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Functional Plant Biology

Supplementary Material

A meta-analysis of plant tissue O_2 dynamics

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Supplementary materials

Literature search

A structured and systematic literature search was performed in the following steps. The search was performed using the Web of Science BIOSIS database. Search terms grouped into blocks were combined using Boolean operators OR, AND, NEAR and NOT since simply searching for the combination of plant tissues (Plant OR root OR leaf) with key words relating to internal O_2 status (oxygen, O_2, aeration, anoxia, hypoxia, etc.) resulted in a very high number of hits (> 50.000). Following multiple attempts and evaluation of the resulting hits, the following search string resulted in a broad but inclusive list of 2,136 studies:

TS= ((O2 OR O-2 OR OXYGEN) NEAR/2(TISSUE OR INTERNAL OR "PARTIAL PRESSURE" OR CONCENTRATION* OR LEVEL* OR GRADIENT* OR DYNAMIC* OR PROFILE* OR CONTENT* OR MEASUREMENT* OR KPA OR "INTERNAL GAS" OR MICROELECTRODE* OR ELECTRODE* OR MICROSENSOR*))

AND

TS=((O2 OR O-2 OR OXYGEN) NEAR/6(PLANT* OR ROOT* OR SEED* OR LEAF OR LEAVES OR GRASS OR SEAGRASS OR RHIZOME* OR MERISTEM* OR PETIOLE* OR BUD* OR STEM* OR NODE* OR INTERNOD* OR "LEAF BLADE*" OR SHOOT* OR "ADVENTITIOUS ROOT*" OR "CROWN ROOT*" OR "NODAL ROOT*" OR STELE OR CORTEX OR "SEMINAL ROOT*" OR NODULE* OR CUTTINGS)) NOT TS=*Algae

The Boolean operator NEAR/6 was chosen after carefully evaluating which papers were excluded in steps from NEAR/2 to NEAR/7. Changing NEAR/5 to NEAR/6 resulted in the retrieval of some relevant papers, while changing NEAR/6 to NEAR/7 resulted in retrieving additional non-relevant papers.

Prior to the above literature search, we had compiled a list of 59 studies already known by us to include data relevant for this review. These 59 studies were retrieved when cross-referencing with the 2,136 studies identified in the systematic literature search, demonstrating that the systematic literature search did in fact identify the relevant studies. Studying the abstract, title, and on some occasions figures and materials and methods sections, of the 2,136 studies allowed us to discard > 90% as non-relevant (no internal O_2 measurements conducted). When reviewing the remaining relevant studies, citations within some of these studies led to the discovery of additional studies. Since the BIOSIS database (preferred since it allows for restricting results to plant studies) only encompasses studies published after 1969, the above search was repeated in Web of Science Core Selection for 1900–1969 which did not identify any additional studies. Finally, the above steps resulted in a final list of 129 studies used for this review.

Data conversions

The studies used for this review provide a wide range of ways to measure and report levels of plant tissue O_2. O_2 levels reported as mm Hg, concentrations (mg L^{-1}, µmol L^{-1}), % of air saturation or % O_2 was converted into kPa as detailed in the following.

Converting data reported as µmol O_2 L^{-1} to kPa O_2 required retrieving the temperature prevailing during the experiment, in order to determine the relevant O_2 solubility. The reported O_2 in µmol L^{-1} was then transformed by dividing by the O_2 solubility and multiplying with the pO_2 at air equilibrium (20.59 kPa assuming atmospheric pressure of 101,33 kPa and 3% water vapour inside plant tissues equalling 100% RH, which is a valid assumption inside hydrated tissues). O_2 values reported as mg L^{-1} were converted in the same way following conversion from mg to µmol.

O_2 levels reported as % O_2 were converted into kPa O_2 by multiplying with the atmospheric pressure of 1 atmosphere (101,33 kPa) and dividing by 100. If O_2 levels were reported as % of air equilibrium, the reported % O_2 was divided by 100 and multiplied by 20.95 which is the percentage of O_2 present in the atmosphere. I.e., 50% of O_2 at air equilibrium corresponding to 10.6 kPa. Finally, mm Hg were converted into kPa using a conversion factor of 0.133 mm Hg kPa^{-1}.

Modelling

We evaluated the influence of environmental conditions, plant species and tissue type on tissue pO_2 using an information-theoretic model selection approach. The model selection was carried-out using R statistical software (R Core Team 2014) with the 'MuMIn' package (Barton and Barton 2022). Prior to modelling, we examined variables for variance inflation factor using the 'vif' function (Fox and Weisberg 2018). The Linear Mixed-effects Models (LMM) were applied using the "lme4" package (Pinheiro *et al.* 2022). We used LMMs with maximum likelihood to estimate model parameters and their importance in defining plant O_2 status. The model included tissue pO_2 as response variable, flooding status, light status, and tissue type as factorial predictors. Flooding status was categorised into three levels (completely submerged, partial submerged or with entire shoot in air) based on descriptions of the experimental conditions. Results from studies where the environmental pO_2 conditions were manipulated (i.e., surrounding the shoot with N_2 gas) were excluded. Light status was categorised into two levels: dark or light, based on descriptions of the experimental conditions. We excluded studies with ambiguous light conditions. We categorised tissue types into root, stem, or leaf tissues. In addition, we included plant species as a random factor. We fitted the full model, compared all the possible factor and interaction combinations and selected the best model using the Akaike Information Criterion (AIC) (Burnham and Anderson 2004). Conditional and marginal R^2 values were obtained using the 'r.squaredGLMM' function. We verified model assumptions looking at diagnostic plot of the distribution of the residuals (Fig. S1). The response variable (tissue pO_2) was square root transformed to improve distribution of the residual.

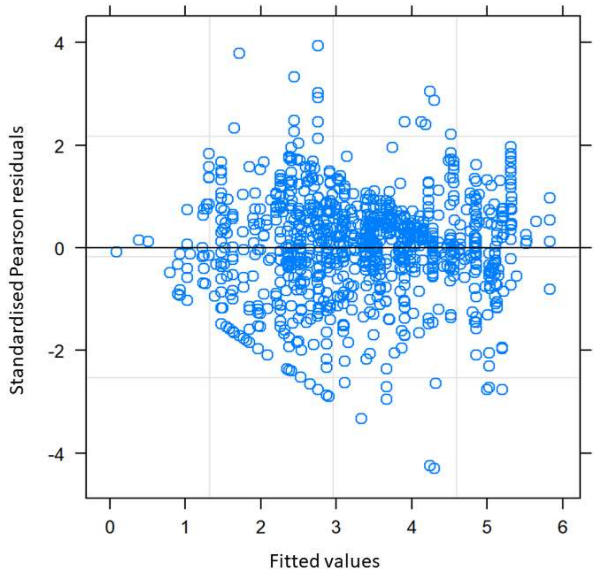

Fig. S1. Residual plot of the full linear mixed-effects model predicting tissue O_2 from 'light', 'tissue', 'submergence' and interactions, with 'species' as a random factor. Fitted square root transformed values vs. standardised Pearson residuals.

Studies used for data extractions

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