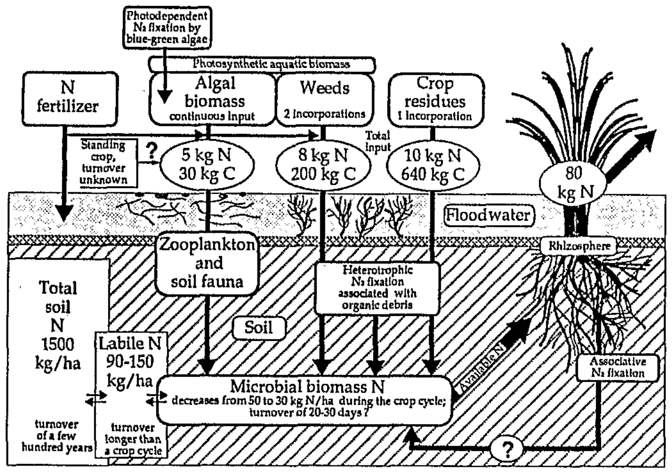
NUTRIENT INPUT BY THE PHOTOSYNTHETIC AQUATIC BIOMASS IN A RICEFIELD AND ITS CONTRIBUTION TO THE MAINTENANCE OF SOIL MICROBIAL BIOMASS

P.A. Roger, R. Jimenez , S. Ardales, I. Watanabe. International Rice Research Institute/ORSTOM. Philippines

1. Introduction, purpose of the study

The photosynthetic aquatic biomass (PAB) that develops in ricefield floodwater is composed of planktonic, filamentous, and macrophytic algae, and vascular macrophytes. These primary producers are one of the sources of organic nutrients that allow the replenishment of the microbial biomass and available nitrogen in wetland rice soils. A conceptual scheme of the pathways involved in this replenishment is presented below.

The purposes of the experiment were (1) to establish, from large numbers of measurements under various management practices, the ranges of nutrient contributions by the PAB; and (2) to study how suppressing photosynthetic activity in ricefield floodwater affects soil microbial biomass.



2. Materials and methods

Measurements were made in the 65 plots (4x4 m) of a long-term experiment established in 1985 on IRRI's farm. The main treatment is N-fertilizer: (none; 30+25 kg urea-N/ha broadcast; 55 kg N/ha deep-placed). Other treatments were: the method of P application, algal inoculation, and control of algal predators. Quantitative measurements involving PAB included:

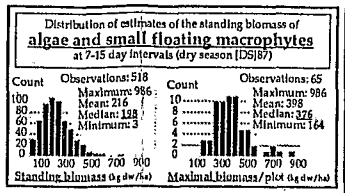
- composition and standing crop of main components of the PAB, estimated on composite samples in each plot;
- photosynthetic activity, estimated as gross primary production in g C/m²/day from 24-h measurements of dissolved O_2 (DO), water temperature, and water depth (a graphic summarization of the method used is presented with the results); and
- photodependent acetylene reducing activity (ARA) (µmol $C_2H_2/m^2/h$), measured on composite samples of 8 cores (2 cm Ø) including floodwater algae and the first 2-3 cm of soil. Cores were incubated under 10% acetylene in air for 1 h in a light chamber (30 klux, 28-30 °C). Acetylene/$^{15}N_2$ ratio was 4.7 ± 0.7 (average of 5 estimates).

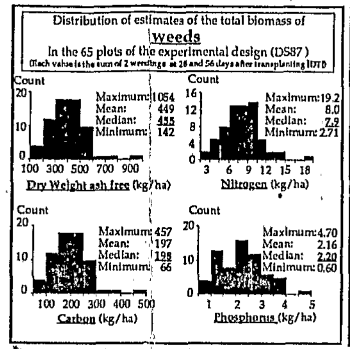
To study the effect of suppressing photosynthetic activity in the floodwater on soil microbial biomass, a metallic frame (1 x 1x 0.5 m) was inserted in 1987 in each plot and covered with black cloth inserted between two plaques of polystyrene foam. The cover had holes to allow rice growth. The effect of weed incorporation versus removal was also tested.

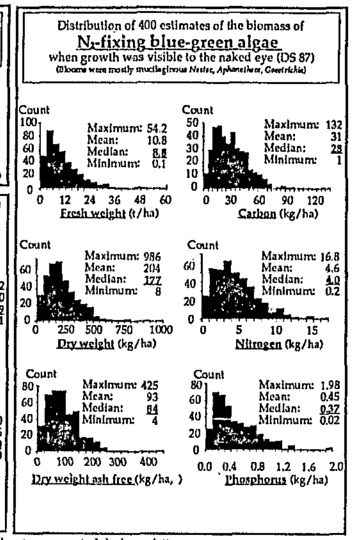
A greenhouse experiment also compared microbial biomass of the unplanted, flooded soil, either exposed to light or kept in the dark for one year.

Soil microbial biomass was estimated as flush-N (ppm NH_4-N of fresh soil) obtained by chloroform treatment followed by 4 weeks of anaerobic incubation.

3a. Standing crops of PAB components*



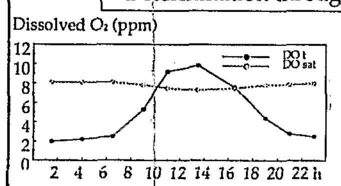


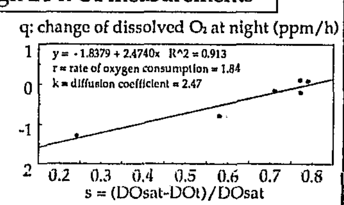


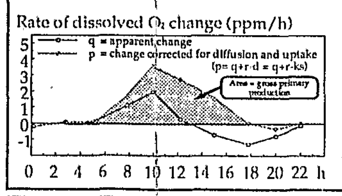
*DS 1987. Mucilaginous N_2-fixing blue-green algae were the dominant component of algal populations.

3b. Gross primary production

Determination through 24-h O_2 measurements

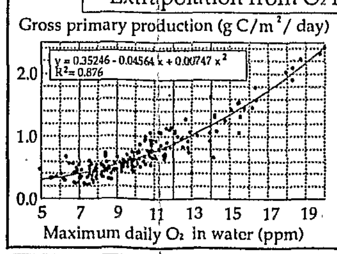






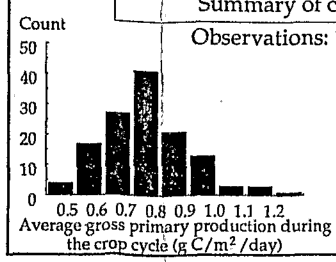
q = rate of change of dissolved oxygen
p = rate of gross primary production
r = rate of oxygen consumption (constant)
DOt = dissolved oxygen at time t
DOsat = dissolved oxygen at saturation
s = (DOsat - DOt)/DOsat
d = rate of oxygen diffusion = ks
During the day: q = p - r + d
At night : q = d - r = ks - r (permits calculation of r and k)

Extrapolation from O_2 measurements at 13:30 h



A study of 195 diurnal cycles shows a correlation between daily gross primary production and maximum O_2 in water during a crop (DS 88) in which no marked changes in temperature and water depth occurred. This allows extrapolations from single O_2 measurements.

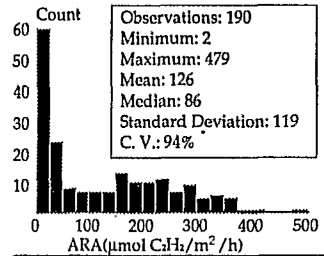
Summary of calculated values



Observations: 130
Maximum: 1.22
Mean: 0.76
Median: 0.75
Minimum: 0.47
C.V. : 20%

Values are average of 38 (DS 87) or 17 (DS 88) daily estimates of gross primary productivity during the crop cycle.

3c. Photodependent N_2-fixation



Each value is the average of 9 to 13 ARA measurements during a crop cycle. The bimodal histogram results from BNF inhibition in plots where urea was broadcast.

Ten µmol $C_2H_2/m^2/h$ over a cropping season is roughly equivalent to 1 kg N fixed/ha.

3d. Soil microbial biomass (flush-N)

Effect of management of photosynthetic aquatic biomass on soil microbial biomass, DS & WS 1988*

	Soil depth	Weeds incorporated	Weeds removed	Dark control	Variance analysis**
Dry season 1988					
27 DT	0-2 cm (ppm)***	47.7	47.7	37.5	1%
(before	2-7 cm (ppm)	41.8	41.8	28.1	1%
weeding)	0-7 cm (kg/ha)	44.2	44.2	30.3	1%
76 DT	0-2 cm (ppm)	36.2	34.5	23.6	5%
	2-7 cm (ppm)	28.2	27.8	26.9	ns
	0-7 cm (kg/ha)	30.9	30.1	25.8	5%
91 DT	0-2 cm (ppm)	36.4	39.9	25.3	1%
	2-7 cm (ppm)	26.5	26.2	25.9	ns
	0-7 cm (kg/ha)	29.7	30.4	25.5	1%
Wet season 1988					
-2 DT	0-7 cm (ppm)	37.9	37.1	32.9	1%
	0-7 cm (kg/ha)	38.7	37.8	33.6	1%
92 DT	0-2 cm (ppm)	40.4	33.9	25.4	1%
	2-7 cm (ppm)	32.7	29.7	28.1	5%
	0-7 cm (kg/ha)	32.8	29.8	27.1	5%
Mean	0-7 cm (ppm)	35.2	34.2	28.2	1%

*Value are mean of duplicate measurements on a composite sample of 20 cores collected from 10 replicated plots. **Level of significance. ***ppm NH_4-N, fresh soil basis.

Comparison of total N content and microbial biomass of unplanted, flooded soil exposed to light or kept in the dark for one year*

	Total N (% soil dw)	Microbial biomass (ppm soil dw)	Microbial biomass (% soil N)
Soil exposed to light			
Initial N content	0.168 c		
1st cm	0.249 a	97.6 a	3.9 a
deeper soil (1-4cm)	0.168 c	51.3 b	3.0 b
Soil kept in the dark			
Initial N content	0.180 b	-	-
1st cm	0.161 c	30.4 c	1.9 c
deeper soil (1-4cm)	0.151 c	27.7 c	1.8 c

*Greenhouse experiment in 0.5 x 0.5 m microplots with 5 cm of soil. In plots exposed to light, algae and weeds were reincorporated every 2-3 weeks. Values are average of duplicate measurements in 10 replicated plots

Abbreviations:
ARA: acetylene reducing activity
DS: dry season; WS: wet season
DT: days after transplanting
DO: dissolved oxygen

4. Summary and conclusions

- Algae and small floating macrophytes (500 estimates over one season) had standing crops averaging 5 kg N and 30 kg C /ha over the crop cycle. Maximum values recorded during each crop cycle were about twice as high.
- Weeding permitted the recyling of an average 8 kg N/ha per crop and 200 kg C/ha per crop (65 estimates over one season) .
- Gross primary production in water over the crop (130 estimates over 2 seasons) averaged 0.75 g C /m²/day. These values are similar to those in eutrophic lakes and correspond to about 10-15 % of the gross primary production of rice.
- Average ARA per plot (190 estimates over 3 seasons) ranged from values equivalent to 2 to 50 kg N_2 fixed/ha / crop. When ARA was not inhibited by broadcast urea it averaged 20-30 kg N_2.
- After one year of submersion of an unplanted soil, microbial biomass (flush-N) was about 60% lower in the first soil cm and 50% lower in the deeper (1-4 cm) layer when soil was kept in the dark as compared with soil exposed to light.
- In the field, weed removal and light elimination significantly decreased soil microbial biomass after two crops. Microbial biomass was about 22% lower in the dark control than in the light treatment with weeds incorporated. The effect was more marked in the upper soil layer (0-2 cm) than in the deeper soil layer. N fertilizer had little effect on flush-N (data not shown).
- In wetland ricefields, the photosynthetic aquatic biomass constitutes a major component and source of nutrients for the microbial biomass in the upper soil layer and a significant source of nutrients for the microbial biomass in deeper soil.