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Evolutionary history of fumitories (subfamily Fumarioideae, Papaveraceae): An old story shaped by the main geological and climatic events in the Northern Hemisphere ☆

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ABSTRACT

Fumitories (subfamily Fumarioideae, Papaveraceae) represent, by their wide mainly northern temperate distribution (also present in South Africa) a suitable plant group to use as a model system for studying biogeographical links between floristic regions of the Northern Hemisphere and also the Southern Hemisphere Cape region. However, the phylogeny of the entire Fumarioideae subfamily is not totally known. In this work, we infer a molecular phylogeny of Fumarioideae, which we use to interpret the biogeographical patterns in the subfamily and to establish biogeographical links between floristic regions, such as those suggested by its different inter- and intra-continental disjunctions. The tribe Hypecoeae is the sister group of tribe Fumarieae, this latter holding a basal grade of monotypic or few-species genera with bisymmetric flowers, and a core group, Core Fumarieae, of more specious rich genera with zygomorphic flowers. The biogeographical analysis shows a subfamily that originated in East Asia at the end of the Early Cretaceous. From here, ancestral range expansions followed three different directions, one at the beginning of the Late Cretaceous by the ancestor of tribe Hypecoeae towards central Asia, and two during the Cretaceous–Palaeogene transition towards western North America and Indochina by the ancestor of the tribe Fumarieae. The ancestor of Core Fumarieae expanded its range from East Asia into the Himalayas before to the middle Eocene. The uplifts of the Qinghai-Tibetan Plateau together with the zonal climate pattern of the Palaeogene are suggested to be responsible both for the accelerated diversification rate resulting in the origin of the basal lineages of Core Fumarieae as well as for the westward migration of the ancestor of Fumarieae s.str. into the Irano-Turanian region. From here, this latter group reached South Africa during late Eocene and Mediterranean basin during Oligocene. There were two colonization waves of the Mediterranean following two different routes: a northern route during the early Oligocene by the subtribe Sarcocapninae, probably facilitated by the land bridge resulting of the Mediterranean microplate accretion; and a southern route into North Africa, through the Gomphotherium land bridge, taken by the subtribe Fumariinae between late Oligocene and middle Miocene.

1. Introduction

A key aspect of the biogeographical studies is the elucidation of historical connections between different floristic regions to understand the genesis of plant diversity in these floristic regions (Linder, 2005). The establishment of biogeographical links between floristic regions requires the evaluation of the current patterns of plant distribution (MacLaughlin, 1994), and therefore key taxa need to be studied. In this sense, the subfamily Fumarioideae Eaton (Papaveraceae Juss.) represents a suitable plant group to use as a model system for studying biogeographical links between Northern Hemisphere floristic regions, involving also the Southern Hemisphere Cape region. On the one hand, Fumarioideae shows a wide, mainly northern temperate distribution (also present in South Africa; Fig. 1) and, on the other hand, its species occupy both forest floor and open-dry habitats, being present in floristic regions

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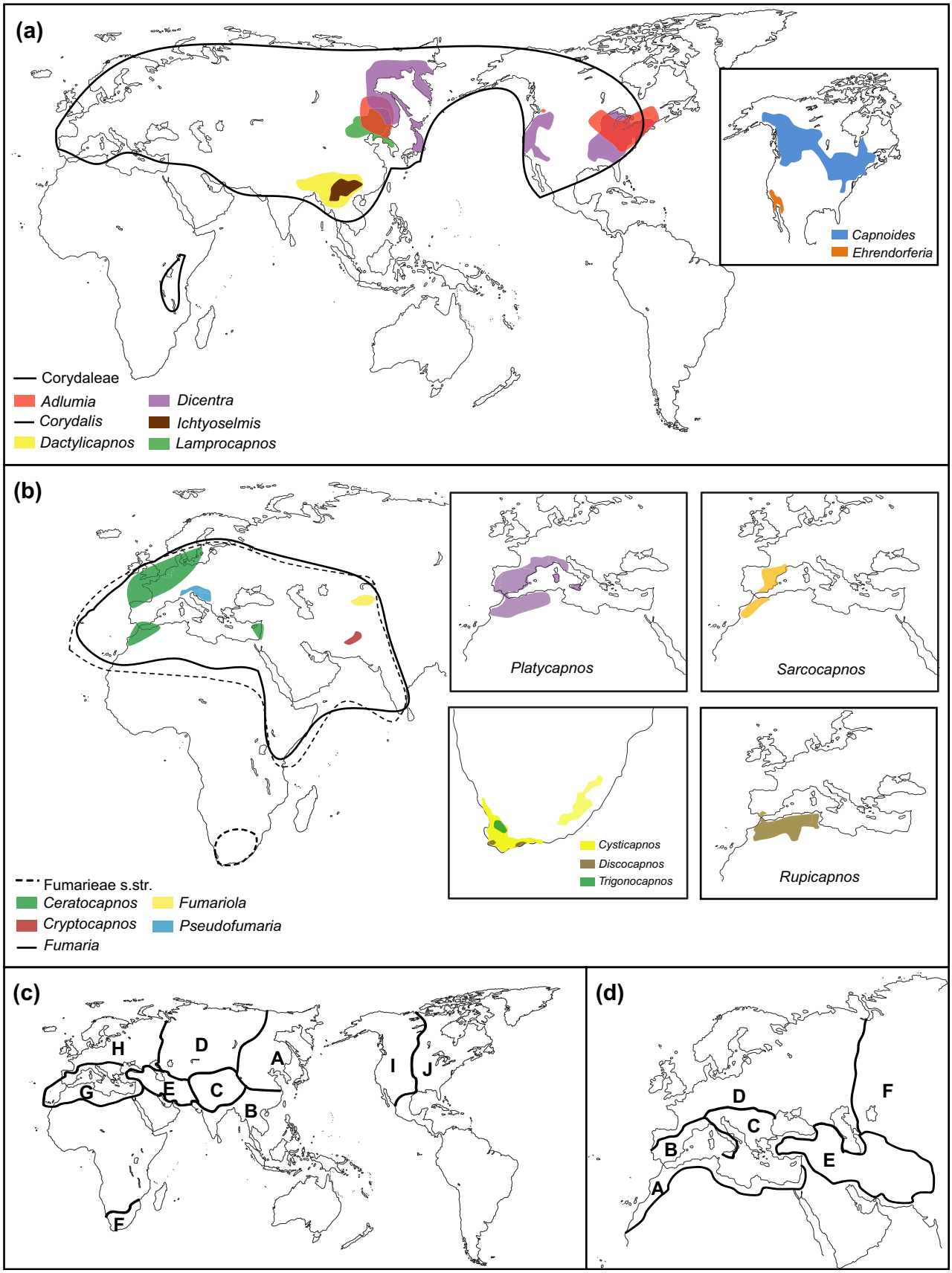

Fig. 1. Geographic distribution of tribe Fumarieae and selected areas. (a) Distribution of genera from tribe Corydaleae *sensu* Lidén. (b) Distribution of genera from Fumarieae s.str. (c) Areas defined for the ancestral range reconstruction analysis of the subfamily Fumarioideae: A, East Asia; B, Indochina; C, Himalayas; D, Central Asia; E, Irano-Turanian, F, South Africa; G, Mediterranean; H, Europe; I, western North America; J, eastern North America. (d) Areas defined in the ancestral range-reconstruction analysis focusing on the Mediterranean taxa of Fumarieae s.str.: A, southern Mediterranean basin; B, Western Mediterranean; C, Eastern Mediterranean; D, Central and Northern Europe; E, Irano-Turanian; F, Central Asia.