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## IN THIS ISSUE

# How plants regulate their body temperatures: Implications for climate change science & policy

Peter G. Kevan, University Professor Emeritus at the School of Environmental Sciences, University of Guelph, explores here how plants regulate their body temperatures, including the implications in this respect for climate change science & policy

The temperature at and near the Earth's surface is rising, much to the consternation of the world.

Terrestrial life, including human, is almost all restricted to a biofilm of few tens of metres above and below the surface. That life-supporting film, the biosphere, has, by comparison with the atmosphere, lithosphere and hydrosphere, the greatest historical, seasonal and daily variation in environmental conditions, including temperature, moisture, solar radiation, atmospheric disturbances, electromagnetic fluxes and chemical composition. Life forms have adapted to those wide swings in environmental conditions and notably to temperature.

It is well recognised that the diversity, abundance and activities of terrestrial life are influenced by two main climatic factors, temperature and water availability. Warmth and water favour life. Environmental temperatures may be too cold or too hot to allow certain life forms to thrive. Environmental moisture has more complex direct and indirect effects on life. There are, additionally, other environmental factors (e.g. salinity, pH, the nature of substrates) that influence life. Global concern for climate change invokes the effects of the atmospheric build-up of greenhouse gases. Global climate change influences all those factors as life's diversity, distribution, abundance and activities are affected. The effects of global climate change on life are mostly inferred from general meteorology without much consideration for the actual environmental conditions close to the ground (micrometeorology) and within life forms (biometeorology). Micrometeorology and biometeorology must be applied to refining scientific understanding of the extent and consequences of climate change.

Micrometeorology provides a more accurate and complex appreciation of ambient conditions affecting life, its diversity, abundance and activities. Biometeorology, in dealing with the relationship between living things and the weather, takes meteorology more directly into biology by seeking general, ecological, physiological and genetic explanations into the processes whereby ambient conditions influence life, its diversity, abundance and activities.

A prime example of how climatology, meteorology and biometeorology combine is presented by geographical patterns (maps) of plant growth and survival, especially as used for agriculture and the predictive utility of heat units (often expressed at growing degree days) and rainfall in farming. Intrinsic to those patterns are micrometeorological effects, amounts of direct and diffuse insolation, as well as atmospheric humidity and wind. The actual temperatures within plants are missing from biometeorological consideration.

Biothermometry (the measurement of body temperatures) is widely applied in medicine, but less often in other biosciences. For medicine, deviations from normal body temperature are regarded as symptomatic of ill health or stress. Human beings, mammals and birds maintain constant and closely regulated body temperatures and are strict homoeotherms (endotherms). Most other animals, plants and fungi are usually considered poikilotherms (ectotherms) even though many have various means to control their body temperatures. Biothermometry has been applied to plants through direct measurements and by remote IR thermometry.

For flowers, the means of warming under cool conditions have been recently reviewed (van der Kooi et al. 2019)[1] and include solar basking by orientation of plant parts to face the sun, closing of leaves or floral parts and so retaining heat, adaptations that emulate translucent miniature greenhouses and, in some special cases, metabolic heating.

For other plants parts, notably stems, Kevan et al. (2018)[2] present data showing that hollowness imbues plants with elevated temperatures in sunny conditions. Cooling under heat stress is less understood. Apart from the orientation of leaves by paraheliotropism to reduce solar heating, cooling is attributed to transpirational heat loss (i.e. heat loss by the evaporation of water through stomata, akin to sweating). The cooling effect of trees is not simply by shading but includes transpiration and may involve paraheliotropism. Those phenomena are increasingly invoked for mitigation of heat in urban landscapes. Herbaceous plants may also exhibit paraheliotropism and so reduce incident solar heating stress, but, additionally, show growth responses mediated by interacting heat and light sensitivities that result in heat avoidance.

Thus, plants, although apparently static and passive, show remarkable capacities to regulate their internal temperatures by a complex variety of strategies. Those include solar heating, as in diaheliotropic solar furnaces (Kevan,1989)[3], microgreenhouse effects (Kevan et al 2018, 2019)[4,5], metabolic endothermy (van der Kooi et al. 2019)[1] and concomitant cooling by evapotranspiration (the swamp cooler effect (Galen C, 2006)[6], paraheliotropism and adaptive morphogenesis (Crawford et al, 2012).[7] Thus, plants are, as Michaletz et al. (2015)[8] argue, but from the viewpoint of metabolism, limited homoeotherms!

A major consequence of plant thermoregulation is atmospheric air conditioning. Transpirational evaporation humidifies the atmosphere above the vegetational canopy. With nocturnal, altitudinal and adiabatic atmospheric cooling, moisture in the air condenses as the dew point is reached – clouds form and rain may result, sometimes with violent electrical discharges (thunderstorms). The more humid the air, as over forests, the lower in the atmosphere the processes are initiated. By comparison, drier and hotter air rises further, even if somewhat faster, to possibly form thinner, higher clouds that may be blown away. Deforestation, devegetation and desertification forestall, or even preclude, autochthonous, locally derived, moisture cycling. Those processes, exacerbated by global heating and the influence of increasing oceanic evaporation, may contribute considerably to extreme weather events far from the sites of forest thermoregulation.

Numerous means for the mitigation of the effects of climate change are advocated and instituted. Strategies range in scale from macro to micro; from direct intervention on atmospheric chemistry (reducing the influx of anthropogenic greenhouse gases, cloud seeding), indirect environmental amelioration (irrigation, reafforestation, smoke smudging), to genetic manipulations (cold, heat, drought and pest tolerant crops and livestock). Plant thermoregulation and its consequences are hardly understood in terms of climate change.

A new, dynamic and highly interdisciplinary, scientific approach to phytomicrometeorology is needed. The cast of players must range from theoretical physicists with interests in atmospheric thermodynamics, to climatologists, meteorologists, micrometeorologists, botanists of all stripes and eclectic ecologists.

With many organisations advocating the need for scientifically based policy, especially for national and international laws and accords on pressing environmental issues, it is vital that policymakers embrace broader perspectives than have been usually taken for initiating action. Governments around the world need to sponsor far-reaching and more expansive, approaches to environmental sciences, especially as they relate to the drivers of local to global climate change. The importance of vegetational thermoregulation in mitigating the effects of both cold and heat, i.e. plants as limited, but highly environmentally influential, homoeotherms, seems like an overlooked dimension to understanding the world's climate problems and in possibly seeking solutions.


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8 Sean T.Michaletz, Michael D.Weiser, JizhongZhou, MichaelKaspari, Brent R.Helliker, Brian J.Enquist. 2015. Plant Thermoregulation: Energetics, Trait-Environment Interactions, and Carbon Economics. TRENDS IN ECOLOGY & EVOLUTION Volume: 30 Issue: 12 Pages: 714-724.


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