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Population status, habitat composition and threats of *Paphiopedilum fairrieanum* (Lindl.) Stein (Orchidaceae: Cypripedioideae) in Jigme Singye Wangchuck National Park

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Abstract

Natural habitats of *Paphiopedilum fairrieanum* (Lindl.) Stein was studied in the Taksha Range, Jigme Singye Wangchuck National Park, Bhutan, to determine the distribution range, population status, ecological conditions, and associated risks of the orchid. A total of 22 quadrat plots were assessed at two different locations at Rukha and Passang Omchu. The study discovered 519 individuals, mostly on steep slopes and cliffs in chirpine-dominated forests with a canopy cover of less than 35% at elevations ranging from 980-1540 m above sea level. The plants were found on a limestone substrate with soil pH ranging from 7.3 to 8.0 and soil moisture content ranging from 1.4 to 2.5%, regardless of aspects and inclination. The greatest threats to the species in the study area were forest fire, browsing by wild ungulates, and anthropogenic activities.

Keywords: Habitat, Jigme Singye Wangchuck National Park, *Paphiopedilum fairrieanum,* population, threat

Introduction

Paphiopedilum Pfitzer, commonly known as slipper orchid, is one of the most threatened genera in the family Orchidaceae with 109 accepted species in the world (Govaerts *et al.*, 2021), distributed mostly in Southern China to Tropical Asia (Cribb, 1998; Chen *et al.,* 2005; Govaerts *et al*., 2021). Pradhan (1976) reported the occurrence of *P. fairrieanum* (Lindl.) Stein and *P. venustum* (Wall. ex Sims) Pfitzer in Bhutan whereas Pearce and Cribb (2002) reported *P. fairrieanum* and *P. spicerianum* (Rchb. f.) Pfitzer, accounting to the presence of three species in Bhutan. Of the three reported species, only two species – *P. fairrieanum* (Lindl.) Stein and *P. venustum* are confirmed to occur in Bhutan (Gurung *et al.,* 2019). Both these *Paphiopedilum* species are listed in the threatened category of the IUCN Red List.

Paphiopedilum fairrieanum (Critically Endangered) (Figure 7) is reported from Leptshanangra under Mongar District (Pradhan, 1978), Surelakha in Sarpang District (Pearce & Cribb, 2002), Gomdar in Samdrup Jongkhar District (Gurung, 2006), Kalikhola in Dagana District (Dorji, 2008), Ngangla Trong

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under Zhemgang District, Gomtu under Samtse District, Sarjung in Samdrup Jongkhar District and at Kheng-Gongdu under Mongar District (Gurung *et al.*, 2019). A recent survey conducted by Gurung *et al.* (2019) has reported that there are no individuals left at Surelakha under Sarpang District. Collection by people and habitat destruction by farm road construction are the two driving factors that lead to the population decline of the species in Bhutan (Gurung *et al*., 2019). Besides anthropogenic activities; forest fire and grazing by cattle and wild ungulates are other threats to the species (Rankou & Kumar, 2015a; b).

Studies on the habitat and distribution range of the species have shown that the taxon is known to occur in subtropical and warm broadleaved forests in Bhutan. While Pearce and Cribb (2002) reported that the altitude range of the species is between 1400 m and 2200 m above sea level (asl), in Bhutan, the lowest altitudinal record of the habitat is at 600 m asl (Gurung *et al*., 2019) and the highest known is at 1690 m asl (Samdrup *et al.,* 2020). This suggests that the search for *P. fairrieanum* distribution beyond 2000 m asl is needed in Bhutan. Moreover, the distribution of the orchid in Wangdue Phodrang District is not yet studied and widely known. The present study provides details of vegetation composition, population status, and some of the common threats of *P. fairrieanum* at Rukha and Passang Omchu under Taksha Range, Jigme Singye Wangchuck National Park (JSWNP), Wangdue Phodrang Dzongkhag.

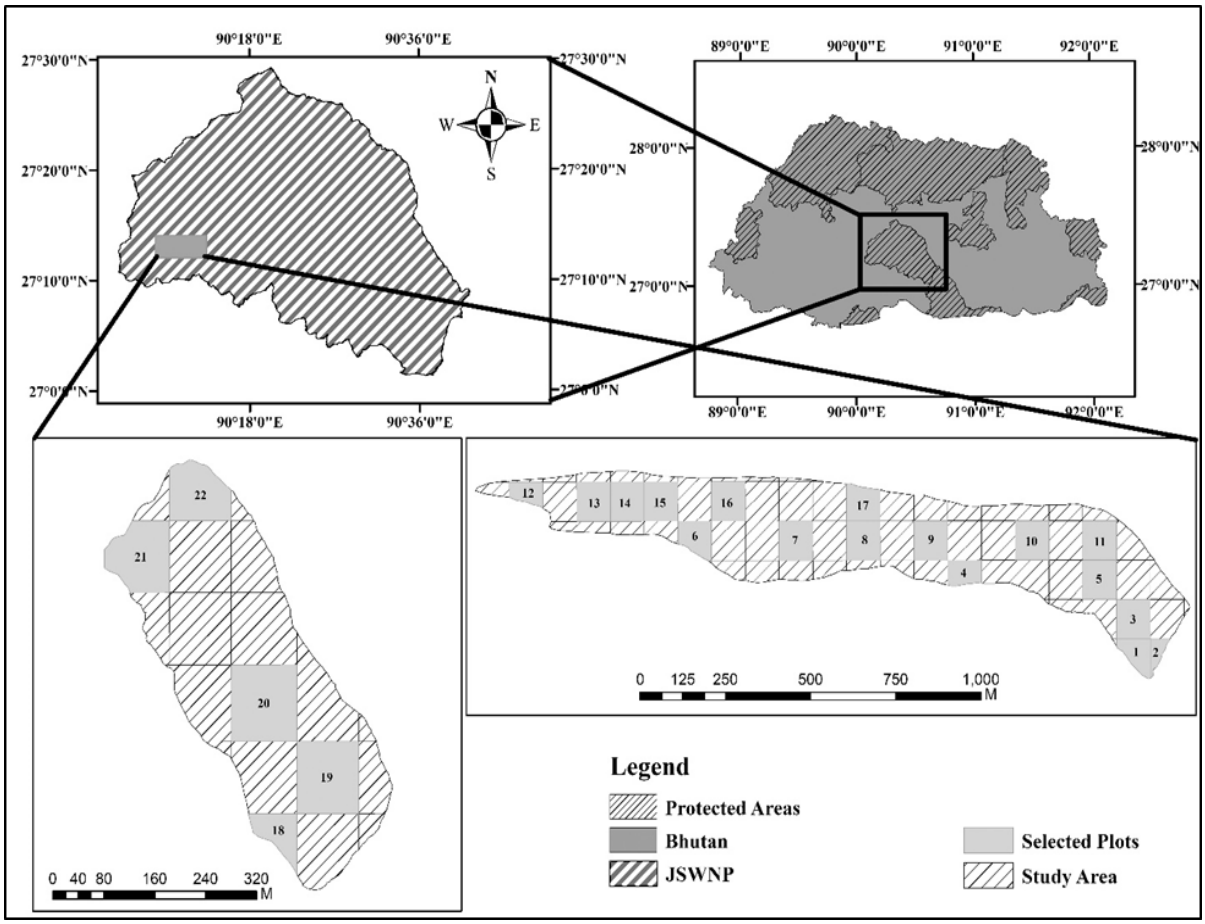

Figure 1: Study area map

Materials and Methods

Study area

The study was conducted in the western part of JSWNP under Taksha Range (27.23°–27.21°N & 90.13°– 90.20°E; Figures 1 & 2). With an area of 1,730 km^2, JSWNP is the third largest protected area in Bhutan, which spreads across 10 'gewogs' (administrative blocks) in five dzongkhags (JSWNP, 2014). JSWNP connects with Jigme Dorji National Park and Wangchuck Centennial National Park in the north, Phrumsengla National Park in the east, and the Royal Manas National Park and Phibsoo Wildlife Sanctuary in the south through biological corridors (JSWNP, 2014). JSWNP comprises four administrative ranges; Langthel Range, Nabji Range, Tingtibi Range, and Taksha Range.

Taksha Park Range covers the whole western part of the national park and is the largest range in the park. It encapsulates diverse habitats, ranging from sub-tropical forests at 500 m asl to alpine scrubs in the Black Mountain peak (4925 m asl). Wide altitudinal variation has endowed the range with six major forest types: (i) subtropical forest, (ii) chirpine forest, (iii) warm temperate broadleaf forest, (iv) cool temperate broadleaf forest, (v) subalpine conifer forest, and (vi) alpine meadow (JSWNP, 2014). These diverse ecological habitats, together with well-drained catchments provide varied habitats, among which one is the critically endangered *Paphiopedilum fairrieanum.*

Data collection and analysis

A reconnaissance survey was conducted in November 2020 to confirm the presence of *Paphiopedilum fairrieanum* in the study area. Bhutan Flora Monitoring Protocol, 2020 (DoFPS, 2020) was used to develop the sampling plan. Using QGIS fishnet, a 100 x 100 m grid cells were laid across the study area and 22 grids were randomly selected for conducting the field work. A 20 × 20 m plot was sampled inside each selected grids to count target species and to measure diameter and height of the trees (inclusive of shrubs). Further, a 2 x 2 m plot was laid to assess herb species in each sampling plot. A digital hypsometer, compass, clinometer, hand-held GPS unit, diameter tape, and measuring tape were among the tools used in the field. For the target species, a clump was enumerated as a single individual. For tree category all species with a height of more than or equal to 1.3 m were classified as trees and the Diameter at Breast Height was measured (DBH). In case of herbs, tallest individual of each species was measured at the tip of the foliage, and the Area of Occupancy (AOO) of each species was estimated within the plot. Soil pH and moisture content were determined in a laboratory using Potentiometric pH meters

Table 1: Summary of environmental variables

Variables	Minimum	Maximum	Average	±SD
Altitude	1160	1550	1333.4091	112.97183
pH	6.5	8	7.3045	0.41573
Soil moisture content	1.2	2.5	1.9591	0.33045
Aspect	SW	N		
Slope	5	90	59.0909	21.74727
Canopy cover	0	90	35.2273	28.96949
Relative density	0	22.2	4.55	6.51838
Diversity	0.14	1.9	1.1418	0.60196
Species richness	6	25	17.3636	4.46729

and Gravimetric method respectively.

DBH of all the individual trees were measured with measuring tape and data were processed using Microsoft Excel to calculate BA cm^2 and RBA in percent. The RBA computed was used to draw vegetation structure and explain floristic composition of *P. fairrieanum* habitat. Species diversity (*H'*) index was calculated using Shannon and Weiner equation. The processed data were analyzed using PC-ORD version 5.1. Cluster analysis was performed using distance measure of Relative Sorensen (Bray-Curtis method) and Group Average as Linkage method to determine the forest types. Qualitative similarity among sample groups was determined using Sørensen's index (Ellenberg and Mueller-Dombois, 1974). To determine the relationship between density of *P. fairrieanum* and environmental variables, Non-metric Multidimensional Scaling (NMS) ordination was performed on the *P. fairrieanum* habitat based on the RBA of each plot as the main matrix data, and the environmental variables as the second matrix data. Pearson and Kendall correlation coefficient are used to explain the strength of correlation of variables with axes and forest types (Wangda and Ohsawa, 2006). For the herb layer, volume was estimated by multiplying the height of the tallest herb species (cm) with its coverage (%) within the sampled quadrat. Threats of the species were observed visting the study area two times a season.

Results and Discussion

Occurrence of *Paphiopedilum fairrieanum* in Bhutan is reported by Pradhan (1976, 1978, 1996); Chowdhery (1998); Cribb (1998); Pearce and Cribb (2002); Rankou and Kumar (2015a), Gurung *et al.* (2019), and Samdrup *et al.* (2020). According to Gurung *et al.* (2019), *P. fairrieanum* is distributed in six districts at 10 locations with more than 6,700 individuals in Bhutan. This study confirmed the presence of this species yet in two other locations which is dominated by Chirpine (*Pinus roxburghii*).

In Taksha Range, *Paphiopedilum fairrieanum* is found in Rukha and Passang Omchu. It is distributed mostly in Chirpine dominated forest or at the edges of Chirpine and sub-tropical broad-leaved forest with a canopy cover of less than 35%, where there is abundant light. As ground dwelling species, it is found on limestone substrate with soil pH ranging from 7.3 to 8.0 and soil moisture content between 1.4 to 2.5% at an elevations range of 980-1550 m asl regardless of aspect or inclination. The orchid occurs within the range reported by Gurung *et al.* (2019) and Samdrup et al. (2020).

Samdrup et al. (2020) found the maximum counts of *Paphiopedilum fairrieanum* occurring in South-east and East aspects, whereas Gurung *et al*. (2019) reported it to occur mostly in Northwest to Southwest facing slopes. However, this study found that most of the *P. fairrieanum* plants were occurring in North, North-west, and North-east facing slopes which indicates that aspect is not an important parameters.

As per Samdrup *et al.* (2020) and Gurung *et al.* (2019), the *Paphiopedilum fairrieanum* habitat are dominated by deciduous shrubs and trees with an open canopy. Whereas, this study found that the dominant species was a conifer tree species (Chirpine). Thus, *P. fairrieanum* seems to grow on any aspects and forest types provided that they have limestone substrate and open canopy.

The largest number of individuals counted in a plot was 115 (22.25% Relative Density [RD]) in P3 (P is plot) and the least number of individuals was two (0.4% RD) in plot 8. P10 with $H' = 1.9$ had the most plant diversity followed by plot 4 with $H' = 1.8$. P2 had the lowest diversity with $H' = 0.14$, whereas P3 and P20 had the highest species richness ($SR = 25$) and P19 had the lowest ($SR = 6$).

The biplot of NMS ordination (Figure 2) depicts the distribution of individual species in the study area with its ecological similarities.

The forest type I (*Pinus roxburghii, Phoenix rupicola, Leea asiatica, Nayariophyton zizyphifolium, Osyris wightiana, Ficus semicordata*) had the highest density of *P. fairrieanum* (P1, P2, P5, P6, P11, P13, P15, P16, P19, P21) and are presented in the positive side of Axis 1. The tree species under this cluster are light demanding (Reddy and Ugle, 2008) with canopy cover of less than 35%. The species in forest type II (*Wendlandia wallichii, Phoebe lanceolata, Diploknema butyracea, Woodfordia fruticosa, Leptodermis stapfiana, Phyllanthus emblica, Grewia eriocarpa, Quercus lanata, Lyonia ovalifolia, Rhododendron arboretum, Searsia paniculata, Indigofera dosua*) were the transition species between Chirpine and broad-leaved forest which was moderately preferred by the target species. The forest type III was broad-leaved forest with canopy cover of more than 50%, which was found to be unsuitable habitat for the target species. The length of arrow indicates the magnitude of the variables on the vegetation distribution and the position of each variable indicates its correlation with that factor (Wangda and Ohsawa, 2006). Axis 1 was determined by species diversity and dominance followed by species richness and aspect, whereas the Axis 2 was determined by pH alone. Correspondingly, ordination biplot showed species diversity with longest arrow length in the opposite direction of *P. fairrieanum* preferred forest type I (P1, P2, P5, P6, P11, P13, P15, P16, P19, P21) with strong Pearson and Ken-dall correlation (r = .51), followed by aspect (r =.42) and pH (r = .018) (Figure 2; Table 2).

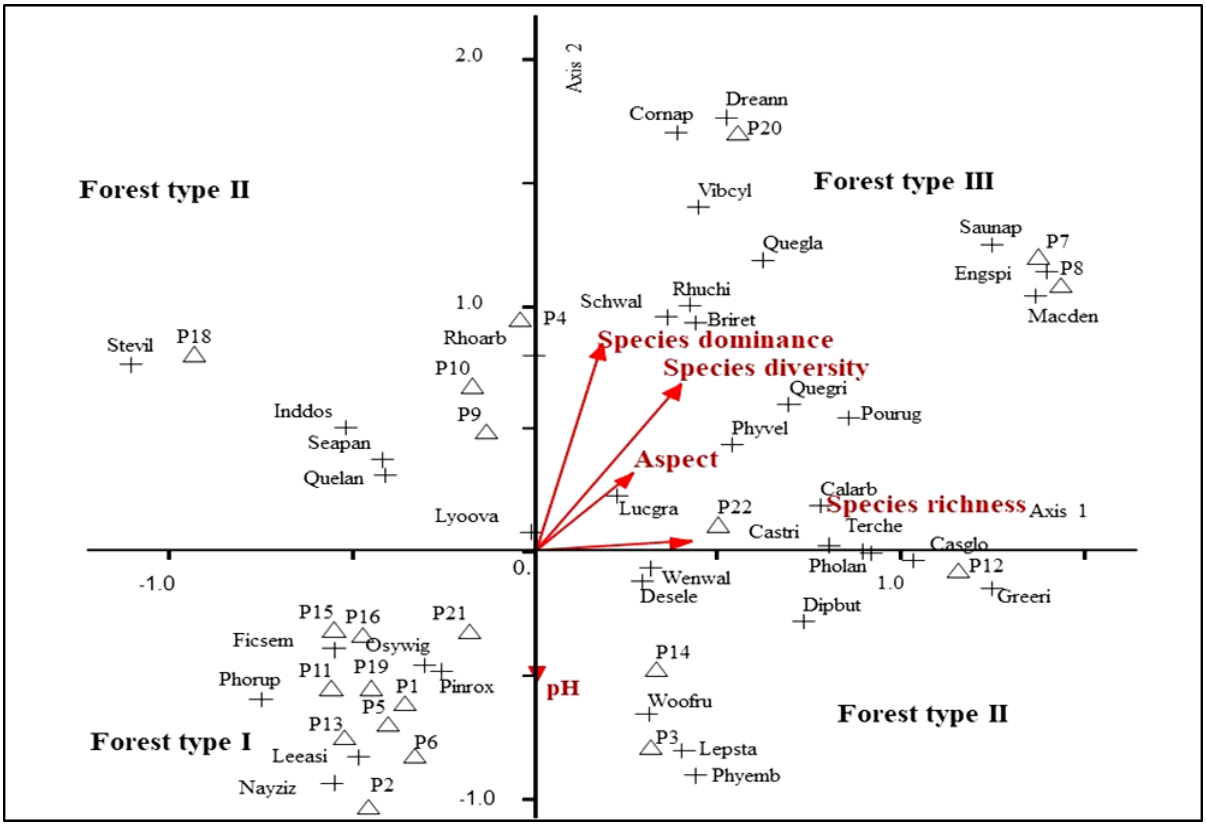

Figure 2: CCA analysis showing correlations of *P.fairrieanum* with vegetation and other environment variables.

Note: Species id provided is combination of three prefix letters of the binomial name

Vegetation Composition of major life forms

The survey recorded 88 species of plants belonging to 32 families and there were 49 species of trees and shrubs and 39 species of herbs. The vegetation study using PC-ORD revealed that the *Paphiopedilum* habitats were divided into three types of forests (Figure 3). Forest type I was conifer forest dominated by Chirpine. Forest type II was mixed forest, also dominated by *Pinus roxburghii* along with other broad-leaved species such as *Diploknema butyracea, Rhododendron arboreum, Quercus lanata, Q. griffithii,* and *Searsia paniculata*. Forest type III was broad-leaved forest dominated by *Q. griffithii, Q. glauca, Engelhardia spicata, Schima wallichii* and *Callicarpa arborea.* Among these three forest types the target species was observed maximum in forest type I followed by forest type II and forest type III.

Forest types were classified into conifer trees, evergreen trees, deciduous trees, evergreen shrubs, and deciduous shrubs under the tree and shrub category to highlight the life-form composition (Figure 4). Conifer trees (Chirpine) accounted for 47% of the total with evergreen trees accounting for 40%, deciduous trees accounting for 10.5%, evergreen shrubs accounting for 2%, and deciduous shrubs accounting for 0.5%. Ground vegetation life form (Figure 5) had 60% grasses, 24.5% ferns, 15% herbs, and 0.5% orchids. These findings suggest that *P. fairrieanum* grows primarily among grasses and ferns in the area - basically on sparsely vegetated areas. The study area also had *Berginia cilliata* and *Lindenbergia grandiflora.*

Considering a single species, it was significantly dominated by *Pinus roxburghii* followed by oak species like *Quercus lanata, Q. griffithii, Q. glauca,* and *Diploknema butyracea*. Whereas, *Neocinnamomum caudatum*, *Osyris wrightina*, and *Leea asiatica* were the least dominant species in the *P. fairrieanum* habitats (Figure 6).

Threats

Forest fire, anthropogenic activities such as collection, cattle grazing, and wild ungulates were the principal hazards noted in the study area. Cattle grazing was less than wild ungulates like Gorals and Serows because most of the habitats are inaccessible to domestic animals. One-time grazing, on the other hand,

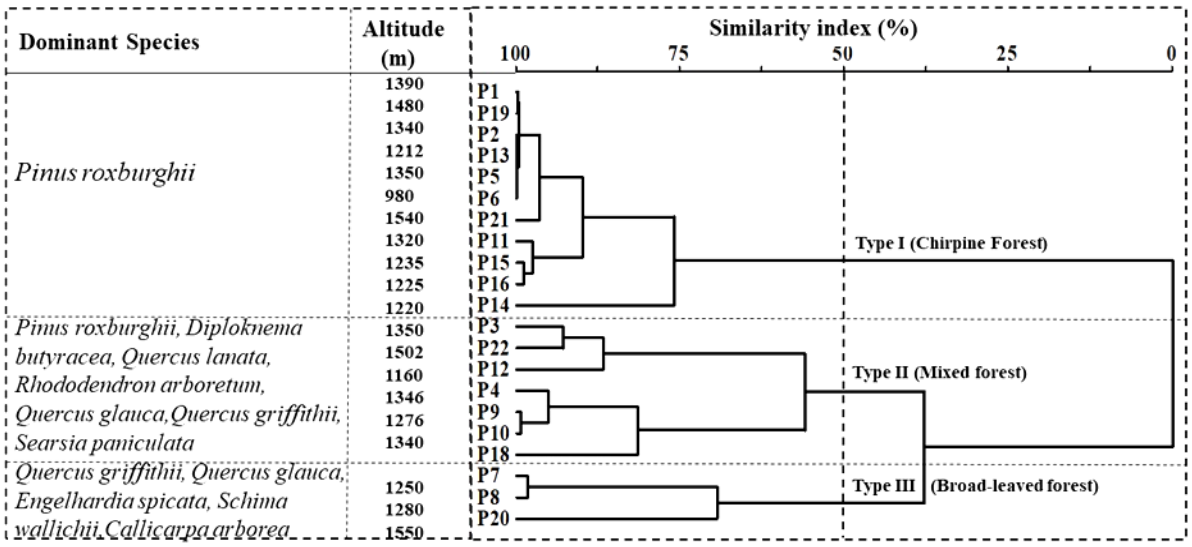

Figure 3: Cluster dendrogram showing sequential clustering of trees and shrubs using Relative Basal Area in % (RBA) with similarity index scale (%) arbitrarily marked at 50 % portraying 3 cluster solutions with dotted lines.

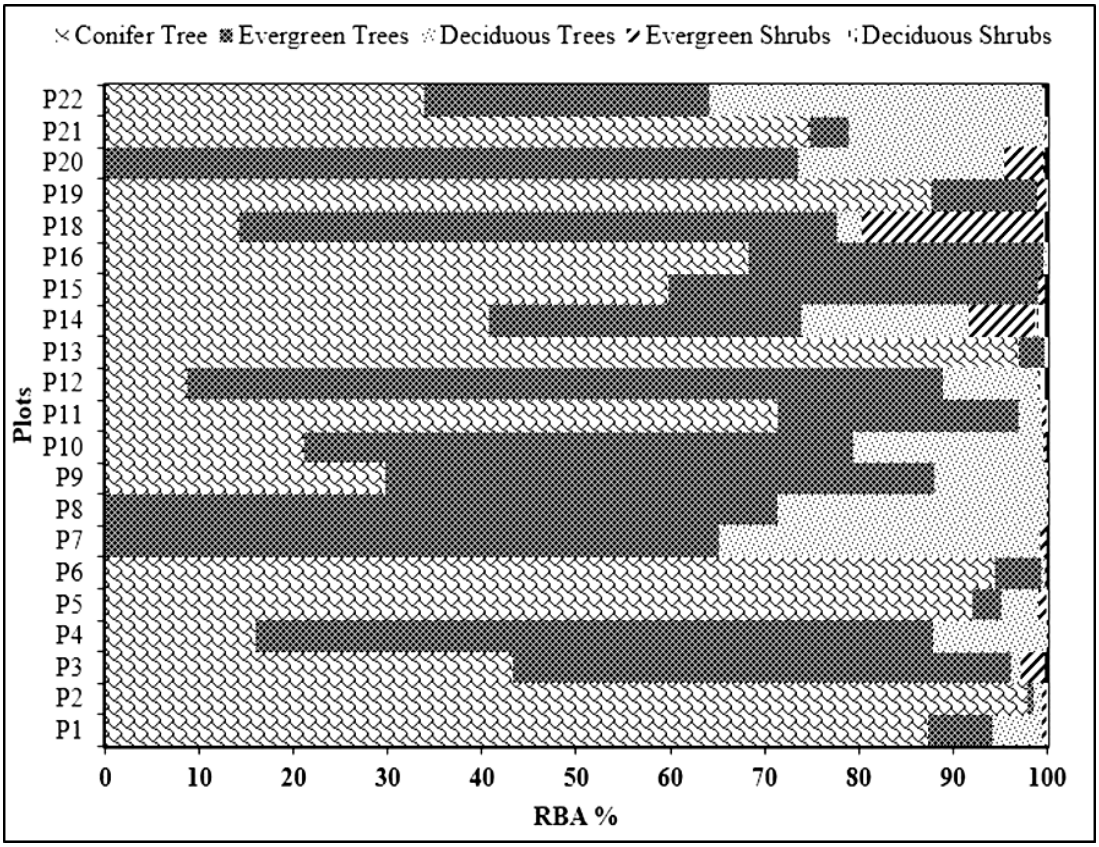

Figure 4: Various life forms of vegetation composition are found in the P. fairrieanum

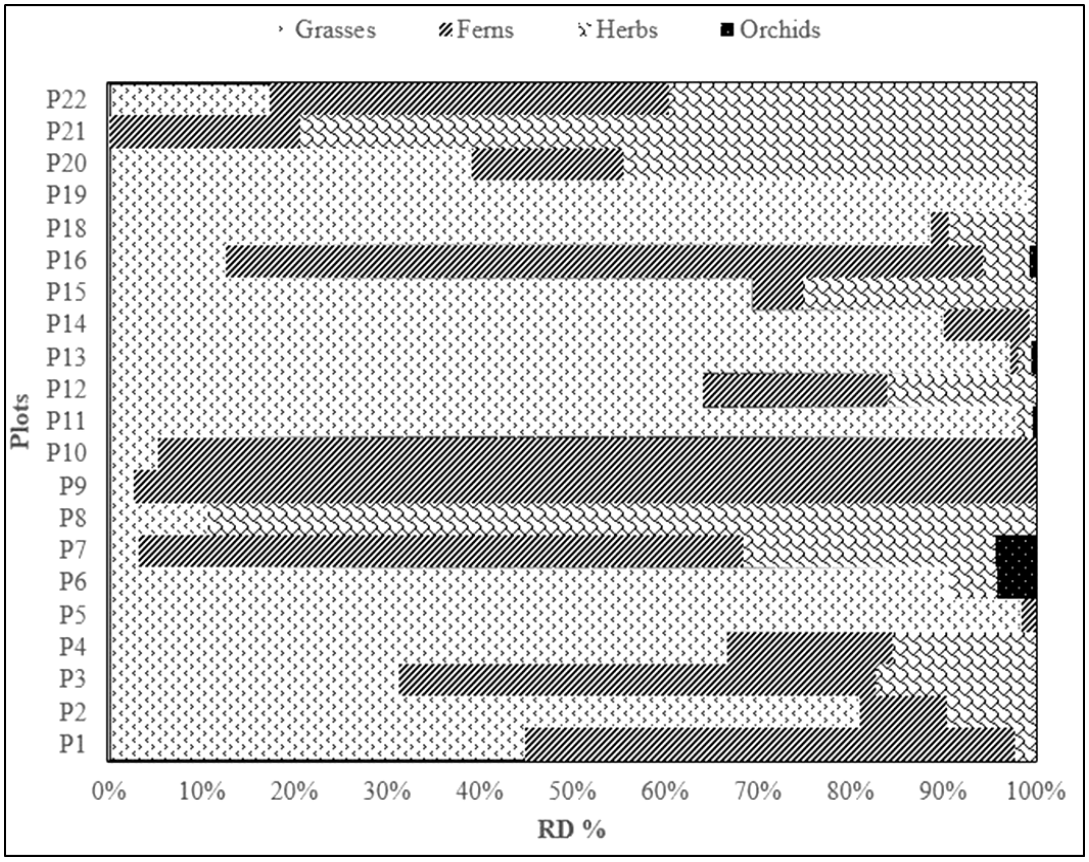

Figure 5: Ground vegetation life forms are associated with *P. fairrieanum* in the area

does not appear to entirely eradicate the species unless uprooted, but it does appear to impair its usual growth for a few seasons (figure 8).

In the study area, *Paphiopedilum fairrieanum* was typically found on steep slopes and cliffs dominated by Chirpine trees. So the area is prone to frequent forest fires, mainly due to the presence of pine needles and lemon grasses. Nonetheless, the species seems to

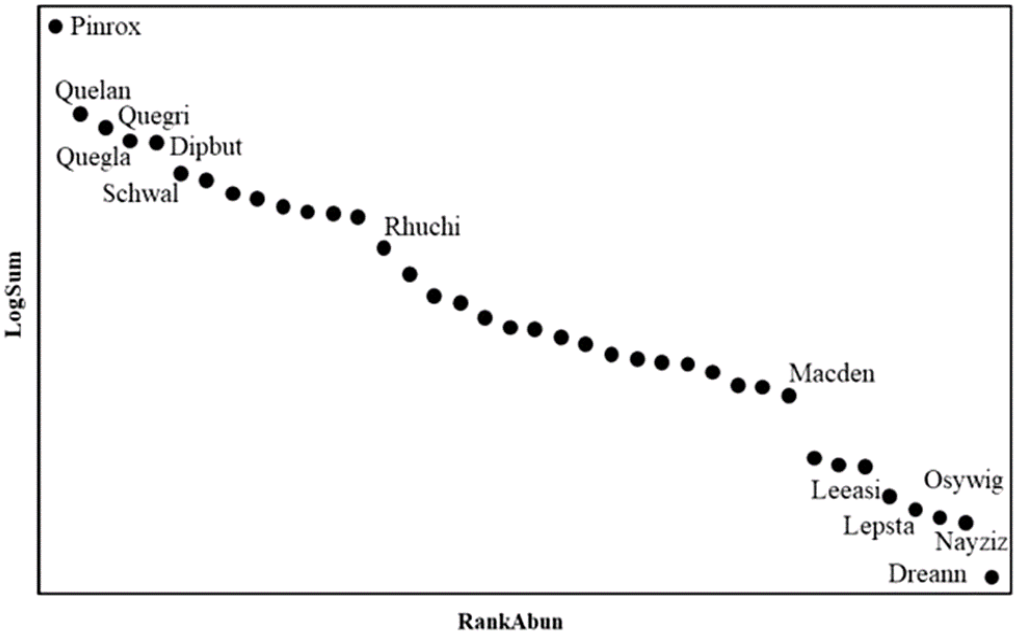

Figure 6: Dominance curve showing a dominant species in the *P. fairrieanum* habitat in the area

Figure 7: *Paphiopedilum fairrieanum* (Lindl.) Stein

Figure 8: Grazed *P. fairrieanum* establishing well the next season

have survived multiple forest fire incidents over the last decade and the forest fire is a common sight in the Chirpine zone during dry season.

According to Rankou and Kumar (2015a; b) forest fire, climate change, cattle grazing, and wild ungulates are the principal threats to *Paphiopedilum fairrieanum* in its natural habitat. Timber extraction, irrigation channel excavation, farm road construction, and unlawful collection appeared to be the major anthropogenic activities. Above all, soil excavation such as from farm road construction is a serious threat as it buries the entire population and eliminates it completely when the orchid is distributed in small patches. However, many of the threats can be minimised or eliminated since the studied habitat occurs in a protected area.

Conclusion

A total of 519 individuals or clumps of *Paphiopedilum fairrieanum* were recorded in Taksha Range, Jigme Singye Wangchuck National Park, Wangdue Phodrang at Rukha and Passang Omchu. Limestone substrate is the key habitat parameter required for the occurance of the species. The orchid mostly prefers open forests and cliffs irrespective of aspects and inclination. In the Chirpine dominated forest, *P. fairrieanum* thrives well in soil pH ranging from 7.3 to 8.0 at an elevations range of 980-1540 m asl.

Forest fire, anthropogenic activities, cattle grazing, and wild ungulates were the main hazards noted in its natural habitat. Education and conservation awareness programmes for local communites in the area could help save the species in the study area. Moreover, there is a possibility of including the area under community forest which could increase protection of the species by local communites and strengthen conservation. In Bhutan, this critically endangered orchid is still not well documented as it is known from scattered populations only. Therefore, continuation of such study might help discover new habitats.

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