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Medicinal Orchids of Nepal: Are They Well Protected?

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Abstract
This paper aims to explore distribution pattern of orchids used for medicinal purpose and their conservation aspect. We compiled information on 82 species of orchids which are used as herbal medicine. Maximum richness of medicinal orchids was observed at an elevation of 1700 msl but, the maximum numbers of protected areas are located at an elevation of 3000 to 3500 msl. There is a negative correlation between number of protected areas and medicinal orchid species richness mentioning that the protected areas are less synchronized with medicinal orchids of Nepal.

***Key words*:** Elevation gradient, Generalized Additive Models, medicinal orchid, species richness

Introduction
The orchid family is regarded as one of the largest, most diverse and distinctive families in the flowering plant kingdom with estimates of about 20,000 to 35,000 species in the world (Dressler, 1993). They are found in wide array of ecological conditions, except in marine environments and habitats with extreme cold throughout the year. Environmental conditions associated with altitude exert a large influence on orchid species composition and their distribution (Jacquemyn *et al*., 2005). The plants are terrestrial, epiphytic, lithophytic and saprophytic in habitat.

In Nepal, nearly 388 orchid's species within 99 genera are reported (Acharya, 2008). Orchids are well known not only for their ornamental value, but also for their uses in herbal medicine (Sumner, 2000). The use of orchids as medicine has a very long history and the Chinese were the first to use them as herbal medicine (Bulpitt, 2005). The presence of phytochemicals such as alkaloids, flavonoids, glycosides have made orchids valuable as medicine (Pengelly, 2004).

In Nepal, studies on orchids are mainly focused on their documentation (Shakya and Chaudhary, 1999; Bajracharya *et al*., 2003; Subedi, 2003; Rajbhandari and Dahal, 2004; Shakya and Shrestha, 2007; Shrestha *et al*., 2007) and on its medicinal uses (Shreshta, 2000; Vaidya *et al*., 2000) but there is lack of quantitative study on their distribution pattern. It is necessary to know distribution patterns along the elevational gradients, because information on altitudinal species richness patterns can be highly instrumental for proper management and conservation of species (Grytnes, 2003). Orchid species are facing the greatest threat due to human encroachment, habitat loss, forest destruction and degradation (Rajbhandari *et al*., 2000; Winkel, 2006). So, we have made an attempt to reveal the distribution pattern of medicinal orchids from Nepal. Specifically, we have tried to answer following questions: (a) what is the distribution pattern of medicinal orchid species along an elevational gradient in Nepal? and (b) are these orchids well conserved in existing protected areas?

Materials and methods

Study area

Nepal (26°22′-30°27′N and 80°40′-88°12′E), in central Himalaya consists of five east-west running ranges: Terai, Siwaliks, Mahabharat, High mountains and High Himalaya (LRMP, 1986). Within this short distance, the elevation ranges from about 60 to 8848 m (highest peak of the world) and comprises tropical to alpine climatic zones.

Nepal has a wide range of climatic conditions. However, the climatic conditions can be broadly divided into two types: dry winter period and wet summer period. The climatic condition is dominated by precipitation of the summer monsoon starting from south, Bay of Bengal. The amount and distribution of precipitation, the duration and altitudes of cloudiness varies considerably in different parts. The amount of rainfall gradually decreases from east to west, but increases from the plain to certain elevations between 800 to 2000 msl to the north and then again decreases.

Data source and interpolation

We collected information on elevational ranges of orchids used for medicinal purposes from various literatures (Jha *et al*., 1996; Rajbhandari *et al*., 2000; Sharma, 2000; Shrestha, 2000; Vaidya *et al*., 2000; Lama *et al*., 2001; Rajbhandari, 2001; Manandhar, 2002; Rokaya, 2002; Subedi, 2003; IUCN, 2004; Baral and Khurmi; 2006; DPR, 2007). The medicinal orchids are distributed from 100 to 4800 msl. So, to examine the relationship between species richness and elevation, the total elevation gradients between 100 m and 4800 m were divided into 48 bands of 100 m elevation each. The number of species present in each elevation band was estimated by the interpolation. A species was defined as being present in every 100 m interval between its upper and lower elevation limits. For example, *Dactylorhiza hatagirea* with its elevation limit between 2800 m and 4000 m was assumed to be present in each elevation band of 2800, 2900, 3000, 3100, 3200, and so on upto 4000 m (Acharya *et al*., 2009). We used the term species richness for the total number of medicinal orchid species present in each 100 m elevation. To find the number of protected areas (national parks, wildlife reserves, conservation areas, and hunting reserves) occurring in each 100 m elevation band, the altitudinal range of each protected areas was taken from GoN/MFSC (2009).

Statistical analysis

We used Generalized Additive Models (GAMs) (Hastie and Tibshirani, 1990) with up to four degrees of freedom to explore the pattern of species richness with elevation. We used elevation as an explanatory variable and species richness and number of protected areas as a response variable. Species richness data were considered to follow a Poisson distribution as it is count (discrete) data (Crawley, 2005) which requires a logarithmic link. However, because of overdispersion, a quasi-Poisson model was used (Crawley, 2005) with a logarithmic link. We used an f-test to check the significance of models because this is more robust when there is overdispersion (Crawley, 2005). We used $R_{2.8.1}$ (R Development Core Team, 2008) for the regression analysis and graphical representations.

Results and discussion

Life forms and distribution of medicinal orchids in Nepal

In total 82 species belonging to 40 genera of orchid species are used for medicinal purposes in Nepal. Out of which, 33 are terrestrial (40%), 43 are epiphytes (53%) and six are of mixed habitat (7%) (Fig. 1, Append. I). Center Nepal harbours highest number of species (69 species i.e., 43%) followed by east Nepal (58 species i.e., 36%) and west Nepal (33 species i.e., 21%) (Fig. 2). Among them, six species are recorded only from east Nepal, eight species only from center Nepal and three species only form west Nepal and rest of the species are recorded from wider distributional ranges. Maximum richness of total medicinal orchid species richness is observed at an elevation of 1700 msl (Fig. 3a).

We found hump-shaped patterns of medicinal orchid species richness along the elevation gradient in Nepal Himalaya. This study supports the findings made by Malla and Shakya (1999) that maximum numbers of medicinal plants are found within the elevation of 1000-2000 msl. However, it differs from the findings made by Acharya *et al*. (2009) that maximum richness of medicinal plants are found at an elevation of

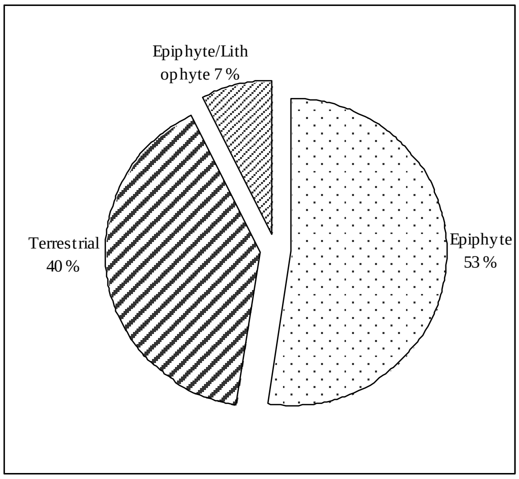

Figure 1. Different life forms of medicinal orchids of Nepal.

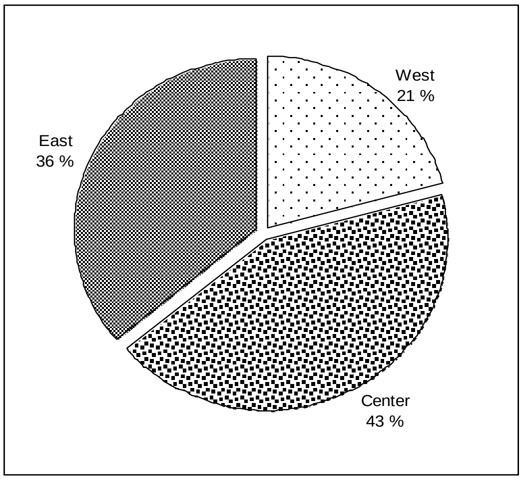

Figure 2. Distribution of medicinal orchids in east, center and west Nepal.

1100 msl. More than thirty different hypotheses have been proposed as possible explanations to explain these patterns. However, climatic variables possibly could explain the best for the patterns of distribution of medicinal orchids in elevational gradient of Nepal. Because maximum richness of species occurs at the locations with maximum rainfall and optimum energy conditions are available (Odland and Birks, 1999). The maximum richness of medicinal orchids at an elevation of 1700 msl might be due to the optimum water energy dynamics (Bhattarai and Vetaas, 2003). West Nepal is the driest part of Nepal and the water-energy dynamics model explained by O'Brien (1998) could also explain about species richness of orchid being highest in centre or east than in west Nepal. More over, central Nepal is the overlap of eastern and western floral elements in central Nepal and thus there are more species in the centre than other regions of Nepal.

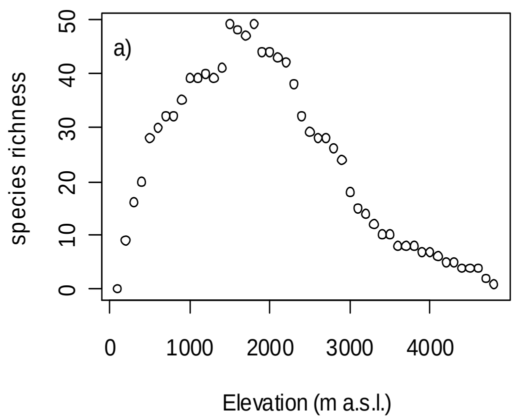

Figure 3a. Distribution of medicinal orchid species with elevation in Nepal.

Mid elevation peak in species richness may be the result of large scale mass effect (Shmida and Wilson, 1985). Mid elevation receives inputs from both the lower elevations and higher elevations. So, mass effect or source sink dynamics may be important to influence variation in species richness within an elevation gradient.

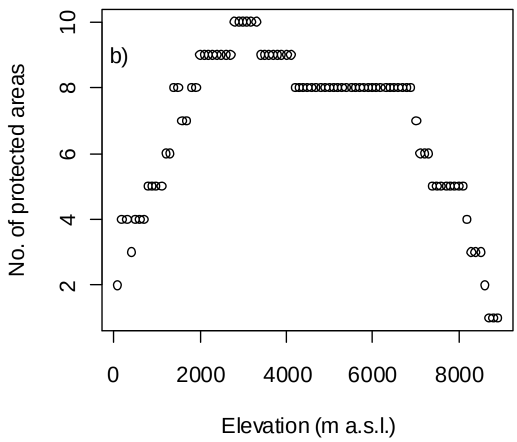

Figure 3b. Distribution of number of protected areas with elevation in Nepal.

Medicinal orchid vs protected areas

There are nine national parks, three wildlife reserves, one hunting reserve and three conservation areas and nine buffer zones covering 19.7% land of Nepal (GoN/MFSC, 2009). These protected areas are distributed from 75 to 8848 msl. Maximum number of protected areas is found at about 3000 to 3500 msl. The number of protected areas increases up to 3000 m and then gradually decreases after 3500 msl. There is a negative correlation between total number of medicinal orchids and number of protected areas (r = - 0.216) (Fig. 4).

Large numbers of medicinal plants and orchids in wild are depleting due to mismanagement in the collection and/or unsustainable harvesting procedures that has been leading plants towards extinction from natural habitat. For example, one endemic species *Pleione coronaria* known from

Ganesh Himal, Center Nepal, is highly threatened due to local deforestation (Winkel, 2006) and also medicinal orchids are generally uprooted as tubers are of medicinal value than other parts of plants. Tree felling for timber is causing significant mechanical damage to the biodiversity, especially the epiphytic orchids (Chaudhary, 2000). To protect from loss of species from

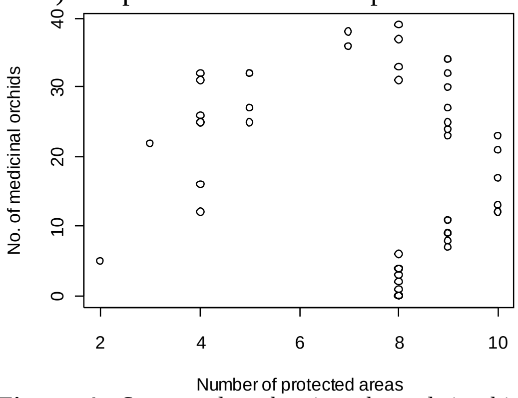

Figure 4. Scatter plot showing the relationship between number of medicinal orchids and number of protected areas of Nepal.

natural habitat, Government of Nepal has banned on collection of some species and their transportation. More over, as Nepal is the member country of CITES, The Convention on International Trade in Endangered species of Wild Fauna and Flora, since 1973 there is restriction in the collection and trade of all species of orchid under CITES Appendix II (Chaudhary, 1998). However, this type of ban and protection is not effective in the conservation of species as well as cannot reduce the volume of collection due to the fact that large part of the country is remote, people are illiterate and there is lack of specific understanding of government rules and regulations. There is also the report of some orchid species being sold even in open markets of Kathmandu (Acharya and Rokaya, 2005) which obviously shows that there is depletion of orchid population in the forest due the trade.

Protected areas can play a major role in protection of biodiversity because within these areas there is a restriction of collection of these species (Sharma *et al*., 2004). In the case of medicinal orchid species, there is negative correlation between number of protected areas and number of medicinal orchid species (Fig. 4). Maximum numbers of protected areas are found at about 3000 to 3500 msl. But, diversity of maximum number of medicinal orchids is found below this elevational range. This shows that our conservation efforts are less focused towards orchids. Protected areas are located at higher elevations where diversity of plants is less (Hunter and Yunzon, 1993). Along with this, there is no complete checklist of orchids distributed in each protected areas. Recently Government of Nepal made an official notice that orchids can be collected and sold. However, there needs the resource inventory form district forest office and should be approved by department of forest. According to this, all orchids (endemic, threatened, endangered and commonly available) are placed under same common name "*Jiwanti*" (locally known as "sungava") and there is no specialist to identify these orchids (*per. com.* with officer at department of forest). If the species is distributed across a large number of middle hill districts, collection and trade of these species is too high from lowland districts or Terai districts (Olsen, 2005). If this situation of collection continues, then large number of medicinal orchids will be threatened from low belts where the diversity is high. Another reason of higher collection from low belts is these areas are easily accessible and are densely populated by human beings.

In order to have sustainable management of orchids, Government of Nepal has given priority on domestication, research and cultivation of species. Some private nurseries are propagating large number of orchid species for sell. If these activities are run in different parts of rural areas, it will help to raise the economic status of poor. One of the successful community conservation programs, the community forest program, can help to produce wide range useful medicinal plants and orchids as projects under this program are at grass root level.

Conclusion

Nepal is rich in medicinal orchids which are generally terrestrial or epiphytic in habitat. There is an uneven distribution of medicinal orchids in horizontal or vertical manner of distribution. The highest numbers of orchids are found in central part of Nepal in horizontal manner whereas vertically maximum richness of medicinal orchid species is observed at an elevation of 1700 msl. As there is a threat to orchid populations due to human caused activities and also there is a vague knowledge about the available populations of orchids, it is necessary to carry out extensive field research to prioritize the conservation needs of such sites in the future. Further, in order to protect medicinal orchid diversity, it is necessary to establish protected areas and also synchronize between protected areas and orchid rich areas in Nepal.

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Appendix I

S.N.	Accepted name of a species	Altitudinal distribution (m)	Medicinal use Source/s
1	*Acampe praemorsa* (Roxb.) Blatt. & McCann	200-1200	Vaidya *et al*. (2000)
2	*Aerides multiflora* Roxb.	200-1100	Vaidya *et al*. (2000)
3	*Aerides odotata* Lour.	200-1200	Shrestha (2000), Vaidya *et al*. (2000)
4	*Anoectochilus setaceus* Blume	1000-1500	Vaidya *et al*. (2000)
5	*Arundina graminifolia* (D.Don) Hochr	400-2300	Vaidya *et al*. (2000)
6	*Brachycorythis obcordata* (Lindl.) Sunnerh.	1000-2638	Jha *et al*. (1996), Shrestha (2000), Vaidya *et al*. (2000), Rajbhandari (2001), Manandhar (2002), IUCN (2004), DPR (2007)
7	*Bulbophyllum careyanum* (Hook.) Sprengel	600-2100	Subedi (2003)
8	*Bulbophyllum leopardinum* (Wall.) Wall. Ex lindl.	1500-3200	Subedi (2003)
9	*Bulbophyllum umbellatum* Lindl.	300-1800	Shrestha (2000)
10	*Calanthe griffithii* Lindl.	2200-2300	Subedi (2003)
11	*Calanthe plantaginea* Lindl.	1500-2200	Subedi (2003)
12	*Calanthe sylvatica* (Thouars) Lindl.	1500-2800	Vaidya *et al*. (2000), Manandhar (2002)
13	*Coelogyne corymbosa* Lindl.	1500-2900	Shrestha (2000), Vaidya *et al*. (2000), Manandhar (2002)
14	*Coelogyne cristata* Lindl.	675-2450	Vaidya *et al*. (2000), Manandhar (2002), DPR (2007)
15	*Coelogyne flaccida* Lindl.	900-1100	Manandhar (2002)
16	*Coelogyne fuscescens* Lindl.	1200-1830	Vaidya *et al*. (2000)
17	*Coelogyne nitida* (Wall. ex. D. Don) Lindl.	1300-2400	Manandhar (2002)
18	*Coelogyne ovalis* Lindl.	500-2700	Shrestha (2000)
19	*Coelogyne prolifera* Lindl.	1000-2300	Rajbhandari *et al*. (2000), Shrestha (2000), Vaidya *et al*. (2000), Manandhar (2002), Subedi (2003)

20	*Coelogyne stricta* (D. Don) Schltr.	14002135	Rajbhandari *et al*. (2000), Shrestha (2000), Vaidya *et al*. (2000)
21	*Conchidium muscicola*(Lindl.) Rauschert	1500-1800	Shrestha (2000)
22	*Cymbidium alofolium* (L.) Sw.	300-1600	Rajbhandari *et al*. (2000), Shrestha (2000), Vaidya *et al*. (2000), Manandhar (2002)
23	*Cymbidium devonianum* Paxton	1500-1800	Manandhar (2002)
24	*Cymbidium iridioides* D.Don	1500-2800	Vaidya *et al*. (2000)
25	*Cymbidium longifolium* D.Don	1500-3000	Vaidya *et al*. (2000), Baral & Khurmi (2006)
26	*Cypripedium cordigerum* D.Don	2800-3800	Manandhar (2002)
27	*Cypripedium elegans* Rchb.f.	2500-4200	Vaidya *et al*. (2000)
28	*Cypripedium himalaicum* Rolfe	3000-4800	Lama *et al*. (2001), Manandhar (2002)
29	*Dactylorhiza hatagirea* (D.Don) Soó	2800-3960	Shrestha (2000), Vaidya *et al*. (2000), Lama *et al*. (2001), Rajbhandari (2001), Manandhar (2002), IUCN (2004)
30	*Dendrobium amoenum* Wall. ex Lindl.	1100-2900	Vaidya *et al*. (2000)
31	*Dendrobium crepidatum* Lindl. & Paxton	1200-2400	Subedi (2003)
32	*Dendrobium densiflorum* Lindl.	900-2900	Manandhar (2002)
33	*Dendrobium fimbriatum* Hook.	200-2135	Vaidya *et al*. (2000)
34	*Dendrobium longicornu* Lindl.	1300-2900	Manandhar (1995), Manandhar (2002)
35	*Dendrobium monticola* P.F.Hunt & Summerh.	1525-2700	Shrestha (2000), Vaidya *et al*. (2000)
36	*Dendrobium moschatum* (Buch.-Ham.) Sw.	200-1200	Subedi (2003)
37	*Dendrobium nobile* Lindl.	400-1500	Shrestha (2000), Vaidya *et al*. (2000)
38	*Dendrobium transparens* Wall. ex Lindl.	700-2000	Subedi (2003)
39	*Ephemerantha macraei* (Lindl.) P.F. Hunt & Summerh.	500-2400	Jha *et al*. (1996), Vaidya *et al*. (2000), IUCN (2004), DPR (2007)
40	*Epipactis gigantea* Douglas ex Hook	2900-3200	Vaidya *et al*. (2000)
41	*Epipactis helleborine* (L.) Crantz	1500-3300	Shrestha (2000), Vaidya *et al*. (2000), Rokaya (2002)
42	*Epipactis royleana* Lindl.	1400-3400	Manandhar (2002)
43	*Eria spicata* (D.Don) Hand.-Mazz.	900-2200	Vaidya *et al*. (2000)
44	*Eulophia comestrs* Wall.	300	Shrestha (2000)
45	*Eulophia dabia* (D.Don) Hochr.	400-2000	Shrestha (2000), Vaidya *et al*. (2000), DPR (2007)
46	*Eulophia spectabilis* (Dennst.) Suresh	400-1800	Rajbhandari *et al*. (2000), Shrestha (2000), Vaidya *et al*. (2000)
47	*Flickingeria fimbriata* (Blume) A.D.Hawkes		Sharma (2000)
48	*Flickingeria macraei* (Lindl.) Seidenf.		Rajbhandari *et al*. (2000), Shrestha (2000), Vaidya *et al*. (2000)
49	*Gymnadenia conopsea* (L.) R. Br.	4300	Rokaya (2002)
50	*Gymnadenia orchidis* Lindl.	1352-4700	Manandhar (1995), Vaidya *et al*. (2000), Manandhar (2002), Rokaya (2002)
51	*Habenaria commelinifolia* (Roxb.) Wall. ex Lindl.	300-1200	Vaidya *et al*. (2000)
52	*Habenaria furcifera* Lindl.	150-800	Manandhar (2002)
53	*Habenaria intermedia* D.Don	1800-3300	Shrestha (2000), Manandhar (2002)
54	*Liparis nervosa* (Thunb.) Lindl.	1200-2800	Shrestha (2000)
55	*Liparis rostrata* Rchb.f.	2000-3000	Vaidya *et al*. (2000)
56	*Luisia trichorrhiza* (Hook.) Blume	1000-1400	Vaidya *et al*. (2000)
57	*Luisia tristis* (G.Forst.) Hook.f.	300-2300	Rajbhandari *et al*. (2000), Shrestha (2000), Vaidya *et al*. (2000), Manandhar (2002)
58	*Malaxis acuminata* D.Don	450-3050	Shrestha (2000), Vaidya *et al*. (2000), DPR (2007)

59	*Malaxis cylindrostachya* (Lindl.) Kuntze	2100-3500	Manandhar (2002)
60	*Malaxis muscifera* (Lindl.) Kuntze	2000-4100	DPR (2007)
61	*Nervilia aragoana* Gaudich.	500-1300	Vaidya *et al.* (2000), DPR (2007)
62	*Oberonia caulescens* Lindl.	1300-2400	Vaidya *et al.* (2000)
63	*Orchis latifolia* Linn.*		Sharma (2000)
64	*Otochilus porrectus* Lindl.	900-2300	IUCN (2004)
65	*Papilionanthe teres* (Roxb.) Schltr.	200-2100	Manandhar (2002)
66	*Pholidota articulata* Lindl.	570-2285	Vaidya *et al.* (2000), Manandhar (2002)
67	*Pholidota imbricata* Lindl.	600-2900	Rajbhandari *et al.* (2000), Shrestha (2000), Vaidya *et al.* (2000), Manandhar (2002)
68	*Platanthera sikkimensis* (Hook.f.) Kraenzl.	2600-2900	Shrestha (2000), Vaidya *et al.* (2000)
69	*Pleione humilis* (Sm.) D.Don	1800-3000	Manandhar (2002)
70	*Pleione maculata* (Lindl.) Lindl. & Paxton	1400-2700	Shrestha (2000), Vaidya *et al.* (2000)
71	*Pleione praecox* (Sm.) D.Don	1500-2500	Rajbhandari (2001), Manandhar (2002)
72	*Ponerorchis chusua* (D.Don) Soó	2400-4900	Rokaya (2002)
73	*Rhynchostylis retusa* (L.) Blume	300-1850	Shrestha (2000), Vaidya *et al.* (2000), Manandhar (2002), DPR (2007)
74	*Satyrium nepalense* D.Don	600-4600	Shrestha (2000), Vaidya *et al.* (2000)
75	*Smitinandia micrantha* (Lindl.) Holttum	500-1400	Vaidya *et al.* (2000), Rajbhandari (2001), Manandhar (2002)
76	*Spiranthes sinensis* (Pers.) Ames	150-4600	Shrestha (2000), Vaidya *et al.* (2000) Rokaya (2002)
77	*Thunia alba* (Lindl.) Rchb.f.	500-1800	Manandhar (2002)
78	*Trudelia praviflora**	350-915	Vaidya *et al.* (2000)
79	*Vanda cristata* Wall. ex Lindl.	620-2300	Vaidya *et al.* (2000), Rajbhandari (2001), Manandhar (2002)
80	*Vanda tessellata* (Roxb.) Hook. ex G.Don	200-600	Rajbhandari *et al.* (2000), Shrestha (2000), Vaidya *et al.* (2000)
81	*Vanda testacea* (Lindl.) Rchb.f.	460	Vaidya *et al.* (2000)
82	*Zeuxine strateumatica* (L.) Schltr.	230-1220	Shrestha (2000), Vaidya *et al.* (2000)