Adapting *Codium tomentosum* and *Chondrus crispus* to indoor culture: assessment of light and nutrient conditions

Mohamed Soula*, Paula Frade, Alexandra Pexegueiro, Víctor González, Yara Melean, Martiña Ferreira.
ANFACO-CECOPESCA, Division of Aquaculture. Estrada Colexio Universitario 36310. Vigo (Spain).
Corresponding author: martina@anfaco.es

Macroalgae cultivation is gaining interest in the EU, both as an alternative to imports from third countries and to the harvesting of wild biomass. Whereas cultivation in coastal waters may involve large areas and production volumes, land-based cultivation in tanks provides the opportunity of including seaweds ein IMTA schemes to remove inorganic nutrients from aquaculture effluents, thus reducing costs of water treatment and providing an additional value-added product. *Codium tomentosum* Stackhouse 1797 and *Chondrus crispus* Stackhouse 1797 are two autochthonous species of commercial interest in Europe, but information on their culture is scarce. In this work we provide some data regarding their acclimation to indoor culture, and their potential of biomass production and capacity of nutrient uptake.

Experiment 1

Materials and methods

C. tomentosum was cultured in aerated 5-l flasks. Light was provided by daylight white LED lamps **(W)** or a combination of daylight white plus red-enriched LED lamps **(WR)**, yielding 330 µmol m^{-2} s^{-1} and 360 µmol m^{-2} s^{-1} respectively. Photoperiod was circadian, 14 h light: 10 dark. Culture medium consisted of filtered seawater supplemented with $NaNO_3$ and NaH_2PO_4. Three culture conditions combining light and nutrient conditions were tested: 19 W, 500 µM $NaNO_3$ + 50 µM NaH_2PO_4 **(W50);** 2) W, 500 µM $NaNO_3$ + 75 µM NaH_2PO_4 **(W75)** and 3), WR, 500 µM $NaNO_3$ + 50 µM NaH_2PO_4 **(WR50)**. After 5 weeks of culture, part of the *C. tomentosum* biomass was removed from culture flasks to avoid self-shading, and Experiment 1 was continued for 3 more weeks. Cultures were run in triplicate.

Results

C. tomentosum grew continuously in both phases of the experiment and in all culture conditions tested (Figure 1A). WR50 cultures experienced the highest SGR, suggesting that the enrichment of light in red wavelengths is beneficial for this species (Figure 1B). *C. tomentosum* cultures fully consumed N and P supplied on a weekly basis. N uptake ranged between 0.030 and 0.045 g kg^{-1} fresh weight d^{-1}, with no statistical differences among culture conditions. P uptake ranged between 0.004 and 0.010 g kg^{-1} fresh weight d^{-1} in W50 and WR50 cultures. W75 cultures responded to the higher P concentration by a 20 % to 30 % increase of P uptake rate, but these differences were statistically significant in some cases only.

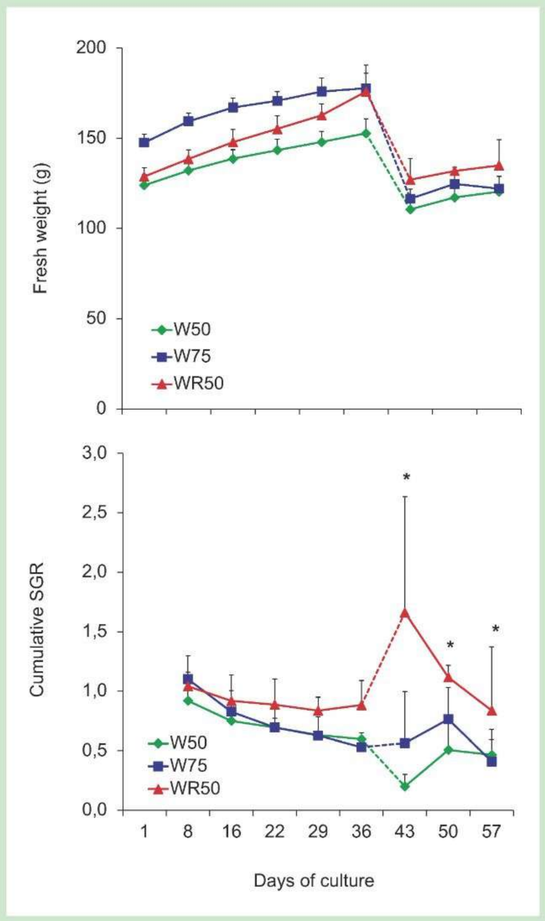

Figure 1. Increase of fresh biomass (A) and cumulative specific growth rate (B) in cultures of *C. tomentosum*. Asterisks mean statistically different values ($p<0.05$) among culture conditions on a given day. Dashed lines indicate when biomass was partially removed from culture flasks.

Experiment 2

Materials and methods

C. crispus was cultured in aerated 1-l flasks and lightened by daylight white LED lamps (81 µmol m^{-2} s^{-1}, photoperiod as in Experiment 1). Culture medium was filtered seawater supplemented with either 500 µM NH_4Cl **(N cultures)** or 250 µM NH_4Cl + 250 µM $NaNO_3$ **(NN cultures)** + 50 µM NaH_2PO_4. After 7 weeks of culture, part of the *C. crispus* biomass was removed from culture flasks and nutrient concentration was doubled. Experiment 2 continued for 7 more weeks. Cultures were run in triplicate.

Results

No statistical differences were observed in the growth of *C. crispus* cultured either with NH_4^+ or a mix of NH_4^+ and NO_3^- as N source during the first phase of the experiment. Nevertheless, when nutrient concentrations were doubled in the second phase, growth was higher in N cultures (Figure 2A). This was also observed in the SGR (Figure 2B). Both N and P uptake significantly increased ($p<0.05$) with the doubling of nutrient concentration, from 0.070-0.106 to 0.127-0.280 g N kg^{-1} fresh weight d^{-1} and from 0.009-0.011 to 0.011-0.045 g P kg^{-1} fresh weight d^{-1}, but in general no differences were found between nutrient uptake among N and NN cultures.

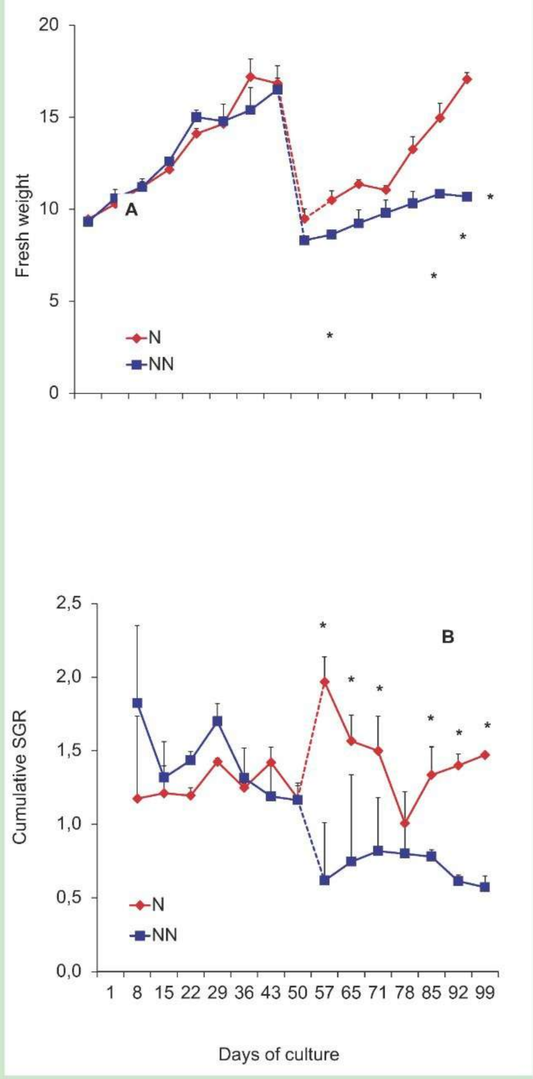

Figure 2. Increase of fresh biomass (A) and cumulative specific growth rate (B) in cultures of *C. crispus*. Asterisks mean statistically different values ($p<0.05$) among culture conditions on a given day. Dashed lines indicate when biomass was partially removed from culture flasks.

Results suggest that both *C. tomentosum* and *C. crispus* can be adapted to indoor cultivation for long periods. Light quality was an important factor in *C. tomentosum* cultures, since the increase of the supply of red wavelenghts resulted on a higher growth rate. Self-shading must be avoided to ensure that light intensity is sufficient to promote growth. In the conditions tested, changes in nutrient concentrations were not relevant for the growth of *C. tomentosum*, but the growth of *C. crispus* decreased when a mixture of NH_4^+ and NO_3^- at high concentrations was used as N source, compared to NH_4^+.

Both light and nutrient quality and intensity are crucial factors for the cultivation of macroalgae and these results may provide useful indications for the establishment of larger-scale indoor cultures of *C. tomentosum* and *C. crispus*.

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