Impress of Climate Change in the Himalaya on Plant Evolution

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Abstract. Currently, species diversity has become a hotpot to biologist. Some researchers find mountains contribute disproportionately to Earth's terrestrial biodiversity, especially in the tropics, where there are unusually rich and confusing hot spots. But current assumptions about large-scale geographic patterns of species diversity cannot explain the extremely high biodiversity in mountain regions, especially in the tropics, where is characterized by a complex spatial configuration of terrain and climate. This paper focuses on three prominent and brief factors which impact species differentiation most in Himalaya to illuminate some researches up to now, include geographical, climatic, and biological. Geographic affect plant diversity by bring alien species, and format monsoon and plateau environment through uplift. Monsoon can advance the formation of landform also. Further, the period climate change can induce variation of endemic species, and the pollinator can impact variation by reproduction, thus the mismatch between pollinator and plants recently may lead the decline of certain species. Besides these, nowadays palynology evidence has become a credible two-way entry point to research plant evolution and climate change in the past era by authenticating how subspecies formatted. What's more, because the vagaries of climate have prompted the breeding of endemic species, the rising temperature currently may alter the vegetation in alpine area.

Keywords: Himalaya; plant evolution; geography; era; monsoon; pollinator.

1. Introduction

It is evidently that heterogeneous habitats contribute species diversification by geographical isolation, specifically elevation increase, physiographic and monsoon change in the orogenic events of Himalaya region. Himalaya is the mountain system who formed by the collide of the India and south Eurasian plats, and relative late in early Kainozoic Era around from 55 to 50 million years ago (Mya), including nearly 3.4 million km^2 range, spreading covered nations of Myanmar, China (Tibetan Autonomous Region and northwestern of Yunnan), Afghanistan, Pakistan, India, Bhutan, and Nepal. For average elevation of it higher than 4000 m, thus, at the altitudes between 5500 m and 6000 m the precipitation, temperature, atmosphere pressure and Ultraviolet radiation exposes the cryosphere to complex spatiotemporal distribution elements, such as permafrost, ice and glaciers, ground frost and seasonal snowfall [1]. Thus, those plants who inhabiting in rough circumstances have developed physiological mechanisms, highly specialized morphological, phenological, and structures. The primitive flora of Himalaya is exogenous. Indian continent who causes the upliftment of Himalaya by uplifting the Tethyan geosyncline coastal sediments and draining the Tethyan sea after deformed by India-Eurasia collision carried along with the host of primitive flora of Gondwanan continent, in instance conifers, seed ferns and lycopods [2].

Currently, the abundance richness of species increased threefold from northwest to east of Himalaya, and has formed five types of zonal flora: alpine shrub, alpine meadows, alpine steppe, desertified grasslands and ice edge vegetation for different humidity and temperature [3]. The eastern Tibet and north Tibet like Qilian mountain has lower altitude and higher humidity that there are also some forest survive. Alpine shrub can be seen in the humid part of Tibet plateau like southern, southeastern part with evergreen leaf shrubland and deciduous broad-leaved shrubland. Specialize Hppophae tibetica is the endemic species in Himalaya region. Alpine meadows colonizes Tibet plateau with Kobresia pygmaea and k. humilis as the main population. Among this, K. littledalei is the endemic species. Alpine steppe colonizes the largest part of Tibet plateau with many species of needle grass in the main group. Stipa purpurea is the endemic species distributed westward to Kashmir, and derived from another variety in the northern part (S. purprea var. arenosa). Afterwards alpine steppe slide into desertified grasslands in the northwestern part because of cold and dry. Glacial edge vegetation and mat-like vegetation are the two most representative vegetation types in the alpine region of the Qinghai-Tibet Plateau. Glacial edge vegetation is distributed sporadic and fragmented between the perpetual snowpack zone and the continuous distribution zone of vegetation [4].

This paper is going to illuminate three factors which advance the plants evolution events in different ways. First, topographical changes in every era triggered climate change at the beginning. Further, climate change affected creature response in different trophic grades and lead to the mutation of reproduction of diverse plants.

2. Primary Factor Leads to Plants Evolution by Topographical Change

Himalaya has underwent primarily uplift for three times. There are the 2-4 stages of the Himalayan uplift since Miocene, and the four uplifting stages can be divided into 4 substages, namely, early Pleistocene [5], late Middle Pleistocene, late Pleistocene and Holocene to modern, and the elevation of Himalaya has obtained 2000 m since Middle Pleistocene [6]. Therefore, Li et al. inferred that the species differentiation rate of the first and second grade plants (families and genera) was slow, from the Miocene to the middle Pliocene (the 2-3 stages of the Himalayan movement), and these species differentiation may be the result of the slow uplift in the early Himalayan region (Table 1) [7]. The first dramatic Himalayan uplift occurred from 17 to 18 Mya in the middle and late Pliocene, which resulted in regional species differentiation, corresponding to changes in species differentiation rates from the 4th to the 3rd order. From 10.9 to 7.5 Mya and 0.9 Mya up to now, the Himalayan region has experienced two periods of dramatic uplift, corresponding to changes in species differentiation rates at grades 6 to 5 and 8 to 7. Because the last uplift period is relatively short, the degree of species differentiation is not obvious, which may be related to the environmental delay effect of uplift and the time delay effect of species differentiation on uplift environment. It can be inferred that according to Hutchinson evolutionary system, the first 1-3 grades of seed plants in the study area may have occurred before 17-18 Ma, the second 4-5 grades may have occurred between 10.9-7.5 Mya and 0.9 Mya, and the third 6-8 grades may have formed after 0.9 Mya.

Table 1. The distribution stage of endemic species in Himalaya region [7].

Evolution stage	Classes number/ratio	Families number/ratio	Genus number/ratio	Species number/ratio
1	2/4.08	2/3.39	10/6.49	39/5.78
2	6/12.24	9/15.25	13/8.44	53/14.4
3	11/22.45	13/22.03	31/20.13	49/13.07
4	11/22.45	14/23.73	51/33.17	162/43.2
5	10/20.41	10/16.95	33/20.75	46/12.27
6	5/10.2	7/11.86	12/7.80	22/5.87
7	2/4.08	2/3.39	2/1.3	2/0.05
8	2/4.08	2/3.39	2/1.3	2/0.05
Sum	49	59	154	375

The ratio of endemic species between the two adjacent evolutionary classes and the previous one was taken as the rate of species differentiation of the adjacent evolutionary classes (Table 1). If the ratio was greater than 1, the rate of species differentiation was increased. On the contrary, the rate of species differentiation is attenuated. In terms of the fluctuation of evolutionary stages 1-7, the evolutionary relationship of endemic species in the Himalayas also showed four peaks of differentiation, which were located before grades 1-2, from grades 4 to 3, from grades 6 to 5, and from grades 8 to 7 (Fig. 1). Among them, there is only one differentiated species in grades 8-7, which is the most recent differentiation stage, and the degree of differentiation is low because they have not experienced enough differentiation time. The occurrence of these three peaks represents three periods of intense species differentiation, and the Himalayan region has exactly experienced three violent uplift processes, which seems to indicate that the rate of species differentiation of different evolutionary levels seems to be closely related to the three violent Himalayan uplifts [7].

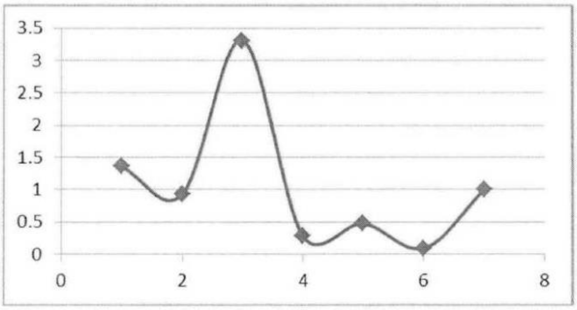

Fig 1. Comparison of differentiation rates of species in different evolutionary stages. https://kns.cnki.net/kcms2/article/abstract?v=3uoqIhG8C447WN1SO36whLpCgh0R0Z-iDdIt-WSAdV5IJ_Uy2HKRAQ57XaxktT8uY67X6QEG1ZkhrmbO80Xzt3CocMsQhIHV&uniplatform=NZKPT

Most endemic species of Himalaya region originated in adjacent regions and situ. Based on molecular evidence, they found that their abundance came from radiative diversity rather than differentiation on the phylogenetic tree, which is multiple parallel descendants from a common ancestor [8]. Simultaneously some genera and clades spread widely in somewhere which is far away from Himalaya in diverse paths, although it is hard to distinguish because of the frequent long-distance dispersals [9]. In addition, montane isolation and earlier Largest Glaciation may have promoted the intraspecitic divergences of species [10]. Significant uplifting promoted continuous allopatric speciation through local vicariance, secondary contact, and providing refuges when climate change. This phenomenon may be combined by interspecific diploid hybridization through secondary symbiosis in relatively stable stages between different uplifts. Researchers has clarified most speciation was formed from highland to lowland. Further, D-statistical analysis showed that there was obvious bidirectional genetic introgression among the neighboring branches of the tall plants, but there was no genetic introgression among the existing species. And the interspecific gene infiltration is asymmetrical. Some models predicts that during the cooling era, Roscoea's habitat shifted to lower elevations. These results suggest that the sudden rise of the Himalayas promoted the variation of high-altitude species and the further formation of new species, while the cooling of the climate encouraged the differentiation of species that could not adapt to the high-cold climate to the lower altitude. What's more, the formation of "Himalaya corridor" prompt the westwards and southwards of numerous plant taxa of Sino-Japanese origin into the Himalaya. With its essentially temperate nature [11]. The Himalayan altitude also plays a leading role in the change of Chl in leaves, and leaves avoid excessive radiation damage by adjusting Chl content [12]. In summary, Chl increases with the environmental gradient and the increase of water availability and soil nitrogen availability, decreases with the decrease of photosynthetically active radiation, and increases with the decrease of latitude and longitude.

3. Ultimate Factor Leads to Plants Evolution by Climate Change

Himalaya was formed in Zenozoic era (55-50 Mya), and the primitive flora here was impacted Due to drastic fluctuations in climate, including the formation and retreat of glaciers, and during intermittent warming and cooling, namely the cycles of glacial and interglacial periods. Glacial period is a period of cold and glaciation on Earth, during this period, most of the glaciers on Earth showed an expanding trend, natural zones moved from high latitudes to low latitudes, organisms migrated from high latitudes to low latitudes, and mountain altitudinal zones retreated from high altitudes to low altitudes. An interglacial period is a period of relative warmth between two ice ages. During the interglacial period, global temperatures began to rise, glaciers showed a tendency to retreat on a large scale, biological zones and natural zones began to move in a two-stage direction, and sea levels rose.

During the repeated advance and retreat of glaciers in the Quaternary Period, comparing with the other mountain system like Alps and Andes, Himalaya had only impacted in peaks and high elevations, may attribute to the tropical location of the mountain range [11]. Thus, some dispersed to warm habitat in the south, some species got extinct, and some found refuges in glacial refugia duo to patchy landscape distribution and diverse environmental conditions.

Another climate factor impacted plant evolution critically is monsoon. The southwest monsoon system triggered when the elevation uplifted in 4000m, which fragmented Himalaya's landscape. The Himalayan front does not form an important barrier until it is 15 milliamps above the average altitude of the plateau, separating the warm, moist air of the Indian mainland from the cool, arid temperate regions in the end of Oligocene (28–23 Mya) or the beginning of Miocene [11]. Given that monsoon obstructed the transition of precipitation in south slope, which resulting extensive weathering and debris dispersal formed the foreland basin and transformed Himalayan vegetation profile from tropical wet evergreen forests to the tall grassland ecosystem that prevailed in the northern and central Himalayas 800 to 600 million years ago, with C3 plants becoming dominant to C4 plants [13]. Further, the heavy precipitation in south slope produced the refuges in interglacial ages and the largest glaciation by fragment landscape. Thus, some species survived in extreme climate, which triggered interspecific infiltration and diploid hybrids, due to the transfer of distribution and secondary contact with relatives [14].

4. Direct Factor Leads to Plants Evolution by Reproduction

Creatures impacted plant evolution by reproduction. Most alpine plants are hermaphrodite and encourage interbreeding that more than 85% of the species in the low and cold areas of the southeastern Tibetan Plateau are hermaphrodite, but they can also self-breed in order to ensure reproductive success without pollinators, and this particular sexual system should optimize the balance between genetic variation, gene flow and reproductive insurance to the greatest extent possible [15]. pollinators also play a significant role when reproduction, especially in wet western Tibet plateau, among this Bumblebees are the pollinators of most species because of their ability to fly in high mountain habitats. Closely related sympatonic species may remain partially isolated by pollination by different branches of the same pollinator or by different flowering times due to environmental factors which causes the mismatch between pollinators and plants. Wind pollination is the main pollination method in the alpine meadow, coniferous forests and grassland of Qinghai-Tibet Plateau in order to maintain outcross and ensure reproductive success under the unfavorable conditions of scarcity of pollinators.

5. Conclusion

The periodic orogenic events led to the evolutionary divergence of life forms by vicariance and climate change along the elevation gradients, such as, variation of monsoon, precipitation and formation of land bridges. The uplift of elevation gradient caused three changes in Himalaya region. First of all, the land bridges formed in preceding eras between three adjacent continents of Sino-Japanese, India and Southwest China. Secondly, the climate type had changed along with the uplift of the range of elevational climate gradient, that from tropical to temperate and alpine. Thirdly, the southwest monsoon had formed because of the formation of orographic barrier in the end of Oligocene when Himalaya reached about 4000m. Given these above, southwest monsoon bring heavy precipitation along the frontal ranges of the Himalaya and has formed streams which format deeply incised valleys, thus, Himalaya had mutate into a highly dissected landscape. As for the corridors who is the reason for the seconded wave of immigration in which many temperate taxa found their way into Himalaya from southwest. To summarize, both climate change and uplift advanced variation pre-adapts organisms to tolerate extremely climate, and during warm climate phases, close proximity niche diversity always accompanied with repeated episodes of genetic isolation in "sky islands", and then they migrated to lower altitudes during cold climate phases, where they mixed and interbred. The complex topography and varied climate of the Himalayan region make it a source of plant diversity for South and East Asia.

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