Designing future roots with the power of databases

[1]Maxime Phalempin, [2,3]Hannah Schneider, [4,5,6]Eusun Han, [7]Lingyun Cheng, [1]Doris Vetterlein

[1]Department of Soil System Science, Helmholtz Centre for Environmental Research, 06120 Halle/Saale, Germany
[2]Leibniz Institute of Plant Genetics & Crop Plant Research (IPK) OT Gatersleben, Corrensstr 3, 06466 Seeland, Germany
[3]Division of Crop Plant Genetics, Department of Crop Science, Georg-August-University Goettingen, Goettingen, Germany
[4]Department of Agroecology, Aarhus University, 8830 Tjele, Denmark
[5]CSIRO Agriculture and Food, PO Box 1700, Canberra, ACT2601, Australia
[6]Department of Plant and Environmental Sciences, University of Copenhagen, 2630 Taastrup, Denmark
[7]College of Resources and Environmental Sciences, National Academy of Agriculture Green Development, Key Laboratory of Plant-Soil Interactions, State Key Laboratory of Nutrient Use and Management (SKL-NUM), Ministry of Education, China Agricultural University, Beijing 100193, P. R. China

Correspondence: maxime.phalempin@ufz.de (M. Phalempin)

Email addresses of the authors:
Maxime Phalempin: maxime.phalempin@ufz.de
Eusun Han: eusun.han@agro.au.dk
Hannah Schneider: schneiderh@ipk-gatersleben.de
Cheng Lingyun: lycheng@cau.edu.cn
Doris Vetterlein: doris.vetterlein@ufz.de
ORCID of the authors:
Maxime Phalempin: 0000-0003-1198-807X
Hannah Schneider: 0000-0003-4655-6250
Eusun Han: 0000-0001-6338-2454
Cheng Lingyun: 0000-0001-5185-1196
Doris Vetterlein: 0000-0003-2020-3262

Abstract

Databases are vital for participative science, particularly in root research. These platforms centralize diverse data, foster collaboration and reduce redundancy. However, underutilization remains a challenge due to lack of incentives, standardization issues, and low visibility. Increased database usage could significantly advance the contribution of root research to crop development.

In the era of big data, the potential role of databases for scientific discovery cannot be overstated. These database platforms are not merely repositories of information but are the foundations upon which modern collaborative research is built. In fields such as root research, where data is highly diverse and dispersed across various institutions, shared databases can offer a solution to the fragmentation of knowledge. By centralizing data, we believe these databases will facilitate collaboration, enabling researchers to share their findings with the global scientific community. This not only reduces redundancy in data collection but also enhances the potential for new discoveries.

Several scientific disciplines have made significant strides in the use of common databases, providing a model that the root research community can adopt and learn from. For example, the permafrost research community has established the Global Terrestrial Network for Permafrost (GTN-P, https://gtnp.arcticportal.org/), which standardizes data collection protocols and provides a centralized platform for data sharing. This has not only streamlined research efforts but also enhanced the predictive power of permafrost models on a global scale [1]. Similarly, the Global Volcanism Program (GVP, https://volcano.si.edu/) in volcanology has created a comprehensive database that is invaluable for both academic research and practical applications, such as hazard mitigation. These disciplines have demonstrated that common databases can be transformative, providing a foundation for collaborative research and advancing knowledge.

Root research is supported by several specialized databases, each offering valuable resources to the community. For example, the Global Root Trait Database (GRooT, https://groot-database.github.io/GRooT/) provides standardized and curated data of key root traits for integration into large-scale comparative studies and global models [2]. GRooT includes data on 38 root traits and over 38,000 species-by-site mean values derived from 114,000 trait records. It encompasses more than 1,000 species with data on several ecological-based traits like root mass fraction, root carbon and nitrogen concentration, lateral spread, mycorrhizal colonization intensity, mean root diameter, root tissue density, specific root length, and maximum rooting depth [2]. Another significant resource is the Fine Root Ecology Database (FRED, https://roots.ornl.gov/) which compiles more than 105,000 observations of root traits along with data on associated site, vegetation, edaphic, and climatic conditions from across the globe [3]. Both GRooT and FRED are well-maintained and regularly exchange information, with their data also submitted to the TRY database, the largest and continuously expanding global database for plant traits [4]. These resources are invaluable, and the dedication of our colleagues who have initiated and continue to maintain these databases deserve recognition.

In an effort to better understand the actors within the root research community, we, a group of dedicated root scientists, conducted a survey among the members of the International Society of Root Research and participants of its meeting in Leipzig in June 2024. Figure 1 illustrates their demographics, career stages, and fields of expertise (Figure 1a-c). We asked the participants in the survey (n=230) whether they were aware of any existing root-related databases. To our surprise, a significant number of participants (81%) with experience in root research at a post-doctoral or faculty level were unaware of the aforementioned databases (Figure 1d). This clearly indicates that current databases in root research are underused and undervalued by our community—a trend that contradicts the broader movement towards big data and open science.

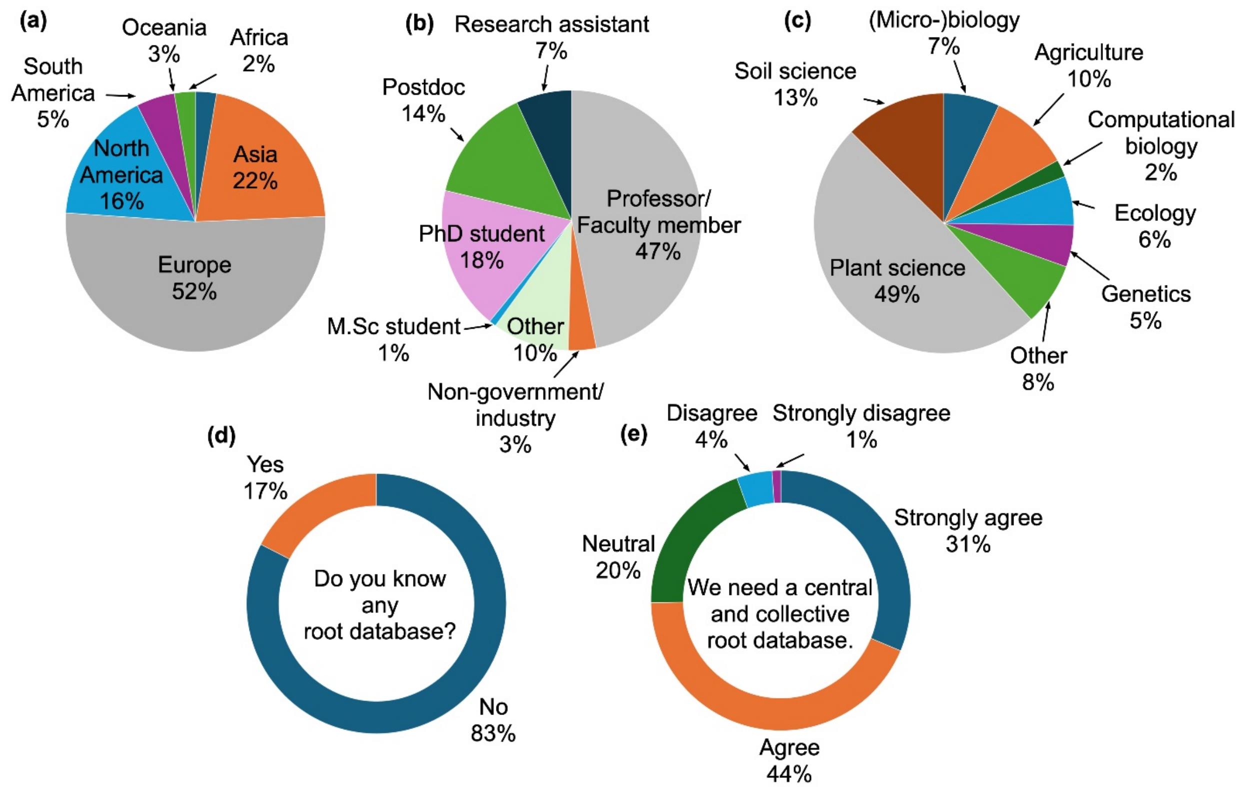

Figure 1. Survey among the members of the International Society of Root Research and participants of the 2024 society meeting in Leipzig. (A-C) Demographics, career stages and field of expertise of the survey participants (n=230). (D) Response on the awareness of root databases (n=206). (E) Opinion on the need for a root database (n=182).

The limited use of databases within the root research community can be attributed to several factors. First, researchers often lack incentives to contribute their data to these platforms. In a field where publishing novel findings is often prioritized, the time and effort required to format and upload data to a database can seem like a low priority, especially when it does not directly lead to career advancement. Second, challenges related to data standardization and methodological differences across studies create significant obstacles. The diversity of experimental designs, measurement techniques, and data formats makes it difficult to establish common standards, leading to inconsistencies that hinder the integration and comparison of datasets. This lack of standardization can discourage researchers from using databases, as aligning their data with existing standards can seem burdensome. To promote standardization in root trait measurements and calculations, we highly encourage practitioners to consult the excellent guide to root ecology by Freschet et al. [5]. Finally, the existing databases likely suffer from a lack of visibility. Many researchers are simply unaware of the resources available to them (Figure 1d). Without proper promotion and user-friendly interfaces, these valuable tools remain underutilized, limiting their impact on the field. We hope this article will help raise awareness of these available resources.

To overcome the aforementioned barriers, several initiatives can be implemented. First, funding agencies should be encouraged to support and prioritize projects that focus on data sharing and database development. Offering specific grants or extending current project funding for data curation and integration would incentivize researchers to contribute to databases. Second, universities and research institutions should recognize database contributions in promotion and tenure decisions. By including the creation, maintenance, contribution to, and use of databases as part of the metrics for academic advancement, researchers would be more motivated to dedicate time to these critical activities. We regard these initiatives as crucial for fostering a culture of collaboration that can drive the field of root research forward.

Despite the challenges highlighted in this article, there is hope for the future. When asked whether the root research community needs a central, common database to enable fast and efficient data exchange, the majority of participants (74%) agreed or strongly agreed (Figure 1e). Additionally, 84% of participants agreed that the root research community needs a more data-driven approach to root phenotyping. This demonstrates the potential for increased database utilization and participative science from the root science community in the near future.

Promoting the use of databases within our community has the potential to propel root research into a new era of discovery. Databases are essential tools not only for supporting open and participative science but also for identifying specific root traits that enable stress tolerance and greater plant performance in particular environments. As we face the dual challenges of a growing global population and a changing climate, the ability to design crops that are more resilient, efficient, and adaptable becomes increasingly critical. Predictive models, powered by big data, are at the heart of this endeavor. By leveraging comprehensive datasets that encompass genomic, phenotypic, and environmental variables, these models can identify the traits that will optimize crop performance under specific conditions. We are convinced that the development of such crops will be significantly accelerated by tapping into shared databases for root research. These databases provide the necessary data infrastructure to support the generation and validation of predictive models, making it possible to design crops that meet the demands of the future. We urge the root research community to come together in this endeavor, recognizing that the future of agriculture and the safeguarding of food security depends on our collective ability to integrate, share, and utilize the wealth of data at our disposal.

Acknowledgements

For the lively discussions during the plenary sessions of the International Society of Root Research held in Leipzig in June 2024, the authors would like to thank the following persons: Amelie Henry, Feike Dijkstra, Klaus Schlaeppi, Malcom Bennett, Peter Gregory, Jianbo Shen, Andrea Schnepf, Eva Oburger, Mika Tarkka, Tim Brodribb and Timothy George. Additionally, we thank all the participants in the survey. Your contribution has inspired this article.

Declaration of interests

The authors declare no competing interests.

References (max 12)

1. Burgess, M., et al. (2000). Global Terrestrial Network for Permafrost (GTNet-P): permafrost monitoring contributing to global climate observations. *Geological Survey of Canada, Current Research (Online)*, 2000-E14, 8. https://doi.org/10.4095/211621
2. Guerrero-Ramírez, N. R., et al. (2021). Global root traits (GRooT) database. *Global Ecology and Biogeography*, *30*(1), 25-37. https://doi.org/https://doi.org/10.1111/geb.13179
3. Iversen, C. M., et al.(2017). A global Fine-Root Ecology Database to address below-ground challenges in plant ecology. *New Phytologist*, *215*(1), 15-26. https://doi.org/https://doi.org/10.1111/nph.14486
4. Kattge, J., et al. (2011). TRY–a global database of plant traits. *Global change biology*, *17*(9), 2905-2935.
5. Freschet, G. T., et al. (2021). A starting guide to root ecology: strengthening ecological concepts and standardising root classification, sampling, processing and trait measurements. *New Phytologist*, *232*(3), 973-1122. https://doi.org/https://doi.org/10.1111/nph.17572