ASSESSING BIOMASS VARIABILITY IN *Salicornia europaea* L. POPULATIONS: LEVERAGING COMPUTER VISION TO DISTINGUISH SALT-TOLERANCE TRAITS

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ABSTRACT: *Salicornia europaea* is a highly promising halophyte species for bio-based applications, particularly in saline agriculture and sustainable biomass production. To assess its phenotypic responses to salinity stress, we implemented a non-destructive computer vision system (CVS) to quantify morphometric and colour traits. By analyzing 96 plants grown under a gradient of salinity treatments, we developed a robust multivariate model that demonstrated a strong correlation between projected area and fresh weight (r = 0.92). Moreover, the model achieved 100% classification accuracy in distinguishing salt tolerance phenotypes. This CVS-based approach offers a scalable, rapid, and reproducible phenotyping tool suitable for breeding programs, trait-based selection, and ecological monitoring in saline environments.
Keywords: computer vision, salt tolerance functional traits, non-destructive approach, biomass estimation, real-time phenotyping

1 INTRODUCTION

Halophytes like *S. europaea* thrive in high-salinity environments and do not require normal freshwater for irrigation, making them highly valuable for cultivation in saline or marginal lands [1,2].

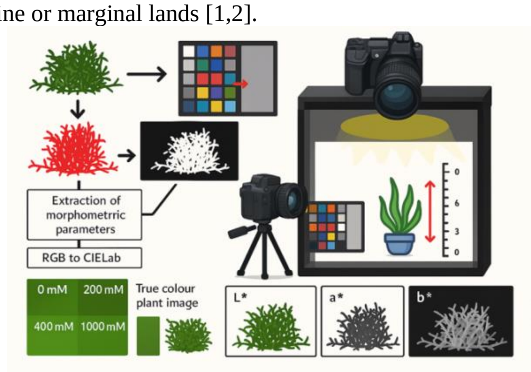

Figure 1: Computer vision system, image capture, processing

This unique trait positions them as excellent models for exploring sustainable biomass productivity [3,4]. However, conventional screening methods used to assess these traits are often destructive, labor-intensive, and time-consuming, highlighting the need for more efficient, non-invasive approaches.

We present a computer vision-based non-invasive approach (Figure 1) to quantify plant biomass growth and stress responses under varying salinity levels.

2 MATERIALS AND METHODS

Plants from two Polish populations Ciechocinek- (Ciech) (low salt tolerance) and Inowrocław- (Inow) (high salt tolerance) were grown under four NaCl concentrations (0, 200, 400, 1000 mM). A computer vision system captured RGB images, from which we extracted projected area (PA), shoot diameter (Sd), height (Ht), and CIELab colour values, L*, a*, b*, S* , Hue and ΔE. Morphometric and colour traits were analyzed through PCA, MDA, and regression modelling.

3 RESULTS AND DISCUSSION

Utilizing a high-throughput approach, Figure 2 presents front and canopy view images processed by the computer vision system (CVS) for both populations across salinity levels.

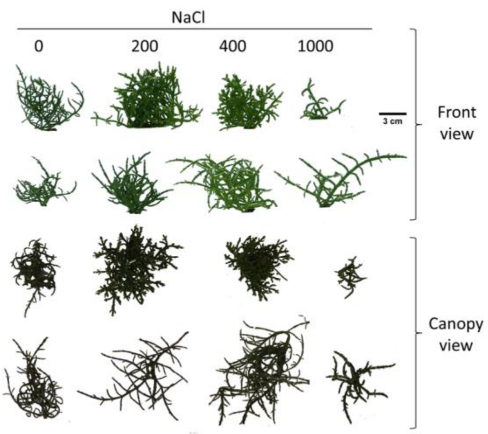

Figure 2: *S. europaea* plants biomass front view images processed for image analysis for two populations Ciechocinek (b) and Inowrocław respectively.

Projected area (PA) correlated strongly with fresh biomass (r=0.93) (Figure 3). Colour variables like ΔE1, L*, a*, and b* reflected pigmentation changes across salinity levels. PCA explained 80% of variance using nine non-destructive parameters (Figure 4).

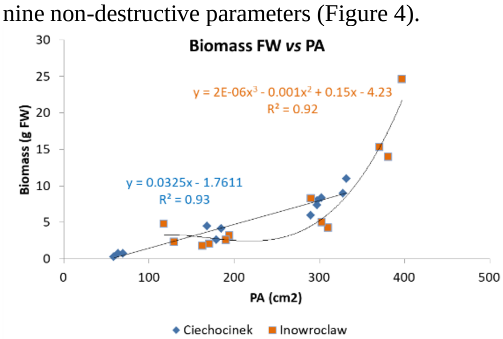

Figure 3: Relationship between projected area (PA) vs plants biomass FW

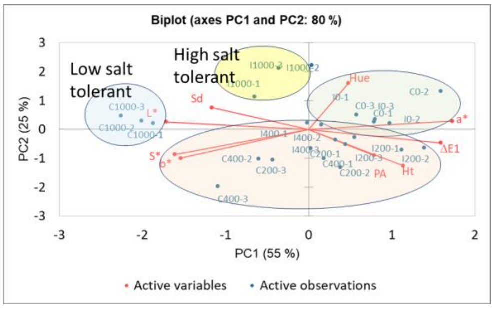

Figure 4: Scatter plot of the first two principal components, differentiating among low and high salt tolerant under severe salinity.

MDA classified salt-tolerance levels and populations with 98.96% and 100% accuracy in training and validation samples respectively (Table 1 and 2).

Table I: Confusion matrix. Training sample

from \ to	CSS	ISS	NOS	OS	Total	% correct
CSS	12	0	0	0	12	100.00%
ISS	0	12	0	0	12	100.00%
NOS	0	0	24	0	24	100.00%
OS	0	0	1	47	48	97.92%
Total	12	12	25	47	96	98.96%

Table II: Confusion matrix. Validation sample

from \ to	CSS	ISS	NOS	OS	Total	% correct
CSS	3	0	0	0	3	100.00%
ISS	0	3	0	0	3	100.00%
NOS	0	0	6	0	6	100.00%
OS	0	0	0	12	12	100.00%
Total	3	3	6	12	24	100.00%

Abbreviations: CSS and ISS: Sever salinity (1000 mM) group for Ciech and Inow respectively, NOS: No salinity, Optimum salinity (200-400 mM).

The linear and polynomial regression analysis was applied to model the relationship between biomass and projected area (PA) (Table 3). Based on this, a predictive model was developed:

$PA = 83.34 - 0.23 \times Sal.s. + 1629.97 \times Sd + 25.71 \times Ht - 6.38 \times \Delta E$

Table III: R^2 performance of biomass and salinity prediction models.

Population	Model	R^2 (Biomass PA)	R^2 (Salinity)
Ciechocinek (Low Tolerance)	Linear	0.93	0.95
Inowrocław (High Tolerance)	Polynomial	0.90	0.97

This model estimates both biomass and substrate salinity. The predictive models, built using the most representative parameters extracted from CVS morphometric segmentation and colour extraction, demonstrated high accuracy in estimating biomass and salinity tolerance of *S. europaea.*

4 CONCLUSIONS

A computer vision system integrated with multivariate statistical modeling effectively predicted biomass production and salinity tolerance in *S. europaea*. By non-destructively extracting morphometric and colorimetric traits, the method achieved high predictive accuracy ($R^2 \geq 0.90$) across populations with different salt tolerance. This scalable and cost-efficient approach supports high-throughput phenotyping for breeding and environmental monitoring. In future applications, the integration of smartphone imaging and AI-driven analysis could further enhance accessibility and automation, enabling real-time phenotyping and decision-making across diverse agro-ecological systems.

5 REFERENCES

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