

## Letter

## Moving forward with fine-root definitions and research

## Response to Zobel's (2016) comment 'Fine roots – functional definition expanded to crop species?'

In the letter 'Fine roots – functional definition expanded to crop species?' Dr Zobel emphasizes the importance of heterogeneity within crop-root systems. We agree. The importance and quantification of architectural and functional diversity of the fine roots of all plant species was a central point in our article 'Redefining fine roots improves understanding of below-ground contributions to terrestrial biosphere processes' (McCormack *et al.*, 2015). Here, we advocated for the increased use of more rigorous approaches to sample, classify, and process fine roots based on their position in the root branching hierarchy rather than an often arbitrary diameter class whenever feasible and appropriate. However, we also recognized the limitations and challenges that most scientists face in the field, which can preclude strictly order-based approaches that can be very time-consuming. Given that continued use of diameter classifications for comparative studies of fine roots (i.e. all roots < 2 mm in diameter) represents a significant limitation to future progress, we suggested a more functional classification as an alternative to strictly order-based or traditional diameter-based classifications. The functional approach, where distal fine roots mainly responsible for resource acquisition are classified as 'absorptive' roots and more proximal fine roots mainly responsible for resource transport are 'transport' roots, captures an important portion of the functional, biochemical, and demographic variability among fine roots that is often missed using the traditional diameter-based classification. Importantly, the functional approach also remains tractable and requires substantially less processing time than order-based approaches.

Dr Zobel is concerned that the division between absorptive fine roots and transport fine roots is likely to change among different species. We agree. We would go a step further and suggest that the division point has the capacity to change within a single species, but in response to different environmental conditions. Further, it seems as though Dr Zobel may have misunderstood our basis for distinguishing absorptive and transport fine roots to be purely morphological. As we stated in McCormack *et al.* (2015), and further emphasize here,

more work needs to be conducted to better understand functional divisions among fine roots of different species. Focused efforts are needed to develop methods that distinguish fine-root functional classes within a species based on fine-root anatomy, chemistry, morphology, and physiology, to enable more rapid determination of functional distinctions in both controlled laboratory and field settings. Moving forward, appropriate use of both order-based and functional classifications will enable significant strides towards improving scientific understanding of fine-root processes at the level of individual plants, whole ecosystems, and across the globe.

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## Author contributions

M.L.M., C.M.I. and D.M.E. planned and wrote the manuscript.

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## References

- McCormack ML, Dickie IA, Eissenstat DM, Fahey TJ, Fernandez CW, Guo D, Helmissaari HS, Hobbie EA, Iversen CM, Jackson RB *et al.* 2015. Redefining fine roots improves understanding of below-ground contributions to terrestrial biosphere processes. *New Phytologist* 207: 505–518.
- Zobel RW. 2016. Fine roots – functional definition expanded to crop species? *New Phytologist*. doi: 10.1111/nph.14099.

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