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1 **Young, disturbed, unsaturated: accelerating species accumulation in the enigmatic tropical alpine**  
2 **flora on the African sky islands**

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22

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25 phylogenetic trees and analysis settings are available via the Open Data Framework, [osf.io/brmjg](https://osf.io/brmjg), including  
26 reference to the respective original publications on which alignments and settings were based and respective  
27 initial publications are cited. Code used for this study is also available via the Open Data Framework  
28 ([osf.io/brmjg](https://osf.io/brmjg)).

29

30 **This PDF file includes:**

31 Main Text

32 Figures 1 to 3

33 **Abstract**

34 Tropical alpine floras are renowned for high endemism, spectacular giant rosette plants testifying to  
35 convergent adaptation to harsh climates with nightly frosts, and recruitment dominated by long-distance  
36 dispersal from remote areas. In contrast to the larger, more recent (late Miocene onwards) and contiguous  
37 expanses of tropical alpine habitat in South America, the tropical alpine flora in Africa is extremely  
38 fragmented across small patches on distant mountains of variable age (Oligocene onwards). How this has  
39 affected the colonization and diversification history of the highly endemic but species-poor afroalpine flora is  
40 not well known. Here we infer phylogenetic relationships of ~20% of its species using novel genome  
41 skimming data and published matrices and infer a timeframe for species origins in the afroalpine region  
42 using fossil-calibrated molecular clocks. Although some of the mountains are old, and although stem node  
43 ages may substantially predate colonization, most lineages appear to have colonized the afroalpine during  
44 the last 5 or 10 My. The accumulation of species increased exponentially towards the present. Taken  
45 together with recent reports of extremely low intra-population genetic diversity and recent inter-mountain  
46 population divergence, this points to a young, unsaturated, and dynamic island scenario. Habitat disturbance  
47 caused by the Pleistocene climate oscillations likely induced cycles of colonization, speciation, extinction,  
48 and recolonization. This study contributes to our understanding of differences in the histories of recruitment  
49 on different tropical sky islands and on oceanic islands, providing insight into the general processes shaping  
50 their remarkable floras.

51 **Significance Statement**

52 Resilience is required to withstand or mitigate the effect of human-induced climate change. Today whole  
53 ecosystems are affected by climate change, but our understanding of their evolution and natural response is  
54 limited, often restricted to individual populations or species. The enigmatic flora on the tops of the African sky  
55 islands is isolated and unique, showing striking adaptations to the harsh tropical alpine conditions. Here we  
56 analyze genome data from a large fraction of afroalpine plants and show that this remarkable flora has a  
57 dynamic history with frequent colonizations and extinctions, most likely caused by previous natural climate  
58 changes during the ice age cycles. The flora will be particularly vulnerable to human-induced climate  
59 warming reducing alpine habitat into successively smaller areas.

60

61 **Main text**

62 **Introduction**

63 The enigmatic floras restricted to high mountains in the tropics provide a unique opportunity to study the  
64 timing and impact of dispersal, establishment, and diversification, allowing us insight into the evolution of  
65 whole floras. These unique, often startlingly rich floras contrast starkly in growth forms and species  
66 compositions with those found in the tropical climates closer to sea level (1, 2). Across the tropics, the upper  
67 elevations of the high mountains in South America, Southeast Asia, and Africa (3) experience similar harsh  
68 environmental conditions: year-round high insolation and extreme diurnal rather than seasonal variation in  
69 temperature (4). The archetypical dwarf shrub forms (e.g., *Alchemilla*, *Lachemilla*) and giant rosette forms  
70 (e.g., *Dendrosenecio*, *Espeletia*) typically found in these habitats provide classic examples of convergent  
71 adaptations independently derived in distantly related plant groups (5, 6).

72 Whereas most mountains that harbor tropical alpine floras are the result of recent uplift (late Miocene, 11.6  
73 million years ago [Ma] onwards; (7, 8)), the high mountains in tropical Africa vary in age from about 40 Ma to  
74 1 Ma (9), with the origins of volcanoes in the rift zone of East Africa and Ethiopia likely resulting in isolated  
75 alpine conditions from the early Miocene (23 Ma) onwards (10). This places maximum bounds on the ages of  
76 present-day species communities but leaves open questions as to the rate with which plants colonized the  
77 emerging high-elevation niches and the relative roles of dispersal leading to successful establishment, *in situ*  
78 diversification, and extinction in generating present day species diversity and endemism (11, 12).  
79

80 These factors can be expected to differ markedly between tropical mountainous regions that differ in age,  
81 spatial extent, and degree of connectivity through time. The rich flora of the high Andes extends thousands  
82 of kilometers through the Americas, with the potential for north-south exchange with 'flickering connectivity'  
83 across wide areas caused by climatic change (13). By contrast, the much less species-rich afroalpine flora  
84 (Figure 1a) is typically restricted to solitary mountains isolated from each other by vast expanses of tropical  
85 lowland vegetation (14). These lowland barriers, in place since the origins of the mountains, largely persisted  
86 throughout the glaciations, despite the eight times greater than present day area of afroalpine habitat  
87 inferred for the Last Glacial Maximum (14). Population genetic studies of several afroalpine plant species  
88 have shown strong inter-mountain isolation of populations with genetic exchange limited to rare long-  
89 distance dispersal events rather than ecological connectivity (15). The pattern of recruitment to the floras on  
90 such isolated continental 'sky islands' might be most similar to that on oceanic islands such as Hawaii (11).  
91

91

92 **Figure 1.** Geographic distribution and recruitment to the afroalpine flora (>3500 m). A) Major mountains and  
93 mountain regions in eastern Africa. The Great Rift Valley is shown as stippled lines. B) Numbers of  
94 afroalpine colonization (orange) and *in situ* diversification (olive) events per 0.5 Ma time bin. Colonizations,  
95 here represented by stem nodes, must be interpreted as maximum age estimates for events that are more  
96 recent to an unknown degree. C) Stem age estimates of afroalpine species in relation to mountain orogeny  
97 (gray bars; Gehrke et al. (7)). Species are colored according to family. Local endemics (species restricted to  
98 one or two mountains) are mapped to individual mountains; the remaining species are classified as 'eastern  
99 African endemics' ('endemicEA') or as 'widespread'. Age estimates in A) and B) represent both Bayesian  
100 median node ages of individual seed plant clades.

101

102 The key to inferring the sequence and timing of the dispersal and speciation events that founded a biome is  
103 comprehensively sampled time-calibrated phylogenetic trees. The afroalpine flora is dominated by genera  
104 that are well known from their numerous species distributed across both northern and southern temperate  
105 regions. Case studies (e.g., *Alchemilla*, *Carex*, *Helichrysum* and *Ranunculus* (15)) have begun to paint a  
106 picture of multiple independent colonizations from the late Miocene c. 10 Ma onwards, particularly from  
107 remote northern as well as southern temperate areas, followed by limited *in situ* diversification (15). A deeper  
108 understanding of the process of recruitment to tropical alpine floras requires a broad comparison of multiple  
109 independent groups (12), but past comparisons in the afroalpine region (11) have been limited by the state of  
110 phylogenetic knowledge across the flora. Here, we address this limitation, analyzing multiple lineages from  
111 the afroalpine flora based on new field-collected material and data from high throughput sequencing.

112

## 113 Results

114 We collected new material during field expeditions to all major mountains in East Africa and Ethiopia and  
115 gathered novel sequence data for 92 species belonging to 33 genera and 13 families (SI Appendix 1, Table  
116 S1). The species were selected to represent 1) both local and regional endemics as well as more  
117 widespread species, 2) species-rich as well as species-poor lineages in the afroalpine flora, 3) different  
118 habitats, and 4) those not previously included in phylogenetic studies. We used genome skimming (16) to  
119 retrieve high copy chloroplast genomes and nuclear ribosomal cistron, obtaining 1.8-9.8 million reads per  
120 sample (NCBI Sequence Read Archive (SRA) database under the BioProject ID PRJNA766027).

121 We used an analytical pipeline to update alignments from published analyses of 1) >35,000 species of seed  
122 plants represented by two chloroplast markers (17) and 2) individual seed plant clades with chloroplast  
123 and/or nuclear sequence data (6, 18–29); SI Appendix S1 Table S3). Our approach (SI Appendix 1) allowed  
124 us to supplement the new data with similar sequences from GenBank, thus increasing the number of  
125 afroalpine species to a total of 102 (19 of which were represented with two or more accessions, SI Appendix  
126 1, Table S2-S4), representing 20% of the 515 species, 18% of the 90 genera and 26% of the 50 families  
127 known from the flora (9) plus non-afroalpine outgroups (SI Appendix 1 Table S3). To infer time windows for  
128 colonization of the afroalpine region and *in situ* diversification within it, we used molecular dating analyses, of  
129 which most were calibrated using fossil evidence. We summarized ages for stem and crown nodes of  
130 afroalpine species and clades. To test the robustness of the results we compared these two datasets and  
131 two different molecular dating methods: seed plant-wide analyses with penalized likelihood (PL), and  
132 individual seed plant clades with both PL and Bayesian statistics (the latter incorporating phylogenetic  
133 uncertainty; matrices and phylogenetic trees in text are available via the Open Data Framework (28) and  
134 figure format phylogenies are presented in SI Appendix 2). Thus, we obtained up to three stem age  
135 estimates for each of the 102 afroalpine species (SI Appendix 1, Table S2), depending on differences in  
136 sampling across datasets, with each approach delivering 91 to 93 dated nodes (representing common  
137 ancestors of afroalpine species/populations and their closest relatives).  
138

139 Our phylogenies revealed that the closest relatives of afroalpine lineages were geographically distant, nested  
140 within wider temperate clades, from which we assumed that afroalpine colonization occurred after  
141 divergence of afroalpine lineages from their most recent common ancestors. We found evidence for  
142 divergent lineages (supported non-monophyly) within some afroalpine species (SI Appendix 1, Table S4),  
143 and more independent dispersals into the afroalpine region than expected if each genus only dispersed once  
144 (SI Appendix 1, Table S5). Each of the genera *Lobelia*, *Ranunculus*, and *Swertia*, for example, colonized the  
145 afroalpine region at least twice independently.

146 The molecular dating results enabled us to place the assemblage of multiple afroalpine plant lineages into a  
147 unified timeframe (Figure 2). Stem node ages may thus substantially predate dispersals (31), but we  
148 nevertheless found a range of ages concentrated towards the present (Figure 1b and c). Of a total of 43  
149 stem nodes of species and clades representing the maximum bounds for times of colonization of the  
150 afroalpine, 58%, 68% and 83% fell within the last 5 million years (My; individual seed plant clades BEAST2  
151 and PL, and seed-plant wide PL) and 72%, 89% and 88% within in the last 10 My. None were consistently  
152 older than 15 My (SI Appendix 1, Table S6). Similar to Rabosky et al. (32), we found no obvious relationship  
153 between the timing of arrival in the afroalpine region and subsequent *in situ* diversification, as illustrated by  
154 the diversifications of both early- and late-arriving lineages of *Lobelia* and of *Swertia* (SI Appendix 1, Figure  
155 S1).

156

157 **Figure 2.** Seed plant-wide dated phylogeny based on our new data combined with the original matrix of  
158 Janssens et al. (17) with afroalpine species indicated in red type and those of the original dataset further  
159 indicated with a red colored star. Clades not including afroalpine species are pruned to crown clade nodes  
160 to increase readability. Afroalpine clades supported by posterior probability  $\geq 0.95$  in the BEAST2 analyses  
161 of the individual seed plant clades are indicated with blue stars. Circles indicate time in million years before  
162 present. Photographs show examples of afroalpine species: A) *Viola eminii*, B) *Swertia crassiuscula*, C)  
163 *Lobelia telekii* and D) *Euryops browneii* (photographs: B. Gehrke, available under a creative commons CC-  
164 BY-NC license at <https://www.inaturalist.org/>).

165

166 We found that most afroalpine lineages diverged from their non-afroalpine relatives after the end of the major  
167 mountain uplifting processes (Figure 1b, the number of colonization events). More than 80% of those  
168 included in the analyses of individual seed plant clades diverged within the last 5 My, with a maximum of  
169 only seven of our 102 sampled species dating back to the early phases of afroalpine habitat existence (SI  
170 Appendix 1, Table S7). Those with narrow distributions typically arrived or diverged from their sister lineages  
171 after the final uplift of the mountain(s) to which they are currently restricted (Figure 1c). The distribution of  
172 node ages within independent afroalpine lineages, as summarized across independent clades, showed  
173 increase towards the present (Figure 1b and c). Species accumulation increased exponentially over time:  
174 fitting our data to an exponential distribution revealed high  $R^2$  values (individual clades BEAST2: 0.98;  
175 individual clades treePL: 0.97; seed plant wide treePL: 0.96; Figure 3). The data showed distinct changes in  
176 accumulation rates through time that were not apparent in modeled curves (Figure 3 and SI Appendix 1,  
177 Figure S2). According to an exponential diversification model, we would only expect a change in rates close  
178 to the present, but we also detected changes that occurred earlier. Depending on the dating method,  
179 changes began around 6 to 5 Ma, and became more frequent within the last 2.5 Ma (Figure 3).

180

181 **Figure 3.** Species accumulation over time in the afroalpine region based on historical lineage diversity esti-  
182 mates and relative branching times obtained from the time-calibrated phylogenies. These plots differ from  
183 standard lineage through time plots in that species accumulation in a region results from colonization events  
184 in addition to regional diversification of multiple independent lineages. Row 1: Number of colonization/diversi-  
185 fication events over time. The black dotted line marks a constant rate model and the black dashed line an  
186 exponential model. Row 2: Change in number of colonization/diversification events over time calculated as a  
187 difference quotient (see text). The red line shows the maximum difference of change in a constant model.  
188 Row 3: number of colonization/ diversification events per 0.5-million-year intervals. Age estimates were sub-  
189 sampled to 50% 200 times. Results for our three different dating methods are shown in A). Simulated results  
190 are shown in B) (exponential model) and C) (constant model), with the left columns representing 200 itera-  
191 tions (one highlighted in blue), and right columns a single iteration subsampled to 50%.

192

## 193 Discussion

194 Although the final uplift of some of the tropical African high mountains date back to the Oligocene (>30 Ma),  
195 and although our stem node ages constitute a considerably conservative estimate for estimating the timing of  
196 colonization of afroalpine plant lineages, we found that most lineages must have colonized the afroalpine  
197 during the last 5 or 10 My. Based on estimated ages of 20% of the afroalpine flora, we show that the  
198 assembly of this flora accelerated towards the present, with a rate of species accumulation within the flora  
199 increasing exponentially (Figure 3). This suggests that the afroalpine region remains below its carrying  
200 capacity for species diversity.

201 We might expect colonization events to accumulate steadily over the time that habitat is available, or even to  
202 tail off towards the present as niches are filled. Our finding of concentrations of both afroalpine colonization  
203 and *in situ* diversification events towards the present (Figure 1b) appears, therefore, to point to a substantial  
204 impact of extinction on the composition of the flora. The pattern we observe is consistent with the extremely  
205 low intra-population genetic diversity and recent inter-mountain population divergence reported for many  
206 individual afroalpine species (15). Palynological and macrocharcoal records from the Bale Mountains in  
207 Ethiopia show a marked reduction of afroalpine communities around 12.5 thousand years before present  
208 (Ka) (33) and paleoenvironmental data from lake cores imply a major climatic incursion in tropical East Africa  
209 around 11.5 Ka (34), suggesting climate induced extinction of afroalpine plants after the last glaciation. Our  
210 results thus provide evidence from across the flora in line with the emerging view of the afroalpine flora as  
211 the product of cycles of colonization, speciation, extinction, and recolonization induced by the Pleistocene  
212 climate oscillations, resulting in unsaturated, fragile communities of species depauperated by frequent  
213 genetic bottlenecks (15).

214 The occurrence of several spikes in species accumulation through the last 7 Ma (Figure 3A row B) suggests  
215 that net species accumulation across lineages within the flora may have been impacted by common factors  
216 such as climate change and mountain uplifting. The precision of our age estimates is not, however, sufficient  
217 to address the effect on *in situ* diversification in more detail. Future analyses could narrow down such  
218 estimates through a combination of denser taxon sampling, coalescence-based dating of species (35), and

219 dating the evolution of key adaptive traits (36), and could incorporate model-based biogeographic analysis to  
220 assess lag times between origins of habitat, colonizations, and *in situ* diversification in individual clades (37).

221 How does the recruitment of the afroalpine flora compare to that of other tropical alpine floras, and to that of  
222 comparably isolated oceanic island floras? The stages of mountain building that pushed colonizable  
223 substrate out of the tropical climate zone were mostly recent in South America and South East Asia, taking  
224 place from the mid-Miocene onwards (7, 8). Global cooling cycles that further contributed to shaping current  
225 day occurrence patterns of tropical-alpine plants intensified since the start of the Quaternary glaciations  
226 about 2.6 million years ago (38). This is consistent with recent dating studies from the tropical alpine flora in  
227 South America (39). Here we show that most of the afroalpine flora also dates to the Plio-Pleistocene (Figure  
228 1), in spite of the much more variable ages of the individual African high mountains, with only few earlier-  
229 arriving lineages.

230 Thus, endemic alpine species diversity is recent in origin across the tropics, making these regions  
231 evolutionary cradles of biological diversity (12, 39). The Andean tropical alpine flora is however much richer  
232 in species than the afroalpine flora and includes hyper-diverse clades such as *Calceolaria*, *Espeletia s.s.*,  
233 *Lupinus* and *Pentacalia* (40). Such large *in situ* species radiations are virtually absent from the afroalpine  
234 flora, probably reflecting the much smaller spatial extent and greater fragmentation of the tropical alpine  
235 habitat in Africa. The high species turnover across the Andean Páramos versus the homogeneity of species  
236 compositions across the isolated fragments of afroalpine habitat is consistent with the hypothesis that  
237 periodic connectivity drives diversification (13). An equivalent analysis of species accumulation in the  
238 Páramo is needed to further compare patterns of past extinction and resilience for tropical alpine floras in  
239 general.

240  
241 The history of recruitment and evolution of the afroalpine flora also differs from that of comparable oceanic  
242 islands. The Macaronesian archipelagos show lower levels of endemism (20%) than tropical alpine regions  
243 (> 60%), probably because they are closer to the source of their floristic diversity, northern Africa. Contrary  
244 to the afroalpine flora but similar to the tropical Andean flora, Macaronesia shows striking species radiations  
245 following establishment in many clades (e.g., *Aeonium* and *Echium*; 41, 42), perhaps due to a combination of  
246 greater age and lower extinction rates given more stable oceanic climates (43). The islands of Hawaii are  
247 more similar to the afroalpine mountains in terms of their degree of isolation, but the estimated <500 km<sup>2</sup> of  
248 vegetation at high elevation in Hawaii, home to just 13 tropical alpine species, is much smaller (11). This is  
249 despite a potentially greater age of the Hawaiian flora, which may originate from older, now submerged,  
250 islands of the chain (44).

251 The differences between the afroalpine flora and other island- and alpine-like floras across the tropics serve  
252 to highlight their unique histories and unique diversity. These floras, with their characteristic giant rosette  
253 plants and dwarf shrubs, have evolved independently in similar extreme environments against common  
254 backgrounds of climatic fluctuation and resulting species diversifications. Our results show that even in the  
255 older African mountains, the present day tropical alpine flora has assembled remarkably recently, most likely  
256 repopulating habitats impacted by extinctions of earlier colonizers. However, the sheer speed and  
257 compounding impact of the current human-caused habitat destruction and climate change is unprecedented  
258 in this evolutionary context. The afroalpine flora inhabits a narrow band of suitable conditions that are  
259 already limited to the upper extremes of the mountains, and it is susceptible to severe and increasing  
260 human-induced impacts such as overgrazing. The already decreasing extent of intact alpine habitat is  
261 projected to be pushed higher into smaller areas and might disappear altogether as the climate continues to  
262 warm (15, 45).

263

## 264 **Materials and Methods**

265 We collected plant material during field expeditions to all major eastern African sky islands (Ethiopia,  
266 Tanzania, Kenya, Uganda). Vouchers and silica-dried leaf samples were deposited in herbaria in the  
267 countries of origin and in the herbarium and DNABank at the Natural History Museum, University of Oslo (SI  
268 Appendix 1, Table S1). Our taxon sampling represents 102 species that occur in the alpine zone above 3200  
269 m (SI Appendix 1, Table S2) (9). We extracted DNA from silica dried leaves using Qiagen DNeasy Plant Mini  
270 Kits (Qiagen, Valencia, CA) and constructed libraries using the TruSeq compatible genomic DNA library  
271 preparation kits for Illumina paired-end sequencing of 550 base pair (bp) inserts with multiplexing for 96

272 samples (Illumina, San Diego, CA, USA). Sequencing was carried out on the Illumina HiSeq v2500 platform  
273 (Illumina, San Diego, CA, USA) at the Norwegian Sequencing Centre (<https://www.sequencing.uio.no/>).

274 We inferred phylogenetic relationships of afroalpine species and clades based on plastid and nuclear  
275 ribosomal DNA sequence markers that have been widely sampled for phylogenetic studies by incorporating  
276 our new sequences into existing alignments of 1) all seed plants (17); and 2) individual seed plant clades (6,  
277 18–29) (see SI Appendix 1, Table S3); most of the latter are based on dense sampling of taxa, variable  
278 sequences, and shallow fossil calibrations. We used PhylUp (46) <https://github.com/mkandziora/PhylUp/>), a  
279 python workflow for finding and adding sequences to the target alignments using blast+ (47) to search both  
280 user-supplied data and GenBank. We first split concatenated matrices into single loci and used  
281 ncbiTAXONparser (<https://github.com/mkandziora/ncbiTAXONparser>) to link taxa to species names  
282 accepted by NCBI. We opted to add new sequences to the original alignments if the BLAST search returned  
283 a blast e-value of <0.001. Maximum sequence length was set to 2000% to add potentially much longer  
284 matching plastid sequences, which were later trimmed to alignment length. Final alignments are available  
285 through the Open Data Framework (30).  
286

287 We estimated ages of afroalpine species and clades based on the seed plant-wide and individual seed plant  
288 clade datasets using two different molecular dating methods: penalized likelihood as implemented in treePL  
289 (48) and Bayesian statistics under an uncorrelated lognormal relaxed clock model as implemented in  
290 BEAST2 (49). Apart from applying current versions of the software we aimed to match the age calibrations  
291 and other settings as reported in the original publications as closely as possible (see SI Appendix 1, Table  
292 S8).

293 We summarized the age distribution of sampled colonization and *in situ* diversification events across the  
294 afroalpine flora as a whole and compared it to expectations given different models of diversification similar to  
295 the approaches in (35, 50). We analyzed the differences between consecutive node ages across  
296 phylogenies (for all individual seed plant clades together and for the seed plant-wide phylogeny), thus  
297 summarizing both colonization and diversification rate heterogeneity across lineages and through time. We  
298 used the difference quotient function incorporating a degree of phylogenetic and age uncertainty by 1)  
299 subsampling and 2) assessing separately results given the different age estimates obtained above (SI  
300 Appendix 1). We compared the resulting distributions of densities of species accumulation through time,  
301 calculating the R2 of the fit with those simulated assuming constant or exponential growth. Code used is  
302 available via data submission through the Open Data Framework (30). Detailed methods are presented in SI  
303 Appendix S1.  
304

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1. C. E. Hughes, G. W. Atchison, The ubiquity of alpine plant radiations: from the Andes to the Hengduan Mountains. *New Phytol.* **207**, 275–282 (2015).
2. P. Sklenář, I. Hedberg, A. M. Cleef, Island biogeography of tropical alpine floras. *J. Biogeogr.* **41**, 287–297 (2014).
3. F. White, The history of the Afroalpine archipelago and the scientific need for its conservation. *Afr. J. Ecol.* **19**, 33–54 (1981).
4. J. M. B. Smith, A. M. Cleef, Composition and origins of the world's tropicalpine floras. *J. Biogeogr.* **15**, 631–645 (1988).
5. B. Gehrke, M. Kandziora, M. D. Pirie, The evolution of dwarf shrubs in alpine environments: a case study of *Alchemilla* in Africa. *Ann. Bot.*, mcv159 (2015).
6. A. Antonelli, Have giant lobelias evolved several times independently? Life form shifts and historical biogeography of the cosmopolitan and highly diverse subfamily Lobelioideae (Campanulaceae). *BMC Biol.* **7**, 82 (2009).
7. A. Graham, The Andes: a geological overview from a biological perspective. *Ann. Mo. Bot. Gard.* **96**, 371–385 (2009).
8. S. L. Baldwin, P. G. Fitzgerald, L. E. Webb, Tectonics of the New Guinea Region. *Annu. Rev. Earth Planet. Sci.* **40**, 495–520 (2012).
9. B. Gehrke, H. P. Linder, Species richness, endemism and species composition in the tropical Afroalpine flora. *Alp. Bot.* **124**, 165–177 (2014).
10. D. I. Axelrod, P. H. Raven, "Late Cretaceous and Tertiary vegetation history of Africa" in *Biogeography and Ecology of Southern Africa*, Monographiae Biologicae., M. J. A. Werger, Ed. (Springer Netherlands, 1978), pp. 77–130.
11. B. Gehrke, Staying cool: preadaptation to temperate climates required for colonising tropical alpine-like environments. *PhytoKeys* **96**, 111–125 (2018).
12. V. S. Merckx, *et al.*, Evolution of endemism on a young tropical mountain. *Nature* **524**, 347–350 (2015).
13. S. G. A. Flantua, A. O'Dea, R. E. Onstein, C. Giraldo, H. Hooghiemstra, The flickering connectivity system of the north Andean páramos. *J. Biogeogr.* **46**, 1808–1825 (2019).
14. D. Chala, N. E. Zimmermann, C. Brochmann, V. Bakkestuen, Migration corridors for alpine plants among the 'sky islands' of eastern Africa: do they, or did they exist? *Alp. Bot.* **127**, 133–144 (2017).
15. C. Brochmann, *et al.*, History and evolution of the afroalpine flora: in the footsteps of Olov Hedberg. *Alp. Bot.*, 1–23 (2021).
16. S. C. K. Straub, *et al.*, Navigating the tip of the genomic iceberg: Next-generation sequencing for plant systematics. *Am. J. Bot.* **99**, 349–364 (2012).
17. S. Janssens, *et al.*, A large-scale species level dated angiosperm phylogeny for evolutionary and ecological analyses. *Biodivers. Data J.* **8**, e39677 (2020).

18. M. Kandziora, J. W. Kadereit, B. Gehrke, Dual colonization of the Palaeartic from different regions in the Afrotropics by *Senecio*. *J. Biogeogr.* **44**, 147–157 (2017).
19. Ł. Banasiak, *et al.*, Dispersal patterns in space and time: a case study of Apiaceae subfamily Apioideae. *J. Biogeogr.* **40**, 1324–1335 (2013).
20. C. D. Bell, A. Kutschker, M. T. K. Arroyo, Phylogeny and diversification of Valerianaceae (Dipsacales) in the southern Andes. *Mol. Phylogenet. Evol.* **63**, 724–737 (2012).
21. Y. Bouchenak-Khelladi, G. A. Verboom, V. Savolainen, T. R. Hodkinson, Biogeography of the grasses (Poaceae): a phylogenetic approach to reveal evolutionary history in geographical space and geological time. *Bot. J. Linn. Soc.* **162**, 543–557 (2010).
22. T. L. P. Couvreur, *et al.*, Molecular Phylogenetics, Temporal Diversification, and Principles of Evolution in the Mustard Family (Brassicaceae). *Mol. Biol. Evol.* **27**, 55–71 (2010).
23. M. S. Dillenberger, J. W. Kadereit, Simultaneous speciation in the European high mountain flowering plant genus *Facchinia* (*Minuartia* s.l., Caryophyllaceae) revealed by genotyping-by-sequencing. *Mol. Phylogenet. Evol.* **112**, 23–35 (2017).
24. K. Emadzade, E. Hörandl, Northern Hemisphere origin, transoceanic dispersal, and diversification of Ranunculaceae DC. (Ranunculaceae) in the Cenozoic. *J. Biogeogr.* **38**, 517–530 (2011).
25. T. F. E. Messerschmid, J. T. Klein, G. Kadereit, J. W. Kadereit, Linnaeus's folly – phylogeny, evolution and classification of *Sedum* (Crassulaceae) and Crassulaceae subfamily Sempervivoideae. *TAXON* **69**, 892–926.
26. M. D. Pirie, G. Litsios, D. U. Bellstedt, N. Salamin, J. Kissling, Back to Gondwanaland: can ancient vicariance explain (some) Indian Ocean disjunct plant distributions? *Biol. Lett.* **11**, 20150086 (2015).
27. G. Ren, E. Conti, N. Salamin, Phylogeny and biogeography of *Primula* sect. *Armerina*: implications for plant evolution under climate change and the uplift of the Qinghai-Tibet Plateau. *BMC Evol. Biol.* **15**, 161 (2015).
28. J. M. Saarela, *et al.*, A 250 plastome phylogeny of the grass family (Poaceae): topological support under different data partitions. *PeerJ* **6**, e4299 (2018).
29. B. Surina, S. Pfanzelt, H. J. R. Einzmann, D. C. Albach, Bridging the Alps and the Middle East: Evolution, phylogeny and systematics of the genus *Wulfenia* (Plantaginaceae). *TAXON* **63**, 843–858 (2014).
30. M. Kandziora, AfroalpineDatingData. [osf.io/brmjg](https://osf.io/brmjg) (2021).
31. C. García-Verdugo, J. Caujapé-Castells, I. Sanmartín, Colonization time on island settings: lessons from the Hawaiian and Canary Island floras. *Bot. J. Linn. Soc.* **191**, 155–163 (2019).
32. D. L. Rabosky, G. J. Slater, M. E. Alfaro, Clade age and species richness are decoupled across the eukaryotic tree of life. *PLoS Biol.* **10**, e1001381 (2012).
33. G. Gil-Romera, *et al.*, “The new Garba Guracha palynological sequence: Revision and data expansion” in *Quaternary Vegetation Dynamics – The African Pollen Database*, (CRC Press, 2021).
34. M. R. Talbot, M. L. Filippi, N. B. Jensen, J.-J. Tiercelin, An abrupt change in the African monsoon at the end of the Younger Dryas. *Geochem. Geophys. Geosystems* **8** (2007).

35. M. van der Merwe, *et al.*, Assemblage accumulation curves: A framework for resolving species accumulation in biological communities using DNA sequences. *Methods Ecol. Evol.* **10**, 971–981 (2019).
36. D. D. Ackerly, Evolution, origin and age of lineages in the Californian and Mediterranean floras. *J. Biogeogr.* **36**, 1221–1233 (2009).
37. P. C. Guerrero, M. Rosas, M. T. K. Arroyo, J. J. Wiens, Evolutionary lag times and recent origin of the biota of an ancient desert (Atacama–Sechura). *Proc. Natl. Acad. Sci.* **110**, 11469–11474 (2013).
38. C. M. Clapperton, Quaternary glaciations in the southern hemisphere: An overview. *Quat. Sci. Rev.* **9**, 299–304 (1990).
39. F. Luebert, M. Weigend, Phylogenetic insights into Andean plant diversification. *Front. Ecol. Evol.* **2** (2014).
40. P. Sklenář, E. Dušková, H. Balslev, Tropical and Temperate: Evolutionary History of Páramo Flora. *Bot. Rev.* **77**, 71–108 (2011).
41. C. García-Verdugo, *et al.*, Pleistocene extinctions as drivers of biogeographical patterns on the easternmost Canary Islands. *J. Biogeogr.* **46**, 845–859 (2019).
42. S.-C. Kim, *et al.*, Timing and Tempo of Early and Successive Adaptive Radiations in Macaronesia. *PLOS ONE* **3**, e2139 (2008).
43. Q. C. B. Cronk, Islands: stability, diversity, conservation. *Biodivers. Conserv.* **6**, 477–493 (1997).
44. D. A. Clague, D. R. Sherrod, “Growth and degradation of Hawaiian volcanoes” (U.S. Geological Survey, 2014).
45. J. B. Valencia, J. Mesa, J. G. León, S. Madriñán, A. J. Cortés, Climate Vulnerability Assessment of the Espeletia Complex on Páramo Sky Islands in the Northern Andes. *Front. Ecol. Evol.* **8** (2020).
46. M. Kandziora, PhylUp: phylogenetic alignment building with custom taxon sampling. *bioRxiv*, 2020.12.21.394551 (2020).
47. C. Camacho, *et al.*, BLAST+: architecture and applications. *BMC Bioinformatics* **10**, 421 (2009).
48. S. A. Smith, B. C. O’Meara, treePL: divergence time estimation using penalized likelihood for large phylogenies. *Bioinformatics* **28**, 2689–2690 (2012).
49. R. Bouckaert, *et al.*, BEAST 2: A Software Platform for Bayesian Evolutionary Analysis. *PLOS Comput. Biol.* **10**, e1003537 (2014).
50. J. A. McGuire, *et al.*, Molecular Phylogenetics and the Diversification of Hummingbirds. *Curr. Biol.* **24**, 910–916 (2014).

327 **SI Appendices**

328 SI Appendix 1: Supplement Methods and Results.

329 SI Appendix 2: Figures of dated phylogenies of individual seed-plant clades.

330

331

332 **Figures**

333

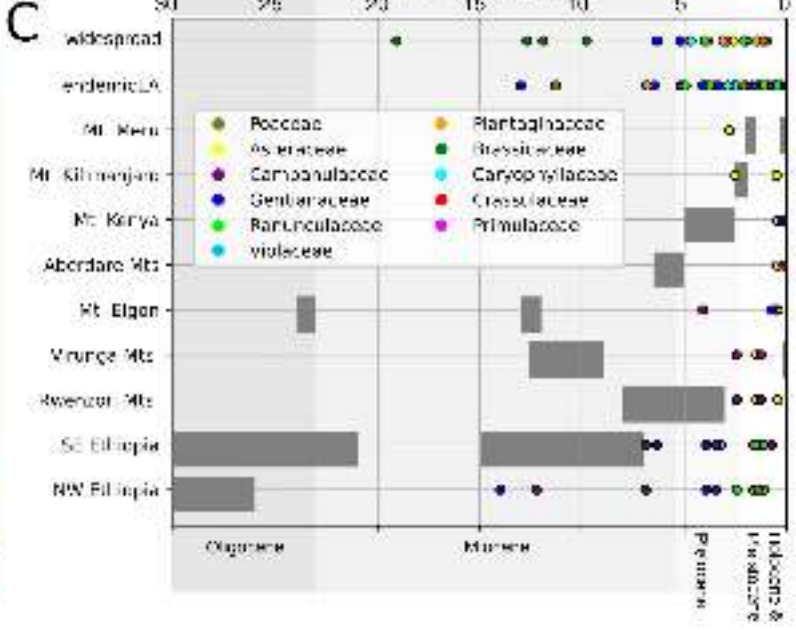
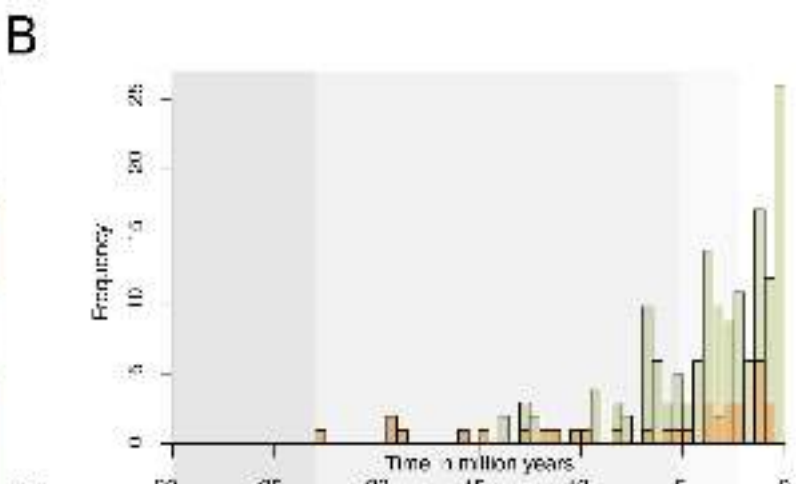
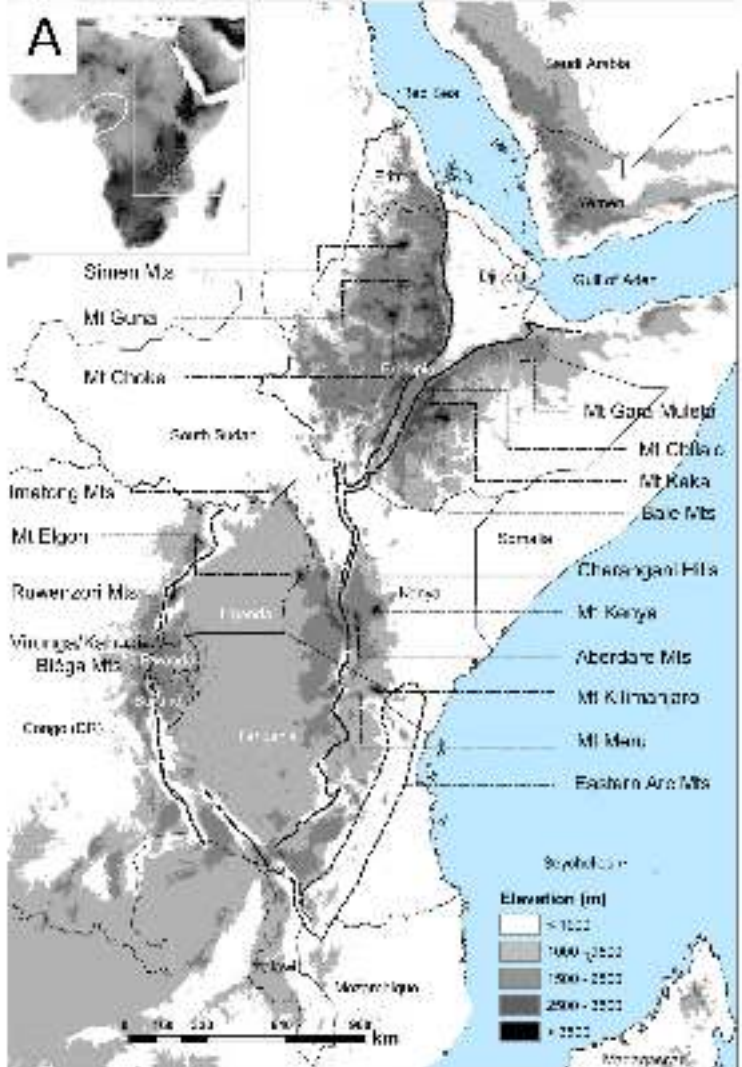
334 **Figure 1.** Geographic distribution and recruitment to the afroalpine flora (>3500 m). A) Major mountains and  
335 mountain regions in eastern Africa. The Great Rift Valley is shown as stippled lines. B) Numbers of  
336 afroalpine colonization (orange) and *in situ* diversification (olive) events per 0.5 Ma time bin. Colonizations,  
337 here represented by stem nodes, must be interpreted as maximum age estimates for events that are more  
338 recent to an unknown degree. C) Stem age estimates of afroalpine species in relation to mountain orogeny  
339 (gray bars; Gehrke et al. (7)). Species are colored according to family. Local endemics (species restricted to  
340 one or two mountains) are mapped to individual mountains; the remaining species are classified as 'eastern  
341 African endemics' ('endemicEA') or as 'widespread'. Age estimates in A) and B) represent both Bayesian  
342 median node ages of individual seed plant clades.

343

344 **Figure 2.** Seed plant-wide dated phylogeny based on our new data combined with the original matrix of  
345 Janssens et al. (17) with afroalpine species indicated in red type and those of the original dataset further  
346 indicated with a red colored star. Clades not including afroalpine species are pruned to crown clade nodes to  
347 increase readability. Afroalpine clades supported by posterior probability  $\geq 0.95$  in the BEAST2 analyses of  
348 the individual seed plant clades are indicated with blue stars. Circles indicate time in million years before  
349 present. Photographs show examples of afroalpine species: A) *Viola eminii*, B) *Swertia crassiuscula*, C)  
350 *Lobelia telekii* and D) *Euryops browneii* (photographs: B. Gehrke, available under a creative commons CC-  
351 BY-NC license at <https://www.inaturalist.org/>).

352

353 **Figure 3.** Species accumulation over time in the afroalpine region based on historical lineage diversity esti-  
354 mates and relative branching times obtained from the time-calibrated phylogenies. These plots differ from  
355 standard lineage through time plots in that species accumulation in a region results from colonization events  
356 in addition to regional diversification of multiple independent lineages. Row 1: Number of colonization/diversi-  
357 fication events over time. The black dotted line marks a constant rate model and the black dashed line an  
358 exponential model. Row 2: Change in number of colonization/diversification events over time calculated as a  
359 difference quotient (see text). The red line shows the maximum difference of change in a constant model.  
360 Row 3: number of colonization/ diversification events per 0.5-million-year intervals. Age estimates were sub-  
361 sampled to 50% 200 times. Results for our three different dating methods are shown in A). Simulated results  
362 are shown in B) (exponential model) and C) (constant model), with the left columns representing 200 itera-  
363 tions (one highlighted in blue), and right columns a single iteration subsampled to 50%.

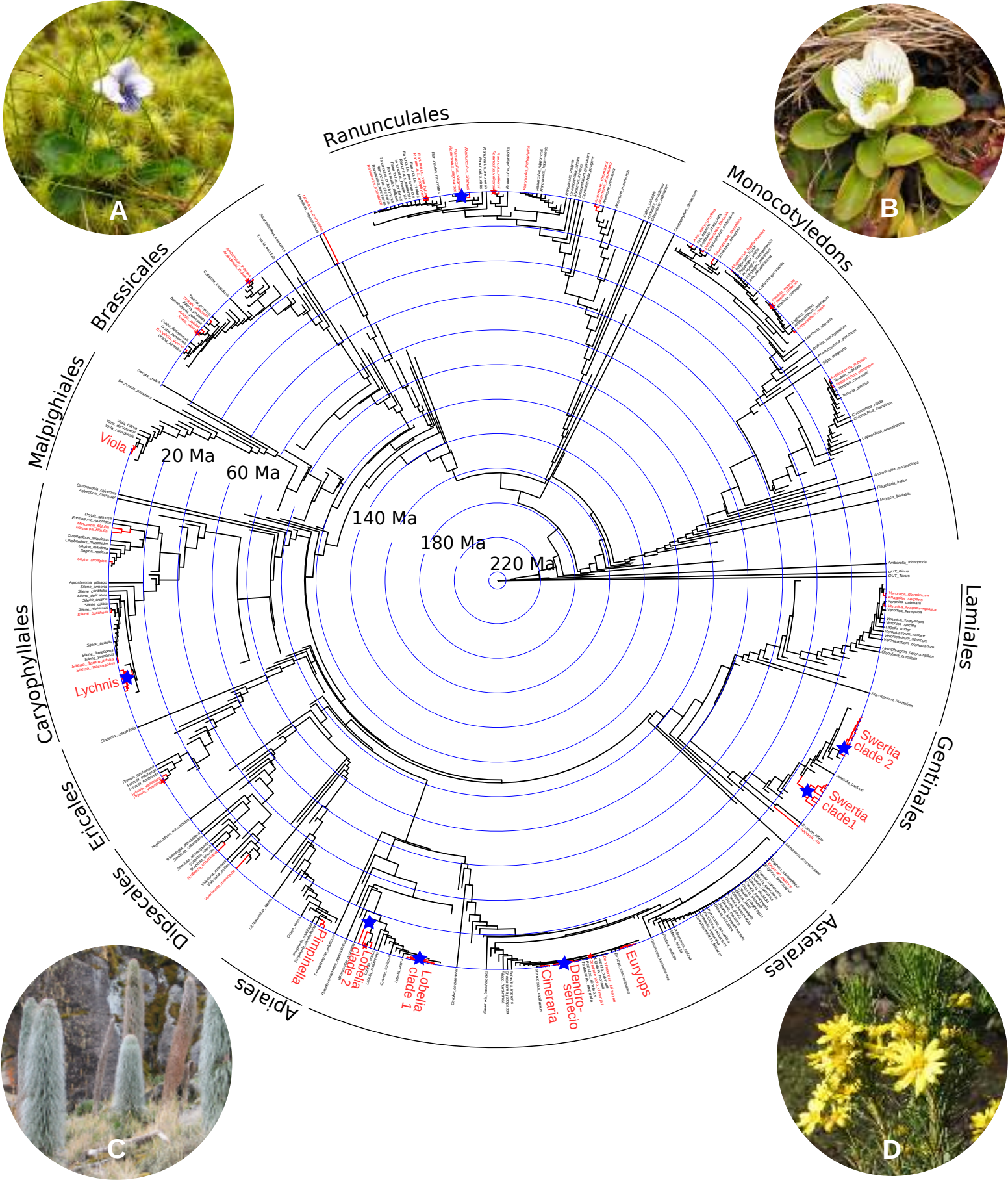




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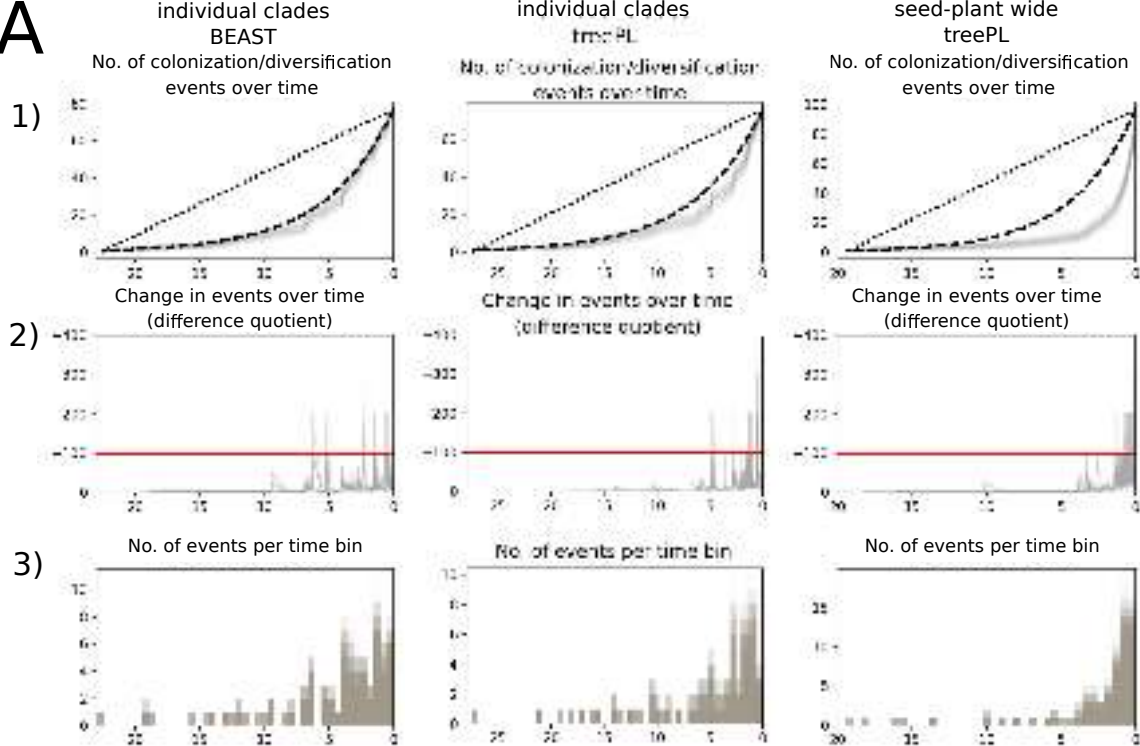
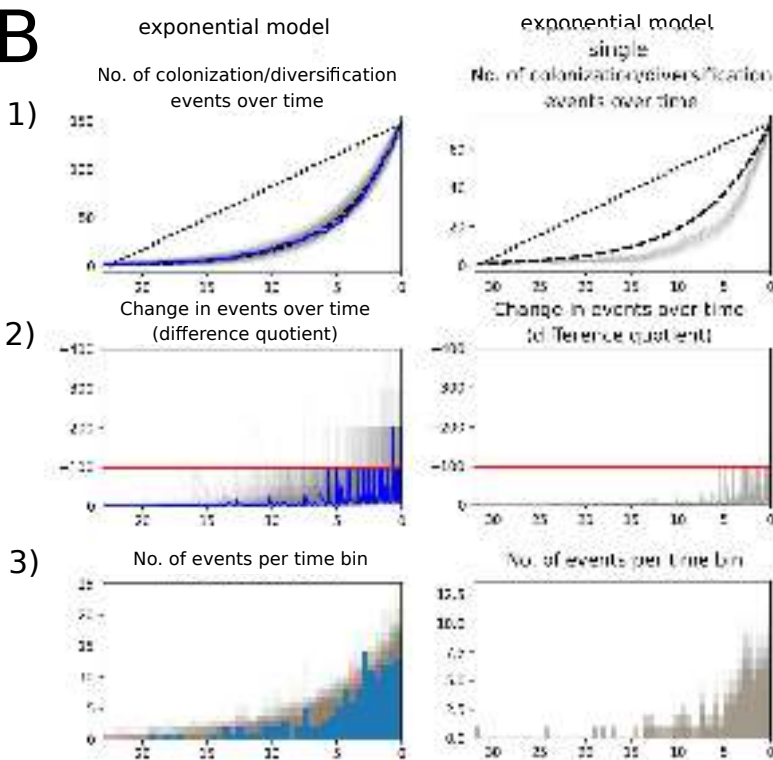
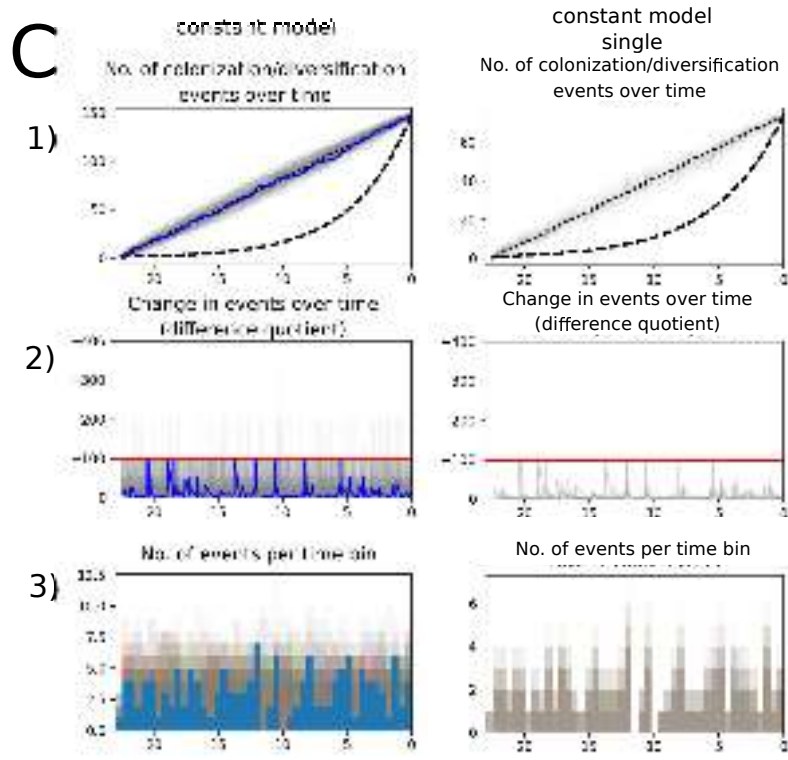
B



C



D

**A****B****C**



**Supplementary Information for**

**The enigmatic tropical alpine flora on the African sky islands is young, disturbed, and unsaturated**

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**This PDF file includes:**

Supplementary text  
Figures S1 to S8  
Tables S1 to S9

Legend for Appendix S2  
SI References

**Other supplementary materials for this manuscript include the following:**

Appendix S2

## Appendix 1. Supplementary Methods and Results

### Methods

#### Material and DNA sequencing

We sampled 102 species that occur in montane and/or alpine areas of eastern Africa (Ethiopia, Kenya, Uganda, and Tanzania), limited to those with an upper altitudinal limit above 2500 m (Table S2). Seventy of these species occur above the tree line (> 3800 m). For this project, we sampled 92 species that were collected over the years (Table S1). We collected leaves on silica gel and pressed three individual plants from each population, deposited in the following herbaria: one in the National Herbarium of Ethiopia, Addis Ababa University, Ethiopia (ETH); one in the Natural History Museum, University of Oslo, Norway (O); and one in the country of collection: East African Herbarium, National Museum of Kenya, Nairobi, Kenya (EA); National Herbarium of Tanzania, Arusha, Tanzania (NHT); or Makerere University Herbarium, Kampala, Uganda (MHU).

In some cases, we pooled DNA of multiple individuals from a single population to obtain sufficient DNA for sequencing. We consider this to be unproblematic for species level analyses. We used FastQC (version 0.11.5; <http://www.bioinformatics.babraham.ac.uk/projects/fastqc/>) to determine the quality of the raw sequences. After sequencing, we removed adapters and low-quality reads using bbduk (bbmap version 38.79; 1) with standard settings (adapter trimming: ktrim=r, k=23, mink=11, hdist=1, tpe, tbo; low quality reads: qtrim=rl, trimq=10). To assemble nuclear ribosomal and plastid sequences we used GetOrganelle (version 1.6.2e; 2). Settings were adapted to plastid and nuclear ribosomal DNA, using the recommended ones (plastid: -R 7 -k 35,85,115; nuclear ribosomal: -R 15 -k 21,45,65,85,105).

#### Dating approach and methodology

To estimate ages of afroalpine lineages, we used datasets from previously published molecular dating analyses (3–16) whenever these were available through public archives or on request from the authors, instead of building new alignments. We could thereby leverage work by experts on the respective lineages, with sampling typically carefully chosen to be representative of the entire lineage, with carefully incorporated fossil calibrations, and often with comparison of results from different analysis settings; the sum of which has passed peer-review process. Most such datasets focused on individual seed plant clades; for comparison we also used an existing dataset spanning seed plants (17) which incorporates an alternative set of fossil calibrations.

We added new sequences to the existing alignments (3–17) using PhylUp (18). PhylUp is a python workflow for finding and adding sequences to a target alignment using blast+ (19) to search for similar sequences. To further increase sampling of the closest relatives of afroalpine taxa we used PhylUp to add 10 additional taxa from GenBank for each of our own new sequences, selecting those that were most similar (but not identical) and which represented species/subspecies not already included. We first split concatenated matrices into their constituent individual marker alignments. Where information about partitioning of the alignment was not available, we used blast searches to determine locus identities and start and end positions within the concatenated alignments. Alignment information is provided in Table S3.

We used different dating approaches. For individual seed plant clades, we used a Bayesian relaxed clock model (BEAST2; 20) and also a penalized likelihood method, treePL (21; Table S8). For the seed plant wide matrix, we used penalized likelihood only (following 17) because the matrix was too large to run successfully using BEAST2. It was not always possible or desirable to implement exactly the same analysis settings as used in the original publications. In two cases (Poaceae and Dipsacales) we combined alignments and molecular dating protocols from two different publications (4–6, 13). For Gentianaceae (11), we added a maximum age constraint for the root node following (22) to restrict overall age estimates to within plausible time frames. The node constraint reported for

*Cleistochloa* in Poaceae (6) was omitted because the relevant node was not represented given the taxon sampling in the available alignment (13). Our BEAST2 analysis using the original Brassicaceae matrix did not converge; we achieved convergence after reducing the density of taxon sampling in the matrix.

For the treePL analyses, we first needed to reconstruct phylogenetic trees from the updated alignments using RAxML-NG (version 0.9.0) or RAxMLv8 on CIPRES (for the seed plant-wide phylogeny; 23–25). We then estimated chronograms using penalized likelihood (based on the RAxML trees) and uncorrelated lognormal relaxed clock models (estimating phylogeny and node ages at the same time). For treePL, we applied node calibrations as minimum and/or maximum age constraints, and for the BEAST2 analyses, we used the same prior distributions for node calibrations as implemented in the original publications (Table S8). For the analyses of individual seed plant clades, we used an existing script ([https://github.com/tongjial/treepl\\_wrapper](https://github.com/tongjial/treepl_wrapper)) for the treePL analysis that automatically runs the ‘prime’ step a hundred times to find the best optimization parameters and to choose the optimal cross validation (cv) parameters, before calculating an ultrametric phylogeny using the corresponding smoothing value. For the seed plant-wide analyses we followed the dating method as reported in the original analysis (17), incorporating the same set of node-defined calibration points and producing a comparable result by using their topology as a backbone constraint under RAxML. In order to compute confidence intervals for the age estimates, we calculated 50 bootstrap trees, dated them using treePL, and combined the dated trees using TreeAnnotator from the BEAST package (version 1.10).

For the BEAST2 analyses, when detailed settings were not provided in the original publications, we partitioned substitution models into pDNA and nrDNA markers, and linked trees and molecular clocks, without further assessment of model fit (Table S8). Convergence of BEAST2 analyses was assessed using Tracer version 1.7.1. Two independent BEAST2 analyses were combined using Logcombiner and TreeAnnotator (version 2.6.2) if the analyses converged and ESS values were above 200 (in a few cases only >100). Sometimes three independent but converging analyses were combined to ensure high ESS values.

To compare species ages with the age of the mountains we used the information from (26). Species were categorized as “local endemics” if they occur on a maximum of two different mountains; otherwise, either as “afrotemperate endemics” (distribution limited to DR Congo, Rwanda, Tanzania, Ethiopia, Sudan, Zimbabwe, Kenya, Uganda, Burundi, Malawi, Zambia, Yemen) or as “widespread species” (also occurring in more distant temperate regions).

### Species accumulation over time

We summarized the ages of species and clades (representing colonization and *in situ* diversification events) across phylogenies for all sampled species occurring in the afroalpine flora, excluding multiple accessions of monophyletic species, and compared the resulting node age distributions through time to expectations based on hypothetical models of diversification. Age estimates were pruned to two decimal positions for this approach.

1) We pooled node ages across all clades analyzed, ordered them by decreasing age, and summed the accumulating number of colonization/diversification events over time, equivalent to the approach of (27). In a few cases, where there was a discrepancy between phylogenies concerning the nodes within species complexes, we omitted these nodes.

2) We estimated a colonization/diversification rate given age intervals between consecutive ages by calculating the difference quotient, an approach similar to (28). The difference quotient is defined as  $f(b)-f(a)/(b-a)$ , which in our case is (cumulative number of colonization/diversification events at age 2 - cumulative number of colonization/diversification events at age 1) / (age 2 - age 1).

3) We summarized the number of colonization/diversification events per time bin.

To account for phylogenetic uncertainty and uncertainty in the age estimates, we employed a

subsampling approach: We randomly selected 50% of the samples 200 times before recalculating the three estimates and overlaid the results. We compared our results to expectations assuming constant and exponential models, simulating colonization/diversification under these two models and comparing the fit of our data using the `fit_curve` method from `scipy v. 1.5.4` (29), an optimization process to find an optimal set of parameters for a defined function that best fits a given set of observations. We calculated  $R^2$  between our dating results and data of the fitted curve. We repeated the above analysis using diversification events only to test whether the pattern we see is driven by the older colonization events.

We modeled a constant colonization/diversification rate by sampling  $N$  colonization/diversification events from a uniform distribution between 0 and the maximum age inferred by the dating method. The corresponding linear function is  $N(t)=a*t+b$ , where  $a$  is the slope and  $b$  is the number of new species, in our case one. The exponential model was generated by drawing samples from an exponential distribution. The corresponding (probability density) function is  $N(t)=N_0*\exp^{\lambda t}$ , where  $N$  is the number of colonization/diversification events,  $t$  is the time point and  $\lambda$  is  $-\ln(N_0/N_{max})/t_{max}$ .

## Results

### Data deposition

We deposited raw reads from shotgun sequencing in an NCBI sequence read archive: <http://www.ncbi.nlm.nih.gov/bioproject/766027>. Alignments (including newly added sequences, as below), phylogenetic trees and analysis settings as well as code used for this study are available via <https://github.com/mkandziora/AfroalpineDating/>, including reference to the respective original publications on which alignments and settings were based.

### Phylogenetic relationships

All newly sampled sequences were represented in at least one of the datasets. However, nine species were only included in the seed plant-wide dating, either because of mismatch between available data and existing matrices (Table S2) or, in the case of Dipsacales and Apiaceae, because of persistent problems with convergence using BEAST2. For the analyses of individual seed plant clades, we included similar sequences from GenBank in addition to our newly sampled individuals to improve the resolution of species relationships of our afroalpine samples. This added nine afroalpine species and corresponding age estimates to the results of the individual seed plant clades only.

Of the genera that are represented by more than five species in the afroalpine flora (26), six were represented by more than one species in our analyses. We found that three of these six genera colonized the afroalpine region more than once: *Lobelia* and *Swertia* both colonized twice, and *Ranunculus* colonized at least four times (of which only two colonizations resulted in diversification into two or more afroalpine species). The two *Silene* species we sampled (out of three in the flora), *S. flammulifolia* and *S. burchellii*, belonged to separate clades, each including non-afroalpine *Silene* species. The genus *Lychnis* (in our dataset nested within *Silene*), represents a further independent origin in the afroalpine region.

Nineteen species were represented by more than one individual in our analyses (Table S4). Five of them were retrieved as clearly monophyletic ( $>0.9$  PP; according to the BEAST2 analyses, which were better supported than the RAxML analyses), and seven were retrieved as para- or polyphyletic, potentially indicating unrecognized species diversity in the afroalpine flora (these cases did not represent additional immigration events). For the remaining seven species, support was too low to confirm or reject monophyly.

### Molecular dating

Based on our three dating methods, we could summarize up to three different age estimates for each of 102 afroalpine species, with and without confidence intervals (Figure S3-S5, Table S2). For the analyses of individual seed plant clades, we used treePL (rate-smoothing a single ML tree to obtain point estimates for node ages) and BEAST2 (estimating the phylogeny and age estimates at the same time, including confidence intervals from posterior probability distributions). For the seed plant-wide analysis we used only treePL (using an ML tree with confidence intervals estimated from bootstrapping). As the two datasets represent different species (as represented in published data) with our newly added sequences, the two datasets delivered two somewhat different sets of results (91 and 93 age estimates from not fully overlapping species sampling).

More than 60% of the BEAST2/treePL median age estimates fell within the seed plant-wide confidence intervals, and >40% of the seed plant-wide median age estimates fell within the individual seed plant clade confidence intervals. Because fossil-calibrated molecular dating results should in principle be interpreted as minimum ages (and other means of rate calibration are subject to various sources of error), deviation between results based on different calibrations can be expected and needs to be assessed. The BEAST2 and treePL analyses resulted in only a few old (> 10 Ma) species, but the two methods identified different species (Table S6). The age estimates were very different for two species: *Umbilicus botryoides* (individual lineage analysis 0.98 Ma, seed plant-wide analysis 19.41 Ma) and *Sebaea* sp. (3.26 Ma and 18.25 Ma); the much younger ages inferred by the better sampled individual lineage analyses may be caused by using more informative, and thus more reliable, age constraints for these lineages. In the case of *Umbilicus*, it should be noted that the Crassulaceae is difficult to date as no fossils are available; the age estimate from the seed plant-wide dating, which is informed by (albeit more distant) fossil calibrations, might be more appropriate.

The inferred ages and resolution in our phylogenies of individual seed plant clades were very similar to those in the original publications (Table S9), except for *Veronica*, for which we estimated the crown age to 10.82 Ma (7.11-15.69 highest posterior density [HPD]) instead of 16.13 Ma (12.46-20.59 HPD, BEAST2 age estimates). We used the same node calibrations as in the original publication; the different results might be due to the use of both ITS and *trnL*F in the original publication whereas our analysis only included ITS, because our sampling for the *trnL*F alignment did not include the nodes needed for calibration.

Notably, our estimates for species stem ages from the treePL and BEAST2 analyses were young compared to the ages of the tropical African mountains, also when considering the maximum confidence intervals (Figures S2 and S3). The median age over all BEAST2 analyses was 2.44 Ma (0.7 - 4.85; median of all HPDs), the treePL median age was 2.57 Ma, and the seed plant-wide median age was 0.84 Ma (0.12 - 7.81; median of all HPDs). All three dating approaches estimated that the majority of species (73 of 102) were younger than 5 Ma. Eighty-four of the species were younger than 10 Ma according to their median age estimates (Figure S3, BEAST2 analyses, Table S7).

We found no correlation between age and altitudinal distribution (Pearson correlation:  $R = 0.11$ ,  $p = 0.3$ ) and no association between age and biogeographic subregion (Figure S6 and S7). Species older than 10 Ma were typically either widespread or only found in Ethiopia and mostly found in alpine habitats. The clades that diversified were often composed of species that occur both above and below the treeline. From our results, it was rarely possible to discern whether clades originated in alpine or montane habitats (Figure S7).

As might be expected from the young stem node ages, the crown nodes of the six afroalpine clades (i.e., *in situ* diversifications) that we recovered were also younger than most of potential alpine or montane habitats (Figure S1).

Accumulation of species over time did not change its main results when not including colonizations events (Figure S8).

**Table S1.** Voucher information. Abbreviations: HC – herbarium code.

family	genus	species name (according to ncbi)	author	collector	collection date	unique id	country	locality	eleva tion	latitude	longitud e	HC	Genban k accessio n	sample_id
Apiaceae	<i>Pimpinella</i>	<i>Pimpinella oreophila</i> var <i>oreophila</i>	Hook. f.	P II team	2009-01-29	O-DP-36064	Kenya	Mt Elgon: S of Mt Koitobos	3629	1.10067	34.6215	O	SAMN21 599645	KN0314- 2_Pimpinella_oreophila_var_oreophila
Apiaceae	<i>Pimpinella</i>	<i>Pimpinella pimpinelloides</i>	H.Wolff	P II team	2007-10-30	O-DP-30849	Ethiopia	Simen Mts: Silki	3760	13.3333	38.23333	O	SAMN21 599646	ET0415- 2_Pimpinella_pimpinelloides
Asteraceae	<i>Cineraria</i>	<i>Cineraria abyssinica</i>	A.Rich.	P II team	2007-10-13	O-DP-33982	Ethiopia	Bale Mts: Habera	3484	7.01867	39.72067	O	SAMN21 599647	ET1413- 2_Cineraria_abyssinica
Asteraceae	<i>Cineraria</i>	<i>Cineraria abyssinica</i>	A.Rich.	P II team	2007-11-12	O-DP-31694	Ethiopia	Bale Mts: Sanetti Plateau	4143	6.85502	39.87802	O	SAMN21 599648	ET0652- 2_Cineraria_deltaoidea
Asteraceae	<i>Cineraria</i>	<i>Cineraria sebalzii</i>	Cufod.	P II team	2007-10-24	O-DP-44436	Ethiopia	Simen Mts: Dirni Gate	3716	13.2879	38.11882	O	SAMN21 599649	ET0225- 2_Cineraria_sebalzii
Asteraceae	<i>Dendrosenecio</i>	<i>Dendrosenecio adnivalis</i> var <i>adnivalis</i>	E.B.Knox	P II team	2008-08-10	O-DP-40704	Uganda	Rwenzori Mts: Upper Bigo Valley	3561	0.38602	29.92632	O	SAMN21 599650	UG2305- 3_Dendrosenecio_adnivalis_var_adnivalis
Asteraceae	<i>Dendrosenecio</i>	<i>Dendrosenecio battiscombei</i>	E.B.Knox	P II team	2009-02-11	O-DP-27466	Kenya	Aberdare Mts: Mt Kinangop area	3069	0.54265	36.71993	O	SAMN21 599651	KN0482- 1_Dendrosenecio_battiscombei
Asteraceae	<i>Dendrosenecio</i>	<i>Dendrosenecio brassiciformis</i>	Mabb.	P II team	2009-02-12	O-DP-42217	Kenya	Aberdare Mts: Mt Satima area	3865	0.31065	36.63192	O	SAMN21 599652	KN0516- 4_Dendrosenecio_brassiciformis
Asteraceae	<i>Dendrosenecio</i>	<i>Dendrosenecio elgonensis</i> ssp	(T.C.E. Fr.)	P II team	2009-01-20	O-DP-34825	Kenya	Mt Elgon: S of Mt	3915	1.10567	34.60183	O	SAMN21 599653	KN0025- 4_Dendrosenecio

		<i>elgonensis</i>	E.B.Knox (R.E.Fr. & T.C.E.F r.)																o_elgonensis_ssp_elgonensis
Asteraceae	<i>Dendrosenecio</i>	<i>erici-rosenii ssp erici-rosenii</i>	E.B.Knox (Baker f.)	AFROAL P II team	2008-07-22	O-DP-39500	Uganda	Virunga Mts: Mt Mgahinga, summit	3457	1.38492	29.6449	O	-	SAMN21 599654	5	Dendrosenecio_erici-rosenii_ssp_erici-rosenii	UG2207-5_Dendrosenecio_erici-rosenii		
Asteraceae	<i>Dendrosenecio</i>	<i>keniensis</i>	Mabb. (R.E.Fr. & T.C.E.F r.)	AFROAL P II team	2009-07-04	O-DP-28618	Kenya	Mt Kenya: Sirimon Route	3652	0.06298	37.29625	O	-	SAMN21 599655	3	Dendrosenecio_keniensis	KN0792-3_Dendrosenecio_keniensis		
Asteraceae	<i>Dendrosenecio</i>	<i>keniodendron</i>	B.Nord.	AFROAL P II team	2009-07-04	O-DP-28581	Kenya	Mt Kenya: Above Old Moses Camp	3696	0.06762	37.2978	O	-	SAMN21 599656	1	Dendrosenecio_keniodendron	KN0781-1_Dendrosenecio_keniodendron		
Asteraceae	<i>Dendrosenecio</i>	<i>kilimanjari ssp kilimanjari</i>	E.B.Knox (Mildbr.)	AFROAL P II team	2008-11-19	O-DP-38340	Tanzania	Mt Kilimanjaro : Betw. Horombo Hut and Mandara Hut, 4 km from Horombo	3288	-3.1508	37.4759	O	-	SAMN21 599657	3	Dendrosenecio_kilimanjari_ssp_kilimanjari	TZ0343-3_Dendrosenecio_kilimanjari_ssp_kilimanjari		
Asteraceae	<i>Erigeron</i>	<i>alpinus</i>	L.	AFROAL P II team	2007-11-20	O-DP-32764	Ethiopia	Bale Mts: Angaso Aberdare Mts: Mt Satima	3986	6.88218	39.8883	O	-	SAMN21 599658	2	Erigeron_alpinus	ET0928-2_Erigeron_alpinus		
Asteraceae	<i>Euryops</i>	<i>brownei</i>	S.Moore	AFROAL P II team	2009-02-14	O-DP-27951	Kenya	Mt Kilimanjaro : S of Mawenzi Peak	3605	0.33533	36.643	O	-	SAMN21 599659	2	Euryops_brownei	KN0599-2_Euryops_brownei		
Asteraceae	<i>Euryops</i>	<i>dacrydioides</i>	Oliv.	AFROAL P II team	2008-11-15	O-DP-37892	Tanzania	Mt Elgon: S of Mt	4109	3.10997	37.42112	O	-	SAMN21 599660	2	Euryops_dacrydioides	TZ0237-2_Euryops_dacrydioides		
Asteraceae	<i>Euryops</i>	<i>elgonensis</i>	Mattf.	AFROAL P II team	2009-01-20	O-DP-34779	Kenya		3915	1.10567	34.60183	O	-	SAMN21 599661	2	Euryops_elgonensis	KN0016-2_Euryops_elgonensis		

							Koitobos												ensis ET1330-
Asteraceae	<i>Euryops</i>	<i>Euryops pinifolius</i>	A.Rich.	AFROAL P II team	2008-10-08	O-DP-33607	Ethiopia	Mt Choke	3960	10.642	37.83567	O	SAMN21 599662	2_Euryops_pini- folius					ET0889-
Asteraceae	<i>Euryops</i>	<i>Euryops prostratus</i>	B.Nord.	AFROAL P II team	2007-11-21	O-DP-32614	Ethiopia	Bale Mts: Batu	4116	6.85003	39.85317	O	SAMN21 599663	2_Euryops_prost- ratus					ET0177-
Brassicaceae	<i>Arabidopsis</i>	<i>Arabidopsis thaliana</i>	(L.) Heynh.	AFROAL P II team	2007-10-24	O-DP-29948	Ethiopia	Simen Mts: Dirni Gate Mt Meru: Saddle Hut area	3716	13.2879	8	38.11882	O	SAMN21 599664	3_Arabidopsis_th- aliana				
Brassicaceae	<i>Arabis</i>	<i>Arabis alpina</i>	L.	AFROAL P II team	2008-11-27	O-DP-38474	Tanzania		3594	-3.217	36.769	O	SAMN21 599665	TZ0375- 3_Arabis_alpina					ET0667-
Brassicaceae	<i>Erophila</i>	<i>Erophila verna</i> var <i>macrosperma</i>	Sebald	AFROAL P II team	2007-11-13	O-DP-31710	Ethiopia	Bale Mts: Sanetti	4000	NA	NA	O	SAMN21 599666	2_Erophila_vern- a_var_Macrosper- ma					
Brassicaceae	<i>Thlaspi</i>	<i>Thlaspi alliaceum</i> (=Mummenhoffia alliacea)	L. R.E.Fr. & T.C.E.Fr.	AFROAL P II team	2007-11-13	O-DP-31715	Ethiopia	Bale Mts: Sanetti Mt Elgon: Near camp site at end of car road	4050	NA	NA	O	SAMN21 599667	2_Thlaspi_alli- aceum					ET0671-
Campanulaceae	<i>Lobelia</i>	<i>Lobelia aberdarica</i>	(E.Wimm.)	AFROAL P II team	2009-01-29	O-DP-27246	Kenya		3557	1.09317	34.62367	O	SAMN21 599668	1_Lobelia_aberd- arica					KN0394-
Campanulaceae	<i>Lobelia</i>	<i>Lobelia acrochila</i>	E.B.Knox	AFROAL P II team	2008-10-17	O-DP-34377	Ethiopia	Bale Mts: Dinsho Mt Kilimanjaro : Shira Plateau near Mt Simba	3281	7.05815	39.7657	O	SAMN21 599669	3_Lobelia_acroc- hilus					ET1503-
Campanulaceae	<i>Lobelia</i>	<i>Lobelia deckenii</i> ssp <i>deckenii</i>	Hemsl.	AFROAL P II team	2008-11-03	O-DP-37017	Tanzania		3636	3.03425	37.243	O	SAMN21 599670	2_Lobelia_decke- nii_ssp_deckenii					TZ0025-
Campanulaceae	<i>Lobelia</i>	<i>Lobelia erlangeriana</i>	Engl.	AFROAL P II team	2008-10-18	O-DP-34150, O-DP-34155	Ethiopia	Bale Mts: Betw. Goba and Sanetti, 4	2918	6.77312	39.72578	O	SAMN21 599671	ET1510- 14_Lobelia_erlan- geriana					



Campanulaceae	<i>Lobelia</i>	<i>Lobelia lindblomii</i>	Mildbr.	AFROAL P II team	2009-02-12	O-DP-27650	Kenya	km from Goba Aberdare Mts: Mt Satima area	3806	0.30533	36.62483	O	SAMN21 599672	KN0527-4_Lobelia_lindblomii	
Campanulaceae	<i>Lobelia</i>	<i>Lobelia mildbraedii</i>	Engl.	AFROAL P II team	2009-02-17	O-DP-28572	Kenya	Aberdare Mts: Near Wanderi Gate	2571	0.32017	36.7685	O	SAMN21 599673	KN0743-2_Lobelia_mildbraedii	
Campanulaceae	<i>Lobelia</i>	<i>Lobelia rhynchopetalum</i>	Hemsl.	AFROAL P II team B.	2007-10-21	O-DP-29729	Ethiopia	Simen Mts: Saha	3711	13.2827	3	38.11077	O	SAMN21 599674	ET0122-2_Lobelia_rhynchopetalum
Campanulaceae	<i>Lobelia</i>	<i>Lobelia schimperii</i>	Hochst. ex A.Rich.	Gebremedhin & G. Tassew	2013-03-26	O-DP-54720	Ethiopia	ETH: Simen Mts: Sherafit	2780	13.2779	5	38.07445	O	SAMN21 599675	BG52-1_Lobelia_schimperii
Campanulaceae	<i>Lobelia</i>	<i>Lobelia stuhlmannii</i>	Schweinf. ex Stuhlmann	AFROAL P II team	2008-07-26	O-DP-43042	Uganda	Virunga Mts: Mt Muhavura, along trail to summit	3600	1.38272	29.67798	O	SAMN21 599676	UG2088-1_Lobelia_stuhlmannii	
Campanulaceae	<i>Lobelia</i>	<i>Lobelia telekii</i>	Schweinf.	AFROAL P II team	2009-02-12	O-DP-27438	Kenya	Aberdare Mts: Mt Kinangop area, Gura River	NA	NA	NA	O	SAMN21 599677	KN0475-3_Lobelia_telekii	
Campanulaceae	<i>Lobelia</i>	<i>Lobelia wollastonii</i>	Baker f.	AFROAL P II team	2008-07-28	O-DP-40212	Uganda	Virunga Mts: Mt Muhavura, summit	4139	1.38277	29.67783	O	SAMN21 599678	UG2173-3_Lobelia_wollastonii	
Caryophyllaceae	<i>Lychnis</i>	<i>Lychnis abyssinica</i> (=Silene abyssinica)	(Hochst.) Liden	AFROAL P II team	2008-09-22	O-DP-33240, O-DP-33225	Ethiopia	Arsi: Betw. Shashemene and Goba, 11 km from Shashemene	2318	7.25575	39.1564	O	SAMN21 599679	ET1300_18_3_Lychnis_abyssinica	
Caryophyllaceae	<i>Lychnis</i>	<i>Lychnis</i>	(Hochst.)	AFROAL	2007-10-	O-DP-44203	Ethiopia	Simen Mts:	3574	13.2666	38.10782	O	SAMN21	ET0098-	

laceae		<i>abyssinica</i> (= <i>Silene</i> <i>abyssinica</i> )	.) Liden	P II team	20															Close to Gich Camp Site			X_Lychnis_abyss inica_LGS
Caryophyl laceae	<i>Lychnis</i>	<i>crassifolia</i> (= <i>Silene</i> <i>kenyana</i> )	(T.C.E. Fr.) M.Popp	AFROAL P II team	2009-02- 11	O-DP-27504	Kenya					3086	-0.5425	36.7175	O					Aberdare Mts: Mt Kinangop area			KN0494- 2_Lychnis_crassi folia
Caryophyl laceae	<i>Lychnis</i>	<i>Lychnis</i> <i>kigesiensis</i> subsp <i>ragazziana</i> (= <i>Silene</i> <i>kigesiensis</i> subsp. <i>ragazziana</i> )	(Ousted ) M.Popp	AFROAL P II team	2008-10- 06	O-DP-41981	Uganda					2300	1.25533	29.80933	O					Echuya Forest: Kanaba Swamp Betw. Keffa and Masha, Chenga Village			UG2600- 1_Lychnis_kigesi ensis_subsp_rag azziana
Caryophyl laceae	<i>Lychnis</i>	<i>Lychnis</i> <i>kiwuensis</i> (= <i>Silene</i> <i>kiwuensis</i> )	(T.C.E. Fr.) M.Popp	AFROAL P II team	2008-10- 01	O-DP-33528	Ethiopia					2257	8.27212	35.7909	O					Aberdare Mts: Mt Satima			ET1320- 3_Lychnis_kiwue nsis
Caryophyl laceae	<i>Lychnis</i>	<i>Lychnis</i> <i>rotundifolia</i> (= <i>Silene</i> <i>afromontana</i> )	(Oliv.) M.Popp	AFROAL P II team	2009-02- 12	O-DP-27521	Kenya					3686	0.32183	36.64067	O					Simen Mts: Gich Camp Site			KN0497- 4_Lychnis_rotun difolia
Caryophyl laceae	<i>Minuartia</i>	<i>Minuartia</i> <i>filifolia</i>	(Forssk. ) Mattf.	AFROAL P II team	2007-10- 25	O-DP-30277	Ethiopia					3652	13.2697	2	38.10588	O				Simen Mts: Dirni Gate Mt Kenya: Shipton's Cave			ET0266- 1_Minuartia_filifol ia
Caryophyl laceae	<i>Minuartia</i>	<i>Minuartia</i> <i>filifolia</i>	(Forssk. ) Mattf.	AFROAL P II team	2007-10- 24	O-DP-29995	Ethiopia					3716	13.2879	8	38.11882	O				Simen Mts: Dirni Gate Mt Kenya: Shipton's Cave			ET0189- 3_Minuartia_filifo rmis
Caryophyl laceae	<i>Sagina</i>	<i>Sagina</i> <i>afroalpina</i>	Hedber g	AFROAL P II team	2009-07- 09	O-DP-29202	Kenya					4193	0.13358	37.2765	O					Aberdare Mts: Mt Satima			KN0944- 2_Sagina_afroal pina
Caryophyl laceae	<i>Silene</i>	<i>Silene</i> <i>burchellii</i>	Oth ex DC.	AFROAL P II team	2009-02- 14	O-DP-27930	Kenya					3526	0.33417	36.64067	O					Simen Mts: Dirni Gate			KN0594- 1_Silene_burchel lii_var_burchellii
Caryophyl laceae	<i>Silene</i>	<i>Silene</i> <i>flammulifolia</i>	Steud. ex	AFROAL P II team	2007-10- 24	O-DP-30053	Ethiopia					3716	13.2879	38.11882	O					Simen Mts: Dirni Gate			ET0205- 2_Silene_flammu

Caryophyllaceae	<i>Silene</i>	<i>Silene macrosolen</i>	A.Rich. Steud. ex A.Rich.	AFROAL P II team	2007-10-27	O-DP-30359	Ethiopia	Simen Mts: Bwahit Mt	13.2513 4035	5	38.20225	O	SAMN21 4_Silene_macrosolen	ET0289-
Dipsacales	<i>Scabiosa</i>	<i>Scabiosa columbaria</i>	L.	AFROAL P II team	2008-11-14	O-DP-37816	Tanzania	Kilimanjaro : Horombo Bale Mts:	- 3650	3.14215	37.44065	O	SAMN21 2_Scabiosa_columbaria	ET0734-
Dipsacales	<i>Valeriana</i>	<i>Valerianella microcarpa</i>	Loisel.	AFROAL P II team	2007-11-15	O-DP-31946	Ethiopia	Garba Guracha Virunga Mts: Mt	4101	6.87028	39.8678	O	SAMN21 2_Valerianella_microcarpa	
Gentianaceae	<i>Sebae</i>	<i>Sebea sp</i>		AFROAL P II team	2008-07-27	O-DP-40093	Uganda	Muhavura	3800	NA	NA	O	SAMN21 3_Sebea_sp	ET1031-
Gentianaceae	<i>Swertia</i>	<i>Swertia abyssinica</i>	Hochst.	AFROAL P II team	2007-11-23	O-DP-33146	Ethiopia	Bale Mts: Angaso	3875	6.8931	39.89735	O	SAMN21 3_Swertia_abyssinica	TZ0710-
Gentianaceae	<i>Swertia</i>	<i>Swertia adolfi-friderici</i>	Mildbr. & Gilg	AFROAL P II team	2009-06-24	O-DP-39272	Tanzania	Mbeya Mts Virunga Mts: Mt Mgahinga, near	2731	8.83633	33.37083	O	SAMN21 5_Swertia_adolphi-friderici	
Gentianaceae	<i>Swertia</i>	<i>Swertia brownii</i>	J.Shah	AFROAL P II team	2008-07-23	O-DP-39501	Uganda	Camp Site	2340	1.35275	29.6201	O	SAMN21 1_Swertia_brownii	UG2008-
Gentianaceae	<i>Swertia</i>	<i>Swertia crassiuscula ssp crassiuscula</i>	Gilg	AFROAL P II team	2009-01-29	O-DP-36039	Kenya	Mt Elgon: S of Mt Koitobos	3629	1.10067	34.6215	O	SAMN21 2_Swertia_crassiuscula	ET1515-
Gentianaceae	<i>Swertia</i>	<i>Swertia crassiuscula ssp robusta</i>	Sileshi	AFROAL P II team	2008-10-18	O-DP-34488, O-DP-34489	Ethiopia	Bale Mts: Sanetti Aberdare Mts: along the car road towards	3700	6.76667	39.75	O	SAMN21 45_Swertia_crassiuscula_ssp_robusta	
Gentianaceae	<i>Swertia</i>	<i>Swertia crassiuscula var leucantha</i>	(T.C.E. Fr.) Sileshi	AFROAL P II team	2009-02-16	O-DP-28318	Kenya	Satima	3697	0.33883	36.6515	O	SAMN21 1_Swertia_crassiuscula_var_leucantha	KN0681-

Gentianaceae	<i>Swertia</i>	<i>Swertia engleri</i> <i>var engleri</i>	Gilg	AFROAL P II team	2007-10-23	O-DP-43467	Ethiopia	Simen Mts: Saha	13.2852 3718	5	38.11838	O	SAMN21 599700	ET0136- 1_Swertia_engleri var_engleri ET1454-
Gentianaceae	<i>Swertia</i>	<i>Swertia engleri</i> <i>var woodii</i>	(J.Shah ) Sileshi	AFROAL P II team	2008-10-14	O-DP-34071	Ethiopia	Bale Mts: Habera Virunga Mts: Mt Muhavura, along trail to 1st Hut	3482	7.00733	39.70983	O	SAMN21 599701	4_Swertia_engleri var_woodii
Gentianaceae	<i>Swertia</i>	<i>Swertia kilimandscharica</i>	Engl.	AFROAL P II team	2008-07-29	O-DP-40220	Uganda	Virunga Mts: Mt Mgahinga	2900	NA	NA	O	SAMN21 599702	UG2175- 1_Swertia_kilimandscharica UG2006- 4_Swertia_macrosepala_ssp_macrosepala ET0443-
Gentianaceae	<i>Swertia</i>	<i>Swertia macrosepala</i> <i>ssp macrosepala</i>	Gilg	AFROAL P II team	2008-07-22	O-DP-39494	Uganda	Virunga Mts: Mt Mgahinga	3470	1.38427	29.64018	O	SAMN21 599703	4_Swertia_macrosepala_ssp_macrosepala ET0443-
Gentianaceae	<i>Swertia</i>	<i>Swertia pumila</i>	Hochst.	AFROAL P II team	2007-10-31	O-DP-30948	Ethiopia	Simen Mts: Silki Sidamo: Wendo Abela Giorgis Church	13.3490 3912	7	38.2625	O	SAMN21 599704	1_Swertia_pumila
Gentianaceae	<i>Swertia</i>	<i>Swertia quartiniana</i>	A.Rich. (Hochst )	AFROAL P II team	2008-09-24	O-DP-33260	Ethiopia	Simen Mts: Near Gich Camp Site Mt Elgon: Mt	1990	6.9158	38.50017	O	SAMN21 599705	ET1304- 5_Swertia_quartiniana ET0187-
Gentianaceae	<i>Swertia</i>	<i>Swertia schimperi</i>	Griseb.	AFROAL P II team	2007-10-25	O-DP-44309	Ethiopia	Simen Mts: Near Gich Camp Site Mt Elgon: Mt	NA	NA	NA	O	SAMN21 599706	x_Swertia_schimperi KN0004-
Gentianaceae	<i>Swertia</i>	<i>Swertia subnivalis</i>	T.C.E.F r.	AFROAL P II team	2009-01-19	O-DP-34720	Kenya	Coitobos Addis Ababa: Kality Mt Elgon: Mt	4224	1.1239	34.60198	O	SAMN21 599707	3_Swertia_subnivalis ET1294-
Gentianaceae	<i>Swertia</i>	<i>Swertia tetandra</i>	Hochst.	AFROAL P II team	2008-09-29	O-DP-33195	Ethiopia	Coitobos Addis Ababa: Kality Mt Elgon: Mt	NA	NA	NA	O	SAMN21 599708	3_Swertia_tetandra KN0085-
Gentianaceae	<i>Swertia</i>	<i>Swertia uniflora</i>	Mildbr. & Gilg	AFROAL P II team	2007-01-23	O-DP-35048	Kenya	Coitobos	3953	1.124	34.59033	O	SAMN21 599709	4_Swertia_uniflora
Gentianaceae	<i>Swertia</i>	<i>Swertia usambarensis</i>	Engl.	AFROAL P II team	2009-06-24	O-DP-39278, O-DP-48440	Tanzania	Mbeya Mts	2616	8.83683	33.3725	O	SAMN21 599710	TZ0711- 4568_Swertia_usambarensis

Gentianaceae	<i>Swertia</i>	<i>Swertia volkensii</i>	Gilg	AFROAL P II team	2007-11-13	O-DP-31750, O-DP-31751	Ethiopia	Bale Mts: Sanetti	4050	NA	NA	O	SAMN21 599711	ET0680-x23_Swertia_volkensii ET0167-	
Poaceae	<i>Aira</i>	<i>Aira caryophyllea</i>	L.	AFROAL P II team	2007-10-24	O-DP-44263	Ethiopia	Simen Mts: Dirni Gate	3716	13.2879	8	38.11882	O	SAMN21 599712	T_Aira_caryophyllea ET0495-
Poaceae	<i>Alopecurus</i>	<i>Alopecurus baptarrhenius</i>	S.M.Phillips	AFROAL P II team	2007-11-01	O-DP-31197	Ethiopia	Simen Mts: Silki Mt	3681	13.3284	7	38.24297	O	SAMN21 599713	5_Alopecurus_baptarrhenius
Poaceae	<i>Anthoxanthum</i>	<i>Anthoxanthum nivale</i>	K.Schum. (L.)	AFROAL P II team	2008-11-03	O-DP-37045	Tanzania	Kilimanjaro : Shira Plateau	3406	2.98662	-	37.22237	O	SAMN21 599714	TZ0031-2_Anthoxanthum_nivale ET0831-
Poaceae	<i>Deschampsia</i>	<i>Deschampsia caespitosa</i>	P.Beauv.	AFROAL P II team	2007-11-18	O-DP-32350	Ethiopia	Bale Mts: Konten	4019	6.85542	39.89647		O	SAMN21 599715	3_Deschampsia_caespitosa TZ0328-
Poaceae	<i>Avenella</i>	<i>Avenella flexuosa</i>	(L.) Drejer (Hochst. ex A.Rich.)	AFROAL P II team	2008-11-18	O-DP-38285	Tanzania	Mt Kilimanjaro : Horombo	3710	-3.1375	37.43683		O	SAMN21 599716	3_Deschampsia_flexuosa_var_afromontana
Poaceae	<i>Helictotrichon</i>	<i>Helictotrichon elongatum</i>	C.E.Hubb.	AFROAL P II team	2007-10-24	O-DP-30063	Ethiopia	Simen Mts: Dirni Gate	3716	13.2879	8	38.11882	O	SAMN21 599717	ET0209-3_Helictotrichon_elongatum TZ0097-
Poaceae	<i>Koeleria</i>	<i>Koeleria capensis</i>	Nees	AFROAL P II team	2007-10-23	O-DP-29614	Ethiopia	Simen Mts: Saha	3718	13.2852	5	38.11838	O	SAMN21 599718	1_Koeleria_capensis ET0925-
Poaceae	<i>Rytidosperma</i>	<i>Rytidosperma subulata</i>	(A.Rich.) Cope	AFROAL P II team	2007-11-20	O-DP-32749	Ethiopia	Bale Mts: Angaso	3986	6.88218	39.8883		O	SAMN21 599719	2_Rytidosperma_subulata ET0691-
Plantaginaceae	<i>Veronica</i>	<i>Veronica anagallis-aquatica</i>	L.	AFROAL P II team	2007-11-03	O-DP-31570	Ethiopia	Simen Mts: Silki	3682	13.3270	5	38.24247	O	SAMN21 599731	1_Veronica_anagallis-aquatica ET0299-
Plantaginaceae	<i>Veronica</i>	<i>Veronica arvensis</i>	L.	AFROAL P II team	2007-10-24	O-DP-30129	Ethiopia	Simen Mts: Dirni Gate	3716	13.2879	8	38.11882	O	SAMN21 599732	14_Veronica_arvensis
Plantaginaceae	<i>Veronica</i>	<i>Veronica glandulosa</i>	Hochst. ex	AFROAL P II team	2007-10-23	O-DP-29615	Ethiopia	Simen Mts: Saha	3718	13.2852	38.11838		O	SAMN21 599733	ET0097-2_Veronica_glandulosa

Primulaceae	<i>Anagallis</i>	<i>Anagallis serpens subsp meyeri-johannis</i>	Benth. (Engl.) Taylor	AFROAL P II team	2007-10-21	O-DP-29581	Ethiopia	Simen Mts: Saha Simen Mts: Near Chenek Camp Site	3711	13.2827 3	38.11077	O	SAMN21 599720	ET0090-3_Anagallis_serpens_subsp_meyeri-johannis
Primulaceae	<i>Primula</i>	<i>Primula verticillata</i>	Forssk.	AFROAL P II team	2007-10-28	O-DP-30520	Ethiopia	Simen Mts: Near Chenek Camp Site	NA	NA	NA	O	SAMN21 599721	ET0330-2_Primula_verticillata KN0605-2_Anemone_thomsonii_var_friesiorum TZ0477-5_Anemone_thomsonii_var_thomsonii
Ranunculaceae	<i>Anemone</i>	<i>Anemone thomsonii var friesiorum</i>	Ulbr.	AFROAL P II team	2007-11-02	O-DP-31586	Ethiopia	Simen Mts: Silki	3643	13.3285	38.24092	O	SAMN21 599722	ET0557-2_Ranunculus_aberdaricus_or_stagnalis
Ranunculaceae	<i>Anemone</i>	<i>Anemone thomsonii</i>	Oliv.	AFROAL P II team	2008-11-30	O-DP-38990	Tanzania	Mt Meru: Saddle Hut area	3589	3.21783	36.754	O	SAMN21 599723	ET0130-1_Ranunculus_distriasis ET0449-2_Ranunculus_oligocarpos TZ0472-5_Ranunculus_oreophytus
Ranunculaceae	<i>Ranunculus</i>	<i>Ranunculus aberdaricus</i>	Ulbr. Steud.	AFROAL P II team	2007-11-02	O-DP-31436	Ethiopia	Simen Mts: Silki	3643	13.3285	38.24092	O	SAMN21 599724	KN0386-2_Ranunculus_stagnalis
Ranunculaceae	<i>Ranunculus</i>	<i>Ranunculus distriasis</i>	ex A.Rich. Hochst.	AFROAL P II team	2007-10-21	O-DP-29766	Ethiopia	Simen Mts: Saha	3711	13.2827 3	38.11077	O	SAMN21 599725	ET0609-2_Ranunculus_trichophyllus
Ranunculaceae	<i>Ranunculus</i>	<i>Ranunculus oligocarpos</i>	ex A.Rich.	AFROAL P II team	2007-11-01	O-DP-30977	Ethiopia	Simen Mts: Silki	3681	13.3284 7	38.24297	O	SAMN21 599726	ET0609-1_Ranunculus_volkensii
Ranunculaceae	<i>Ranunculus</i>	<i>Ranunculus oreophytus</i>	Delile Hochst.	AFROAL P II team	2008-11-30	O-DP-38965	Tanzania	Mt Meru: Saddle Hut area	3166	3.22075	36.78395	O	SAMN21 599727	
Ranunculaceae	<i>Ranunculus</i>	<i>Ranunculus stagnalis</i>	ex A.Rich.	AFROAL P II team	2009-01-31	O-DP-27222	Kenya	Mt Elgon: S of Mt Koitobos	3873	1.107	34.60317	O	SAMN21 599728	
Ranunculaceae	<i>Ranunculus</i>	<i>Ranunculus trichophyllus</i>	Chaix	AFROAL P II team	2007-11-02	O-DP-31595	Ethiopia	Simen Mts: Silki	3643	13.3285	38.24092	O	SAMN21 599729	
Ranunculaceae	<i>Ranunculus</i>	<i>Ranunculus volkensii</i>	Engl.	AFROAL P II team	2008-11-04	O-DP-37229	Tanzania	Mt Kilimanjaro : Shira	3536	-3.0056	37.24155	O	SAMN21 599730	

Violaceae	<i>Viola</i>	<i>Viola abyssinica</i>	Steud. ex Oliv.	AFROAL P II team	2008-07- 27	O-DP-39897	Uganda	Plateau Virunga Mts: Mt Muhavura, along trail to summit Virunga Mts: Mt Muhavura, along trail to summit	3700	-1.3782	29.67333	O	SAMN21 599734	UG2096- 2_Viola_abyssini ca
Violaceae	<i>Viola</i>	<i>Viola eminii</i>	R.E.Fr.	AFROAL P II team	2008-07- 25	O-DP-39721	Uganda	to summit Rwenzori Mts: Lower Bigo Valley	3550	1.37628	29.67153	O	SAMN21 599735	UG2035- 1_Viola_eminii
Violaceae	<i>Viola</i>	<i>Viola nannae</i>	R.E.Fr. Hochst.	AFROAL P II team	2008-08- 11	O-DP-40505	Uganda	Simen Mts: Gich Camp Site	3425	0.38502	29.9273	O	SAMN21 599736	UG2247- 2_Viola_nannae ET0230- 2_Umbilicus_bot ryoides
Crassula ceae	<i>Umbilicu s</i>	<i>Umbilicus botryoides</i>	ex A.Rich.	AFROAL P II team	2007-10- 25	O-DP-30133	Ethiopia		3652	13.269 72	38.1058 8	O	SAMN2 1599737	

**Table S2.** Distribution and age of species. Distribution and elevation of sampled species according to the Flora of East Africa and the Flora of Eritrea. In some cases, information are adapted to more recent information(indicated). *Lychnis* information are also based on Ousted (1985) A taxonomic revision of the genus *Uebelinia* Hochst.(Caryophyllaceae). Bulletin du Jardin botanique national de Belgique/Bulletin van de Nationale Plantentuin van Belgie, pp.421-459. *Cineraria* information based on Cron, G.V., Balkwill, K. and Knox, E.B., 2006. A revision of the genus *Cineraria* (Asteraceae, Senecioneae). Kew Bulletin, pp.449-535.. *Viola* information are solely based on information provided by “Conservatoire et Jardin botanique de Geneve” (<http://www.ville-ge.ch/musinfo/bd/cjb/africa/details.php?langue=en&id=175422>). Abbreviations: Ci: confidence interval; sA: strict Afroalpine (>3800m, according to Gehrke et al. (3)); oSA: occurs in the strict Afroalpine and below; obsA: occurs only below the strict Afroalpine (< 3800m)

family	genus	species name (according to ncbi)	individual clades				seed plant wide – treePL				elevation in m		altitud coding	Distribution	distribution coding	sample_id	
			BEAST2		treeP L	age	treePL			Ci							
			media n	Ci max	Ci min			media n	ma x	Ci min	min	x					
Apiaceae	<i>Pimpinella</i>	<i>Pimpinella oreophila</i>					1.83	5.82	0.16	230	420	0	0	oSA	Ethiopia, Kenya, Rep. South Sudan, Tanzania, Uganda, Cameroon, Gulf of Guinea Islands	endemicEA	KN0314-2_Pimpinella_oreophila_var_oreophila
Apiaceae	<i>Pimpinella</i>	<i>Pimpinella pimpinelloides</i>					1.83	5.82	0.16	420	452	0	0	sA	Native to Ethiopia (Simen)	Simen	ET0415-2_Pimpinella_pimpinelloides
Asteraceae	<i>Cineraria</i>	<i>Cineraria abyssinica</i>	2.58	7.71	0.19	1.25	0.37	1.52	0.01	250	410	0	0	oSA	Ethiopia, Saudi Arabia, Yemen	endemicEA	ET1413-2_Cineraria_abyssinica
Asteraceae	<i>Cineraria</i>	<i>Cineraria deltoidea</i>	2.58	7.71	0.19	1.25	0.5	0.71	0.02	110	430	0	0	oSA	Ethiopia, Kenya, Uganda, Tanzania, Rep. South Sudan, DR Congo, Rwanda, Malawi, Zambia, Zimbabwe, South Africa	widespread	ET0652-2_Cineraria_deltoida
Asteraceae	<i>Dendrosenecio</i>	<i>Dendrosenecio adnivalis</i>	0.42	2.5	0	0.59	0.48	9.75	0.01	325	450	0	0	oSA	Uganda, DR Congo; endemic to Mt	RwenzoriMts	UG2305-3_Dendrosenecio



Asteraceae	<i>Dendrosenecio battiscombei</i>	0.41	2.51	0	0.59	0.55	4.68	0.01	295	400	0	0	osA	Rwenzori Kenya; endemic to Mt Kenya and Aberdare Mts	MtKenya, Aberdares	_adnivalis_var_a dnivalis KN0482- 1_Dendrosenecio _battiscombei KN0516-
Asteraceae	<i>Dendrosenecio brassiciformis</i>	0.42	2.5	0	0.59	0.46	5.52	0	295	395	0	0	osA	Kenya; endemic to Aberdare Mts	Aberdares	4_Dendrosenecio _brassiciformis
Asteraceae	<i>Dendrosenecio cheranganiensis</i>	1	3.61	0.02	0.99				260	350	0	0	obsA	Kenya; endemic to Cherangani Hills	Cherangani Mts	Dendrosenecio_c heranganiensis KN0025-
Asteraceae	<i>Dendrosenecio elgonensis</i>	0.41	2.51	0	0.54	0.22	2.36	0.01	275	422	0	5	osA	Kenya, Uganda; endemic to Mt Elgon Uganda, Rwanda, DR Congo; endemic to Mt Rwenzori, Virunga Mts, Mt	MtElgon	4_Dendrosenecio _elgonensis_ssp _elgonensis  UG2207-
Asteraceae	<i>Dendrosenecio erici-rosenii</i>	1.46	4.85	0.12	1.98	0.33	8.23	0.03	275	447	0	5	osA	Mt Kenya, Mt Nyeri, Mt Kilimanjaro	RwenzoriMts , VirungaMts	5_Dendrosenecio _erici- rosenii_ssp_erici- rosenii
Asteraceae	<i>Dendrosenecio johnstonii</i>	0.49	2.95	0	0.67				275	335	0	0	obsA	Tanzania; endemic to Mt Kilimanjaro	MtKilimanjar o	Dendrosenecio_j ohnstonii KN0792-
Asteraceae	<i>Dendrosenecio keniensis</i>	0.44	2.7	0	0.59	0.22	3.2	0.01	330	427	0	5	osA	Kenya; endemic to Mt Kenya	MtKenya	3_Dendrosenecio _keniensis KN0781-
Asteraceae	<i>Dendrosenecio keniodendron</i>	0.44	2.7	0	0.54	0.46	2.54	0	365	435	0	0	osA	Kenya; endemic to Mt Kenya and Aberdare Mts	MtKenya, Aberdares	1_Dendrosenecio _keniodendron TZ0343-
Asteraceae	<i>Dendrosenecio kilimanjari</i>	0.49	2.95	0	0.67	0.23	2.56	0	300	427	0	5	osA	Tanzania; endemic to Mt Kilimanjaro	MtKilimanjar o	3_Dendrosenecio _kilimanjari_ssp_ kilimanjari
Asteraceae	<i>Dendrosenecio meruensis</i>	2.79	8.75	0.13	1.34				285	335	0	0	obsA	Tanzania; endemic to Mt Meru	MtMeru	Dendrosenecio_ meruensis

Asteraceae	<i>Erigeron</i>	<i>Erigeron alpinus</i>	3.86	8.82	0.55	1.36	0.03	1.76	0	0	0	osA	Ethiopia and Kenya. Also Europe to N. Iran	widespread	ET0928- 2_Erigeron_alpinus KN0599- 2_Euryops_brownei	
Asteraceae	<i>Euryops</i>	<i>Euryops brownei</i>	0.54	3.06	0	0.6	0.52	4.25	0	0	0	obsA	Kenya, Tanzania	endemicEA	TZ0237- 2_Euryops_dacrydioides KN0016- 2_Euryops_elgonensis	
Asteraceae	<i>Euryops</i>	<i>Euryops dacrydioides</i>	2.5	7.07	0.07	2.2	0.3	6.2	0	0	0	osA	Tanzania; endemic to Mt Kilimanjaro	MtKilimanjaro	2_Euryops_dacrydioides KN0016- 2_Euryops_elgonensis	
Asteraceae	<i>Euryops</i>	<i>Euryops elgonensis</i>	0.54	3.06	0	0.6	0.52	4.47	0	0	0	osA	Kenya, Uganda; endemic to Mt Elgon	MtElgon	ET1330- 2_Euryops_pinifolius ET0889- 2_Euryops_prostratus	
Asteraceae	<i>Euryops</i>	<i>Euryops pinifolius</i>	1.61	5.73	0.02	1.44	0.43	4.25	0	0	0	obsA	Ethiopia; Simen Mts, Mt Choke	Simen	ET0889- 2_Euryops_prostratus	
Asteraceae	<i>Euryops</i>	<i>Euryops prostratus</i>	1.61	5.73	0.02	1.75	0.3	4.5	0	0	0	sA	Ethiopia, endemic to ale Mts	Bale	ET0889- 2_Euryops_prostratus	
Brassicaceae	<i>Arabidopsis</i>	<i>Arabidopsis thaliana</i>	11.91	15.7	9	8.21	3.66	2.11	6.14	0.01	0	0	osA	Ethiopia, Uganda, Kenya, DR Congo, Tanzania. Also in Northern Africa, Macaronesia, Europe and much of Asia.	widespread	ET0177- 3_Arabidopsis_thaliana
Brassicaceae	<i>Arabis</i>	<i>Arabis alpina</i>	19.09	25.1	4	5	6.14	3.81	8.75	0.31	0	0	osA	Ethiopia, Kenya, Uganda, Tanzania, DR Congo. Also widespread in Europe, N. Asia, and N. America, extending within the Arctic Circle.	widespread	TZ0375- 3_Arabis_alpina
Brassicaceae	<i>Erophila</i>	<i>Erophila verna</i>	9.77	14.4	5.26	2.74	1.02	7.93	0.12	390	450	osA	Ethiopia. Simen	widespread	ET0667-	

														Mts, Bale Mts. Also in Europe, Northern Africa, Mediterranean Region, South-West and Central Asia. Ethiopia, Kenya, Uganda, Tanzania. Also in Southern Europe.		2_Erophila_verna_var_Macrosperma
Brassicaceae	<i>Thlaspi</i>	<i>Thlaspi alliaceum</i> (=Mummenhoffia alliacea)	12.7	3	7.01	4.41	1.57	9	0.35	0	0	sA			widespread	ET0671-2_Thlaspi_alliaceum
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia aberdarica</i>	4.03	6.94	1.95	2	0.6	8.27	0.3	0	0	obsA	Kenya, Uganda	endemicEA		KN0394-1_Lobelia_aberdarica
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia acrochila</i>	0.72	2.17	0.04	5	0.17	8.59	0.06	0	0	obsA	Ethiopia; Mt Bale, Sidamo, Arsi, Harar	Bale		ET1503-3_Lobelia_acrochilus
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia bambuseti</i>	0.15	0.82	0	2.17				0	0	obsA	Mt Kenya and Aberdare Mts	MtKenya, Aberdares		Lobelia_bambuseti
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia deckenii</i> subsp. <i>bequaertii</i>	2.44	5.09	0.75	6.05				0	0	osA	Uganda, DR Congo; endemic to Mt Rwenzori	RwenzoriMts		Lobelia_bequaertii
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia deckenii</i>	4.03	6.54	1.95	2	0.92	7	0.14	0	0	osA	Tanzania, Kenya, Uganda	endemicEA		TZ0025-2_Lobelia_deckenii_ssp_deckenii
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia giberroa</i>	0.57	2.14	0	1.57				0	0	obsA	Zambia, Zaïre	endemicEA		Lobelia_giberroa
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia graniticola</i>	4.09	1.08	8.6	4.76	3.13	9	1.17	0	0	obsA	Tanzania	endemicEA		Lobelia_graniticola
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia</i>	0.57	2.14	0	1.57	0.84	14.7	0.53	180	300	obsA	Burundi, Malawi,	endemicEA		KN0743-

ae		<i>mildbraedii</i>							3	0	0		Rwanda, Tanzania, Uganda, DR Congo Burundi, Malawi,		2_Lobelia_mildbrae aedii	
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia mildbraedii2</i>	3.45	6.68	1.23	8.87				180	300		Rwanda, Tanzania, Uganda, DR Congo	endemicEA	Lobelia_mildbrae dii	
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia rhynchopetalum</i>	3.45	6.68	1.23	10.3	3	0.17	8.59	0.06	300	435	Mts, Bale Mts, Choke, Arsi, Harar	Simen, Bale	ET0122- 2_Lobelia_rhynchopetalum	
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia stuhlmannii</i>	1.25	2.94	0.3	3.67		0.5	7.81	0.24	290	380	Uganda, Rwanda, DR Congo; endemic to Mt Rwenzori, Virunga Mts	RwenzoriMts , VirungaMts	UG2088- 1_Lobelia_stuhlmannii	
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia telekii</i>	5.18	8.59	2.66	14.0	2	0.79	11.4	7	0.12	295	455	Mts, Mt Kenya Uganda, Rwanda, DR Congo; endemic to Mt Rwenzori, Virunga Mts	endemicEA	KN0475- 3_Lobelia_telekii
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia wollastonii</i>	2.44	5.09	0.75	6.05		0.5	7.81	0.24	335	425	Virunga Mts	RwenzoriMts , VirungaMts	UG2173- 3_Lobelia_wollastonii	
Campanulaceae	<i>Lobelia2</i>	<i>Lobelia erlangeriana</i>	6.88	12.4	4	2.82	6.26	8.12	35.1	1.99	320	410	Ethiopia; Bale Mts, Arsi Kenya, Uganda; endemic to Mt.Elgon, Aberdare Mts	Simen, Bale	ET1510- 14_Lobelia_erlangeriana	
Campanulaceae	<i>Lobelia2</i>	<i>Lobelia lindblomii</i>	4.09	8.6	1.08	4.76		3.1	21.1	1	1.17	310	425	Mt.Elgon, Aberdare Mts	MtElgon	KN0527- 4_Lobelia_lindblomii
Campanulaceae	<i>Lobelia2</i>	<i>Lobelia schimperii</i>	12.23	20.0	5	6.03	8	13.68	43.2	3	2.21	240	380	Ethiopia; endemic to Simen Mts	Simen	BG52- 1_Lobelia_schimperii
Caryophyllaceae	<i>Lychnis</i>	<i>Lychnis abyssinica</i> (= <i>Silene abyssinica</i> )	1.98	3.25	1.03	0.98		1.37	14.3	0.47	135	400	Ethiopia, Kenya, Rwanda, Uganda, DR Congo, Burundi, Eritrea, Nigeria,	widespread	ET1300_18_3_Lychnis_abyssinica	

Caryophyllaceae	<i>Lychnis</i>	<i>Lychnis abyssinica</i> <sup>2</sup> (= <i>Silene abyssinica</i> )	4.67	6.81	2.85	2.57	2.4	1	1.15	0	0	osA	12.9	135	400	Cameroon Ethiopia, Kenya, Rwanda, Uganda, DR Congo, Burundi, Eritrea, Nigeria, Cameroon	widespread	ET0098- X_Lychnis_abyssinica_LGS
Caryophyllaceae	<i>Lychnis</i>	<i>Lychnis crassifolia</i> (= <i>Silene kenyanana</i> )	2.45	4.14	1.26	1.53	2.11	10.2	0.68	0	0	osA		200	390	Kenya, Tanzania	endemicEA	KN0494- 2_Lychnis_crassifolia
Caryophyllaceae	<i>Lychnis</i>	<i>Lychnis kigesiensis</i> (= <i>Silene kigesiensis</i> subsp. <i>ragazziana</i> )	1.98	3.25	1.03	0.98	1.37	11.3	0.47	0	0	obsA		150	300	Uganda, Rwanda, Ethiopia	endemicEA	UG2600- 1_Lychnis_kigesiensis_subsp_ragazziana
Caryophyllaceae	<i>Lychnis</i>	<i>Lychnis kiwuensis</i> (= <i>Silene kiwuensis</i> )	2.45	4.14	1.26	1.53	2.11	10.2	0.68	0	0	obsA		180	380	Uganda, Ruanda, Burundi, DR Congo, Ethiopia Kenya, Tanzania; endemic to Aberdare Mts, Mt. Kenya, Mt Kilimanjaro	endemicEA	ET1320- 3_Lychnis_kiwuensis
Caryophyllaceae	<i>Lychnis</i>	<i>Lychnis rotundifolia</i> (= <i>Silene afromontana</i> )	3.9	5.81	2.36	2.88	1.98	8	0.68	0	0	osA	16.6	260	395	Ethiopia; Gughe highland, Amaro Mts	Bale	KN0497- 4_Lychnis_rotundifolia
Caryophyllaceae	<i>Lychnis</i>	<i>Lychnis scottii</i> (= <i>Silene scottii</i> )	3.22	4.91	1.87	1.96				0	0	obsA		270	330	Ethiopia, Tanzania, Eritrea, Rep. South Sudan, Yemen, Saudi Arabia, Somalia	Bale	Uebelina_scottii
Caryophyllaceae	<i>Minuartia</i>	<i>Minuartia filifolia</i>	5.05	7.94	2.88	3	10.19	3	4.03	0	0	osA	13.9	180	405	Ethiopia, Kenya,	endemicEA	ET0266- 1_Minuartia_filifolia
Caryophyllaceae	<i>Sagina</i>	<i>Sagina afroalpina</i>	2.87	4.8	1.29	2.78	1.44	16	1.15	315	460	osA				Ethiopia, Kenya,	endemicEA	KN0944-

ae										0	0	Uganda, DR Congo Ethiopia, Kenya, Uganda, Tanzania, Eritrea, Rep. South Sudan, Somaliland, South Africa, Angola, Rwanda, DR Congo, Tropical Arabia	widespread	2_Sagina_afroalp ina	
Caryophyllaceae	<i>Silene</i>	<i>Silene burchellii</i>	2.94	5.68	1.09	9.62	0.66	6	0.34	150	405			KN0594- 1_Silene_burchel lii_var_burchellii	
Caryophyllaceae	<i>Silene</i>	<i>Silene flammulifolia</i>	0.51	1.2	0.08	3.72	0.26	3.8	0.11	300	370	Ethiopia, Somalia, Yemen	endemicEA	ET0205- 2_Silene_flammu lifolia	
Caryophyllaceae	<i>Silene</i>	<i>Silene macrosolen</i>					0.26	3.8	0.11	180	360	Ethiopia, Kenya, Tanzania, Rep. South Sudan	endemicEA	ET0289- 4_Silene_macros olen	
Crassulaceae	<i>Umbilicus</i>	<i>Umbilicus botryoides</i>	0.98	1.97	0.31	2.76	19.41	8	4.92	135	415	Ethiopia, Kenya, Uganda, DR Congo, Eritrea, Rwanda, Somalia, Sudan, Cameroon	widespread	ET0230- 2_Umbilicus_botr yoides	
Dipsacales	<i>Scabiosa</i>	<i>Scabiosa columbaria</i>				0.99	5.48	12.8	1.08	200	410	Cameroon, South Africa and Europe	widespread	TZ0218- 2_Scabiosa_colu mbaria	
Dipsacales	<i>Valerianella</i>	<i>Valerianella microcarpa</i>				12.2	8	10.23	8	22.5	220	410	Ethiopia, Kenya, North Africa, Europe (Mediterranean region)	widespread	ET0734- 2_Valerianella_m icrocarpa
Gentianaceae	<i>Sebaea</i>	<i>Sebaea</i> sp	3.26	5.76	1.28	2.35	18.25	9	4.99					UG2145- 3_Sebea_sp	
Gentianaceae	<i>Swertia1</i>	<i>Swertia</i>	5.17	8.43	2.24	4.8	0.58	3.11	0.1	150	335	Ethiopia, Kenya,	widespread	ET1031-	

													Uganda, Tanzania. Also in South Sudan, Malawi, Cameroon, Mozambique, Equatorial Guinea, Eritrea and Zambia. Ethiopia, Kenya, Uganda, Tanzania, Burundi, Rwanda, DR Congo			3_Swertia_abyssi nica
										0	0					
Gentianaceae	Swertia1	<i>Swertia brownii</i>	6.47	9.85	3.46	4.8	0.45	4.1	0.07	750	0	obsA	300		endemicEA	UG2008- 1_Swertia_brown ii
Gentianaceae	Swertia1	<i>Swertia crassiuscula</i>	13	7	8.99	9.74	1.64	6.74	0.07	0	0	osA	260	420	endemicEA	Kenya, Tanzania, Uganda KN0309- 2_Swertia_crass iuscula
Gentianaceae	Swertia1	<i>Swertia crassiuscula ssp robusta</i>	6.33	9.65	3.39	4.8	1.18	4.45	0.15	0	0	osA	360	405	endemicEA	Ethiopia; endemic to Mt Bale ET1515- 45_Swertia_cras siuscula_ssp_rob usta
Gentianaceae	Swertia1	<i>Swertia engleri var engleri</i>	13.99	3	9.82	9.87	0.82	4.79	0.13	0	0	osA	335	450	endemicEA	Ethiopia; Simen Mts and Wello ET0136- 1_Swertia_engler i_var_engleri
Gentianaceae	Swertia1	<i>Swertia engleri var woodii</i>	6.83	9.94	3.91	4.84	2.94	6.97	0.27	0	0	obsA	245	335	endemicEA	Ethiopia, Yemen, Saudi Arabia ET1454- 4_Swertia_engler i_var_woodii
Gentianaceae	Swertia1	<i>Swertia pumila</i>	3.93	6.53	1.78	2.63	0.58	3.11	0.1	0	0	obsA	305	375	endemicEA	Ethiopia; Simen Mts, Bale Mts ET0443- 1_Swertia_pumil a
Gentianaceae	Swertia1	<i>Swertia quartiniana</i>	5.17	8.43	2.24	4.8	0.9	4.19	0.19	900	285	obsA	0		widespread	Ethiopia, Kenya, Uganda, Tanzania, DR Congo, Zambia, Malawi, Mozambique, Zimbabwe, ET1304- 5_Swertia_quarti niana

Gentianaceae	<i>Swertia1</i>	<i>Swertia usambarensis</i>	6.33	9.65	3.39	5.8	0.45	5.89	0.07	135	310	0	0	obsA	Cameroon, Nigeria Ethiopia, Kenya, Uganda, Tanzania, Burundi, Rwanda, DR Congo, Zimbabwe, Mozambique, Malawi	widespread	TZ0711- 4568_Swertia_us ambarensis	
Gentianaceae	<i>Swertia2</i>	<i>Swertia adolfi-friderici</i>	3.32	7.09	1.9	2.57	2.25	8	0.27	12.9	230	300	0	0	obsA	Uganda, Rwanda, DR Congo, Burundi Ethiopia, Kenya, Uganda, Tanzania, Burundi, Rwanda, DR Congo, Malawi	endemicEA	TZ0710- 5_Swertia_adolphi- friderici
Gentianaceae	<i>Swertia2</i>	<i>Swertia kilimandscharica</i>	0.71	2.75	0	2.7	1.14	4	0.58	11.5	210	400	0	0	osA	DR Congo, Malawi	endemicEA	UG2175- 1_Swertia_kilima ndscharica
Gentianaceae	<i>Swertia2</i>	<i>Swertia macrosepala</i>	0.22	1.08	0	0.35	3.33	9.79	0.27	11.5	335	420	0	0	osA	Tanzania, Uganda, Rwanda, DR Congo, Ethiopia Ethiopia, Uganda, Tanzania, Malawi, South Sudan	endemicEA	UG2006- 4_Swertia_macro sepala_ssp_macr osepala
Gentianaceae	<i>Swertia2</i>	<i>Swertia schimperi</i>	4.09	7.09	1.9	2.57	1.14	4	0.58	11.5	140	390	0	0	osA	Tanzania, Malawi, South Sudan	endemicEA	ET0187- x_Swertia_schim peri
Gentianaceae	<i>Swertia2</i>	<i>Swertia subnivalis</i>	0.22	1.08	0	0.35	3.33	4	0.33	13.0	360	420	0	0	osA	Kenya; endemic to Mt. Kenya.	MtKenya	KN0004- 3_Swertia_subni valis
Gentianaceae	<i>Swertia2</i>	<i>Swertia uniflora</i>	0.71	2.75	0	1.55	6.11	7	0.27	11.3	375	430	0	0	osA	Kenya, Uganda; endemic to Mt Elgon	MtElgon	KN0085- 4_Swertia_uniflor a
Gentianaceae	<i>Swertia2</i>	<i>Swertia volkensis</i>	1.67	3.57	0.39	1.26	5.19	6	0.27	15.5	285	450	0	0	osA	Ethiopia, Kenya, Tanzania	endemicEA	ET0680- x23_Swertia_volk ensii
Poaceae	<i>Aira</i>	<i>Aira caryophyllea</i>	2.89	5.53	0.7	1.73	2.11	11.3	0.56	1	210	450	0	0	osA	Ethiopia, Kenya, Uganda, Tanzania, Rep. South Sudan.	widespread	ET0167- T_Aira_caryophyl lea



													Also in South Africa, Northern Europe and Asia. Introduced to many other parts of the world					
Poaceae	<i>Alopecurus</i>	<i>Alopecurus baparrhenius</i>	1.4	2.72	0.37	1.22	0.4	4.29	0.03	270	400	0	0	osA	Ethiopia; Bale Mts (also in Shewa Region) Bale, Simen	ET0495- 5_ <i>Alopecurus_ba</i> <i>ptarrhenius</i>		
Poaceae	<i>Anthoxanthum</i>	<i>Anthoxanthum nivale</i>	2.1	4.37	0.42	1.6	1.38	8.95	0.28	240	480	0	0	osA	Kenya, Uganda, DR Congo, Rwanda, Tanzania	endemicEA TZ0031- 2_ <i>Anthoxanthum</i> <i>nivale</i>		
Poaceae	<i>Avenella</i>	<i>Avenella flexuosa</i>	11.29	16.9	2	6.04	11.4	9	0.88	7.36	0.37	260	460	0	0	osA	Ethiopia, Uganda, Kenya, Tanzania, DR Congo	endemicEA TZ0328- 3_ <i>Deschampsia</i> <i>flexuosa_var_afr</i> <i>omontana</i>
Poaceae	<i>Deschampsia</i>	<i>Deschampsia caespitosa</i>	1.29	2.46	0.35	0.95	3.76	9.07	0.12	290	430	0	0	osA	Ethiopia, Kenya, Uganda, DR Congo, Tanzania. Also in temperate regions of both hemispheres and mountains of the Cameroun	endemicEA	ET0831- 3_ <i>Deschampsia</i> <i>caespitosa</i>	
Poaceae	<i>Helictotrichon</i>	<i>Helictotrichon elongatum</i>	1.43	2.61	0.28	0.33	1.32	2.83	0.05	180	450	0	0	osA	Ethiopia, Kenya, Uganda, DR Congo, Rwanda, Tanzania, Rep. South Sudan, Cameroon, Malawi, Zimbabwe, Madagascar	widespread	ET0209- 3_ <i>Helictotrichon</i> <i>elongatum</i>	
Poaceae	<i>Koeleria</i>	<i>Koeleria capensis</i>	1.15	2.48	0.15	0.9	1.49	7.02	0.02	180	530	0	0	osA	Ethiopia, Kenya, Uganda, Tanzania, Rep. South Sudan. Also in Cameroon,	widespread	TZ0097- 1_ <i>Koeleria_cape</i> <i>nsis</i>	

Poaceae	<i>Rytidosperma</i>	<i>Rytidosperma subulata</i>	1.43	2.61	0.28	0.75	0.77	2.97	0.07	300	430	0	0	osA	Southern Africa Ethiopia; Simen Mts, Bale Mts. Also in Northern Yemen.	endemicEA	ET0925- 2_ Rytidosperma_ subulata	
Plantaginaceae	<i>Veronica</i>	<i>Veronica abyssinica</i>	3.11	5.03	1.54	1.37				120	390	0	0	osA	Ethiopia, Kenya, Uganda, Tanzania, Burundi, Cameroon, Malawi, Mozambique, Nigeria, Rwanda, Somalia, Rep. South Sudan, Zambia, DR Congo, Zimbabwe	widespread	Veronica abyssinica	
Plantaginaceae	<i>Veronica</i>	<i>Veronica anagallis-aquatica</i>	1.47	2.62	0.7	0.4	1.11	3.62	0.12	480	300	0	0	obsA	Ethiopia, Kenya, Uganda, Tanzania, also in Rwanda, Zambia, Zimbabwe and widespread in N America and Europe	widespread	ET0691- 1_ Veronica_ anag allis-aquatica	
Plantaginaceae	<i>Veronica</i>	<i>Veronica glandulosa</i>	6.79	10.0	4.35	2.65	0.74	7.87	0.2	200	410	0	0	osA	Ethiopia, Kenya, Uganda, DR Congo, Rwanda, Tanzania	endemicEA	ET0097- 2_ Veronica_ glan dulosa	
Primulaceae	<i>Anagallis</i>	<i>Anagallis serpens</i>					0.74	0.2	7.87	250	450	0	0	osA	Tanzania, Ethiopia, Rep. South Sudan, Zimbabwe			
Primulaceae	<i>Primula</i>	<i>Primula verticillata</i>	0.91	2.02	0.22	1.21	4.84	8.63	0.11	200	420	0	0	osA	Ethiopia, Somalia, Saudi Arabia, Yemen	endemicEA	ET0330- 2_ Primula_ vertici llata	
Ranunculaceae	<i>Anemone</i>	<i>Anemone thomsonii</i>					3.48	10.4	5	0.6	270	390	0	0	osA	Ethiopia, Kenya, Rep. South Sudan, Tanzania, Uganda, DR Congo	endemicEA	KN0605- 2_ Anemone_ tho msonii_ var_ friesi orum

Ranunculaceae	<i>Ranunculus_ noclade</i>	<i>Ranunculus distrias</i>	2.44	4.12	0.89	6.76	2.75	9	0.01	17.2	240	310	0	0	obsA	Ethiopia; Northern and central Ethiopia, Kenya, Tanzania, Uganda, Rwanda, Rep. South Sudan, DR Congo	Simen	ET0130-1_ <i>Ranunculus_ distrias</i>
Ranunculaceae	<i>Ranunculus_ noclade</i>	<i>Ranunculus oreophytus</i>	3.74	5.93	1.86	8.67	3	7.53	0.04		224	435	0	0	osA	Ethiopia and widely distributed from N America, through Europe to Asia, Australia and Tasmania	endemicEA	TZ0472-5_ <i>Ranunculus_ oreophytus</i>
Ranunculaceae	<i>Ranunculus_ noclade</i>	<i>Ranunculus trichophyllus</i>	2.1	4.29	1.6	5.17	0.56	4.29	0.11		250	405	0	0	osA	Ethiopia, Kenya, Uganda, DR Congo, Rwanda, Tanzania, Burundi	widespread	ET0609-2_ <i>Ranunculus_ trichophyllus</i>
Ranunculaceae	<i>Ranunculus_ noclade</i>	<i>Ranunculus volkensis</i>	4.93	7.15	3.1	13.5	2.68	4	0.45	10.0	270	405	0	0	osA	Ethiopia, Kenya, Uganda, Tanzania, Burundi	endemicEA	TZ0069-1_ <i>Ranunculus_ volkensis</i>
Ranunculaceae	<i>Ranunculus1</i>	<i>Ranunculus aberdaricus</i>	1.22	3.1	0.17	3.27	0.32	3.56	0.02		270	300	0	0	obsA	Ethiopia, Kenya, Uganda, Tanzania and widespread in tropical and south Africa, Madagascar and Arabia	endemicEA	ET0557-2_ <i>Ranunculus_ aberdaricus_ or_ st agnalis</i>
Ranunculaceae	<i>Ranunculus1</i>	<i>Ranunculus multifidus</i>	4	9.13	2.06	9.13	0.22	3.56	0.01		117	380	0	0	obsA	Ethiopia, Kenya, Uganda; endemic to Mt Elgon	widespread	<i>Ranunculus multifidus</i>
Ranunculaceae	<i>Ranunculus2</i>	<i>Ranunculus cryptanthus</i>					0.37				405	410	0	0	sA		MtElgon	
Ranunculaceae	<i>Ranunculus2</i>	<i>Ranunculus oligocarpus</i>	0.44	1.43	0	0.79	0.63	8.91	0.02		200	407	0	0	osA	Ethiopia, Kenya	endemicEA	ET0449-2_ <i>Ranunculus_ oligocarpos</i>
Ranunculaceae	<i>Ranunculus2</i>	<i>Ranunculus</i>	1.44	2.44	0.59	3.5	0.42	5.2	0.01		240	315	obsA		Ethiopia, Simen	Simen, Bale	<i>Ranunculus</i>	

e		<i>simensis</i>							0	0		Mts, Bale Mts, Arisi Ethiopia, Kenya, Uganda, Tanzania, DR Congo		simiensis KN0386- 2_Ranunculus_st agnalis			
Ranunculaceae	<i>Ranunculus2</i>	<i>stagnalis</i>	0.44	1.43	0	0.79	0.63	8.91	0.03	225	475	0	0	osA	endemicEA		
Ranunculaceae	<i>Ranunculus2</i>	<i>stagnalis2</i>	1.09	2.02	0.39	3.1	0.37							osA	endemicEA		
Ranunculaceae	<i>Ranunculus2</i>	<i>tembensis</i>	1.09	2.02	0.39	3.1	0.42	4.37	0.01	305	350	0	0	obsA	Simen, Bale		
Violaceae	<i>Viola</i>	<i>Viola abyssinica</i>					0.61	5.28	0.08	120	340	0	0	obsA	Madagascar Burundi, Kenya, Rwanda, Rep. South Sudan, Tanzania, Uganda, DR Congo	widespread	UG2096- 2_Viola_abyssini ca
Violaceae	<i>Viola</i>	<i>Viola eminii</i>					0.32	4.96	0.04	200	405	0	0	osA	Kenya; endemic to Mt Kenya and Aberdare	MtKenya, Aberdares	UG2035- 1_Viola_eminii
Violaceae	<i>Viola</i>	<i>Viola nannae</i>					0.32	4.9	0.0	255	360	0	0	obsA			UG2247- 2_Viola_nannae

**Table S3.** Alignment information.

Alignment dataset	Locus	No. of seq. in original dataset	No of seq. added from new material	No of seq. added from GenBank	Total no. of seq.	Total seq. length	Missing new samples
Seed plant wide	<i>rbcL</i>	22399	92	0	27982	682	0
	<i>matK</i> (incl. <i>trnK</i> )	27891	92	0	22489	4215	0
	concatenated				36197	4897	
Asteraceae	<i>trnLF</i>	29	17	61	107	890	0
	<i>rbcL</i>	29	17	15	55	1429	0
	<i>ndhF</i>	29	17	20	64	1718	0
	concatenated				90	4031	0
Brassicaceae	<i>trnLF</i>	55	4	37	96	1064	0
	<i>rbcL</i>	26	4	29	59	1153	0
	<i>ndhF</i>	95	4	22	121	2068	0
	<i>nad4</i>	97	0	0	97	1481	4
	<i>matK</i>	58	4	29	91	1045	0
	ITS	211	4	34	249	819	0
	<i>chl</i>	26	0	0	26	999	4
	<i>adh</i>	14	0	0	14	1986	4
	concatenated <sup>1</sup>				54	7270	
Campanulaceae	<i>trnLF</i>	76	11	31	119	1347	0
	<i>rbcL</i>	67	11	27	106	1400	0
	<i>ndhF</i>	31	11	29	72	1234	0
	concatenated				118	3776	
Caryophyllaceae	ITS	63	10	58	132	766	0
Crassulaceae	<i>trnLF</i>	90	1	9	100	1168	0
	<i>rps16</i>	58	1	9	68	1052	0
	<i>matK</i>	89	1	9	99	1232	0
	ITS	322	1	9	332	1005	0
	concatenated				324	4440	
Dipsacales	ITS	120	2	13	122	743	0
	<i>matK</i>	126	2	20	128	1226	0

<sup>1</sup>no *chl*, *adh* used for concatenation, samples with less than 4 loci were removed, alignment edited.

	<i>psbAH</i>	109	2	4	111	459	0
	<i>trnL</i>	123	2	16	125	1028	0
	concatenated				149	3448	0
Gentianaceae	<i>trnLF</i>	162	19	58	239	667	0
	ITS	153	18	39	210	732	1
	concatenated				181	1384	
Poaceae (dataset A)	<i>rbcL</i>	250	8	28	286	1486	0
	<i>ndhF</i>	250	8	30	288	2451	0
	<i>matK</i>	250	8	27	285	3321	0
	concatenated				282	7442	
Plantaginaceae	ITS – Plantago	38	2	23	63	741	0
Primulaceae	<i>trnLF</i>	13	2	9	24	1070	0
	<i>rps16</i>	11	2	9	22	879	0
	<i>rpl16</i>	13	2	8	22	1099	0
	<i>rbcL</i>	13	2	10	25	1396	0
	<i>ndhF</i>	9	2	5	16	1938	0
	<i>matK</i>	13	1	8	23	1573	1
	concatenated				20	7911	
Ranunculaceae	<i>trnL-matK</i>	237	7	42	286	2013	2
	<i>psbJ-petA</i>	225	7	24	256	762	2
	ITS	238	6	39	283	656	3
	concatenated				249	3425	

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**Table S4.** Species represented by more than one individual in the phylogenies of individual seed plant clades generated using BEAST2 and retrieved as monophyletic or non-monophyletic. PP = posterior probability.

<b>Species retrieved as monophyletic</b>	
> 0.9 PP	<i>Arabidopsis thaliana</i> , <i>Arabis alpina</i> , <i>Minuartia filifolia</i> , <i>Lobelia deckenii</i> (excl. <i>L. d. bequaertii</i> ), <i>Silene burchellii</i>
< 0.9 PP	<i>Lobelia telekii</i> , <i>Lobelia acrochila</i> , <i>Cineraria abyssinica</i>
<b>Non-monophyletic</b>	
> 0.9 PP	Potentially paraphyletic species (nested species in parenthesis): <i>Veronica glandulosa</i> ( <i>V. abyssinica</i> ); <i>Lobelia aberdarica</i> ( <i>L. bambuseti</i> ); <i>Lobelia stuhlmannii</i> ( <i>L. wollastonii</i> )  Potentially polyphyletic species: <i>Ranunculus stagnalis</i> ; <i>Lychnis abyssinica</i> ; <i>Lobelia mildbraedii</i> , <i>Lobelia deckenii</i> ( <i>Lobelia deckenii</i> spp. <i>bequaertii</i> clade with <i>L. stuhlmannii</i> , <i>L. wollastonii</i> ); <i>Swertia crassiuscula</i> (Ethiopian sample together with <i>S. engleri</i> , distantly related to other <i>S. crassiuscula</i> )
< 0.9 PP	<i>Ranunculus trichophyllus</i> ; <i>Veronica anagallis-aquatica</i> ; <i>Lobelia rhynchopetalum</i> ( <i>L. acrochilua</i> ); <i>Ranunculus volkensis</i> ( <i>R. ficariifolius</i> , <i>R. cheirophyllus</i> )

**Table S5.** BEAST2 age estimates of afroalpine clades containing min. two sampled species. Asterix indicates unsupported stem nodes.

family	clade	number of species	crown age	stem age
Asteraceae	<i>Dendrosenecio</i> *	11	7.89 (2.07 - 16.77)	22.62 (15.18 - 30.73)
Asteraceae	<i>Cineraria</i> *	2	2.58 (7.71 - 0.19)	3.54 (0.55 - 8.28)
Asteraceae	<i>Euryops</i> *	6	6.34 (1.93 - 13.03)	14.61 (7.4 - 22.87)
Campanulaceae	Giant <i>Lobelia</i> *	14	9.49 (5.01 - 15.17)	15.79 (9.63 - 22.98)
Campanulaceae	Herbal <i>Lobelia</i>	4	12.23 (6.03 - 20.05)	18.7 (10.37 - 28.99)
Caryophyllaceae	<i>Lychnis</i>	7	6.62 (4.33 - 9.4)	8.35 (9.4 - 5.56)
Gentianaceae	Swertia clade 1	9	13.99 (9.82 - 18.63)	19.02 (14.19 - 24.44)
Gentianaceae	Swertia clade 2	6	4.09 (1.9 - 7.09)	10.49 (5.08 -

				17.19)
Plantaginaceae	Veronica	7	3.93 (2.2 - 6.14)	6.79 (4.35 - 10.01)
Ranunculaceae	<i>Ranunculus</i> clade 1	3	4 (2.06 - 6.13)	5.53 (3.83 - 7.58)
Ranunculaceae	<i>Ranunculus</i> clade 2	4	2.2 (1.13 - 3.47)	3.49 (2.31 - 4.8

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**Table S6.** Lineages estimated to be older than 10 Ma in at least one of the analyses (Table S2). Differentiated into being part of an afroalpine clade or not. Sorted according to families, and then sorted according to the dating method and then alphabetically. Bold indicates taxa having across all available dating methods age estimates > 10Ma.

family	genus	taxon	number of species	individual seed plant clades – BEAST2	individual seed plant clades – treePL	seed plant-wide – treePL
Asteraceae	<i>Dendrosenecio</i>	<i>Dendrosenecio</i>	11	22.62		0.77
Asteraceae	<i>Euryops</i>	<i>Euryops</i>	6	14.61		0.93
<b>Campanulaceae</b>	<b><i>Lobelia2</i></b>	<b><i>Lobelia 2</i></b>	<b>4</b>	<b>18.7</b>		<b>13.68</b>
Campanulaceae	<i>Lobelia1</i>	<i>Lobelia 1</i>	12	15.79		1.42
Caryophyllaceae	<i>Lychnis</i>	<i>Lychnis</i>	7	8.35		3.35
Gentianaceae	<i>Swertia1</i>	<i>Swertia 1</i>	11	19.02		2.94
Gentianaceae	<i>Swertia2</i>	<i>Swertia 2</i>	7	10.49		8.82
Plantaginaceae	<i>Veronica</i>	<i>Veronica</i>	2	6.79		
Brassicaceae	<i>Arabis</i>	<i>Arabis alpina</i>	1	19.09	6.14	3.81
Brassicaceae	<i>Thlaspi</i>	<i>Thlaspi alliaceum</i>	1	12.7	4.41	1.57
Brassicaceae	<i>Arabidopsis</i>	<i>Arabidopsis thaliana</i>	1	11.91	3.66	2.11
Caryophyllaceae	<i>Minuartia</i>	<i>Minuartia filifolia</i>	1	5.05	13.93	10.19
Crassulaceae	<i>Umbilicus</i>	<i>Umbilicus botryoides</i>	1	0.98	2.76	19.41
<b>Dipsacales</b>	<b><i>Valerianella</i></b>	<b><i>Valerianella microcarpa</i></b>	<b>1</b>		<b>12.28</b>	<b>10.23</b>
Gentianaceae	<i>Sebaea</i>	<i>Sebaea</i> sp	1	3.26	2.35	18.25
Poaceae	<i>Avenella</i>	<i>Avenella flexuosa</i>	1	11.29	11.49	0.88

**Table S7.** Statistics for the different dating methods (Table S2). Abbreviations: ci – confidence intervals.

	individual seed plant clades – BEAST2			individual seed plant clades – treePL	seed plant-wide – treePL		
	stem age	ci max	ci min	stem age	stem age	ci min	ci max
min	0.15	0.82	0	0.33	0.03	0	0.20
max	19.09	25.14	13.05	14.02	19.41	7.87	65.78
median	2.44	4.85	0.70	2.57	0.84	0.12	7.81
mean	3.37	6.00	1.68	3.81	2.12	0.53	10.28
number of species		91		93		93	
<=5	73	47	82	79	84	90	31
< 10	84	81	90	84	88	91	60
>= 10	7	10	1	9	5	0	31
>=15	1	7	0	0	2	0	14

**Table S8.** Molecular dating settings for individual seed plant clades.

lineage	constraint		BEAST2						treePL			
			linked substitutio on rates	linked trees	linked clocks	starting tree	substitutio n rate model	prior settings		min	max	
Asteraceae	mrca	incl. All samples	no	yes	yes	yes	GTR+G+I	uniform	73	101	73	101
	Barnadesi oideae	incl. <i>Barnadesia</i> , <i>Dasyphyllum</i>						Exponenti al	1.5	72.1	72.1	100
	Famathin antus	excl. <i>Acicarpha</i> , <i>Barnadesia</i> , <i>Boopis</i> , <i>Dasyphyllum</i> , <i>Famatinanthus</i> , <i>Schlechtendalia</i> excl. <i>Tropaeolum minus</i> , <i>Moringa oleifera</i> , <i>Carica</i> <i>papaya</i> , <i>Batis maritima</i> , <i>Reseda lutea</i> , <i>Capparis</i>	cp and nr					Exponenti al	1.5	47.5	47.5	65
Brassicaceae	ingroup	<i>flexuosa</i> , <i>Cleome viscosa</i>	split	yes	yes	no	GTR+G+I	normal	89.5	1	87.9	91.1
Campanulaceae	mrca	all	no	yes	yes	no	GTR+G+I	normal	93	1	90	96
	Hawaii	incl. <i>Brighamia insignis</i> , <i>Clermontia kakeana</i> , <i>Cyanea angustifolia</i> , <i>Cyanea koolauensis</i> , <i>Delissea undulata</i> , <i>Lobelia hypoleuca</i> , <i>Lobelia</i> <i>yuccoides</i> , <i>Trematolobelia macrostachys</i>						uniform	0	29.8	not set	29.8
	Campanul oideae	incl. <i>Campanula asperuloides</i> , <i>Campanula latifolia</i> , <i>Campanula trachelium</i> , <i>Legousia hybrida</i> excl. <i>Corrigiola andina</i> , <i>Corrigiola litoralis</i> , <i>Paronychia argentea</i> , <i>Paronychia lindheimeri</i> , <i>Gymnocarpos rotundifolius</i> , <i>Gymnocarpos</i> <i>decander</i> , <i>Herniaria glabra</i> , <i>Philippiella patagonica</i> , <i>Drymaria cordata</i> , <i>Pycnophyllum bryoides</i> , <i>Cordia</i> , <i>Polycarpon tetraphyllum</i> , <i>Illecebrum verticillatum</i> ,						uniform	5.33	y	5.33	not set
	Alsinoide ae-	<i>Cardionema ramosissimum</i> , <i>Loeflingia hispanica</i> , <i>Dicheranthus plocamoides</i> , <i>Pteranthus</i>		Only								
Caryophyllacea e	Caryophyl loideae	<i>dichotomus</i> , <i>Scopulophila parryi</i> , <i>Sphaerocoma</i> <i>aucherii</i> , <i>Spergularia rubra</i> , <i>Telephium imperati</i>	Only 1 locus	1 locus	Only 1 locus	no	GTR+G+I	lognormal	34	0	34	42.5
	Crassulaceae	incl. <i>all</i>	yes	yes	yes	no	GTR+G+I	normal	94	7.6	3	120.59
	Crassulac eae	excl. <i>Aphanopetalum</i> , <i>Glischrocaryon</i> , <i>Gonocarpus</i> , <i>Haloragis</i> , <i>Laurembergia</i> , <i>Meionectes</i> , <i>Myriophyllum</i> , <i>Penthorum</i> ,						normal	58.2	19.5	26.2	88.39
									7		3	

		<i>Proserpinaca, Tetracarpaea, Trihaloragis</i>											
Dipsacales <sup>1</sup>	Macaronesia	incl. <i>Aeonium, Greenovia, Monanthes</i>						uniform	0	21	set	21	
	mrca	all	no	yes	yes	yes	GTR+G+I	uniform	44	62	44	62	
Gentianaceae	ingroup	all	no	yes	yes	yes	GTR+G+I	Normal	52.0	7	3	40.4	68.8
	<i>Emmenopterys</i>	incl. <i>Emmenopteris, Fadogia, Vangueria</i>						lognormal	1.0/1.	45	0	45	65
	sectGentiana	incl. <i>G.cruciata, G. decumbens</i>						lognormal	1.0/1.	1	5	5	25
	Lisianthus crownPoa	incl. <i>Lisianthus</i>						lognormal	1.0/1.	40	0	40	60
Poaceae	ceae	excl. <i>Anomochloa</i>	yes	yes	yes	yes	GTR+G+I	uniform	90	y	90	no set	
	BEP+PA CCMAD	excl. <i>Anomochloa, Leptaspis, Pharus, Puelia, Streptochaeta</i>						lognormal	1.0/1.	55	0	55	75
Plantaginaceae	<i>Distichlis</i>	incl. <i>Bouteloua, Distichlis</i>						lognormal	1.0/1.	14	0	14	34
	<i>Aragoa</i>	incl. <i>Aragoa</i>	yes	yes	yes	no	GTR+G+I	uniform	0	3.3	0	3.3	
	PlatArag	incl. <i>Plantago and Aragoa</i>						Exponential	39.9	1	19.4	19.4	24
Primulaceae	mrca	all	yes	yes	yes	no	GTR+G+I	normal	15.9	9	11.49	9	58.9
	ingroup	excl. <i>Androsace, Anagallis, Soldanella</i>						lognormal	2.1/0.	7	63	18.9	39
Ranunculaceae	Ranunculaceae	excl. <i>Anemone quinquefolia, Isopyrum</i>	Only 1 locus	Only 1 locus	Only 1 locus	no	GTR+G+I	normal	46.6	1	44.6	48.2	
	<i>Myosurus gen_dist</i>	excl. <i>Anemone quinquefolia, Arcteranthis, Beckwithia andersonii, Callianthemoides semiverticillatus, Coptidium lapponicum, Coptidium pallasii, Cyrtorhyncha ranunculina, Ficaria fascicularis, Ficaria verna, Halerpestes, Hamadryas Isopyrum, Oxygraphis polypetala, Peltocalathos baurii</i> incl. <i>Ranunculus carpaticola, Ranunculus notabilis</i>						Exponential	1	23	23	not set	
								normal	0	0.914	0	2.56	

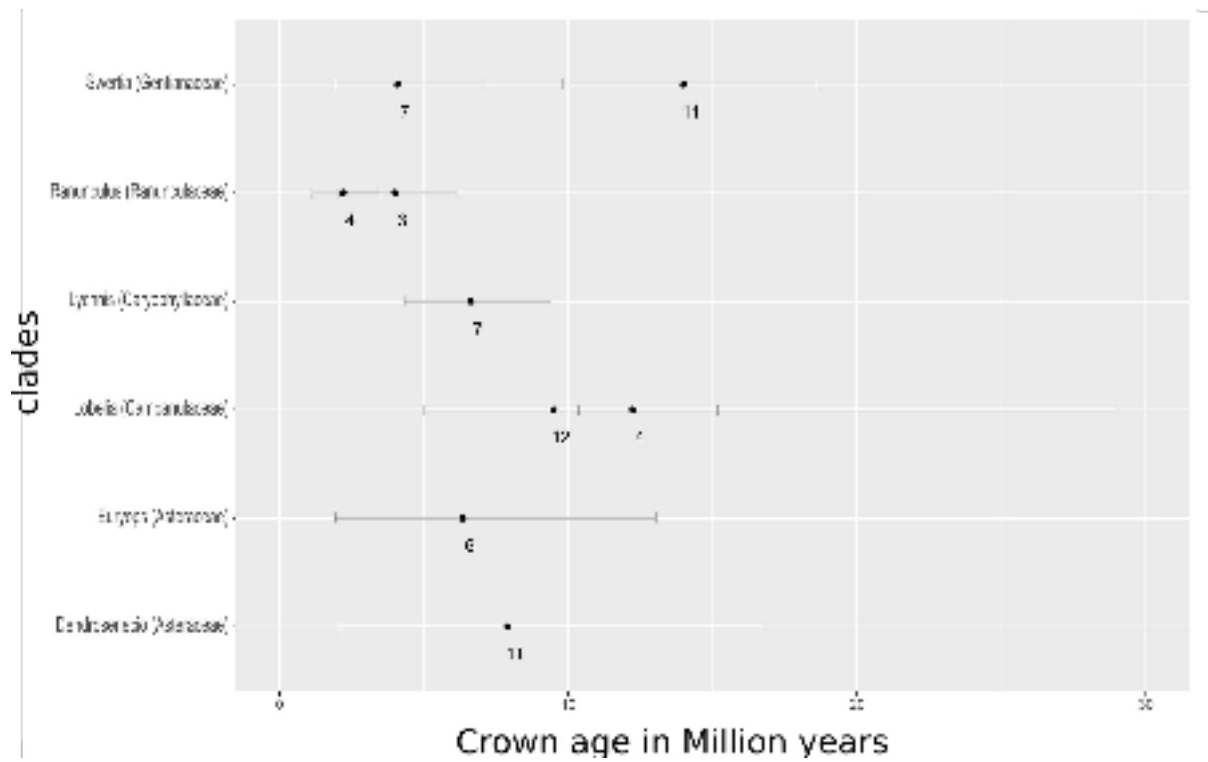
island	incl. <i>R. caprarum</i> , <i>R. peduncularis</i>	uniform	0.1	/0.25	not 2 set	2
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<sup>1</sup>based on Bell&Donoghue 2012

**Table S9.** Comparison of our age estimates to previous Bayesian estimates. Abbreviations: CI – confidence intervals.

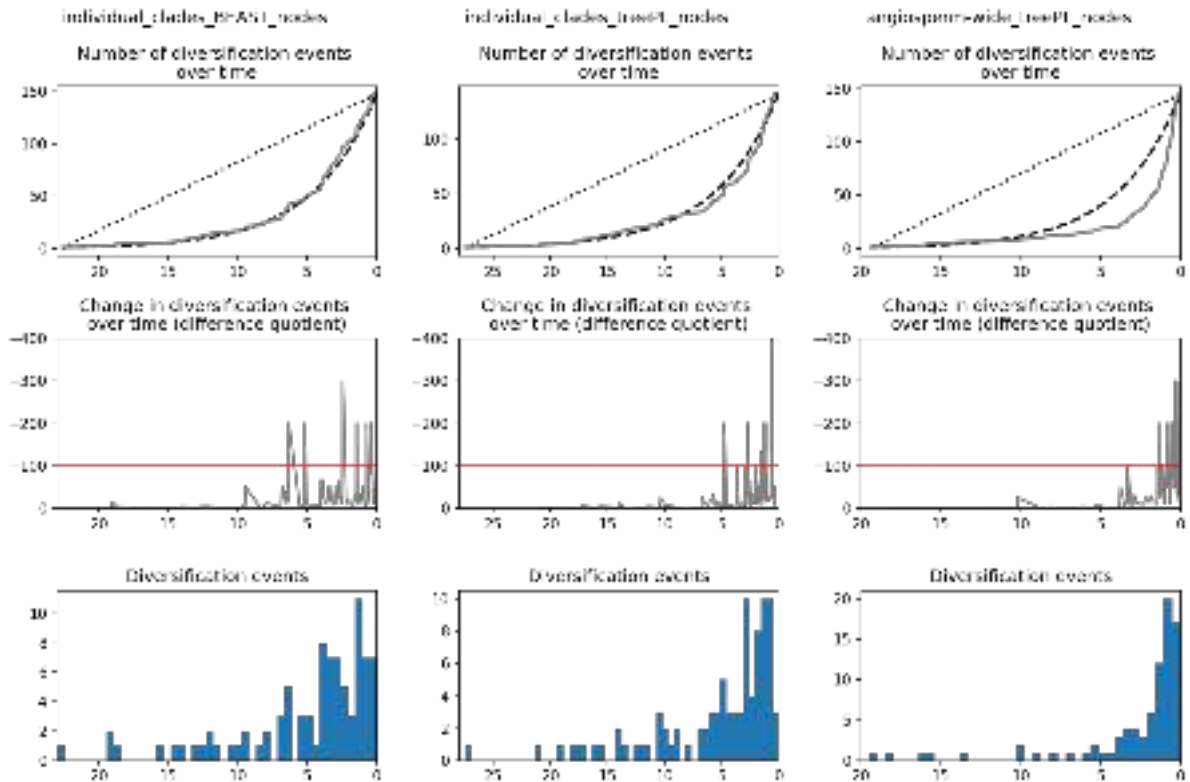
lineage	node	Individual clades – BEAST2			compared to publication (references see main text)		
		median	min 95% CI	max 95% CI	median	min 95% CI	max 95% CI
Asteraceae	Asteraceae crown	84.5	76.08	94.08	80.5	75.41	86.99
	Senecioneae crown	28.66	26.21	35.87	24.59	17.76	31.45
Brassicaceae	Root - Moringaceae/Brassicaceae ae split	89.46	87.47	91.4	72	47.9	90.5
	Brassicaceae crown	47.19	35.82	58.35	37.6	24.2	49.4
Campanulaceae	N2	47.58	32.84	64.37	45.5	30.9	59.2
	N3	42.78	30.07	57.59	39.7	27.4	53.1
	N4	26.04	16.03	37.38	24.5	15.1	36.6
	N5	19.53	12.44	27.65	20.8	12.4	30.5
	N7	33.55	24.06	43.89	36.7	25.1	49.5
	N8	31.3	19.96	39.75	32.8	22	45.4
	N9	29.48	22.22	41.61	29.6	18.9	41.3
Caryophyllaceae	<i>Faccinia</i> stem	10.37	6.77	14.38	9.41	5.02	13.93
	<i>Faccinia</i> crown	3.93	2.16	6.58	3.3	1.67	5.18
	<i>Stellaria-Faccinia</i> root	27.01	21.36	32.22	25.46		
Crassulaceae	root	101.38	87	115.78	107.54	93.9	121.43
	excl. <i>Crassula</i> and <i>Calanchoe</i>	60.16	46.32	74.82	65.92	53.39	79.53
Gentianaceae					Pirie et al. 2015 does not report ages incl. root constraint		
Poaceae	Poaceae crown	96.18	90	109.39			
	BEP+PACCMAP	61.79	55.15	72.16	57	51	75
	Danthonooideae	27.47	20.27	36.3	30	21	38
Plantaginaceae	stem <i>Veronica</i>	14.69	9.81	20.99	19.91	15.47	25.09
	crown <i>Veronica</i>	10.82	7.11	15.69	16.13	12.46	20.59
Primulaceae	<i>Primula</i> crown	11.15	7.78	15.58		results not shown	
Ranunculaceae	<i>Ranunculus</i> stem	20	16.13	23.45	21.25	14.13	28.43
	<i>Ranunculus</i> crown	17.74	14.01	21.19	18.11		



**Figure S1.** BEAST2 crown ages from the seed plant wide dating analysis indicating the start of lineage radiations. Numbers depict number of species sampled in clades.

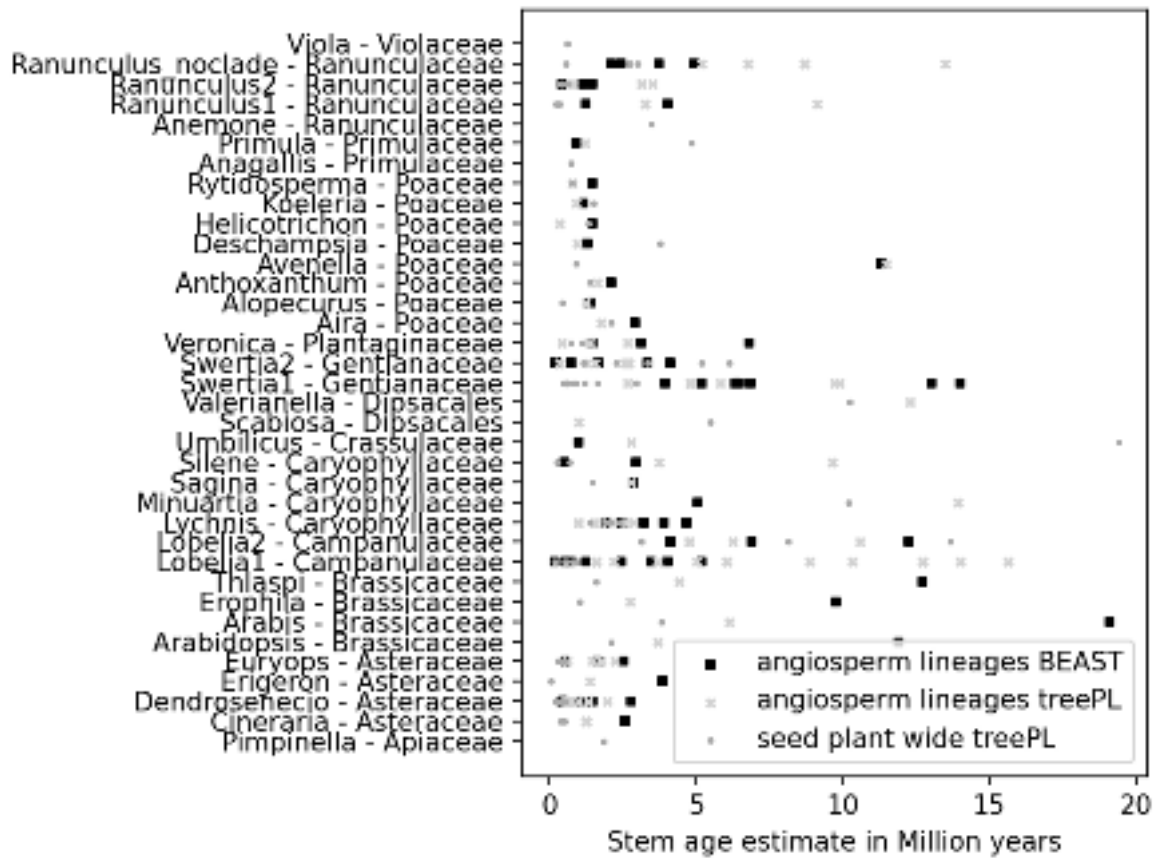




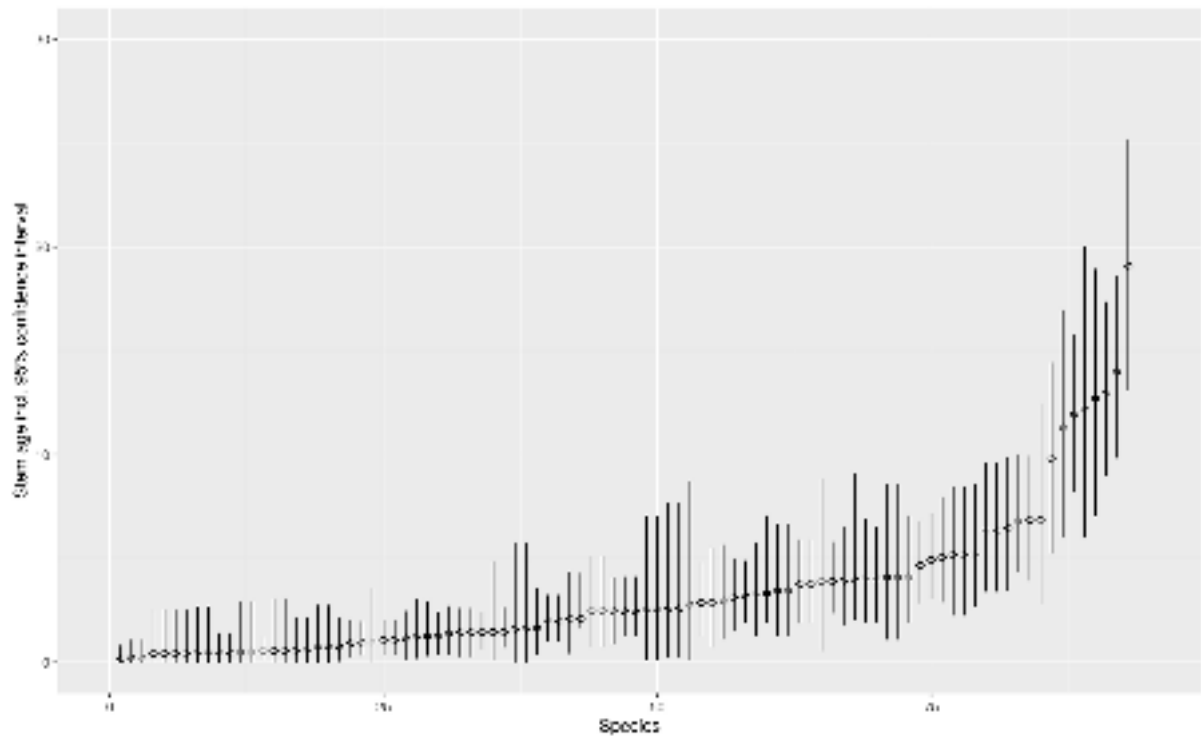


**Figure S2.** Species accumulation over time in the afroalpine region based on historical lineage diversity estimates and relative branching times obtained from the time-calibrated phylogenies. These plots differ from standard lineage through time plots in that species accumulation in a region results from colonization events in addition to regional diversification. Row 1: Number of colonization/diversification events over time. The black dotted line marks a constant rate model and the black dashed line an exponential model. Row 2: Change in number of colonization/diversification events over time calculated as a difference quotient (see text). The red line shows the maximum difference of change in a constant model. Row 3: number of colonization/ diversification events per 0.5-million-year intervals.

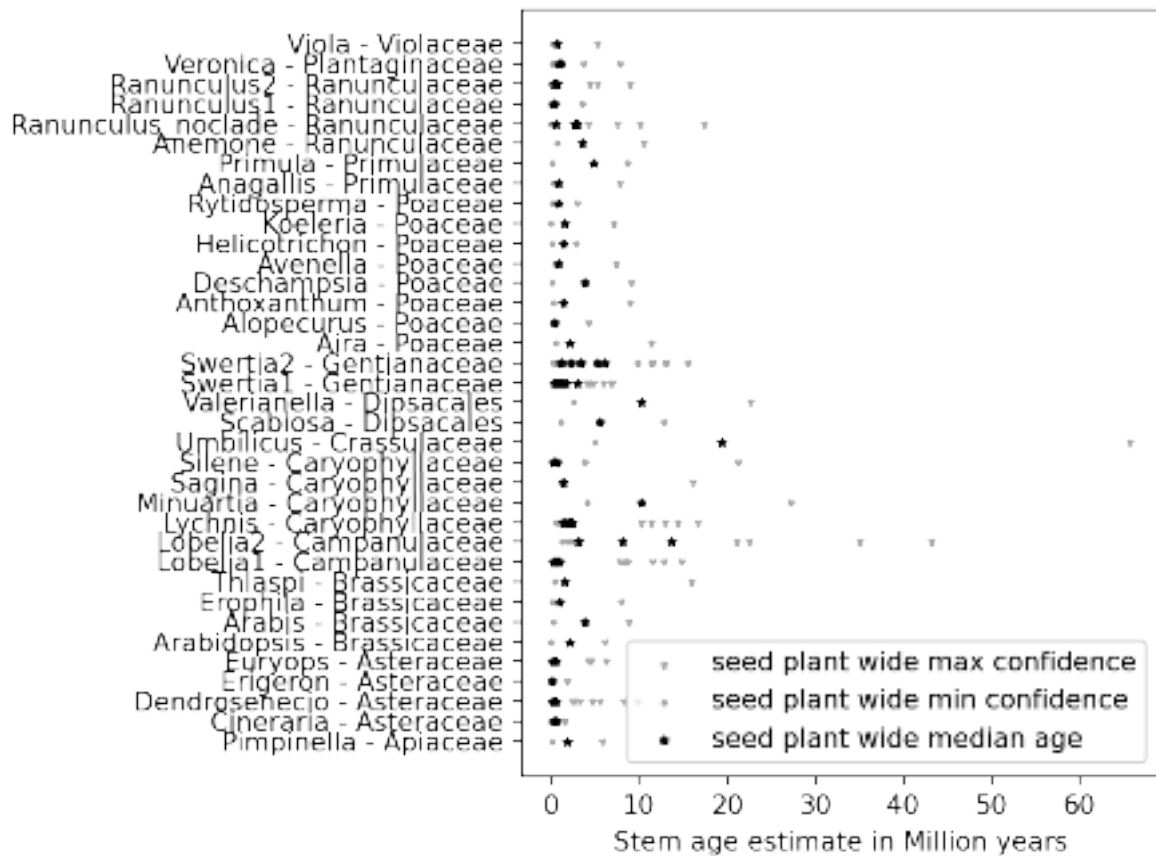




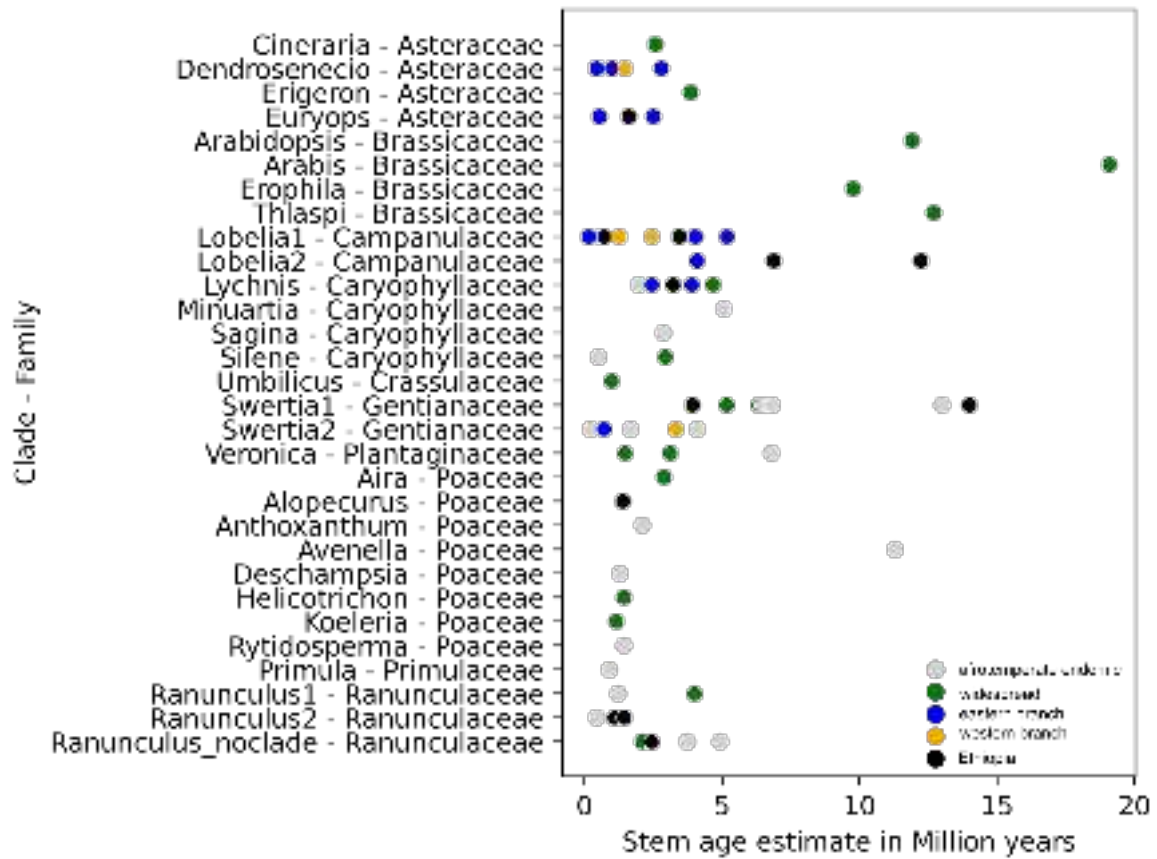
**Figure S3.** Median age estimates of afroalpine species based on the three different dating approaches.



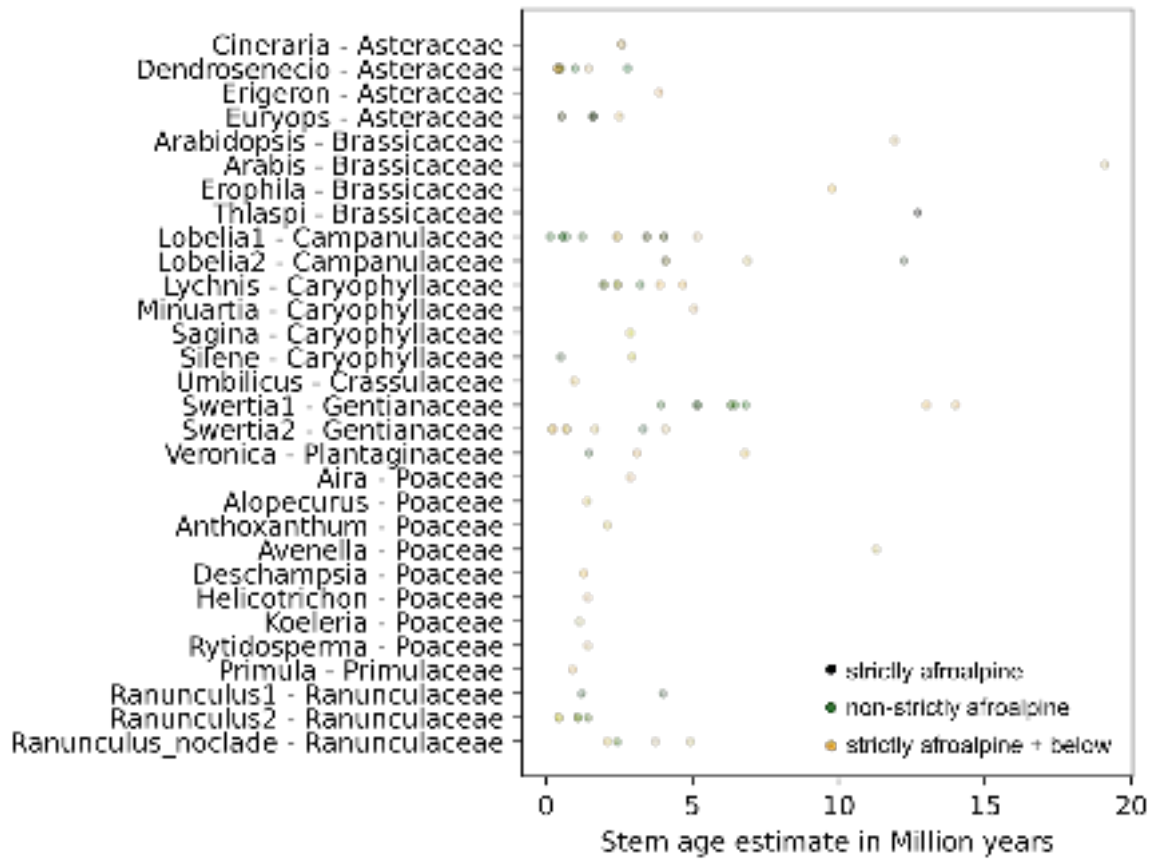
**Figure S4.** Individual seed plant clades stem age estimates (BEAST2) of all afroalpine species, ordered by median age.



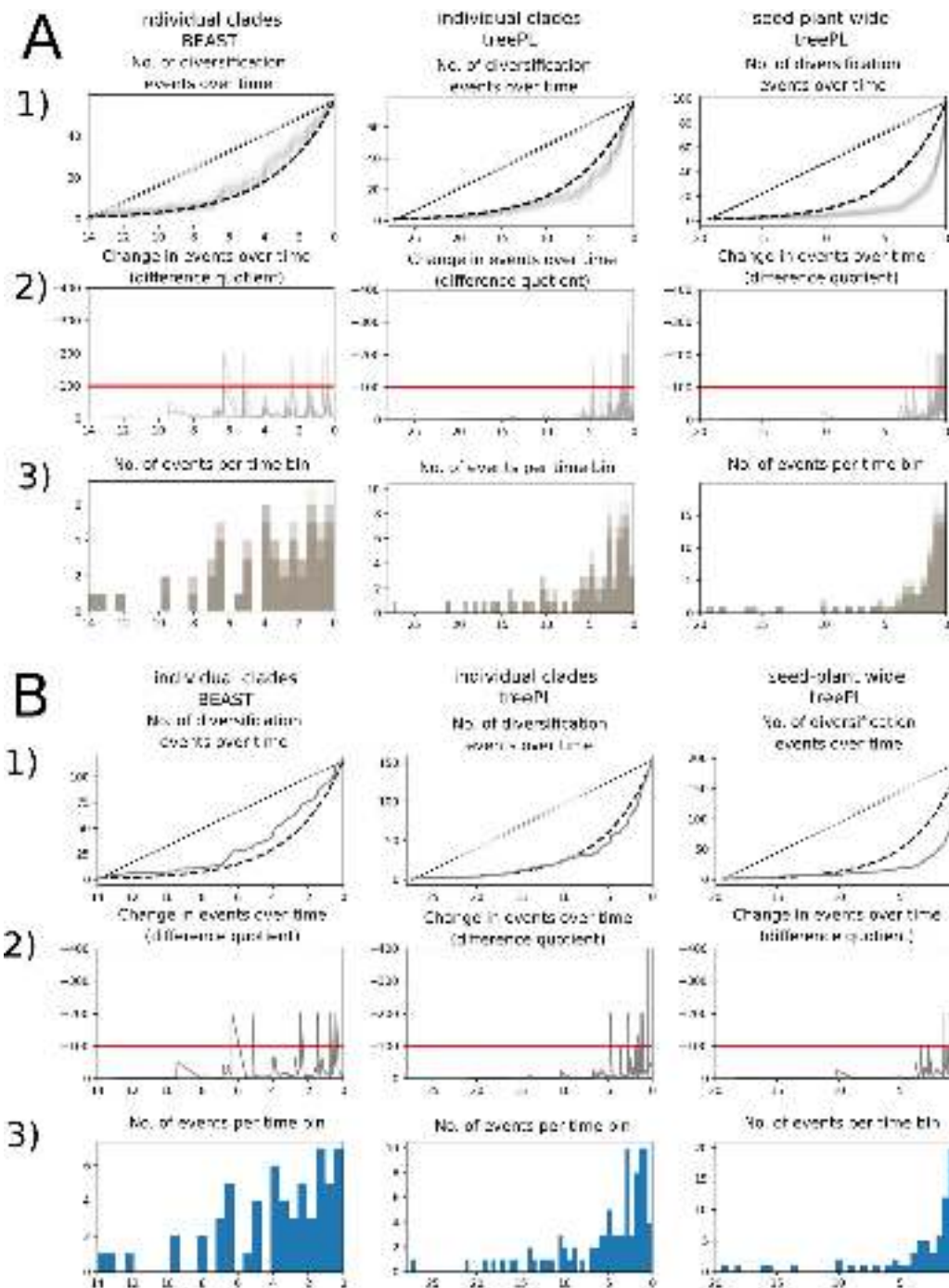
**Figure S5.** treePL stem ages from of the seed plant wide dating analysis, showing median and 95% confidence interval.



**Figure S6.** BEAST2 stem ages from the seed plant wide dating analysis and geographic distribution of species. Distribution of species has been assigned to subregions, species found in more than one subregion but being restricted to eastern Africa are coded as 'afrotemperate endemic' and if they occur beyond these limits as "widespread". See text for details on distribution coding.



**Figure S7.** BEAST2 stem ages from the seed plant wide dating analysis. The species are categorized as 'strictly afroalpine (lower altitudinal limit above 3800 m)', 'strictly afroalpine + below' and 'non-strictly afroalpine' (upper altitudinal limit below 3800 m), median age estimates are 7.16 (n=2), 2.45 Ma (n=32) and 2.21 Ma (n=57) respectively.



**Figure S8.** Species diversification (excluding colonization events) over time in the afroalpine region based on historical lineage diversity estimates and relative branching times obtained from the time-calibrated phylogenies. These plots differ from standard lineage through time plots in that species accumulation in a region results from colonization events in addition to regional diversification. Row 1: Number of diversification events over time. The black dotted line marks a constant rate model and the black dashed line an exponential model. Row 2: Change in number of diversification events over time calculated as a difference quotient (see text). The red line shows the maximum difference of change in a constant model. Row 3: number of diversification events per 0.5-million-year intervals. Row 3: number of colonization/ diversification events per 0.5-million-year intervals. A. Results for the three different dating methods are shown in A) and B). For A) age estimates were subsampled to 50% 200 times; B) shows the actual data.



**Legends for further SI Appendices:**

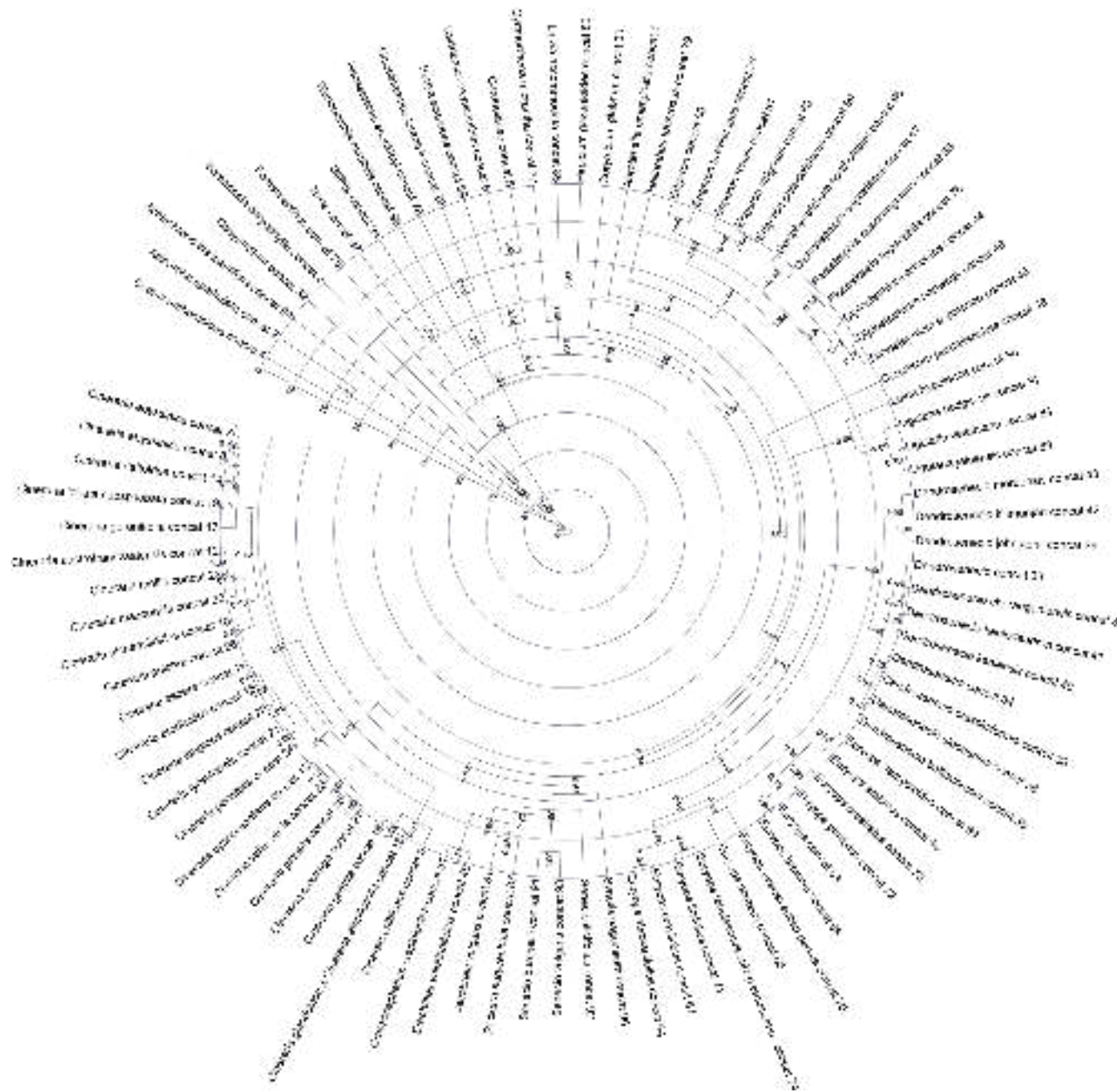
SI Appendix S2: Figures of dated phylogenies of individual seed-plant clades.

## SI References

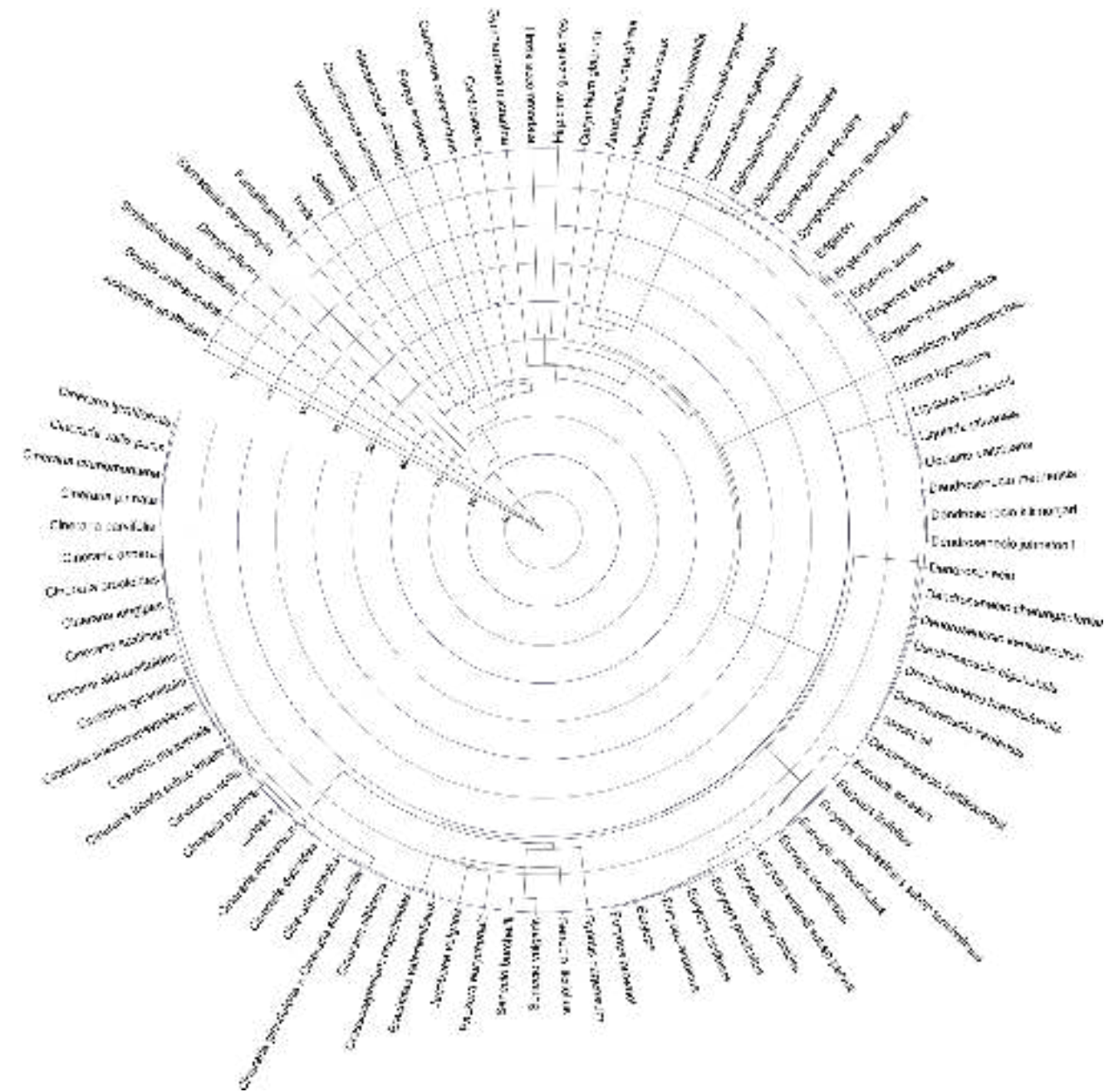
1. B. Bushnell, "BBMap: A Fast, Accurate, Splice-Aware Aligner" (Lawrence Berkeley National Lab. (LBNL), Berkeley, CA (United States), 2014) (December 2, 2020).
2. J.-J. Jin, *et al.*, GetOrganelle: a fast and versatile toolkit for accurate de novo assembly of organelle genomes. *Genome Biology* **21**, 241 (2020).
3. Ł. Banasiak, *et al.*, Dispersal patterns in space and time: a case study of Apiaceae subfamily Apioideae. *Journal of Biogeography* **40**, 1324–1335 (2013).
4. C. D. Bell, Phylogenetic placement and biogeography of the North American species of *Valerianella* (Valerianaceae: Dipsacales) based on chloroplast and nuclear DNA. *Molecular Phylogenetics and Evolution* **44**, 929–941 (2007).
5. C. D. Bell, A. Kutschker, M. T. K. Arroyo, Phylogeny and diversification of Valerianaceae (Dipsacales) in the southern Andes. *Molecular Phylogenetics and Evolution* **63**, 724–737 (2012).
6. Y. Bouchenak-Khelladi, G. A. Verboom, V. Savolainen, T. R. Hodkinson, Biogeography of the grasses (Poaceae): a phylogenetic approach to reveal evolutionary history in geographical space and geological time. *Bot J Linn Soc* **162**, 543–557 (2010).
7. T. L. P. Couvreur, *et al.*, Molecular Phylogenetics, Temporal Diversification, and Principles of Evolution in the Mustard Family (Brassicaceae). *Mol Biol Evol* **27**, 55–71 (2010).
8. M. S. Dillenberger, J. W. Kadereit, Simultaneous speciation in the European high mountain flowering plant genus *Facchinia* (*Minuartia* s.l., Caryophyllaceae) revealed by genotyping-by-sequencing. *Molecular Phylogenetics and Evolution* **112**, 23–35 (2017).
9. K. Emadzade, E. Hörandl, Northern Hemisphere origin, transoceanic dispersal, and diversification of Ranunculeae DC. (Ranunculaceae) in the Cenozoic. *Journal of Biogeography* **38**, 517–530 (2011).
10. T. F. E. Messerschmid, J. T. Klein, G. Kadereit, J. W. Kadereit, Linnaeus's folly – phylogeny, evolution and classification of *Sedum* (Crassulaceae) and Crassulaceae subfamily Sempervivoideae. *TAXON* **69**, 892–926 (2020).
11. M. D. Pirie, G. Litsios, D. U. Bellstedt, N. Salamin, J. Kissling, Back to Gondwanaland: can ancient vicariance explain (some) Indian Ocean disjunct plant distributions? *Biology Letters* **11**, 20150086 (2015).
12. G. Ren, E. Conti, N. Salamin, Phylogeny and biogeography of *Primula* sect. *Armerina*: implications for plant evolution under climate change and the uplift of the Qinghai-Tibet Plateau. *BMC Evolutionary Biology* **15**, 161 (2015).
13. J. M. Saarela, *et al.*, A 250 plastome phylogeny of the grass family (Poaceae): topological support under different data partitions. *PeerJ* **6**, e4299 (2018).
14. B. Surina, S. Pfanzelt, H. J. R. Einmann, D. C. Albach, Bridging the Alps and the Middle East: Evolution, phylogeny and systematics of the genus *Wulfenia* (Plantaginaceae). *TAXON* **63**, 843–858 (2014).
15. M. Kandziora, J. W. Kadereit, B. Gehrke, Dual colonization of the Palaeartic from different regions in the Afrotropics by *Senecio*. *J. Biogeogr.* **44**, 147–157 (2017).
16. A. Antonelli, Have giant lobelias evolved several times independently? Life form shifts and historical biogeography of the cosmopolitan and highly diverse subfamily Lobelioideae (Campanulaceae). *BMC biology* **7**, 82 (2009).
17. S. Janssens, *et al.*, A large-scale species level dated angiosperm phylogeny for evolutionary and ecological analyses. *Biodiversity Data Journal* **8**, e39677 (2020).
18. M. Kandziora, PhylUp: phylogenetic alignment building with custom taxon sampling. *bioRxiv*, 2020.12.21.394551 (2020).
19. C. Camacho, *et al.*, BLAST+: architecture and applications. *BMC Bioinformatics* **10**, 421 (2009).
20. R. Bouckaert, *et al.*, BEAST 2: A Software Platform for Bayesian Evolutionary Analysis. *PLOS*

- Computational Biology* **10**, e1003537 (2014).
21. S. A. Smith, B. C. O'Meara, treePL: divergence time estimation using penalized likelihood for large phylogenies. *Bioinformatics* **28**, 2689–2690 (2012).
  22. S. Magallón, S. Gómez-Acevedo, L. L. Sánchez-Reyes, T. Hernández-Hernández, A metacalibrated time-tree documents the early rise of flowering plant phylogenetic diversity. *New Phytologist* **207**, 437–453 (2015).
  23. A. M. Kozlov, D. Darriba, T. Flouri, B. Morel, A. Stamatakis, RAxML-NG: a fast, scalable and user-friendly tool for maximum likelihood phylogenetic inference. *Bioinformatics* **35**, 4453–4455 (2019).
  24. A. Stamatakis, RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics* **30**, 1312–1313 (2014).
  25. M. A. Miller, W. Pfeiffer, T. Schwartz, Creating the CIPRES Science Gateway for inference of large phylogenetic trees. *Proceedings of the Gateway Computing Environments Workshop (GCE), New Orleans*, 1–8 (2010).
  26. B. Gehrke, H. P. Linder, Species richness, endemism and species composition in the tropical Afroalpine flora. *Alpine Botany* **124**, 165–177 (2014).
  27. J. A. McGuire, *et al.*, Molecular Phylogenetics and the Diversification of Hummingbirds. *Current Biology* **24**, 910–916 (2014).
  28. M. van der Merwe, *et al.*, Assemblage accumulation curves: A framework for resolving species accumulation in biological communities using DNA sequences. *Methods in Ecology and Evolution* **10**, 971–981 (2019).
  29. E. Jones, T. Oliphant, P. Peterson, others, SciPy: Open source scientific tools for Python (2001).

# Asteraceae

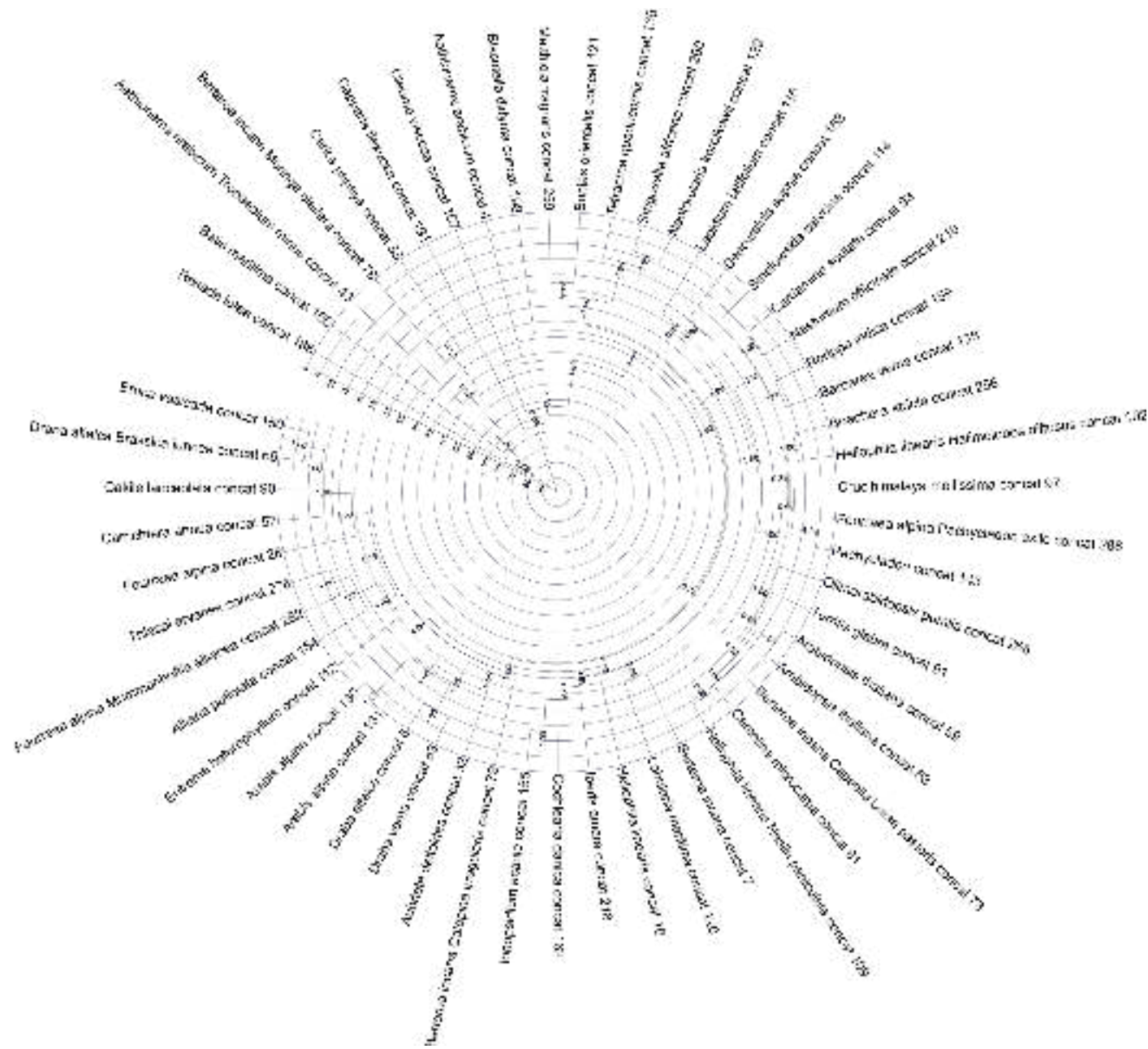


BEAST2 result

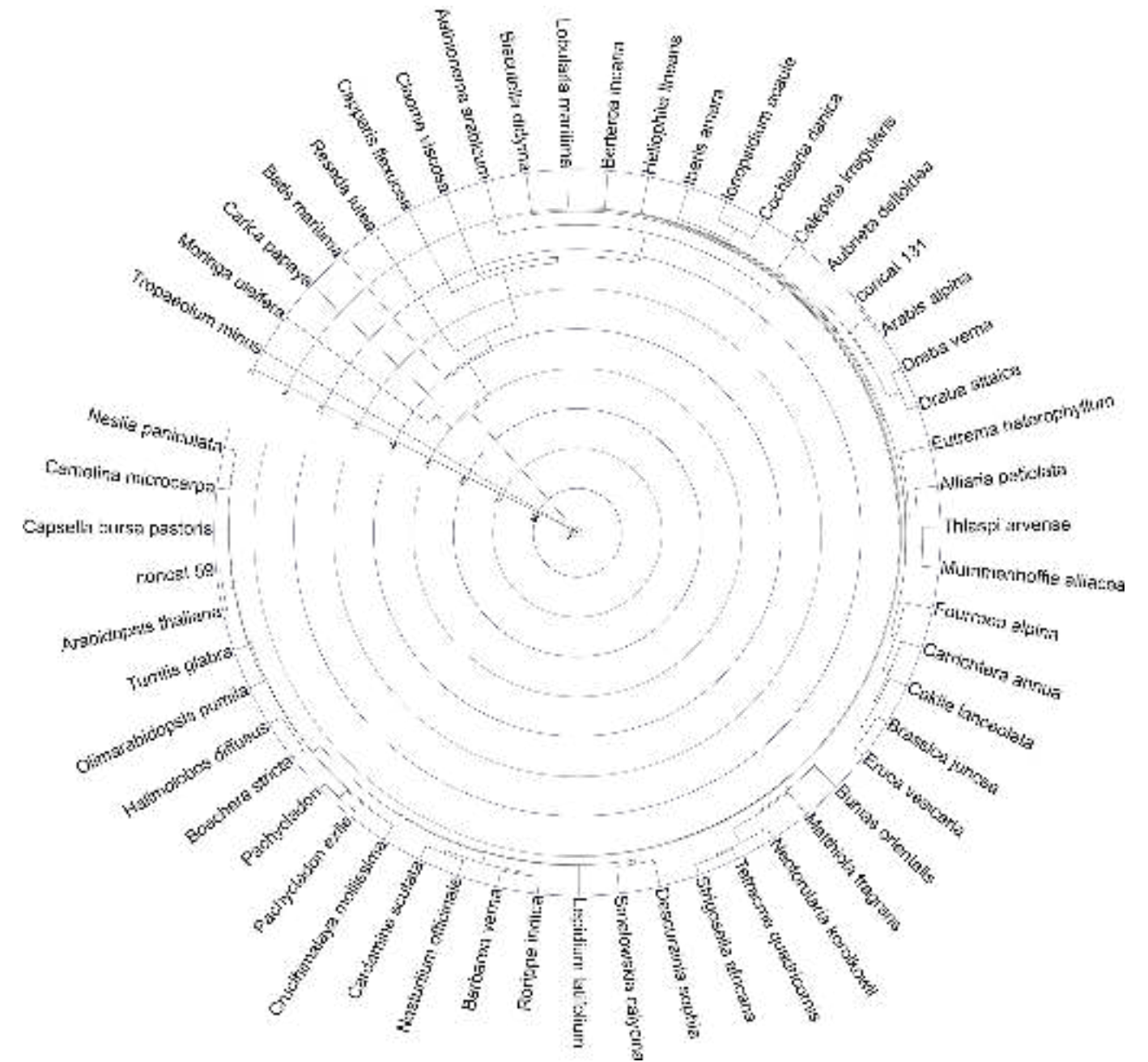


treePL result

# Brassicaceae



BEAST2 result

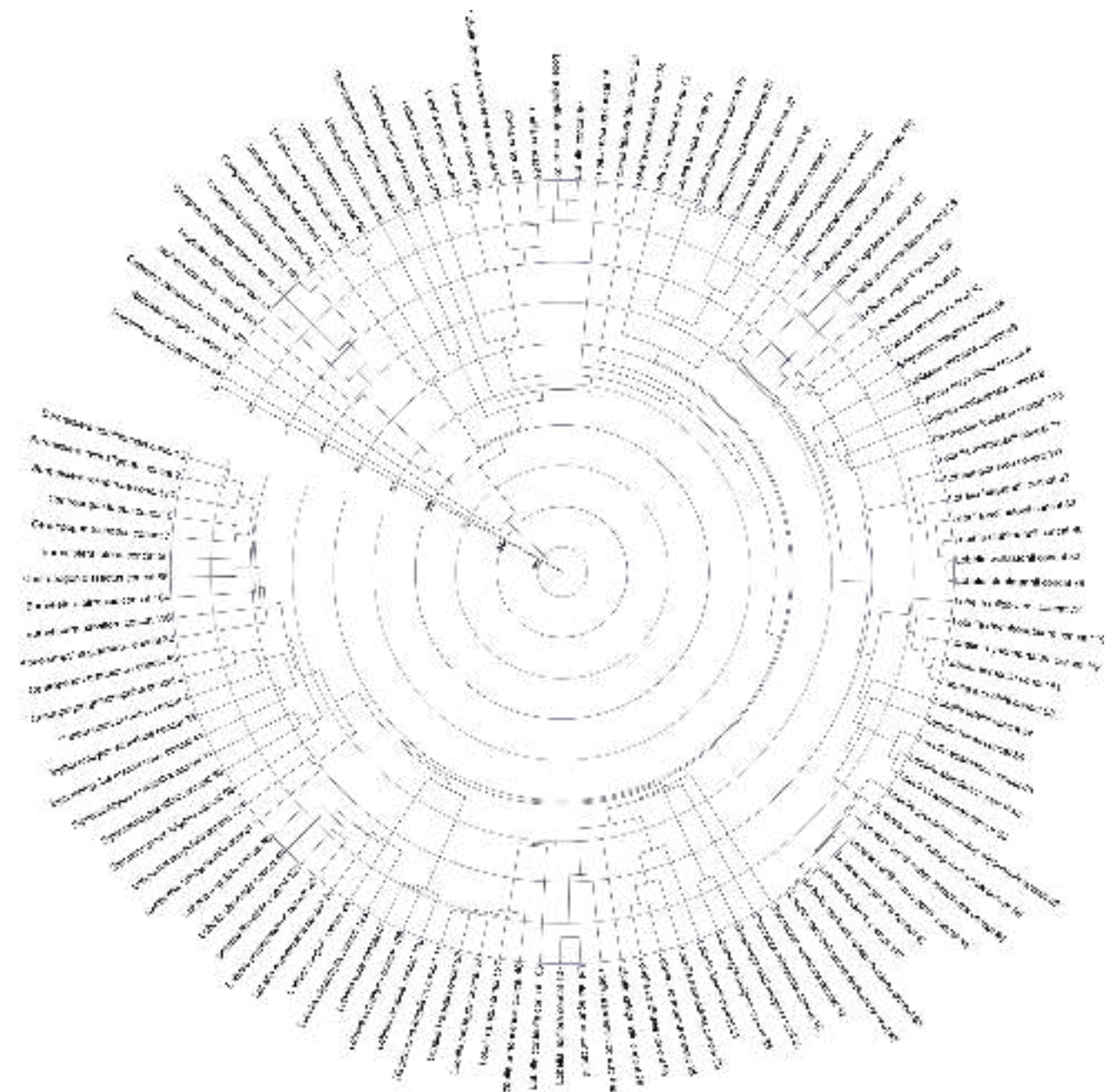


treePL result

# Campanulaceae

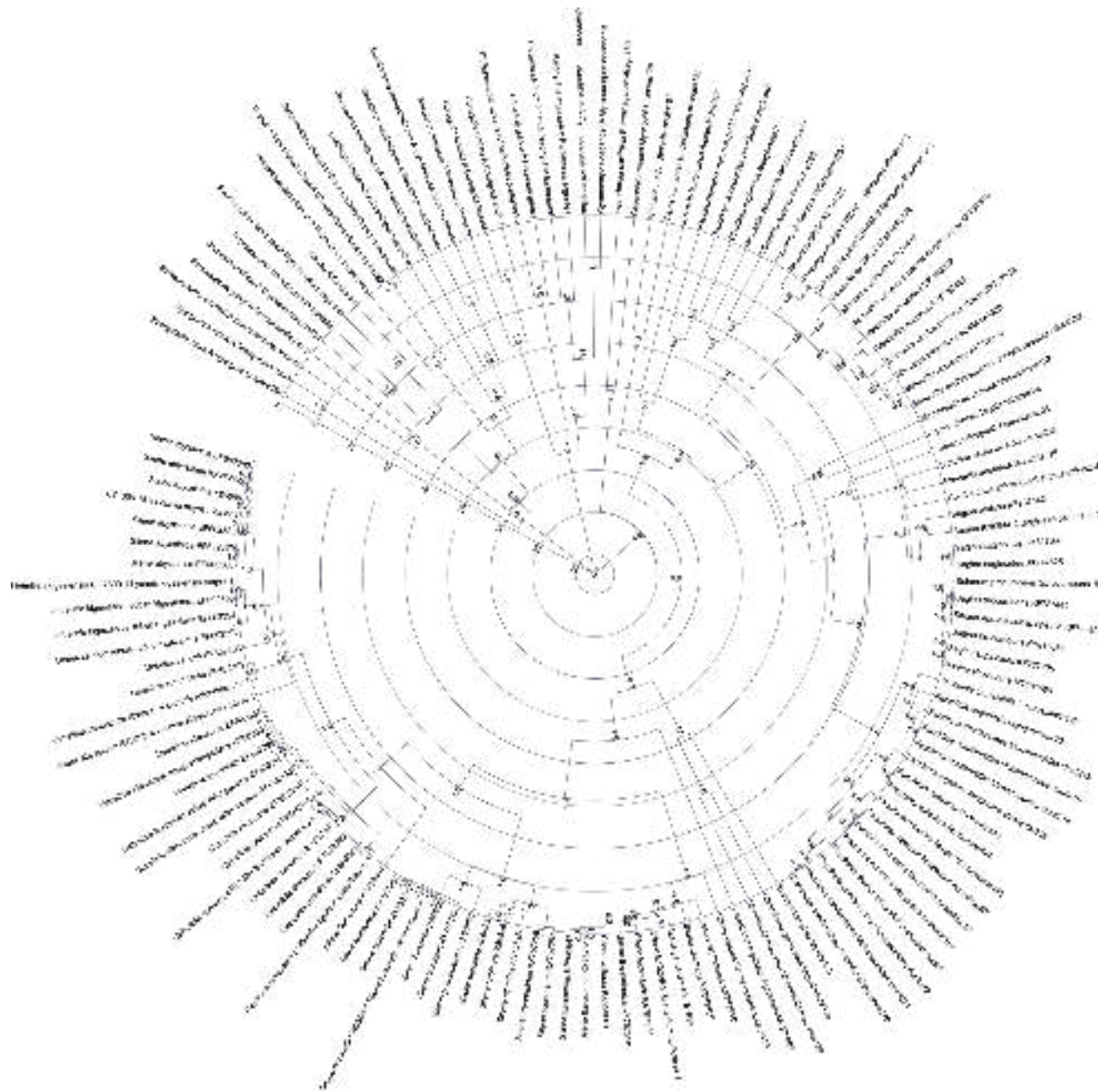


BEAST2 result

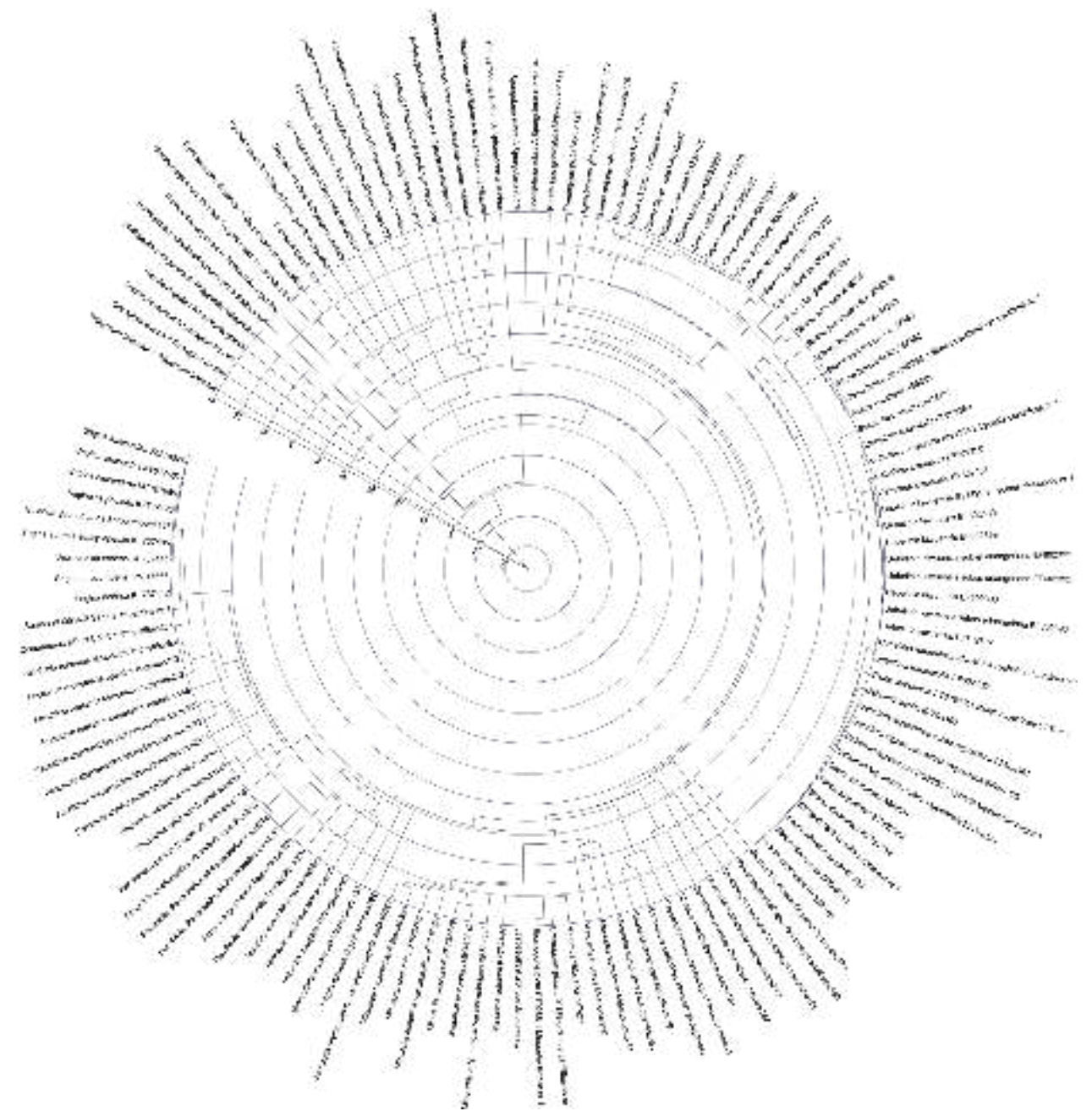


treePL result

# Caryophyllaceae

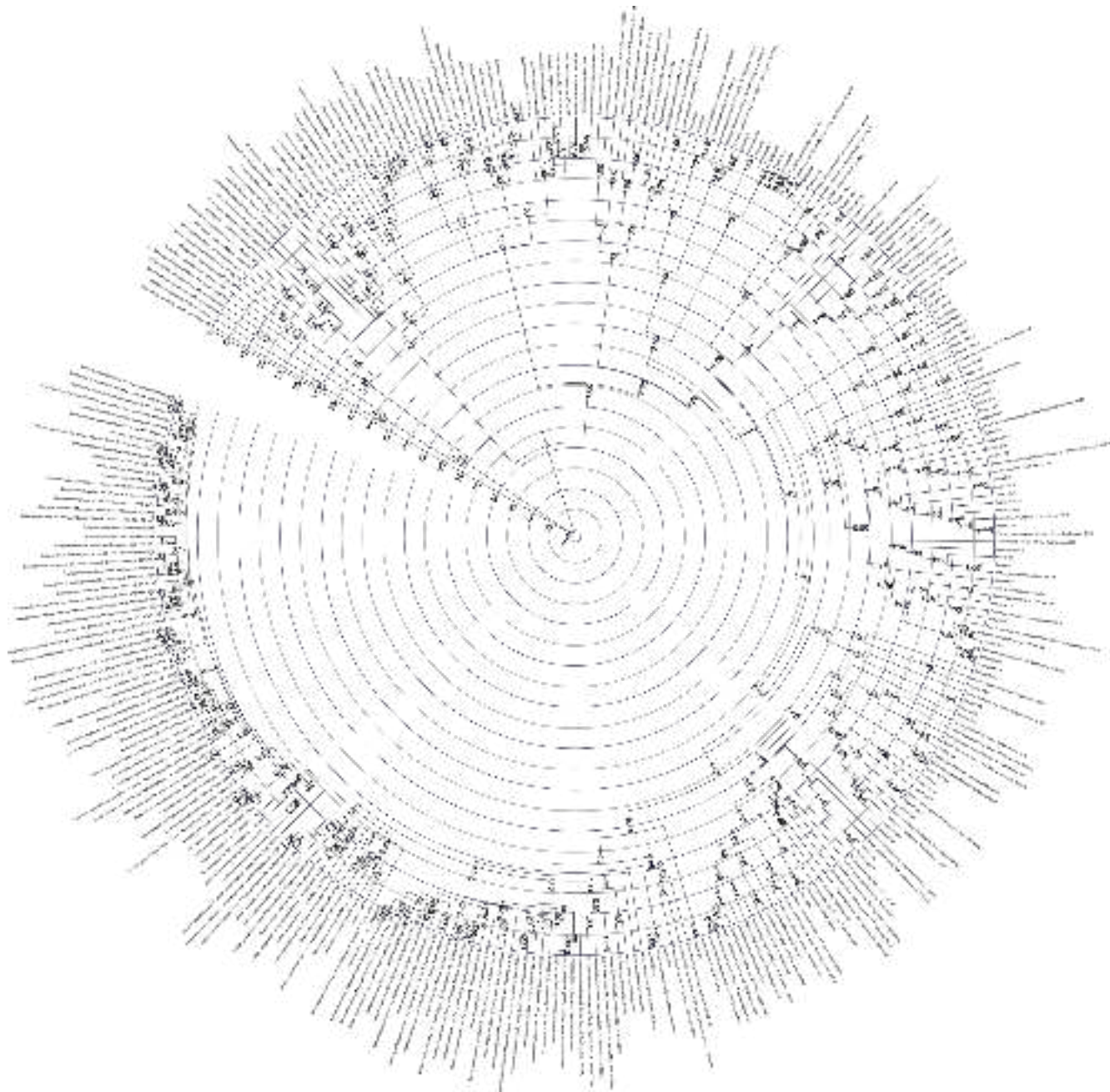


BEAST2 result

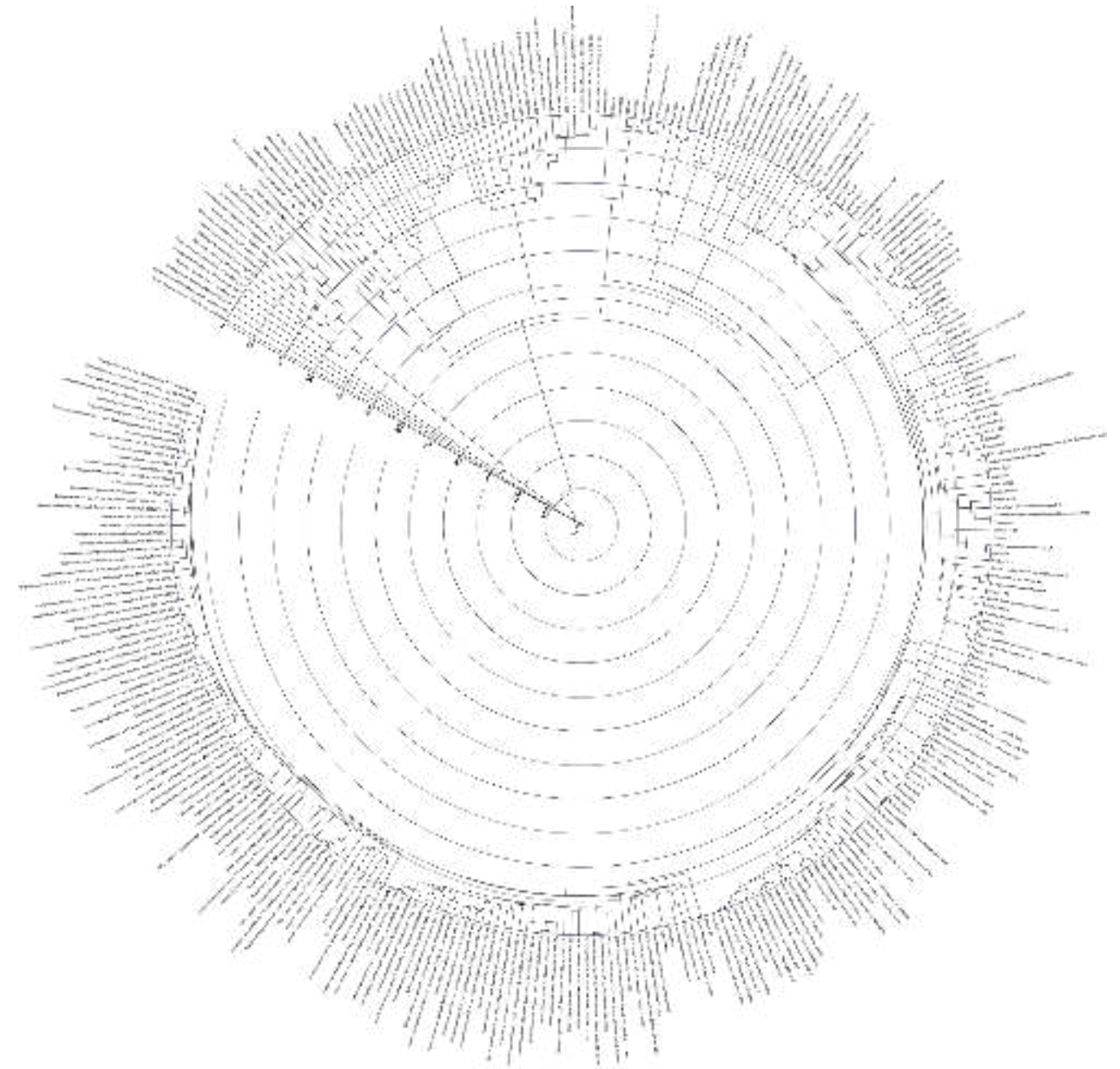


treePL result

# Crassulaceae



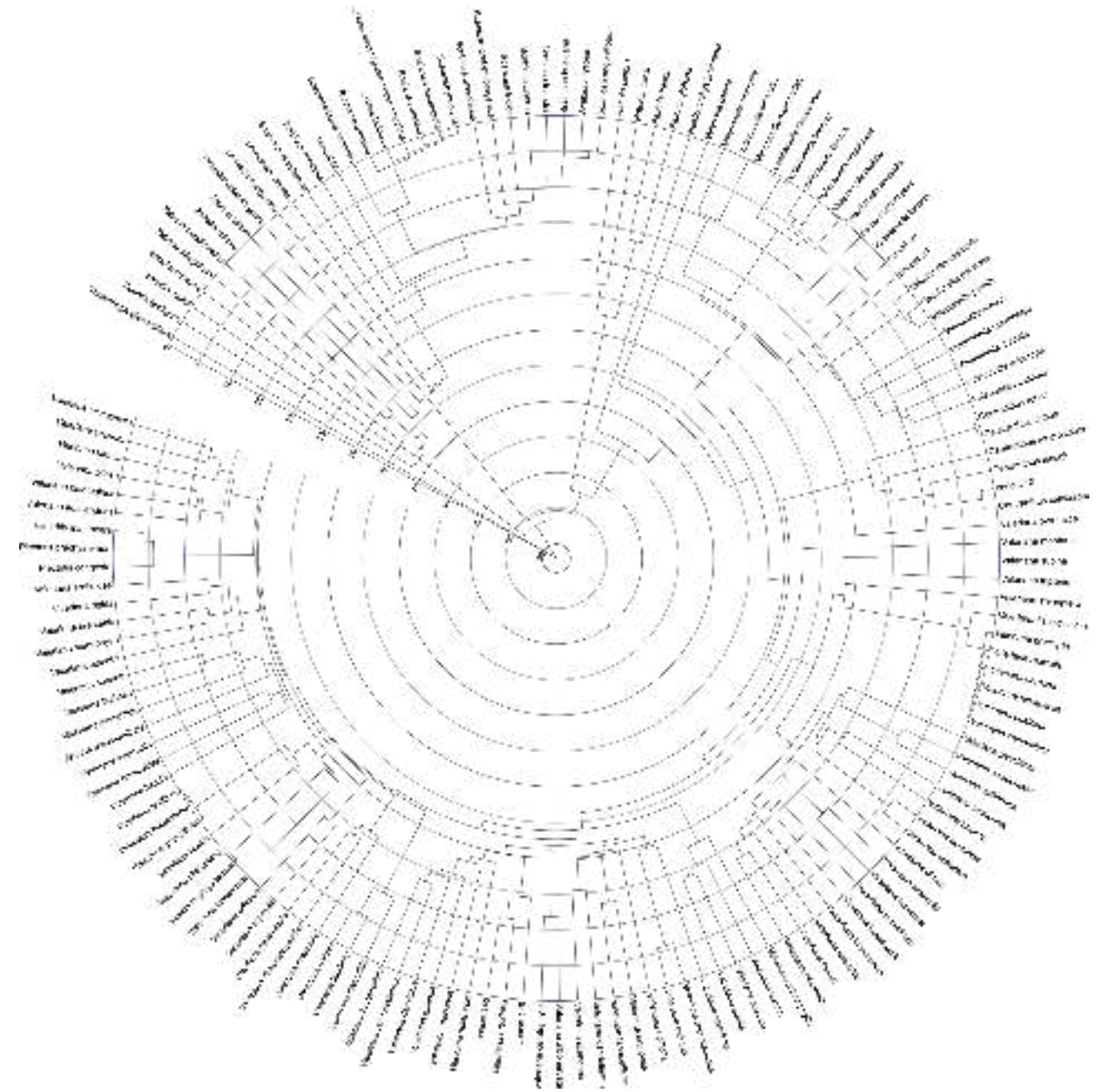
BEAST2 result



treePL result



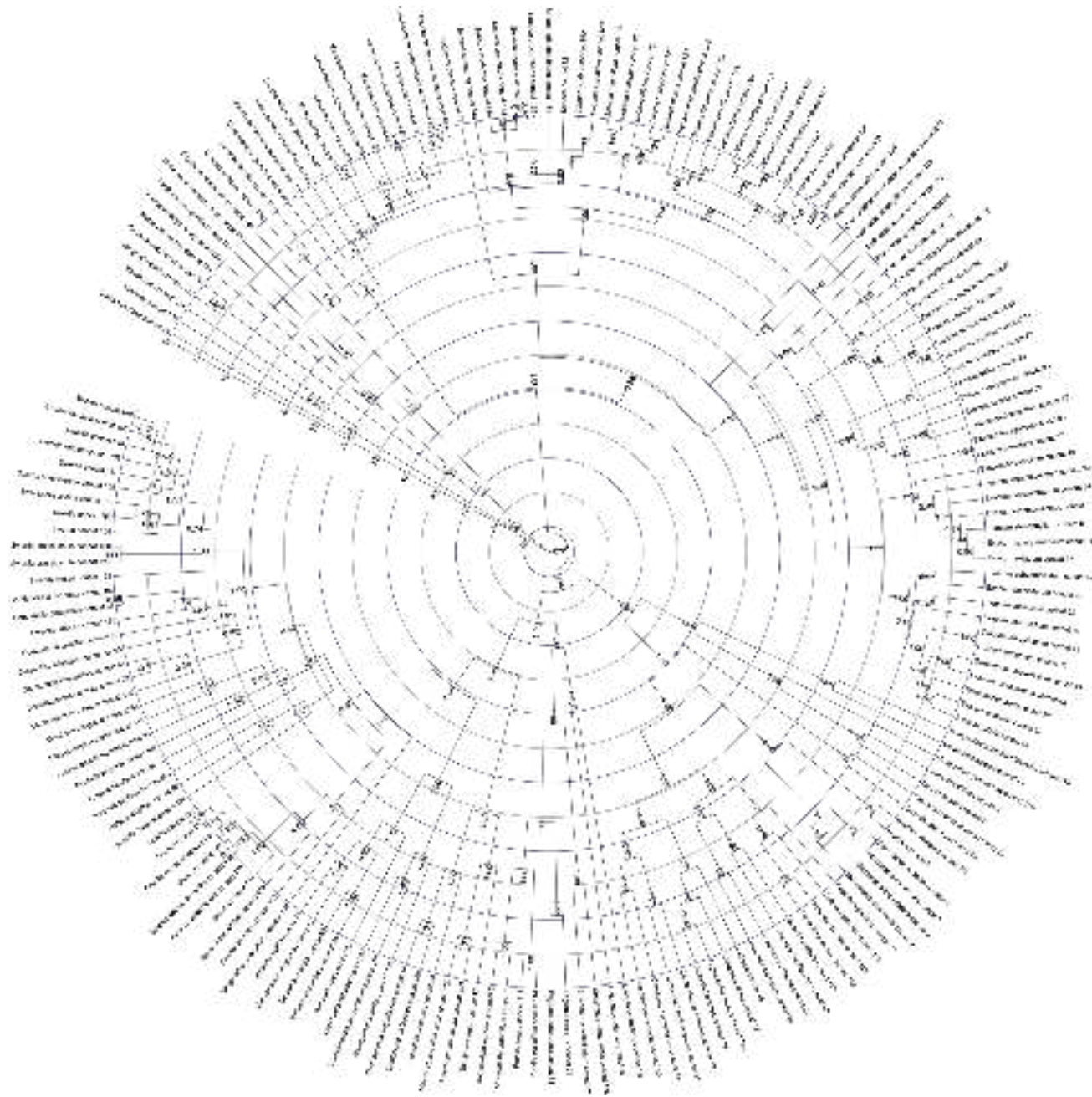
# Dipsacales



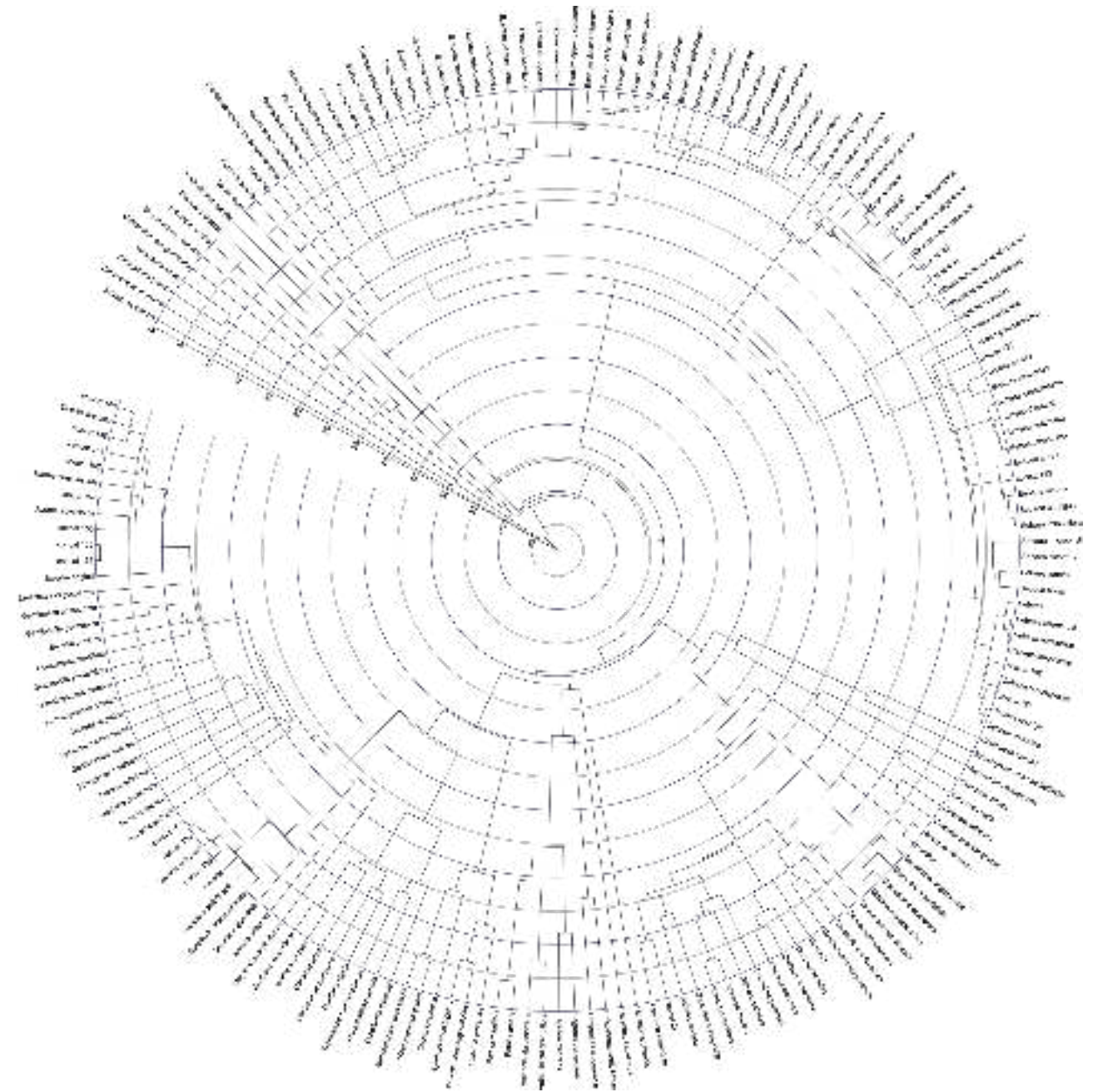
BEAST2 result

treePL result

# Gentianaceae

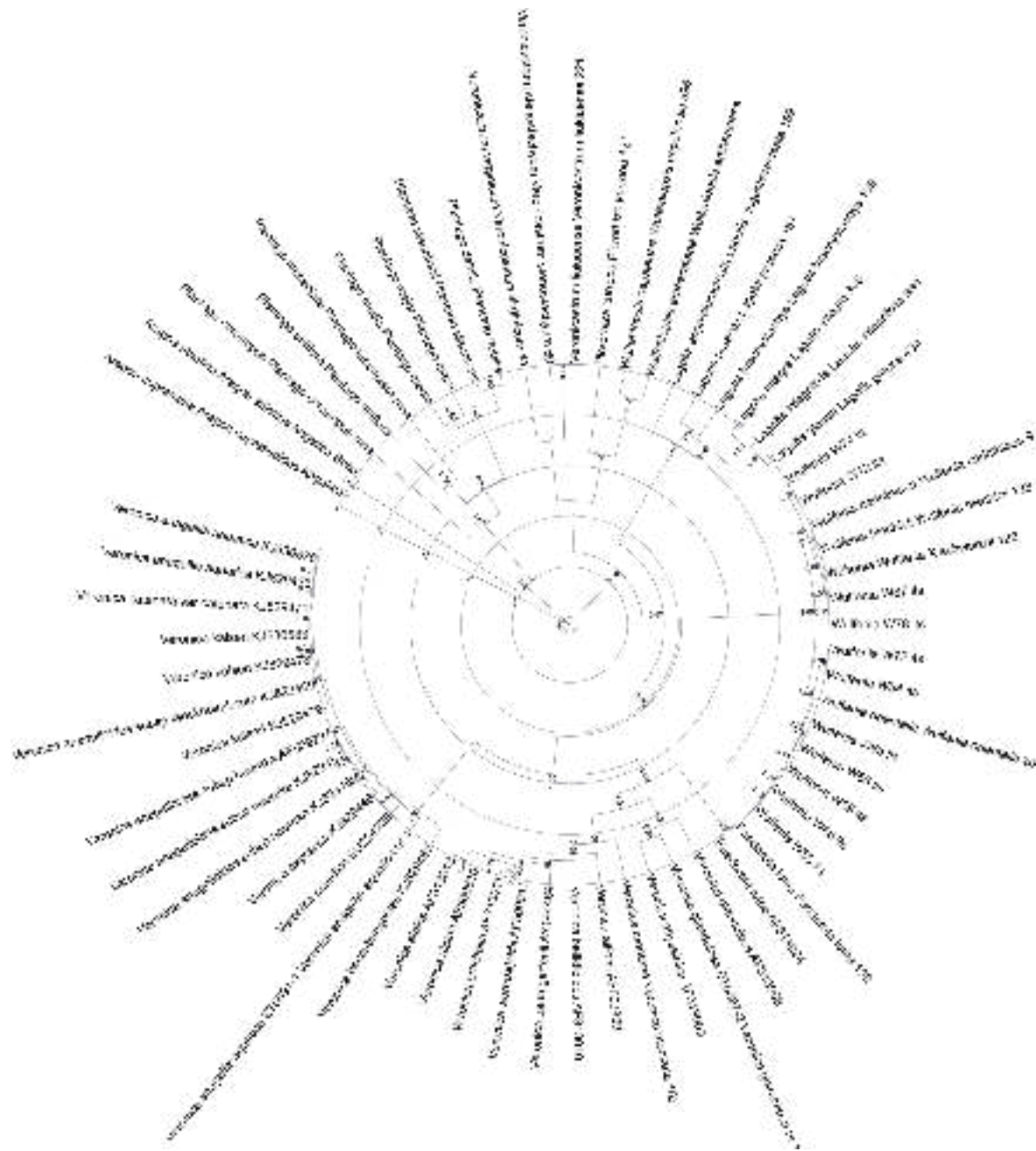


BEAST2 result

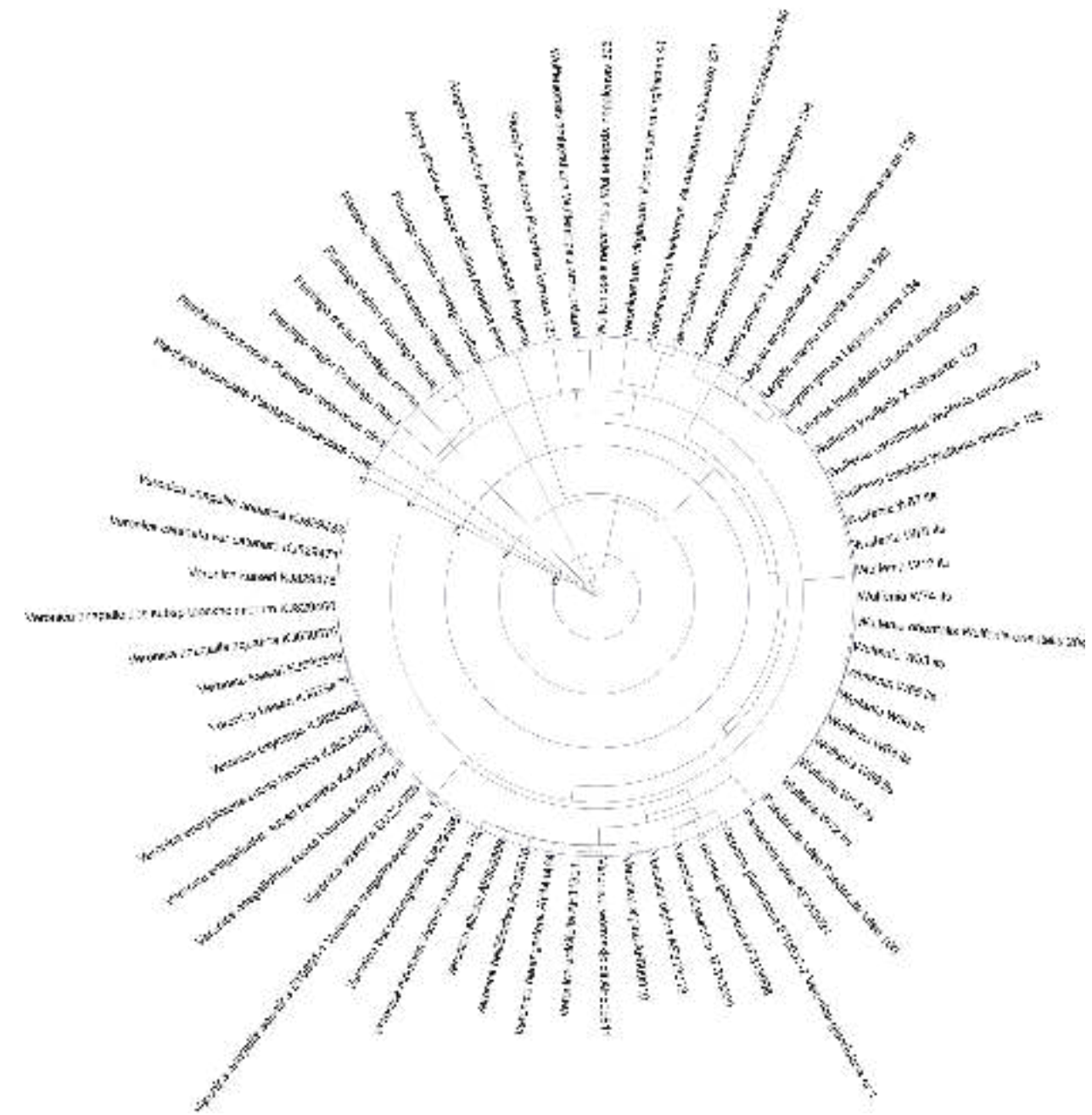


treePL result

# Plantaginaceae

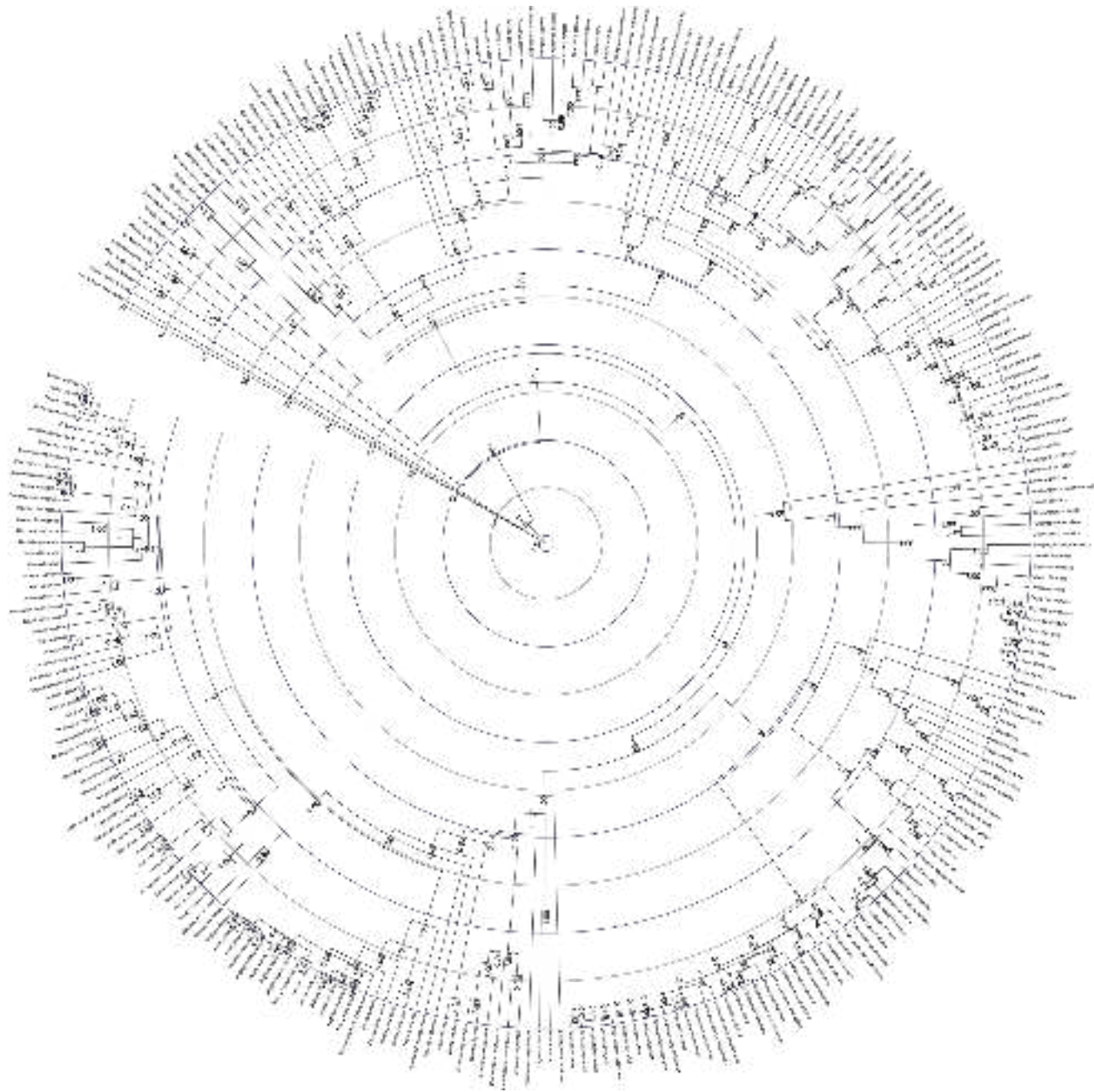


BEAST2 result

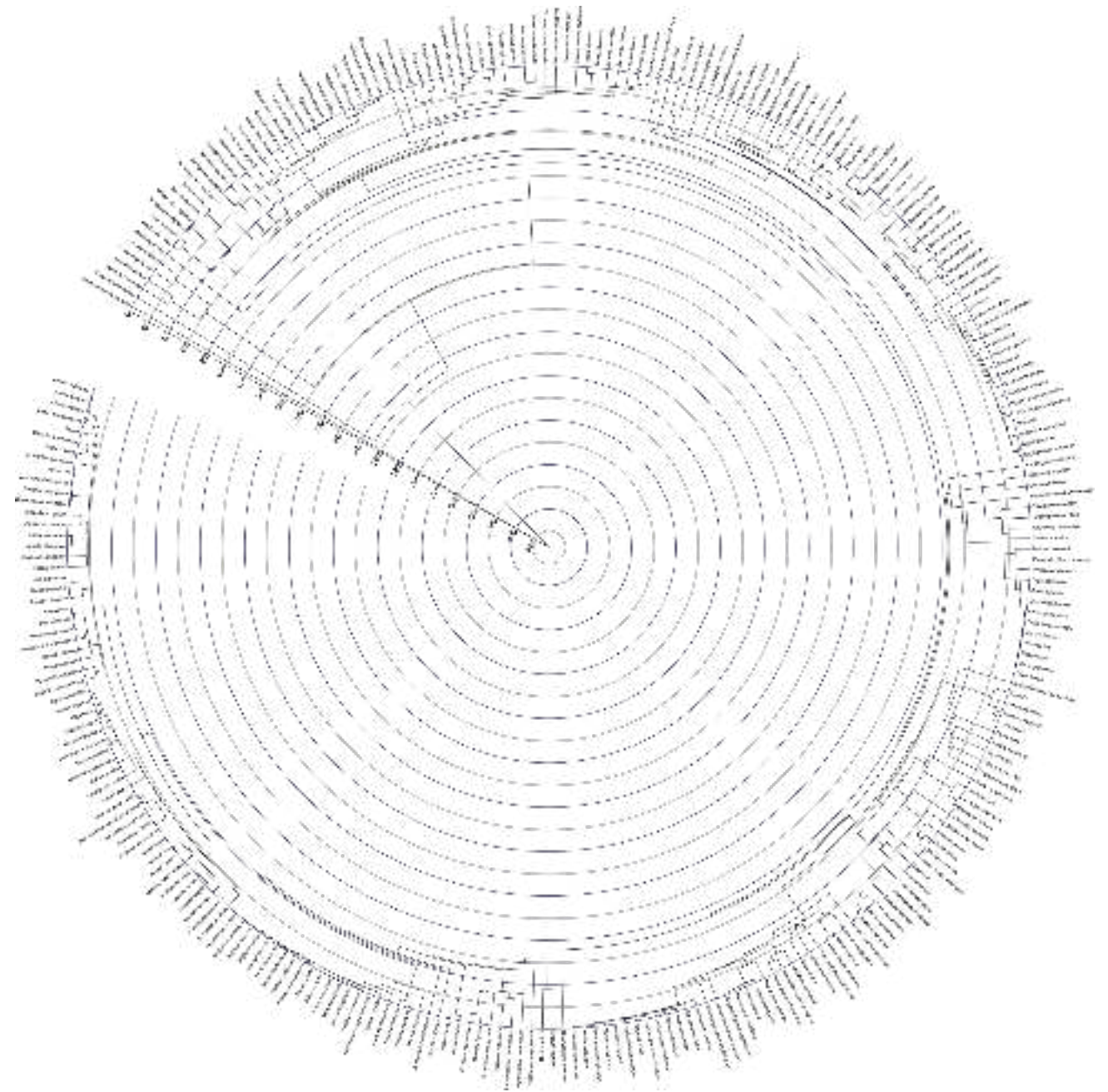


treePL result

# Poaceae



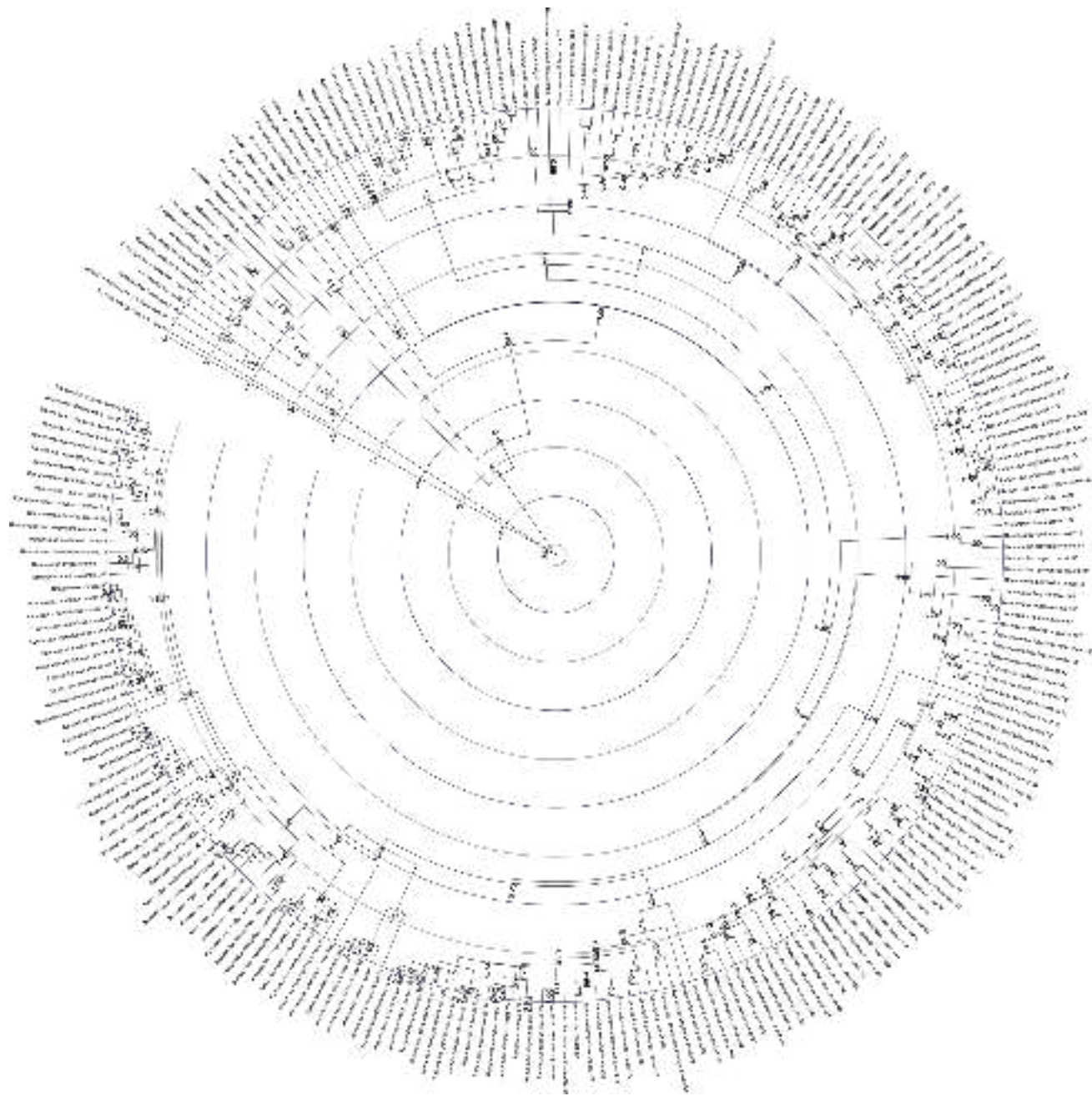
BEAST2 result



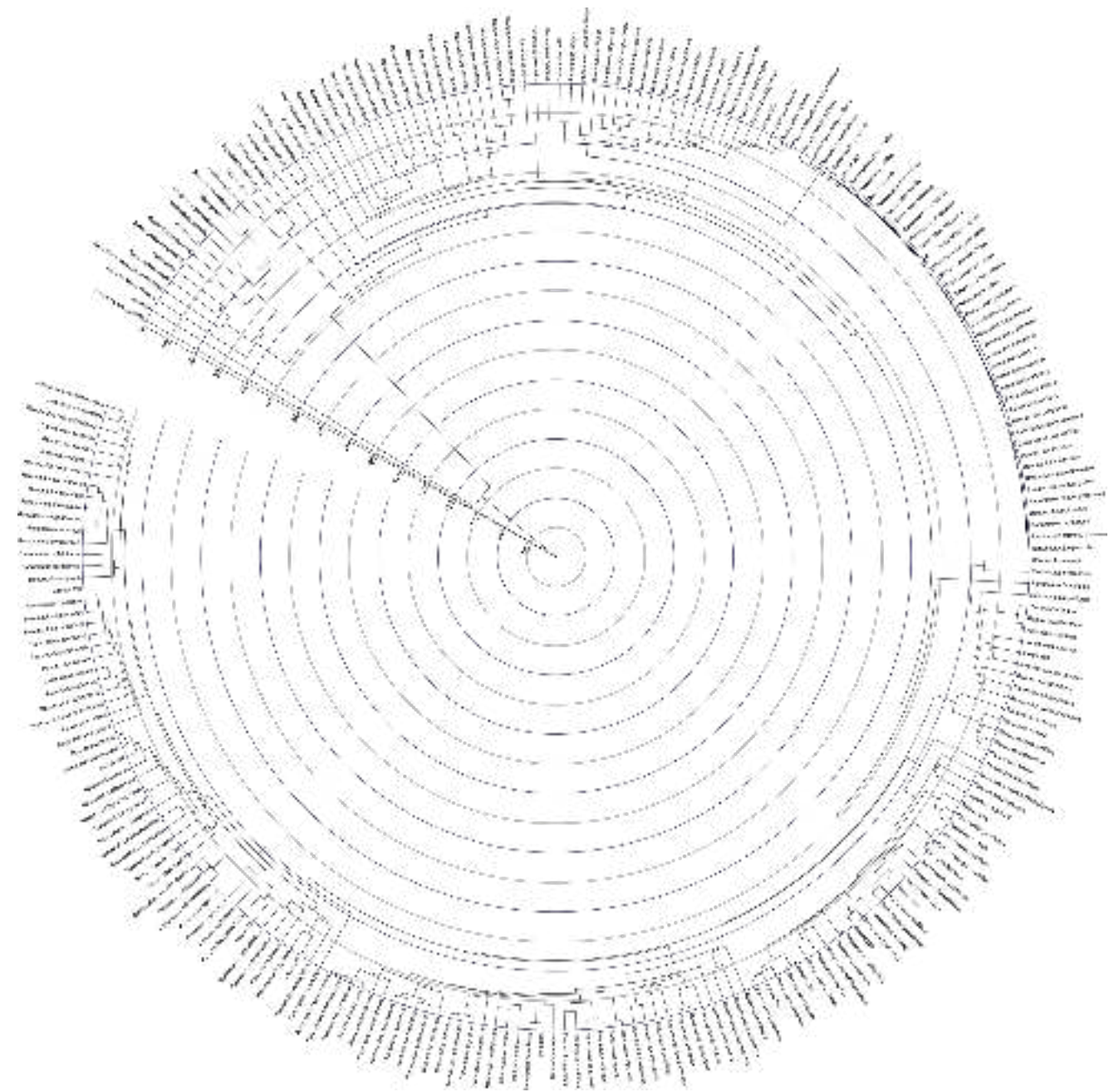
treePL result



# Ranunculaceae



BEAST2 result



treePL result