Developing Designer Microalgae Consortia: A Suitable Approach to Sustainable Wastewater Treatment

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1 Introduction

1.1 Natural Source of Microalgae Consortia

Recycling of microalgae polycultures for aqueous-phase co-products (ACP) is not only feasible but in fact increases biomass production through the recycling of nutrients. Mixed cultures outperformed even the most effective single species in terms of co-product tolerance and productivity at the time of utilization of ACP (Godwin et al. 2017). CO_2 effectively increased light energy conversion and storage into lipids through the interaction of heterotrophy in microalgae consortia (Sun et al. 2016). Consortia species have been evaluated for exact analysis of protein, amino acids, fatty acids, and pigments. The approximate values, especially protein, are as much as 45% of the entire mixture (Yahya et al. 2016). The growth of consortium of native protoctist (protist) strains isolated from dairy-farm effluents is appropriate for the production of biodiesel in addition to wastewater quality improvement (Hena et al. 2015). The drying procedure for a microalgae consortium is characterized by drying rate and moisture diffusion (Viswanathan et al. 2011). In the carpet business, combining stream effluent with a 10% to 15% waste matter mixture was found to produce a good growth medium for the cultivation of microalgae. Bioenergy

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production using carpet factory effluent exploiting an algal consortium might make the management of sewage effluent purification a cost-effective business for future industry operations (Chinnasamy et al. 2010).

The microalgae consortium has the capability to intake *p*-chlorophenol under different sources of light energy. *p*-Chlorophenol adsorbed by zeolite has been frequently used in biodegradation (Lima et al. 2003). The mixed algal consortia enhance removal of nutrients within the scope of biofuel production (Mahapatra et al. 2014). The alga–bacterial community interaction could be widely used for the detoxification of commercial wastes to develop new treatment strategies, such as membrane photobioreactors to boost biomass management and separate edible algae from inedible algae by inhibition (Munoz and Guieysse 2006). The design pool for quick growth rate with lipid accumulation and separability from liquid parts is another facet of consortium development (Aneesh et al. 2015). The association of filamentous strains from native surroundings followed as a dominating priority in nutrient removal efficiency to increase biomass (Renuka et al. 2013). Agroforestry might enhance primary production in microbiome community ecosystems, although altered diversity effects are less well studied (Bruno et al. 2005). The utilization of resources and space occupied by a microalgae consortium indicates that species richness improves the consistency of the idea that the community is related to biomass stability (May 1974), although the stability of the aggregate community tends to increase, such as in biomass and effective density (Tilman 1996; Tilman and Lehman 2001). Moreover, in the case of enormous resource delimitation, replacement of dominant genera after competition or on a hotspot-specific vast scale, the availability of resources or their utilization remains completely unaffected through ecosystem processes. The mechanisms of physiological vital activities as well as molecular coherent identity have been identified for enormous production by interactive trait-dependent or trait-independent factors (Crooks 2002). To date, the taxonomic functional groups have been mostly sessile; the availability of resources and structural shape, size, and texture may be less well studied than in similar properties in photosynthetic microorganism groups, for example, mobile species. The research of interest suggested by Levine (2000) is that data-based synthesis, including experimental and simulation approaches, may additionally be profitable when examining the microalgae consortia in primary and secondary biome functions. According to Emmerson and Huxham (2002), observation suggests gaining insight into microalgae consortia function and improvement and regulative services relationships at a very large scale and in a diversity-rich community. This topic is similar to what is ascertained in allopatric and sympatric variations that at the time of invasions eventually cease to exist; however, most regions gain the total variety of species, except some resident species (Marshall et al. 1982; Vermeij 1991). Invasive species can affect ecosystem shape, size and texture, structure, density, and provisory and regulatory function, less well studied in this regard. Ecosystems lacking dominant filter-feeding photosynthetic microorganisms experience altered behavior at the time species are introduced (Alpine and Cloern 1992). Evaluation of the impact of invasion-mediated enhanced productivity with respect to diverse habitat and ecosystem processes would allow a more interesting experiment of the diversity–function associations (Stachowicz and Byrnes 2006). The ecological niche or weather-mediated partitioning and agonistic growth-dependent biotic and abiotic factors of one species over another, based on niche and predation, are relatively dominant in monocultures and with decreased productivity (Rakowski and Cardinale 2016). The effect of temperature change on biomass productivity with respect to phycocyanin analysis greatly affected the resulting change in diversity (Rakowski and Cardinale 2016; Burgner and Hillebrand 2011). The use of global carbon-mediated factors such as glucose, ethanol, and acetate will overcome less rich consortium growth rates on morning heating of the media caused by biomass loss during the nighttime (Londt and Zeelie 2013). The microalgae consortia address queries about structuring processes, diversity, dominance, relative abundance, stability, and bionomics in the range of various useful groups (Steneck and Dethier 1994). Microalgal biovolume is often calculated to assess the relative abundance of co-occurring algal variables in form or size for formulae applying the surface-to-volume quantitative relationship (Hillebrand et al. 1999). Cyanobacterium mats are an ecological indicator, in specific participating in diversity and connectivity between niche portioning across a range of vegetation (Micheli et al. 2014). The microalgae consortia with respect to bacteria cell factories are significant in complex coherent manipulation engineering of fundamental CO_2 pathways for nitrogen fixation for better bioenergy and biofuels for the future demands of humanity (Ortiz-Marquez et al. 2013).

1.2 Community Behavior

Species richness as added in a consortium has a directly proportional utilization of biological resources to meet human demands and provide new biomass. This combined role of microalgae consortia and assemblage interactions alters primary productivity, sustainability, and services. In this regard also showed that resource capture and biomass production by the consortia begin to become saturated at a low level of richness. Many microalgae consortia use an astonishing amount of resources and manufacture more biomass than their best species singly. Biodiversity–ecosystem function (BEF) experiments for the fundamental study of photosynthetic physiological pathways that have been ongoing for several generations show that the impacts of diversity on microalgae consortia biomass tend to grow stronger with time (Cardinale et al. 2007). The multifarious impact should grow stronger in additional realistic environments with greater spatial and temporal nonuniformity. The relationship of biomass richness using a large distribution of agroforestry maintains algal diversity and consortia biomass. Statistical analysis of the functional relationship of algal richness to develop consortia biomass shows positive values that remain. The interspecific interactions tend to steady consortia biomass in numerous communities (Gross et al. 2014). However, the impact of species richness on growth-level stability is ambiguous. The latest strategy magnifies the community relationship among a number of species across different levels of species richness (Gross et al. 2014). In general, with decrease in aggregate productivity of the selected sampling cluster, resource depletion also decreases. At the same time, the biomass stability and resources captured through the foremost genera in a rich polyculture do not show an exact discrepancy from that of the most efficient species alone employed in the known mechanism; results are most in keeping with what is referred to as the 'sampling effect.' Sampling impact happens when numerous communities of consortia are elucidated through the interaction of the foremost dominant genera. A polyculture system is more productive than a single best species (Weis et al. 2008).

2 Evolutionary Principle Behind Microalgae Consortia Development

2.1 Selection Effect

The total aggregate or primary production of different nutrient factors of the microalgae consortia is most probably decreased by similar resources being taken up by other organisms. In a community of microalgae consortia, the net primary productivity is similar to the individually most productive species in the community by utilization of resources at a given time. The mechanism behind gross primary productivity and net primary productivity could be determined by designing the community towards the number of species added in microalgae consortia; if consistent regarding change in diversity, this is called the sampling effect (Cho et al. 2017). The microalgae consortia of different niche habitats are dominant or more productive over the most productive single species in the community by the sampling effect. In another way, we can say that designing of microalgae consortia of highly diverse habitats produced less biomass than the highest producing individual species, called the selection effect. The selection effect is also known as sampling effect or selection probability (Fox 2004).

2.2 Species Richness Effect

The stepwise substitution of several species at a given time is most probably responsible for varying the future of microalgae consortia among different habitats. There are great opportunities in the fate of next-generation productivity because interactions among diverse microalgae consortia vary from the average individual producing species in ecosystem functioning (Zimmerman and Cardinale 2014) (Fig. 1).

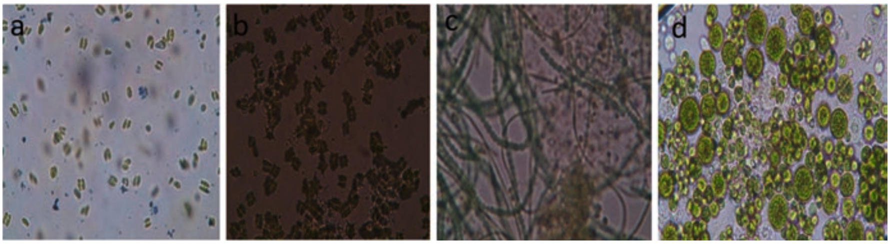

Fig. 1 Microscopic examination of monocultures and their consortia showing the species richness effect: (**a**) *Chlorella* sp., (**b**) *Scenedesmus abundans*, (**c**) *Anabaena variabilis*, (**d**) consortia

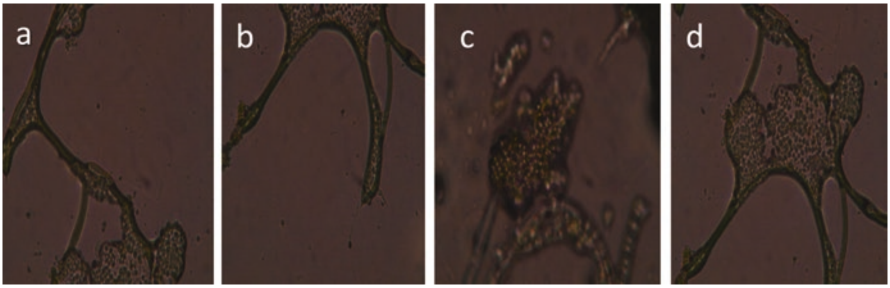

Fig. 2 Biofilm image of microalgae consortia shows identity effect: (**a**) consortia of *Lyngbya* sp., *Scytonema* sp., *Chlorella* sp.; (**b**) *Scytonema* sp., *Phormidium* sp.; (**c**) *Lyngbya* sp., *Oscillatoria* sp.; (**d**) *Oscillatoria* sp., *Scytonema* sp., *Phormidium* sp

2.3 Random Effect or Identity Effect

Discrimination in individual indigenous species through the microalgae consortia combination can be directly evaluated by primary productivity, sustainability, functioning, and services resulting from the randomness of identical species, shape size, characteristic features, and interactive properties (either premitotic phase or postmitotic phase interaction behavior) (Cardinale et al. 2012) (Fig. 2).

2.4 Complementarity Effect

In microalgae consortia, it is commonly assumed that the diverse habitats directly affect biomass productivity through species compatibility. This fact is the subject of controversy in applied experimental designing. The complementation in or within species at the time of niche partitioning by microalgae consortia of similar or dissimilar properties such as an organism discriminate by resource capturing capability and by compatibility interaction modes regarding time or space.

Trait-Independent Complementarity

The conversion of species in microalgae consortia produces higher productivity than individual species alone, called trait-independent complementarity (TIC). The TIC of an individual species growth rate and productivity is not determined by interactive species behavior. The enhanced value of TIC shows that dissimilar properties such as organism productivity are less because of similar properties such as heterogeneity and homogeneity behavior. Microbiome productivity in a niche habitat could elucidate the productivity of individual genera and microalgae consortia by portioning total abundance accessed through trait-dependent complementarity (TDC), trait-independent complementary (TIC), and dominant effect (DE).

Trait-Dependent Complementarity

If the recurring individual species gains rich production alone rather in a mixed culture, this is called trait-dependent complementarity (TDC). TDC occurs not only in interactions among community species. If the value of TDC increases, it demonstrates that the biomass of higher providing species is affected in coexistence rather than in irreversible interactions with a low biomass-producing individual species.

Dominant Complementarity

The exact productivity of consortia is directly affected at the premitotic or post-mitotic interaction stage. Species richness with respect to the exact productivity of other species is called dominant complementarity. The denominator indigenous individual species exhibit yields like other component species (Loreau 2000). The macroalgae consortia of diverse habitats did not overyield with respect to the highly efficient individual genera or the optimum yielding individual culture for primary production. The results of TIC are positive; however, effective intraspecific competition among genera recessively and in becoming workable with a community is enhanced. The enhanced value of trait-dependent complementarity (TDC) among the interactions of species and with their natural habitat for improved services were directly lower with dominance and alternative negative selection effects. The impact of interactive species for element effects will enhance gross primary production and net primary production proportionally. This change might suggest less identity impact in alternative environments and recommend improved evolutionary patterns to reverse efficiency against global warming impact within microalgae consortia interactions on species loss (Bruno et al. 2006).

2.5 Competition

The higher diverse microalgae consortia utilize available resources within their habitat. Some researchers believe that the consortia of higher dense microclimates are less productive than individuals or a community of a few species because of the invasion of new species in premitotic or postmitotic stage interaction. Interaction among microalgae consortia in the terrestrial environment is identified by experimental data and debatable by researchers: typically decreased competition and coaction occur with increasing species richness within an environment, and experimental evaluation shows alternative services (Davinson 1991). The great impact of sampling frequently elaborates the arrangement of environmental variation nonuniformity, which affects each microalgae consortia by increasing the natural habitat area (Zimmerman and Cardinale 2014).

2.6 Facilitation

Microalgae consortia diversity directly alter the structure participants of epiphytic algae and cyanobacteria, which inhabit by enhanced phototrophic productivity through greater primary production; in another way, participation of large and more structural and functional services affects the heterogeneity and homogeneity of behavior. Experimental evaluation of similar properties as in consortia is mixed. A few reports in this regard suggest the seagrass community has less interaction with associated lower nonchordates; however, it was strongly associated with species aggregations (Stachowicz 2006). In this regard, in diverse treatments dense shoots did have a significant role; one experiment reported an impact of variance on behalf of dominance for gross texture, structure, and compactness (Power and Cardinale 2009).

2.7 Coexistence

In coexistence, the stability of microalgae consortia is positively determined on the basis of sympatric and allopatric variation for the impact of producer richness. A study reported the impact of microalgae consortia on biomass stability within the interaction of macroalgal mats through modification of bioprocess engineering for stoichiometry. Participants of consortia showed durability of primary productivity along with weather with respect to applicable resource capturing among compatibility in participating microalgae consortia. In comparative analysis of microalgae consortia, experimental information resulted in an equivalent bridge connection with relevancy of duration and area (Bruno et al. 2005, 2006). Microalgae consortia have a tendency to achieve heterogeneity. Interaction-induced variation in total productivity was approximately increased for individual Firmicutes strains, with respect to average producing strains among highest species-rich microalgae consortia. In this approach, researchers apply microalgae grass growth kinetics with eventual low production within species-rich microalgae consortia rather than less species richness productivity with respect to sediment and temperature variation. Conclusively, we can say that marine microalgae, seaweeds, and ocean grasses showed decreased total productivity in microalgae consortia after genetic manipulation.

3 Designer Microalgae Consortia

3.1 Edible Algae Versus Nonedible Algae

In a previous study for the production of desired compounds and physiology of the organisms, every factor of specific individual algae thought to be important underwent separate experimentation (He et al. 2012; Weyhenmeyer et al. 2013; Weis et al. 2008). So, to preserve available resources, we considered independent variables at the same time by using statistical methods such as factorial, mixture optimal, central composite design (CCD), and response surface methodology (RSM). A number of other optimization methods are available but these have several limitations. Forecasting desired response with a point change in each variable, the concentrations of different variables were altered one at a time and the altered level of response or product ions was measured at each point through a computer device (Patel et al. 2014; Loreau et al. 2001; Tillman et al. 1982, 1996). To study the effect of different components of media BG11+ (important upstream parameters) on growth, enhancement of biomass, carbohydrate, and carbon fixation contents in eight different consortia in factorial design, a minimum and maximum level of nutrient concentration level L-1 for each medium component was chosen. The maximum concentrations were taken as described by Rippka et al. (1979); minimum concentrations were chosen randomly to a certain extent. For industrial productivity, we would refer to as “edible” algae, dominant over the “inedible” algae. Other Chlorophyta cannot grow on a bacteria-only diet, although alternative strains can do so (personal observation). The Cyanobacteria (members of Cyanophyta) and microalgae (members of Chlorophyta) commonly co-occur in nature but were not indicated to mimic any specific natural system.

3.2 Microalgae Consortia Functioning

The functioning of microalgae consortia was determined from a wide range of morphological and physiological categories to confirm some chance of community delineation and to assist association. Feeding trials indicated that microalgae consortia readily consume and grow best. Of seven better primary production yields, designer microalgae communities were a suitable size for intake by percent CO_2 and perhaps are expanded at higher levels. Occasionally microalgae consortia support growth on their own survivalists from their environment. The results also show highest heterogeneity could show better production. Inspection of population dynamic statistics indicated that rates of modification in algal biovolume usually slowed over the course of the experimentation, typically approaching a quasi-steady state when mean total consortium effectiveness varied considerably among microalgae compositions (block effects were not significant).

Primary Functioning

The aggregate productivity in each microalgae consortium of the most productive individual cultures significantly exceeded the premitotic phase (lag phase) in time. In individual cultures regarding postmitotic phase (stationary phase) interaction in time, assessments of the two most productive individual species and their consortia on the day of harvesting discriminated between them. The transgressed yield of microalgae consortia in individual cultures was directly related to overall productivity with respect to the consortia on the day of harvesting (Fig. 3).

Photosynthetic Quantum Yield

Developing microalgae consortia with different environmental factors suggests enormous resources through biodiversity by the evaluation of developing microalgae consortia participants for their better productivity and sustainability in their environment. The synthetic microalgae consortia could be designated in a targeted approach for heavy metal detoxification, water quality improvement, and

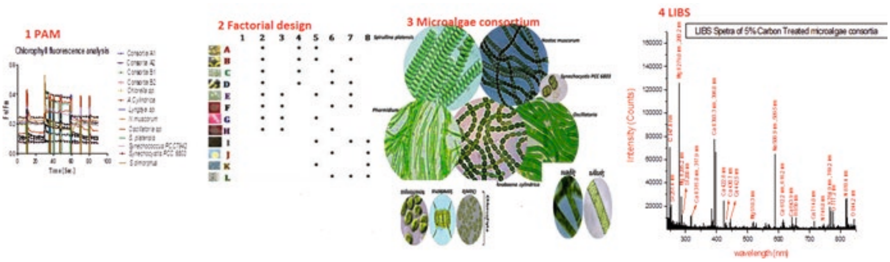

Fig. 3 Graphical diagram shows (1) pulse amplitude modulation chlorophyll fluorescence analysis; (2) factorial design through response surface methodology software via central composite design (CCD); (3) development of enhanced productivity consortia by optimal resource capture; (4) elemental characterization for responsible factor through laser-induced breakdown spectroscopy (LIBS)

fulfillment of human services. The microalgae consortia most often gain higher capacity than individual species. The enhanced photosynthetic functioning of the heterogeneity route of selected gene expression in developing microalgae consortia and the next generation of developed consortia is less well studied. To start, the biotechnology of microalgae consortia can be determined by one or two physiological trait factors for primary productivity that can be optimized for targeted achievements. The metabolic pathway among microalgae consortia cells with respect to different traits can be analyzed on the basis of the participants in the consortia. Fv/Fm (Fmax−Fmin/Fmax) was observed in all the cultures. Fv/Fm is a substantive means for assessing the potential of photosynthesis in microalgae consortia, chiefly for highlighting photoinhibition in excess illumination. Pulse-amplitude-morphometry (PAM) fluorometry results indicated that at optimum magnitudes, Fv/Fm ratios were completely different in various monocultures and consortia were found to be statistically different from each other ($p < 0.001$). In all cases, with increasing chlorophyll content, a lower Fv/Fm was determined with all the monocultures and consortia. This result indicated that the microalgal cells were growing and performing photosynthesis efficiently and were active within the photoinhibition process. The quenching analysis by PAM fluorometer showed the measure of photosynthetic efficiency in terms of quantum efficiency or quantum yield. Generally, the monocultures were poor in achieving maximum quantum yield, in comparison to all the consortia (Fig. 4).

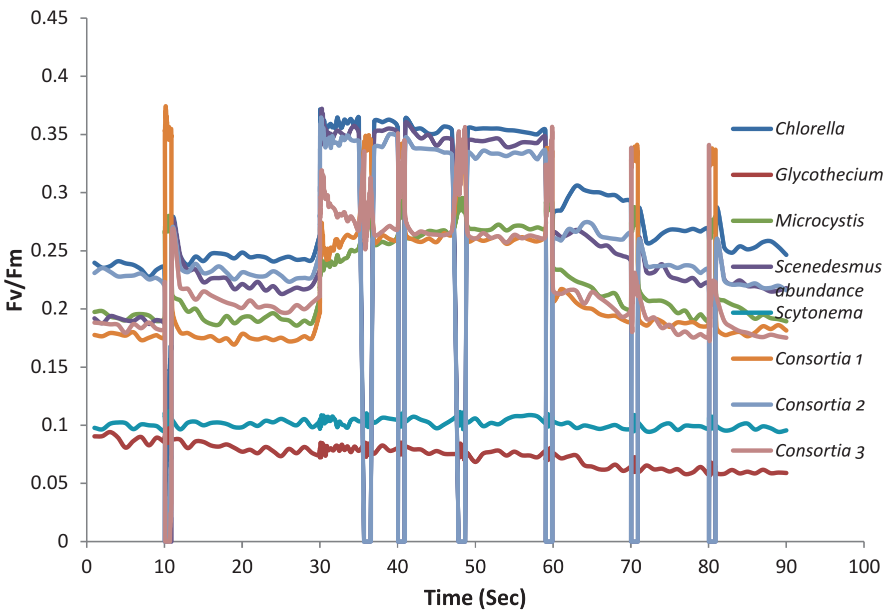

Fig. 4 Photosynthetic quantum yield in various monocultures and microalgae consortia

Photochemical and Nonphotochemical Quenching

According to the PAM graph obtained, we noticed that of all consortia *Scenedesmus dimorphus* was the foremost effective species (or the foremost effective strain) showing the greatest photosynthetic effectiveness. Equally, *Synechocystis* PCC6803, *Synchococcus* PCC7942, and *Spirulina platensis* had good photosynthetic ability compared to the alternative strains studied. As we know, nonphotosynthetic quenching provides a standard for complete quantum efficiency and is reciprocally related to it; here, *Anabaena cylindrica* is the least efficient strain regarding photosynthetic efficiency and shows the highest quenching. Intended for establishment of the purposeful arrangement for photosynthetic efficiency of photosynthetic blue-green algae, variable fluorescence magnitude relationships were monitored. The value of the initial fluorescence by the first electron acceptor from PS II antennae varied among blue-green algae samples. The maximum quantum yield of filamentous strains was at a low level. Altogether, consortia, *Spirulina platensis,* and *Chlorella* sp. displayed the maximum variable fluorescence value; next were *Anabaena cylindrica*, *Oscillatoria*, *Lyngbya*, *Nostoc muscorum*, *Synechococcus* PCC7942, and *Scenedesmus dimorphus*.

The higher Fv/Fm ratio for *Spirulina platensis* indicates higher photosynthesis assimilation for alternative blue-green algae. Fv/Fm (Fmax−Fmin/Fmax) was assessed in all individual strains and consortia cells, fully grown at completely different levels of light intensity. Fv/Fm is also a utile parametric quantity to gauge photosynthetic ability in algae and in the first place specializing in photoinhibition owing to excess light. PAM fluorometry outcomes indicate that at optimal light and contrasting optimum growing parametric quantity, the quantum efficacy is greatest. In all cases together with the accelerative chlorophyll content, a minimal value of variable fluorescence was scrutinized, pointing out that the microalgal cells were thriving and achieving photosynthesis and moreover were striving for total adaptation for survival in high-intensity light. The quenching investigation by PAM fluorometer gave the measure of photosynthetic potency in terms of quantum efficacy or yield. The Fv/Fm ordination depicts the evolutionary divulgence of these photosynthetic autotrophic organisms and indicates many attainable sources for improving potency. Fv/Fm (Fmax-Fmin/Fmax) was monitored in all the microalgal and consortia cultures. PAM fluorometry results indicated that at optimum intensity level, Fv/Fm ratios of totally different monocultures and consortia were observed to be significantly different from one another ($p < 0.001$).With increasing chlorophyll content, a lower Fv/Fm was ascertained in every case together with all the monocultures and consortia. The results made it clear that the cells were thriving and carrying out effective photosynthesis and were active in the photoinhibitory process. The quenching investigation by PAM fluorometry recorded the measure of photosynthetic potency in terms of quantum efficacy or yield. Broadly speaking, monocultures were poor in maximum quantum efficiency, in contrast to the consortia (Nath et al. 2017a, b) (Fig. 5).

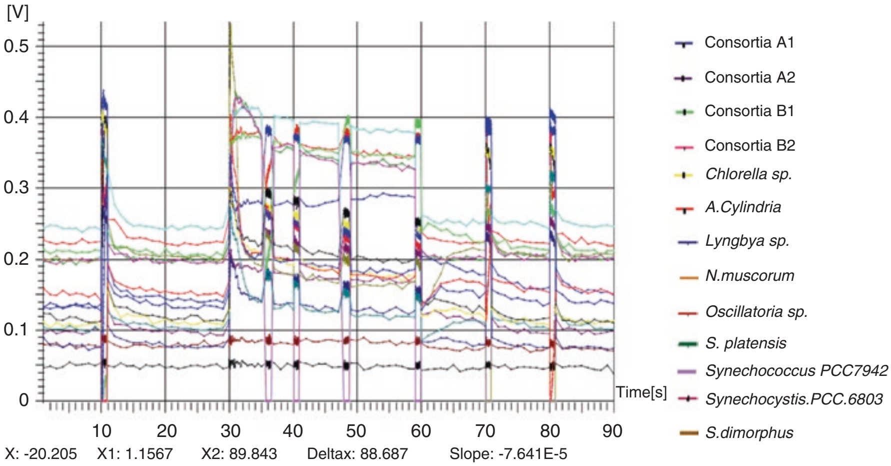

Fig. 5 Direct heat dissipation analysis in different individual cultures and their consortia

Fresh and Dried Biomass Productivity

Biomass productivity was successfully achieved by raising the temperature tolerance of microalgal consortia as well as an acceptable screening method. The delineated strategies should be applicable to induce a range of interesting characteristics in numerous microalgal consortia, which is often particularly engaging for systems wherever it is not obvious that genes need modification. Coupling contemporary production with the next-generation screening strategies would be enabling in choosing the strains with characteristics that do not yield a better fitness and cannot be chosen for in vitro experimentation. At the very least, random impact strategies will be used as a primary step during a combined approach with genetic alteration (which is analyzed through next-level strategies and techniques), to see appropriate target genes for many centered and comprehensive strategies for microalgal consortia improvement and alteration (Godwin et al. 2018; Nath et al. 2017b).

3.3 Microalgae Consortia Services

Carbon Regulatory Services

CO_2 effectively improved actinic light capacity transfer and storage into bioorganic compounds through higher concentration, that is mostly in a surprising way the properties of heterotrophy in microalgae consortia. Insight has not clearly identified through standardization a number of traits illustrating better proficiencies within the coupled dark biochemistry of bioenergy production and bioorganic molecule

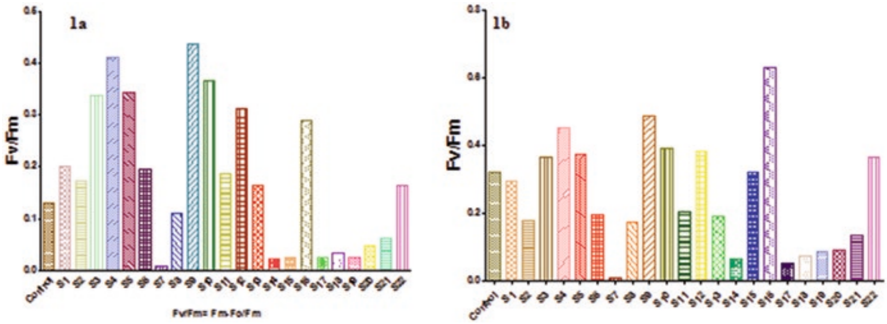

Fig. 6 Plant efficiency analyzed by a central composite designed from 22 trials from pulse amplitude modulation fluorescence

formation. The results progressively created associated economical instrumental quantification of photosynthesis for biodiesel formation at a high level, and carbon capture and storage from flue gases for carbon credit (Sun et al. 2016).

Nutrient Uptake Provisioning Services

To establish the functional position of photosynthesis rates, Fv/Fm ratio was measured in two different microalgae consortia with 22 runs of each in a test tube. This experiment imitated the highest photosynthetic quantum yield of PS II reaction centers of diverse dark-adapted microalgae culture conditions. In general, run filaments of each of the two microalgae consortia were identified for maximum rich quantum yield in the 16th run. The corresponding values of Fv/Fm of MC1(Scytonema sp., Microcystis aeruginosa, Gloeocapsa sp., Chlamydomonas reinhardtii, Scenedesmus abundance and Scenedesmus dimorphus) and MC2 (Calothrix sp., Westiellopsis prolifica, Aphanothece nageli, Chlamydomonas reinhardtii, Scenedesmus quadricauda, Chlorella sp) were 0.52 and 0.61, respectively. The lower Fv/Fm ratios in the microalgae consortia indicate their lower photorespiration rates resulting from lack of oxygen in competitive resources stress compared to other individual microalgae. The microalgae cell groups having a greater surface-to-volume proportion were found to have higher photosynthesis rates (Fig. 6).

4 Microalgae Consortia in Wastewater Treatment

4.1 Heavy Metal as a Nutrient Source

Exogenous supplementation of various doses of chromium (Cr) considerably delayed the growth and biomass productivity of assorted microalgae monocultures similarly to artificial consortia. To determine the temperature-bearing capacity of cyanophycean, chlorophycean, and microalgae consortia among hexavalent Cr, the biomass of natural habitat species was enriched with four regimes of Cr in several sampling analyses up to a 16-day cultivation time. Regular observance of growth curves showed varied growth behavior in microcosms and metalloid microalgae consortia. The presence of Cr in the culture environs of microalgae greatly distorted their morphology at completely different extents with increasing dosages. Morphological analysis processed the drastic effect within the structure of varied chromium-added microalgae consortia and individual cultures. Within the natural community, niche partitioning of the environment was vital in the acclimation of various microalgae. The branched green algae typically affected aquatic areas: *Lyngbya* was floating on the surface whereas *Oscillatoria* was random within the *Lyngbya cells*. In distinction, unicells of *Chlorella* and coenobia of *Scenedesmus dimorphus* gathered close to the lowest portion. However, with increasing degree of metal toxicity, the niche partitioning and growth rates were altered from the natural community: the stationary phase arrived sooner with synchronization of almost all the cells of *S. dimorphus* at the highest concentration of the metal. In distinction, algae and *Lyngbya* were found to possess sensible stress-tolerating options among all the evaluated organisms; continuous growth observation from the 1st to 16th day showed fascinating changes within the doubling patterns of those microbes. Their growth rates were considerably affected at the various metal concentrations. The growth behavior of those four organisms at 0.5 ppm Cr was not greatly affected ($p \geq 0.05$), and at the end of cultivation about the same quantity of biomass yields was obtained with respect to the natural control. Furthermore, with increasing the Cr doses, *Chlorella* and *Lyngbya* showed good response against Cr up to 1.0 ppm and their growth and biomass productivity were not significantly affected. However, growth of *S. dimorphus* and *Oscillatoria* was highly affected at doses above 0.5 ppm, and between 1.0 and 5.0 ppm their growth rates and biomass yield were reduced significantly ($p \leq 0.01$). Their succession rates were very high at 5.0 ppm, and they arrived at their carrying capacities much earlier with very low cell counts and biomass yields. The structure of those photosynthetic organisms was distorted by increasing the doses of metal. However, at an all-time low dose of 0.5 ppm, slightly swollen cells were seen under the light microscope, which would be the reason behind their increased metabolic attributes and increased yields of biochemicals such as carotenoids and carbohydrates. Moreover, increasing the doses of chromium above 0.5 ppm not only affected the morphology but also the ecophysiology and biomass production of these organisms significantly. A similar trend was recorded in the behavior of the community at different doses of Cr. The natural community of these four organisms produced higher biomass than monocultures and all the communities with these four treatments of Cr. Growth rates, biomass yields, and microscopic examination of various photosynthetic cells verified the following order of tolerance for the tested organisms: *Oscillatoria* sp. ˂ *S. dimorphus* ˂ *Lyngbya* sp. ˂*Chlorella* ˂ consortia, respectively, in a healthy environment. The monoculture richness or uniformity in the natural community greatly affected community biomass productivity. Within the community, *Chlorella* was the dominant species. Therefore, it contributed significantly in Cr adsorption and biomass production.

Consequently, a notable factor was the improved tolerance behavior and biomass productivity of those microbes at the lowest dose of Cr, indicating their combinatorial positive interactions towards chromium surface assimilation. Interaction of these organisms against Cr tolerance was reduced with regular increase in the doses of Cr, which led to distortion in their morphology and response towards biomass production. As in a natural community, *Chlorella* was found to be dominant in all communities. Compared to a natural community, the 0.5 Cr-treated community produced 1.26% more biomass. With further increase in Cr levels, the morphology of these microbes was greatly distorted, which finally led to regular reduction in biomass yields. With respect to the natural community, communities at 1.0, 3.0, and 5.0 ppm showed 29.4%, 62.0%, and 78.1% of reduction in biomass yields, respectively ($p \leq 0.01$). Also noted at the lowest dose of 0.5 ppm Cr^{+6} was slow augmentation in multiplication rates and altered morphology in monocultures or in consortia. The volumetric appearance of these monocultures and various consortia, respectively, are shown in Fig. 7. *Chlorella* biomass was found to be highest among all the monocultures. Consequently, the maximum cell counts of *Chlorella* that were recorded in the community showed the richness of these algae in a natural community over other individuals. The microalgae consortia could restore water quality by alleviating the Cr levels in water parameters up to 0.5 ppm; beyond this level, these organisms would have a negligible contribution in adsorption of Cr. Consequently, at the end of cultivation, *Chlorella* and *Lyngbya* were found to be dominant species within the community, followed by *S. dimorphus* and *Oscillatoria*, respectively. The total biomass yield of a control community was found to be highest over

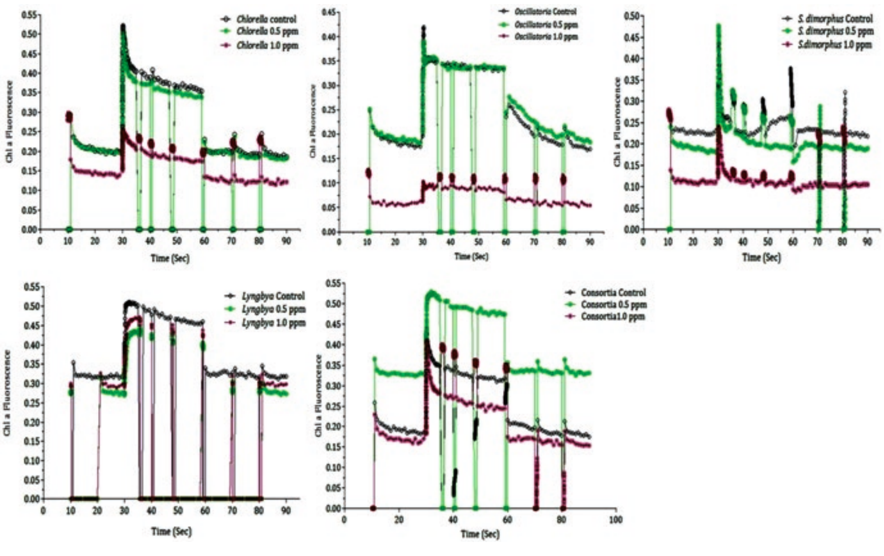

Fig. 7 O First excitation peak, J second excitation peak, K Tertiary excitation signal, I Quartenary peak and P is Stationary peak (OJKIP) curve of different monoculture and consortia showed stress level against heavy metal

monocultures of Cyanobacteria and green algae, providing as a concluding remark that within the community these organisms can have better physiology and biomass yields compared to monocultures. The growth patterns and biomass yields of various organisms and community, respectively, are provided in Fig. 7. The results were further confirmed by microscopic examinations. In various communities, *Chlorella* was the most dominant species, followed by *Lyngbya*, *S. dimorphus*, and *Oscillatoria*, respectively. An interesting characteristic of these microbes was enhanced metabolic rates and other services at the 0.5 ppm dose of Cr. A gradual increase in growth patterns was recorded at that dose until the cultures reached their carrying capacity. However, at higher concentrations (1.0, 3.0, and 5.0 ppm) of Cr, growth and biomass yields were found to be much poorer than the control and 0.5 ppm Cr^{+6} communities. At higher concentrations all the cultures reached their carrying capacity before the control with lower cell counts, decreased biomass yields, and enhanced doubling times. The morphology of cells was highly distorted with increasing Cr^{+6} toxicity levels. Consequently, in the treated community, formation of penetration on the surface of media at the end of cultivation indicated the initiation of their succession. Micrographs recorded at the end showed that during succession *Oscillatoria* sp. was highly affected whereas *Chlorella* dominated in the community. Therefore, in natural habitats affected with severe levels of Cr, similar trends may be expected with some deviations, because in natural water reservoirs there are many different independent factors or variables that could affect the structure and performance of organisms in the community. Therefore, above 1.0 ppm chromium, these microalgae lose their original features (Nath et al. 2017a, b).

4.2 Enhancing Water Quality by Niche Portioning

In blue-green algae, a consortium has an increased probability to increase effectual size contrasting to the foremost effective manufacturing respective strains. The principle for the improvement of consortia was measure of joint variability at intervals, the reciprocality effect in consortia, and conjointly the state of strains individually (Cardinale et al. 2006). Explicating compositional and purposeful features in consortia may well be a topic of extraordinary peculiarity that assists us to grasp the interaction of blue-green algae with the environment. Earlier studies have shown many diverse groups of various species drastically utilizing and capturing available restricted environmental resources and with a large amount of biomass production compare to the less different species population. The principle of massive biomass in aggregating abundance production was in response to the phototropic quality of the microalgal population. Korner (in 2004) counselled that algal populations would not intensify the photosynthetic rate exclusively, notwithstanding capture and storage of greenhouse gas from their environment, although this might not correspond to the tangibleness of the biomass by carbon storage attributable to increase in total species population. Through photosynthesis, flora uptake greenhouse gas, produce oxygen, and yield critically quantified biomass. Although various studies have generally acknowledged this, fewer data reveal preliminary activities taking place in photosynthesis in phototropic beings. In this present research we have deliberated that, if the copiousness of strains is inflated at intervals in the quantitative relationships of three, six, or more, then there is a depletion of accessible resources by resource pool methodology, leading to improvement of microalgal consortia biomass stability. The stableness of blue-green algae populations may result in various settings or the best yielding single strain in terms of biomass production, of the most overwhelming and effective strains. Treatment of ethyl methane sulfonate (EMS) with microalgae species with lower doses (0.42 and 1.2 M) significantly ($p < 0.05$) increased Fv/Fm by 2.4%, 7.2%, 32.8%, and 42.2%, respectively, while qP increased by 4.4%, 7.1%, 15.6%, and 30.2%, respectively, and nonphotochemical quenching (NPQ) inclined by −0.73%, −3.65%, −5.85%, and −8.03%, respectively. However, at higher doses (0.72 and 1.2 M) Fv/Fm decreased by 1.3%, −10.3%, and −13.7%, respectively; similarly, photochemical quenching (PQ) also decreased by 3.2%, −10.4%, and −18.1%, respectively, while NPQ increased by 6.57%, 10.95%, and 16.06%, respectively. The NPQ was high in the dark and in consortia that measure the ratio of quenched to remaining fluorescence (Fig. 8). The value of NPQ does suffer from distortion by the underlying protein fluorescence. This potential problem is addressed by fluorescence measurement with an alternate modulated source, which allows excitation of chlorophyll fluorescence without interference from phycobiliprotein emissions. The mutant strains reduce cellular pigment content and exhibited improved photosynthetic activity, thus improved biomass productivity. The isolated mutant strains with photosynthetic alterations pool by better photosynthesis regulation insight. Tillich et al. determined point mutation through chemical mutagenesis raised temperature tolerance about 2 °C in many generations of mutagens in *Synechocystis* PCC6803. Random coupled mutagenesis yields higher fitness for in vitro selection of strains. The quantification of living cells on selection plate rates was equivalent to mutation with nonlethal doses. The developed microalgae consortium has the capability to use enormous amounts of nutrients through the water and improve water quality through trophic factors.

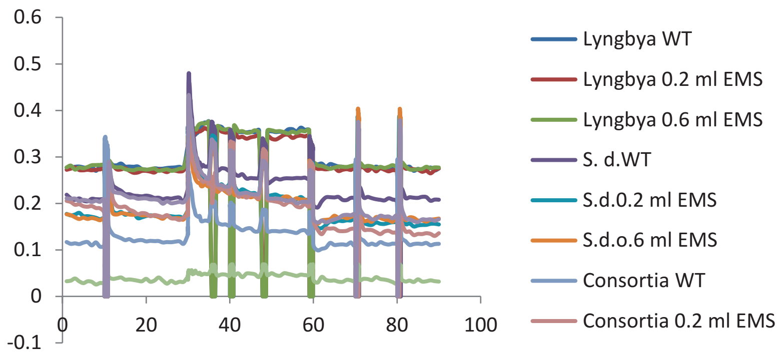

Fig. 8 Chemical mutagenesis by ethyl methane sulfonate (EMS) shows carcinogenesis in monocultures and polycultures

4.3 Improve Water Quality Through Fresh Gross Productivity

The microalgae consortia is only unfeasible for recycling of fresh gross productivity, yet often recycling of trophic factors increased production of biomass. The microalgae consortia, productivity, and tolerance capability with respect to their co-product provides higher amounts in individual species on aqueous-phase recycle time. With the highest tolerance capacity with respect to aqueous-phase co-production, microalgae consortia must have less dilution or a higher concentration during the recycle pathway. The point of interest is ecological interactions in microalgae consortia using the best efficient methods and reducing the waste stream productivity for improving trophic factors substantially harnessed that are significant; otherwise, role eutrophication will ensue (Godwin et al. 2017).

5 Molecular Approach of Microalgae Consortia

5.1 Transcriptomics and Gene Functioning Analysis

The concerned media for growth of organisms were applied to isolation. The partial evaluation of cDNA interpretation systematizes the sequestered as a number of organisms that participated in the microalgae community. These isolates included microalgae orders, families, genera, or species. A number of the isolates that were antagonistic or agonistic within the fermentation medium had properties similar to microorganisms, for example, *Aeromonas*, *Vibrio*, *Acinetobacter*, and *Pseudomonas*, which are directly responsible as causative agents for disease in humans and animals and should be effective in the assessment during negative impact caused by microalgae blooms. The various species inhibited or enhanced the growth of cyanobacteria within community and designer microalgae consortia with respect to media optimization: trophic factors, spatial variation, space, or time could improve it. Such types of consortia had an improving impact on microalgae growth. A large group of isolated microorganisms was applied in the assessment and management of the negative impact of microalgae (Berg et al. 2009). The phytoplankton species interactions and coexistence provided unique insight into the transcriptomic deviations that are acquired without restraints. First, the statistical model was developed with respect to transcriptome-wide investigation of gene expression for associations of genes that were expressed in participating individual cultures. The purpose of RNA spikes to establish detection criteria and similarities–dissimilarities of actual expression intensities provides assistance for future human requirements. The exploration of the constricted roles of shared genes versus uniquely expressed genes for contributing species interfaces, and in precise niche variation and facilitation within microalgae consortia. Second, the gene expression on postmitotic phase point to time during competition; herewith, altered in gene expression in this time would have a role in comparisons of gene expression on behalf of the mid-log growth section, dependence of density, and therefore the complete impact of competitive species. The comparisons of metagenomics basis of huge resources utilized growth versus community-dependent growth of variations versus interspecies microalgae consortia among surroundings would alter gene expression over time. Third, in the thought of the recent analysis during this regard, the illation of gene functions was, by necessity, supporting transitive annotations. The climatic issue is a crucial role example; temporal and abstraction biotic and abiotic complexness of microalgae consortia on gene expression, species interactions, and existence are areas of interest for researchers operating in this area in future. Finally, in this regard to the big plan control notion that visible morphological similarity results in competitive exclusion, the results found that similarity in gene expression among the microalgae community across the transcriptome tends to steer to weaker competition, much possible facilitation, and larger coexistence. The analysis provides support that the expression of the largely preserved normal expressed genes is needed for future survival and fitness in an exceedingly explicit environment; on the opposite hand, niche variations and helpful interactions could also be encoded by simply a number of, or presumably rare, genes. The various varieties of species interactions were investigated directly for their role in deciding known gene functions to lie within the future (Narwani et al. 2017).

5.2 Proteomics Approach

Although detectable using a light microscope, the photosynthetic lamellae of the cyanobacteria were first observed with electron microscopy, initially in shadowed metal preparations and later in thin sections. The lamellae are closed discs termed thylakoids. Observance of the lamellae, or the adjacent membranes, varies greatly with the fixative that is employed. After permanganate fixation, the double membrane is seen in the section as three lines in parallel having thickness of 20 Å, 40 Å, and 20 Å, between which lie spaces of 30–35 Å, whereas following osmic acid fixation the membrane apparently appears as two parallel lines each 355 Å to 655 Å thick, separated by a space of about 50 Å. The only chlorophyll that is found in cyanobacteria is chlorophyll *a*. It has been discovered that the chlorophyll from *Phormidium luridum* has phytol. In vivo, the absorption spectrum is shifted to a wavelength around 13 nm greater than the absorption peak in methanol solvent. Representative values of chlorophyll as the percent of algae are 2.2 (667) and 0.2–1.0 (741) [dried weight]. Analysis of the quantities of individual carotenoids found that a large variety of cyanobacteria contains 13-carotene, echinenone, myxoxanthophyll, sometimes zeaxanthin, and most frequently present carotenoids, albeit exceptionally canthaxanthin, caloxanthin, nostoxanthin, oscillaxanthin, and glycoside have been also found to account for almost 10% or more of the total carotenoid present. 13-Carotene is the only one of its kind present in blue-green algae (Fig. 9).

Effect of exogenous bicarbonate-anhydrase addition on total chlorophyll (mg g^{-1} fresh weight), carotenoids (mg g^{-1} fresh weight), total protein (mg g^{-1} fresh weight), and chlorophyll florescence parameters of microalgae and their consortia

Name of organism	Pigments		Biochemical compound		Chlorophyll florescence		
	Chlorophyll-a	Carotenoid	Carbohydrate	Protein	Fv/Fm	qP	NPQ
Chlorella sp.	1.72 ± 0.03e	0.531 ± 0.01f	15.4 ± 0.30ef	10.3 ± 0.18ef	0.73 ± 0.10de	0.758 ± 0.009f	1.37 ± 0.06d
Gleocapsa sp.	1.76 ± 0.12d	0.542 ± 0.01d	15.8 ± 0.21d	10.8 ± 0.21d	0.75 ± 0.07cd	0.791 ± 0.011d	1.36 ± 0.06d
Microcystis aeruginosa	1.81 ± 0.03c	0.548 ± 0.08c	16.3 ± 0.41c	11.2 ± 0.33c	0.78 ± 0.11c	0.812 ± 0.015c	1.32 ± 0.09e
Scytonema sp.	1.87 ± 0.11b	0.553 ± 0.10b	17.2 ± 0.56b	11.8 ± 0.27b	0.80 ± 0.14b	0.876 ± 0.019b	1.29 ± 0.08ef
Scenedesmus abundance	1.92 ± 0.07a	0.559 ± 0.06a	17.9 ± 0.55a	12.4 ± 0.19a	0.82 ± 0.19a	0.987 ± 0.020a	1.26 ± 0.10g
Consortia 1	1.74 ± 0.05de	0.536 ± 0.09e	15.6 ± 0.42de	10.5 ± 0.24de	0.69 ± 0.10f	0.782 ± 0.017e	1.46 ± 0.09c
Consortia 2	1.52 ± 0.04f	0.491 ± 0.07g	14.3 ± 0.32g	9.4 ± 0.33g	0.65 ± 0.06g	0.679 ± 0.016g	1.52 ± 0.14b
Consortia 3	1.48 ± 0.04g	0.472 ± 0.012h	13.8 ± 0.26h	0.61 ± 0.20h	0.61 ± 004h	0.621 ± 0.016h	1.59 = 0.19a

Data are means ± standard error of three replicates. Values with different letters within same column show significant differences at $p < 0.05$ level between treatments according to Duncan's multiple range test

The result was seen as the explanation of the initial rise in the fluorescence signal when CO_2 was suddenly removed from a plan: parts once reduced QA as the reaction center in PSII normally passes electrons, via other electron carriers, to PSI and finally CO_2 via XADP in pathway. As density of treatment increases, it would decrease quantum yield (David Walker)

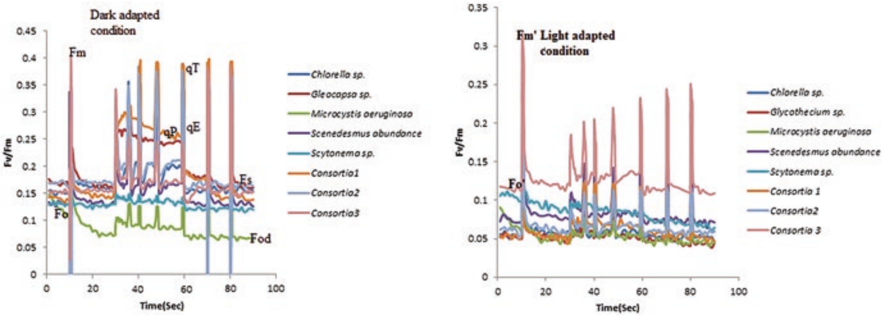

Fig. 9 Light- and dark-adapted analysis in monoculture and consortia for light harvesting complex

6 Conclusion and Future Prospects

Trait-dependent and trait-independent factors, such as level of light, quality of light, water quality, capturing of food, warmth, snow, chemical microorganisms, herbicides, detoxification of metals, pathogen control, and inherent features – all these factors simultaneously affect assimilation in photosynthetic organisms, their health and condition. These factors have a significant role in PS II fluorescence signaling, so by using a pulse amplitude modulator, improvement of biomass production by controlling the foregoing factors was evaluated and easily elucidated the functioning and services of the microbiome. The fluorescence of the PS II reaction center dissipated the energy of photons in the dark-adapted chlorophyll state; the transport of electrons comes back to the maximum oxidized condition after the chain of reduction-oxidation state. Even fluctuations in the microorganisms that affect stoma opening and gas exchange with the atmosphere are suggested by changes in the fluorescence features of an organism. In the present communication, the photochemical quenching (PQ) and nonphotochemical quenching (NPQ) of microalgae and their consortia would be studied in fermentation broth; the Fv/Fm ratio of different individual algal strains and their consortia will be used for determination of maximum quantum yields. The present proposal is expected to develop new technology for sustainable algal biofuels to limit future energy demands and economy-related problems. The designer microalgae consortia interactions would allow for unlimited, less time consuming, and cost-effective technology for bioenergy improvement, by applying the dominant complementarity industrial approach for biofuels.

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