Impact of variable light intensities and wavelengths on growth and oxygen production of algae cultivated under low-pressure conditions relevant to Mars and their differential gene expression analysis

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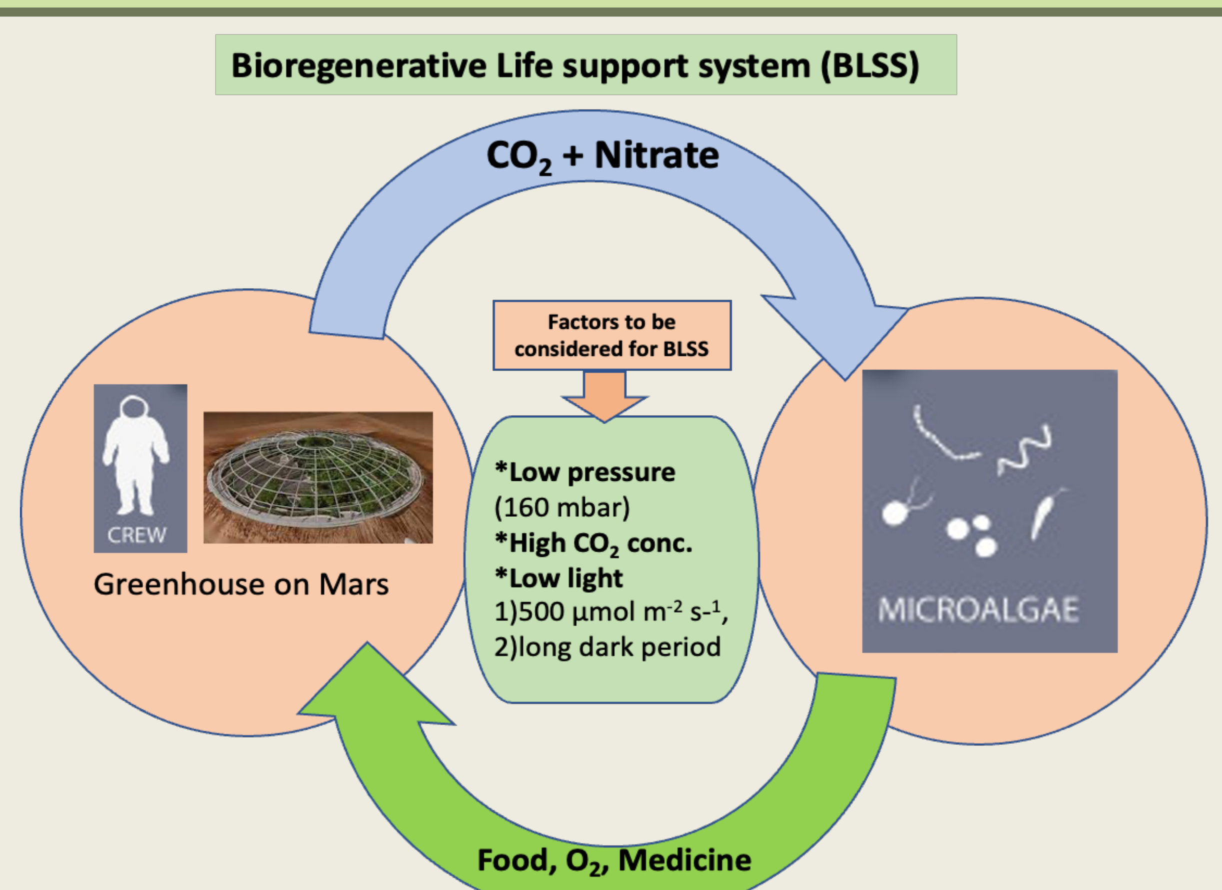
OVERVIEW

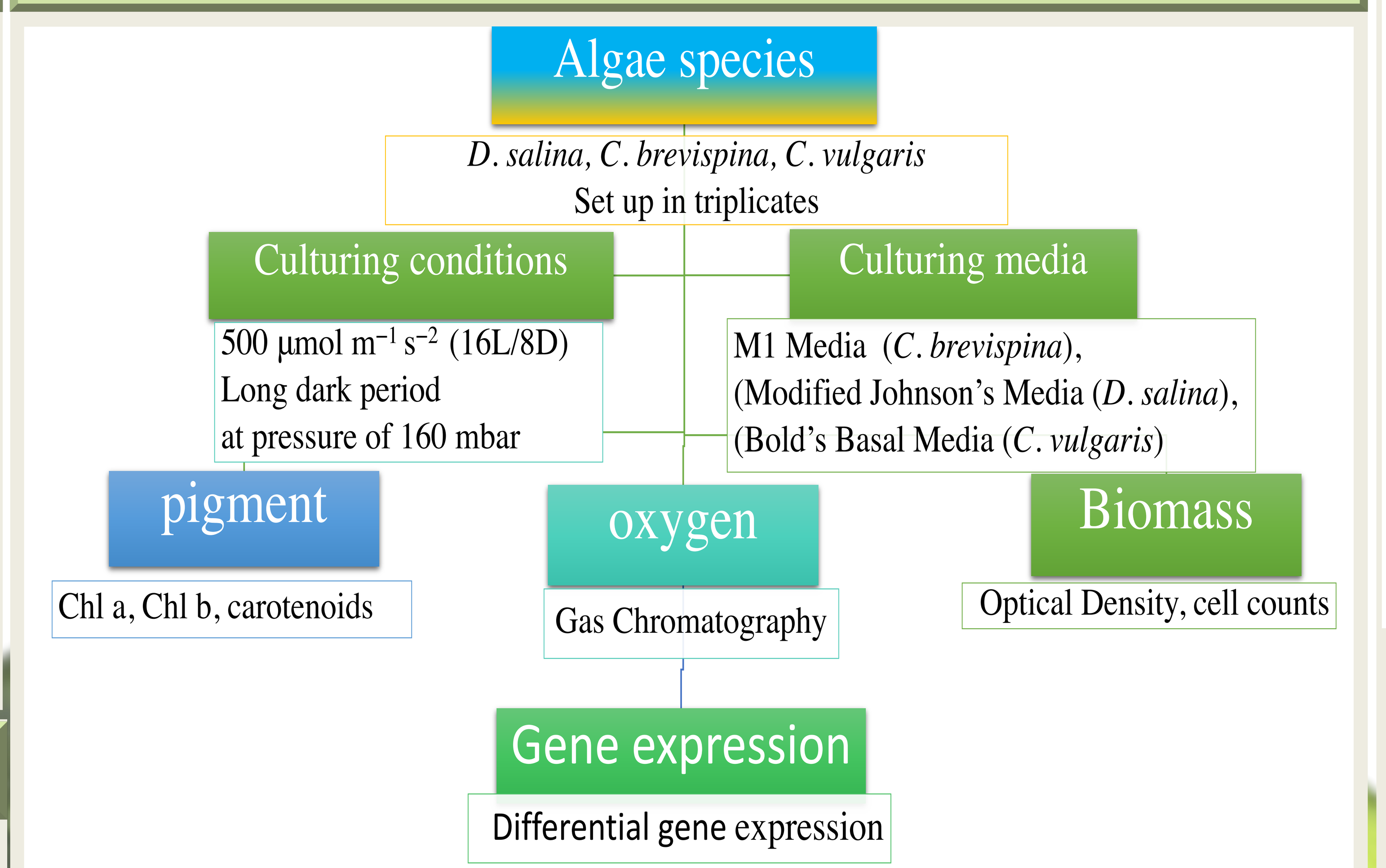
This study examined how varying light intensities and wavelengths impact algae growth and oxygen production under low-pressure conditions resembling Mars' environment. Conducted within a controlled low-pressure chamber, algae cultures were subjected to different light conditions while their growth rates and oxygen output were monitored. The gene expression profiles of these algae species were also analyzed to identify their adaptive mechanisms. This study provided insights into the molecular mechanisms underlying algae responses to these environmental stimuli. Overall, the findings contribute crucial knowledge for optimizing algae-based bioregenerative life support systems for long-duration space missions, advancing our understanding of space habitation beyond Earth.

INTRODUCTION



Algae, with their fast growth rates and high photosynthetic efficiency under prolonged exposure to harsh environmental conditions, could serve as an important component of self-sustaining bio-regenerative life support systems (BLSS) to allow *in situ* production of food and oxygen. Understanding their photosynthetic activity and the adaptions of these algae under different Mars-relevant conditions, such as low pressure and low light intensity, could therefore be key in future space exploratory missions [1]. However, there is a lack of in-depth systematic studies exploring the photosynthetic adaptations, physiology changes and gene expression analysis of photosynthetic organisms exposed to Mars-like environments [2]. Here, we explored the growth and photosynthetic potential of the candidate algae species, *Chloromonas brevispina, Dunaliella salina*, and *Chlorella vulgaris* under Mars-relevant low-pressure and low light conditions and determined their gene expression levels under low pressure conditions to establish their suitability as components of BLSS for long-term space exploratory missions.

METHOD



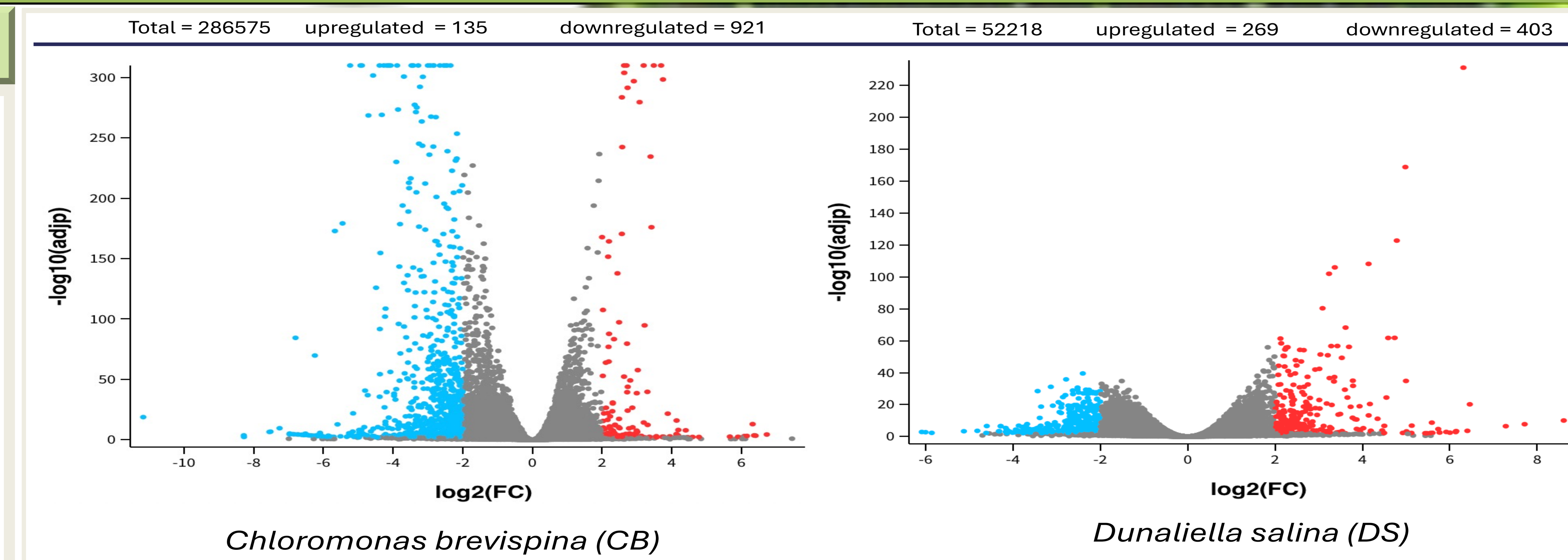


Figure 3. *Volcano plot displaying the differential gene expression (DEG) in C. brevispina-CB and D. salina-DS growing at 160 mbar as compared to the control growing at atmospheric pressure. The red points indicate the up-regulated genes compared with the control; the blue points indicate the down-regulated genes compared with the control; the grey points mean that there is no difference between the treatment and the control. Fold changes in log2 were used to generate the volcano plots.*

RESULTS

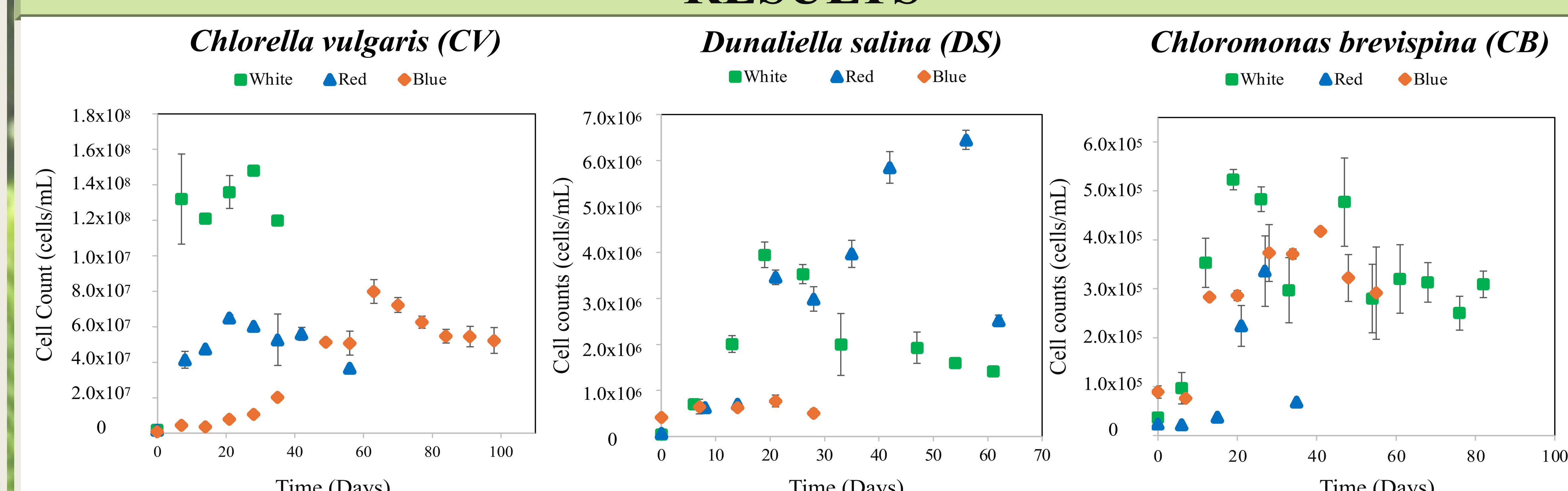


Figure 1. *Growth curves of Chlorella vulgaris (CV), Chloromonas brevispina (CB), and Dunaliella salina (DS) at different light intensities: full spectrum white light, red (620-750 nm), and blue (450-495 nm) plotted as a mean value (n=4) of duplicate cell count measurements of duplicate experiments. Error bars are 1 standard deviation of mean cell count values. Where error bars are not seen they lie within the points.*

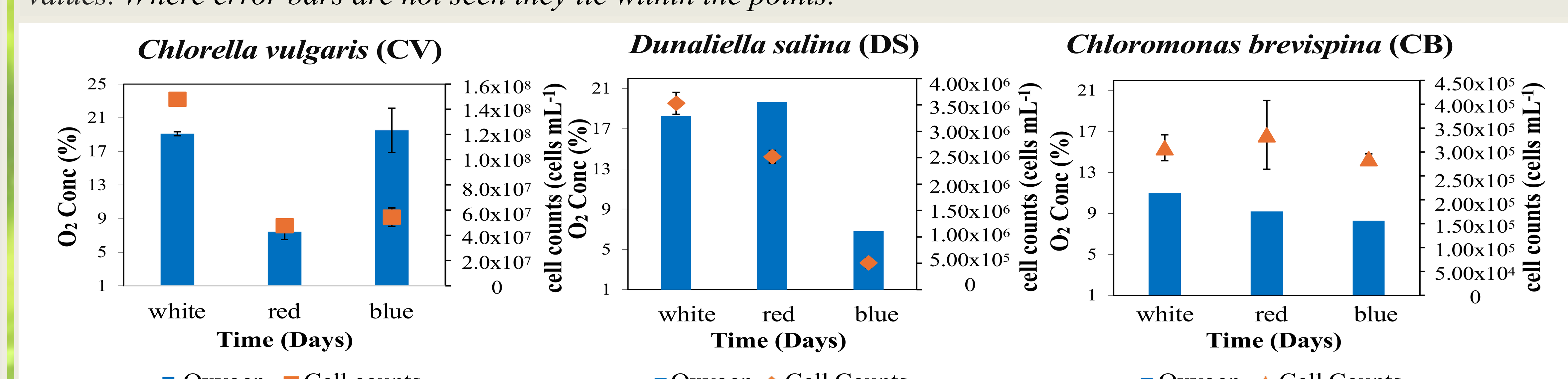


Figure 2. *Maximum O_2 and associated cell counts observed under white, red and blue light at a pressure of 160 mbar pressure and 500 µmol m^{-2} s^{-1} of light intensity for, C vulgaris (CV), D. salina (DS) and C. brevispina (CB). Error bars on the cell counts are the standard deviation of the mean cell count values. The error bars of the O_2 measurements are the percent error on O_2 concentrations. Where error bars are not seen they lie within the points.*

CONCLUSION

The substantial biomass production and O2 generation at low pressure, low light intensities and different wavelengths by the candidate algae species indicate the remarkable potential and suitability of these algae species to be used as component of BLSS. Together these results indicate that these species may be able to contribute to potential BLSS on Mars using low pressure (~200–300 mbar) greenhouses and inflatable structures that have already been conceptualized and designed. The differential gene expression analysis of algae species *C. brevispina* and *D. salina* indicate clear differences between the transcriptome profiles of algae growing under the two different pressure conditions. Comparison between the expression of *C. brevispina* and *D. salina* also showed that *C. brevispina* expressed much more genes as compared to *D. salina* to survive under low pressure indicating the *D. salina* may have already established genetic makeup to survive multiple stress conditions. Ongoing work includes specific gene annotation and classification to further understand the potential of these candidate algae species to be used in BLSS.

REFERENCES

[1] Cycil, L.C et al., (2020) LPI, 2326, 1517.

[2] Verseux, C. et al., (2016) Int J Astrobiol, 15-65-92.

ACKNOWLEDGEMENTS

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