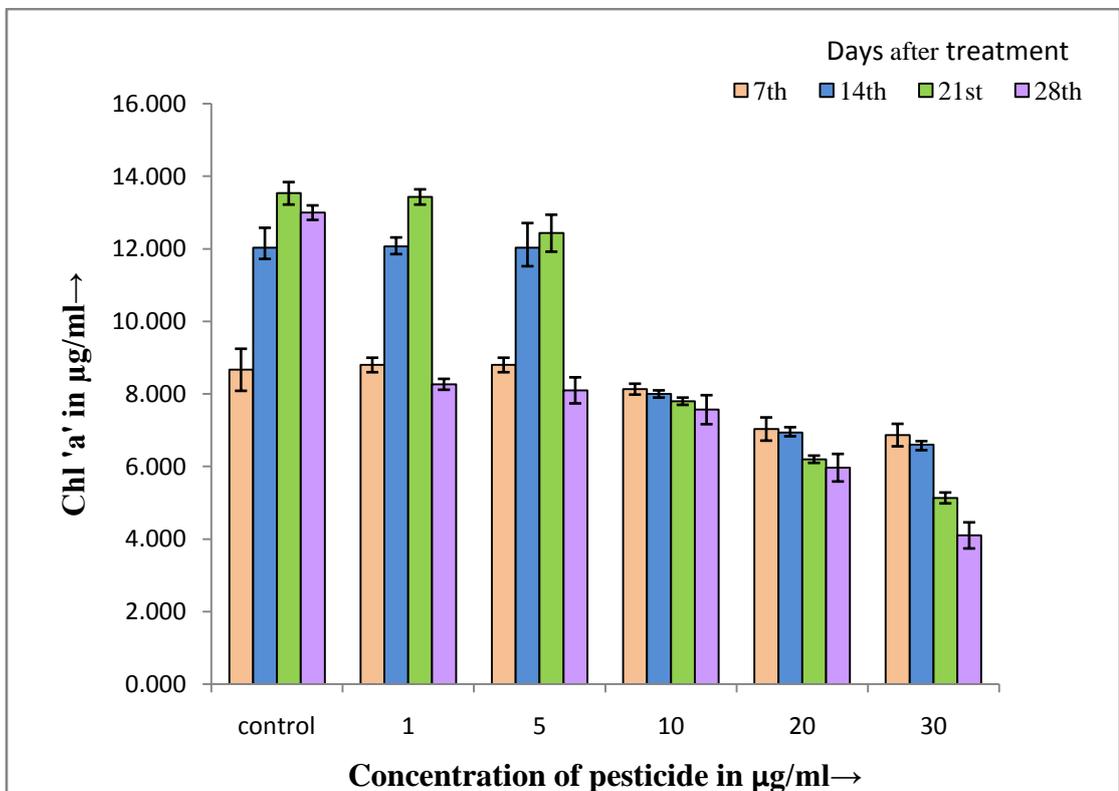


Fig.8.22: Effect of Monocrotophos on chlorophyll a content of *N. rivulare*.

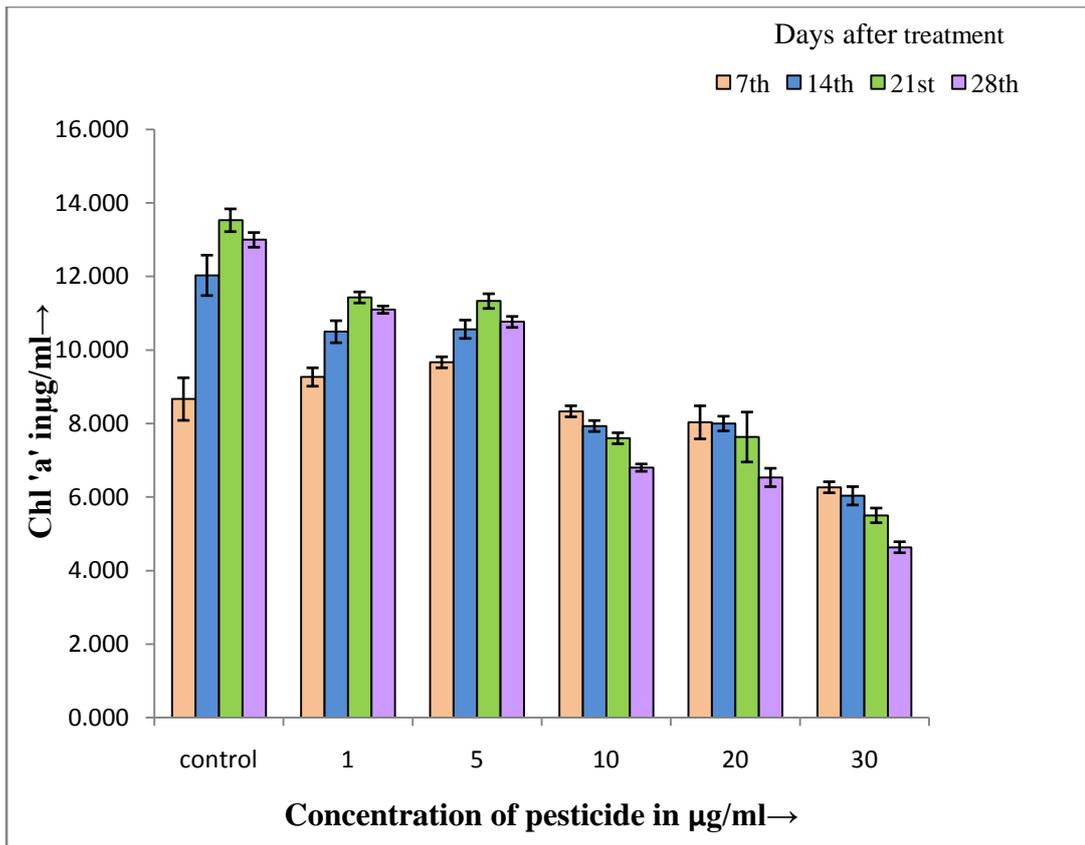


Fig. 8.23: Effect of Butachlor on chlorophyll a content of *N. rivulare*.

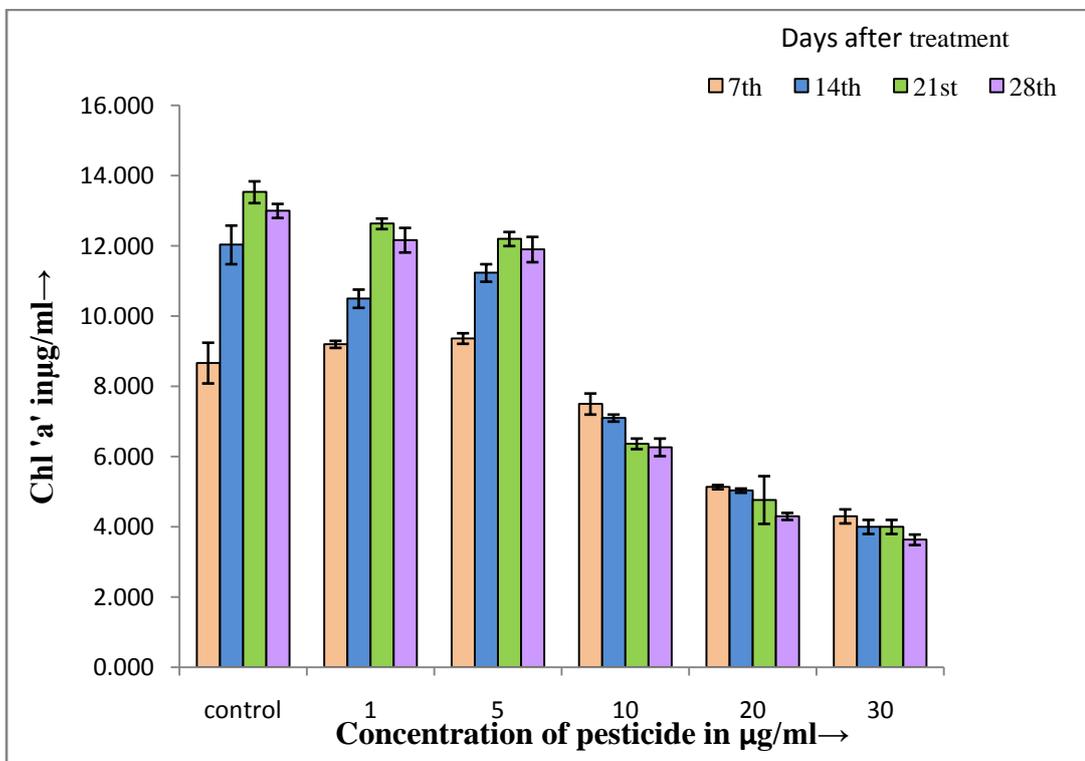


Fig.8.24: Effect of Phorate on chlorophyll a content of *N. rivulare*.

c. Total Protein content

When BGA were treated with the four different pesticides and analyzed for their protein content, they showed variable results. Rogar 30, Butachlor & Phorate showed initial increase in total proteins, at very low concentration of 1µg/ml but at higher concentrations, the protein content decreases with increase in concentration of pesticides. Monocrotophos however showed decline in total protein content of BGA even at low concentrations, Butachlor and Phorate showed initial stimulatory increase at low concentration but declines later at higher concentration and maximum reduction in total proteins is seen with 30µg/ml of pesticides as compared to control.

Anabaena oryzae when treated with 30µg/ml of Rogar 30 showed 48% decrease in total proteins content on 7th day, 52% on 14th day and 53% decrease on 21st day as compared to control. When treated with 30µg/ml of Monocrotophos, *A. oryzae* showed a decline of 54.6% total protein on 7th day, 55.7% decline on 14th day and 58.9% decline on 21st day as compared to control. After treating with 30µg/ml of Butachlor, *A. oryzae* showed a decline of 56.2% on the 7th day, 57.54% on 14th day and 63.38% on 21st day as compared to control. When treated with 30µg/ml of Phorate, *A. oryzae* showed a decline of 48.8% on 7th day, 52.6% on 14th day and 58.6% decline in total protein content on 21st day with respect to control.

Calothrix membranacea (*Cm*) when treated with 30µg/ml of BGA showed 40% decrease in total proteins content on 7th day, 49.9% on 14th day and 63.7% decrease on 21st day as compared to control. When treated with 30µg/ml of Monocrotophos, *Cm* showed a decline of 59% total protein on 7th day, 63.2% decline on 14th day and 67% decline on 21st day as compared to control. After treating with 30µg/ml of Butachlor, *Cm* showed a decline of 37.9% on the 7th day, 57.9% on 14th

day and 62.74% on 21st day as compared to control. When treated with 30µg/ml of Phorate, *Cm* showed a decline of 33.79% on 7th day, 57.2% on 14th day and 59% decline in total protein content on 21st day with respect to control.

Nostoc rivulare (*Nr*) when treated with 30µg/ml of BGA showed 33.4% decrease in total proteins content on 7th day, 50% on 14th day and 57.8% decrease on 21st day as compared to control. When treated with 30µg/ml of Monocrotophos, *Nr* showed a decline of 24.3% total protein on 7th day, 27% decline on 14th day and 33.6% decline on 21st day as compared to control. After treating with 30µg/ml of Butachlor, *Nr* showed a decline of 57% on the 7th day, 53.6% on 14th day and 54.5% on 21st day as compared to control. When treated with 30µg/ml of Phorate, *Nr* showed a decline of 54.6% on 7th day, 51.9% on 14th day and 55.6% decline in total protein content on 21st day with respect to control.

d. Total carbohydrate content

When the selected BGA viz., *A. oryzae*, *C. membranacea*, *N. rivulare* were treated with the four different pesticides and analyzed for their total carbohydrate content, showed considerable reduction in total carbohydrate with increase in concentration of pesticides with respect to control. Rogar 30, Monocrotophos, Butachlor and Phorate showed initial increase in total carbohydrate content, at low concentration of 1µg/ml but the carbohydrate content decreases with increase in concentration of pesticides and maximum reduction in total carbohydrate is observed at 30µg/ml of pesticides as compared to control.

Anabaena oryzae (*Ao*) when treated with 30µg/ml of Rogar 30 showed 24.7% decrease in total carbohydrate content on 7th day, 29% on 14th day and 45% decrease on 21st day as compared to control. When treated with 30µg/ml of Monocrotophos, *Ao*

showed a decline of 24.9% total carbohydrate on 7th day, 33.6% decline on 14th day and 56.9% decline on 21st day as compared to control. After treating with 30µg/ml of Butachlor, *Ao* showed a decline of 33.5% on the 7th day, 36% on 14th day and 59% on 21st day as compared to control. When treated with 30µg/ml of Phorate, *Ao* showed a decline of 27.8% on 7th day, 30% on 14th day and 53% decline in total carbohydrate content on 21st day with respect to control.

Calothrix membranacea (*Cm*) when treated with 30µg/ml of Rogar 30 showed 40% decrease in total carbohydrate content on 7th day, 41% on 14th day and 42% decrease on 21st day as compared to control. When treated with 30µg/ml of Monocrotophos, *Cm* showed a decline of 38.5% total carbohydrate on 7th day, 41% decline on 14th day and 44% decline on 21st day as compared to control. After treating with 30µg/ml of Butachlor, *Cm* showed a decline of 13.8% on the 7th day, 38.8% on 14th day and 40.7% on 21st day as compared to control. When treated with 30µg/ml of Phorate, *Cm* showed a decline of 11% on 7th day, 38.8% on 14th day and 40.7% decline in total carbohydrate content on 21st day with respect to control.

Nostoc rivulare (*Nr*) when treated with 30µg/ml of Rogar 30 showed 28% decrease in total carbohydrate content on 7th day, 37% on 14th day and 41% decrease on 21st day as compared to control. When treated with 30µg/ml of Monocrotophos, *Nr* showed an increase of 1.9% total carbohydrate on 7th day, 50% decline on 14th day and 52% decline on 21st day as compared to control. After treating with 30µg/ml of Butachlor, *Nr* showed a decline of 25% on the 7th day, 41% on 14th day and 45% on 21st day as compared to control. When treated with 30µg/ml of Phorate, *Nr* showed a decline of 32% on 7th day, 45.8% on 14th day and 50% decline in total carbohydrate content on 21st day with respect to control.

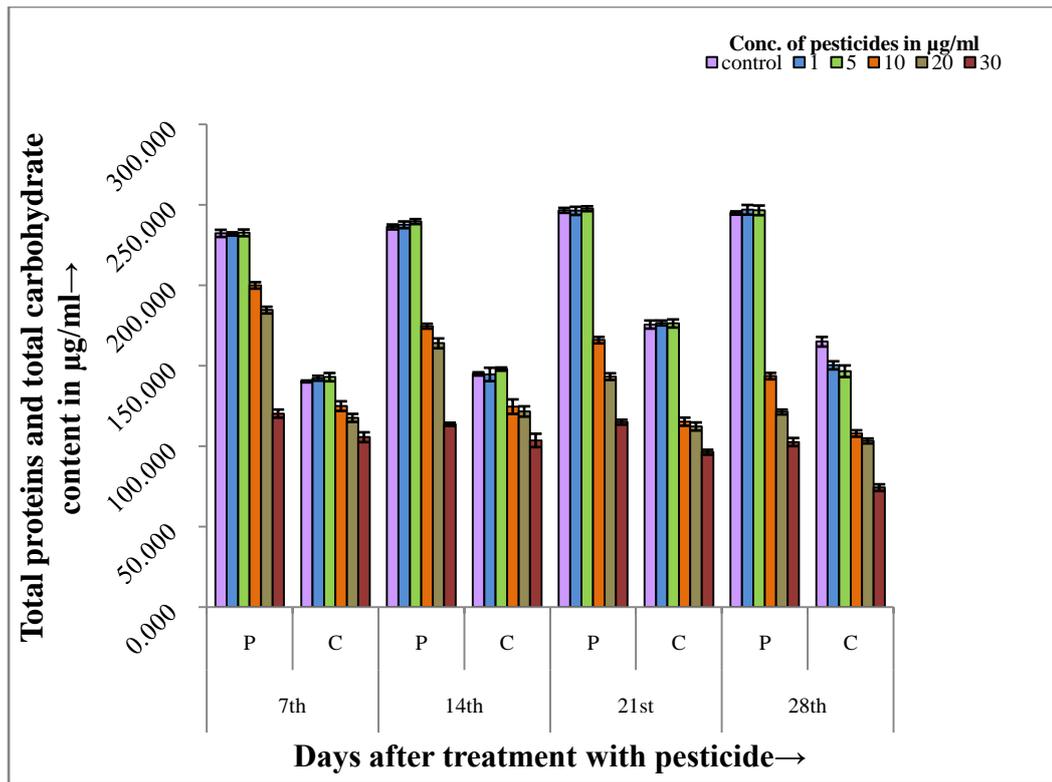


Fig. 8.25: Effect of Rogar 30 on total protein and total carbohydrate content in *A. oryzae*.

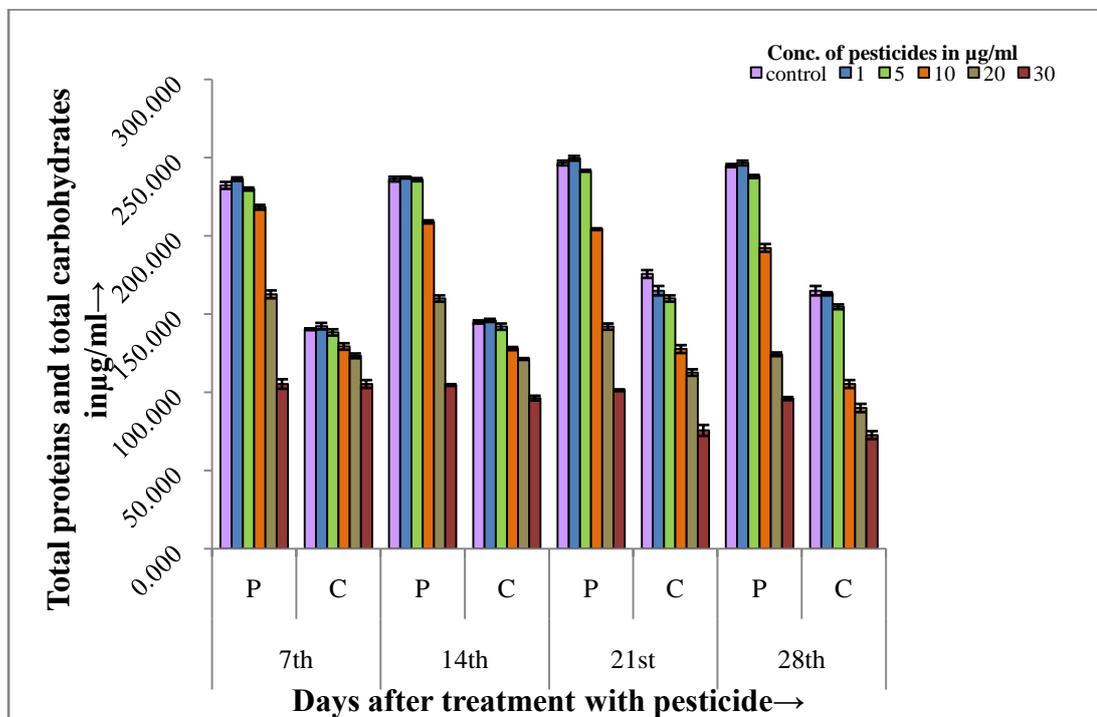


Fig. 8.26: Effect of Monocrotophos on total protein and total carbohydrate content of *A. oryzae*.

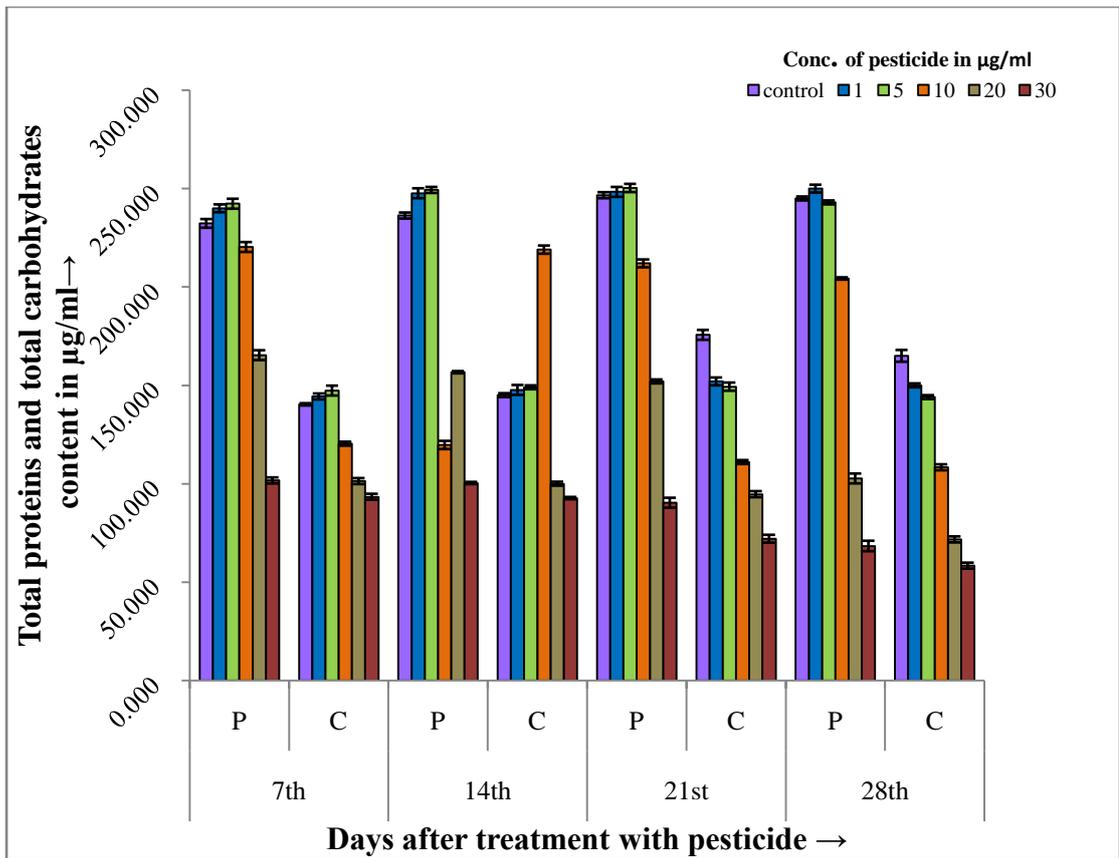


Fig. 8.27: Effect of Butachlor on total protein and total carbohydrate content of *A. oryzae*.

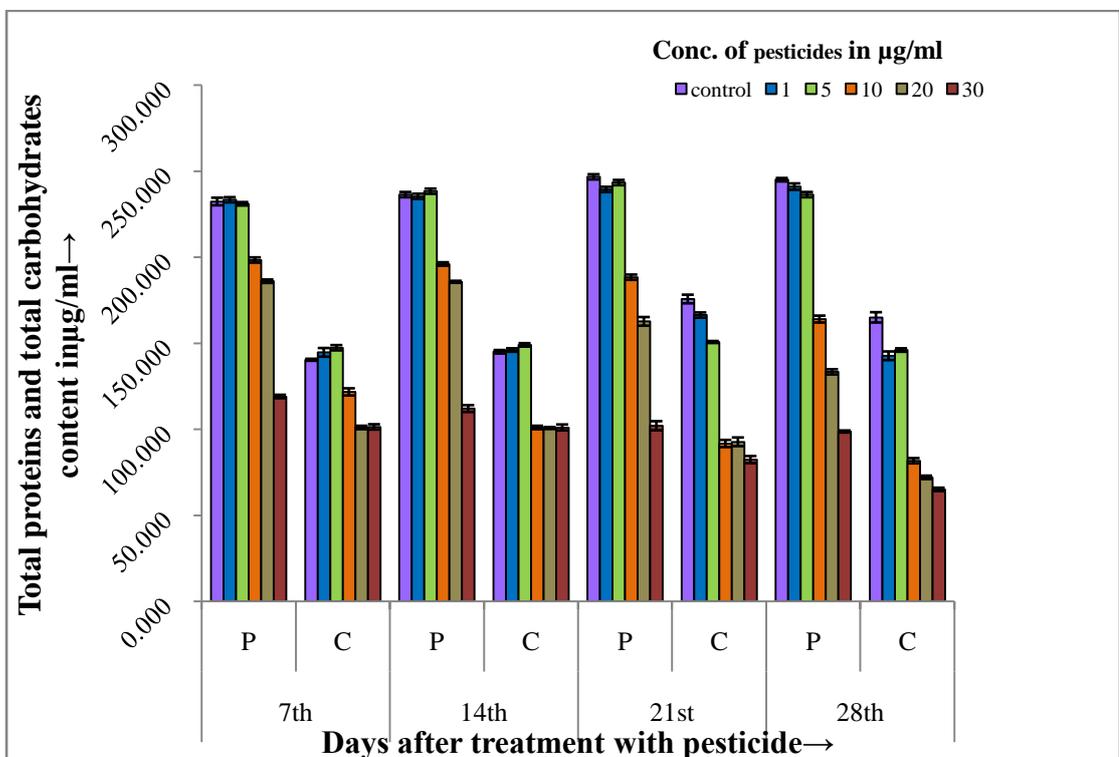


Fig. 8.28: Effect of Phorate on total protein and total carbohydrate content of *A. oryzae*.

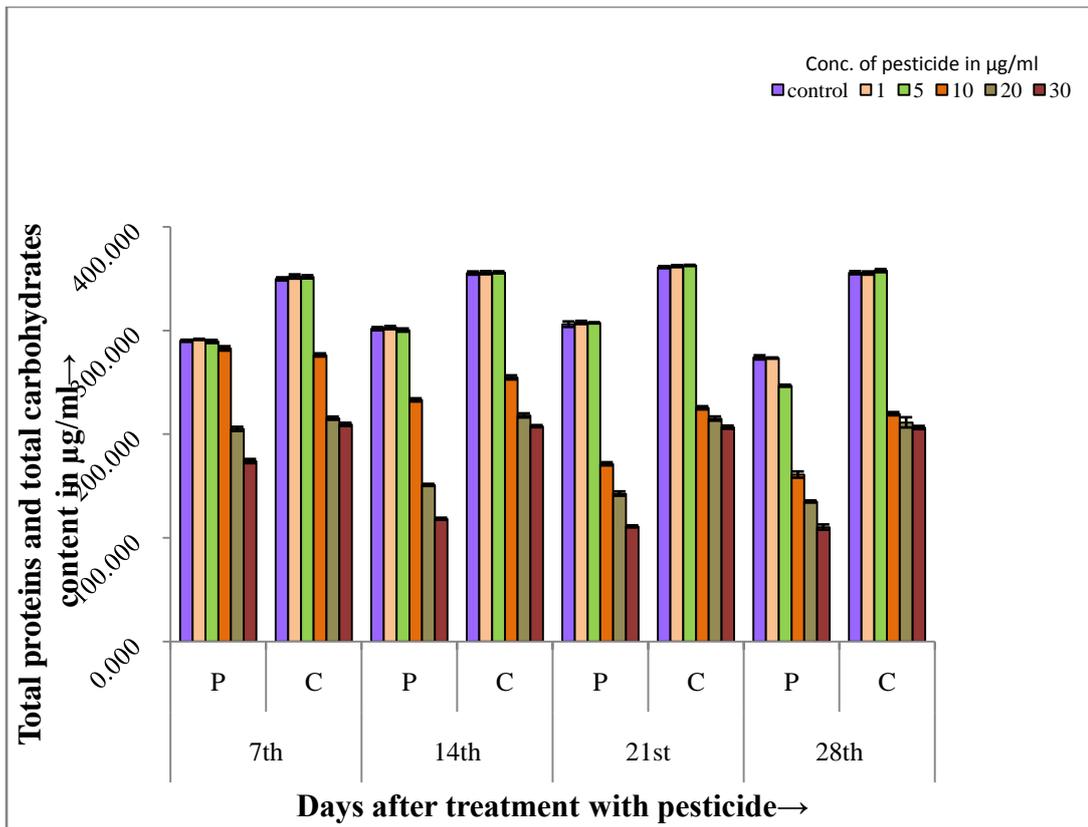


Fig. 8.29: Effect of Rogar 30 on total protein and total carbohydrate content of *C. membranacea*.

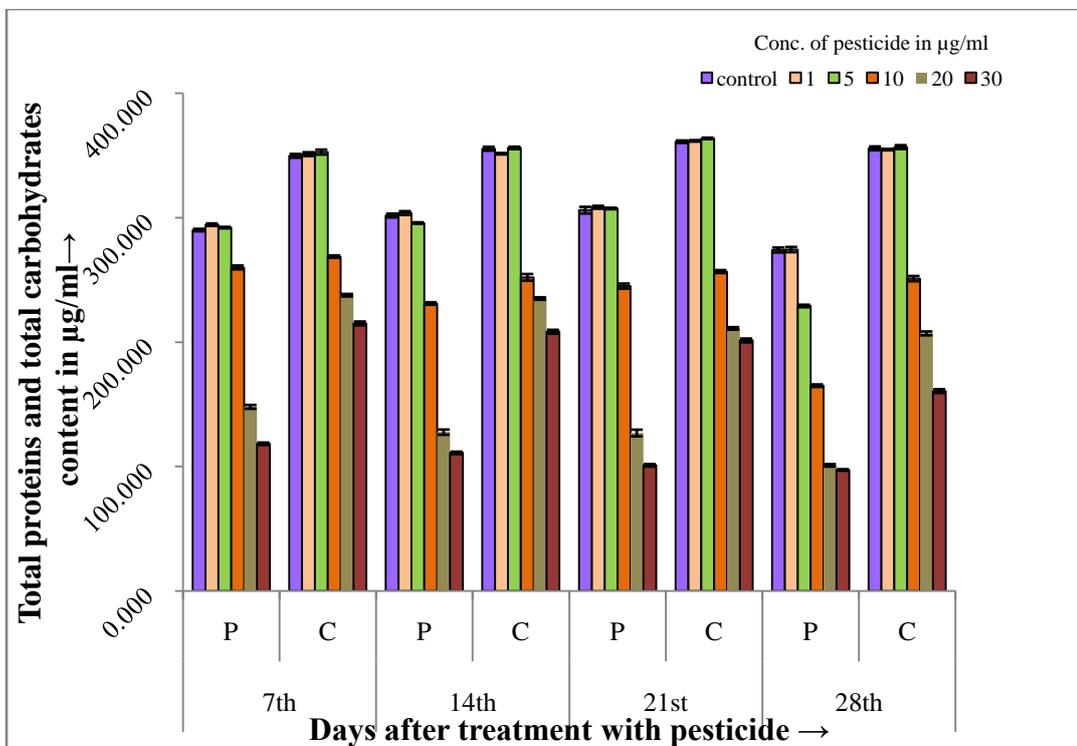


Fig. 8.30: Effect of Monocrotophos on total protein and total carbohydrate content of *C. membranacea*.

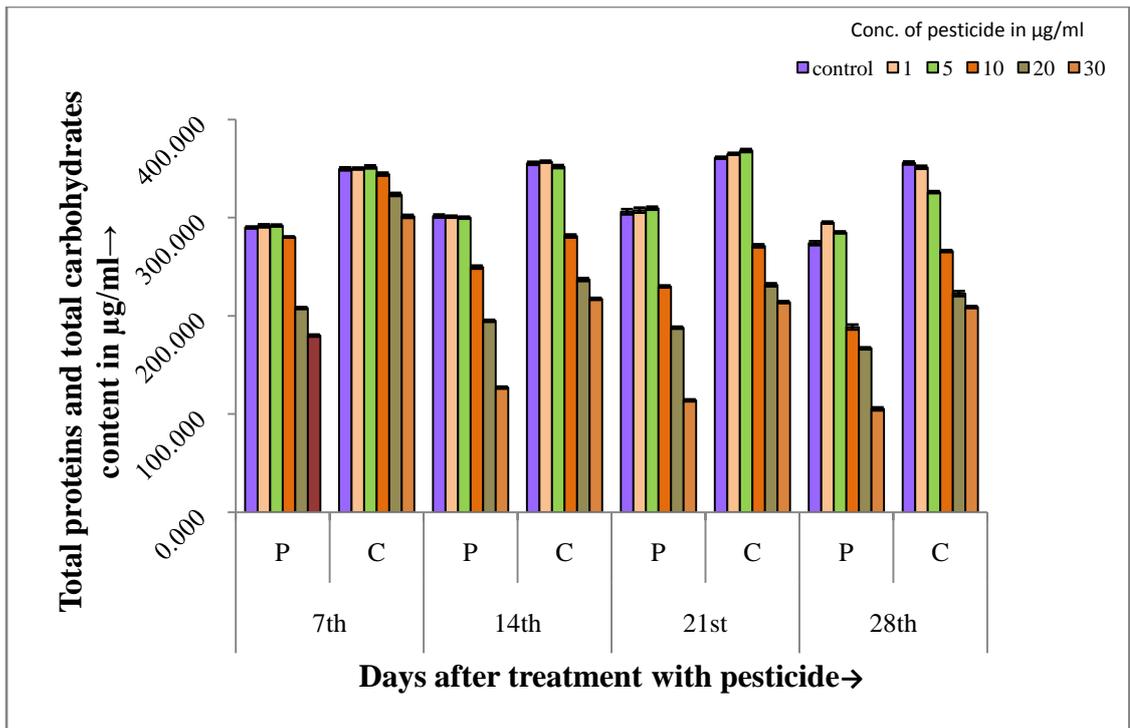


Fig.8.31: Effect of Butachlor on total protein and total carbohydrate content of *C. membranacea*

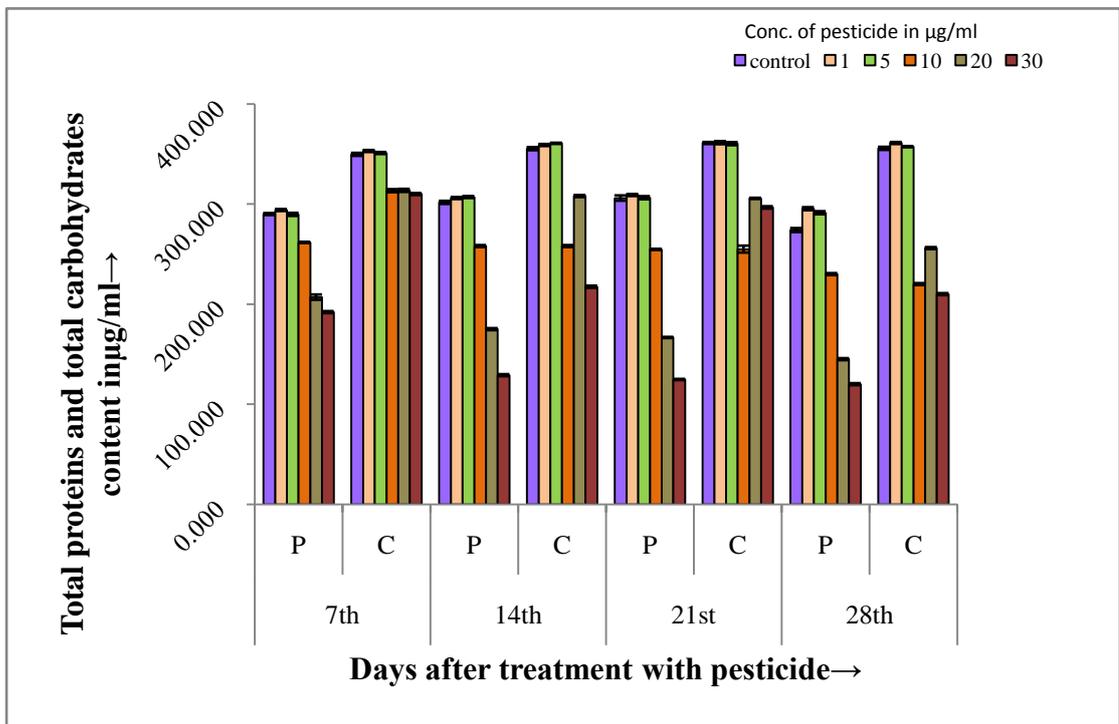


Fig. 8.32: Effect of Phorate on total protein and total carbohydrate content of *C. membranacea*.

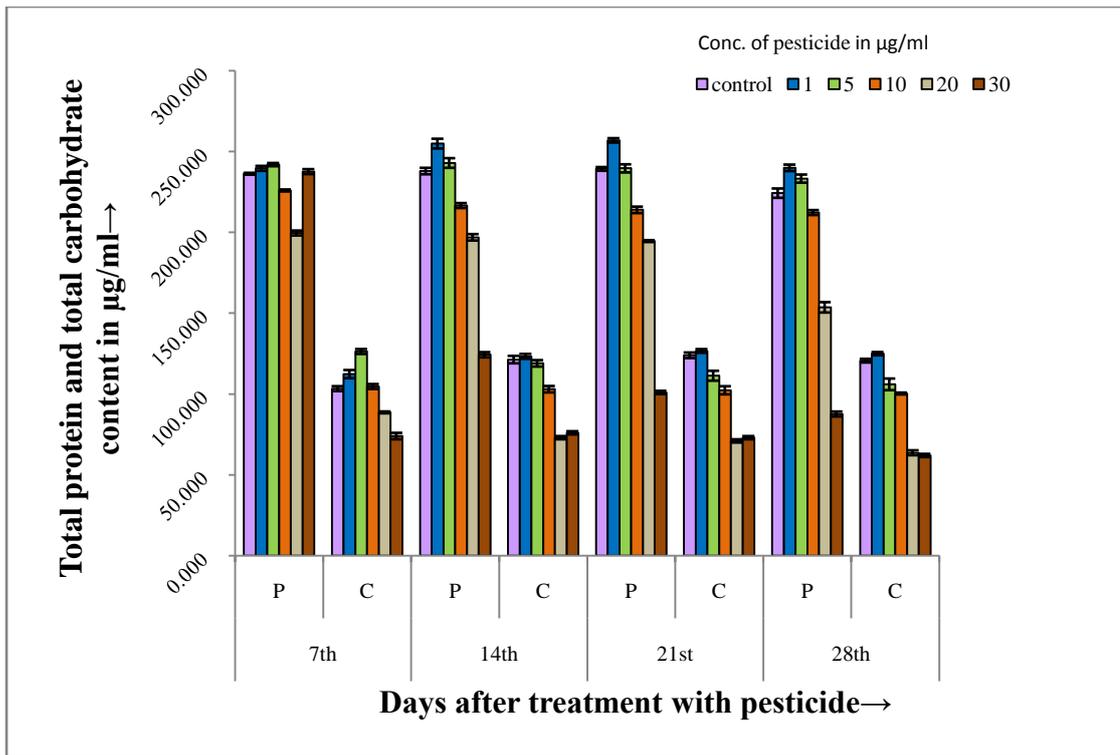


Fig. 8.33: Effect of Rogar 30 on total protein and total carbohydrate content of *N. rivulare*.

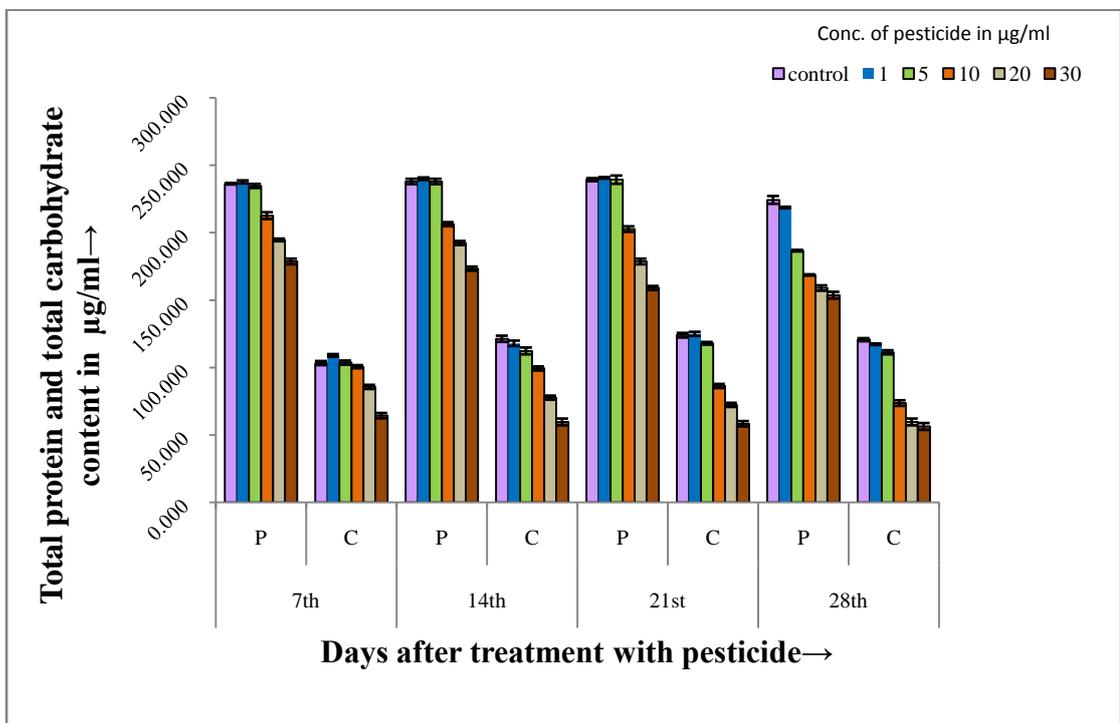


Fig. 8.34: Effect of Monocrotophos on total protein and total carbohydrate content of *N. rivulare*.

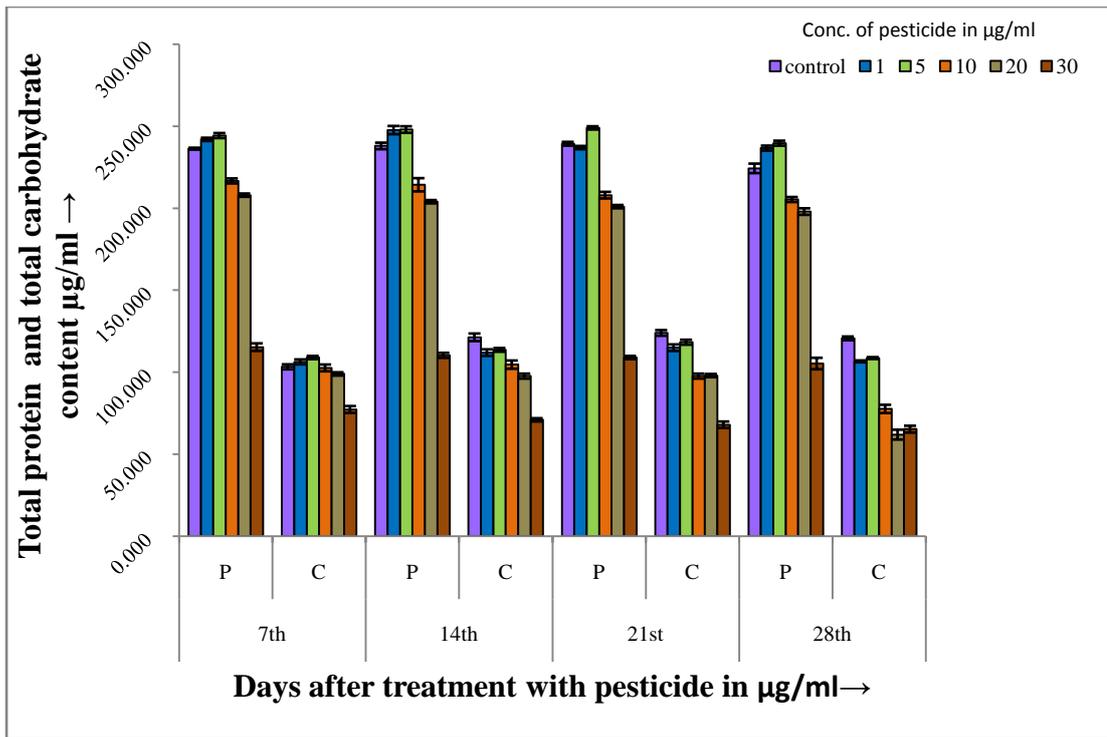


Fig. 8.35: Effect of Butachlor on total protein and total carbohydrate content of *N. rivulare*.

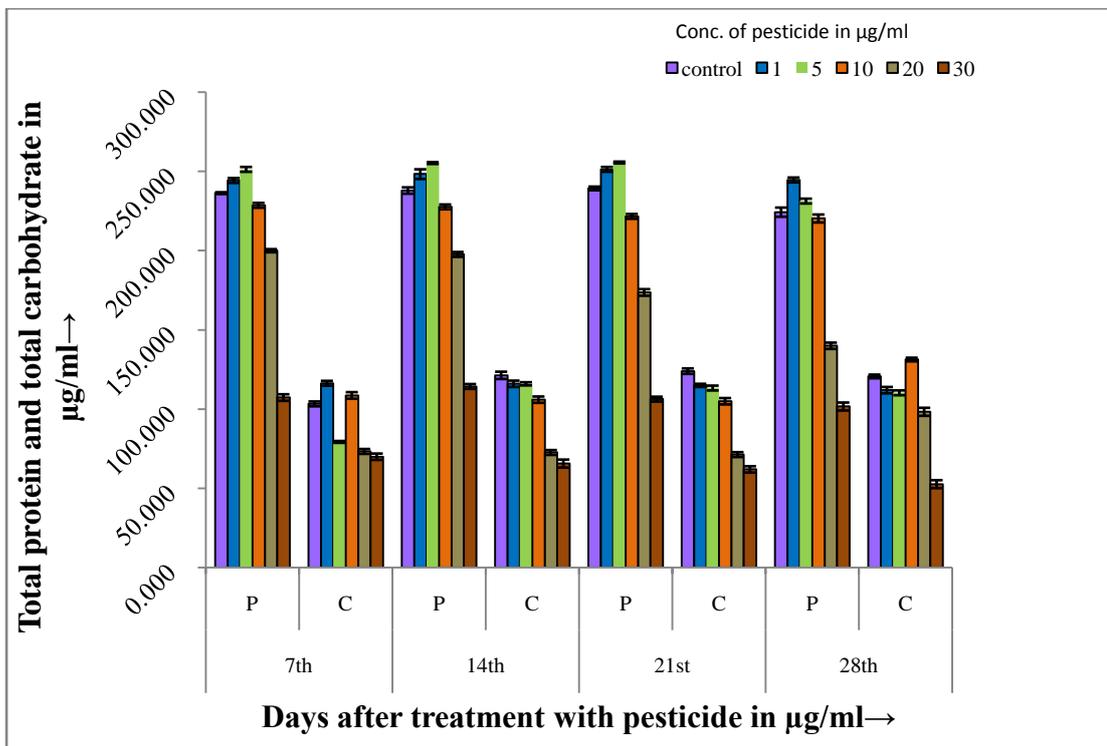


Fig. 8.36: Effect of Phorate on total protein and total carbohydrate content of *N. rivulare*.

In order to study the effect of different concentrations of pesticides Rogar 30, Monocrotophos, Butachlor and Phorate on biomass, chlorophyll content, total proteins and total carbohydrate content for each blue green algae *A. oryzae*, *C. membranacea* and *N. rivulare*, correlation and regression analysis was performed. Pearson's correlation co-efficient (r-values) were determined and its significance was tested by t-test to determine P-value (significance level). A significant negative correlation was observed in *A. oryzae* where increasing concentration of pesticides there was a decrease in biomass (**Table 8.2**), chlorophyll a content (**Table 8.3**), total protein content and total carbohydrate content (**Table 8.4**). This was observed for all the four pesticides. A significant negative correlation was observed in *C. membranacea* where increasing concentration of pesticides showed decrease in biomass (**Table 8.5**), chlorophyll a content (**Table 8.6**), total protein content and total carbohydrate content (**Table 8.7**). This was observed for all the pesticides. A significant negative correlation was found in *N. rivulare* between increasing concentration of pesticides with decrease in biomass (**Table 8.8**), chlorophyll a content (**Table 8.9**), total protein content and total carbohydrate content (**Table 8.10**). This was observed for all the pesticides. Whenever significant correlation was found, it was used to estimate the effect on biomass, chlorophyll content, total protein and total carbohydrate content for a given concentration of the pesticides. This was done by regression analysis. From this the desired correlation is estimated for required biomass, chlorophyll content, total protein content and total carbohydrate content. The correlation as well as the prediction of biomass, chlorophyll a content, total protein and carbohydrate content was done for each time intervals of 7th, 14th, 21st and 28th day.

Table 8.2: Effect of Rogar 30 , Monocrotophos, Butachlor and Phorate on biomass in *A. oryzae*.

Treatment	Day after treatment	Correlation coefficient		Regression coefficient	Regression equation*
		r	p	(b)	(y=a+bx)
Rogar 30	7 th	-0.80	0.06 ns	-21.15	y=3.81-21.15x
	14 th	-0.91	0.01	-6.73	y=5.95-6.73x
	21 st	-0.94	0.01	-2.90	y=2.78-2.90x
	28 th	-0.81	0.05	-15.30	y=3.29-15.3x
Monocrotophos	7 th	-0.75	0.09 ns	-21.80	y=3.71 - 21.8x
	14 th	-0.97	0.01	-6.26	y=5.48 - 6.26x
	21 st	-0.97	0.01	-3.64	y=3.32 - 3.64x
	28 th	-0.98	0.01	-35.50	y=6.10 - 35.5x
Butachlor	7 th	-0.97	0.01	-38.40	y=5.30 - 38.40x
	14 th	-0.92	0.01	-3.85	y=3.38 - 3.85x
	21 st	-0.88	0.02	-2.58	y=2.36 - 2.58x
	28 th	-0.91	0.01	-18.60	y=3.82 - 18.6x
Phorate	7 th	-0.88	0.02	-25.10	y=4.06 - 25.1x
	14 th	-0.97	0.01	-5.82	y=5.17 - 5.82x
	21 st	-0.84	0.04	-2.25	y=2.22 - 2.25x
	28 th	-0.88	0.02	-16.4	y=3.36 - 16.4x

Significance at (p<0.01) and (p<0.05); ns= not significant

*y and x stand for effect and concentration respectively.

Table 8.3: Effect of Rogar 30, Monocrotophos, Butachlor and Phorate on chlorophyll a content of *A. oryzae*.

Treatment	Day after treatment	Correlation coefficient		Regression coefficient	Regression equation*
		r	P	(b)	(y=a+bx)
Rogar 30	7 th	-0.95	0.01	-0.40	y=4.65 - 0.40x
	14 th	-0.98	0.01	-0.35	y=4.39 - 0.35x
	21 st	-0.96	0.01	-0.28	y=3.76 - 0.28x
	28 th	-0.95	0.01	-0.26	y=3.44 - 0.26x
Monocrotophos	7 th	-0.98	0.01	-0.59	y=6.28-0.59x
	14 th	-0.99	0.001	-0.52	y=6.22 - 0.52x
	21 st	-0.97	0.01	-0.41	y=5.19 -0.41x
	28 th	-0.95	0.01	-0.36	y=4.42 - 0.36x
Butachlor	7 th	-0.95	0.01	-0.50	y=5.70 -0.50x
	14 th	-0.98	0.01	-0.47	y=5.55 - 0.47x
	21 st	-0.96	0.01	-0.23	y=4.24 - .32x
	28 th	-0.97	0.01	-0.33	y=3.92 - 0.33x
Phorate	7 th	-0.94	0.01	-0.39	y=4.59 - 0.39x
	14 th	-0.94	0.01	-0.37	y=4.63- 0.32x
	21 st	-0.95	0.01	-0.32	y=4.29 - 0.32x
	28 th	-0.95	0.01	-0.29	y=3.69 - 0.29x

Significance at (p<0.01) and (p<0.05); ns= not significant

*y and x stand for effect and concentration respectively.

Table 8.4: Effect of Rogar 30, Monocrotophos, Butachlor and Phorate on total protein and total carbohydrate content of *A. oryzae*.

Treatment		Day after treatment	Correlation coefficient		Regression coefficient	Regression equation*
			r	P	(b)	(y=a+bx)
Rogar 30	P	7 th	-0.97	0.002	-36.1	y=240 - 36.1x
		14 th	-0.96	0.002	-42.2	y=241 - 42.2x
		21 st	-0.94	0.004	-47.9	y=247 - 47.9x
		28 th	-0.92	0.010	-53.1	y=243 - 53.5x
	C	7 th	-0.97	0.002	-12.6	y=143 - 12.6x
		14 th	-0.95	0.003	-14.1	y=147- 14.1x
		21 st	-0.90	0.013	-29.0	y=174 - 29.0x
		28 th	-0.95	0.003	-28.1	y=155 - 28.1x
Monocrotophos	P	7 th	-0.98	0.001	-43.6	y=245 - 43.6x
		14 th	-0.99	0.000	-45.3	y=247 - 45.3x
		21 st	-0.99	0.000	-52.3	y=255 - 52.3x
		28 th	-0.98	0.001	-54.9	y=251 - 54.9x
	C	7 th	-0.98	0.000	-11.6	y=143 - 11.6x
		14 th	-0.98	0.000	-15.9	y=147 - 15.9x
		21 st	-0.98	0.000	-31.7	y=171 -31.7x
		28 th	-0.95	0.004	-32.7	y=161 - 32.7x
Butachlor	P	7 th	-0.97	0.002	-45.8	y=251 - 45.8x
		14 th	-0.84	0.035	-48.2	y=238 -48.2x
		21 st	-0.99	0.000	-54.7	y=260 - 54.7x
		28 th	-0.98	0.001	-66.2	y=258 - 66.2x
	C	7 th	-0.95	0.003	-18.7	y=145 - 18.7x
		14 th	-0.57	0.238	-21.8	y=166 - 21.8x
		21 st	-0.96	0.003	-32.0	y=161 - 32.0x
		28 th	-0.97	0.001	-36.2	y=156 - 36.2x
Phorate	P	7 th	-0.96	0.002	-36.3	y=240 - 36.3x
		14 th	-0.95	0.002	-39.7	y=244 - 39.7x
		21 st	-0.98	0.001	-47.9	y=250 - 47.9x
		28 th	-0.97	0.002	-51.6	y=243 - 51.6x
	C	7 th	-0.92	0.009	-16.6	y=144 - 16.6x
		14 th	-0.82	0.043	-17.5	y=143 - 17.5x
		21 st	-0.88	0.021	-31.3	y=161 - 31.3x
		28 th	-0.89	0.017	-33.1	y=148 - 33.1x

Significance at (p<0.01) and (p<0.05) Legends: P-Total proteins C-Total carbohydrates; ns= not significant

*y and x stand effect and concentration respectively.

Table 8.5: Effect of Rogar 30, Monocrotophos, Butachlor and Phorate on biomass of *C. membranacea*

Treatment	Day after treatment	Correlation coefficient		Regression coefficient	Regression equation*
		r	p	(b)	(y=a+bx)
Rogar 30	7 th	-0.97	0.01	-0.18	y=0.81 - 0.18x
	14 th	-0.99	0.001	-0.22	y=0.86 - 0.22x
	21 st	-0.96	0.01	-0.25	y=0.91 - 0.25x
	28 th	-0.98	0.01	-0.04	y=0.21 - 0.04x
Monocrotophos	7 th	-0.94	0.01	-0.17	y=0.83 - 0.17x
	14 th	-0.98	0.01	-0.21	y=0.93 - 0.21x
	21 st	-0.96	0.01	-0.23	y=0.94 - 0.23x
	28 th	-0.98	0.01	-0.04	y=0.22 - 0.04x
Butachlor	7 th	-0.96	0.01	-0.16	y=0.76 - 0.16x
	14 th	-0.98	0.01	-0.23	y=0.91 - 0.23x
	21 st	-0.97	0.01	-0.25	y=0.91 - 0.25x
	28 th	-0.98	0.01	-0.03	y=0.21 - 0.03x
Phorate	7 th	-0.96	0.01	-0.18	y=0.78 - 0.18x
	14 th	-0.98	0.01	-0.25	y=0.94 - 0.25x
	21 st	-0.97	0.01	-0.26	y=0.91 - 0.26x
	28 th	-0.98	0.01	-0.04	y=0.21 - 0.04x

Significance at (p<0.01) and (p<0.05); ns= not significant

*y and x stand for effect and concentration respectively.

Table 8.6: Effect of Rogar 30 , Monocrotophos, Butachlor and Phorate on chlorophyll a content of *C. membranacea*

Treatment	Day after treatment	Correlation coefficient		Regression coefficient	Regression equation*
		r	p	(b)	(y=a+bx)
Rogar 30	7 th	-0.95	0.01	-1.63	y=8.58 - 1.63x
	14 th	-0.92	0.01	-2.80	y=11.0 - 2.80x
	21 st	-0.94	0.01	-2.78	y=10.7 - 2.78x
	28 th	-0.86	0.05	-1.97	y = 8.13 - 1.97x
Monocrotophos	7 th	-0.89	0.05	-1.29	y=9.22 - 1.29x
	14 th	-0.95	0.01	-2.08	y=10.9 - 2.08x
	21 st	-0.95	0.01	-2.78	y=10.7 - 2.78x
	28 th	-0.98	0.01	-1.90	y=9.44 - 1.90x
Butachlor	7 th	-0.74	0.09 ns	-0.66	y=9.28 - 0.66x
	14 th	-0.89	0.05	-1.35	y=10.4 - 1.35x
	21 st	-0.88	0.05	-2.21	y=11.9 - 2.21x
	28 th	-0.96	0.01	-1.20	y=8.89 - 1.20x
Phorate	7 th	-0.66	0.15 ns	-0.94	y=10.3 - 0.94x
	14 th	-0.80	0.05	-1.65	y=11.8 - 1.65x
	21 st	-0.94	0.01	-1.28	y=10.3 - 1.28x
	28 th	-0.96	0.01	-1.47	y=9.39 - 1.47x

Significance at (p<0.01) and (p<0.05); ns= not significant

*y and x stand for effect and concentration respectively.

Table 8.7: Effect of Rogar 30 , Monocrotophos, Butachlor and Phorate on total protein and total carbohydrate content of *C. membranacea*.

Treatment		Day after treatment	Correlation coefficient		Regression coefficient	Regression equation*
			r	p	(b)	(y=a+bx)
Rogar 30	P	7 th	-0.96	0.002	-48.4	y=302 - 48.4x
		14 th	-0.98	0.001	-68.2	y=309 - 68.2x
		21 st	-0.92	0.008	-72.4	y=304 - 72.4x
		28 th	-0.94	0.005	-58.2	y=264 - 58.2x
	C	7 th	-0.95	0.004	-54.8	y=353 - 54.8x
		14 th	-0.92	0.009	-56.4	y=353 - 56.4x
		21 st	-0.87	0.024	-59.0	y=354 - 59.0x
		28 th	-0.86	0.028	-57.3	y=347 - 57.3x
Monocrotophos	P	7 th	-0.97	0.001	-65.2	y=306 - 65.2x
		14 th	-0.97	0.001	-72.9	y=309 - 78.9x
		21 st	-0.97	0.001	-78.2	y=319 - 78.2x
		28 th	-0.95	0.004	-64.8	y=261 - 64.8x
	C	7 th	-0.94	0.005	-50.2	y=351 - 50.2x
		14 th	-0.92	0.009	-53.4	y=352 - 53.4x
		21 st	-0.93	0.008	-61.5	y=360 - 61.5x
		28 th	-0.96	0.002	-70.5	y=358 - 70.5x
Butachlor	P	7 th	-0.97	0.002	-40.7	y=302 - 40.7x
		14 th	-0.99	0.000	-60.1	y=312 - 60.1x
		21 st	-0.98	0.001	-66.8	y=316 - 66.8x
		28 th	-0.96	0.003	-62.3	y=288 - 62.3x
	C	7 th	-0.97	0.001	-16.6	y=355 - 16.6x
		14 th	-0.96	0.002	-51.6	y=357 - 51.6x
		21 st	-0.94	0.006	-56.4	y=364 - 56.4x
		28 th	-0.95	0.003	-52.5	y=346 - 52.5x
Phorate	P	7 th	-0.98	0.001	-37.4	y=297 - 37.4x
		14 th	-0.98	0.001	-63.6	y=316 - 63.6x
		21 st	-0.99	0.000	-66.9	y=318 - 66.9x
		28 th	-0.96	0.002	-62.3	y=294 - 62.3x
	C	7 th	-0.86	0.029	-15.5	y=349 - 15.5x
		14 th	-0.84	0.035	-43.1	y=357 - 43.1x
		21 st	-0.61	0.196ns	-23.1	y=349 - 23.1x
		28 th	-0.84	0.037	-51.3	y=350 - 51.3x

Legends: P – Total proteins C- Total carbohydrates

Significance at (p<0.01) and (p<0.05); ns= not significant

*v and x stand for effect and concentration respectively

Table 8.8: Effect of Rogar 30, Monocrotophos, Butachlor and Phorate on biomass of *N. rivulare*.

Treatment	Day after treatment	Correlation coefficient		Regression coefficient	Regression equation*
		r	p	(b)	(y=a+bx)
Rogar 30	7 th	-0.96	0.01	-0.02	y=0.11 - 0.02x
	14 th	-0.98	0.01	-0.21	y=0.92 - 0.21x
	21 st	-0.99	0.01	-0.24	y=0.96 - 0.24x
	28 th	-0.96	0.01	-0.05	y=0.25 - 0.05x
Monocrotophos	7 th	-0.81	0.05	-0.03	y=0.15 - 0.03x
	14 th	-0.97	0.01	-0.14	y=0.89 - 0.14x
	21 st	-0.99	0.01	-0.16	y=0.95 - 0.16x
	28 th	-0.93	0.01	-0.07	y=0.23 - 0.07x
Butachlor	7 th	-0.70	0.12, ns	-0.04	y=0.18 - 0.04x
	14 th	-0.90	0.05	-0.27	y=0.85 - 0.27x
	21 st	-0.87	0.05	-0.32	y=0.88 - 0.32x
	28 th	0.78	0.07 ns	-0.11	y=0.33 - 0.11x
Phorate	7 th	-0.71	0.11 ns	-0.04	y=0.18 - 0.04x
	14 th	-0.96	0.01	-0.28	y=0.88 - 0.28x
	21 st	-0.92	0.01	-0.32	y=0.91 - 0.32x
	28 th	-0.86	0.05	-0.08	y=0.26 - 0.08x

P-Total proteins C-Total carbohydrate Significance at (p<0.01) and (p<0.05); ns= not significant

*y and x stand for effect and concentration respectively.

Table 8.9: Effect of Rogar 30, Monocrotophos, Butachlor and Phorate on chlorophyll a content of *N. rivulare*.

Treatment	Day after treatment	Correlation coefficient		Regression coefficient	Regression equation*
		r	p	(b)	(y=a+bx)
Rogar 30	7 th	-0.95	0.01	-1.09	y=8.90 - 1.09x
	14 th	-0.99	0.01	-2.32	y=11.8 - 2.32x
	21 st	-0.94	0.01	-2.87	y=12.3 - 2.87x
	28 th	-0.92	0.01	-2.84	y=11.6 - 2.84x
Monocrotophos	7 th	-0.96	0.01	-0.72	y=8.84 - 0.72x
	14 th	-0.91	0.01	-2.08	y=11.9 - 2.08x
	21 st	-0.94	0.01	-3.03	y=13.1 - 3.03x
	28 th	-0.85	0.05	-2.15	y=10.2 - 2.15x
Butachlor	7 th	-0.89	0.05	-0.90	y=9.36 - 0.90x
	14 th	-0.93	0.05	-1.74	y=11.1 - 1.74x
	21 st	-0.93	0.01	-2.37	y=12.1 - 2.37x
	28 th	-0.92	0.01	-2.55	y=11.6 - 2.55x
Phorate	7 th	-0.96	0.01	-1.76	y=9.30 - 1.76x
	14 th	-0.94	0.01	-2.72	y=11.3 - 2.72x
	21 st	-0.92	0.01	-3.37	y=12.6 - 3.37x
	28 th	-0.93	0.01	-3.35	y=12.2 - 3.35x

Significance at (p<0.01) and (p<0.05) ; ns= not significant

*y and x stand for effect and concentration respectively.

Table 8.10: Effect of Rogar 30 , Monocrotophos, Butachlor and Phorate on total protein and total carbohydrate content of *N. rivulare*

Treatment		Day after treatment	Correlation coefficient		Regression coefficient	Regression equation*
			r	p	(b)	(y=a+bx)
Rogar 30	P	7 th	-0.38	0.453ns	-5.17	y=236 - 5.17x
		14 th	-0.96	0.003	-38.7	y=255 - 38.7x
		21 st	-0.95	0.004	-45.5	y=258 - 45.5x
		28 th	-0.97	0.001	-49.0	y=246 - 49.0x
	C	7 th	-0.85	0.032	-13.1	y=116 - 13.1x
		14 th	-0.95	0.004	-18.3	y=123 - 18.3x
		21 st	-0.95	0.003	-19.6	y=123 19.6x
		28 th	-0.96	0.002	-22.3	y=121 22.3x
Monocrotophos	P	7 th	-0.99	0.000	-20.7	y=239 - 20.7x
		14 th	-0.97	0.001	-23.3	y=240 - 23.3x
		21 st	-0.98	0.001	-29.3	y=242 - 29.3x
		28 th	-0.89	0.019	-22.7	y=210 - 22.7x
	C	7 th	-0.97	0.002	-13.7	y=109 - 13.7x
		14 th	-0.99	0.000	-20.8	y=121 - 20.8x
		21 st	-0.96	0.002	-23.6	y=123 - 23.6x
		28 th	-0.92	0.008	-23.4	y=116 - 23.4x
Butachlor	P	7 th	-0.91	0.011	-37.7	y=252 - 37.7x
		14 th	-0.93	0.008	-40.9	y=255 - 40.9x
		21 st	-0.92	0.008	-40.4	y=252 - 40.4x
		28 th	-0.91	0.011	-38.5	y=244 - 38.5x
	C	7 th	-0.88	0.020	-8.52	y=109 - 8.52x
		14 th	-0.96	0.002	-14.5	y=119 - 14.5x
		21 st	-0.95	0.004	-16.4	y=122 - 16.4x
		28 th	-0.90	0.015	-18.4	y=111 - 18.9x
Phorate	P	7 th	-0.92	0.009	-42.0	y=258 42.0x
		14 th	-0.93	0.006	-41.0	y=259 - 41.0x
		21 st	-0.97	0.002	-47.4	y=260 - 47.4x
		28 th	-0.96	0.002	-47.6	y=246 - 47.6x
	C	7 th	-0.76	0.081	-12.8	y=106 - 12.8x
		14 th	-0.97	0.001	-19.9	y=122 - 19.9x
		21 st	-0.98	0.001	-21.1	y=122 - 21.1x
		28 th	-0.83	0.040	-19.4	y=126 - 19.4x

Legends: P-Total proteins C-Total carbohydrates

Significance at (p<0.01) and (p<0.05); ns= not significant

*y and x stand for effect and concentration respectively.

DISCUSSION

The present study revealed that the pesticides Rogar 30, Monocrotophos, Butachlor and Phorate had stimulatory effect on growth of BGA at lower concentrations as determined by the increasing biomass, chlorophyll a content, total carbohydrates and total proteins content. Similar stimulation of physiological parameters at very low concentration of pesticides has been observed earlier (Srivastava and Singh, 1981; Chowdhary *et al.*, 1985; Dutta *et al.*, 1992). The study also revealed that in all the three species of BGA retarded growth and showed decline in chlorophyll a, total proteins and total carbohydrates at higher concentrations of pesticides but showed considerable decline at 30µg/ml for all the four pesticides. Bharati and Giriyappanavar, (1986), reported that Rogar 30 had stimulatory effect on vegetative growth of *Cm* at a very low concentration of 0.2ppm but at higher concentration growth and nitrogen fixation capacity was inhibited. Numerous effects of herbicides on non-target cyanobacteria have been reported, including effects on growth, photosynthesis, nitrogen fixation and metabolic activities (Bueno *et al.*, 2004; Kaur *et al.*, 2002; Miquel and Ivo, 2006; Shen *et al.*, 2004 and 2005).

The study recorded maximum decline with 30µg/ml on the 21st day. The indigenous cyanobacteria differ in their sensitivity to the pesticides and the pesticides are differentially toxic to the selected BGA with regard to the different parameters studied. The decreasing order of toxicity for biomass of *A. oryzae* is Butachlor>Rogar 30>Monocrotophos>Phorate, for *C. membranacea* toxicity order is Phorate>Butachlor>Rogar 30>Monocrotophos and decreasing order of toxicity for *Nostoc rivulare* is Phorate>Butachlor>Monocrotophos>Rogar 30. For chlorophyll a content, decreasing order of toxicity of pesticides for *A. oryzae* is

Butachlor>Phorate>Monocrotophos>Rogar 30, for *C. membranacea* toxicity order is Monocrotophos>Rogar 30>Butachlor>Phorate and for *N. rivulare* decreasing order of toxicity is Rogar 30>Phorate = Monocrotophos>Butachlor. The decreasing order of toxicity for total proteins also differ in the three BGA studied. The decreasing order of toxicity for total proteins of *A. oryzae* is Butachlor>Monocrotophos>Rogar 30>Phorate, for *C. membranacea* decreasing order of toxicity is Monocrotophos>Rogar 30>Butachlor>Phorate and for *N. rivulare*, decreasing order of toxicity is Rogar 30>Butachlor>Phorate> Monocrotophos, decreasing order of toxicity of pesticides for total carbohydrates content, for *A. oryzae* is Butachlor>Monocrotophos>Phorate>Rogar 30, for *C. membranacea* decreasing order of toxicity is Monocrotophos>Rogar 30>Butachlor & Phorate and for *N. rivulare*, decreasing order of toxicity is Monocrotophos>Phorate>Butachlor>Rogar 30.

Thus the present study revealed the differential sensitivity of indigenous cyanobacteria to the locally used pesticides in the paddy fields. The decreasing order of sensitivity of the BGA to all the four pesticides studied is *Anabaena oryzae*> *Calothrix membranacea*>*Nostoc rivulare*. Similar studies have been conducted earlier on the comparative sensitivity of pesticides towards various green algae (Abou-Waly *et al.*, 1991, Junghans *et al.*, 2003; Ma *et al.*, 2003 and 2004a). However there are few reports concerning the differential response of various cyanobacteria (Bhaskar *et al.*, 2004).

Since the late 1940's, pesticides have played an important role in increasing the productivity of cropping system in many regions of the world. However cyanobacteria are very sensitive to pesticides as they possess many characteristics of higher plants (EL-Sheekh *et al.*, 1994). Numerous effects of herbicides on non-target cyanobacteria have been reported, including effects on growth, photosynthesis,

nitrogen fixation and metabolic activities (Bueno *et al.*, 2004; Kaur *et al.*, 2002; Miquel and Ivo, 2006; Shen *et al.*, 2004 and 2005). Depending on the type, biological properties, concentration of pesticides and algal strain, their effect on BGA could be inhibitory, selective and even stimulatory (Roger and Kulasooriya, 1980). Venkataraman and Krishnakumari, (1992), reported that cyanobacterial forms used as biofertilizers are capable of tolerating pesticide levels recommended for field applications. Several nitrogen fixing cyanobacteria (*Anabaena* spp.) commonly found in paddy fields of the Shanghai region of China before the extensive use of herbicides such as Bensulfuron, Propanil, Benthocarb and Butachlor are now absent from these system (Shen *et al.*, 2005; Shen and Lu, 2005). Therefore it can be said that if pesticides are not used within recommended doses of field application, sensitive BGA will be more susceptible to replacement than resistant ones which can only lead to a loss of valuable nitrogen fixers of paddy field ecosystem. Rathinasamy (1978) has reported that in higher concentrations there is a breakdown of chlorophyll, proteins, enzymes, respiration and photosynthesis. Rosenberg *et al.*, (1997) reported that pesticides affect all the phytoplanktons including BGA to a lesser or greater extent depending on the pesticide which may lead to the missing of an important link in the food chain. From the present study it is also indicative that the important indigenous nitrogen fixers from the paddy fields of Goa should be protected from being lost by indiscriminate use of agrochemicals.

SUMMARY:

The thesis begins with a general description of cyanophyta followed by review of literature on various aspects of cyanophyta pertaining to the research objectives. In the present study four paddy field habitats showing different soil conditions were selected. These include the hinterland paddy fields in Quepem, coastal area paddy fields in Utorda, khazan paddy fields in Quellossim and mining affected paddy fields in Velguem.

The soil and water samples from all the four paddy field habitats were analyzed for physico-chemical parameters which include pH, EC, DO, Ca, Mg, Cl, P, N, K and micronutrients. The results of the physico-chemical analyses of soil and water showed variations in different habitats. Maximum pH was recorded in the hinterlands, followed by coastal fields, khazans fields and least in the mining affected fields. Other parameters such as P, DO, Ca, Mg, N, K and micronutrients showed higher amounts in the hinterlands, followed by coastal fields, khazans fields and least in mining affected paddy fields.

According to the meteorological data, kharif and rabi season showed adequate sunshine, rainfall and optimum temperature during the study period. The study revealed that the hinterlands are most suitable whereas the mining affected paddy fields are least suitable for the growth of BGA.

The study revealed 84 species belonging to 16 genera from the study areas. The three year study revealed variations in the distribution of genera and species in the two growing seasons of paddy *i.e.*, kharif and rabi.

The study also revealed that the species of BGA documented in the study belonged to the three different groups viz., unicellular, heterocystous and non-heterocystous forms. All the 13 species of unicellular forms belonging to five genera were members of family Chroococcaceae of order Chroococcales. *Microcystis* is represented by two species viz., *M. aeruginosa* and *M. elabens*, *Chroococcus* is represented by *C. turgidus*, *C. minutes*, *C. pallidus* and *C. cohaerens*; *Gloecapsa* is represented by *G. punctata*, *G. aeruginosa* and *G. kuetzingiana*; *Aphanocapsa* is represented by *A. banarensensis*; while *Aphanothece* is represented by *A. stagnina*, *A. saxicola* and *A. castegnei*.

The non-heterocystous forms belonged to family Oscillatoriaceae of order Nostocales. The study recorded 30 species belonging to four genera of non-heterocystous forms. *Lyngbya* is represented by *L. spiralis*, *L. bergei*, *L. dendrobia*, *L. confervoides* and *L. martensiana*; *Oscillatoria* is represented by 19 species viz., *O. ornata*, *O. limosa*, *O. subbrevis*, *O. curviceps*, *O. princeps*, *O. anguina*, *O. proboscidea*, *O. chlorina*, *O. martini*, *O. chalybea*, *O. tenuis*, *O. simplissima*, *O. limnetica*, *O. pseudogeminata*, *O. claricentrosa*, *O. formosa*, *O. salina*, *O. acuminata*, *O. brevis*; *Spirulina* is represented by *S. meneghiniana*, *S. princeps*; while *Phormidium* is represented by *P. jadinianum*, *P. microtomum*, *P. purpurascens* and *P. mucosum*.

The heterocystous forms identified belonged to three families viz., Nostocaceae, Scytonemataceae and Rivulariaceae. A total of 41 species belonging to seven genera of heterocystous forms were recorded during the study period. Family Nostocaceae was represented by genera *Cylindrospermum*, *Nostoc* and *Anabaena*. *Cylindrospermum* is represented by *C. stagnale* and *C. musicola*; *Nostoc* is represented by 14 species viz., *N. punctiforme*, *N. entophyllum*, *N. paludosum*, *N.*

linkia, *N. rivulare*, *N. carneum*, *N. ellipso sporum*, *N. calcicola*, *N. passerinianum*, *N. muscorum*, *N. commune*, *N. microscopium*, *N. hatei* and *N. sphaericum*; *Anabaena* is represented by six species viz., *A. sphaerica*, *A. oryzae*, *A. fertilissima*, *A. naviculoides*, *A. variabilis* and *A. torulosa*. Family Scytonemataceae is represented by two genera viz., *Scytonema* and *Tolypothrix*. *Scytonema* is represented by five species viz., *S. simplex*, *S. coactile*, *S. bohneri*, *S. schmidtii* and *S. fremyii* while *Tolypothrix* is represented by five species viz., *T. nodosa*, *T. tenuis*, *T. fragilis*, *T. byssoidea* and *T. conglutinata*. Family Rivulariaceae recorded nine species belonging to two genera. *Calothrix* is represented by *C. castellii*, *C. elenkinii*, *C. braunii*, *C. parietina*, *C. weberi*, *C. membranacea* and *C. marchica*. *Rivularia* is represented by only two species viz., *R. aquatica* and *R. globiceps*. The forms showed variations in their occurrence during both kharif and rabi seasons. Maximum diversity of the BGA forms was observed in the hinterlands fields, followed by coastal fields and khazan fields, while the least diversity was recorded in mining affected paddy fields.

Studies on the density and diversity of cyanobacteria from the four selected paddy field habitats of Goa revealed that the hinterlands showed highest density of 64×10^3 BGA/ml in kharif season for heterocystous forms followed by coastal paddy fields (54×10^3 BGA/ml), followed by khazan fields (50×10^3 BGA/ml) and mining affected fields (32×10^3 BGA /ml). Rabi season recorded 61×10^3 BGA/ml in the hinterlands, 56×10^3 BGA/ml in coastal fields, 47×10^3 BGA/ml in khazan fields and 34×10^3 BGA/ml in mining affected fields. Overall, the data indicates the predominance of heterocystous forms in all the four habitats followed by non-heterocystous and unicellular forms.

Diversity indices of the different groups of BGA in the study sites showed variations. Shannon's diversity index (H) in the study sites for all groups of BGA was in the range 1.5 to 1.6. The highest Shannon's diversity index of 1.608 was recorded in kharif season during the study period 2008-09 in coastal and khazan paddy fields for heterocystous forms while lowest Shannon's diversity index of 1.587 was recorded in kharif season during the study period 2008-09 in mining affected paddy fields for unicellular forms.

Simpson diversity index (1-D) in all the habitats of all groups of BGA was in the range 0.79-0.80. The highest Simpson diversity index of 0.80 was recorded during the study period 2008-09 in rabi season for non-heterocystous in the hinterlands, whereas lowest Simpsons diversity index of 0.790 was recorded in kharif season during the study period 2008-09 in mining affected paddy fields for unicellular forms.

The Margalef's diversity indices in all the habitats of all three groups of BGA were in the range of 0.9 to 1.2. The highest Margalef's diversity index of 1.294 was recorded during the kharif season of study period 2007-08 and rabi season of 2008-09 for unicellular forms in mining affected paddy fields, whereas lowest Margalef's diversity index of 0.9618 was recorded in kharif season during the study period 2006-07 in hinterlands for heterocystous forms in kharif season. Thus the present study indicates that, the overall density and diversity of BGA is highest in the hinterlands followed by coastal fields, khazans and was least in mining affected fields.

Thus the present study on the density and diversity of BGA in paddy fields of Goa would help in developing niche specific inocula of indigenous species of BGA for paddy fields in the state.

Biofertilization of *Oryza sativa* L. (var. jaya) with BGA

Dominant heterocystous forms of BGA viz., *Anabaena oryzae* Fritsch, *Calothrix membranacea* Schmidle and *Nostoc rivulare* Kützing ex Born et Flah, were screened and identified using standard keys. These were cultured using BG-II Medium and used for 'algalization' pot experiments to test their biofertilization potential using a locally grown hybrid paddy variety, *Oryza sativa* L. (var. jaya). The algal treatments were single and in different combinations of the three BGA species used in the study.

The results indicate that BGA either single or in combination with other blue greens produce significant increase in most of the growth, yield and biochemical parameters in *O. sativa* (var. jaya). The combination treatment of local BGA (*Ao* + *Cm* + *Nr*) resulted in maximum increase in plant height, plant weight, spike length, number of tillers per hill, length of panicle and grain yield compared to control. Carbohydrate content increased significantly in the combination treatment *Ao+Cm+Nr* over control. Protein content also showed an increase over control in all single as well as combined treatments. Maximum protein content of grains was recorded in combination treatment of *Ao+Cm+Nr*. Maximum increase in leaf chlorophyll was recorded in the combination treatments of *Ao+Cm* (21%) followed by *Ao+Cm+Nr* (20%) increase over control.

Effect of different BGA combinations on plant growth parameters and grain yield were studied and their comparative results analyzed by one way ANOVA. Most of the parameters analyzed showed significant results, significant at $P < 0.05$ and $P < 0.01$. The study revealed the combination treatment *Ao+Cm+Nr* showed significant and maximum increase in growth and yield parameters in paddy. It also

improved the grain carbohydrate and protein content. Thus the study indicates that the indigenous cyanobacterial strains showed positive response and could be used to fertilize the paddy fields.

Effects of commercial fertilizers on BGA

Effect of two commercial fertilizers *viz.*, Samarth and Samrat was studied on selected species of indigenous BGA. The study revealed that the growth of the indigenous cyanobacterial species from paddy fields is not affected at recommended levels of commercial fertilizers used in paddy fields of Goa. Enhanced growth was seen in the exponential growth phase between 200 to 300 µg/ml. The study suggests that different cyanobacterial species respond differently to different fertilizers depending on the type of fertilizers and their concentration.

Effect of pesticides on BGA

Effect of pesticides *viz.*, Rogar 30, Monocrotophos, Butachlor and Phorate on biomass, chlorophyll a content, total proteins and carbohydrate content in *Anabaena oryzae*, *Calothrix membranacea*, *Nostoc rivulare* was studied. The results indicate that at low concentrations (1 and 5 µg/ml) pesticides stimulated growth as it increased the biomass, chlorophyll a content, total protein and total carbohydrates content but at higher concentration they retarded growth showing by showing a decline in biomass, chlorophyll 'a' content, total protein and carbohydrate content. The study recorded maximum decline at 30 µg/ml on 21st day of analysis.

The indigenous cyanobacteria differed in their sensitivity to pesticides as the pesticides were differentially toxic to the selected species of BGA. The decreasing order of toxicity for biomass of *Anabaena oryzae* was Butachlor > Rogar

30>Monocrotophos>Phorate; for *Calothrix membranacea* it was Phorate>Butachlor >Rogar 30>Monocrotophos and decreasing for *Nostoc rivulare* was Phorate>Butachlor>Monocrotophos>Rogar 30.

For chlorophyll 'a' content, decreasing order of toxicity of pesticides for *Anabaena oryzae* was Butachlor>Phorate>Monocrotophos>Rogar 30, for *Calothrix membranacea* it was Monocrotophos>Rogar 30>Butachlor>Phorate and for *Nostoc rivulare* it was Rogar 30>Phorate = Monocrotophos>Butachlor.

The decreasing order of toxicity for total proteins of *Anabaena oryzae* was Butachlor>Monocrotophos>Rogar30>Phorate, for *Calothrix membranacea* it was Monocrotophos>Rogar30>Butachlor>Phorate and for *Nostoc rivulare* it was Rogar 30>Butachlor>Phorate> Monocrotophos.

Decreasing order of toxicity of pesticides for total carbohydrates content in *Anabaena oryzae* was Butachlor>Monocrotophos>Phorate>Rogar 30, for *Calothrix membranacea* it was Monocrotophos>Rogar 30>Butachlor and Phorate and for *Nostoc rivulare* it was Monocrotophos>Phorate>Butachlor>Rogar 30.

Thus the present study revealed the differential sensitivity of indigenous cyanobacteria to the locally used pesticides in the paddy fields. From the studied species of BGA, the decreasing order of sensitivity to the pesticides used in the study was *Anabaena oryzae*>*Calothrix membranacea* >*Nostoc rivulare*.

CONCLUSION :

An understanding of the physico-chemical parameters of the study sites revealed that the hinterlands can support better growth of BGA than the mining affected paddy fields. According to the meteorological data, kharif and rabi season of crop showed adequate sunshine, rainfall and optimum temperature during the study period in all study sites but variations in their physico-chemical parameters limited the density of BGA. Therefore hinterlands, coastal fields and khazan fields with optimum conditions for growth of BGA viz., pH, EC, DO, P, N, Ca proved to support better growth of BGA than mining affected paddy fields with poor conditions due to influx of mine rejects.

Thus the study revealed rich density and diversity of indigenous flora of BGA in the undisturbed paddy fields of Goa. However disturbed sites like the mining affected paddy fields recorded less density and diversity of BGA. An understanding of the physico-chemical parameters, density and diversity of indigenous BGA in the paddy fields helps in studying the distribution of BGA and thus develop niche specific inocula for biofertilization. It can be applied for sustainable agricultural practices by reducing the application of chemical fertilizers to obtain indigenous inocula for algalization of fields. The present study also revealed that the use of indigenous cyanobacterial strains for 'algalization' with pot experiments using *Oryza sativa* L. (var. jaya) was encouraging and proved to be an efficient biofertilizer. It may be thus concluded that biofertilization of jaya variety of paddy could be extended for field trials in future. The study also revealed that these indigenous nitrogen fixers are affected by agrochemicalization of paddy fields but recommended doses of fertilizers do not affect the BGA. Most of these cyanobacteria have dual role of being able to fix elemental nitrogen and also utilize various types of nitrogenous fertilizers for their

growth. Selection of such cyanobacterial strains to develop niche specific inocula of indigenous cyanobacterial species will be highly beneficial.

But however sensitivity of BGA to pesticides is more even at low concentration. Therefore it can be said that if pesticides are not used within recommended doses of field application, sensitive BGA will be more susceptible to replacement than resistant ones which can only lead to a loss of valuable nitrogen fixers of paddy field ecosystem. At higher concentrations of all pesticides, BGA exhibit no active growth and in very high concentrations there is breakdown of chlorophyll, proteins, enzymes, respiration and photosynthesis of BGA. Pesticides affect all the phytoplankton's including BGA to a lesser or greater extent depending on the pesticide which may lead to the missing of an important link in the food chain. From the present study it may be concluded that the important indigenous nitrogen fixers from the paddy fields of Goa should be protected from being lost due to indiscriminate use of agrochemicals.

Role of cyanobacteria in agriculture and industry has both promise and potential. The effect of BGA has so far been studied mainly in paddy fields that are ideal for the growth of BGA, but their effect on dry crops need experimentation and will further boost their role in agriculture. Effective utilization of cyanobacterial biofertilizers will not only provide economic benefits but also improve and maintain soil fertility and sustainability in natural ecosystem. Applications of BGA for human and animal nutrition, cosmetics and production of high value molecules like fatty acids, pigments *etc.* has also gained importance in recent years. Development of different systems implying varied kinds of sophisticated bioreactors can lead to quality biomass production and further enhance their use in functional foods and nutraceuticals.

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APPENDIX

LIST OF PUBLICATIONS

PAPERS PUBLISHED

1. “Effect of algal biofertilizers on growth and yield of *Oryza sativa* L. (var. jaya) in coastal region of Goa” in *Int. J. Pharmacol. Bio. Sci.* Vol. 5 (2) 2011, 103-114.
2. “Density and Diversity of Blue Green Algae from the rice fields of Goa” in *Int. J. Advanced Biological Research* Vol. 1[1] December 2011.
3. “Effect of local fertilizers on indigenous species of BGA in rice fields of Goa” 2011. In: Proc. Natl. Conf. on “Biodiversity and Biotechnology for Sustainable Development” March 21st-22nd at Karnatak University and PG Department of studies in Botany, UGC-SAP-DRS-III, Dharwad India.

RESEARCH PAPERS PRESENTED

1. “Biodiversity of Cyanophycean members from the paddy fields of Khazan Lands” presented at National Conference on “Sustainable Management of Agriculture-Changing Scenario in 21st century” held from 5th and 6th February 2009 organized by Department of Botany and Zoology in association with Directorate of Agriculture at NIO Dona Paula Goa.
2. “Blue green algae from the rice fields of selected habitats of Goa” was presented at National Symposium on Phycology in India: Basic to Applied. Feb 12th -13th 2009, Punjabi University, Patiala.
3. “Effect of pesticides on indigenous species of blue green algae selected from coastal rice growing regions of Goa” was presented at the 12th Annual Conference of Society of Science and Environment “Interdisciplinary Approaches in Environmental Sciences” held from 6th-8th Oct. 2010 at Maharaja Sayajirao University, Vadodara, Gujarat.
4. “Density and Biodiversity of BGA in rice fields of Goa” was presented as poster at a National Symposium “Lake 2010: Wetlands, Biodiversity and Climate Change 22nd-24th December 2010” organized by Energy & Wetlands Research Group, Centre for Ecological Sciences (CES), Indian Institute of Science (IISc), Bangalore.

PLATE - I

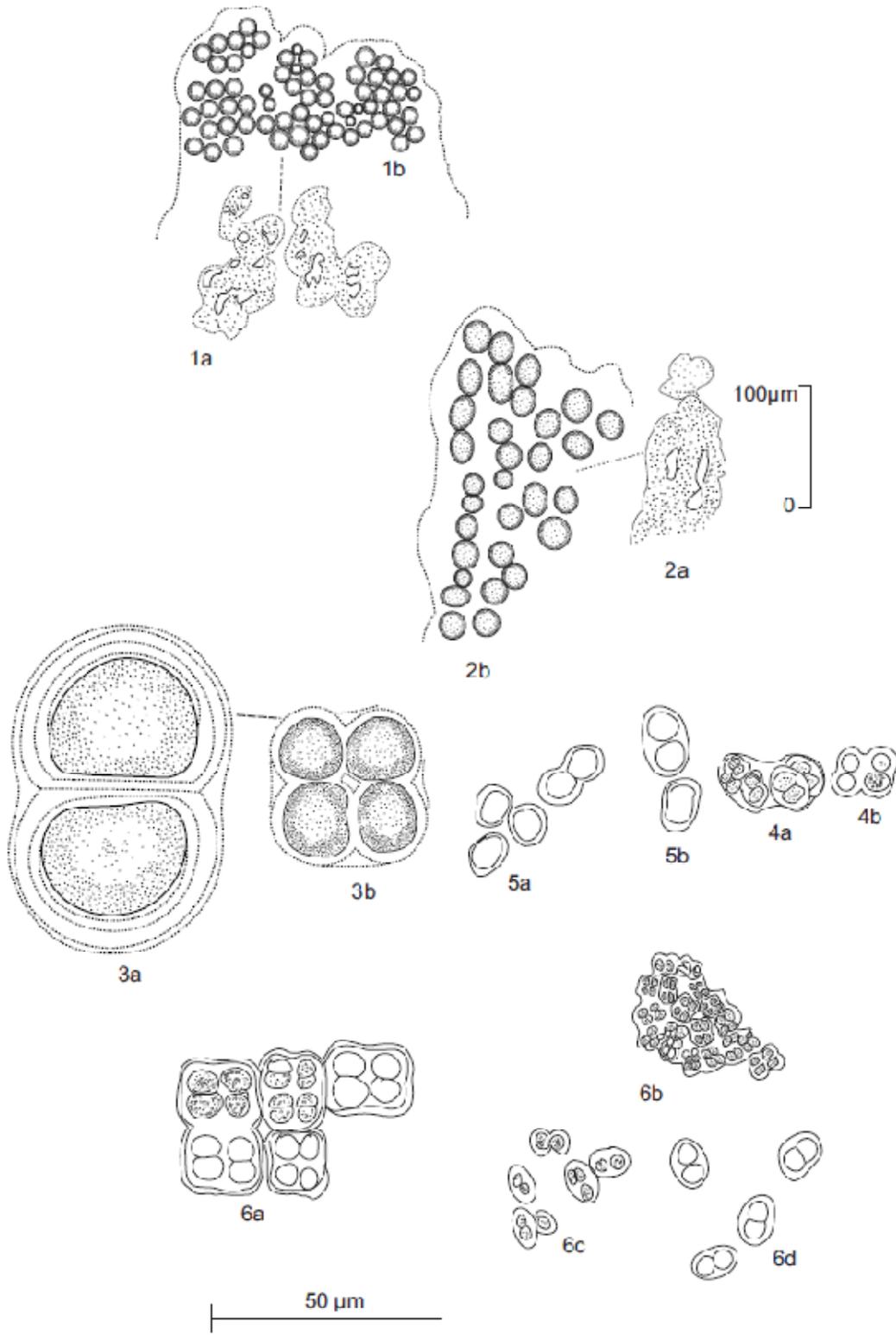
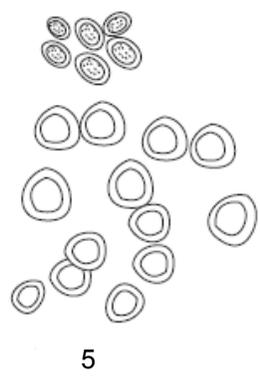
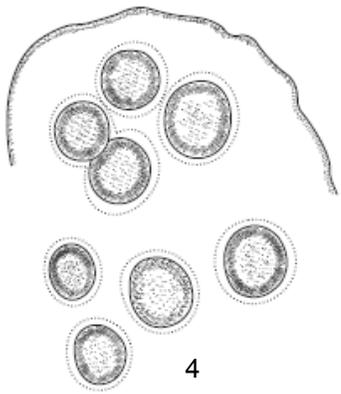
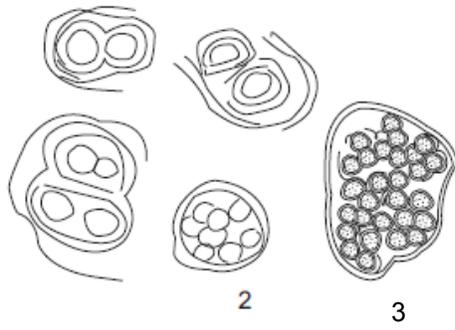
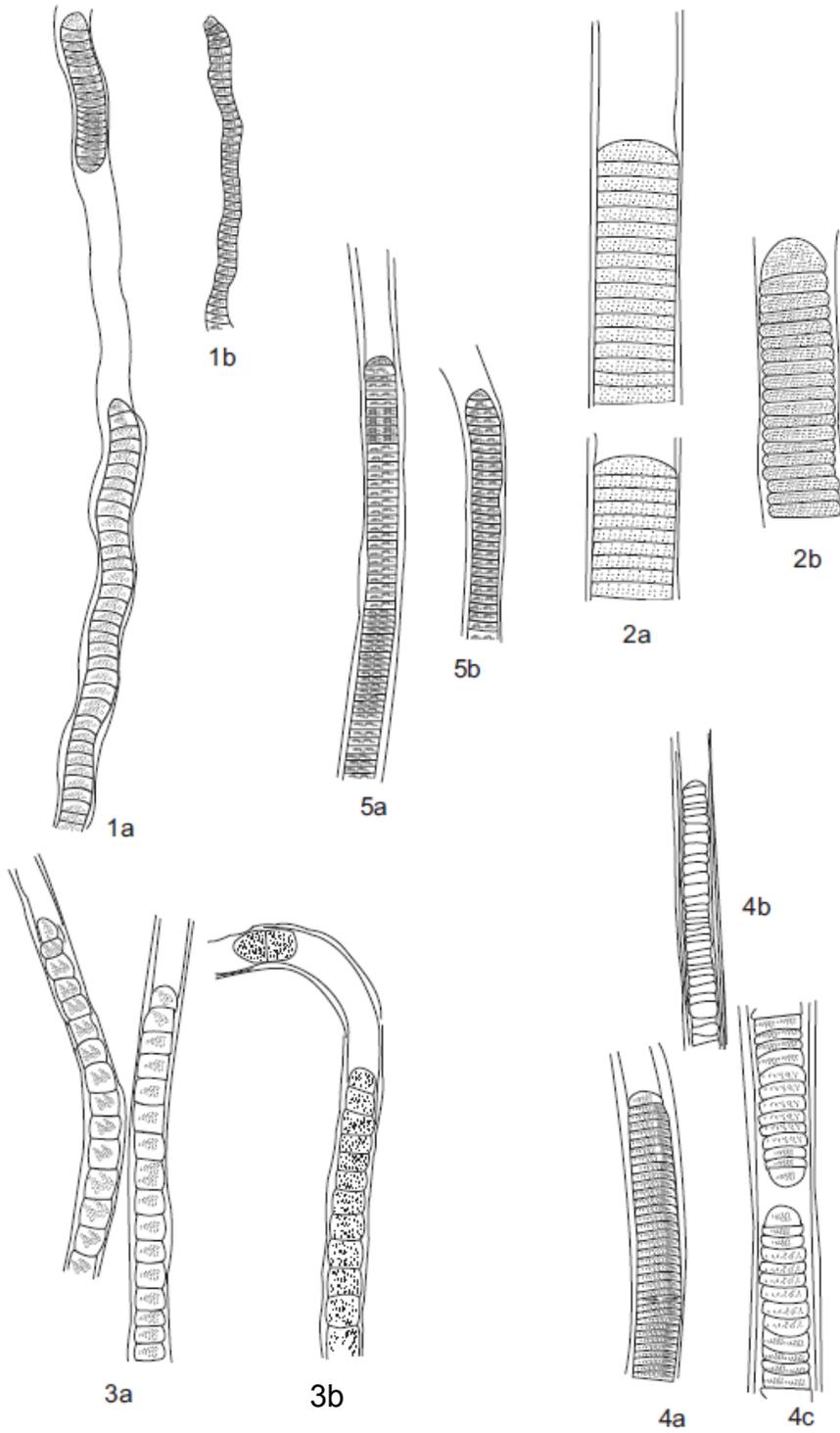


PLATE - II



50 μ m

PLATE - III



25 μ m

PLATE - IV

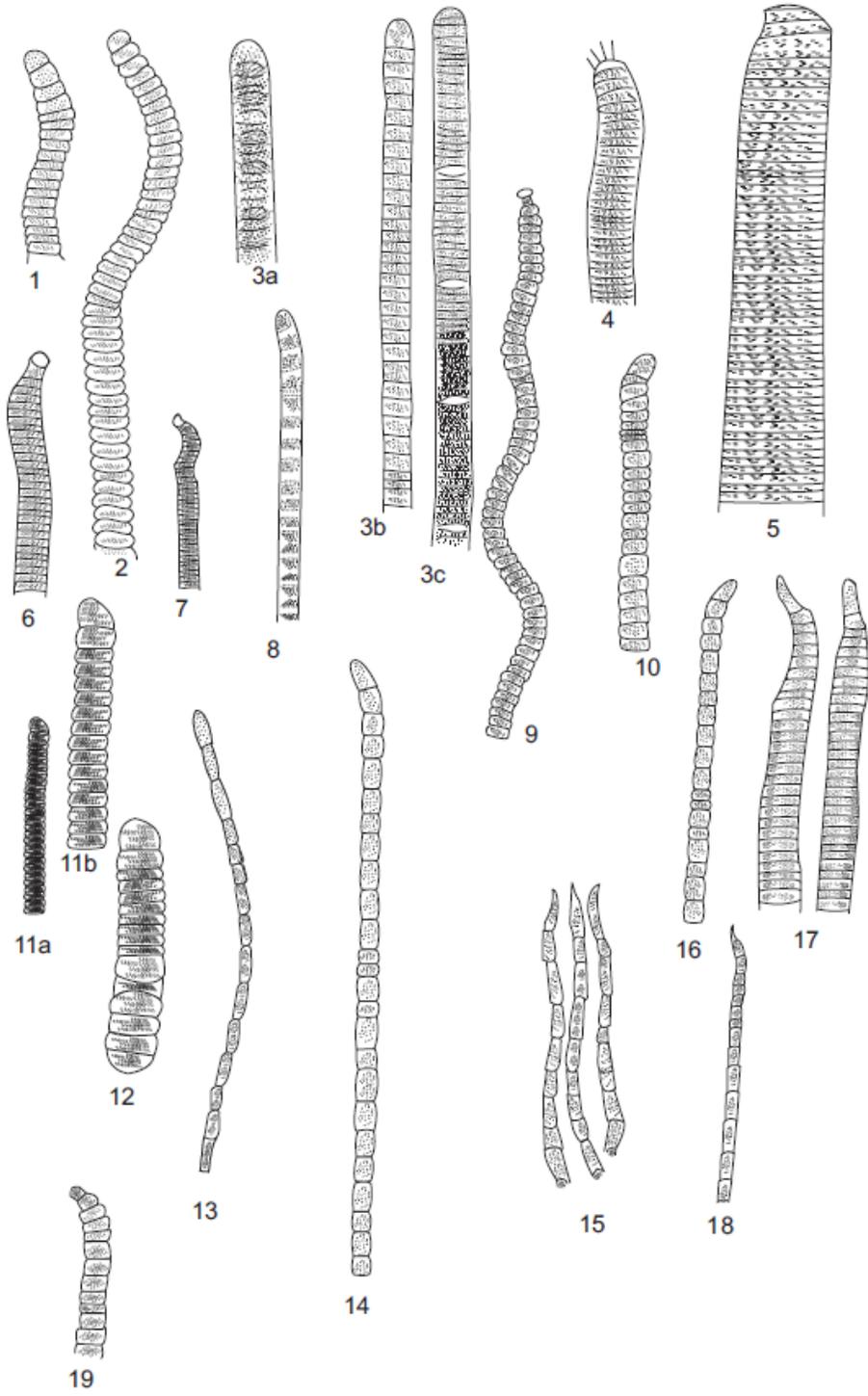


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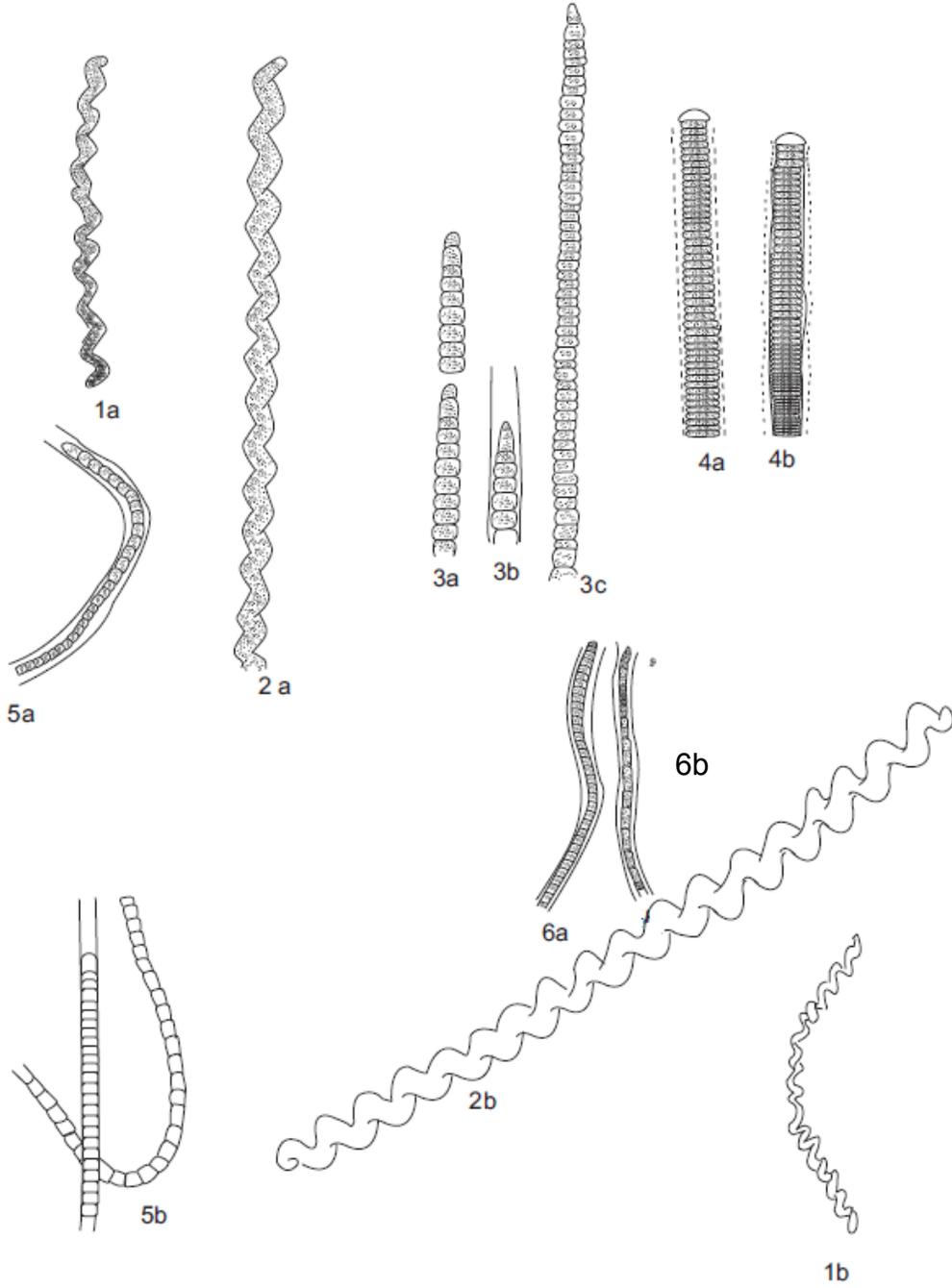


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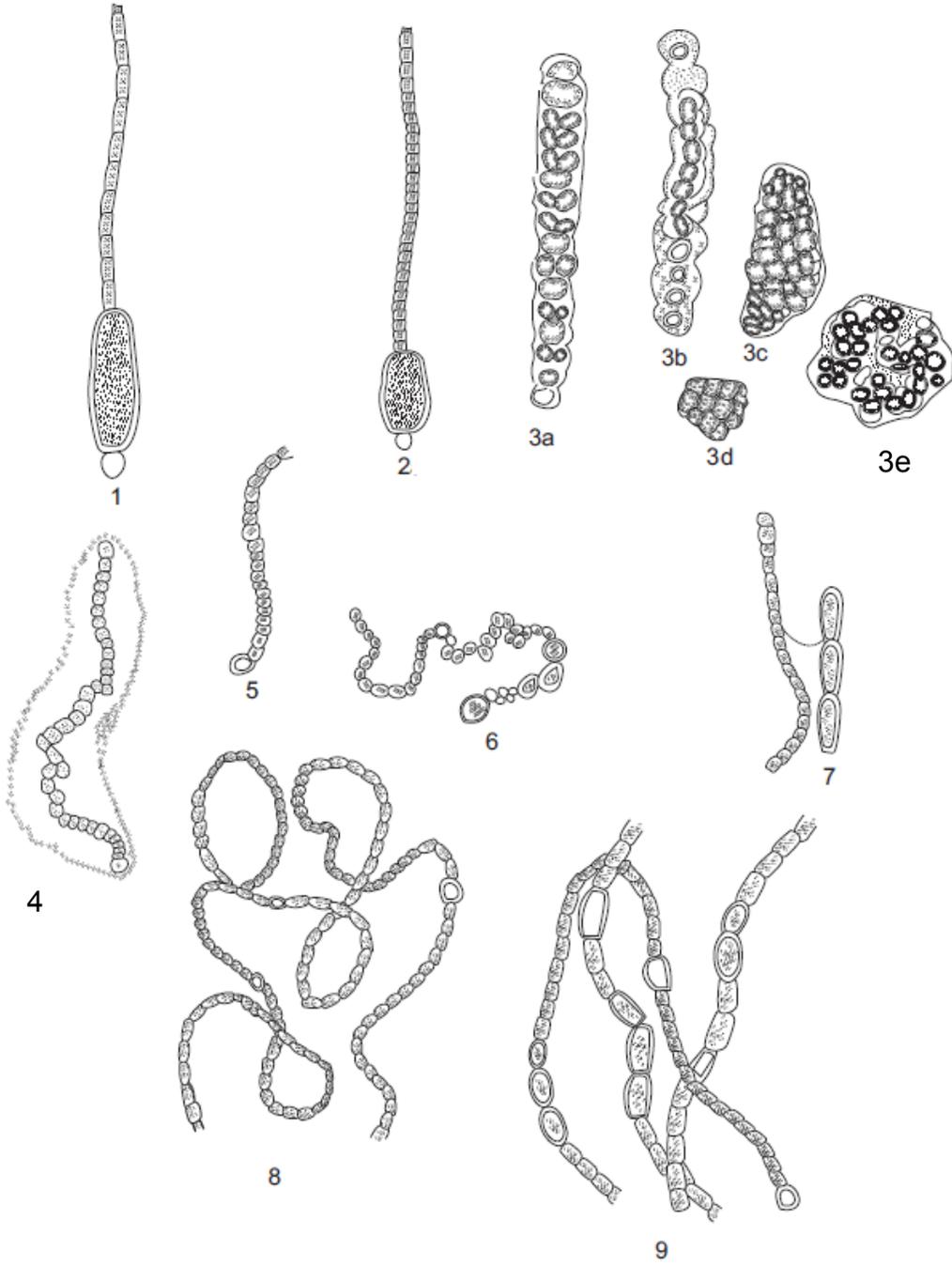


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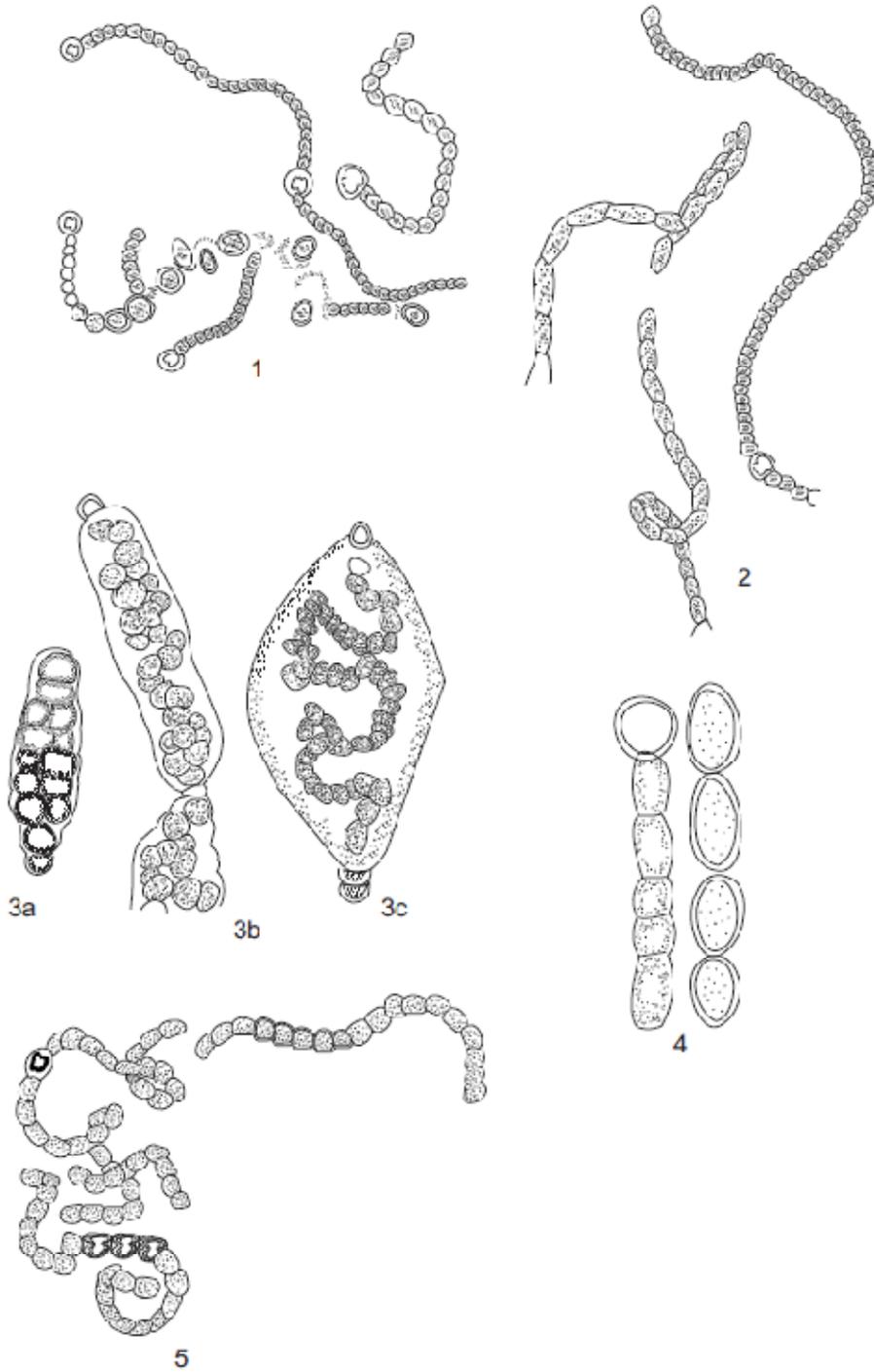


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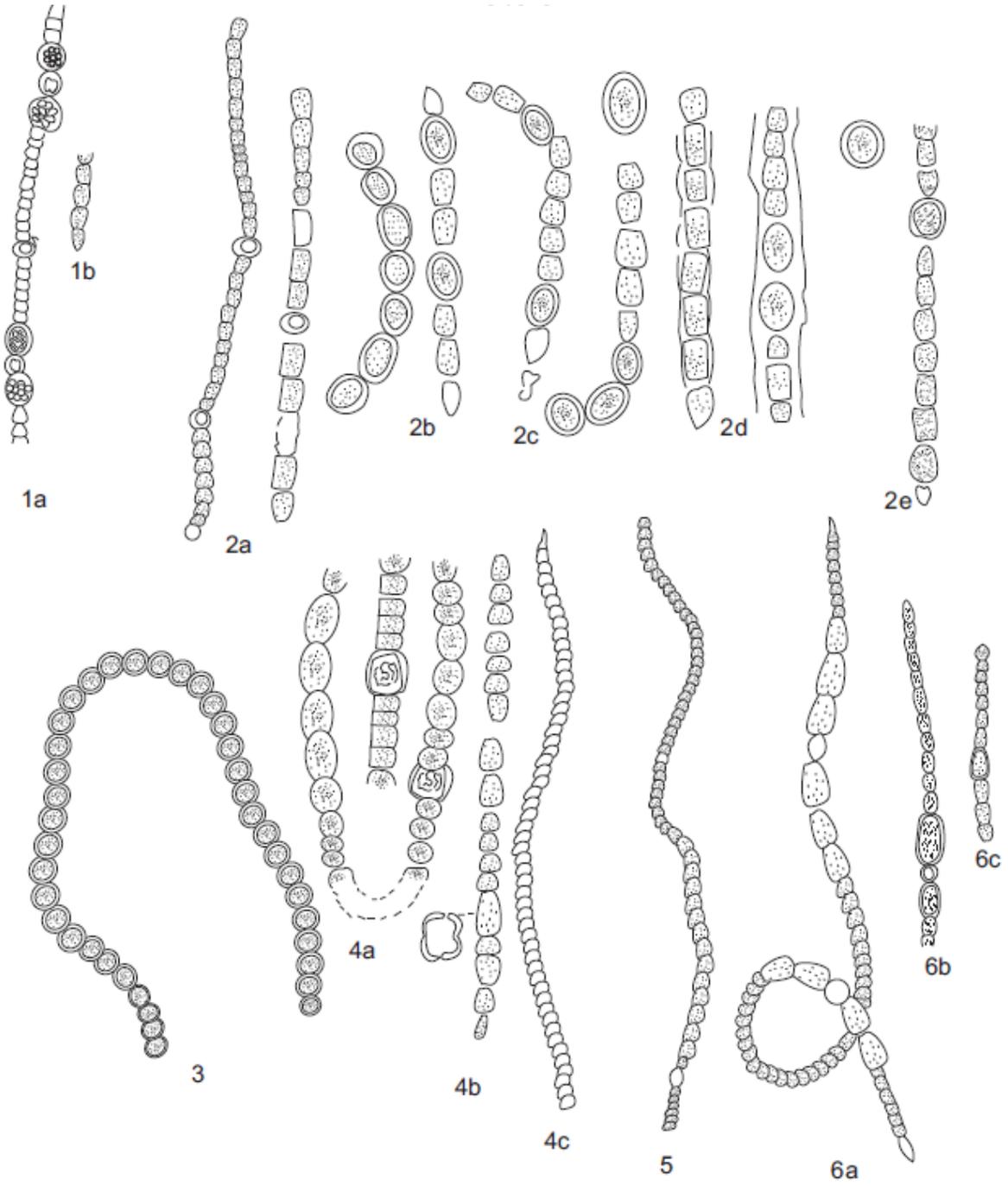


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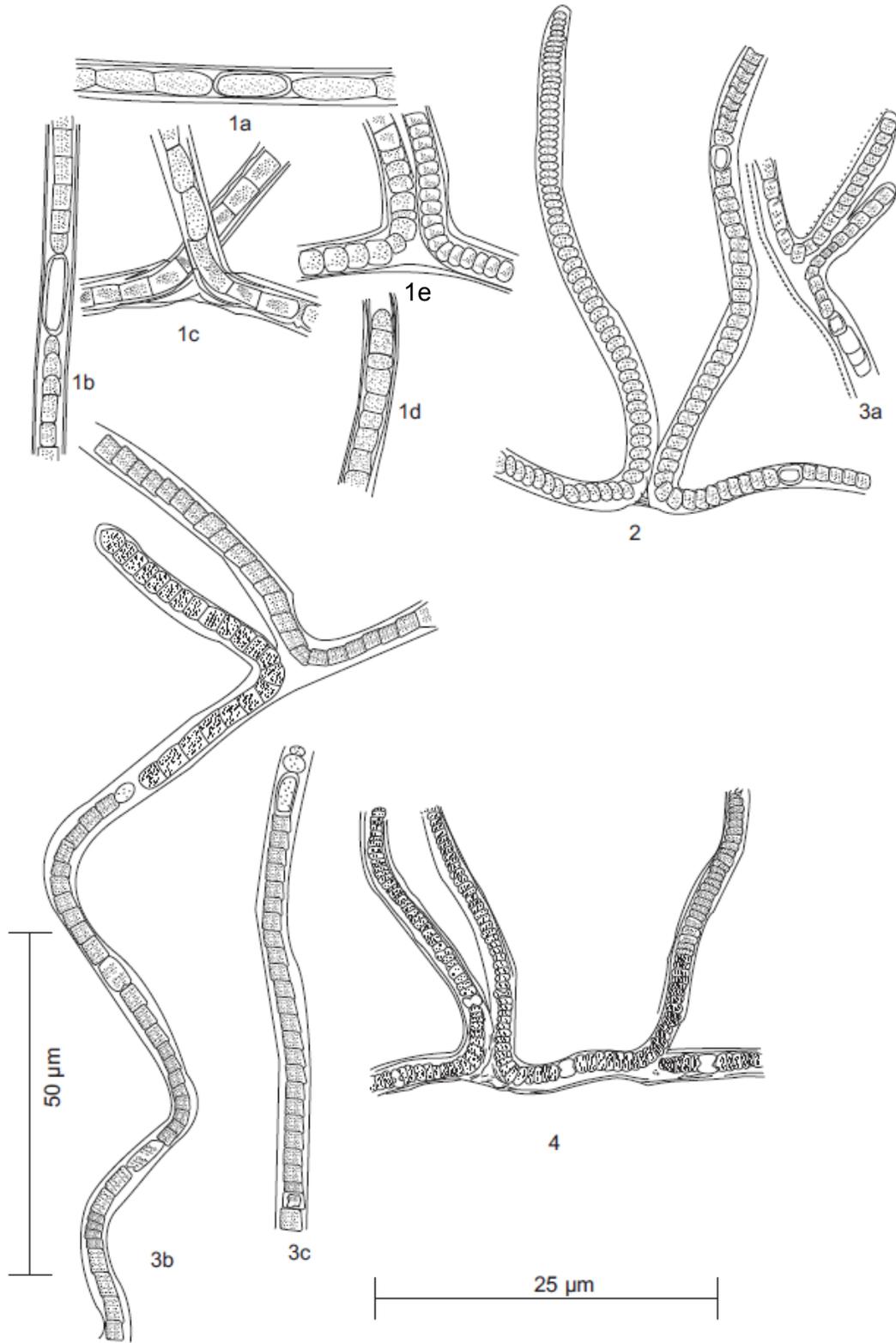


PLATE - X

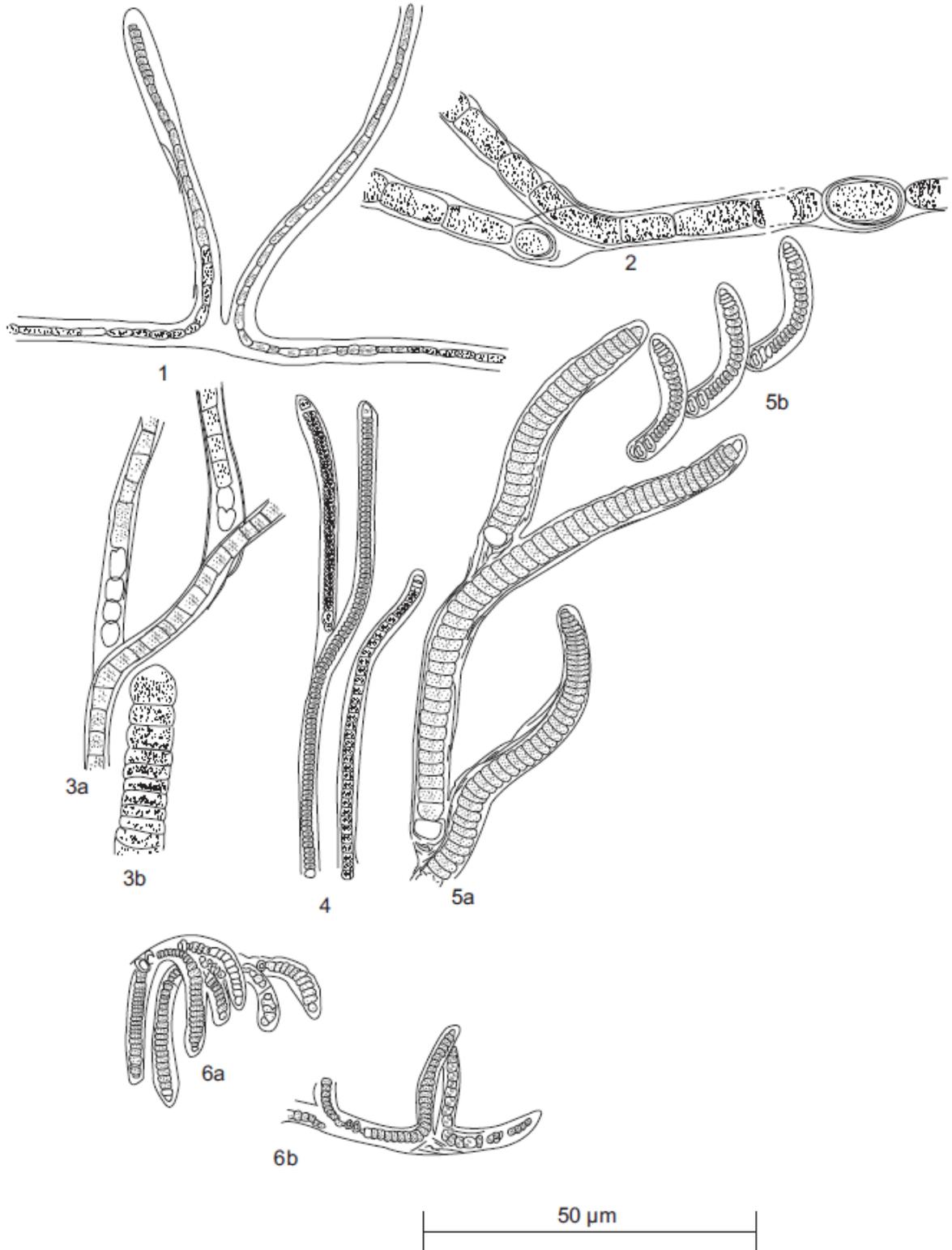


PLATE - XI

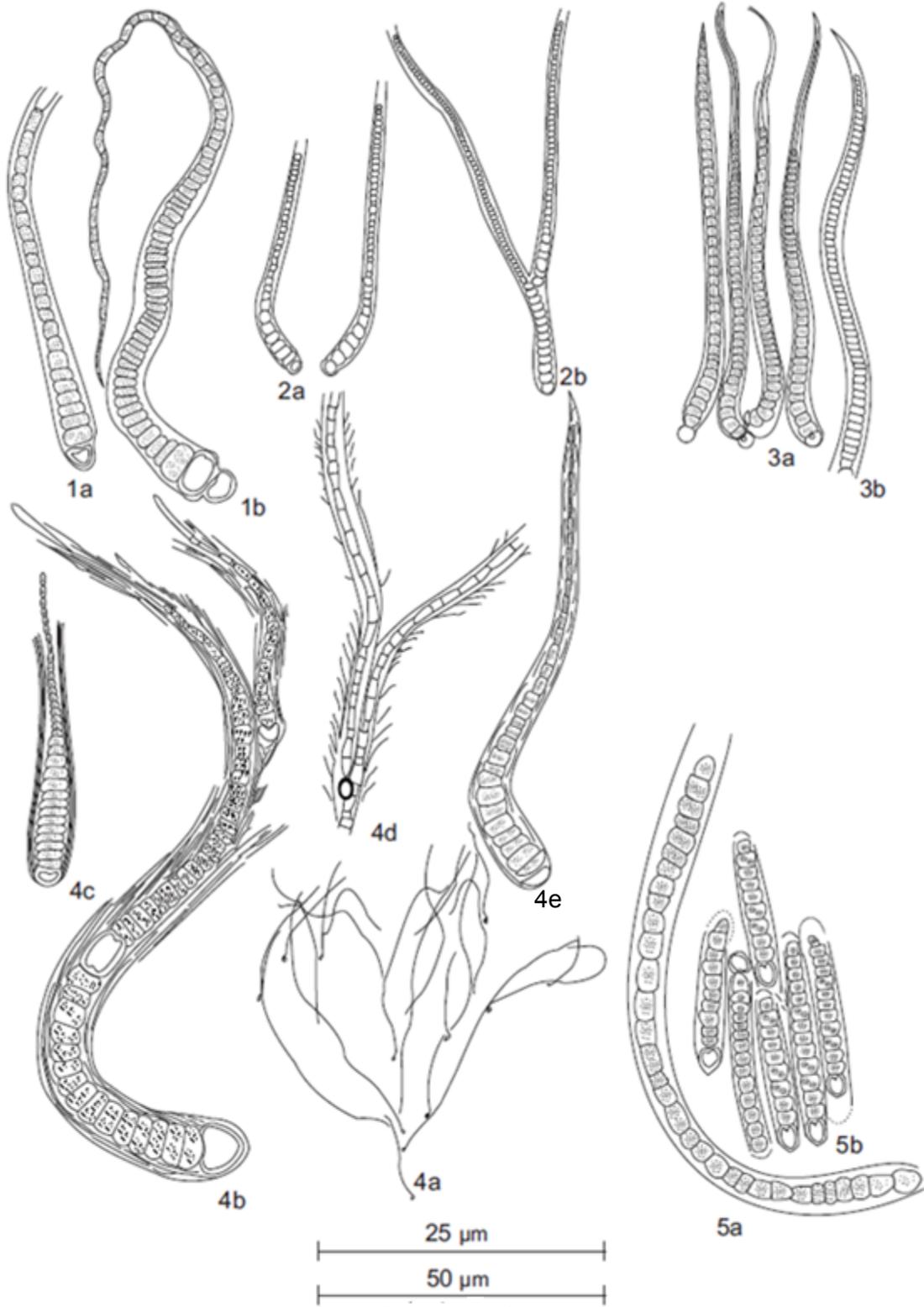
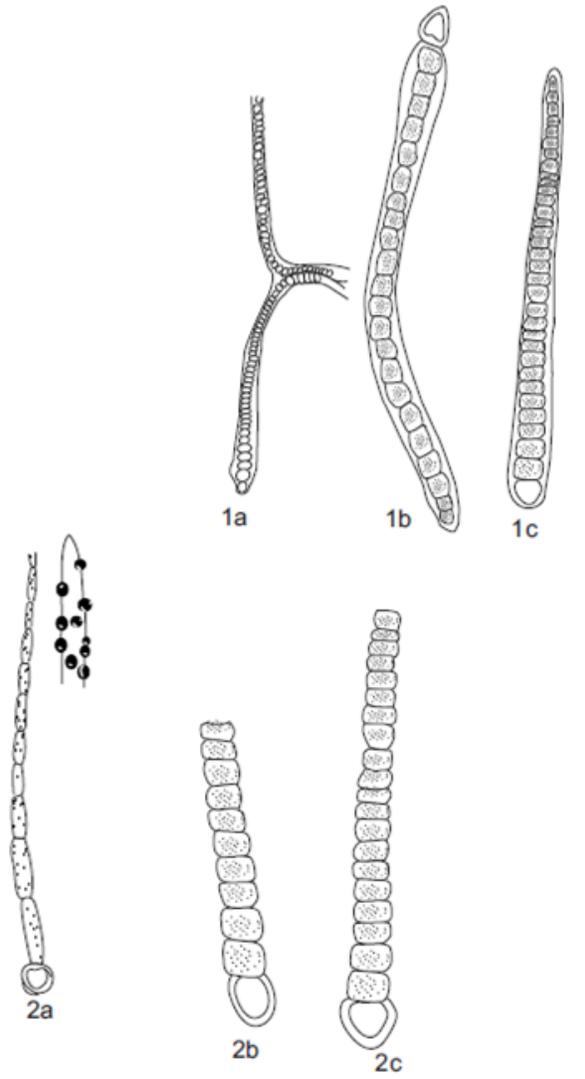


Fig. 4a, 2a & 2b

PLATE - XII



25 μ m
100 μ m

Fig. 1a & 2a

PLATE 1

- | | |
|--------------------|---|
| Fig. 1a & b. | <i>Microcystis aeruginosa</i> Kütz. |
| Fig. 2a & b. | <i>Microcystis elabens</i> (Bréb.) Kütz. |
| Fig. 3a & b. | <i>Chroococcus turgidus</i> (Kütz.) Näg. |
| Fig. 4a & b. | <i>Chroococcus minutes</i> (Kütz.) Näg. |
| Fig. 5a & b. | <i>Chroococcus pallidus</i> Näg. |
| Fig. 6a, b, c & d. | <i>Chroococcus cohaerens</i> (Bréb.) Näg. |

PLATE II

- Fig. 1. *Gloecapsa punctata* Näg.
- Fig. 2. *Gloecapsa aeruginosa* Näg.
- Fig. 3. *Gloecapsa kuetzingiana* Näg.
- Fig. 4. *Aphanocapsa banarensis* Bharadwaja
- Fig. 5. *Aphanothece stagnina* (Spreng.) A. Br.
- Fig. 6. *Aphanothece saxicola* Näg.
- Fig. 7a & b. *Aphanothece castegnei* (Bréb.) Rabenh.

PLATE III

- Fig. 1a & b. *Lyngbya spiralis* geitler
- Fig. 2a & b. *Lyngbya bergei* Smith, G. M.
- Fig. 3a & b. *Lyngbya dendrobia* Bruhl et Biswas
- Fig. 4a, b & c. *Lyngbya confervoides* C. Ag. ex Gomont
- Fig. 5a & b. *Lyngbya martensiana* Menegh. ex Gomont

PLATE IV

- Fig. 1 & 2. *Oscillatoria ornate* Kütz. ex Gomont
- Fig. 3a, b& c. *Oscillatoria limosa* Ag. ex Gomont
- Fig. 4. *Oscillatoria subbrevis* Schmidle
- Fig. 5. *Oscillatoria curviceps* Ag. ex Gomont
- Fig. 6. *Oscillatoria princeps* Vaucher ex Gomont
- Fig. 7. *Oscillatoria anguina* (Bory) Gomont
- Fig. 8. *Oscillatoria proboscidea* Gomont
- Fig. 9. *Oscillatoria chlorina* Kütz. ex Gomont
- Fig. 10 *Oscillatoria martina* Frémy
- Fig. 11a & b. *Oscillatoria chalybea* (Mertens) Gomont
- Fig. 12. *Oscillatoria tenuis* Ag. ex Gomont
- Fig. 13. *Oscillatoria simplissima* Gomont
- Fig. 14. *Oscillatoria limnetica* Lemm.
- Fig. 15. *Oscillatoria pseudogeminata* G. Schmid
- Fig. 16. *Oscillatoria claricentrosa* Gardner
- Fig. 17. *Oscillatoria formosa* Bory ex Gomont
- Fig. 18. *Oscillatoria salina* Biswas
- Fig. 19. *Oscillatoria accuminata* Gomont

PLATE V

Fig. 1a & b. *Spirulina meneghiniana* Zanard. ex Gomont

Fig. 2a & b. *Spirulina princeps* W. et G. S. West

Fig. 3a, b & c. *Phormidium jadinianum* Gomont

Fig. 4a & b. *Phormidium microtomum* Skuja

Fig. 5a & b. *Phormidium purpurascens* (Kütz.) Gomont

Fig. 6a & b. *Phormidium mucosum* Gardner

PLATE VI

- Fig. 1. *Cylindrospermum stagnale* (Kütz.) Born. et Flah.
- Fig. 2. *Cylindrospermum musicola* (Kütz.) ex Born. et Flah.
- Fig. 3a, b, c, d & e. *Nostoc punctiforme* (Kütz.) Hariot
- Fig. 4. *Nostoc paludosum* Kützing ex Born. et Flah.
- Fig. 5. *Nostoc entophytum* Born. et Flah.
- Fig. 6. *Nostoc linkia* (Roth) Born. ex Born. et Flah.
- Fig. 7. *Nostoc rivulare* Kützing ex Born. et Flah.
- Fig. 8. *Nostoc carneum* Ag. ex Born. et Flah.
- Fig. 9. *Nostoc ellipso sporum* (Desm.) Rabenh. ex Born. et Flah.

PLATE VII

- Fig. 1. *Nostoc calcicola* Brebisson ex Born. et Flah.
- Fig. 2. *Nostoc muscorum* Ag. ex Born. et Flah.
- Fig. 3a, b & c. *Nostoc commune* Vaucher ex Born. et Flah.
- Fig. 4. *Nostoc microscopium* Carm. ex Born. et Flah.
- Fig. 5. *Nostoc hatei* Dixit

PLATE VIII

- Fig. 1a & b. *Anabaena sphaerica* Born. et Flah.
- Fig. 2a, b, c, d & e. *Anabaena oryzae* Fritsch
- Fig. 3. *Anabaena fertilissima* Rao, C. B.
- Fig. 4a, b & c. *Anabaena naviculoides* Fritsch
- Fig. 5. *Anabaena variabilis* Kützing ex Born. et Flah.
- Fig. 6a, b & c. *Anabaena torulosa* (Carm.) Lagerh. ex Born. et Flah.

PLATE IX

- Fig. 1a, b, c, d & e. *Scytonema simplex* Bharadwaja
- Fig. 2. *Scytonema coactile* Montagne ex Born. et Flah.
- Fig. 3 a, b & c. *Scytonema bohneri* Schmidle
- Fig. 4. *Scytonema schmidtii* Gomont.

PLATE X

- Fig. 1. *Scytonema fremyii* nom. nov.
- Fig. 2 *Tolypothrix nodosa* Bharadwaja
- Fig. 3a & b. *Tolypothrix tenuis* (Kütz.) Johs. Schmidt em.
- Fig. 4. *Tolypothrix fragilis* (Gardner) Geitler
- Fig. 5a & b. *Tolypothrix byssoidea* (Berk.) Kirchner
- Fig. 6a & b. *Tolypothrix conglutinate* Borzi ex Born. et Flah.

PLATE XI

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| Fig. 1a & b. | <i>Calothrix castelii</i> (Massal.) Born. et Flah. |
| Fig. 2a & b. | <i>Calothrix elenkini</i> Kossinskaja |
| Fig. 3a &, b. | <i>Calothrix braunii</i> (A. Br.) Born. et Flah. |
| Fig. 4a, b, c, d & e. | <i>Calothrix parietina</i> Thuret ex Born. et Flah. |
| Fig. 5a & b. | <i>Calothrix membranacea</i> Schmidle |

PLATE XII

Fig. 1a, b & c. *Calothrix marchica* Lemm.

Fig. 2a, b & c. *Rivularia aquatica* De Wilde.