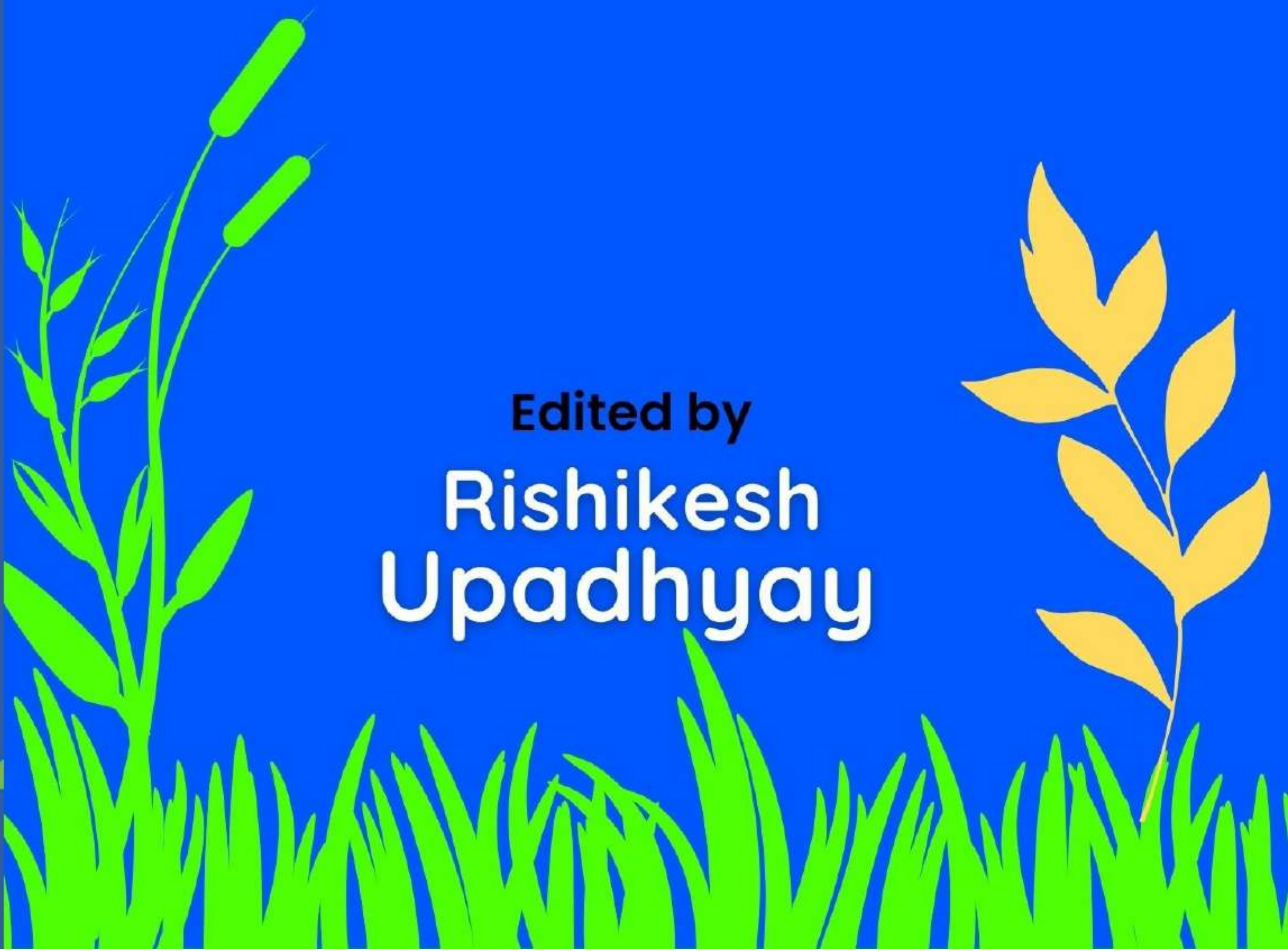
STRESS IN PLANTS

The Hidden Half



Edited by

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minor L., *Eichornia crassipes*, and *Polygonum hydropiperoids* are all excellent accumulators of heavy metals like cadmium and copper (Qian et al., 1999). The percentage of accumulation is always higher in the roots than in leaves in both these aquatic plant species (Deng et al., 2006). Still, the degree of accumulation depends on the species, the metal type, and other environmental conditions, like pH, temperature, salinity, organic matter content, and the presence of other ions, etc. (Fritioff et al., 2005; Greger, 1999). Most aquatic plant species exhibit optimal rates of photosynthesis at relatively high temperatures. Temperature increases may lead to prolonged and more intense anoxia phases that stimulate microbial processes and increase nutrient availability, with consequent stresses on aquatic plants (Weltzin et al., 2003). In natural environments with high light perception, the maximum depth at which aquatic plants occur is limited by temperature. This is because plant species occurring at such depths do not require oxygen for root growth (e.g. *Ceratophyllum, Utricularia*, etc.). Water movement also has indirect effects on aquatic plants. Under stagnant conditions, photosynthesis can be limited by gas diffusion and nutrients. Moderate water stirring reduces the thickness of the boundary layer and leads to enhanced nutrient and gas fluxes, increasing photosynthesis and plant growth. An abiotic stress like flooding results in the scouring of the substrate, which is then recolonized by pioneer species that cohabit with species tolerant of flooding, increasing their diversity.

Metal accumulated through different sources in aquatic plants causes changes in their physiological and biochemical metabolism, with toxic effects on growth and natural vegetation. Aquatic plants like *Ipomea aquatica* and *Phragmites karka* appear to be the best species for monitoring metal pollution. Such aquatic macrophytes or microphytes are used as biomonitors or biofilters. Aquatic plants have an inherent tolerance to abiotic stresses, such as those caused by the presence of heavy metals (McCabe et al., 2001), the reason for which may be due to the biogeochemistry of the soil of the rhizosphere associated with them in water (Matthews et al., 2005). It is, therefore, possible that aquatic plants may typically be exposed to a higher concentration of metals than in open environments due to human anthropogenic activities mainly affecting the aquatic ecosystem. A different strategy for adaptation in natural environments involves changes in growth and metabolism and their detoxification during adaptation, as shown in **figure 21**.

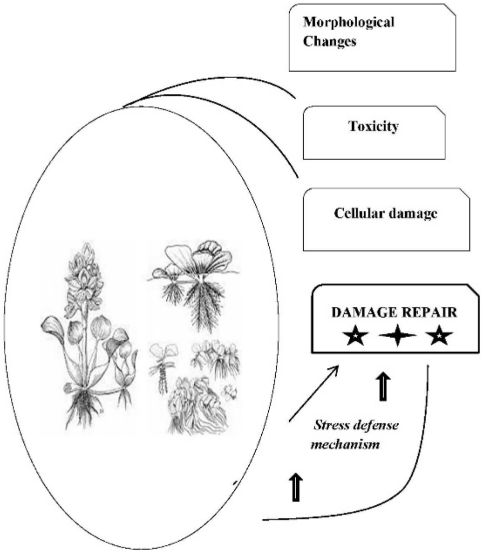

Figure 21. Basic strategy for stress adaptation in aquatic plants.

Aquatic plants absorb heavy metals through roots, leaves, or fronds. Different species show different behaviours regarding their ability to accumulate these metals in roots, stems, or leaves. In the aquatic ecosystem, where pollutant inputs are discontinuous and pollutants are quickly diluted, analyses of plant tissues can provide relevant information about the system's quality (Baldatoni et al., 2005). However, biomonitoring of pollutants using aquatic plants as accumulator species can see them accumulate a relatively large amount of contaminants without noxious effects (Ravera et al., 2003). For example, high levels of heavy metals and metalloids such as aluminium (Al), silicon (Si), manganese (Mn), and iron (Fe) have been found to accumulate in *Vellisnaria spiralis*, *Hydrilla verticillate*, and *Azolla pinnata* L. Some aquatic plants, such as *Eichornia* sp., *Typha* sp., *Ipomea* sp., and *Phragmites* sp. concentrate large amounts of various metals and are thus useful indicators of local pollution. The ability of aquatic plants to hyper-accumulate different heavy metals makes them attractive, especially for the treatment of industrial effluents and sewage wastewater in nature. The extensive use of aquatic macrophytes such as *Azolla*, *Eichornia*, *Lemna*, and *Spirodela*, etc., with their hyper-accumulating ability, is recognised as an environmentally friendly option to restore naturally-polluted aquatic resources. The free-floating habitat of