doi 10.18699/PlantGen-2025-244

The use of digital phenotyping technologies to study the effects of beneficial microorganisms in plant breeding, genetics and biotechnology

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Motivation and aim: To discuss opportunities and prospects and to highlight the application of digital phenotyping technologies to assess the effectiveness of the phytobiome of epiphytic and endophytic beneficial microorganisms in plant biotechnology.

Materials and methods: The study includes articles, reviews and patents published mainly in the last twenty years.

Results: One of the tools of information technology, digital phenotyping is playing an increasingly important role in agriculture, allowing rapid assessment of individual plant phenotypes using a variety of information devices. These include, our available digital phenotyping systems TraitFinder 3D PlantEye Dual Scan scanner (Phenospex, Netherlands), iRay AT61P4FSHT thermal imager and MUSE-9HS hyperspectral camera (Spectricon, Greece). The digital phenomics strategy includes end-to-end measurement of phenotypic traits, which allows to understand the dynamic interactions between plants and microorganisms, from phyllosphere architecture and morphology to water and nutrient transport mechanisms. The use of these systems is a powerful tool for understanding the complexities of plant-microorganism interactions, both in terms of nutrient uptake and utilization, general assessment of health and disease susceptibility, and elucidation of breeding performance. They become especially important in the conditions of accelerated breeding under speed breeding technology. The relative confinement of space in climatic chambers and the focus on rapid completion of each generation cycle, modulate biotic and abiotic stress factors affecting physiological, biochemical and molecular processes of growing plants. Incorporating effective beneficial microorganisms that reside in both above- and belowground plant parts, as well as within and on the plant surface, is a pressing issue in intensive crop biotechnology. Plant-associated microorganisms play a critical role in plant tolerance by increasing plant resistance to abiotic and biotic stresses, promoting nutrient uptake and improving plant health. They can stimulate growth, development, control water balance, promote general adaptability and rapid plant maturation, and prevent disease. Utilization of the positive effects of beneficial microorganisms will improve and accelerate agricultural production and breeding technologies, in particular speed breeding, which has not been discussed in the literature so far. The controlled practical use of microorganisms under speed breeding conditions should contribute to programmable results. In addition, this approach opens new avenues in biotechnology for the production of plant secondary metabolites. The utilization of plant microflora will require accurate measurement and monitoring in a multifactorial soil-plant-atmosphere-microorganism system using digital phenotyping and under the control of artificial intelligence. Thus, the present work aims to highlight the development of phenomic approaches used to understand plant-microorganism interactions, including visualization technologies, the use of various sensors, and deep data analysis. New technologies will help to understand the functional role of beneficial microorganisms in plant physiological processes, nutrient transport and uptake at the cellular and tissue levels. In addition, the integration of genomic, transcriptomic and metabolomic information with phenomics will provide a holistic approach to understanding plant-microbial symbiosis and suggest new strategies to improve yields, including under speed breeding conditions.

Conclusions: The practical use of effective beneficial microorganisms becomes an urgent task of modern research and requires appropriate attention. Our findings and previous experience allow us to consider digital phenotyping technologies as a convenient and effective tool for analyzing the performance of the beneficial phytobiome and assessing plant health. The application of phenomics can be a powerful tool for identifying microbial strains and plant genotypes that are best suited for sustainable agriculture under strictly defined conditions.

Funding: The research was supported by the Ministry of Science and Higher Education of the Russian Federation, State Assignment FGUM-2025-0010.