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Drylands: unexpected plant diversity enables adaptation to extreme climates

Three scientists from INRAE, the CNRS and the King Abdullah University of Science and Technology in Saudi Arabia have coordinated a large-scale international study involving 120 scientists from 27 countries to understand how the plants found in drylands have adapted to these extreme habitats. For 8 years, the teams collected samples from several hundred selected dryland plots across six continents, enabling the analysis of over 1300 sets of observations of 300+ plant species, a first on this scale. The results, published in Nature, show that plants in arid zones adopt many different adaptation strategies and that, surprisingly, this diversity increases with aridity levels. The isolation of these plants in more arid zones would appear to have reduced competition between species, allowing them to express a diversity of forms and functions that is globally unique, displaying double the diversity found in more temperate zones. This study sheds new light on our understanding of plant architecture, plant adaptation to extreme habitats, historical plant colonisation of terrestrial environments, and the capacity of plants to respond to current global changes.

The Earth is home to a diversity of plants with highly varied forms and functions. This extraordinary morphological, physiological and biochemical diversity determines how plants adapt and respond to ongoing global changes, with significant consequences for the functioning of ecosystems. Yet, 90% of current knowledge on the functional diversity of plants concerns only agricultural ecosystems and temperate zones. By contrast, drylands (see inset), making up 45% of the Earth's terrestrial area, remain underrepresented in the data. These important zones are now directly threatened by increases in aridity, grazing pressure and desertification. We need to understand how plants respond to such pressures before we can establish the possible future evolution of these fragile ecosystems in terms of their biodiversity and functioning. To meet this urgent need, an international team of 120 scientists from 27 countries has carried out the first worldwide investigation of the functional diversity of plants in arid zones.

Having developed a standardised sampling protocol, the scientists collected and processed samples from the 301 plant species found across 326 representative plots from all continents (other than Antarctica) to characterise the functional diversity of the zones, generating a total of 1347 full sets of trait observations for analysis. Particular attention was paid to the characterisation of the plant elementome, that is, the diversity of chemical elements and trace elements (such as nitrogen, phosphorus, calcium, magnesium and zinc) found in plants, as these often-unrecorded traits exert a strong influence on how the latter function. Overall, the study involved more than 130 000 individual plant trait measurements.

A key hypothesis at the start of the study had been that aridity would reduce the diversity of plants through selection, leaving only those species capable of tolerating extreme water scarcity and heat stress. However, we found the opposite to be the case in the most arid rangelands of the planet, where plants instead exhibit a wide range of individual adaptation strategies. For example, some plants have developed high calcium levels, strengthening cell walls as a protection against desiccation. Others contain high concentrations of salt, reducing transpiration. Although fewer species are observed at local scale than in other regions of the planet (in temperate or tropical zones), plants in arid zones display an extraordinary diversity of forms, sizes and functioning, double that in more temperate climatic zones. This increase in trait diversity occurs abruptly at the point where rainfall volumes drop below the annual threshold of 400 mm. This is also the threshold for a pronounced decline in plant cover and the appearance of large areas of bare soil. To explain this phenomenon, the study's authors suggest that the loss of plant cover leads to 'plant loneliness syndrome', where increased isolation and reduced competition for resources produces high degrees of trait uniqueness and functional diversity that are globally exceptional. This adaptive diversity could equally reflect complex evolutionary histories dating back to the initial colonisation of terrestrial habitats by plants more than 500 million years ago, when these habitats presented extreme conditions for living organisms.

This study reveals the importance of drylands as a global reservoir of functional diversity in plants. It provides a fresh lens through which to view plant architecture, the adaptation of plants to extreme habitats, historical plant colonisation of terrestrial environments, and the capacity of plants to respond to current global changes.

What are drylands?

Drylands are defined as tropical and temperate zones with an aridity value below 0.65. They cover 45% of the Earth's terrestrial area and are home to a third of the global human population. They include sub-humid, semi-arid, arid and hyper-arid ecosystems such as the Mediterranean landscape, steppes, savannahs and deserts.

Reference

Gross N., T. Maestre F., Liancourt P. et al. (2024). Unforeseen plant phenotypic diversity in a dry and grazed world. *Nature,* DOI : https://doi.org/10.1038/s41586-024-07731-3

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