Image Processing-Based Analysis of Morphological Changes in *Pediastrum duplex* Under Copper Sulfate Stress.

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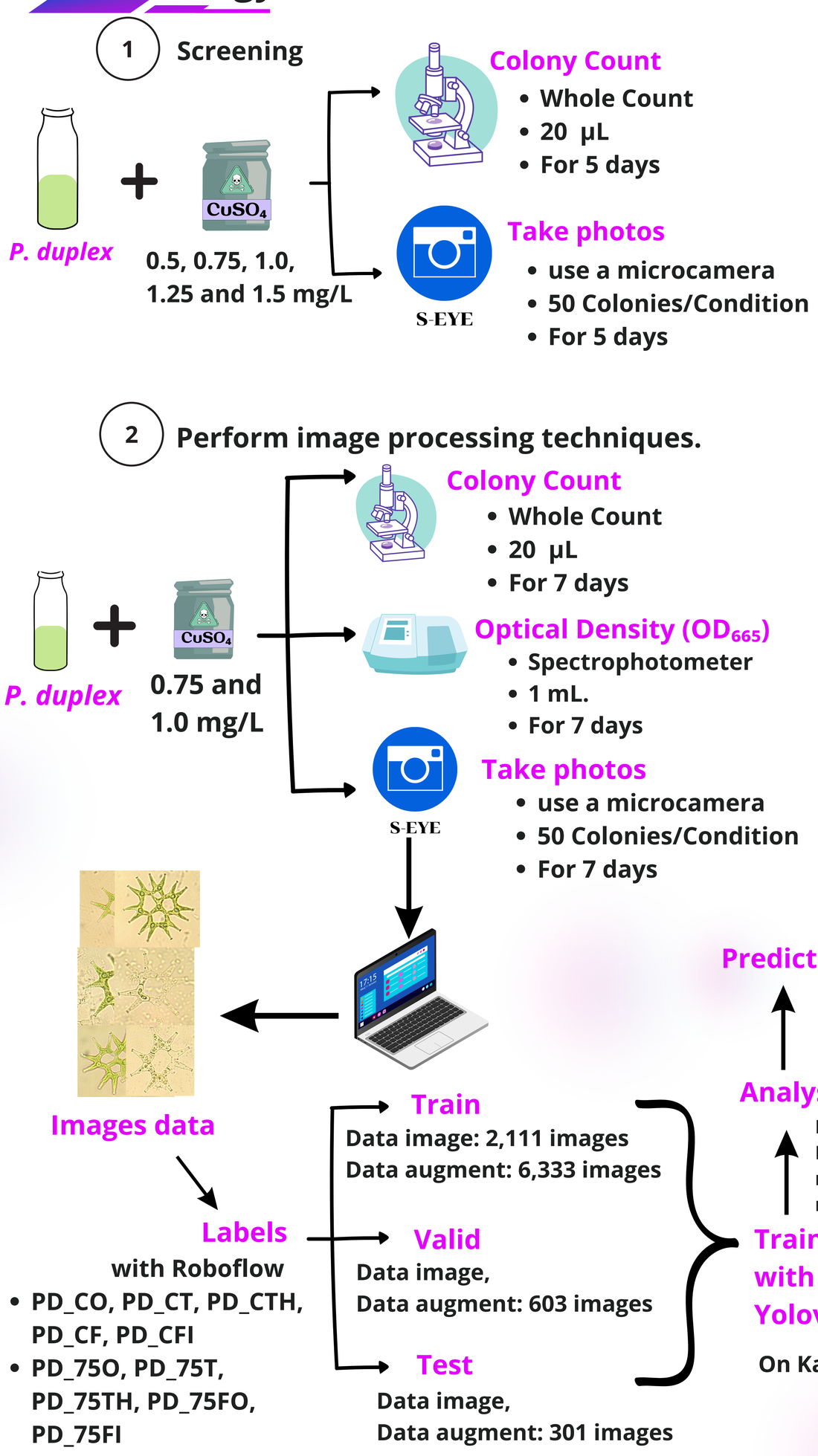
Abstract

Heavy metal contamination in aquatic environments, primarily from industrial and agricultural activities, poses a significant threat to ecosystems, especially heavy metals contamination. Algae are widely used as bioindicators due to their high sensitivity to pollutants, rapid response to environmental changes, and ease of cultivation. Monitoring algal morphological and physiological changes can provide valuable insights into metal toxicity. This study investigated the morphological changes in *Pediastrum duplex* under copper sulfate ($CuSO_4$) stress using image processing techniques. Algal cells were exposed to $CuSO_4$ at concentration of 0.5, 0.75, 1.0, 1.25, and 1.5 mg/L with significant reductions in cell density observed at 0.75 and 1.0 mg/L compared to the control. These concentrations were further analyzed using image processing to assess morphological alterations. The image processing technique exhibited a high average accuracy of 0.9, confirming its effectiveness in detecting cell structure changes. However, precise determination of heavy metal exposure levels and standardized criteria for identifying abnormal algal cells are essential to minimize misclassification and enhance analytical reliability.

Methodology



Results

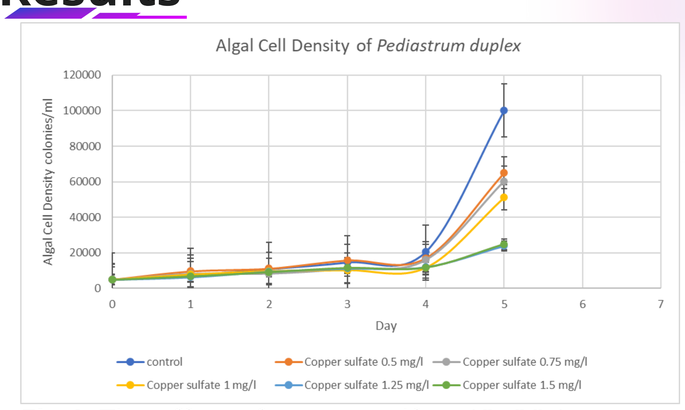


Fig 1. The effect of copper sulfate ($CuSO_4$) concentration on the growth of *Pediastrum duplex* colonies over 5 days.

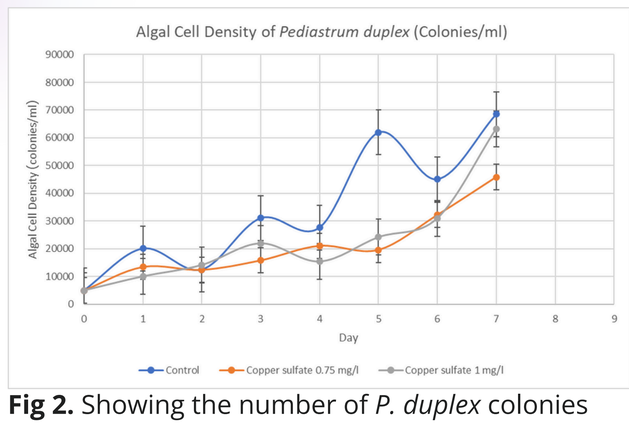


Fig 2. Showing the number of *P. duplex* colonies cultured in different concentrations of copper sulfate ($CuSO_4$) for 7 days.

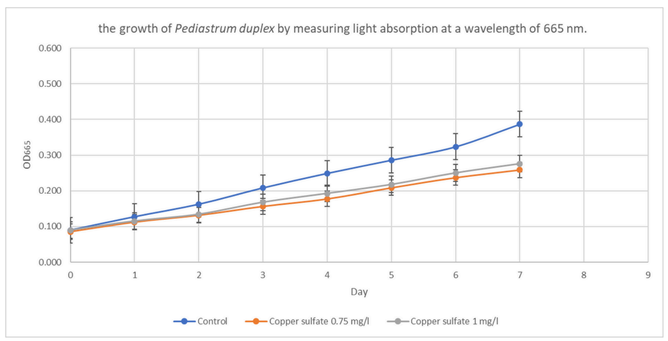


Fig 3. The growth of *P. duplex* by measuring light absorption at a wavelength of 665 nm for 7 days.

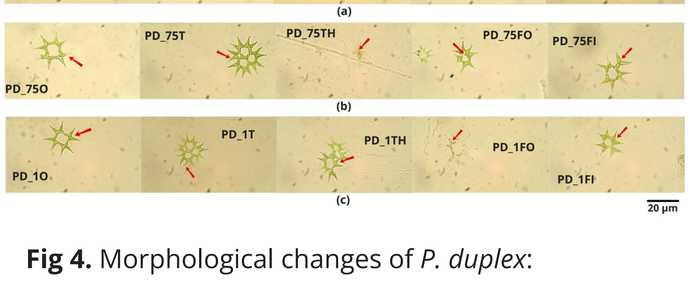


Fig 4. Morphological changes of *P. duplex*: (a) control; (b) 0.75 mg/L copper sulfate concentration; and (c) 1.0 mg/L copper sulfate concentration. Scale bar = 20 µm

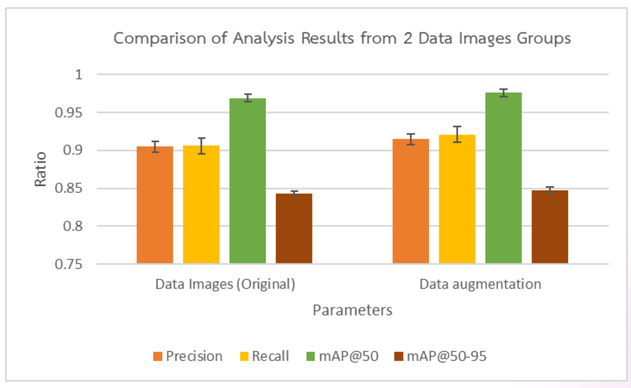


Fig 5. Analysis Results from YOLOv11

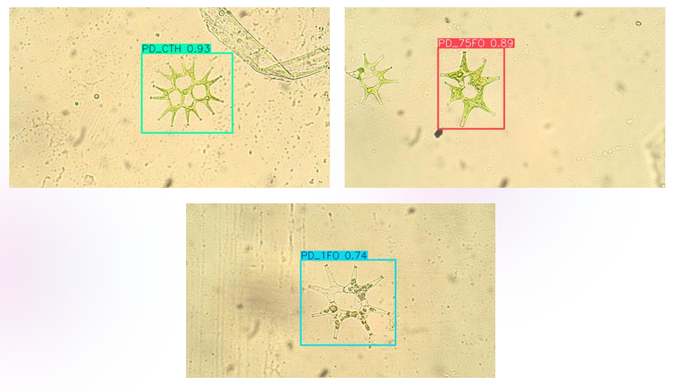


Fig 6. Prediction results of YOLOv11 models.

Pediastrum duplex grown under copper sulfate stress exhibited a decreased cell density compared to the control. **(Fig 1)**

The cell density of *P. duplex* exposed to copper sulfate at concentrations of 0.75 and 1.0 mg/L exhibited a decline compared to the control. However, the cell density at 1.0 mg/L was higher than that observed at 0.75 mg/L. Nevertheless, the cell count on certain days was lower because only living cells were counted **(Fig 2)**, optical density at a wavelength of 665 nm indicated an increase in *P. duplex* growth, with cultures exposed to copper sulfate at concentrations of 0.75 and 1.0 mg/L exhibiting a trend consistent with the observed algal cell density results. **(Fig 3)** and *P. duplex* exhibits alterations in its morphology under copper sulfate stress, including an increase in the angle between cell poles, cellular shortening, and a loss of chlorophyll or cell death, as indicated by the red arrows. **(Fig 4)**

The analysis revealed that the YOLOv11 model was able to correctly identify *P. duplex* (true positive detections). However, the precision of both detection and classification was suboptimal, as indicated by the low mAP@50-95 score.This could be due to the morphological similarities between Pediastrum duplex in control and under copper sulfate stress. **(Fig 5)**

Conclusion

copper sulfate affected the growth of algae, causing morphological changes in *Pediastrum duplex*. The classification of abnormal algae using computer image processing techniques effectively detected and identified algae with abnormal morphology.