ENHANCING URBAN TREE HEALTH WITH BIOCHAR AND BIOFERTILIZER

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Background

- Street trees face many stressors unique to the urban environment such as air pollution, poor soil quality, unbalanced nutrient supply, limited rooting volume and salt stress[1]
- Soil amendments can be effective as it's been suggested that up to 90% of urban tree health issues are soil related[2]
- Inactivated yeast (IY) is a natural "slow release" N fertilizer due to its chemistry
- Biochar and IY therefore present the potential for enhancing urban tree health

Study Objectives

1. Examine soil amendment effect on tree health
2. Assess treatment responses to salt-stress
3. Investigate feasibility of biochar + inactivated yeast in the context of Toronto's street trees

Methods

Greenhouse Experimental Design

- American elm (*Ulmus americana*), a common fast-growing Toronto street tree selected for study

Table 1: 12 treatment groups with 8 replicates each

Treatment	No Salt	Salt
Control	AAA	AAS
Biochar	BAA	BAS
IY (L)	ALA	ALS
IY (M)	AMA	AMS
Biochar+IY(L)	BLA	BLS
Biochar+IY(M)	BMA	BMS

- SPF biochar sourced from Titan Clean Energy Products
- Two types of brewer's yeast, *Saccharomyces cerevisiae*, IY (L) from Lallemand Inc. and IY (M) locally sourced and dried in our lab from Bellwoods Brewery

Tree Growth Metrics

- Leaf area, stem diameter, biomass
- Biomass measured using a LI-3100C Area Meter at time of harvest

Tree Physiological Metrics

- Leaf chlorophyll content, Nitrogen Balance Index (NBI), Flavanols, Anthocyanins assessed using the Dualex sensor
- Gas exchange (A, gsw, E) measured using the LI-6800 Portable Photosynthesis System
- Chlorophyll Fluorescence (Fv/Fm ratio) measured via Mini-PAM fluorometer

Tree Health Results

Tree Growth Response

- Biochar and IY both independently significantly increase leaf area, total biomass and stem diameter ($p < 0.05$)
- There is a significant effect of Biochar x IY on total biomass and stem diameter ($p < 0.05$) but not leaf area
- Combination of Biochar + IY, regardless of yeast type, showed best tree growth response
- No strong salt effect across any of the tree growth metrics

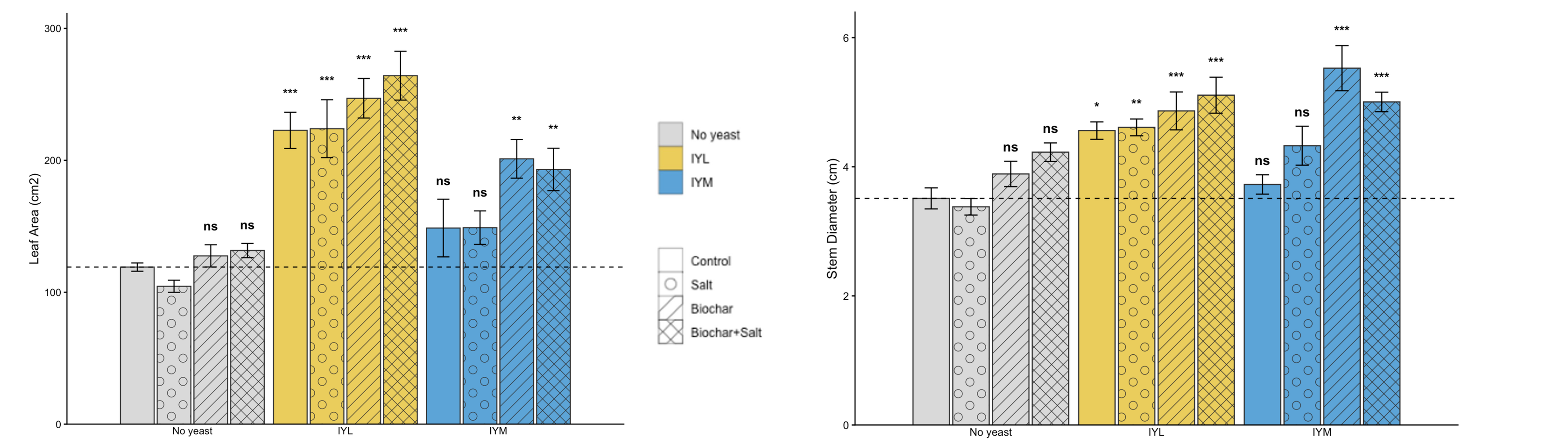

Figure 1: Mean value ± SE of plant growth metrics taken before harvest: Leaf Area (cm2) on the left and Stem Diameter (cm) on the right, IY(L) = inactivated yeast from Lallemand Inc. only, IY(M) = inactivated yeast from Bellwoods Brewery only. Statistical significance are indicated by asterisks (= $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$) of post-hoc results compared to AAA (control) treatment group*

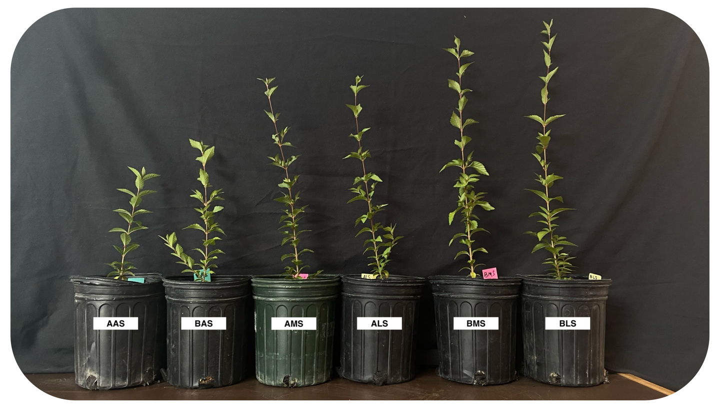

Table 2: Mean % change relative to control of final biomass (DW (g)) and height (cm)

Growth parameter	Treatment					
	Control	BC	IY(L)	IY(M)	BC + IY(L)	BC + IY(M)
Leaf (DW)	0.0%	+7.0%	+95.7%	+27.8%	+131.3%	+65.2%
Stem (DW)	0.0%	+26.9%	+148.1%	+71.2%	+219.2%	+115.4%
Root (DW)	0.0%	+15.3%	+57.6%	+28.2%	+104.7%	+81.2%
Total Biomass (DW)	0.0%	+14.2%	+84.6%	+34.7%	+131.5%	+81.0%
Height	0.0%	+15.1%	+53.1%	+40.1%	+79.1%	+50.3%

Tree Photosynthetic/Physiological Response

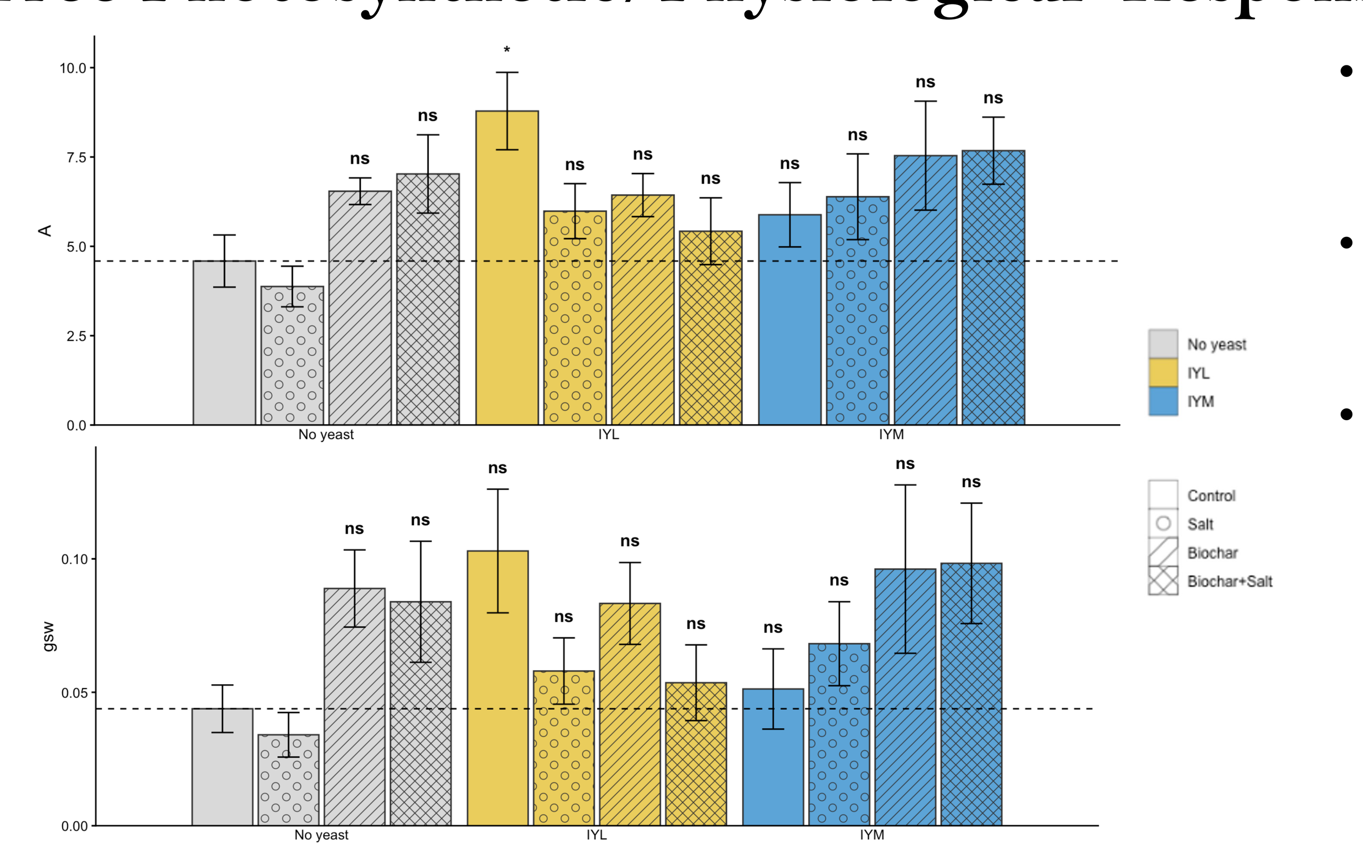

Figure 2: Mean value ± SE of gas exchange metrics (June 2025): Net photosynthesis (A_{sat}) on the top and stomatal conductance (gsw) on the bottom, Statistical significance are indicated by asterisks (= $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$) of post-hoc results compared to AAA (control) treatment group*

Gas Exchange

- Net photosynthesis (A_{sat}) showed significant Biochar x IY interaction ($p < 0.05$)
- Stomatal conductance (gsw) showed significant Biochar x IY interaction ($p < 0.05$) and significant Biochar effect independently
- No strong salt effect

Fv/Fm

- IY, regardless of type displayed highest Fv/Fm, around 0.812
- Biochar x IY had significant effect ($p < 0.01$)

Table 3: Mean Fv/Fm values, optimal ~0.83

Treatment	Mean Fv/Fm
Control	0.791 ± 0.01
Biochar	0.806 ± 0.012
IY(L)	0.812 ± 0.015
IY(M)	0.812 ± 0.008
Biochar + IY(L)	0.808 ± 0.012
Biochar + IY(M)	0.806 ± 0.012

- Nitrogen Balance Index (NBI) is the ratio of chlorophyll to flavonoids. Higher NBI values indicate higher nitrogen use capacity[3]
- IY (L) showed the highest NBI scores across the experiment, although IY (M) showed relatively comparable results
- The NBI values taken upon harvest showed a strong significant effect of IY independently ($p < 0.01$)

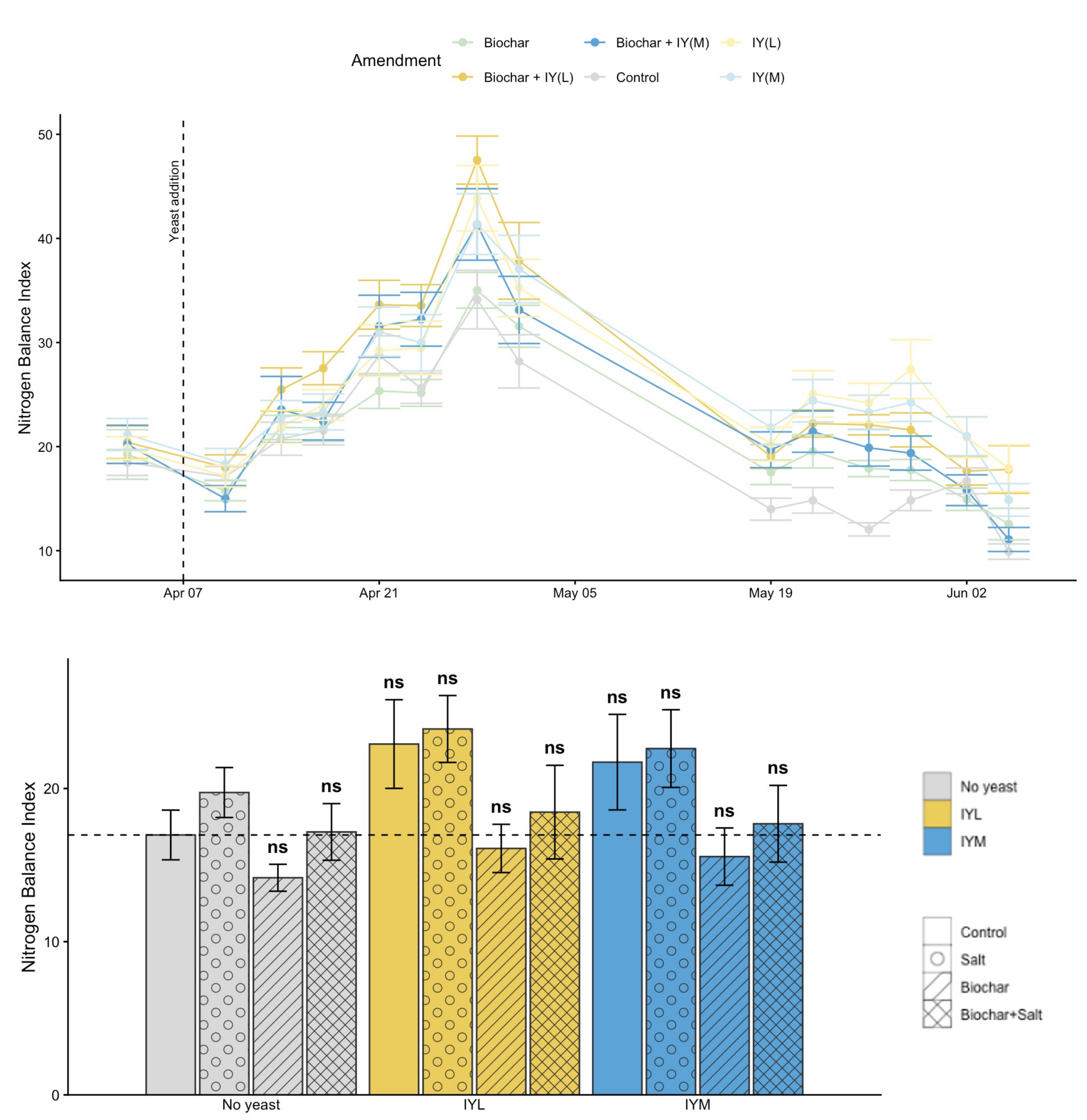

Figure 3: Top graph shows Nitrogen Balance Index (NBI) across the different treatment groups, measurements taken from April – June 2025. Bottom graph shows Mean NBI value ± SE of plant pigment parameters taken before harvest (June 5, 2025):

Discussion

- Biochar and IY improved both growth and physiological plant responses, with the combination of biochar x IY showing the best results
- Generally, IY (L) performed slightly better than IY (M) but both IY results were relatively comparable
- There was no strong salt-stress effect witnessed, a higher salt dosage may be needed to analyze whether previously findings on biochar decreasing Na+ uptake by plants hold[4]
- Elms may be particularly resistant to salt effect as previous studies with the same dosage severely impacted plants[5]
- Improved growth and physiological responses likely due to biochar's ability to increase soil porosity, soil moisture retention and enhance properties such as pH, organic carbon and cation exchange[6]
- Brewer's yeast alone has not been widely used especially outside an agricultural context but has been found to enhance nitrogen and phosphorus availability in soils[7]
- Together the biochar + IY combination have additive benefits and shows the greatest potential for urban tree health
- The locally sourced IY (M) is typically a waste product, integrating it as a potential soil amendment in an urban setting provides the chance to contribute towards a circular economy model

References

1. Dmuchowski, W., Brągoszewska, P., Gozdowski, D., Baczewska-Dąbrowska, A. H., Chojnacki, T., Jozwiak, A., Swiezewska, E., Suwara, I., & Gworek, B. (2020). Strategies of urban trees for mitigating salt stress: a case study of eight plant species. *Trees 2020 36:3*, *36*(3), 899– 914. http://doi.org/10.1007/S00468-020-02044-0

2. Scharenbroch, B. C., Carter, D., Bialecki, M., Fahey, R., Scheberl, L., Catania, M., Roman, L. A., Bassuk, N., Harper, R. W., Werner, L., Siewert, A., Miller, S., Hutyra, L., & Raciti, S. (2017). A rapid urban site index for assessing the quality of street tree planting sites. *Urban Forestry & Urban Greening*, *27*, 279–286. https://doi.org/10.1016/J.UFUG.2017.08.017

3. Fan, K., Li, F., Chen, X., Li, Z., & Mulla, D. J. (2022). Nitrogen Balance Index Prediction of Winter Wheat by Canopy Hyperspectral Transformation and Machine Learning. *Remote Sensing 2022, Vol. 14, Page 3504*, *14*(14), 3504. https://doi.org/10.3390/RS14143504

4. Ali, S., Rizwan, M., Qayyum, M. F., Ok, Y. S., Ibrahim, M., Riaz, M., Arif, M. S., Hafeez, F., Al-Wabel, M. I., & Shahzad, A. N. (2017). Biochar soil amendment on alleviation of drought and salt stress in plants: a critical review. *Environmental Science and Pollution Research*, *24*(14), 12700–12712. https://doi.org/10.1007/S11356-017-8904-X

5. Thomas, S. C., Frye, S., Gale, N., Garmon, M., Launchbury, R., Machado, N., Melamed, S., Murray, J., Petroff, A., & Winsborough, C. (2013). Biochar mitigates negative effects of salt additions on two herbaceous plant species. *Journal of Environmental Management*, *129*, 62–68. https://doi.org/10.1016/J.JENVMAN.2013.05.057

6. Li, Y., Hu, S., Chen, J., Müller, K., Li, Y., Fu, W., Lin, Z., & Wang, H. (2017). Effects of biochar application in forest ecosystems on soil properties and greenhouse gas emissions: a review. *Journal of Soils and Sediments 2017 18:2*, *18*(2), 546–563. https://doi.org/10.1007/S11368-017-1906-Y

7. Singh, V. K., Singh, M., Singh, S. K., Kumar, C., & Kumar, A. (2019). Sustainable Agricultural Practices Using Beneficial Fungi Under Changing Climate Scenario. *Climate Change and Agricultural Ecosystems: Current Challenges and Adaptation*, 25–42. https://doi.org/10.1016/B978-0-12-816483-9.00002-5

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