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EDITORIAL

Insights and benefits from monocot palaeobiology: DNA, fossils and phylogenetic analyses

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In the last decade, there has been an increase in the integration of fossil data with molecular studies to answer critical questions on the origin, diversification and relationships of various plant groups and for the calibration of the tree of life. This is because the fossil record holds unique and considerable power for addressing these questions as fossils provide solid data on the presence, absence and distribution of taxa over the course of the history of the Earth. From them, it is possible to infer when, how and why changes have occurred, which has impacts on other areas of research, such as the prediction of future ecosystem responses to anthropogenic climate change. The fossil record is also crucial in systematic studies, which cannot be complete without the unique insights into diversity and novel combinations of characters offered by extinct taxa. Indeed, fossils are fundamental for the testing and more robust resolution of hypotheses based on morphological and molecular evidence alone.

Undoubtedly, further integration of palaeo- and neobotanical studies, with greater awareness of the strengths and weaknesses of the fossil record, is needed. This is particularly evident for the monocotyledon flowering plants. The monocots, which form a monophyletic clade sister to the eudicots (APG III, 2009), constitute *c*. 22% of angiosperm species, with *c*. 3000 genera and 60 000 species in *c*. 70 families. They include some of the most economically and ecologically important groups of plants, such as grasses (Poaceae; including bamboo, maize and wheat), palms (Arecaceae; including date palm, coconuts and oil palm) and the only marine angiosperms, the seagrasses (various families of Alismatales). Nevertheless, for many decades, the monocot fossil record was considered scarce because of the low probability of fossilization (being generally herbaceous, with annual reproduction and insect pollination, among other reasons) as pointed out previously (Daghlian, 1981; Herendeen & Crane, 1995; Gandolfo, Nixon & Crepet, 2000; Stockey, 2006; Smith, 2013). This, added to the fact that the putative apomorphies listed for the group (see APG III, 2009) are not unique to the monocots, and almost none is suitable for fossilization, makes the recognition of fossil monocots challenging. Nevertheless, fossils that preserve and show specific combinations of characters can be related with confidence to extant taxa and, although monocot palaeobiology still remains understudied as a result of these issues, significant advances are constantly being made.

During the Fifth International Conference on Comparative Biology of Monocotyledons (Monocots V), held in New York City in 2013, a symposium on monocot palaeobiology was organized with the idea of bringing together researchers using a historical approach in their studies, including the investigation of the timing and evolution of lineages, origins of major ecosystems and biogeography, with the main goal of promoting the benefits of monocot palaeobiological studies and demonstrating how the fossil record can be used in combination with morphological and molecular evidence to address important questions. The symposium was dedicated to highlighting the recent advances made in understanding the monocot fossil record and its critical value in combination with extant taxa and modern techniques for addressing the origin, diversification, relationships and biogeography of the flowering plants in general.

In this issue, the contributions of several participants from this symposium, which in one way or another used monocot fossils, are presented. The information offered in the following pages reflects the most advanced knowledge so far on the monocot fossil record and its relationships with modern taxa.

In the paper by Iles *et al*. (2015), a detailed evaluation of 34 monocot fossils, representing 19 families and eight orders, is presented. This review includes not only an assessment of the systematic position of the fossils, but also the age of the sediments in which each of the fossils was collected, synthesizing which of these particular fossils are suitable for the calibration of the ages of major monocot clades. The approach of Hertweck *et al*. (2015) was to use monocot fossils as calibration points for the provision of phylogenetic, divergence time and diversification estimates based on the analysis of three genomic partitions in monocots, in particular for the orders Poales and Asparagales.

The contributions of Benedict *et al*. (2015), Conran *et al*. (2015a, b), Kvaček & Smith (2015) and Thomas & Boura (2015) represent the types of study that are fundamental for interpreting the fossil record, understanding the origins of lineages and character evolution, inferring diversification patterns and palaeobiogeography, reconstructing palaeoenvironments and demonstrating that advances in interpreting the monocot fossil record will come only with a further understanding of the morphology and anatomy of extant monocots. Benedict *et al*. (2015) examine the seed morphoanatomy of subfamily Alpinioideae (Zingiberaceae, Zingiberales) and show greater structural variation, some of which is taxonomically significant, than had previously been documented in this group, with implications for the recognition of fossils of Zingiberaceae. Conran *et al*. (2015a) review the fossil record of monocots in Australia and New Zealand, which has expanded significantly in recent years, providing novel data on the origin and occurrences of several smaller monocot groups from the Southern Hemisphere. The fossil record of monocots based on pollen from New Zealand is also reviewed by Conran *et al*. (2015b); this constitutes a major accomplishment as the pollen of monocots is similar to that of early diverging dicots, but most important are the implications for explaining the past climate and environments of New Zealand during a period of time with great geological changes. Kvaček & Smith (2015) investigate a fossil that had been interpreted as a ginger (Zingiberales); if correct, this would have made it one of the oldest and therefore important to evolutionary studies of the group, but comparative leaf anatomy shows that it does not belong in this group, instead representing a fossil of Araceae. This highlights the importance of the critical re-investigation of fossil taxa before using them in broader studies. Finally, Thomas & Boura (2015) evaluate palm stem anatomical characters and their phylogenetic and ecological significance, finding that tropical forest palms and non-tropical forest palms, largely correlated to two of the major subfamilies, have distinct anatomical features. These types of character will help us to re-interpret some of the extensive fossil palm stem record for additional systematic and ecological data.

In summary, these papers demonstrate clearly that the fossil record of monocots is abundant and constantly being improved with new studies on both fossil and extant taxa. Palaeobotanical studies provide critical, concrete data for answering questions on the origin, evolution and distribution of this important group of flowering plants and for understanding palaeoenvironments and ecosystem change. This symposium highlights the usefulness of studying the palaeobotanical record, illustrating that this is an exciting time as our knowledge improves and further integrative studies are carried out.

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