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Effects of warming, elevated CO_2, and drought on root water uptake and its relation to root traits

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Plants can modulate the source and magnitude of water uptake under environmental stresses, ultimately constraining water and energy fluxes across Earth's surface. These alterations are scarcely quantified for future climatic scenarios such as warming, elevated atmospheric CO_2 (eCO_2), and droughts—all projected by the end of this century. Here we use diurnal soil moisture dynamics throughout the 2019 growing season to quantify the impacts of these three global change factors on root water uptake in a managed C_3 mountain grassland in Austria; a key agricultural landscape within central Europe. To determine whether plants alter water uptake via root trait adjustments, we then compared water uptake to root morphological traits. We expected that 1) drought and eCO_2 (+300 ppm) would reduce root water uptake relative to ambient conditions due to supply limitation and a lower stomatal conductance, whereas 2) greater vapor pressure gradients in warmed systems would elevate transpiration rates, increasing root water uptake. Plants reduced water uptake in droughted plots by ~35% regardless of other factors applied, due to decreased water extraction from the soil surface during the peak drought. Warmed plots had unexpectedly lower water uptake by 17-25% relative to control plots. Finally, vegetation in eCO_2 plots displayed similar water uptake to plots under ambient conditions; however, eCO_2 effects did buffer warming effects, such that plots with eCO_2 and warming extracted less water than those subjected to warming alone. Root morphological traits showed strong linear correlations ($R > 0.7$, or $R < -0.7$) to root water uptake in ambient, drought, and eCO_2 plots, yet no significant relationship was found for plots under warming or multifactor treatments. Relationships were strongest and most abundant following a drought. This suggests that—though plants may optimize root structure for drought recovery—plants may alter their root systems to account for resource limitations other than water in a warming climate. Altogether, we show that warming, eCO_2, and droughts may significantly alter the root water extraction in managed C_3 mountain grasslands, but changes in water availability alone may not fully explain plant water uptake responses.