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INTRODUCTION

A review of the uptake of all plant nutrients would seem to require a whole volume of this series rather than a single chapter, since there are many levels at which nutrient acquisition could be considered. There are about 19 different elements that are considered essential for plant growth and of these many are absorbed into plants in multiple forms (e.g., N as NO3, NH4, amino acids). Then there is the question of uptake into different tissues with varying absorption structures, not to mention the diversity that International Review of Cytology exists among plants and the differences in nutritional requirements that this imposes. Fortunately, there are some simplifications that can be made, since C, H, and O are usually obtained from gases or from water and the pathways for their uptake are uncomplicated and have been well described. The remaining 16 or so are considered mineral elements and are mostly obtained either from soil in the case of terrestrial plants, or from the bathing medium in the case of aquatic plants. A further simplification comes from the fact that during evolution, many transport systems were conserved and can be found across a wide range of plant and animal types. There is also a relatively small range of transport mechanisms, the selection of which is largely determined by electrochemical considerations: central to these are H+-ATPases in the plasma membrane. The mechanisms for the uptake of most macronutrients (K, Ca, Mg, S, P, N) are now reasonably well understood. Unfortunately this is not the case with any of the micronutrients except Cl, and perhaps Fe. Understanding how transport of both micro- and macronutrients is regulated has also proved to be a very difficult task. Thus, the length of a review of nutrient uptake in plants can be shortened because of the evolutionary economy in design of transporters and by the gaps in our knowledge as to how uptake is controlled. This review will focus on the primary mechanisms for uptake across the plasma membrane of cells and will mainly consider the uptake systems applying to mineral.

MASS FLOW

Mass flow, the most important of these mechanisms quantity wise, is the movement of plant nutrients in flowing soil solution. Movement of ions in the soil solution to the surfaces of roots is an important factor in satisfying the nutrient requirement of plants. This movement is accomplished largely by mass flow and diffusion.

Mass flow is a convective process in which plant nutrient ions and other dissolved substances are transported in the flow of water to the root due to transpirational water uptake by the plant. Some mass flow can also occur due to evaporation and percolation of soil water.

DIFFUSION

Diffusion is the movement by normal dispersion of the nutrient from a higher concentration through soil water to areas of lower concentration of that nutrient.

Diffusion process operates when an ion moves from an area of high concentration to one of low concentration by random thermal motion. As plant roots absorb nutrients from the surrounding soil solution, a diffusion gradient is set up. A high plant requirement or a high root "absorbing power" results in a strong sink or a high diffusion gradient favouring ion transport.

There are mainly three soil factors which can influence the movement of nutrient ions into the root through diffusion mechanism namely diffusion coefficient, concentration of the nutrient in the soil solution and the buffering capacity of the solid phase of the soil for the nutrient in the soil pollution phase.

ROOT INTERCEPTION

Root interception is the extension (growth) of plant roots into new soil areas where there are untapped supplies of nutrients in the soil solution. All these three processes are in constant operation during growth. The importance of each mechanism in supplying nutrients to the root surface for absorption by the root varies with the chemical properties of each nutrient element.

The importance of root interception mechanism for ion absorption is enhanced by the growth of new roots throughout the soil mass and probably also by mycorrhizal infections. As the root system develops and exploits the soil more completely, soil solution and soil surfaces retaining adsorbed ions are exposed to the root mass and absorption of these ions by the contact exchange phenomenon is accomplished.

The exact mechanisms for ion absorption into the root cells are not well understood. The cell walls are porous and the soil solution can move through some or all of the cell walls, causing intimate contact of the soil solution with the outer membranes of the cells.

For a nutrient element to cross a cell membrane into the cell, it is necessary for each nutrient element to be attached to some carrier. The carrier nutrient complex can pass through the membrane into the cell.

The necessary carriers are different for many of the nutrients. Some nutrient elements can be partially but not entirely excluded from absorption, others can be preferentially absorbed, even against a concentration gradient.

CONCLUSION

Nutrient uptake in plants is a very broad topic and it has been necessary to limit our focus to covering the principal processes involved in accessing and absorbing essential nutrients from their environment. This is but one of several layers of nutrient uptake that need to be considered in the context of development of the whole plant. Loading into the xylem and the interplay between xylem and phloem in the redistribution of nutrients, particularly under deficiency conditions, require closer scrutiny, as does the role of the vacuole in temporary and long-term storage of nutrients. Likewise, the regulation of nutrient uptake has mostly been considered only in relation to the factors that directly avect the rate of membrane transport, neglecting the important hormonal signaling that often serves as the communication between nutrient-absorbing structures and nutrient- consuming organs. Gene control of membrane transport has been considered briefly for some transporters where empirical data exist but this is an area of research that will undoubtedly reveal much in the next decade. It is relatively easy to detect the induction or increased expression of transporter genes, but in many cases it may be that morphological changes facilitating better access to nutrients are more important than synthesis of more or higher-affinity transporters. This is particularly true of nutrients with low soil mobility such as P and Fe. The relative importance of this aspect of nutrient uptake has yet to be defined.

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