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Altitudinal distribution and quantitative vegetation analysis of the monocotyledonous flora in Mt. Pangasugan, Leyte, Philippines

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ABSTRACT

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The altitudinal distribution of monocotyledonous species in Mt. Pangasugan, Leyte, Philippines was described. Quantitative vegetation analysis to evaluate altitudinal effect was also done from the four sites established in the western side of the mountain.

Hierarchical cluster analysis showed that the families Araceae, Gramineae, Orchidaceae, Palmae, and Zingiberaceae can adapt to wide environmental conditions since these groups were observed in all sites. Cyperaceae preferred the open, well-lighted and cooler summit. Widely distributed species were *Alocasia heterophylla, Alocasia zebrina,* and *Homalomena philippinensis* (Araceae), *Schizostachyum diffusum* (Gramineae), *Languas haenkei, Languas illustris* and *Globba marantina* (Zingiberaceae), *Scleria scrobiculata* (Cyperaceae), and *Heterospathe philippinensis* (Palmae). Discriminant analysis revealed that the families Pandanaceae and Apostasiaceae, Palmae and Araceae, Liliaceae to Orchidaceae and Zingiberaceae were related based on their distribution and frequency in the different sites.

Keywords: Quantitative analysis, discriminant analysis, altitude

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INTRODUCTION

Studies on the altitudinal zonation of forests in the Philippines are few (Buot and Okitsu, 1997). Pendry and Proctor (1997) reported that there are also few studies on altitudinal zonation of vegetation on the small mountains (ca. 1,000 m ASL) in Southeast Asia. Such works are essential for a better understanding of terrestrial ecosystem structure and processes. The vegetation could have a permanent zone of establishment at a certain elevation of a mountain. Above and below this elevation, upper and lower zones of temporary establishments could occur. Elevation effect as conceived by Van Steenis (1962) may apply to different forest communities and plant groups and certain plant groups are confined to a particular altitudinal level (Aragones, 1996).

Quantitative vegetation analysis is a data analysis using quantitative variables such as frequency, population, ecological indices, and population density applying mathematical methods (i.e. multivariate statistical methods) (Johnson and Wichen, 1992).

This study was conducted to describe the distribution of monocotyledonous vegetation and to make quantitative vegetation analysis of the monocotyledons at different altitudes.

MATERIALS AND METHODS

Description of the Study Site

Location

The study site was the western slope (Baybay portion) of Mt. Pangasugan in Leyte, Philippines. The site represented the entire catena from the summit with an elevation of 1,150 m above sea level (ASL) down to the alluvial plain with an elevation of close to 0 ASL.

Climate

The climate of the site is characterized as humid tropical monsoon with no pronounced maximum rain period and no dry season (Type 4 of the Coronas climate classification). Records from the LSU Agromet station showed an average rainfall of 2,600 mm per year in the coastal plain and more than 3,000 mm per year in the mountains. Regarding temperature, previous research has shown that there is a decrease of 0.6 °C per 100 m rise in elevation and it is estimated that at 500 m elevation, temperature could be 24 °C (Asio, 1996).

During the conduct of the study in Mt. Pangasugan, environmental variables such as temperature, relative humidity and light intensity were gathered from different sites. However, these data were obtained at different times of the day and were also obtained during the sampling of the monocot species, hence, they were taken at different days. The temperature of the four sites ranged from 23°C to 29°C. The average temperature in site 1(lower elevations) was 29.86°C while sites 2 & 3 varied only slightly at 27.5°C and 27°C, respectively. There was a relative decrease in temperature to 23°C near or at the summit (site 4). Relative humidity varied slightly in all sites and ranged from 73% (site 1) to 85.5% (site 4). It averaged 79% and 78.25% in sites 2 and 3, respectively. Light intensity was low in the lower elevation (site 1 = 25.57 foot-candles and site 2 = 57.63 foot-candles) and increased with an increase in elevation to 107.5 foot-candles (site 3) and 76 foot candles (site 4).

Geology and soils

The geology of Mt. Pangasugan is dominated by andesitic and basaltic pyroclastics ranging in age from Pliocene to Holocene. They commonly occur as volcanic agglomerates and pyroclastic breccia referred to as Pangasugan formation (Asio, 1994).

Soil samples were collected at a depth of 0-20 cm which represents the rooting depth of most tropical plant. They were taken at random in every site and were composited. Chemical analyses revealed a slightly acid to near neutral condition. Site 1 had a pH of 5.70, sites 2 and 3 had 5.7 and 5.36, respectively, and site 4 had the highest pH of 6.30. Organic matter was highest (22.75%) in site 3 and lowest (4.97%) in site 4. Sites 1 and 2 had 10.50%

and 15.50%, organic matter content, respectively.

Total nitrogen (N) increased from 0.41% in site 1 to 0.50% in site 2 and 0.79% in site 3. It abruptly dropped, however, to 0.25% in site 4. Troeh and Thompson (1993) reported that N in soils is mineralized as a result of the decomposition of complex organic compounds from plants. It follows then that higher OM would also yield high levels of soil N.

Available phosporous (P) was low (below 10 ppm) in all the sites. In fact, the highest value in site 4 was only 3.02 ppm. This implies that P is the most limiting nutrient in the study area.

Potassium (K) showed a decreasing trend from site 1 (507.35 ppm), site 2 (420.28 ppm) to site 3 (353.66 ppm) and relatively increased to 1264.87 ppm in site 4. All values of K are however suffficient.

Vegetation sampling

The Belt transect method was used to collect the data in all four sites. This consisted of laying out at least 20 transects up slope at approximately equal spacing within each sampling site. Following the method used by Iskandar and Kotanegara (1995), the transects measured 100 sq. m. (25 m x 4 m) and a total of 32 quadrats were systematically placed across the sampling area in each site. The entire transect (25 m x 4 m) served as the sampling areas for trees while quadrats with dimensions of 4 m x 4 m and 1 m x 1 m were the sampling areas for shrubs and herbs, respectively.

All monocot species intercepted along the transect were listed and counted. In counting, the method used by Lott (1987) was used wherein the stems of herbs and multiple-stemmed shrubs ascending from different rooting points were counted separately.

Quantitative vegetation analysis

Quantitative analysis of the vegetation was accomplished using a computer software through Hierarchical Cluster Analysis and Discriminant Analysis using pairwise generalized squared distances between groups of monocotyledons and linear discriminant function.

In hierarchical cluster analysis, the average linkage method was adopted (Johnson and Wichen, 1992). Average linkage treats the distance between two clusters as the average distance between all pairs of species where one member of a pair belongs to each cluster. The distance matrix D= $\{d_{ik}\}$ was computed to find the most similar species, for example species U and V. The distances between two species (UV) and the other cluster (W) were determined by:

$$d_{(UV)W} = \frac{\sum_{i}\sum_{k} d_{ik}}{N_{(UV)}\, N_{W}}$$

where: d_{ik} = distance between species i in the cluster (UV) and species k in the cluster W

$N_{(UV)}$ and N_W= the number of items in clusters (UV) and W, respectively.

Discriminant analysis is a procedure for identifying boundaries between groups of objects (example species), the boundaries being defined in terms of those variable characteristics which distinguish or discriminate the objects in the respective criterion groups (Kachigan, 1986). Pairwise generalized squared distances between groups was analyzed using SAS computer software and the following formula was used:

$$D^2 (i/j) = (\bar{X}_i - \bar{X}_j)'\ COV^{-1}\ (\bar{X}_i - \bar{X}_j)$$

where: $D^2(i/j)$ = Generalized squared distance between *i* and *j* family/group

$\bar{X}_i$ =mean for *i* family or group

$\bar{X}_j$ =mean for *j* family or group

COV^{-1} =covariance matrix of the total number of families/groups

Linear discriminant function using discriminant analysis was analyzed using SAS computer software also. This analysis was used to identify as to which site a particular group may favorably thrive. The following formula was used:

$$\text{Constant} = -.5\ \bar{X}_j'\ COV^{-1}\ \bar{X}_j$$

where: $-.5\ \bar{X}_j'$ = vector of means of a family or group or group of means of a particular family

$COV^{-1}\ X_j$ = coefficient vector or coefficients of the different sites

RESULTS AND DISCUSSION

Altitudinal Distribution of Monocotyledons

Table 1 shows the altitudinal distribution of monocotyledons collected from the four sampling sites in Mt. Pangasugan. Plant groups such as Palmae, Zingiberaceae, Araceae and Cyperaceae have a wide altitudinal distribution. This suggests that these plant groups can adapt more to varying habitat types with a change in altitude. The results conform with the findings of Merrill and Merritt (1910) who observed that most aroid species in Mt. Pulog, Philippines were found at low altitudes below 1,100 m ASL.

Table 1. Altitudinal distribution of monocotyledonous species collected in the 4 sampling sites* in Mt. Pangasugan.

FAMILY	PLANT SPECIES	SITE 1	SITE 2	SITE 3	SITE 4
Araceae	*Aglaonema oblongifolium*	- x x x**	x - - -		
	Alocasia heterophylla	- - - x	- x x x	x - - -	
	Alocasia pubera		x - - -		
	Alocasia zebrina	- - x x	x - - -	x - - -	
	Amydreum medium		x - - -		
	Homalomena philippinensis	- x x x	x x x -	- - x -	
	Pothoidium lobbianum		x - - -		
	Rhaphidophora		x - - -		
	Rhaphidophora monticola			- x - x	
	Rhaphidophora pinnata	- - x x	x - - -		
	Schismatoglottis calyptrata	- x x x	x - - -		
	Scindapsus hederaceus		- - - x		
	Spathiphyllum commutatum		x - - -		
Zingiberaceae	*Languas haenkei*	- x - x	x x x x	- x - -	
	Kolowratia elegans		x - x -		
	Languas illustris	- - x -	x - - x	x - - -	
	Globba marantina	- - x -	- - x x	- - x x	
	Costus speciosus	- - x x			
	Kolowratia congesta	- - x -	- - x -		
	Catimbium speciosum		x - x x	x - - -	
	Languas sp.		- - x -		- - x x
	Globba sp.		- - x -		
	Adelmeria rupa		- - x x		
Gramineae	*Schizostachyum diffusum*	- x - x	x - - -	- - - x	
	Schizostachyum lima	- - x -			
	Gigantochloa laevis	- - - x			
	Cyrtococcum oxyphyllum	- - - x			
Cyperaceae	*Scleria scrobiculata*		x x x x	- x x -	- - - x
	Hypolytrum latifolium		x - x x		- - - x
	Carex nodiflora				- - - x
Commelinaceae	*Cyanotis cristata*		x - - -		
	Dictyospermum vitiense	- - x x	x - - -		
	Pollia secundiflora	- - x x			
	Forrestia hispida	- - x x			
	Pollia thyrsiflora	- - - x			
	Pollia macrophylla	- - x -			

* Site 1=91-300 m ASL; Site 2=301-600 m ASL; Site 3=601-900 m ASL; Site 4=901-1150 m ASL

** Positions of the "x" indicates the presence and "-" absence of the species in an interval of 75 m ASL.

Table 1. Altitudinal distribution ... continuation.

FAMILY	PLANT SPECIES	SITE 1	SITE 2	SITE 3	SITE 4
Orchidaceae	*Calanthe furcata*		x - - -		
	Galeola philippinensis	- - - x			
	Spathoglottis sp.		x - x x	- x x x	
	Acanthopippium sp.		- - x -		
	Cymbidium sp.		- - x -		
	Acoridium tenellum			x - - -	
	Habenaria sp.				- - x x
Marantaceae	*Phacelophrynium interruptum*	- x x x	x - x -		
	Donax cannaeformis	- x x x	- x x -		
	Phrynium philipinense	- x - x	x - - -		
	Maranta sp.		- - x -		
Dioscoreaceae	*Dioscorea pentaphylla*	- x - -			
	Stenomeris dioscoreaefolia	- x - -			
Musaceae	*Musa balbesiana*	- x x -			
	Musa textilis	- - x x			
	Musa acuminata	- - x -			
Palmae	*Calamus ornatus*	- - x -			
	Pinanga maculata	- - x x	x - x -		
	Heterospathe philippinensis	- - x x		x - - x	- - - x
	Caryota cumingii	- - x x	x x - -		
	Areca ipot	- - - x	x - - -		
	Areca catechu	- - - x			
	Calamus maximus		- - x -		
	Pinanga insignis		- - x -	- - - x	
	Calamus sp. (A)		- - x x		
	Daemonorops mollis		- - x -		
	Heterospathe sp.		- - - x		
	Calamus daemonorops			x - - -	
	Pinanga philippinensis				- - - x
	Calamus sp. (B)		- - x x		
Pandanaceae	*Pandanus mapola*	- - x -			
	Pandanus sp.	- - x -	- - x x		
	Freycinetia multiflora	- - - x			
	Freycinetia vidalii		- - x -		
	Freycinetia negrosensis		- - x x		
	Freycinetia sp.				- - - x
Liliaceae	*Dianella caerulea*		x - x -	- - - x	
	Smilax leucophylla				- - - x
Apostasiaceae	*Apostasia sp.*		- - x -		
Hypoxidaceae	*Molineria capitulata*	- x x x	x x x x		

Palms in Philippine mountains are distributed from low to middle altitudes (Guzman and Fernando, 1986) while zingibers are found at 50 m to 900 m ASL in Southeast Africa (Nordal and Poulsen, 1998).

Members of the Commelinaceae and Marantaceae occupied the lower elevations while most of the summit species belong to family Cyperaceae. Orchids and pandans were distributed from low to medium elevations and a very few were found at high elevation. The species that were widely distributed were *Alocasia heterophylla, Alocasia zebrina* and *Homalomena philippinensis* (Araceae), *Schizostachyum diffusum* (Gramineae), *Languas haenkei, Languas illustris* and *Globba marantina* (Zingiberaceae), *Scleria scrobiculata* (Cyperaceae), and *Heterospathe philippinensis* (Palmae).

Hierarchical cluster analysis

Cluster analysis (Figure 1) separated the different species of monocotyledons surveyed from Mt. Pangasugan and confirmed a relationship between species based on their abundance and distribution at different elevations.

A cluster at a dissimilarity distance of 2 separated the Araceae members such as *Rhaphidophora* sp., *Scindapsus hederaceus, Alocasia pubera* and palms like *Pinanga insignis* and *Calamus* sp. together with *Freycinetia negrosensis* (Pandanaceae) and *Adelmeria rupa* (Zingiberaceae) from the other monocots collected. Other clusters that were observed at a dissimilarity level of 2 were: cluster 2) *Acoridium tenellum* (Orchidaceae), *Calamus daemonorops* (Palmae), *Pothoidium lobbianum* (Araceae), *Stenomeris dioscoraefolia* (Dioscoreaceae); cluster 3) *Pollia secundiflora* and *Forrestia hispida* of Commelinaceae, *Musa balbesiana* (Musaceae) and *Areca ipot* (Palmae); cluster 4) *Kolowratia elegans* (Zingiberaceae), Pandanaceae members like *Freycinetia multiflora* and *Pandanus mapola*, palms such as *Areca catechu* and *Calamus ornatus*, grasses such as *Gigantochloa laevis* and *Schizostachyum lima*, *Pollia macrophylla* (Commelinaceae), *Galeola philippinensis* (Orchidaceae) and *Dioscorea pentaphylla* (Dioscoreaceae).

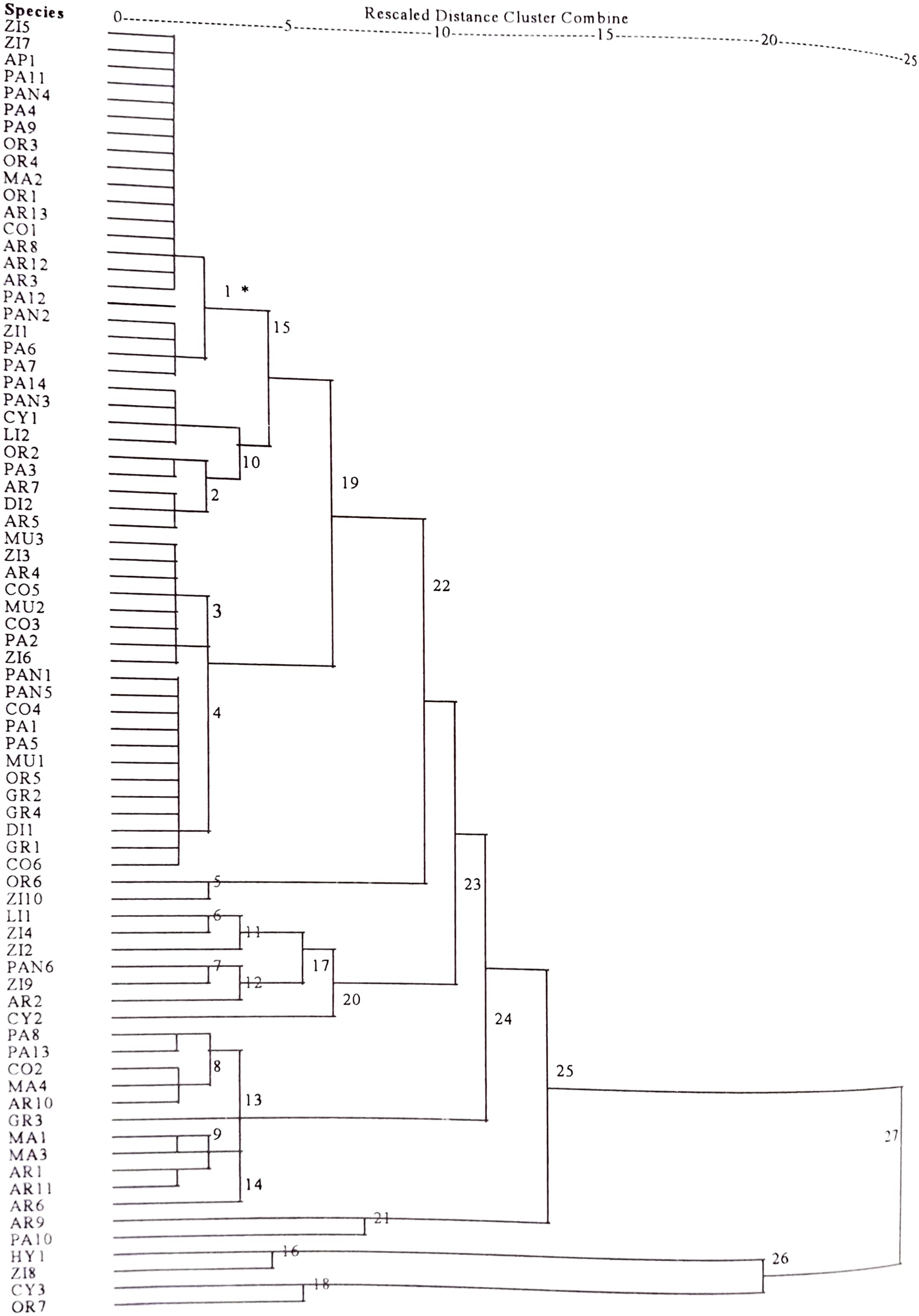

Figure 1. Hierarchal Cluster Analysis. A dendrogram using average linkage betwen monocotyledons in Mt. Pangasugan. (Note: Numbers* indicate the cluster number)

In addition, clusters 5) *Habenaria* sp. (Orchidaceae) and *Languas* sp. (Zingiberaceae); 6) *Dianella caerulea* (Liliaceae) and *Globba marantina* (Zingiberaceae); 7) *Pandanus* sp. (Pandanaceae) and *Languas illustris* (Zingiberaceae); 8) Palms like *Caryota cumingii* and *Pinanga maculata* and *Dictyospermum vitiense* of Commelinaceae and *Phrynium philippinense* of Marantaceae and 9) Maranta family members like *Donax cannaeformis* and *Phacelophrynium interruptum* with an aroid *Aglaonema oblongifolium* are other groups of monocot species observed to be distantly related at 2.0 to the other monocotyledons.

More distant clusters were observed at a distance of 3 compared to the rest of the monocots surveyed are the following: cluster 10) cluster 2 combined with a cyperus *Carex nodiflora* and *Smilax leucophylla* of Liliaceae; cluster 11) cluster 6 which was observed to be composed of a zingiber is also combined with another zingiber *Catimbium speciosum*; cluster 12) cluster 7 together with an aroid *Alocasia heterophylla*; cluster 13) clusters 8 and 9 with *Rhaphidophora pinnata* (Araceae) and *Schizostachyum diffusum* (Gramineae); cluster 14) cluster 9 added by 2 aroids *Schismatoglottis calyptrata* and *Homalomena philippinensis*.

A bigger cluster (15) was formed at a dissimilarity distance of 4.0, which combined clusters 1 and 10. With the same distance as cluster 15, cluster 16 comprised only *Molineria capitulata* (Hypoxidaceae) and *Languas haenkei* (Zingiberaceae). Clusters 11 and 12 are grouped accordingly to cluster 17 which composed mostly of zingibers while *Scleria scrobiculata* (Cyperaceae) and *Spathoglottis* sp. (Orchidaceae) to cluster 18 and both clusters were found to be at distance 5.0 from the other monocots' cluster.

Distance 6.0 from the different clusters formed were found to be of clusters 15 and 4 at cluster 19 which comprised mostly of Araceae and Palmae and some pandans and grasses. Cluster 20 (cluster 17 added with *Alocasia heterophylla* and *Hypolytrum latifolium*) comprised more of Zingiberaceae and Araceae.

Clusters 22 to 27 were group of monocotyledonous species that were observed to be very distantly related to the other monocotyledonous species in Mount Pangasugan in relation to their abundance and distribution in the different sites. Monocotyledons belonging to phylogenetically the same or related families tend to belong to the same group.

Discriminant analysis (linear discriminant function)

It can be deduced from Figure 2 that members of Araceae, Gramineae, Orchidaceae, Palmae and Zingiberaceae can adapt to a wide range of environmental condition (site 1 to 4). Moreover, Cyperaceae thrives more in an open well-lighted site and a relatively low temperature in site 4. On the lower elevations, more of Musaceae, Marantaceae, Araceae, Commelinaceae, Dioscoreaceae and Gramineae favor shady and humid environmental conditions. At 900 m ASL to the summit (site 4) where the area is more exposed to direct sunlight and the temperature is a little bit cooler, *Cyperus*, lilies, orchids,palms and pandans thrive favorably in this place.

Discriminant analysis (Pairwise generalized squared distance)

Results in Table 2 show matrix of a pairwise generalized squared distances between monocotyledonous families using discriminant analysis. The table also shows how the families are related to each other in terms of their abundance and distribution at different elevations.

In terms of relatedness between families of monocotyledons, Pandanaceae was found to be closely related to Apostasiaceae, Palmae to Araceae and Liliaceae to Orchidaceae and Zingiberaceae based on their composition and distribution at different altitudes. Families Cyperaceae and Hypoxidaceae were not related to other monocot families nor these two families are either related to each other. The results suggest that related monocot families based on their vertical distribution and frequency at different sites may have similar environmental requirements as affected by altitude. orchids, palms and pandans favorably thrive in this site.

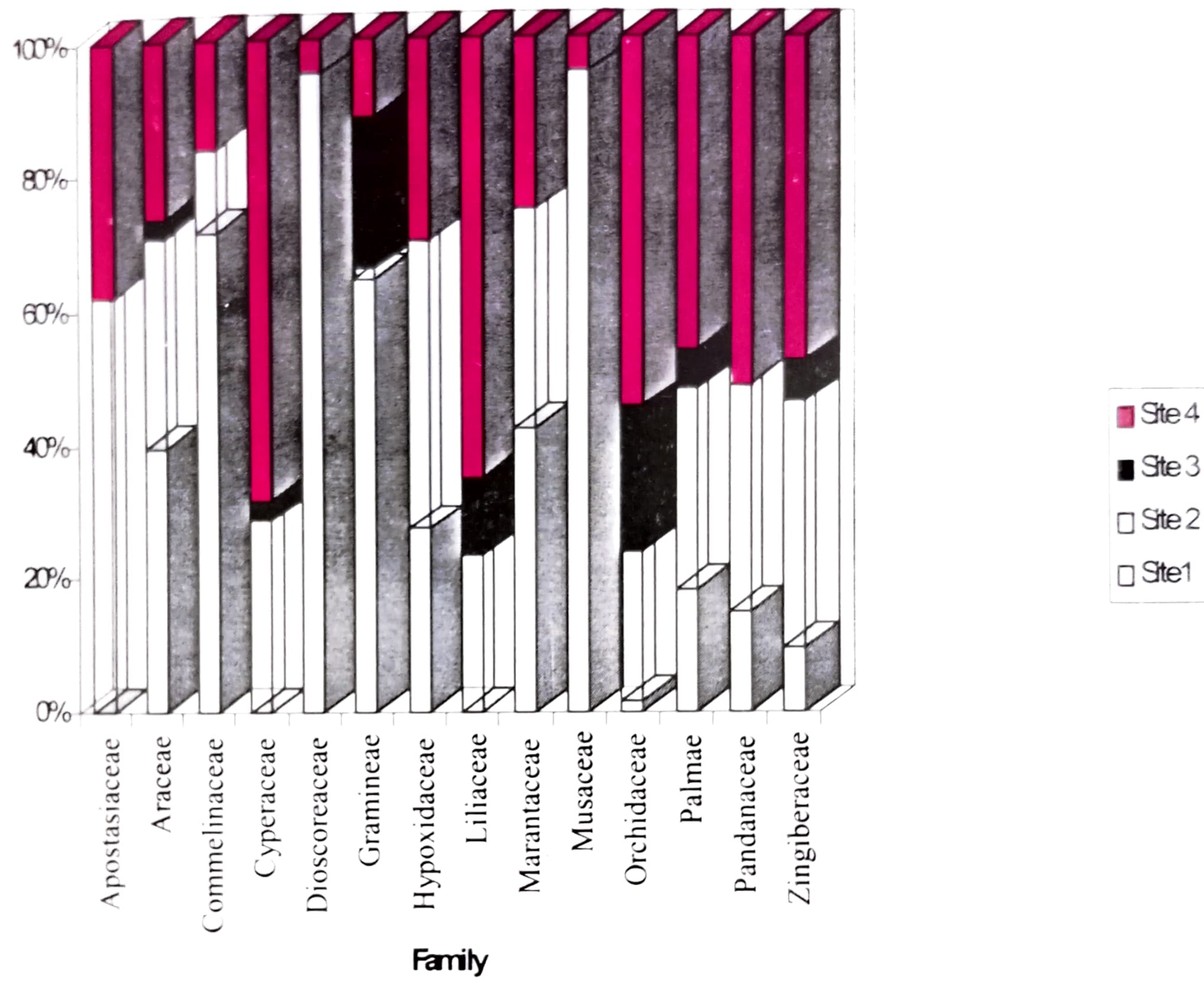

Figure 2. Discriminant analysis of different monocotyledonous families at different sites in Mt. Pangasugan

Table 2. Discriminant analysis (Pairwise generalized squared distances between monocotyledonous family)

FAMILY	AP*	PA	PL	OR	AR
Apostasiaceae (AP)	0				
Pandanaceae (PA)	0.52525	0			
Palmae (PL)	0.90889	0.22459	0		
Orchidaceae (OR)	1.50424	1.12087	0.66266	0	
Araceae (AR)	1.64837	0.6879	0.37395	1.89574	0
Zingiberaceae (ZI)	1.78173	1.23981	0.84581	1.13238	1.66544
Dioscoreaceae (DI)	1.80432	1.36065	1.43056	2.47948	1.33085
Liliaceae (LI)	2.3253	1.75173	1.50318	0.44133	3.31171
Commelinaceae (CO)	3.06946	1.62710	1.4738	3.59008	0.58224
Gramineae (GR)	3.35718	1.95737	1.45808	3.05482	0.69978
Marantaceae (MA)	5.09413	3.13008	2.9339	6.04337	1.68109
Musaceae (MU)	5.28456	3.29895	2.98644	5.4570	1.63655
Cyperaceae (CY)	11.43564	10.22993	10.03007	8.05863	13.21984
Hypoxidaceae (HY)	21.1383	18.6228	18.4738	23.1907	16.90755

*/ Abbreviation of the monocotyledonous familes.

ZI	DI	LI	CO	GR	MA	MU	CY	HY
0								
4.40979	0							
1.23699	4.34848	0						
4.05633	0.94883	5.47609	0					
4.11236	0.83688	5.12741	0.21035	0				
3.43994	5.28458	7.16469	2.20092	3.11390	0			
6.32201	1.70785	7.75338	0.31973	0.42838	3.06361	0		
6.1074	17.86153	5.009	17.80695	17.96583	14.71577	21.59937	0	
14.40071	26.93216	22.51641	20.13235	22.470	9.08366	22.55477	19.7028	0

CONCLUSION

In hierarchical cluster analysis, monocot species belonging to phylogenetically the same or related families belong to the same group. Using the discriminant analysis (linear discriminant function), it can be deduced that families Araceae, Gramineae, Orchidaceae, Palmae and Zingiberaceae can adapt to a wide range of environmental conditions since these plant groups were present in sites 1 to 4. Cyperaceae thrives more at the summit area with some species of Liliaceae, Orchidaceae, Palmae and Pandanaceae. In terms of relatedness between families based on the distribution and frequency using discriminant analysis (pairwise generalized squared distance), Pandanaceae was closely related to Apostasiaceae, Palmae to Araceae, Liliaceae to Orchidaceae and Zingiberaceae. Families Cyperaceae and Hypoxidaceae were not related to other monocot families nor these two families related to each other. The results suggest that related monocot families based on their vertical distribution might have similar environmental condition requirements as affected by altitude.

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