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Review on Inomics

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A high-throughput elemental profiling method called ionomics is used to look at the molecular processes governing the makeup of nutrients, minerals, and trace elements in living organisms. Significant strides have been made in identifying the gene networks that govern the ionome since the ionomics concept was first introduced over 11 years ago. In this update, we provide a summary of the ionomics approach's ten-year progress, which includes studying natural ionomic variation and forward genetics-based gene identification. We also go over how ionomics might be used to study how ionomic alleles work ecologically in terms of environmental adaptation.

Keywords: Ionomics; minerals; nutrients; metabolics.

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1. INTRODUCTION

"The composition of minerals, nutrients, and trace elements in an organism and the inorganic part of cellular and organismal systems is the definition of the ionome" (Salt and others, 2008). "From the introduction of the notion of the ionome more than 11 years ago, significant progress has been made in the field of ionomics, which combines genetics and high-throughput elemental profiling to identify the genes that control the ionome" [1]. Danku and colleagues (2013).

2. IMPORTANT EVENTS IN IONOMICS

"The idea of plant ionomics emerged from the merging of metabolomics with mineral nutrition. It all started with the idea that an organism's metabolite profile reflects its physiological condition, which was held by Robinson and Pauling in the late 1960s and early 1970s. Considerable progress has been made in describing and understanding the biology of nutrient ion balance in plants since the 19th century, when it was initially acknowledged as a scientific field" (Marschner 2011). The early metabolomics theories of Robinson and Pauling may be related to mineral ions, as numerous trustworthy techniques have been created to evaluate the metabolites and mineral nutrition components of live organisms simultaneously. This was the first instance of an ion reflecting the physiological condition of an organism [2,3]. The concept of the ionome has made remarkable progress in describing and understanding the basic biology of nutritional ion homeostasis. Today, ionomics is gaining strength daily thanks to bioinformatics and other genetic tools like DNA microarrays and sequenced genomes. Lahner et al. [1] mapped "an ionome encompassing all metals, metalloids, and non-metals found in an organism for the first time. The term "plant ionome" was first used in 2008 by Salt and associates to describe the overall elemental concentration found in a sample of plant tissue". "Regarding the functional condition of a cell, tissue, or organism, it provides both quantitative and qualitative data. Research on the ionome is just getting begun, but studies on the links between the transcriptome, metabolome, proteome, and genome are still being conducted" (Fleet et al., 2011).

2.1 Forward Genetics-Assisted Identification of Ionomics Genes

To find mutants with modified leaf ionomic profiles, Lahner et al. [1] carried out a thorough analysis. In this first screening, 338 putative mutants exhibiting differences in the accumulation of one or more elements in the leaves were found among 4747 M2 fast neutron (FN) mutant plants. 51 of these 338 putative mutations were shown to be real after all M3 families underwent further screening. Using 2000 mutagenized M2 Lotus japonica plants, Chen and colleagues (2009) carried out a comparable large-scale ionomic screen. In this type of large-scale research, plants need to be routinely grown in different experimental blocks over several months in order to facilitate the gathering and analysis of thousands of plant samples. "Interestingly, the ionome is also subject to variation in growth rates. In every plant growing tray of the FN-mutated Arabidopsis thaliana screen, the controls were the wild type and the known ionomic mutant frd3. When the plants were five weeks old, they were harvested [4-6]. Numerous studies have demonstrated the importance of the citrate transporter encoded by FRD3 in the Fe-deficient response. A mutation in FRD3 causes an excess of Mn and Co to accumulate in leaves, among other metals" (Delhaize, 1996). Hierarchical clustering of 44 verified FN mutants using the leaf ionome as the phenotype revealed that mutant frd3 is generally independent of the plant cultivation tray or the soil batch [1]. Additionally, frd3 was cultivated in a range of growth trays and soils.

3. PLANT IONOMIC TECHNIQUES: RECENT ADVANCEMENTS

The current sample preparation techniques frequently contribute enough interference to change the internal elemental profile of the cell when studying variations in elemental composition. To properly understand and maintain ion homeostasis—which includes the movement and storing of particular ions at the cellular and subcellular levels—more study is required. Within this framework, synchrotron-based X-ray fluorescence microscopy (SXRF) is a particularly useful technique for offering basic understandings of metal abundance. With the use of this technology, important spatially resolved information on plant metal homeostasis can be obtained, along with specifics regarding the cellular compartments and membranes involved in ion uptake, transit, and storage. Fahrni (2007) also addresses "the functions that transport systems have in influencing the bioavailability of an element. Sample preservation or sectioning is not necessary since SXRF, a multi-elemental technique, enables the simultaneous analysis of many metals without changing the original state of the sample". It allows for the non-destructive quantitative imaging of several elements by analyzing a variety of tissues, from dried seeds to moist roots, utilizing high-energy, focused X-rays from synchrotron sources (Yang et al. 2012). The method uses X-rsay beams to excite inner shell electrons, resulting in visible X-ray fluorescence specific to the spectra of each element (Qin et al. 2011). SXRF was used by Yang et al. (2012) to investigate calcium distribution in various seed tissues and cells, demonstrating the capacity of SXRF to spatially resolve components in recently harvested, well-hydrated.

4. PLANT ELEMENTS PROFILING TECHNOLOGY

Plant ionomics necessitates measuring the elements and ion content of the entire plant, tissue, and even individual cells. Numerous cutting-edge technologies and equipment are involved, ranging from specialized instruments to sample preparation techniques [7-10]. The variables to be evaluated—sample size availability, sample throughput, dynamic quantification range, sensitivity, accuracy, and dependability—could all affect these. These instrumental methods use an atom's property to detect things. Certain elements are based on their electrical properties, while others are based on their nuclear properties. All methods are categorized into two groups based on data from the literature: (i) methods based on elemental electronic characteristics, such as X-ray fluorescence spectroscopy (XRF), ion beam analysis (IBA), and atmospheric absorption spectrometry (AAS). Strategies depending on an element's nuclear properties: Plasma spectroscopy using inductive coupling (ii) Analysis of neutron activation (NAA).

5. PLANT IONS ARE USED FOR

"Ionomics is used to find potential transporter genes and validate their functionalities in order to comprehend the mechanism of mineral transport in plants. Utilizing high-throughput elemental analysis technology in conjunction with genetic and bioinformatics techniques is necessary. Plant physiological status is assessed, and this technique identifies biomarkers (ionome profiles) for each status" [11]. The phylogenetic study of plant species is another application for ionomic data (White et al. 2012). Here, we've discussed a few ionomics applications for researching plant mineral transport and storage.

• QTL and gene identification • Gene(s) functional validation

6. CONCLUSIONS AND PERSPECTIVES

Over the last ten years, plant ionomics has advanced significantly, combining genetic and high-throughput elemental profiling techniques to clarify the regulation of nutrients and minerals. Through this method, important gene networks governing the ionome have been revealed, and the significance of ionomic variation in environmental adaptation has been emphasized. Technological developments like synchrotron-based X-ray fluorescence microscopy (SXRF) have improved our knowledge of ion dynamics by offering precise insights into the distribution of metals in plant tissues. Elements have been measured even more precisely because to enhanced sample preparation and analytical methodologies. In the future, plant ionomics has the potential to improve our understanding of mineral transport, find physiological indicators, and aid in phylogenetic research. New facets of plant physiology and adaptation will probably continue to be discovered as technology develops, providing a wider range of uses and new perspectives on the resilience and health of plants.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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