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RESEARCH ARTICLE

ALTITUDINAL VARIATION IN *DROSOPHILA* SPECIES OF HADYA, WESTERN GHATS, KARNATAKA STATE OF INDIA

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ABSTRACT

Drosophila (L.) (Diptera: Drosophilidae) is a very good model organism since the time of Morgan it has been used to understand the pattern of inheritance, variation, speciation and evolution. In addition to this basic research work, it has also been utilized to understand many of human metabolic disorders due to availability mutants and conserved physiological mechanism in both of it. Further species of *Drosophila* not only show cosmopolitan nature but also exhibits. Complexities in species compositions form good model to study the eco-distributional patterns of various species. This study analysed the altitudinal variation in *Drosophila* species of hadya, of Western ghats, Karnataka state, India. A total of 2548 *Drosophila* flies belonging to 11 species of 4 subgenera were collected at altitudes of 800, 1000 and 1200 m a.s.l. The subgenus *Sophophora* was predominant, with 8 species. Subgenus *Drosophila*, *Dorsilopha* and *Scaptodrosophila* were represented by 1 species each. Population densities and relative abundances of the different species at different altitudinal variations were studied. The diversity of the *Drosophila* community was assessed by applying Simpson's diversity index. Diversity of species of *Drosophila* was more at altitude 800m and it started decling with increasing altitude. The results suggest the distributional pattern of a species *Drosophila* at different altitude was uneven in space and time.

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INTRODUCTION

The fruit fly *Drosophila* (L.) (*Drosophilidae*) since the time of Morgan it has been utilised to understand the pattern of inheritance, variation, speciation and evolution. Due to its cosmopolitan nature and complexities in species compositions forms a very good model for studying the eco-distributional patterns of various species (Carson, 1965). Therefore it is necessary to have scientific analyse of biodiversity of *Drosophila* which analysis the species compositions and the patterns of distribution of various members of the genus *Drosophila* in different geographical regions of the world which enable in understanding the principles underlying adaptive radiation and certain mechanisms involved in speciation (Muniyappa, 1981). India is one of the Asian country which has got diverse climatic conditions forms richest repositions of biodiversity in the world. Genus *Drosophila* comprises of more than 3,500 species, of which 200 species belonging to 20 genera have been reported from different parts of India.

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However no information is available regarding the *Drosophila* fauna of the hadya of western ghats of the Indian subcontinent. Hadya, a malnad part of the district has rich biodiversity coupled with higher endemism could be attributed to the humid tropical climate, topological and geographical characteristics and geographical isolation (Arabian sea to the west and the semiarid Deccan Plateau to the east). The Western ghats, is a chain of mountains, stretching north south along the western peninsular India for about 1,00km, harbours rich in flora and fauna is one among 34 global hotspots (Myers *et al*., 2000, Sreekantha *et al*., 2007). Various forest types such as tropical evergreen, semi-evergreen, moist and dry monocultures, river valley. It forms an important watershed for the entire peninsular India, being the source of 37 west flowing rivers and the three major east flowing rivers and their numerous tributaries. The stretch of central western ghats of Karnataka, from 12° N to 14°N, from the Coorg district to the south of Uttara Kannada district and covering the western portions of Hassan, chikamagalore and Shimoga districts, is exceptionally rich in flora and fauna. Whereas the elevation from 400m to 800m is covered with evergreen to semi-evergreen forests, especially along stream courses and rich grasslands in between. This portion of Karnataka Western Ghats is extremely important agriculturally and horticultural.

Whereas the rice fields in valleys, coffee and cardamom. Black pepper, ginger, areca nut, rubber are notable crops here, in addition to various fruit trees and vegetables. Some of the higher altitudes are under cultivation of tea. This place is at a height of 1200 feet from the sea level and the average rainfall is about 150-180 inches/ year and temperature will be 26°-28°C. In the studies of biodiversity it has been shown that ecology and biodiversity of a given species is known to be influenced by its ecological and biological factors which involved in the given ecosystem (Guruprasad *et al*., 2010). Apart from this animal distribution is also affected by seasonal and altitudinal changes occur in different geographical regions (Koushik and Krishna 2013). According to Reddy and Krishnamurthy (1977) in their study have suggested that elevation and seasonal changes may not have much effect on the distribution of animal. Therefore more studies of altitudinal variation in biodiversity is of *Drosophila* is warranted. Variation in biodiversity of *Drosophila* in nature could be explained by Gause's competitive exclusive theory which reveals that no two related species competing for the same resource cannot co-exist together for a long time. (Gause, 1934). On the other hand two experiments also questioned the validity of Gause principle (Ayala 1969). Therefore, it is very important to study biodiversity of *Drosophila* to understand Gause principle (1934). Hence the present investigation was undertaken in Hadya, a hilly region of Western ghat. The study revealed a total of eight different species. Therefore, the present study has been undertaken at this place to understand the biodiversity of *Drosophila* in relation to microhabitat variations.

MATERIALS AND METHODS

In the present study sweeping and bottle trapping method, were used to collect *Drosophila* from Hadya, Hassan district in the western ghats during the spring season to account for the biodiversity of drosophila fauna. Various rotting fruits such as *Musca paradisca* (banana), *Citrus sinensis* (orange), *Malus domestica* (apple), *Carica papaya* (papaya), *Citrous aureanthium* (lime) and chiku were used to species of Drosophila using net sweeping method. This fruits were then allowed them for 24 hours, then spread under shaded areas to attract flies. After a day of spreading, the flies were collected by sweeping using fine net. The flies were then transferred to the bottles containing wheat cream-agar medium and brought to the laboratory for identification. From this bottles males and females were separates out and males were identified using taxonomical markers such as body pigmentation, sex comb and genital plate. However, females of *Drosophila* species do not carry any species specific characters, therefore the collected females were subjected to isofemale lines. Thus species were identified by using male flies obtained from the progenies of isofemale lines. Uniformity was maintained by using the techniques and in the number of baits used in the collection sites.

Flora of the collection sites

Following is a brief description of the flora available in each of the collection spots. Flora at 800 m a.s.l., coffee*, Coffea arabica;* Basiri, *Ficus religiosa*; jackfruit, *Artocarpus heterophyllus*; Nandi, *Lagestroemia microcarpa*; Silver, *Gravelia robusta*; orange, *Citrus reticulate*; Honne, *Pterocarpus emblica*; Palwan, *Erythrina subumbrans*. Flora at 1000 m a.s.l., Coffee, *Coffea arabica*; Mango, *Mangifera indica*; jackfruit, *Artocarpus heterophyllus*; Nerale, *Schizizium cumini*; Teek wood, *Techtona grandis*; Silver*, Gravelia robusta*; orange, *Citrus reticulate*; Antuwala, *Sapindus emarginatus*; Palwan, *Erythrina subumbrans.* Flora at 1200 m a.s.l., coffee, *Coffea arabica*; Honge, *Pongania pinnata*, Bilva, *Aegle marmelos*; Palwan*, Erythrina subumbrans*; Rose wood, *Dalbergia latifolia*; Balanji, *Acrocarpus fraxinifolicus*; Honne, *Pterocarpus emblica.*

Data analysis

Simpson's diversity index (Simpson 1949) says about the relationship between the abundance, richness, and diversity of all groups of flies collected were studied using Simpson's diversity index (Simpson 1949). Simpson's diversity index (D) measures the probability that 2 individuals randomly selected from a sample will belong to the same species, and was calculated using the following formula: where n= the total number of organisms of a particular species, and N = the total number of organisms of all populations.

$$D = \frac{\sum n\,(n-1)}{N\,(N-1)}$$

In order to verify the qualitative distribution of different species of was understood from the occurrence constancy method (Dijoz 1983). In this method, the constancy value (C) was obtained by dividing the number of collections in which one species occurred by the total number of collections, and then multiplying that result by 100. Based on constancy value, the species collected were grouped as constants when $C \geq 50$, accessory species when $C \geq 25$ and < 50, and accidental species when $C < 25$. Species that occurred in only one area were considered exclusive. Cluster analysis was performed using Win STAT software (www.winstat.com) to design, analyze and compare different populations, as described by Giri *et al*. (2007). In the cluster study, Euclidean was chosen to measure the similarity between different species, and ward's strategy (Giri *et al*., 2007) was performed to unite two clusters.

RESULTS

The list of drosophila species collected at different altitudes of hadya from January to march2015 and their taxonomic position are given in Table 1. A total of 11 species were collected belonging to 4 subgenera (Sophophora, Drosophila, Drosilopha and Scaptodrosophila). Pooled data on collections of Drosophila yielded a total of 2548 individuals. Out of these, 2470 individuals (96.93%) belonged to 8 species of subgenus Sophophora, 35 (1.37) individuals belonged to 1 species of the subgenus Drosophila, 27 (1.05%) individuals belonged to 1 species of the subgenus Drosilopha, 16 (0.62%) individuals belonged to 1 species of the subgenus Scaptodrosophila. The value of the Simpson's index, indicating the abundance, richness, and diversity of Drosophila flies at different altitudes (Table 3). At the lowest altitude (800 ma.s.l.), The Simpson's index was 0.21, and at the highest altitude (1200 m).

Table 1. The list of species of *Drosophila* collected, and the number of *Drosophila* collected at different altitudes (m a.s.l.) of Hadya, Western ghat in January to March, 2015

Genus	Subgenus	Species	Altitudes			Total
			800	1000	1200	
Drosophila	*Sophophora*	*D.ananassae*	35	-	-	35
		D. varians	10	-	-	10
		D.malerkotliana	400	300	225	925
		D.bipectinata	350	175	150	675
		D. anomelani	120	75	60	255
		D.kikawai	110	70	55	235
		D. jambulina	100	65	45	210
		D.rajashekari	65	45	15	125
		Total				2470
	Drosophila	*D.nasuta*	15	-	20	35
		Total				35
	Scaptodrosophila	*D.nigara*	15	07	05	27
		Total				27
	Phorticellastriata	*D.phorticellastriata*	06	-	10	16
		Total				16
	Total		1226	737	585	2548

Table 2. Absolute (A) and relative abundance (r) and constancy values (c) for each species collected at different altitudes of Hadya in January to march, 2015

Subgenus	Species	800m a.s.l			1000m a.s.l			1200m a.s.l		
		A	r	c	A	R	C	A	R	C
Sophophora	*D. ananassae*	35	0.03	33.3	-	-	-	-	-	-
	D. varians	10	0.01	33.3	-	-	-	-	-	-
	D.malerkotliana	400	0.32	100	300	0.40	100	225	0.38	100
	D.bipectinata	350	0.28	100	175	0.23	100	150	0.25	100
	D. anomelani	120	0.10	100	75	0.10	100	60	0.10	100
	D.kikawai	110	0.08	100	70	0.09	100	55	0.09	100
	D.jambulina	100	0.08	100	65	0.09	100	45	0.07	100
	D.rajashekari	65	0.05	100	45	0.06	100	15	0.02	100
	Total	1190								
Drosophila	*D. nasuta*	15	0.01	66.6	-	-	66.6	20	0.03	66.6
	Total									
Scaptodrosophila	*D.nigara*	15	0.01	100	07	00	100	05	00	100
	Total									
Phorticellastriata	*D.phorticelastriata*	06	00	66.6	-	-	-	10	0.01	66.6
	Total	1226			737			585		

Table 3. Simpson's diversity index (D) according to the altitudes of Hadya

Altitude (ma.s.l)	Simpson's index (D)
800	0.21
1000	0.25
1200	0.23

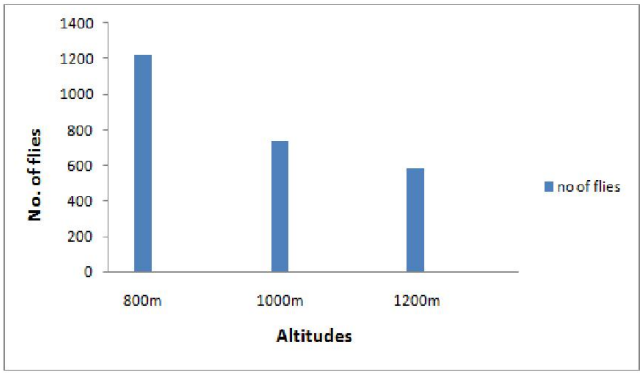

Figure 1. Altitudinal variation in the population of *Drosophila* species on Hadya

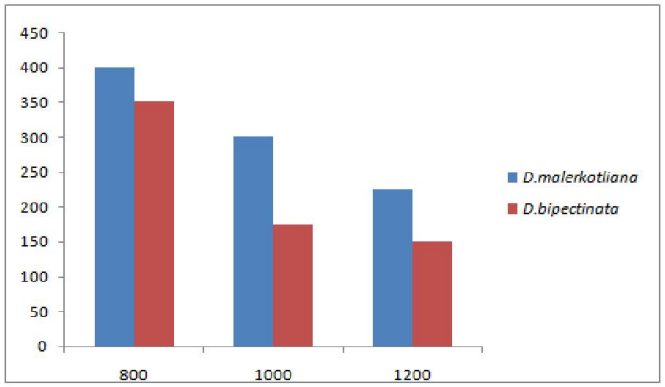

Figure 2. Altitudinal variation in the population of the most abundant *Drosophila* species on Hadya

The altitudinal variation of the Drosophila population is depicted in (Figure 1). The number of Drosophila flies decreased with increasing altitude. The altitudinal variations of the most abundant Drosophila species are shown in (Figure 2). The constancy value (C) of all species at three altitudes along with absolute numbers and relative abundance are presented in Table 2. Constant species (C ≥ 50) represented 100% of the

total collected species (7 out of 11), while 4 species were considered accessory (66.66%). Constant species were D. malerkotliana, D. bipectinata, D. anomelani, D. kikawai, D. jambulina, D. rajashekari, D. nigara an accessory species were D. ananassae, D. varians, D. nasuta, D. phorticelastriata. The constant species lie at the bottom of the cluster. D. ananassae, D. varians, D. nasuta belongs to the subgenus Sophophora. The constant species D.malerkotliana, D. bipectinata, D. anomelani, D. kikawai comes under the same cluster and belongs to the subgenus Sophophora. D. anomelanI, D. kikawai, D. jambulina, D. rajashekari comes under the other cluster and belongs to the same same subgenus Sophophora. D. nigara and D. phorticelastriata comes under the same cluster but belongs to different subgenus Scaptodrosophila and D. phorticelastriata.

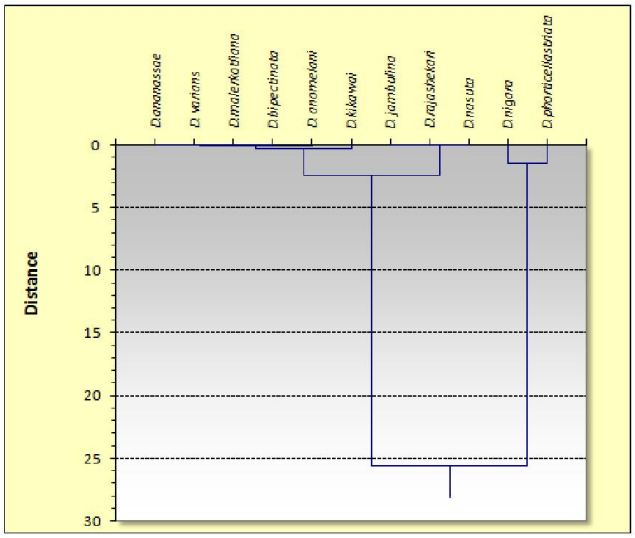

Figure 3. The cluster analysis of *Drosophila* species found on Mount Japfu (dendrogram using Ward's method)

DISCUSSION

The density of Drosophila on Hadya, Western ghats decreased with increasing altitude. The density was high at 800 and was low at 2700 m a.s.l. (Figure 1). The results indicate that the Drosophila community in Hadya was affected by elevation. Wakahama (1961, 1962) who while studying distribution of Drosophila on Mt.Dakesan in Japan has also found altitudinal variation in species of Drosophila. He noticed that the total density of all species decreased with increasing altitude. Reddy and Krishnamurthy (1977) also found such altitudinal variation in Drosophila populations in the Jogimatii hills of Karnataka. Present study also confirms seasonal and altitudinal variation in Drosophila populations of Chamundi Hill in Mysore, Karnataka, India (Guruprasad *et al*., 2010). However the reasons behind the observed phenomenon can be attributed to changes that occur as one ascends an altitudinal transect, potentially involving changes in temperature, precipitation, partial pressure of atmospheric gases, atmospheric turbulence and wind speed, and radiation input, including short-wave ultra-violet radiation at different wavelengths (Barry 1992). According to Hodkinson (2005), the above-mentioned changes are often strongly interactive and together create an environmental envelope within which insect species survive and reproduce. Hodkinson (2005) further emphasizes that the above mentioned parameters combine to produce a general decrease in the overall structural complexity of the insects' habitat with increasing altitude. According to Hegde *et al*. (2000a), the growth and size of a population depends on several environmental factors in addition to genetic structure. In the present study, consideration of the common and abundant species shows that numerical variation exists in regard to these species at all three altitudes. The occurrence of the dominance of one species over the others in any given area can be correlated with the dominant species' ecological versatility to exploit the conditions available in those habitats. The present study corroborates with the work of Muniyappa and Reddy (1981), Hegde *et al*. (2001), and Vasudev *et al*. (2001). There may be many other unknown microclimatic conditions that could also affect the density of Drosophila.

The results of our study are in concurrence with the work of Cooper and Dobzhansky (1956), Reddy and Krishnamurthy (1977), Hegde *et al*. (2001), all of which have shown the influence of microclimatic conditions on the diversity of Drosophila. The present findings are also in agreement with the work of Cooper and Dobzhansky (1956) on species of Drosophila inhabiting the Sierra Nevada Mountains of the Yosemite region of California, where some of the species occurred at all elevations at which collections were made (259–3353 m a.s.l.). The results of our study are also in agreement with the work of Guruprasad *et al*. (2010), who showed that the number and density of Drosophila species decreased with increasing altitude at Chamundi Hill in Mysore, Karnataka. In our study, the presence of more species at lower altitudes can be attributed to the existence of thick vegetation, which provided good sources of food, and a more congenial environment at lower altitudes than at the higher altitudes. According to the constant, accessory, and accident species, as well as the cluster analysis, our study indicates several species that coexisted had similar ecological preferences.

In Simpson's diversity index (D), 0 represents infinite diversity, and 1 represents no diversity i.e., the greater the value of D, the lower the diversity. Applying this index to understand the measures of biodiversity of flies at different altitudes of Hadya shows that the lowest altitude studied (800 ma.s.l.) had the lowest D-value, indicating more biodiversity compared to other altitudes. Hodkinson (2005) suggested that the altitudinal distribution of an insect species is controlled by its environmental tolerances, with maximum population size being achieved at some optimum elevation and population density declining with altitude above the optimum. The results of our study suggest that the optimum elevation on Hadya for Drosophila diversity is at 800 m a.s.l. From the eco-distributional analysis of Drosophila species on Hadya, it is clear that the distributional pattern of a species or related group of species is uneven in space and time. The Drosophila community of Hadya was highly diverse and depended on several environmental factors in addition to the genetic structure of the species present in it.

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