Nitrogen fixation at night in nature

The nitrogen balance of natural ecosystems is sustained partly by Cyanobacteria, the autotrophic prokaryotes, that occur as free-living individuals or associated symbionts. These organisms are unique due to their capacity to carry on the oxygen-evolving photosynthesis and the oxygen-sensitive nitrogen fixation[1]. One of the recent findings in cyanobacterial nitrogen fixation is the light/dark modulation of the nitrogenase activity in unicellular members like *Gloeothece*[2], *Oscillatoria*[3,4] and *Lyngbya*[5]. All these forms have been shown to have an active nitrogenase under defined laboratory conditions. These forms, unlike the heterocystous filamentous ones, separate the two processes temporally (by time). Photosynthesis occurs in the light phase and nitrogen fixation in dark. In heterocystous filamentous forms, spatial separation of the two processes is the *modus operandi*. Nitrogenase activity is restricted to the thick-walled heterocysts while the vegetative cells carry out photosynthesis[6]. We asked ourselves the question whether the cyanobacteria that lack heterocysts would fix nitrogen at night and leave the process to be carried on by heterocystous forms during the day. Our experiment was carried out in a rice-paddy field from 3.30 in the afternoon till 12.30 p.m. the next day. The paddy field harboured nonheterocystous members like *Oscillatoria*, *Lyngbya*, *Microcoleus* and *Phormidium*, forming a dense mat and intertwinning trichomes of a *Nostoc* species. Samples of cyanobacterial mat at six different spots were collected and transferred to assay bottles. Acetylene (10%) was introduced and the reaction terminated after one hour incubation in the field with trichloroacetic acid (10%). Samples were collected every three hours. On completion of the experiment the samples were brought to the laboratory for acetylene reduction assay[7] to estimate nitrogen fixation. Figure 1 shows results of the field experiment. Considerable amount of nitrogen fixation is observed in the night possibly due to the mat formed by the nonheterocystous filamentous strains. The activity was maximum at 3.30 a.m. (1.81 nmole acetylene reduced/h/mg algal mat). The activity in the day was maximum at 9.30 a.m. (1.14 nmole acetylene reduced/h/mg algal mat) probably due to the few trichomes of *Nostoc*. The light/dark modulation of nitrogenase operating in cyanobacteria under laboratory condition is shown in Figure 2, in which a *Phormidium* strain fixed nitrogen during the dark phase and the heterocystous *Nostoc* strain showed nitrogenase activity in light.

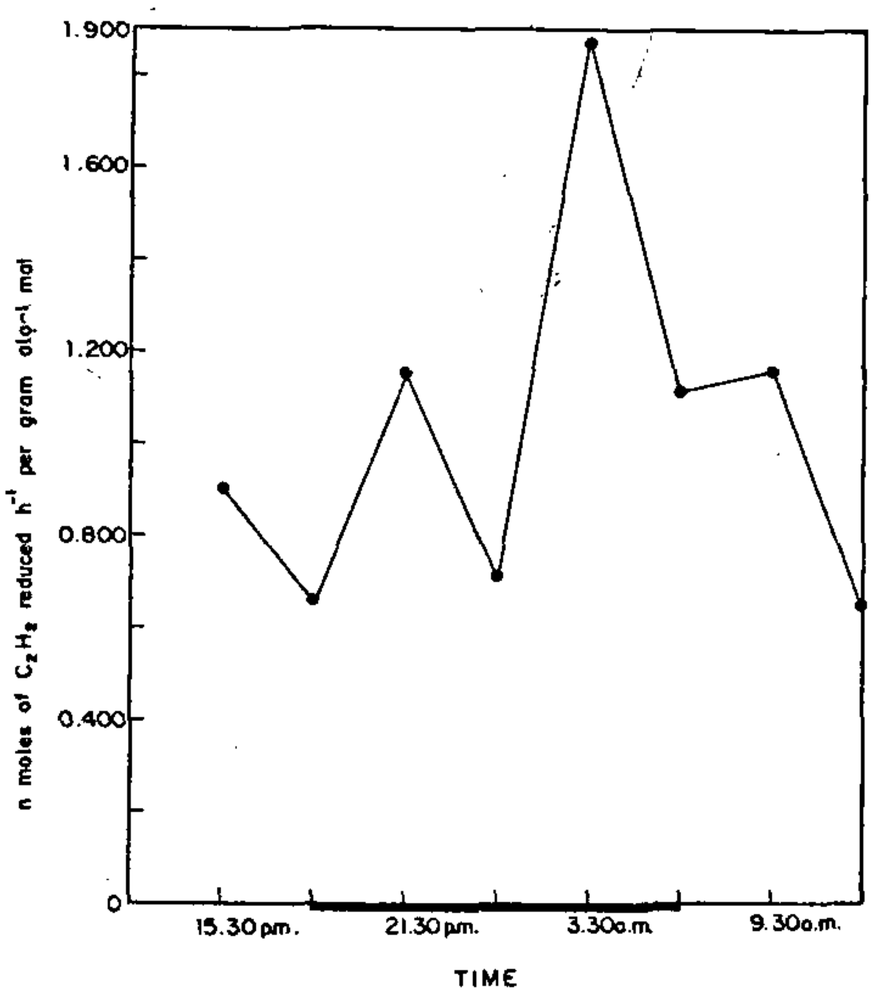

Figure 1. Nitrogenase activity by cyanobacterial mat in the rice-paddy field.

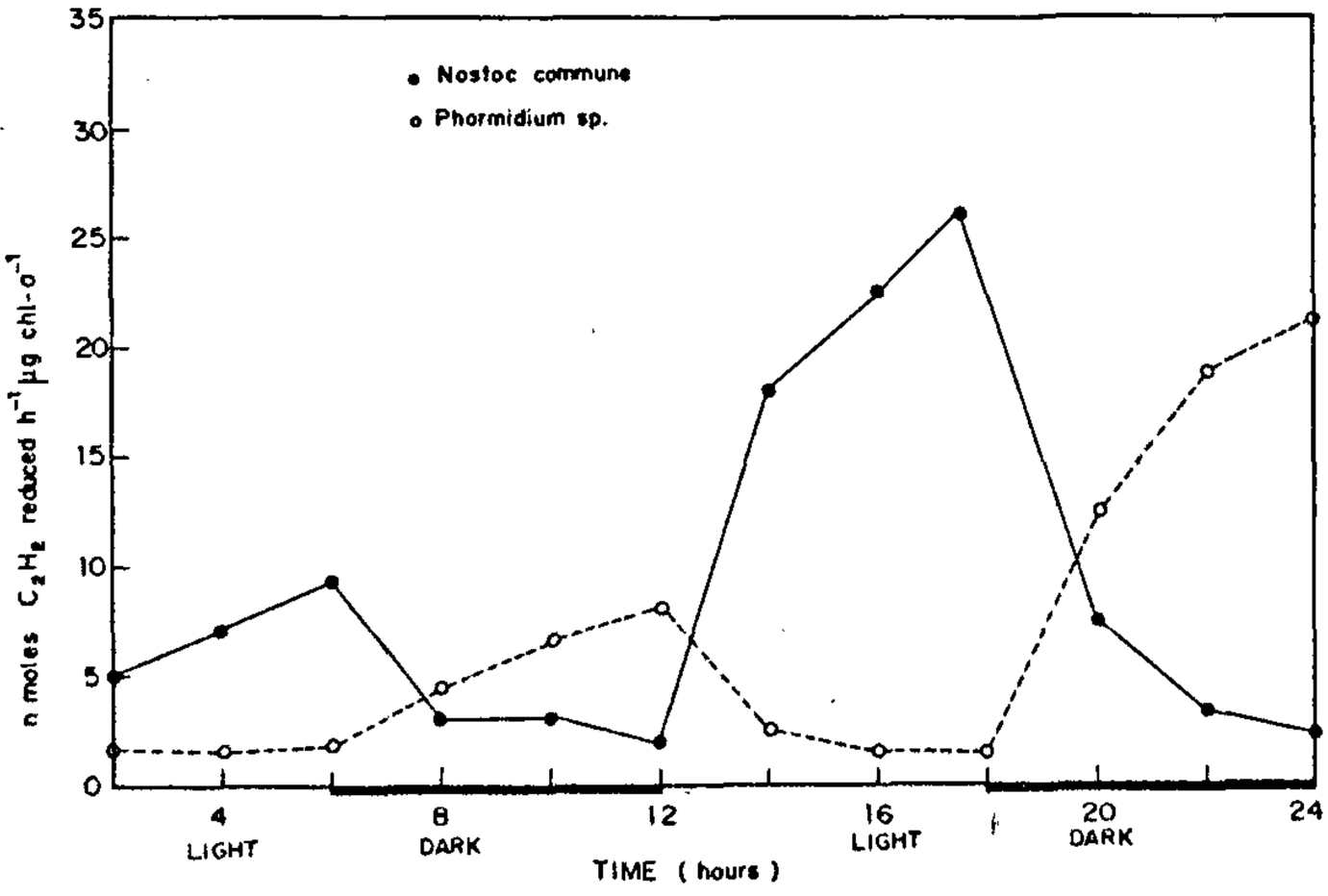

Figure 2. Nitrogenase activity by strains of cyanobacteria in the laboratory.

Cyanobacteria seem to play a prominent role in the replenishment of the depleting nitrogen source of paddy field soils through a round-the-clock process of nitrogen fixation, shared equally between themselves by morphologically different entities coexisting in the soil ecosystem. Nitrogen fixation linked to photosynthesis occurs during the day and the process continues at night in Nature.

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V. S. R. M

Centre of Advanced Study in B
University of Madras,
Guindy Campus,
Madras 600 025, India

Occurrence of *Actinoporella cretacica* Raineri, an echinod from the Bagh beds, Dhar area, Central India

Actinoporella cretacica Raineri is recorded for the first time from the uppermost horizon of the Bagh beds of Dhar area. This form is an index fossil of the Late Cretaceous and thus its presence in the bed supports Late Cretaceous age for the Bagh beds. The genus *Actinoporella* Gumbel is known from the Upper Jurassic and Cretaceous of Iraq, Hungary, Italy and Guatemala[1]. However, *A. cretacica* is the only form which had been recorded by Raineri[2] and Pia[3] from the Cenomanian/Turonian strata exposed near Tripoli, North Africa. This form is now recorded from the uppermost horizon of the Bagh beds of Dhar area. The small, detached outcrops of marine sedimentary rocks of Cretaceous age are found along the Narmada valley covering a stretch of about 350 km and were named as Bagh bed by Bose[4] after the Bagh township of Dhar District in Madhya Pradesh. In course of palaeontological studies, a rich and well-preserved fossil assemblage has been recovered from this formation by many workers[5–19]. *A cretacica* Raineri has been recorded from the Coralline Limestone.

In the Dhar District, M.P., the Bagh Formation (generally referred to as Bagh beds) represents a thin Cretaceous marine sequence dominated by argillo-calcareous sediments. The Bagh sediments overlie the Nimar Sandstone and is in turn overlain by the Deccan Traps. The stratigraphic succession of the Bagh Formation according to Bose[4] is as follows:

Deccan Trap

Unconformity

Coralline limestone
Deola and Chirakhan Marl
Nodular limestone
Nimar sandstone

Unconformity

Metamorphics.

About 1 km from Zirabad on Zirabad–Dhar motor road, a good section of Bagh Formation is seen (Figure 1). Only

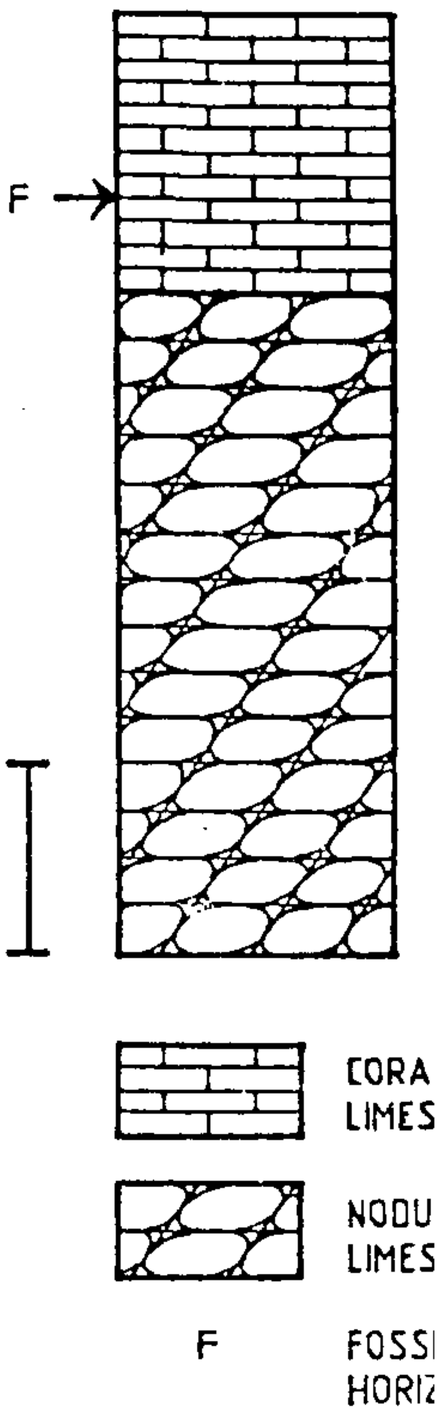

Figure 2. Lithocolumn of foss

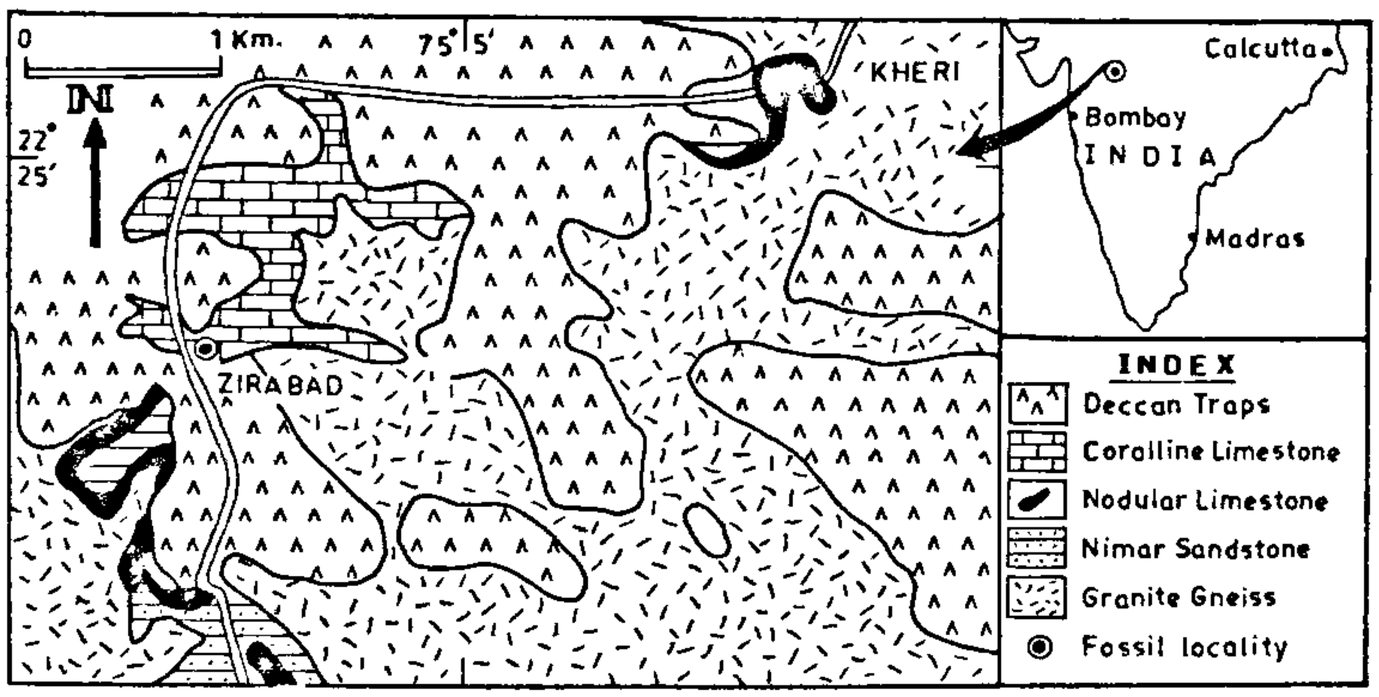

Figure 1. Geological map around fossil locality.

two stratigraphic horizons
oped here. At the base about
nodular limestone is seen in
with grey shales. Nodular nat
is the characteristic sedimen
ture. It grades upwards into
thick, hard, compact, lig
Coralline Limestone (Figur
dominant bedding type is
cross bedding. Small-scale