Prosperi, Carlos H.
Cyanobacteria in human affairs
Interciencia, vol. 25, núm. 6, septiembre, 2000, pp. 303-306
Asociación Interciencia
Caracas, Venezuela

Available in: http://www.redalyc.org/articulo.oa?id=33904806
Summary

Few people know what are the so-called Cyanobacteria or Blue-Green Algae, although these organisms are responsible both for benefits and nuisances in human affairs. They are halfway between Bacteria and Algae, because their cellular organization is prokaryotic, but their photosynthesis physiology is very similar to that of the Algae. Among the benefits humans get from them, is their utilization as biofertilizers in rice fields, thanks to their capacity of fixing atmospheric nitrogen and producing nitrogen-rich organic compounds that contribute to increase the rice yield. On the other side, these organisms also grow very well in lakes and ponds used as water reservoirs for human consumption, where they frequently produce water blooms with release of neuro- and hepato-toxins.

Key Words / Cyanobacteria / Rice Fields / Nitrogen fixation / Eutrophication / Cyanotoxins /
They were called “Cyano-
phyles”, from the Greek 
words “cyanos”, meaning 
“blue”, and “phyton”, mean-
ing “plant”. Some are unicel-
lar, others are multicellular, 
most are filamentous. They 
all contain chlorophyll A, and 
thus, are active photosynthetic 
organisms living in water (ei-
ther marine or freshwater) or 
at least in wet habitats. Li-
chens are formed by the syn-
biosis of fungi and algae, that 
generally are Green Algae or 
Blue-green Algae. By the 
way, they are called “blue 
green” or also “olive-green” 
because, apart from the al-
ready mentioned chlorophyll 
A, they have in abundance 
blue (and “allos” - red) auxil-
ary pigments called “phyco-
bioproteins”.

On the other side, they lack 
a cellular organization like 
the one of the rest of plants 
and animals, that is, the mod-
ern (in terms of evolution) or 
eucaryotic cell type. Their 
cellular organization is similar 
to that of bacteria, called pro-
caryotic or primitive cell type. 
The cell walls in plants, in-
cluding algae, are mainly 
made of cellulose, whereas in 
bacteria and in Blue-Greens 
the most important component 
of cell walls is mureine. The 
terms pro- or eu-caryotic de-
rive from the Greek “karyon”, 
meaning “nucleus”, and the 
bacterial cell lacks a nucleic 
wall enveloping their DNA. 
Lyn Margulis, from the Uni-
versity of Massachusetts, 
Amherst, explained (with lots 
of factual arguments) in 
many papers and in a recent 
article (Margulis and Dolan, 
1997), her theory that the eu-
caryotic cells could derive from 
the intracellular symbiosis 
of two procaryotic cells, the smaller and internal 
ones functioning as chloro-
plasts or mitochondriae. 
Margulis states: “On one side 
are the so-called neodarwin-
ists, who assert that new or-
ganisms and organs evolve 
primarily through the accru-
mulation of random mutation in 
DNA. In contrast, we and 
our allies maintain that a 
more important source of 
Darwinian evolutionary nov-
eltivity in living beings is 
symbiogenesis, evolutionary change through long-term 
physical contact between 
members of different species”.

Thus, we have Blue-Greens 
that are procaryotic and 
mureine-walled, like bacteria, 
but many of them are pluricel-
lar, aquatic, photosynthetic 
organisms, like algae. And 
here is where the question 
arises: are they algae or bacte-
ria? The question has no an-
swer, or better said, has too 
many answers, which is almost 
the same as having none. 
In fact, they are what they are, 
no matter how we scientists 
call them. Like *Australopi-
thecus* or *Archeopteryx* they 
are intermediate and not well 
defined living forms, half way 
between two other, better de-
defined ones. This is something 
very common in nature. Mi-
croscopic organisms like 
Euglenoids or Dinoflagellates 
are partly algae and partly 
protozoans, and you can learn 
about them both in Botany or 
in Zoology books. To quote 
an authority like Darwin on 
this respect, in his Origin of 
Species he states... “As pro-
fessor Asa Gray has remarked, 
the spores and other reproduc-
tive bodies of many of the 
lower algae may claim to have 
first a characteristically animal, 
and then an unequivocal 
vegetable, existence”.

The Benefits from 
Cyanobacteria

It was stated that they live 
in stagnant waters, and a rice 
field is an ideal place for 
their growth: they have sun, 
moderately high temperatures, 
and a lot of nutrients in the 
form of organic matter and 
mineral salts.

A particular feature of Blue-
Greens is that they can fix ni-
trogen. Every living organism, 
including humans, needs nitro-
gen to build some of the vital 
aminoacids. But we cannot get 
that nitrogen from the atmos-
phere, where it constitutes 
about 80% of the air we 
breathe. Instead, we get nitro-
gen from nitrogen compounds, 
either organic or inorganic. 
Plants also are capable of getting 
nitrogen only in this way, and that is why 
they all need the addition of 
fertilizers that, among other 
compounds, are very rich in 
nitrogen, in the forms of ni-
trates or urea. Legumes, it is 
well known, do enrich the 
soils with nitrogen. What actu-
ally happens is that they have 
symbiotic bacteria living in 
their radical nodules. These 
bacteria are the ones that can 
take the nitrogen from the air, 
fix it in the form of various 
compounds, and use them 
later to build their own ami-
noacids and proteins, and still 
produce enough compounds 
for the use of the legumes and 
the soil.

As said, some free-living 
Blue-Greens can also fix nitro-
gen from the air (another 
characteristic shared with bac-
teria), use its compounds to 
their own profit, and leave 
the rest in the enveloping wa-
ter, to be used, for example, 
by rice plants.
In general, Cyanobacteria grow naturally in the same fields that are used for rice culture. In spite of that, inoculation of these microorganisms in order to increase yields is a very common practice in most Asian countries, specially in those cases when the Blue Greens are not abundant. Ancient farmers in South East Asia empirically knew that fields that formed a blue-green “scum” after irrigation were better than others for rice. The abundance of Cyanobacteria increases with the rise in pH and phosphorous soil content. Other important environmental factors regulating them are light intensity, temperature, and grazing by aquatic zooplankton or small invertebrates.

According to Pierre Roger, from the International Rice Research Institute, the Philippines, “…Agronomic potential of N$_2$-fixing Cyanobacteria is about 30 kgN ha$^{-1}$ for a cultural cycle. This is not sufficient to obtain high rice yields. Nevertheless, this moderate potential can be used to increase yields in rice fields with weak productivity, or as a part of nitrogen fertilization in systems with medium to high productivity” (Roger, 1989).

Even being moderate, this potential is much better than nothing for farmers that can not afford the high costs of industrial or chemical fertilizers. Such is the case of the majority of farmers in poor countries like India, Bangladesh, Vietnam or China. And since many centuries ago, Cyanobacteria growing naturally in wetlands have been a blessing for those people whose basic diet is rice.

Also in Western countries attempts have been made to use Blue-Greens as fertilizers, being called “biofertilizers” in contrast with the artificial fertilizers. The reasons are not economical, but ecological. The intense use of nitrogen compounds in order to obtain high yields has an undesirable consequence: the excess of nitrate or ammonium is a strong contaminant of continental waters, whether shallow or underground. Visible results are the eutrophication of freshwater bodies, becoming inappropriate for human consumption, and the death of fish. Modern agronomic practice tends to sustainable agro-ecosystems; that is, a rational exploitation of fields without serious damage to the natural environment. Cyanobacteria, even if inoculated in soils, do not produce any harm to the habitat.

In Valencia, Spain, rice culture is very intensive, with huge additions of fertilizers. As a result, it is quite common to see the white bellies of dead fish floating on the surface of the Albufera, a lake located close to the Mediterranean coast, that collects the waste waters from the rice-fields, loaded with trouble-causing nitrogen compounds. A research team at the Autonomous University of Madrid, with which I cooperated for a couple of years, is working on a solution to this problem, with benefits both for the ecosystem and the farm producers. One possibility is saturating the field with nitrogen-fixing Cyanobacteria, and, in order to keep the high standards of productivity, supplement with small amounts of chemical fertilizers. This sounds well, but things are not that easy: nitrogen-fixing Cyanobacteria can take nitrogen from the air, but can also take it from the nitrogen compounds dissolved in the water, if available. In terms of energy (in the form of ATP), the nitrogen present in the air is much more “expensive” for the cells than the compounds in the water. As a result, there are several mechanisms that, in the presence of nitrogen in the water, will inhibit fixation from the air. That means that in a rice field with fertilizers added, Cyanobacteria will get their nitrogen from the fertilizers and not from the air, competing with the rice plant instead of helping its growth (Prosperi et al., 1992).

But, fortunately, this is not as strict as stated above. According to the strain used, there are several environmental factors that regulate nitrogen fixation, so that in certain conditions it is possible to have cells fixing nitrogen from the air even in the presence of nitrogen salts in the envirvon water. Calothrix marchica, a conspicuous species growing naturally in Valencia, behaved in such a way under laboratory conditions. This and some other few strains are the ideal ones to be used in a sustainable cropping system, with high rice productivity and low levels of water contamination (Prosperi and Valiente, 1994).

In Argentina, the rice culture area is located mainly in the Province of Corrientes, along the Parana River, the most important affluent of the La Plata River. There, the INTA -National Institute for Agricultural Technology- has experimental lands and a research station for the study of rice. Several trips were made there from our University of Cordoba, to carry out field research and take water and soil samples to be analyzed in our own laboratories. It was a nice surprise to find Calothrix marchica among other indigenous strains. The amount of organic pollution in the Parana River is not considerable at the moment, but can get worse in future years. To avoid problems, a possible contribution would certainly be the use of that Cyanobacterial strain, alone or combined with some other ones, as an alternative fertilizer (Prosperi et al., 1996).

The Nuisances from Cyanobacteria

As already stated, not all the species behave in the same way. Not all of them fix nitrogen from the air, and thus many are useless as biofertilizers. But more than that, many strains produce harmful toxins that can kill many kinds of living forms, including humans, depending on toxin concentration.

Because the Blue-Greens are very simple organisms, they can also reproduce very rapidly, in a logarithmic way, by binary cell division, like simple bacteria. In any lake they are almost always present as small populations, sharing the environment with other algae, aquatic bacteria, zooplankton and higher plants and animals. When certain conditions occur, that are optimal for their growth, like certain pH values, temperature, light radiation, and concentration of nutrients (specially phosphorus and nitrogen) they start reproducing very fast, duplicating their biomass in hours. This kind of demographic explosion is known as a bloom or, more precisely in this case, a waterbloom. When the cell concentration is high and depending on the strain, they generally produce toxins, probably developed to avoid predation from zooplankton.

There are many kinds of toxins. The two more common ones are neurotoxins and hepatotoxins which can affect, respectively, the nervous system or the digestive system, specially the liver. When these toxins are purified and injected into laboratory mice they can kill in a few hours, either from a cardio-respiratory shock or hepatic coma. There are reports of cows, sheep or dogs that died after drinking water from a pool with a toxic bloom (Pizzolon, 1996).

But the blooms are specially dangerous if they take place in a body of water intended for human consumption. The standard potabilization process, consisting basically in mechanic filtration and addition of chlorine, is rather ineffective for the neutralization of the toxins. Boiling the water is also useless, as the toxins are not denatured by heating, even at high temperature and for a long time.

At lower concentrations the toxins are not deadly, but may cause digestive problems with moderate to severe symptoms. It is also believed that they have an accumulative effect, and the chronic drinking of water containing...
Cyanobacteria toxins could be carcinogenic in medium to long periods of time, depending on many factors (Carmichael, 1994).

As recently as 1996 a tragedy happened in Caruaru (Brazil) involving the death of human beings by ingestion of hepatotoxins. These persons were hemodialysis patients in a hospital using water not properly treated from a lake infested with Microcystis aeruginosa. This cyanobacterial strain produces a potent hepatotoxin, called “microcystin” on behalf of its generic name. On first approach, the medical team failed to diagnose it because they suspected the patients were suffering from cholera, an illness producing similar symptoms: vomit, diarrhea, abdominal pain, fever, etc. The results were that 110 (84%) of 131 patients experienced visual disturbances, nausea and vomiting following routine treatment on February 17-20, 1996. On February 20 one patient died. By March 6, twelve patients had died due to seizures or acute hemorrhage. Thereafter, 83 patients showed signs of liver disease and, of these, 32 had died from complications of liver failure by April. By August 4, 55 patients died, with 44 of them having a syndrome related to liver failure.

There are many important public health measures to be considered after this important case of human poisoning caused by cyanotoxins. Most of the world reservoirs used for water supply, including those in Cordoba, are subject to increasing nutrient levels, and therefore it is probable that similar cases of cyanotoxin poisoning could happen unless urgent measures are taken to prevent them.

Cordoba City, in Argentina, with a population of almost one and a half million people, is supplied with water from the San Roque Dam, an artificial lake used as a water reservoir. The lake, surrounded by mountains and with nice weather during most of the year, is an important and widely recognized tourist resort. But the influx of visitors, together with several stable populations located around the lake or the inflowing rivers, have produced an increase of organic matter reaching the lake. This process is known in limnology with the term “eutrophication”, again a Greek word meaning “good food”. In fact, the phosphorous content of that organic matter is really a good food for Cyanobacteria, increasing their population and forming several toxic blooms throughout the whole year (D’Angelo et al., in press).

At Cordoba University we are working on the systematic and general ecology of these organisms in the reservoir, and the most conspicuous strain, at least since the beginning of this decade is precisely Microcystis aeruginosa. We are presently working on the problem, with the cooperation of teams from Rio Cuarto University and the Catholic University, both located also in Cordoba Province (Lerda and Prosperi, 1996; Rodriguez et al., in press).

Cyanobacteria or Blue Green Algae are also very important for human affairs in the development of biotechnology, industrial uses, alternative food sources and a wide range of theoretical studies about the morphology, physiology, ecology and evolution of both Bacteria and Algae. But I personally think that the most important relation between these microorganisms and we humans is based either on our use as non-contaminating rice fertilizers or our fight against their toxins in water reservoirs.

In the words of B. A. Whitton and N.G. Carr, from the Universities of Durham and Liverpool, England, “During the past two decades Cyanobacteria have become generally recognized as a major group in the procaryote kingdom - certainly one of the most diverse, judged by variety and number of species - and perhaps the largest” (Carr and Whitton, 1982).

REFERENCES


Pizzolon L (1996) Importancia de las Cianobacterias como factor de toxicidad en las aguas continentales. InterCiencia: 239-245


La formación de investigadores es condición sine qua non para el adelanto de la humanidad. Un país no es una gran nación si no forma y cuida a sus hombres de ciencia que realizan investigación original

Bernardo A. Houssay