

THEORETICAL APPROACH TO LIFE PROCESSES Part II. Propagation of Plant Life and Nutrient Uptake

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A hypothesis is presented for propagation of plant life suggesting that entry of a nutrient into and its assimilation by a plant system takes place if the former has hydrogen bondable groups as its integral part and the latter has ingrained coordination polymers, also having hydrogen bondable groups at their periphery or surface. Membranes which are responsible for controlling ionic movements, their reaction rate and energy requirements are suggested to comprise a set of coordination polymers containing specific metal ions for selective absorption and/or transportation of organic molecules and ions. Carriers react with an ion at the hydrated surface, transport it across the membrane and release it inside the cell. The cells themselves are considered as coordination polymers having Na^+ and K^+ on exchangeable sites. The movement of cations through cells follows the laws for conducting electrons through semiconducting crystals. Electrolytes combine with substances having a hydrogen bond such as HX of the protoplasm. The coordination polymers function as ion binding and ion releasing complexes by the exchange processes such as those occurring in ion exchange resins. Changes in pH and ionic concentration determine the entry and/or assimilation of nutrients into a macromolecule through hydrogen bondable sections.

Key words: Ions, Plant life, Nutrient.

INTRODUCTION

Metal ions encased into a macromolecular framework form coordination polymers [1]. Such polymers can be ideal for the propagation of life processes if they have hydrogen bondable groups attached at their periphery or surface. For entry into and assimilation by a living system it has been suggested [2] that substances should not only be hydrogen bondable but also should not disturb the hydrogen bonding super-structure. They would, otherwise, enter the living body as toxic materials and will have to be biodegraded by enzymic action which again is a process occurring through coordination polymers. Alcohol was cited as an example of a hydrogen bondable substance whose hydrogen bond framework is not extensive and since it reacts with organic acids and amino acids producing esters and with water it depolymerises the hydrogen bonding superstructure, it is unable to propagate life processes [2]. Further evidences in support of this mechanism are provided by examining the uptake of nutrients by plants which is the subject of this paper.

Life processes in the plant system comprise reactions of simple compounds like carbon dioxide and water in an ionic environment of sodium, potassium, calcium and magnesium. Water is a reactant as well as a medium for the biochemical processes taking place in the plant system. It is responsible for translocation of ions from the root to the various parts of the plant and by encasing coordination

complexes into its super-structure it acts as a carrier of nutrients.

Plant life propagation could be considered as an interaction, in the presence of sunshine, of (1) soil, a solid phase which supplies mineral matter, (2) water, the liquid phase which besides constituting 80% of the plant matter, leaches the ions from the mineral provided by the soil and acts as their carrier, with (3) air, the gas phase from which carbon dioxide is obtained. These three phases are among the four essential elements considered by Al-chemists to be responsible for various natural processes and reactions.

Coordination polymers in biological systems. Reactions in isolated systems may proceed without control but in biological systems they are controlled by membranes. Membranes not only regulate the ionic movement and thus the reaction rate but they also control their energy requirements [3]. Energy for the biochemical reactions and for transportation of ions is provided by electron processes which energize the membranes. The energized membranes transport ions across, against concentration gradient [4].

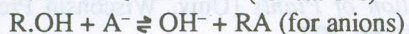
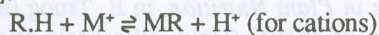
Membranes are now known to contain a variety of macromolecules required for specialized functions [5]. This implies, in the present context, the presence of several coordination polymers, each playing a different role in being selectively permeable to different ions. A coordination polymer containing citrate ions and water would be responsible for the transport of iron [6]. Similarly the sucrose

phosphorylase polymer would be responsible for the entry of sucrose and not glucose into tomato roots [7].

Membranes, in the light of the above findings, may be considered as coordination polymers which have not only the specific metal ion or ions to permeate the desirable ions but also their casing, comprising water to act as carriers. The presence of the latter controls permeability of the membranes, which have to remain hydrated in order to be permeable the more highly hydrated the more permeable they are [8]. Hydration itself is a formation of a superstructure having water on its outer sphere or surface. Similar is also the case with cells where the availability of water determines the degree of hydration of cell colloids, with the electrolyte concentration remaining constant.

Water occurs in different structural forms for the performance of the above functions. In the cells it is present in ice-like lattice while in tissues it has a semi-crystalline structure [9]. In the present context cells may be considered as coordination polymers which have Na^+ and K^+ located on exchangeable sites. Movement of the two cations through the ice-like lattice of water is governed by laws for the conduction of electrons in semiconducting solids and cells behave like semiconducting crystals [10].

Water in the form of a large hydrogen bonding network acts as the carrier of ions and molecules. It is present in the cell colloids as well as in the polypeptide chains where it acts as a lubricant for the protein chains. Its hydrogen bondable character allows it to play the role of ion binding and ion releasing macromolecule. Carbon dioxide, as an example, produced by respiration, is diffused into the soil solution where it forms carbonic acid whose hydrogen bondable character promotes the exchange of proton by potassium and other cations [11]. It has been suggested that there are sufficient substances in plants with a general formula R.H from which a proton can easily be ionised. Protoplasm is, as a whole, a negatively charged substance; it contains appreciable quantities of strong acidic moieties [12]. Cations from the soil and water exchange for the protons in the plasmalemma and proceed through the protoplasm along paths of acid dissociation. Such a mechanism would also depend on the nature of the R.OH . The exchange process may be explained as follows where R.H and R.OH represent metabolically produced ionic substances [13].



As another example one could cite Fe ion in the haem group of a respiratory enzyme, such as, cytochrome oxidase which is well suited to the transport of anions since the Fe^{3+} attracts more anions than Fe^{2+} [12]. The transference of an electron between two iron atoms moves one anion along the path or chain. Respiration would be the source of electrons and the ultimate controlling factor for absorption and accumulation of ions resides in the oxygen

gradient in the cell [14], with a hydrogen bonding environment of water as superstructure.

Hydrogen bondable character of carriers and nutrients. Salt absorption in many cases is linked to various enzymic processes. Being coordination polymers themselves, these enzymes may be viewed as providing sites for the exchange of anions as well as cations, on interaction with the salt. This exchange takes place near the membranes since they are able to provide the site for binding or exchange of ions for the uptake of the essential nutrients. There are evidences [15] that cations like potassium and sodium and not calcium or magnesium stimulate respiration and, therefore, the phenomena of salt respiration is not necessarily limited to anions which may or may not be promoters of hydrogen bondability.

The enzyme carbonic anhydrase has been found responsible for increase in the transportation of carbon dioxide across the membranes. In solution, bicarbonate is almost as fast as carbon dioxide, but in a membrane the latter diffuses 100 times faster than the anion. In the presence of carbonic anhydrase, the bicarbonate is converted to carbon dioxide and facilitates diffusion of carbon [16]. The rapid passage of carbon dioxide becomes possible on interaction with the coordination polymer carbonic anhydrase.

The essence of the coordination polymer approach is that nutrients have to present themselves as hydrogen bondable substances which then combine with cellular constituents during passage through the membranes. In the case of carbon dioxide it enters the system by forming carbonic acid. Electrolytes enter cells by combining reversibly with a constituent having a hydrogen bond such as HX of the protoplasm.

Carriers are special compounds which function in the membrane and they react with an ion at the surface, transporting it across the membrane and releasing it inside the cell or vacuole [17]. The coordination polymer can function as ion binding and ion releasing complex by the exchange processes. Obviously they have to be hydrogen bondable substances, for example, those containing hydroxyl groups or hydrates. Cations would then be bound in plants in the form of coordination complexes or chelated complexes and the proteins, amino acids and organic acids would form the chelated compounds with polyvalent cations [17]. Ion binding coordination polymers would be effective in salt absorption in such cases. The region between the vacuoles and the external surface of the cytoplasm is relatively impermeable to free ions but permeable to the complex ions and ion binding compounds [18]. Ions combine with carrier molecules and the resulting ion complexes traverse membranes of limited permeability to free ions. At the inner surface of the membranes, the ions are released from the carriers. An active transport of ions across the plant membrane by a carrier depends on the metabolic energy and their absorption on metabolically produced ion binding

compounds [13].

Absorption of salts through the roots comprises two processes; one is rapid entry into the apparent free space while the other is slow accumulation into vacuoles. The former depends on diffusion and exchange while the latter does so on carriers produced endogenously [19]. Here again one of the main requirements for the carriers to be effective in transportation is their hydrogen bondable character since movement of molecules of carbohydrates, amino acids, organic acids, plant hormones, etc., already possessing hydrogen bonds, is facilitated by the water superstructure.

Roots owe their capability to absorb ions or molecules to their sponge-like character which provides a large surface area for contact feeding of nutrients. According to estimates 1mm² of root surface can be in contact with 10⁸ clay particles each of which may carry from 6000 to 7000 exchangeable cations [20]. Substances in contact with water take up a negative charge and they include roots which provide site for the charge.

The uptake of nutrients through coordination polymers is also supported by the study on the promotion of uptake of ions by ion exchange materials known as Amberlites, as cation and anion sources. Amberlites like coordination polymers are polymeric substances with large surface area and exchange sites. It has been noted that calcium, magnesium, and phosphate and sulphateous absorbed on Amberlites impart healthy growth of the plant using potassium nitrate as the feeding material [21].

It has been demonstrated earlier [1] that change in pH or hydrogen ion concentration determines entry of metal and organic acid ions into a macromolecule. In the case of plants also the formate, acetate and succinate anions are absorbed into barley root mainly as ions from solution at pH 5-7 [22]. Entry of organic acids at pH 5 takes place in the form of their ions through the hydrogen bondable sections.

Calcium and phosphorus uptake has been shown to be markedly affected through a change in the pH. Absorption of magnesium, potassium and nitrate ions by tomatoes, lettuce and Bermuda grass, is found unaffected between pH 4 and 9. At pH 3 their roots are found to be injured and instead of uptake, calcium and phosphorus are lost to the solution [23]. Phosphorus absorption has a marked decrease at pH 9 while calcium uptake is diminished at pH 4. Low pH and/or low calcium, increase the permeability of cell membranes and this is the hydrogen ion concentration at which the roots are reactive because of their own low pH (4.1 for root zone water and 2.9 for root surface [24] which makes negative sites available. These negative sites are attributed to ionised carboxyl groups in the cell wall.

CONCLUSION

It is suggested that lower pH in the plant material ionises its acidic moieties and prepares negative sites so that

hydrogen bondable nutrients become available for absorption. Their entry into the biological system is controlled by membranes which have been considered as coordination polymers encasing specific metal ions. This approach is in line with Tanada's postulate which proposes a chain of negative sites through a membrane as a pathway for cation entry (25).

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