Toxic metals in plants

A strict definition of a metal is difficult to obtain but usually includes hard, heavy, and lustrous elements that forms basic oxides and hydroxides. Certain metals however also form acidic oxides e.g. bismuth, chromium and manganese. Toxic metals cause an inhibitory effect on the growth of animals, plants, fungi and bacteria and, often on all four groups. Metals such as copper, iron, manganese, nickel and zinc are essential nutrients for all living organisms but become toxic at higher concentrations. Others such as aluminium, cadmium, lead and mercury do not appear to have any essential role in metabolism. The term "heavy metals" is also used to include metals in the periodic table with atomic numbers greater than 20, or having specific gravities greater than 5 $g.cm^{-3}$. As this term is somewhat misleading and also has connotations in the music business, we have not used it here.

Toxic metals occur naturally in rocks and they are released slowly into the soil by mineral weathering. Normally they are only available to living organisms in general, or plants in particular, at low concentrations, although aluminium and iron are exceptions to this rule. However, increasingly larger quantities of certain toxic metals have been released into the environment by anthropogenic activities, primarily associated with industrial manufacturing and also the application of fertilisers in agriculture. The industrial use of cadmium was minor until about 60 years ago. Today it is used for electroplating, pigments in paints, batteries, plastics, ceramics, glass and steel coatings and cadmium has become a key toxic metal. The use of lead additives in petrol/gasoline has now thankfully been reduced to a minimum.

Plants have evolved several mechanisms to prevent the toxic action of metals, these include reduction of uptake into the root cells by changes in the kinetic properties of transporters and exudation of complexing agents into the rhizosphere. Once metals have entered the plant they induce the synthesis of the glutathione containing peptides phytochelatins and high cysteine containing proteins, the metallothioneins, which are able to bind to the metal ions. Ultimately the metals are stored in the vacuole in a relatively non-toxic form. There have been a number of attempts by different laboratories to construct novel plants using genetic manipulation technologies, that may have a greater tolerance to the presence of toxic metals. Such plants may in the future be very important in the removal of toxic metals from the environment through the process of phytoremediation. Certain plants termed hyperaccumulators have been identified that are able to accumulate high concentrations of toxic metals in their stems and leaves. These plants are currently under intensive study, to establish the mechanisms involved and also again, for their possible use in phytoremediation.

The presence of unusual metal ions within a plant cell can cause dramatic effects upon metabolism. There is often the formation of reactive oxygen species (ROS) that can include superoxide ($O_2^{\bullet-}$), hydrogen peroxide (H_2O_2), and the hydroxyl radical ($^{\bullet}OH$). Plants have a number of efficient enzymatic and non-enzymatic antioxidant defence systems that allow scavenging of ROS and protection of the cellular contents from oxidative damage. When these defences fail, toxic ROS can cause significant damage to the cell. In many cases, plants can exhibit symptoms similar to those observed during leaf senescence before cell death occurs.

In this special issue, we have attempted to bring together a team of international experts who have written a total of twelve review articles, each describing the latest advances in their own field. These articles should be of considerable value to practicing research scientists, in a range of subject areas from molecular biology to the environment and of course to the undergraduate and postgraduate students, who will take over this work in the near future.

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