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Leaf transpiration compared with tree stem sap flux and water usage of old growth Quercus robur under elevated CO2 at BIFoR FACE, UK

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Leaf-level transpiration is an indicator of tree species' response to soil water status and atmospheric conditions and is known to vary in response to photosynthetic radiation at a sub minute timescale. Here we report results from replicate measurement of stomatal conductance to water over 30 second intervals using a porometer, and leaf vapour pressure deficit (VPD_{leaf}), requiring measurement of abaxial leaf temperature. At Birmingham Institute of Forest Research (BIFoR) Free-Air CO_2 Enrichment (FACE) forest in Staffordshire UK, we use leaf-level transpiration data during leaf-on season (May to October) to explore diurnal tree water usage results from 18 mature oaks (*Quercus robur L.*) under elevated CO_2 conditions. In six of our nine experimental arrays (3 patches with elevated CO_2 infrastructure (eCO_2); 3 with infrastructure but ambient CO_2 (aCO_2)) we accessed the top tree canopy of one tree per array during full leaf-on months over three years from 2019-2021 to measure stomatal conductance using a porometer and pre-measurement of abaxial leaf temperature. We compare the results between treatments to determine the effects of elevated CO_2 on stomatal regulation, to predict the dynamics of leaf level transpiration and the relationship to whole tree water usage determined from sap flux measurements, underpinning previously reported results of both water usage, and of carbon assimilation measured at leaf level using a Licor chamber method. An alternative porometric transpiration measurement method, using cut twig samples, was adopted for three trees in the final three control arrays (3 'ghosts' (no treatment, no infrastructure)) during 2018-2021 as limited in-situ access to top canopy was available via arborists. Cut twig samples from infrastructure arrays were also measured during 2019-2021. We compare leaf-level stomatal conductance results sub-diurnally to our previously reported stem sap flux and water usage responses from stem sap transducers (whole canopy) measures in the same trees. Maximum sap flux rates (ca. 0.04 litres s^{-1}) occur around midday (UTC) and predict that tree radius and canopy area determine variability of total water usage per tree per day across this tree radius range (ca. 2.4 litres per millimetre radius, range; 274mm £ radius £ 465 mm). We report a delayed response in the water flows in the stem relative to the leaf (from the in-situ measurements), implying a buffering factor relating to the height and age of the trees studied and use of stored water at branch level. We note the differences and limitations of measuring transpiration by porometry from cut twigs. Interpretation

of these results, from our tree-centred forest view, provide further understanding of future-forest tree-based water usage which can be expanded to predict responses at ecosystem levels, contribute to development of more realistic vegetation models and identify optimum methods for canopy leaf transpiration measurement in forest wide experiments.