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A few islands of preliminary research among a sea of unknown: moving plant ecophysiology forward in megadiverse countries

Report on the Symposium "Advances in Plant Ecophysiology," within the VII Mexican Ecology Congress, Sociedad Científica Mexicana de Ecología, Juriquilla, Querétaro, Mexico, 3 October 2019

Unas cuantas islas de investigación preliminar en un mar de incógnitas: avanzando la ecofisiología de plantas en países megadiversos

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Plant physiological ecology is not a new scientific discipline in Mexico. Indeed, ecophysiological research has been conducted in this country since at least 1976, when the late Carlos Vázquez-Yanes, a dear professor of some of us, first published his work on germination of tropical rainforest plants (Vázquez-Yanes 1976, Vázquez-Yanes & Orozco-Segovia 1984). Indeed, Prof. Vázquez-Yanes is considered the founder of Mexican plant ecophysiology. At present, however, the development of this discipline appears lagging relative to other Mexican ecological sciences. Factors contributing to this deceiving perception might include its technological dependence, the elevated costs of some research protocols, and the intrinsic difficulties of combining extensive fieldwork with a precise knowledge and use of first principles of physics and chemistry, which are essential for understanding physiological processes.

A principal intention of ecological sciences is to explain biodiversity: why are some species and not others found in certain places (Lambers *et al.* 2008). As an experimental science, plant ecophysiology focuses on the interactions among plants, the environment, and other biological species. In this context, the VII Mexican Ecology Congress focused on "addressing the complexity of nature." Some examples of how ecophysiology can address said complexity were discussed during the symposium.

From elucidating fundamental processes to anticipating climate change responses. A basic understanding of physiological functions is still lacking for many species. This is certainly the case for the establishment phase of ferns from the Mexican cloud forest (Oscar Briones, Instituto de Ecología AC, Xalapa, Ver., México). Although cloud forests receive large amounts of rainfall, the soil surface and tree branches are exposed to frequent periods of water scarcity that can cause mortality of gametophytes and young sporophytes of fern species. Experimental evidence with herbaceous, arborescent, and epiphytic ferns shows that the water requirement of spore germination is correlated with the distribution of the adult sporophyte in the forest and that the spores can germinate with very low light availability. In turn, gametophyte growth depends on multiple environmental conditions and resources, with amount of light, relative humidity, thickness of litter layer, and disturbance being most important. The distribution and abundance of sporophytes and spore physiology support the hypothesis that the coexistence of fern species in the cloud forest occurs by differentiation in the regeneration niche. However, ecological interactions during the establishment of gametophytes and young sporophytes are still virtually unknown.

Considering that ample portions of Mexico are arid or semiarid and that climate change scenarios anticipate an increase in air temperature and a decrease in annual precipitation in various regions of the country (Sáenz-Romero *et al*. 2010), current arid lands can be considered natural laboratories for studying plant responses to impending climate change. Water stress is one of the main selection factors in such regions, giving rise to different coping strategies. Plant responses to drought can actually be placed along an isohydric-anisohydric continnum, a conceptual axis that describes how plants regulate their water potential, based on their water relations strategies (Tardieu & Simonneau 1998). This framework integrates multiple components of water transport and stomatal regulation of water status, based on which, the anatomical, morphological, and physiological hydraulic characteristics of tree species of the Sonoran Desert with different phenology and age (young and adult plants) have been classified (Clara Tinoco-Ojanguren, Universidad Nacional Autónoma de México, Hermosillo, Son., Mexico), finding a clear expression of the different strategies of desert tree plants living under the same stress conditions. For young and adult plants, isohydric and anisohydric groups were clearly differentiated by their hydroscape area and phenology; both characteristics showed a high correlation with leaf and stem hydraulic characteristics and other important variables. Studies of several species growing under extreme conditions have provided important information of functional diversity and plant responses to climatic change.

While arid and semiarid lands are commonly associated with low primary productivity, studies across the arid northwestern Mexico over the past two decades have revealed otherwise (Alejandro E. Castellanos, Universidad de Sonora, Hermosillo, Son., Mexico). In particular, high maximum photosynthetic rates, leading to high ecosystem productivity, have been found across different vegetation types, including much simplified socio-ecosystems, such as pastures sown with the exotic buffelgrass. Thus, the current arid environment-low productivity paradigm needs to be revisited, in particular its relation to resource use efficiencies and nutrient stoichiometry interactions (Castellanos *et al*. 2018).

Ecophysiology in anthropic environments. Human activities, such as industrial manufacturing and the use of motor vehicles, release a substantial amount of pollutants to the environment, with dire consequences on biodiversity and human health (Rockström *et al*. 2009, Landrigan *et al*. 2017). For the particular case of carbon and nitrogen gaseous emissions, pollutants have specific isotopic signatures that depend on the source. For this reason, the spatial distribution of atmospheric pollution is traceable by means of the isotopic composition of the vegetation (Edison A. Díaz-Álvarez, Universidad Veracruzana, Xalapa, Ver., Mexico). For example, plants that take up carbon from anthropic sources show a significant reduction of their $\delta^{13}C$ values, while the $\delta^{15}N$ values tend to increase for plants exposed to nitrogen emissions from urban areas (Díaz-Álvarez & de la Barrera 2018). This is not the case, for instance, for orchids from a cloud forest in the Colombian Andes, which display $\delta^{15}N$ values indicative of negligible pollution despite their close proximity (less than 50 km) to the megalopolis of Bogotá (Díaz-Álvarez *et al*. 2019). Biomonitoring of atmospheric emissions can thus be useful for evaluating ecosystem integrity (Díaz-Álvarez *et al*. 2018).

Another important component of pollution is the release of heavy metals, such as lead, which is normally discharged in tropical coastal areas, where mangroves occur. Mangrove

forests, which are the most productive and diverse natural wetland systems, grow in a complex environmental network governed by salinity and hydro-period. To help restoring affected mangrove areas, we need to make detailed experiments to observe anatomical and physiological changes in controlled environments. From such experiments, mangrove species have been identified that accumulate lead in roots in the absence of salt, with a greater translocation to the leaves under conditions of higher salinity (José Luis Andrade, Centro de Investigación Científica de Yucatán, Mérida, Yuc., Mexico).

Habitat fragmentation is well characterized as having a negative effect on ecosystems and biodiversity (Aide *et al.* 2013, Haddad *et al.* 2015), but the physiological ecology effects on tropical plants are hardly documented, as discussed for ecosystems within the Yucatan Peninsula (Casandra Reyes-García, Centro de Investigación Científica de Yucatán, Mérida, Yuc., Mexico). Permanent plots set up across the Peninsula show that forests and coastal sand dune scrubs in the north of the Peninsula are experiencing higher population decline in both trees and epiphytic bromeliads, compared to those in the southern region. The northern region is highly fragmented, mainly as a result of urbanization, which is especially grave for coastal dune communities (Martínez *et al.* 2014). There are differences among susceptible and resilient species. For example, trees with higher water demand, associated with permanent water table access, are having higher mortality. This raises the question whether the water table contamination and excessive aquifer exploitation are reducing tree access and/or affecting water quality. The most affected trees are also those that host the highest numbers of epiphytic bromeliads, in turn affecting their populations.

Parallel to what occurs in urban ecosystems, agricultural landscapes display a reduction of biological species and ecosystem functions stemming from land use change, greenhouse gas emissions, and agrochemical pollution (McDonald 2010). However, agriculture is also one of the most vulnerable sectors to global environmental change, as agricultural operations greatly depend on certain climatological regularity (de la Barrera 2016). Considering that food is a topic that everybody has some familiarity with, it can be a useful heuristic for bringing biodiversity to the public discourse, just like "global warming" has become a well-known environmental issue (Erick de la Barrera, Universidad Nacional Autónoma de México, Morelia, Mich., Mexico).

Moving forward. A logical starting point for developing an action plan for further advancement of plant ecophysiology is a two-fold diagnosis: determine the scope and urgency of environmental questions and problems that the discipline can answer. However, despite that the combined work of the research groups participating in the symposium has considered a few hundred different species over the past several decades and various studies describing our current knowledge on plant physiological diversity from different ecosystems have already been published (Castellanos-Villegas *et al.* 2010, Tinoco-Ojanguren *et al.* 2018), the syntheses presented in the symposium should still be considered preliminary, as they represent a minuscule fraction of plant biodiversity, *i.e.*, less than 3 % of the species from the Sonoran Desert, a region with a high frequency of endemism (*Shreve* & Wiggings 1964), and less than 3 % of the species from the Yucatán Peninsula, a region with high rates of deforestation (Valdez-Hernández *et al.* 2015). It is almost like a "few islands of knowledge among a sea of unknown". We identified a need to train more ecophysiologists to work in the different parts of the country. As an initial step, we are releasing a website at http://ecofisiologia.mx/, as a point of access for sharing new research, information on graduate programs, and other academic activities.

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