Emerging roles of cyclic nucleotide gated channels in plants

Plants are vulnerable to various biotic and abiotic stresses imposed in their respective growth environment. These stresses negatively affect the normal growth, development and productivity. Unlike animals, which can move to conditions conducive for growth and development; plants being sessile have to re-program their internal machinery to adapt. These machineries include diverse molecules and proteins. Maintaining a steady and required amount of ions is one of the important parameters for successful survival and stress tolerance. Many plant cation transporter and channel protein families such as glutamate receptor homologs (GLRs) and cyclic nucleotide gated ion channel (CNGC) have been implicated in providing stress tolerance. The members of CNGC family are involved in uptake of cations and regulate plant growth and development.

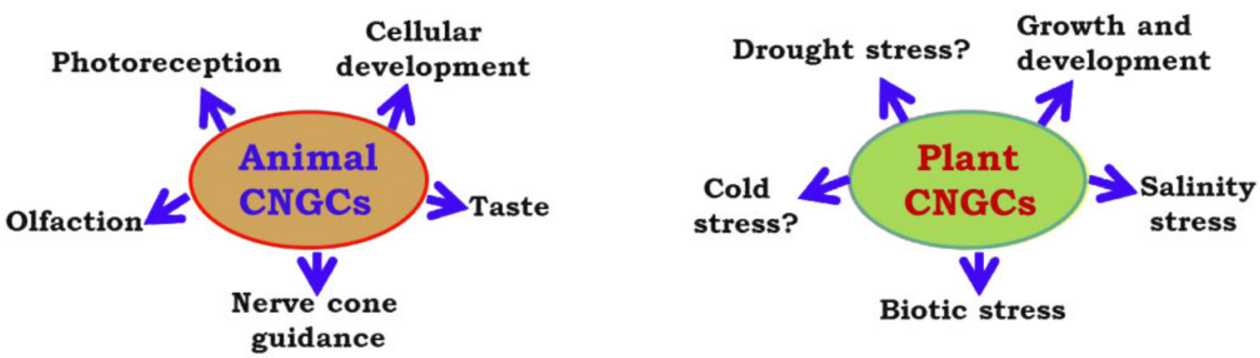

Fig. 1. Roles played by animal and plant CNGCs: CNG channels are involved in a variety of processes in animal and plant systems. In animals, CNGCs are involved in sensory processes like photoreception, taste and olfaction while in plants they mediate defense responses against pathogens, salinity stress etc. Some of the recent transcriptomic studies promise their role in cold and drought stress (highlighted with question (?) marks).

In animals, CNGCs have been well characterized and they pass on external signals needed for sensory processes. Animal CNGCs are expressed almost everywhere in various regions of neuronal and non-neuronal cells. CNGCs are activated by binding of cyclic nucleotides (CNs) and are inhibited by calmodulin (CaM) binding to a region of the protein distinct from that of CNs binding. In their original forms, CNGCs are heterotetramers composed of A-(CNGA1-A4) and B-type (CNGB1 and B3) subunits. A-type subunits can form functional homomeric channels while B-type subunits do not. While animal native CNGCs are uniformly heterotetrameric in nature; no experimental evidence so far supports this fact in plant membranes. Most of the studies done to show effects of CNs on plant CNGCs have shown that cAMP acts to activate the channel.

Genomes of many plant species have been reported to encode CNG channels that have been implicated to play many important functions. Ion homeostasis is one of the mechanisms for the optimal physiological processes in plants. A disruption in ionic equilibrium can have dangerous effects on normal growth and development. Forward and reverse genetic studies have contributed in identifying functions of *Arabidopsis CNGC* genes. Many of the CNGCs allow passage of Ca^{2+} ions but owing to similar physicochemical properties and inability to distinguish between other cations, the channels have been shown to allow entry of toxic heavy metals such as Ni^{2+}, Sr^{2+} and Pb^{2+}.

Structurally plant CNG channels are similar to members of the superfamily of 6 transmembrane 'Shaker-like' pore-loop ion channels. CNGCs exhibit ubiquitous expression and most of them are localized to the plasma membrane. CNGCs are directly related to stress adaptive responses, Ca^{2+} uptake, in developing response against pathogens, cellular ionic homeostasis, salt stress response and growth and development. However, contrary to animal, plant CNGC has overlapping binding domains of CN and calmodulin (CaM). This overlapping binding may facilitate cross talk between CN and CaM signaling and may have unique outcome for CNGC-dependent Ca^{2+}-signaling to adaptive responses in plants.

Based on bioinformatics studies, CNGC genes have been identified in several different plants, however the functional role of several of these CNGC needs to be investigated in these plant species. In contrary to animal kingdom where the functional role of CNGC channels is well characterized, in plant, the function of these is still elusive. Nevertheless, the functional role of CNGC in plants is an emerging area and some of the functions regulated by CNGCs are highlighted in the Figure 1. Though animal and plant CNGC function and regulation are different but one commonality between them is the involvement of Ca^{2+} ions. Both of them transduce the signal to downstream components via Ca^{2+} signaling. With more detail investigation of CNGC channels in agronomically important crops, the potential candidate genes can be biotechnogically manipulated to develop crops suitable for changing global climate, soil toxicity and to contribute towards reducing food insecurity.

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Publication

Role of Cyclic Nucleotide Gated Channels in Stress Management in Plants.
Jha SK, Sharma M, Pandey GK
Curr Genomics. 2016 Aug