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Preliminary study on phytogeography of Dipterocarpaceae Blume family in Vietnam

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ABSTRACT

Biogeographically mapping flora of Vietnam requires the studies on the distribution of some important species groups for identifying the typical species composition of each phytochorion. The Dipterocarpaceae family contains taxa originated in tropical Asia and its subfamily of Dipterocarpoideae is proved to have Southeast Asia origin. In Vietnam, this family includes 43 species in 7 genera. In this study, Dipterocarpaceae species from 645 sites in Vietnam are assessed and compared to those in over the world. In Vietnam, this family distributes in tropical and/or slightly passing to subtropical climate but none of its species is naturally found in the Red River and the Mekong River deltas. In the world, the Dipterocarpaceae species found in Vietnam concentrated distributes in Indochina floristic region, corresponding to the originative area of South Myanmar. Statistically, there are 12 endemic species for the Indochinese floristic region and five of them are endemic for four provinces of this region related to Vietnam, respectively as follows: South China - 1, North Indochina - 1, South Indochina - 2 and Annam - 1. Additionally, some species distribute in East Asia floristic region of Holarctic Kingdom because of expanding the distribution area from the Indochinese floristic region. All genera of this family in Vietnam were originated in the Indochinese floristic region. Moreover, the floristic data and phytogeographical phylogeny diagram, based on analyses of phytogeography and DNA, would be better to use for finding out the distributional source or the forming time of species or genus, then the phylogenetic diagram.

Keywords: Dipterocarps family; Indochina floristic region; North Indochinese floristic province; Annamese floristic province; South Indochinese floristic province; Phytogeographical phylogeny; Endemic species.

1. Introduction

In a purpose of biogeographically mapping Vietnam flora, the taxon distributions are required to find out the typical species composition for each area. Dipterocarps family (Dipterocarpaceae Blume) (Angiosperm Phylogeny Group, 2009), with its taxon distributing in the Asia and its sub-family of Dipterocarpoideae, including 475 species of 13 genera, distributing from Seychelles, Sri Lanka, India, Southeast Asia to New Guinea and most of Borneo islands was identified to be originated from Southeast Asia (Myanmar). In Vietnam, there are 43 species and 7 genera of Dipterocarps family, all of them belong to Dipterocarpoideae sub-family (Nguyen Hoang Nghia, 2005). The distributions of these genera were

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defined as follows (Nguyen Hoang Nghia, 2005): *Anisoptera* from Bangladesh, Myanmar, to Indochina and New Guinea; *Dipterocarpus* in Sri-Lanka, India, Myanmar, Thailand, Indochina, Malay peninsula, Sumatra, Borneo and Philippines; *Vatica* from Sri-Lanka, India, Myanmar, Thailand, Indochina, Malay peninsula to Hainan and New Guinea; *Hopea* in Sri-Lanka, India, Myanmar, Thailand, Indochina, Malesia and South of China; *Shorea* in Sri-Lanka, Myanmar, Thailand, Indochina and most of Malesia; *Parashorea* from Myanmar, South of China, Thailand, Indochina to Philippines and Borneo. Genetic relationships of Asian Dipterocarps species were analyzed in term of nuclear DNA and chloroplast DNA (Dayanandan et al., 1999). Based on DNA analysis, a genetic phylogeny diagram expressing the relationships of the species in genera *Anisoptera, Dipterocarpus* and *Vatica* (including species in Vietnam) was introduced (Kress et al., 2003). However, there is an unequal between results of analysis of nuclear DNA and chloroplast DNA as the position of species in phylogeny diagram (Figure 1).

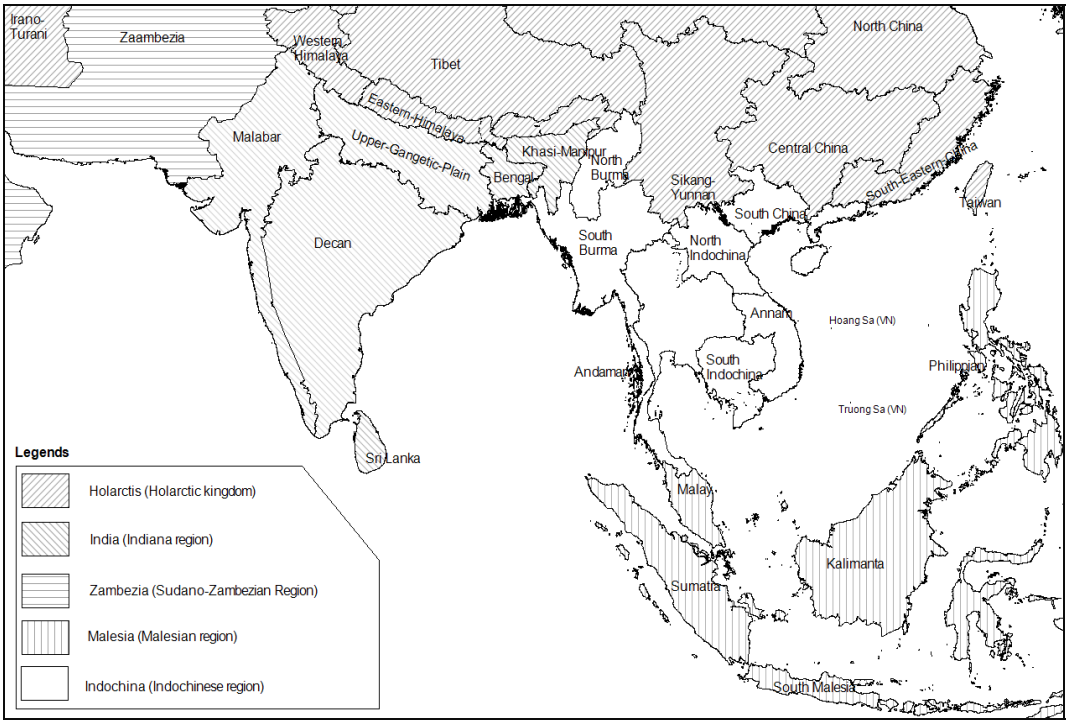

Figure 1. Diagram of floristic provinces in the Southeast Asia
(Drawing base on Takhtajan (1986) and Averyanov et al., 2003)

Takhtajan (1986) had established a global phytogeographical system with the basic unit of the floristic province. According to this system, Vietnam territory is situated in 2 kingdoms: Holarctic Kingdom (Eastern Asiatic region, Sikang-Yunnan floristic Province); and Paleotropical Kingdom (Indochina region with 4 floristic provinces as South China, North Indochina, Annam and South Indochina). However recent studies in Vietnam are some different from Takhtajan (1986), for example, the Asian phytogeographical elements

cover whole the Asia (Le Tran Chan et al., 1999) or the Eastern Asian elements are in all eastern part of Asia on the Pacific coast (Nguyen Nghia Thin, 2004). Both of those elements have been not identified in the Takhtajan's system (1986); and moreover, the "phytogeographical element" conception has not been defined in this system. Most recently, detailing floristic provinces related to Vietnam territory, Averyanov et al. (2003) have divided the Annamese floristic province in Takhtajan's system (1986) into 2 subprovinces: Southern Annam and Central Annam. In that study, the species, especially endemic ones, for each province were inventoried but no species group in relation with the surrounding floristic provinces or regions was mentioned. Thus it is necessary to study phytogeographical distributions of some taxa for gradually establishing a phytogeographical map of Vietnam flora. In addition, the study on distribution of species, genera could give an idea such as: generating and overlapping points of the distributions of various species or genera, points would be checked with fossil evidence. On the contrary, the taxa distributing far from the overlapping point would be reputed as lately formed species. Based on these analyses, it would be established a phytogeographical phylogeny diagram, one of the important keys for phytogeographically mapping Vietnam flora.

2. Materials and Methodology

This study is basically synthesized the publications on Dipterocarps species existing in Vietnam and their distributional evidence in Vietnam and over the world, including online data of herbaria over the world and data published in Ashton P.S., 1982; Kress W.J. et al., 2003; Li X.W. et al., 2007; Nguyen Hoang Nghia, 2005; Nguyen Kim Dao, 2003; Nguyen Nga Phi, 2009; Pham Hoang Ho, 2001; Smitinand T.; 1969; 1990). The species are scientifically named by using The Plant List online version 1.1 (The Plant List, 2013). Distribution areas of the Dipterocarps taxa are defined by the interpolation method using 645 pieces of evidence (specimens and published information) of species found in Vietnam. The GIS tools are applied to develop distribution area of all subjects on the world floristic region map (Takhtajan, 1986), in particular within Vietnam territory; the boundaries of floristic provinces are based on the results of Averyanov et al., 2003 and the work of Takhtajan (1986) is added for determining the boundary of Central/Southern Annamese subprovinces. In this study, a method forming phytogeographical phylogeny diagram is suggested to regard the species in principle that the closely related species have close spatial distributions, but the result would only be ensured by comparing and checking with the phylogenetic diagram.

3. Results

3.1. Distribution of Dipterocarps family in Vietnam

The Dipterocarps species naturally distribute in most of Vietnam, except the Red River delta and Mekong River delta. Most of these species are found in the tropical climate with an elevation below 700 m (in the North) or bellow 1000 m (in the South) a.s.l. (Thai Van Trung, 1978). Some species can develop in both tropical and sub-tropical climate with an elevation above 700 m in the North or 1000 m in the South, such as *Hopea siamensis*, *Pentacme siamensis*, *Dipterocarpus obtusifolius* and *Shorea roxburghi, etc.*, while some others are present only in narrow band of 500-700 m high in the North or 600-1000 m in the South, belonging to cold tropical climate such as *Dipterocarpus grandiflorus*, *Hopea ferrea*, *Shorea henryana*, *Shorea hypochra*… (Table 1).

Table 1. List of species of the Dipterocarps family in Vietnam

No	Scientific name	Vietnamese name	Elevation
1	*Anisoptera costata* Korth.	Vên vên	<700
2	*Anisoptera scaphula* (Roxb.) Pierre	Kiền kiền nhẵn	<800
3	*Dipterocarpus alatus* Roxb. ex G. Don	Dầu rái	200-500
4	*Dipterocarpus baudii* Korth.	Dầu lông	200-800
6	*Dipterocarpus condorensis* Pierre	Dầu cát	200-500
5	*Dipterocarpus costatus* Gaertn.f.	Dầu cát	600-1000
7	*Dipterocarpus dyeri* Pierre	Dầu song nàng	<800
8	*Dipterocarpus grandiflorus* Blanco	Dầu giọt tía	500-700
9	*Dipterocarpus hasseltii* Blume	Dầu rái	<1000
10	*Dipterocarpus intricatus* Dyer	Dầu trai	500-700
11a	*Dipterocarpus obtusifolius* Teijsm. ex Miq. var. *obtusifolius*	Dầu trà beng	500-1500
11b	*Dipterocarpus obtusifolius* var. *subnudus* Ryan & Kerr	Dầu song nàng	< 1300
12	*Dipterocarpus retusus* Blume	Chò nâu	800-1500
13a	*Dipterocarpus tuberculatus* Roxb. var. *tuberculatus*	Dầu đồng	800-1000
13b	*Dipterocarpus tuberculatus* var. *grandifolius* (Teijsm. ex Miq.) Craib	Dầu đồng lá to	800-1000
14	*Dipterocarpus turbinatus* Gaertn.f.	Dầu con quay	30-1100
15	*Hopea chinensis (*Merr.) Hand.-Mazz.	Táu vu	100-1100
16	*Hopea cordata* J. E. Vidal	Sưng đắng	100-1100
17	*Hopea ferrea* Pierre	Chò kiền kiền	<700
18	*Hopea hainanensis* Merr. & Chun	Sao hải nam	350-600
19	*Hopea helferi* (Dyer) Brandis	Sao xanh	<1000
20	*Hopea odorata* Roxb.	Sao đen	100-750
21	*Hopea pierrei* Hance	Kiền kiền phú quốc	<1000
22	*Hopea recopei* Pierre	Chò chay	<700
23	*Hopea reticulata* Tardieu	Sao mạng	200-600
24	*Hopea siamensis* Heim	Kiền kiền	<1200
25	*Hopea* sp.	Sao đá	<700
33	*Parashorea chinensis* H. Wang	Chò chỉ	100-1000
27	*Pentacme siamensis* (Miq.) Kurz	Cà chắc xanh	100-1500
28	*Shorea falcata* J. E. Vidal	Sao lá lệch	100-500
29	*Shorea guiso* (Blanco) Blume	Chăn	<600
30	*Shorea henryana* Pierre	Bô bô	<900
31	*Shorea hypochra* Hance	Vên vên	700
32	*Shorea obtusa* Wall. ex Blume	Cà chắc	200-1000
26	*Shorea roxburghii* G. Don	Sến cát	>1300
34	*Shorea stellata* (Kurz) Dyer	Chò đen	<600
35	*Shorea thorelii* Pierre	Trai	50-550
36	*Vatica chevalieri* (Gagnep.) Smitinand	Táu muối	50-300
37	*Vatica cinerea* King	Táu nước	<900
38	*Vatica diospyroides* Symingt.	Táu muối	<900
39	*Vatica mangachopoi* Blanco	Táu duyên hải	<600
40a	*Vatica odorata* (Griff.) Symingt. subsp. *odorata*	Táu mật	300-900
40b	*Vatica odorata* subsp. *brevipetiolata* Phamh.	Táu lá nhỏ	300-800
41	*Vatica pauciflora* (Korth.) Blume	Táu ít hoa	<700
42	*Vatica philastreana* Pierre	Làu táu nước	<700
43	*Vatica subglabra* Merr	Táu nước	100-900

3.2. Phytogeographically regioning the Dipterocarps family of Vietnam

Analyzing 645 present sites of the Dipterocarps family of Vietnam shows that the distribution area of all members of this family in Vietnam covers on 2 floristic kingdoms: Paleotropis (4 floristic regions, 14 floristic provinces) and Holartis (2 floristic regions, 6 floristic provinces) (Table 2). The Dipterocarps of Vietnam, first concentratedly distributed in Indochina province with 43 species and then

northwards expanded to Sikang - Yunnan with herein presence of *Dipterocarpus retusus*, *D. turbinatus*, *Hopea chinensis*, *Parashorea chinensis* (Li et al., 2007), *Vatica diospyroides* and *V. subglabra* (Nguyen Kim Dao, 2003) or westwards expanded to Sudano-Zambezian region with the *Dipterocarpus turbinatus* (Nguyen Kim Dao, 2003) and was southwards limited in the Malesian region with 25 species. Among the floristic provinces, there are 5 provinces covering all Vietnamese territory: Sikang - Yunnan belonging to Holartis, South China, North Indochina, Annam and South Indochina belonging to the Indochinese region of Paleotropics.

Table 2. Distribution of species of Dipterocarps family of Vietnam in floristic units

No	Kingdom	Holarctis: 8					Paleotropis: 43													
	Region	Eastern Asia: 6				(a)	India: 9		Indochina: 43							Malesia: 25				(b)
	Floristic Province	(1)	(2)	(3)	(4)		(5)	(5)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	
	Number of species	1	2	2	6	1	5	5	21	5	7	31	33	35	31	25	4	7	6	11	1
1	*Anisoptera costata*											+	+	+	+	+	+	+	+	+	
2	*A. scaphula*						+		+			+	+	+	+	+				+	
3	*Dipterocarpus alatus*							+	+			+	+	+	+	+		+		+	
4	*D. baudii*								+			+		+	+	+			+	+	
5	*D. condorensis*(*)														+						
6	*D. costatus*			+			+		+			+	+	+	+	+					
7	*D. dyeri*											+	+	+	+	+					
8	*D. grandiflorus*								+	+		+		+	+	+	+	+	+		
9	*D. hasseltii*											+	+	+	+	+	+	+	+	+	
10	*D. intricatus*(**)											+	+	+	+						
11	*D. obtusifolius*								+	+		+	+	+	+	+					
12	*D. retusus*		+	+	+		+	+	+		+	+	+	+	+	+		+	+	+	
13	*D. tuberculatus*						+		+			+	+	+	+						
14	*D. turbinatus*	+	+			+	+		+	+		+	+	+	+	+	+		+	+	+
15	*Hopea chinensis*				+						+		+								
16	*H. cordata*(*)													+							
17	*H. ferrea*								+			+	+	+	+	+					
18	*H. hainanensis*				+						+		+	+							
19	*H. helferi*								+	+		+	+		+	+					
20	*H. odorata*								+	+		+	+	+	+	+					
21	*H. pierrei*											+	+	+	+	+				?	
22	*H. recopei*(**)											+	+	+	+						
23	*H. reticulata*(**)										+	+		+							
24	*H. siamensis*(**)											+		+							
25	*Hopea* sp. (*)(***)												+								
26	*Parashorea chinensis*				+						+		+	+							
27	*Pentacme siamensis*								+			+	+	+	+	+					
28	*Shorea falcata*(*)													+							
29	*S. guiso*											+		+	+	+		+	+	+	
30	*S. henryana*								+			+	+	+	+	+					
31	*S. hypochra*											+	+		+	+					
32	*S. obtusa*(**)								+			+	+	+	+						
33	*S. roxburghii*							+	+			+	+	+	+	+					
34	*S. stellata*								+			+	+	+	+	+					
35	*S. thorelii*(**)								+			+	+	+	+						
36	*Vatica chevalieri*(*)												+								
37	*V. cinerea*											+	+	+	+	+					
38	*V. diospyroides*				+							+	+								
39	*V. mangachapoi*										+	+		+		+		+		+	
40	*V. odorata*								+		+	+	+	+	+	+					
41	*V. pauciflora*							+	+			+	+	+	+	+			+	+	
42	*V. philastreana*(**)											+		+	+						
43	*V. subglabra*				+			+	+		+		+								

←**Note:** Floristic region: (a): Irano Turano, (b): Sudano-Zambezian; Floristic provinces: (1): Eastern Himalaya, (2): Khasi-Manipur, (3): Northern Burma, (4): Sikang-Yunnan, (5): Bengal, (6): Malabar, (7): Southern Burma, (8): Andaman, (9): South China, (10): Thailand, (11): North Indochina, (12): Annam, (12): South Indochina, (14): Malay, (15): Kalimanta, (16): Philippian, (17): Sumatra, (18): South Malesia; (*): Endemic for Vietnam; (**): Endemic for Indochina; (***): *Hopea* sp. (according to Nguyen Hoang Nghia, 2005)

None of the Dipterocarps species found in Vietnam is endemic for any floristic province of the Holartis and there is a North - South trend separating these species. The appearance of Dipterocarps species in South China province seems to be result from a distributional expansion of those in Indochinese floristic region. There are 5 endemic species for 3 provinces of the Indochinese floristic region: *Dipterocarpus condorensis* for North Indochina; *Hopea* sp., *Vatica chevalieri* (Nguyen Hoang Nghia, 2005) for South China; *Hopea cordata* and *Shorea falcata* (Smitinand et al., 1990; Nguyen Hoang Nghia, 2005) for Annam; 7 other species are endemic to the Indochinese floristic region: *Dipterocarpus intricatus*, *Hopea recopei*, *H. reticulata*, *H. siamensis*, *Shorea obtusa*, *S. thorelii* and *Vatica philastreana* (Smitinand et al., 1990).

Based on the comparison between the distributions of Dipterocarps species found in Vietnam and those in other areas, in the Indochinese floristic region, the 2 provinces of Thailand and Southern Burma have the close relationship with 3 Indochinese floristic provinces covering Vietnam (North Indochina, Annam and South Indochina). Moreover, Malay floristic province in the Malesian floristic region also has the good relationship with these 3 provinces. To explain this phenomenon, there may be a reason directly connecting Malay and Indochina Peninsulas. The other floristic provinces of the Malesian and Indochinese regions have a small number of Dipterocarps species found in Vietnam. Therefore, together with Thailand, Eastern Burma and Malay, the 3 floristic provinces covering Vietnam as the North Indochina, Annam and South Indochina are core distribution area of the Dipterocarps family through the species discovered in Vietnam.

3.3. Phytogeographic phylogeny diagram of Dipterocarp family in Vietnam

A phytogeographical distribution of Dipterocarps genera found in Vietnam is formed by combining the distributions of their species (Figure 2). Comparing these data with the distribution area of genera in Dipterocarps family of Vietnam published by Smitinand et al., 1990, shows that:

Genus *Anisoptera* has 2 species limitedly distributing in Paleotropis, including the Indochinese and Malesian regions and a small part in the Indiana region (Bengal floristic province, adjacent to Indochinese region). According to data of Nguyen Kim Dao (2003), it is new record of genus distribution in Indiana region with species of *A. scaphula*.

Genus *Dipterocarpus* with 12 species has most distribution area of Dipterocarp family of Vietnam except Sudano-Zambezian region. Its distribution area expands to the Southern of the China, to the Holartis kingdom: *Dipteorcarpus retusus* distributed in Sikang - Yunnanese floristic province (Li X.W et al., 2007).

Genus *Hopea* with 11 species has relatively wide distribution, from the centre of the Indochinese floristic region: northwards to Sikang - Yunnanese floristic province of Holartis, mostly expanding in Vietnam and somewhere in Yunnan administrative province of the China; southwards to the Southern Malesian floristic provinces, excluding the Philippine, Sumatra and Kalimantan floristic provinces. In comparison with the data of Smitinand et al., 1990, there is no evidence

for distribution of this genus in the Indian region.

Genus *Parashorea* has only one species distributing from Indochinese floristic region to Sikang - Yunan province of the Holartis kingdom and to Malay province in the Malesiana floristic region. The study of Smitinand et al., 1990) gave similar result.

Genus *Pentacme* has only one species limitedly distributing within floristic provinces of Indochinese region and in Malay floristic province. This is also similar with the data of Smitinand et al., 1990 with the species *Shorea siamensis* (it is a synonym of *Pentacme siamensis*).

Genus *Shorea* has 8 species, concentratedly distributing within the Indochinese and Malesian floristic region except the Kalimantan floristic province, expanded to the Indianan floristic region at Malabar floristic province with one species as *S. roxburghii*; and there is no species discovered in the Holartis. This result corresponds to that of Smitinand et al., 1990.

Genus *Vatica* with 8 species concentrated distributes within the Indochinese and Malesian floristic regions, expanding to Malabar province of Indian floristic region and to Sikang - Yunnan and Southeastern China provinces of Horiatis kingdom, but there is no evidence found in Kalimantan and Sumatra provinces of Malesian floristic regions. This result is also similar with the data of Smitinand et al., 1990.

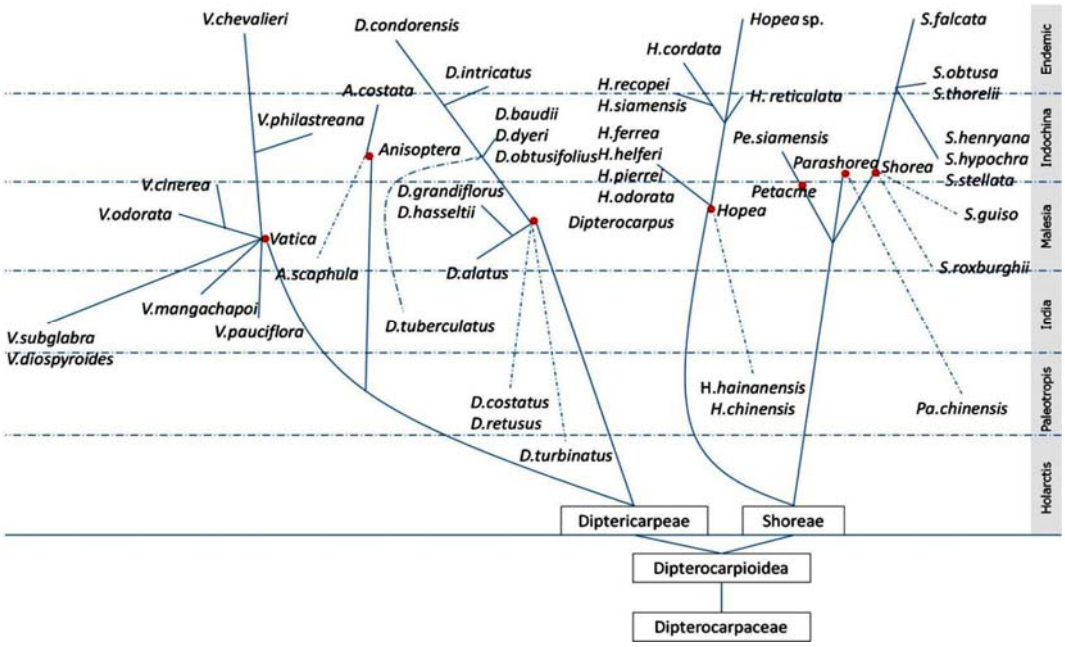

Figure 2. Phytogeographic phylogeny diagram of Dipterocarps family found in Vietnam

4. Conclusions

Analyzing geographical distribution of the Dipterocarps family of Vietnam shows that family has concentrately distributed in Indochinese floristic region, concurring with origi-native centre in Burma (Myanmar). There are 5 endemic species for 4 floristic provinces, covering whole Vietnam territory, belonging to Indochinese floristic region, while this region has total 12 endemic species of Dipterocarps of Vietnam. In addition, it also suggests that the species ancestors of Dipterocarps in Vietnam appeared in Holarctis due to the distributional

expansion from Indochinese floristic region. All genera had originated from the Indochinese floristic region. In comparison with data of Smitinand et al. (1990), the genera distributions are firstly recorded in Indian floristic region with *Anisoptera*, in the Sikang - Yunnanese floristic province of Eastern Asian floristic region with the *Dipterocarpus*.

Combining phytogeographical species, genera data and genetic data enables to form the phytogeographical phylogeny diagram, reconstructing the evolution of the Dipterocarps found in Vietnam through the time with natural conditions such as geology, climate, geography, etc. In some particular cases, the phytogeographic phylogeny diagram has certain advantages; it would be replaceable or even better than genetic phylogeny diagram. The phytogeographic phylogeny diagram is more useful tool in case of deficiency of genetic data.

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