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## Impacts of Ecological Factors on the Distribution of *Amauroderma murrill* genus in central highlands of Vietnam

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**Abstract** The Lingzhi (*Ganoderma lucidum*) has been in the wild for thousand years but its precious gene pool has been eroded day by day in the innovation period and current deforestation situation. Therefore, research on the role of ecological factors on *Amauroderma* genus (black lingzhi) is indispensable for predicting its diversity or declining of mushroom species. The understanding about the impact of ecological factors on the appearance of *Amauroderma* genus is the foundation for conservation and propagation of precious gene of such genus. Hence, this study was focused on evaluate five ecological factors including temperature (t°), humidity (m), elevation (h), and light intensity (l) and occurrence frequency (density) which have caused impacts on appearance of of *Amauroderma* genus in Central Highland of Vietnam. The results revealed that 02 ecological factors important to the occurrence frequency and distribution of mushroom species in *Amauroderma* genus expressed through following equation:  $\text{Frequency appears}^2 = -167.788 + 3.2837 \cdot \text{doam} + \text{sqrt}(\text{height})$ . The elevation of 200-800m and the humidity larger than 90% are the most suitable for the growth and development of mushroom species in *Amauroderma* genus. This study has provided very useful information for further conservation and propagation the precious genetic resource.

**Keywords** *Amauroderma*, lingzhi, regression model, Central Highlands

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### 1. Introduction

*Amauroderma* genus (black Lingzhi) in the *Ganodermataceae* family includes species which are saprophytic or parasites on wood or plant remains. They play an important role in the material cycles in nature due to their ability of decomposing organic materials. Some species are also used as food and medicine like *Amauroderma niger* (Lloyd), *Amaurodermasubresinosum* (Murrill) [1]. In Vietnam, the Lingzhi is available source from the wild which has not been fully discovered but its precious gene pool has been annually eroded in the innovation period and the current deforestation situation.

Besides, within the ecological areas from the North to the South, the Central Highlands are unique area where cover more typical tropical varieties in different climate conditions as the sub-regions. It is rich in biodiversity of mushroom species including *Amauroderma* genus. Therefore, the natural resource of mushroom needs to be developed and protected. Also, studying the roles of ecological factors on this genus is necessary for predicting the diversity or declining of mushroom species in general and *Amauroderma* genus in particular. The understanding about the impact of ecological factors on the appearance of *Amauroderma* genus is the foundation for conservation and propagation the precious gene of such genus.

Several studies reported on classification of some mushroom species in Vietnam included *Amauroderma* genus. It showed that 19 mushroom species which consisted of 9 *Amauroderma* genus [2-3]. Tham *et al.* [4] and Nguyen *et al.* [5] worked on the diversity of *Ganodermataceae* family including *Amauroderma*, however, classification and characterization of the medicinal value have not been done. From international researches,



some attempts were done on few classification of key fungi kingdom [6]. Nevertheless, there are few researches on classification of *Ganodermataceae*. Recently, some reports have focused on assessing the diversity of *Ganodermataceae*, included *Amauroderma* genus [7-8]. Also, several studies have reported about the medicinal and life longevity as well as health promotion of *Amauroderma* species, specifically its inhibiting tumor growth, modulating immune response, enhancing hematopoietic activity and anticancer effects *in vitro* and *in vivo* studies [9-10].

As the above judging, most researches have concentrated on evaluating of diversity of mushroom species without the concern of the relationship-interaction between ecological factor and diversity of the mushroom.

The Central Highlands located at the southernmost of Anammite mountain range, including 5 provinces which are Kon Tum, Gia Lai, Dak Lak, Dak Nong and Lam Dong. Besides that, the terrain of the Central Highlands is divided into wide different mountain ranges (Ngoc Linh, An Khe, Chu Dju, Chu Yang Sin...) with many Nature Reserves and National Parks like Chy Yang Sin, Kon Ka Kinh, Yok Don, Chu Mom Ray etc. (Figure 1).

At the average elevation from 400-2200m a.s.l., the climate of the Central Highlands is grouped into 2 different seasons, whereas the rainy season occurs annually from May to November and the dry season is from December to April. The annual average precipitation is relatively large, from 1500-3600mm. The annual average temperature at the elevation of 450-800m varies within 21- 23<sup>0</sup>C, and the area at higher elevation is always cool as temperate zone. The plant fauna of the Central Highlands are shown very abundant and diverse including coniferous forest, broadleaf forest, and the mixed forest of conifer and broadleaf, bamboo forest... The ecology diversity created by natural conditions have founded many different types of habitats, leading to the diversity of mushroom in general and *Amauroderma* genus in particular. Therefore, the objective of this study was to evaluate the impacts of ecological factors on the distribution of *Amauroderma* genus in the wild.

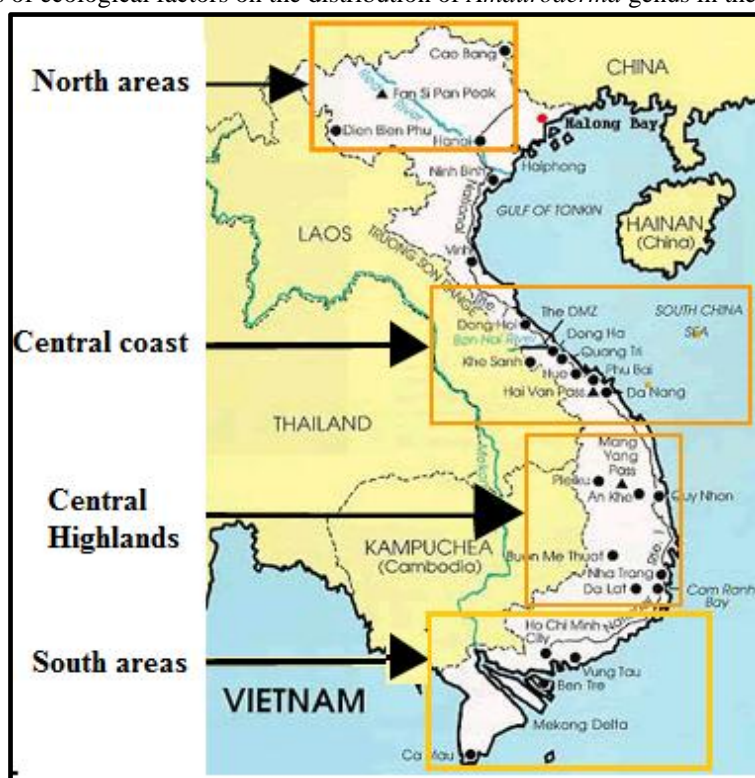


Figure 1: Map of Vietnam areas included the Central Highlands

2. Materials and Methods

2.1. Materials

The mushroom samples were collected and identified following the morphology and anatomy method, and comparison made based on the materials of Steyaert [11]; Perreau [12]; Teng [13]; Kiet [2]; Dung [14], respectively.

**2.2. Methods**

The methods of identifying the ecological factors at the area where mushroom growing was conducted by use of the machines: Moisture meter TigerDirect HMAMT-110 (USA), light intensity meter TigerDirect LMLX1010B (USA), elevation GPS Garmin Trex Vista HCx (USA), temperature Extech 445703.

Supervised indicators: Temperature, humidity, light, elevation and the appearance frequency of sample in the wild.

Two ecological factors used in this study which showed great impact on the occurrence frequency and distribution of mushroom species through following equation:  $Frequency_{appears}^2 = -167.788 + 3.2837 * doam + \sqrt{Height}$  (Table 1).

With  $n = 27$  and all the variables were tested with t under the condition of  $P < 0.1$ ; 02 ecological factors which are air humidity (doam), elevation (height) have clear impacts on the occurrence frequency of mushroom species of *Amauroderma* genus.

**2.3. Statistical analysis**

Statgraphic Centurion XV software is used to establish multiple regression model and analyze the correlations, frequency of occurrence (density) of mushroom species of *Amauroderma* genus with the ecological factors.

**3. Results and Discussion**

Our attempts have evaluated on the relationship between occurrence frequencies of the mushroom species in *Amauroderma* genus based on the key ecological factors in wild which included temperature ( $t^0$ ), humidity (m), elevation (h), and light intensity (l) and frequency of occurrence (density), occurrence locations of the mushroom growing. With the total of 27 sites of mushroom species in *Amauroderma* genus and 401 specimens in the Central Highlands, the correlations between the ecological factors and the occurrence of the mushroom in *Amauroderma* genus were analyzed.

With the database to be investigated at 27 sites which were synthesized on Excel, 2010, and using Statgraphic Centurion XV software to establish multiple regression models and analyze the correlations between the occurrence frequencies of mushroom species in *Amauroderma* genus with the ecological factors. With the sample size of 27 sites, regression analysis with 05 important ecological factors, variables which are not adapted to the condition of relating to the occurrence frequency are excluded at  $P > 0.1$ . The search for the relations from the simple function to complicated function, from one variable to the combination of variables and variable adjustment has constructed a multiple regression function for mushroom species in *Amauroderma* genus as shown in Table 1.

**Table 1:** The regression analysis related to *Amauroderma* genus

Parameters	Values	Errors	T	P-value
A	-167.788	149.341	-1.12353	0.2719
doam+sqrt(Height)	3.2837	1.25618	2.61403	0.0149

With 05 variables of ecological factors, 02 ecological factors were found which have caused great impact on the occurrence frequency and distribution of mushroom species through following equation:  $Frequency_{appears}^2 = -167.788 + 3.2837 * doam + \sqrt{Height}$

The results have revealed that  $R^2 = 21.4656\%$  and  $P < 0.1$  showed that the correlations between the occurrence frequency of mushroom species in *Amauroderma* genus with 2 above ecological factors are disclosed low relation and the interactions because the occurrence frequency of mushroom species in *Amauroderma* genus is directly proportional to the humidity and height above mean sea level, which indicates that if the higher the elevation is, the increasing in air humidity will make the occurrence frequency of such mushroom species increases.

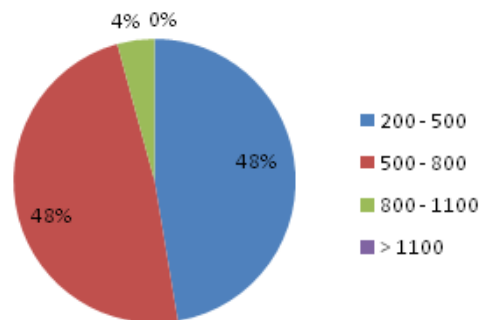
The regression model helps comprehend about initial ecological requirements for these mushroom species. This is the foundation for discovering the species distribution, as well as for the propagation and developing of these species.



**Table 2:** Distribution of mushroom species following the elevation

No.	Scientific names	200 - 500	500 - 800	800 - 1100	> 1100	In sum
1	<i>Amauroderma niger</i> (Lloyd)	27				27
2	<i>Amauroderma subresinosum</i> Murr.	15	14			29
3	<i>Amauroderma rugosum</i> (Blume &T.Nees) Torrend 1920	31				31
4	<i>Amauroderma rude</i> (Berk.)	32	15			47
5	<i>Amauroderma conjunctum</i> (Lloyd.) Torrend 1920		16	17		33
6	<i>Amauroderma exile</i> (berk) Torr	15	45			60
7	<i>Amauroderma coltricioides</i> T.W. Henkel, Aime & Ryvardeen 2003	14	30			44
8	<i>Amauroderma</i> sp1	15	30			45
9	<i>Amauroderma</i> sp2.	13	18			31
10	<i>Amauroderma</i> sp3	14	13			27
11	<i>Amauroderma</i> sp4	14	13			27
<b>Sum</b>		190	194	17	0	401
<b>Number of species</b>		10	9	1	0	

**Percentage (%) of distribution of mushroom species in *Amauroderma* genus following the elevation**



*Graph 1: Distribution percentage of *Amauroderma* genus following the elevation*

The results shown in Table 2 and Graph.1 demonstrated on the impact of elevation to the occurrence of mushroom species in *Amauroderma* genus within the elevation of 200-1400 m a.s.l., the occurrence frequency of mushroom species in *Amauroderma* genus which most occurs at the elevation from 200-800 m, accounts for 96%. However, the mushroom occurrence found prompt decrease at the elevation ranged from 800m to 1100m, accounts for 4% and 0%, respectively. The elevation above 800m a.s.l. can be explained due to unsuitable condition for the growth of mycelium and fruiting body of *Amauroderma* genus. Therefore, the elevation of 200-800m is conformed to the elevation range for mushroom of *Amauroderma* genus growth.

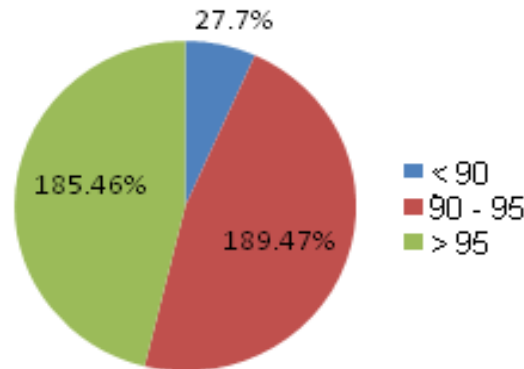
**Table 3:** Distribution of mushroom in *Amauroderma* based on humidity

No.	Scientific names	< 90	90 – 95	> 95	Total
1	<i>Amauroderma niger</i> (Lloyd)		27		27
2	<i>Amauroderma subresinosum</i> Murr.		14	15	29
3	<i>Amauroderma rugosum</i> (Blume &T.Nees) Torrend 1920		16	15	31
4	<i>Amauroderma rude</i> (Berk.)		30	17	47
5	<i>Amauroderma conjunctum</i> (Lloyd.) Torrend 1920			33	33
6	<i>Amauroderma exile</i> (berk) Torr		45	15	60



7	<i>Amauroderma coltricioides</i> T.W. Henkel, Aime & Ryvardeen 2003	44	44
8	<i>Amauroderma</i> sp1		45 45
9	<i>Amauroderma</i> sp2. THP26	13	18 31
10	<i>Amauroderma</i> sp3		27 27
11	<i>Amauroderma</i> sp4	27	27
Total		27	189 185
Number of species		1	7 8

**Percentage (%) of mushroom species in *Amauroderma* following humidity**



Graph 2: Percentage of mushroom species in *Amauroderma* based on the humidity

The results from Table 2 and Graph 2 showed very striking impact on the occurrence of mushroom species in *Amauroderma* genus, specifically in the humidity larger than 90%, there are 374/401 samples, account for 93% number of occurred mushrooms. This is also the most suitable humidity for the growth of mushrooms in *Amauroderma* genus, within the humidity range of 75%-100%. It means that the Central Highlands attaining high humidity where is suitable for the growth of mushroom species in *Amauroderma* genus. In last decades, some reports were shown that the productivity of fruit bodies of the mushroom are mostly involved in average monthly rainfall and temperature [15]. Also, Andrew *et al.* [16] documented the diversity and distribution of 177 macrofungal species which adapted in rainy and dry seasons as well as low and high altitudes. This study is the first report to evaluate the ecological factors which are directly related to the distribution and diversity of *Amauroderma* genus in this country.

**4. Conclusions**

Among 05 variables of ecological factors studies including temperature ( $t^0$ ), humidity (m), elevation (h), and light intensity (l) and occurrence frequency (density), there have been 02 ecological factors having important impact on the occurrence frequency and distribution of mushroom species in *Amauroderma* genus, which is expressed through following equation:  $Frequency\ appears^2 = -167.788 + 3.2837 * doam + sqrt(Height)$ . The elevation ranged from 200 to 800m showed to be the most suitable elevation for the growth and development of *Amauroderma* genus within the studied elevation of 200-1400m a.s.l. The humidity is higher than 90% which shows the best for the growth and development of mushroom species in *Amauroderma* genus. This study has provided very useful information for further conservation and propagation the precious genetic resource.

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