



## **Medicinal Plant, *Anoectochilus*: Distribution, Ecology, Commercial Value and Use in North Vietnam**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Author TVD managed the literature searches, performed the statistical analysis and wrote the first draft of the manuscript. Author PDT performed the statistical analysis. Authors TNB, TTH, TCN, DTHH, NTHA, HTS, THL, PQT, NVK, THQ and VVN designed the study and conducted the field works. All authors read and approved the final manuscript.*

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### **ABSTRACT**

**Background:** *Anoectochilus* orchids have been widely used as medicine. However, it has been overharvested in nature because of high commercial values. This study aims at identifying distribution ranges and ecological characteristics of *Anoectochilus* orchids serving for sustainable development and describing traditional uses by ethnic people in Lai Chau Province, North Vietnam. **Methods:** Twenty-one plots of 100 m<sup>2</sup> each (10 m × 10 m) were established for ecological survey and stand structures were analyzed for vegetation characteristics. While interviewing was applied to gather information on harvesting method, marketing, and medicinal uses. **Results:** Three *Anoectochilus* orchids (*A. lanceolatus*, *A. calcareus*, and *A. setaceus*) were found

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in Lai Chau Province, North Vietnam. These species distribute in both evergreen old-growth and secondary broadleaved forests, and mixed broadleaf-bamboo forest on the elevations of 996–2,134 m. They grow in forests with a high canopy cover of 67 m<sup>2</sup> canopy area/ 100 m<sup>2</sup> land and high cover (> 90% land) of low vegetation (< 2 m tall). It is believed that using the whole plant of *Anoectochilus* can treat hypertension and diabetes mellitus and improve the development of underdeveloped children. The folk uses include soaking in alcohol and boiled water for daily drinks like green tea, and consuming as a vegetable. The best harvesting season is during Autumn–Winter and fresh product is mainly marketed with the price of up to 100 U\$D/1 kg fresh mass.

**Conclusion:** *A. lanceolatus*, *A. calcareus* and *A. setaceus* are potential forest herbs for poverty reduction to ethnic communities in North Vietnam. The natural populations have been reduced remarkably because of overharvesting. Growing techniques are an urgent need for the conservation and sustainable development of such valuable orchids.

**Keywords:** Climate condition; elevation zone; folk medicine; herb; poverty reduction.

## 1. INTRODUCTION

*Anoectochilus* is a genus belonging to the family Orchidaceae. There are about 50 species described in genus *Anoectochilus*. These species are known as terrestrial, perennial, deciduous, sympodial herbs with a creeping rhizome, an upright flowering stem, and dark-colored leaves with contrasting veins [1,2]. The flowers are relatively large, hairy and velvety, and arranged in a short spike. While the fruit is a hairy capsule containing winged seeds [3,4]. The *Anoectochilus* orchids have natural distributions from the Himalaya to South China, Southeast Asia, Australia, New Guinea, Melanesia, and Hawaii [5]. It is found in evergreen forests with high moisture and deep shade [1,2]. For example, *Anoectochilus roxburghii* is found in India, Thailand, China, Laos and Vietnam. Its current status and medicinal uses were studied in Darjeeling Himalaya of West Bengal, India [6], indicating threatened status and value in controlling fever, lung diseases, and hypertension. While indiscriminate collection, deforestation, and extension of agricultural lands are major threats.

Plants of *Anoectochilus* genus are known as medicinal orchids and have various functions in traditional medicines such as anti-tumor, lipase decreasing, anti-diabetes, and antihepatitis [7]. The chemical constituents and biological activities of some *Anoectochilus* herbs were described [8-11] such as helvolic acid from *A. setaceus* for antibacterial activity [12]. The major chemical components in *A. setaceus* include  $\alpha$ -cadinol, (E,E)-farnesol, and terpinen-4-ol [13]. While *A. formosanus* contains  $\beta$ -sitosterol, 4-hydroxycinnamic acid,  $\beta$ -D-glucopyranosyloxy, and butanoidglucosides acid [14]. *A. formosanus* is used to treat many diseases such as chest

pain, stomachache, diabetes, nephritis, high fever, high blood pressure, impotence, liver dysfunction, spleen dysfunction, and chest throbbing pain [15]. *A. setaceus* is used for medicinal oils, treating snakebite poisoning [16,17], and *A. roxburghii* is used to treat tuberculosis [18]. In addition, *Anoectochilus* leaves are used as vegetables by local communities and these plants are also widely used for ornamentalations because of their beautiful leaves and flowers [19].

*Anoectochilus* orchids have been recorded to distribute in high mountainous areas in the Northern provinces of Vietnam [20,21]. It has been widely harvested in nature for commercials and therefore contributed significantly to poverty reduction to ethnic communities. This has led to a remarkable reduction of natural populations. Therefore, understanding the distribution and ecology of *Anoectochilus* orchids could support the development plan and sustainable management for poverty reduction. This work aims at identifying distribution ranges and ecological characteristics of *Anoectochilus* orchids and describing traditional uses by ethnic people in Lai Chau Province, North Vietnam.

## 2. METHODS

### 2.1 Study Site

The study was conducted in Lai Chau Province, North Vietnam (Fig. 1a; Hoang Sa and Truong Sa Islands of Vietnam are not shown on the map). Interviewing responsible persons belonging Provincial Department of Forest Development and local citizens was applied to know the potential forests, where *Anoectochilus* species distribute. The potential areas were first marked on the maps and then assessed in the

fields. Old-growth forest (intact and/or less disturbed forests) and secondary forest (forests recovered after shifting cultivation and/or selective logging) were selected for field data collection.

## 2.2 Data Collection

In the field, main plots of 100 m<sup>2</sup> each (10 m × 10 m) were established for data collection. All stems with a diameter at breast height (DBH) ≥ 5 cm were identified to species, measured for DBH (in cm), height (in meter), and crown diameter (D<sub>c</sub> in meter). In each main plot, five subplots of 4 m<sup>2</sup> each (2 m × 2 m) were established in four corners and the middle for a low vegetation survey. All vegetation < 2 m tall were recorded in these five subplots, including species, height, density and covering (% of land area).

## 2.3 Commercial Value and Medicinal Use

Interviewing was applied. The interviewees included local ethnic people, *Anoectochilus* harvesters, and marketers. Interviewing contents included harvesting, marketing and medicinal uses.

## 2.4 Data Analysis

Characteristics of stand structure were calculated, including stem density, mean DBH, height, basal

area, crown areas, and low vegetation cover. A comparison was conducted by univariate analysis of variance (ANOVA) using SAS 9.2 at  $p = 0.05$ .

## 3. RESULTS

### 3.1 Distribution and Ecology

Three *Anoectochilus* orchids were found in the study site, Lai Chau Province, North Vietnam (Table 1), including *Anoectochilus calcareus*, *A. lanceolatus*, and *A. setaceus* (Fig. 1b). In 21 survey plots, *A. calcareus* was found in five plots in old-growth broadleaved forests, *A. lanceolatus* was found in four plots in the secondary broadleaved forest, and *A. setaceus* was found in 13 plots in both old-growth and secondary forests of broadleaves and mixed broadleaf-bamboo (Fig. 1c). *A. calcareus* and *A. lanceolatus* were grown together in one plot, while in other plots only one species was found. The location with the appearances of these three *Anoectochilus* orchids ranged from 996 m up to 2,134 m elevation above sea level.

All three *Anoectochilus* orchids were found in evergreen forests of pure broadleaved trees and mixed forest of both broadleaves and bamboo. The forests included both old-growth forest (less disturbed forest) and secondary forest, recovered

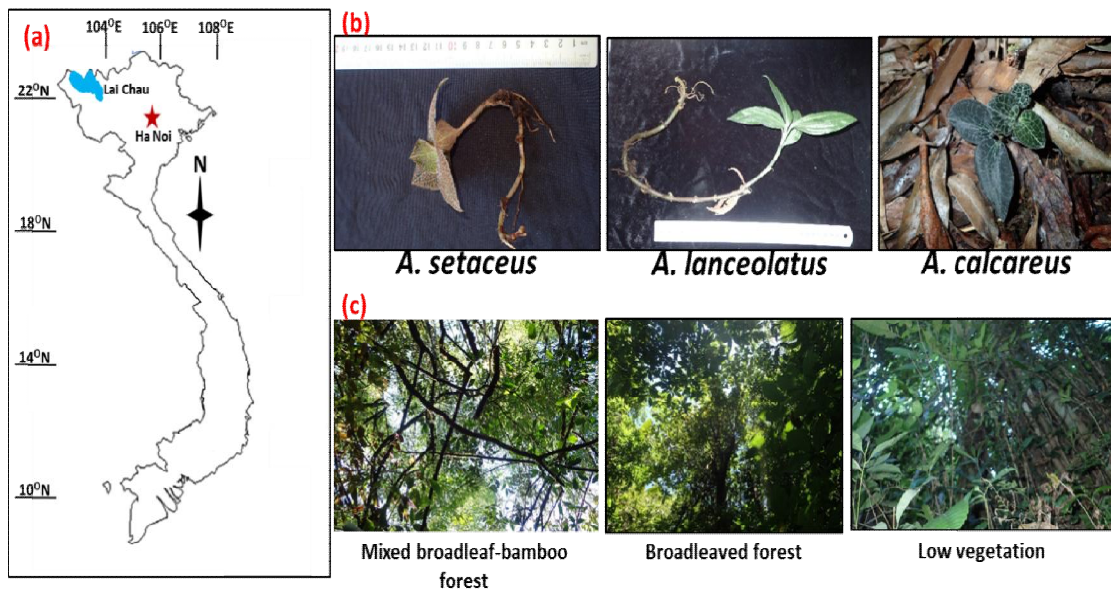


Fig. 1. Map of Vietnam and Lai Chau Province (a), three *Anoectochilus* species in survey areas (b) and forest cover (c)

after shifting cultivation and/or selective logging. The tree stem densities in these study plots ranged 5–12 stems/100 m<sup>2</sup>, while the range of species number was 3–12. The forests had a mean DBH of 11.6–42.7 cm, height of 6.8–18.0 m. While the largest stem had DBH of 74.5 cm and a height of 26 m. The total crown area was in the range of 67.5–343.2 m<sup>2</sup>/100 m<sup>2</sup>. While in low vegetation of shorter than 2 m tall, the number of plant clumps was in the range of 5–43 clumps/20 m<sup>2</sup>, and land covering of low vegetation was in the range of 90–273.3% (Table 1).

There were significant differences of structures (distribution elevation, low vegetation, crown area of canopy trees, mean DBH, and size of largest trees) among stands of three orchids (Table 2). *A. setaceus* prefers to distribute on the lowest elevation of around 1,264 m above sea level, the distribution elevation (1,777 m) is higher in *A. lanceolatus*, and the highest distribution elevation (2,034 m) was found in *A. calcareus*. Low vegetation significantly affected the distribution of three orchids as *A. setaceus* distributes in the highest cover of 195% and numerous vegetation clumps of 35/20 m<sup>2</sup>, reducing to *A. lanceolatus* with a cover of 153% and 29 clumps/20 m<sup>2</sup>. While *A. calcareus* seems to distribute in the lowest vegetation cover of 150% and vegetation clump of 17/20 m<sup>2</sup> (Table 2). In addition, *A. calcareus* grows in the old-growth forest with the highest difference of stem sizes including DBH and height. While *A. lanceolatus* grows in secondary forest with much similar stems sizes.

The differences of stand structures in terms of stem density, height and maximum height among three orchids were not significantly different (Table 2). Which were in the range of 7–8 stems/100 m<sup>2</sup> and canopy height of 9–11 m.

Structure of crown area distribution in different height classes of tree stems was different among stands of three orchids (Fig. 2). *A. lanceolatus* grows in simplest canopy forest, which has only four height classes and less crown area (Fig. 2b) with the highest crown area in the stems of 9–13 m tall. While *A. calcareus* and *A. setaceus* grow in forests with more complex canopy, which has five height classes (Fig. 2a, c). Between these two orchids, there are also differences. The highest crown area focused on stems of 14–21 m tall in *A. calcareus* (Fig. 2a), while that was in stems of > 17 m tall in *A. setaceus*, which is double that in stems of < 17 m tall (Fig. 2c).

### 3.2 Commercial Value and Medicinal Use

The price of *Anoectochilus* orchids is depending on species. *A. lanceolatus* costs 0.5 USD/1 kg fresh mass, it is 50 USD/1 kg fresh mass for *A. calcareus* and 100 USD/1 kg fresh mass for *A. setaceus*. Generally, after harvesting from natural forests the fresh product is sold at homes or local markets to outside consumers, who will resell to trading companies of China mostly. The best harvesting season is during Autumn-Winter when *Anoectochilus* has the highest production and quality by traditional knowledge. It was recorded that the availability of *Anoectochilus* in natural forests 10 years ago was numerous

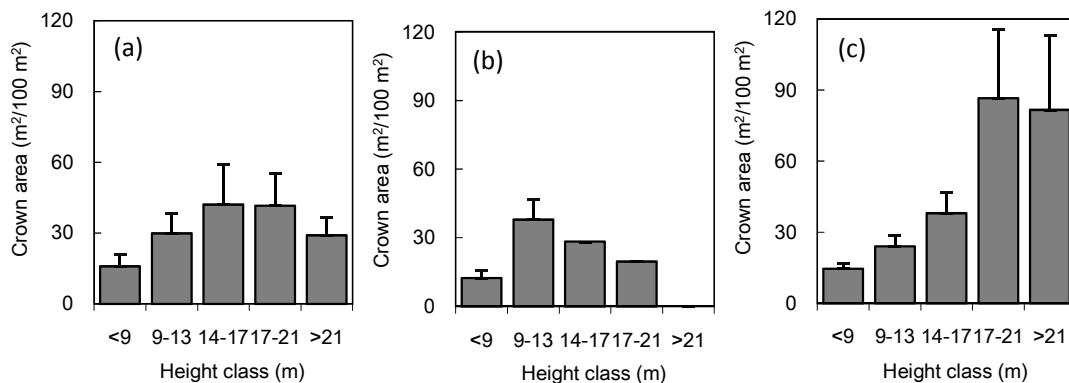


Fig. 2. Vertical crown structure for *A. calcareus* stand (a), *A. lanceolatus* stand (b) and *A. setaceus* stand (c). Vertical bars indicate +SE

Table 1. General characteristics of 21 survey plots

Plot	ELV (m)	Canopy layer (per 100 m <sup>2</sup> plot; ±SE)								Low vegetation (per 20 m <sup>2</sup> )		<i>Anoectochilus</i> orchids
		Stems	Species	DBH (cm)	DBH <sub>max</sub> (cm)	H (m)	H <sub>max</sub> (m)	Basal area (m <sup>2</sup> )	Crown area (m <sup>2</sup> )	Clumps	Cover (%)	
1	1,930	10	6	15.5 ±3.2	43.6	8.4 ±0.6	11.0	0.263	139.0	27	156.2	<i>Anoectochilus calcareus</i>
2	2,057	5	4	18.8 ±5.1	29.6	8.9 ±1.7	13.0	0.179	107.0	24	237.8	<i>Anoectochilus calcareus</i>
3	2,123	7	6	25.6 ±6.8	58.3	14.0 ±2.4	24.0	0.513	146.1	5	100.0	<i>Anoectochilus calcareus</i>
4	2,134	6	6	42.7 ±8.7	74.5	18.0 ±1.7	24.0	1.038	175.9	15	141.5	<i>Anoectochilus calcareus</i>
5	1,930	9	8	17.2 ±2.5	27.7	9.7 ±0.7	12.0	0.243	168.9	14	119.0	<i>A. calcareus</i> and <i>A. lanceolatus</i>
6	1,906	5	4	15.5 ±2.0	20.4	8.8 ±1.0	12.0	0.100	67.5	23	99.9	<i>Anoectochilus lanceolatus</i>
7	1,894	7	4	13.4 ±2.3	23.2	8.1 ±1.2	14.0	0.116	97.4	19	131.7	<i>Anoectochilus lanceolatus</i>
8	1,915	8	8	16.2 ±2.2	26.9	10.9 ±1.0	17.0	0.185	134.5	27	198.9	<i>Anoectochilus lanceolatus</i>
9	1,395	12	10	11.6 ±1.3	23.6	8.7 ±0.8	14.0	0.143	134.3	51	184.6	<i>Anoectochilus setaceus</i>
10	1,434	12	9	14.3 ±1.5	24.8	9.3 ±0.7	13.0	0.216	106.8	26	244.0	<i>Anoectochilus setaceus</i>
11	1,009	7	3	19.9 ±2.3	26.1	12.6 ±0.6	14.0	0.234	166.5	38	174.4	<i>Anoectochilus setaceus</i>
12	996	6	5	14.4 ±3.5	26.4	9.8 ±1.6	15.0	0.127	106.0	30	272.5	<i>Anoectochilus setaceus</i>
13	1,010	6	6	18.5 ±3.6	29.0	10.3 ±1.3	14.0	0.191	81.7	37	136.1	<i>Anoectochilus setaceus</i>
14	1,192	8	4	16.6 ±2.4	24.5	9.8 ±0.9	13.0	0.200	125.7	35	209.5	<i>Anoectochilus setaceus</i>
15	1,220	8	6	18.7 ±4.7	39.5	11.2 ±1.8	19.0	0.318	168.1	39	273.3	<i>Anoectochilus setaceus</i>
16	1,208	7	7	14.4 ±3.3	30.9	9.9 ±1.4	16.0	0.149	84.0	35	222.1	<i>Anoectochilus setaceus</i>
17	1,229	9	8	17.0 ±2.8	29.9	11.1 ±1.3	17.0	0.248	118.6	38	219.8	<i>Anoectochilus setaceus</i>
18	1,472	7	7	13.4 ±3.0	24.8	6.8 ±0.6	8.5	0.128	48.7	38	90.0	<i>Anoectochilus setaceus</i>
19	1,472	8	7	11.6 ±1.2	16.2	8.4 ±0.8	12.0	0.090	74.6	35	138.5	<i>Anoectochilus setaceus</i>
20	1,459	7	6	10.1 ±0.9	12.7	8.3 ±0.9	11.0	0.059	63.6	32	126.1	<i>Anoectochilus setaceus</i>
21	1,473	7	7	35.2 ±7.0	65.9	17.0 ±2.1	26.0	0.842	343.2	43	236.7	<i>Anoectochilus setaceus</i>

ELV is elevation above sea level

Table 2. Comparisons of stand structures (±SE) among three *Anoectochilus* orchids

Canopy layer (per 100 m <sup>2</sup> plot)						Low vegetation (per 20 m <sup>2</sup> )		ELV (m)	<i>Anoectochilus</i> orchids
Stems	DBH (cm)	DBH <sub>max</sub> (cm)	H (m)	H <sub>max</sub> (m)	Crown area (m <sup>2</sup> )	Clump	Cover (%)		
7.4 ±0.9	23.9 <sup>a</sup> ±5.0	46.7 <sup>a</sup> ±8.9	11.8 ±1.8	16.8 ±3.0	147.4 <sup>a</sup> ±12.2	17.0 <sup>a</sup> ±3.9	150.9 <sup>a</sup> ±23.7	2,034 <sup>a</sup> ±44.8	<i>A. calcareus</i>
8.0 ±1.5	14.2 <sup>b</sup> ±1.0	23.5 <sup>b</sup> ±1.3	9.1 ±0.6	14.2 ±1.0	108.4 <sup>b</sup> ±16.2	29.9 <sup>ab</sup> ±7.2	153.7 <sup>a</sup> ±23.1	1,777 <sup>b</sup> ±127.6	<i>A. lanceolatus</i>
7.6 ±0.5	17.0 <sup>c</sup> ±1.9	29.2 <sup>c</sup> ±3.9	10.3 ±0.7	14.8 ±1.3	123.9 <sup>ab</sup> ±22.6	35.5 <sup>b</sup> ±1.3	195.2 <sup>b</sup> ±17.6	1,264 <sup>c</sup> ±55.7	<i>A. setaceus</i>

Different letters <sup>a, b, c</sup> in a column indicate significant difference of means at p = 0.05. ELV is the elevation above sea level

which can be easily found at any old-growth forest. Recently, it is difficult to find out *Anoectochilus* even in remote old-growth forests. A person takes one day to harvest 0.2 kg fresh mass of *Anoectochilus* nowadays, compared to several kilograms in the past ten years. Around 80% harvest product is marketed and the rest is used by local people.

In the study site, the whole plant of *Anoectochilus* is used to treat hypertension and diabetes mellitus. Underdeveloped children can use this to improve appetite and support digestion. Folk uses include soaking in alcohol for daily drinks and soaking in boiled water like green tea, or consuming as vegetables.

## 4. DISCUSSION

### 4.1 Distribution and Ecology

*Anoectochilus* species are terrestrial plants, growing in soil, leaf litter, humus, and also on mossy rocks in lowland and mid-mountain forests up to 2,135 m elevation [6,22]. Like other forest herbs [23,24], *Anoectochilus* is shade-tolerant plants (Fig. 1 b, c), which can only survive and grow under shade. The shading level is different among *Anoectochilus* species [25]. This was confirmed in the present study as the differences of stand structures among three *Anoectochilus* species, especially in terms of low vegetation and crown area (Table 2; Fig. 2). In addition, in 20 of 21 plots surveyed only single *Anoectochilus* orchid was found in a plot. This indicated the difference in ecology requirements among three orchids. Therefore, it is difficult for these orchids to grow in the same vegetation. The many differences of vertical crown structures among three orchids (Fig. 2) indicate the difference of light regime penetrating to the forest floor, which plays an important role in survival and growth of forest herbs.

*Anoectochilus lanceolatus* Lindl is found in the Himalayas, Nepal, Bangladesh, Myanmar, Taiwan, Thailand, and Vietnam [5]. It grows on shaded rocks in deep shade broadleaved forests on elevations of 800–2,200 m [26]. In the present study, the species was found in North Vietnam (22°07'43.3"N and 103°54'44.2"E) on the elevation of 1,894–1,915 m close to streams with high humidity. The species was found in both secondary and old-growth evergreen broadleaved forest. It grows in deep shade evergreen broadleaved forest but even can grow in secondary forest with some levels of human

disturbance, while still keeps suitable canopy cover. The plants were only found near water bodies, growing on soil with a high humus layer and high humidity, indicating the importance of humidity on the distribution and growth of *A. lanceolatus*.

*Anoectochilus calcareus* Aver is native species of Vietnam and found in evergreen coniferous and broadleaved forests on rocky limestone in northern Vietnam on the elevations of 450–1,600 m [27]. In the present study, the species was found in North Vietnam (22°08'20.1"N and 103°54'34.3"E) on the elevation of 1,930–2,134 m in the old-growth evergreen broadleaved forest. The elevation range is higher than previously reported, indicating a wider distribution range of *A. calcareus*. In addition, it was found growing on soil other than rocky limestone previously reported [27]. This again indicates the wider ecological conditions for distribution and growth of *A. calcareus*, and therefore it could be found to have natural distributions further to southern Vietnam.

*Anoectochilus setaceus* Blume is found in China, India, Bangladesh, Nepal, Himalayas, Sri Lanka, Myanmar, Thailand, Vietnam and Indonesia. The species grows in evergreen broadleaved forests on the elevations of 1,200–1,800 m [28,29]. In the present study, it was found in North Vietnam (22°44'35.4"N and 103°24'56.7"E) on the elevation of 996–1,473 m in both old-growth and secondary evergreen broadleaved forests and mixed broadleaf-bamboo forest in all foot, middle and top of the mountains. The lower elevation distribution found in the present study indicates the wider distribution of *A. setaceus*. In addition, it can grow in several types of vegetation which have high shading levels and in all mountain positions. Therefore, ecological conditions for *A. setaceus* are quite wide. But the most important condition is the vegetation cover. It should be high enough to ensure shading for this orchid (Table 2; Fig. 2c).

The natural populations of *Anoectochilus* are under threat from overharvest, habitat reduction, and forest fragmentation [6,7,19,30]. Therefore, in each region and country where such plants are now available [6], preservation plan should be established for successful protection and future development. The commercial price of these three *Anoectochilus* orchids is much different. This is believed to relate to the medicinal values of compounds in each species. Therefore, further studies on medicinal compounds must be

conducted for further recommendations on conservation, usage and development.

#### 4.2 Commercial Value and Medicinal Use

*Anoectochilus* species have been widely used as folk medicine in China, Sri Lanka, Taiwan, and Vietnam for centuries [22,31,32]. It is used to treat cancer, hypertension, diabetes mellitus, lung and liver diseases, nephritis, impotence, spleen disorder, pleurodynia, and underdeveloped children [33-35]. Therefore, currently, it has been widely used in modern medicines. For example, quercetin-7-O- $\beta$ -D-[6"-O-(trans-feruloyl)]-glucopyranoside compound isolated from an extract of *A. roxburghii* exhibits strong scavenging activity against the 1,1-diphenyl-2-picrylhydrazyl free radical [36]. *Anoectochilus* orchids could be considered as potential plants for both folk and modern medicines recently and in the future.

With a high price of up to 100 USD/1 kg fresh mass of *A. setaceus* in Vietnam recently, it is a potential forest herb for poverty reduction. As the local community in mountainous areas is living in a much lower standard compared to other parts of Vietnam. However, growing *Anoectochilus* is not easy work and the plants grow quite slow. Growing *Anoectochilus* orchids in local communities for production purposes is not available other than for ornamentation. Therefore, researching for simple and applicable growing techniques for *Anoectochilus* orchids should be conducted and the best one must be recommended for practical application.

#### 5. CONCLUSION

*Anoectochilus lanceolatus*, *A. calcareus*, and *A. setaceus* are three orchids found in Lai Chau Province, North Vietnam. These species distribute in evergreen old-growth and secondary broadleaved forests, and mixed broadleaf-bamboo forest on the elevations of 996–2,134 m above sea level. These orchids are used locally by soaking in alcohol and boiled water for daily drinks like green tea, and consuming as vegetables. This is believed to have positive impacts on hypertension, diabetes mellitus and underdeveloped children. Such high medical values have led to remarkably reduced populations of *Anoectochilus* orchids in nature. Therefore, researches on growing, harvesting, and processing are an urgent need, which can contribute to preserving and developing

*Anoectochilus* orchids in North Vietnam sustainably.

#### CONSENT

It is not applicable.

#### ETHICAL APPROVAL

It is not applicable.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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