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# ROOT HOLOPARASITE *BALANOPHORA POLYANDRA* GRIFF. (BALANOPHORACEAE) IN EASTERN HIMALAYA (SIKKIM, INDIA): DISTRIBUTION, RANGE, STATUS AND THREATS

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**Abstract:** *Balanophora* J.R. Forster & G. Forster (Balanophoraceae) is a poorly studied genus of root holoparasite native to temperate and tropical regions of Asia and the Pacific. The occurrences of *Balanophora polyandra* Griff. were first reported within two protected areas in eastern Himalaya (Sikkim, India), namely, Khangchendzonga National Park and Pangolakha Wildlife Sanctuary. The study assessed the distribution range of *B. polyandra* in Sikkim using data collected from both field surveys and herbarium records, and discussed the threats faced by *Balanophora* populations in the region.

**Keywords:** *Balanophora*, India, root holoparasite, Sikkim Himalaya.

Botanical surveys have exponentially increased throughout the eastern Himalaya over the past decade (Kandel et al. 2016). The diversity and status of parasitic plants, however, remain poorly understood (O'Neill & Rana 2016). *Balanophora* J.R. Forster & G. Forster (Balanophoraceae) is a genus of root holoparasite, native to the temperate and tropical regions of Africa, Asia, and the Pacific. There is a paucity of ecological records (Shumei & Murata 2003; Pelser et al. 2014; Rao

et al. 2015). Around the world, 19 species in this genus have been recognized so far, of which four are reported in the Himalaya: *Balanophora dioica* R.Br. ex Royle, *B. harlandii* Hook.f., *B. involucrata* Hook.f. & Thomson, and *B. polyandra* Griff. (Eberwein et al. 2009; Su et al. 2012; Rai et al. 2014). These species exhibit drastically reduced morphologies, including minute flowers and scaly leaves (Nickrent & Garcia 2009; Su et al. 2012). They forego photosynthesis, and obtain nutrients from diverse hosts using tuberous organs similar to haustoria (Eberwein et al. 2009). In this article, the occurrence of *B. polyandra* populations within two protected areas in Sikkim Himalaya (India), namely, Khangchendzonga National Park and Pangolakha Wildlife Sanctuary (Fig. 1), are discussed. Further, the distribution range of *B. polyandra*, *B. dioica*, *B. harlandii*, and *B. involucrata* in Sikkim is assessed using data collected from both field surveys and herbarium records of the Botanical Survey of India, Gangtok, Sikkim. Our report addresses the necessary aspects of conservation planning in eastern

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Himalaya, which may guide future IUCN Red List of Threatened Species assessments.

## METHODS

### Study area

Sikkim is located in northeastern India between 27.53300°N and 88.51944°E surrounded by Bhutan in the east, Nepal in the west, West Bengal in the south, and the Tibetan Autonomous Region of the People's Republic of China in the north, and is contiguous with the Himalayan Biodiversity Hotspot (Telwala et al. 2013).

### Data collection

Quarterly surveys were conducted in two protected areas, namely, Khangchendzonga National Park (IUCN Category II) and Pangolakha Wildlife Sanctuary (IUCN Category IV), between October 2015 and March 2017, following a systematic pollard walk transect methodology (see Pollard & Yates 1993; Kerr et al. 2000). While the transect in Khangchendzonga National Park extended from Kisong-Tholung to Panchpokhari, and in Pangolakha Wildlife Sanctuary extended from Lingtam to Zuluk (c. 1,600–4,500 m). During surveys, we recorded botanical characters and ecological notes, and confirmed our identifications at Regional Centre of Botanical Survey of India in Gangtok, Sikkim (see O'Neill

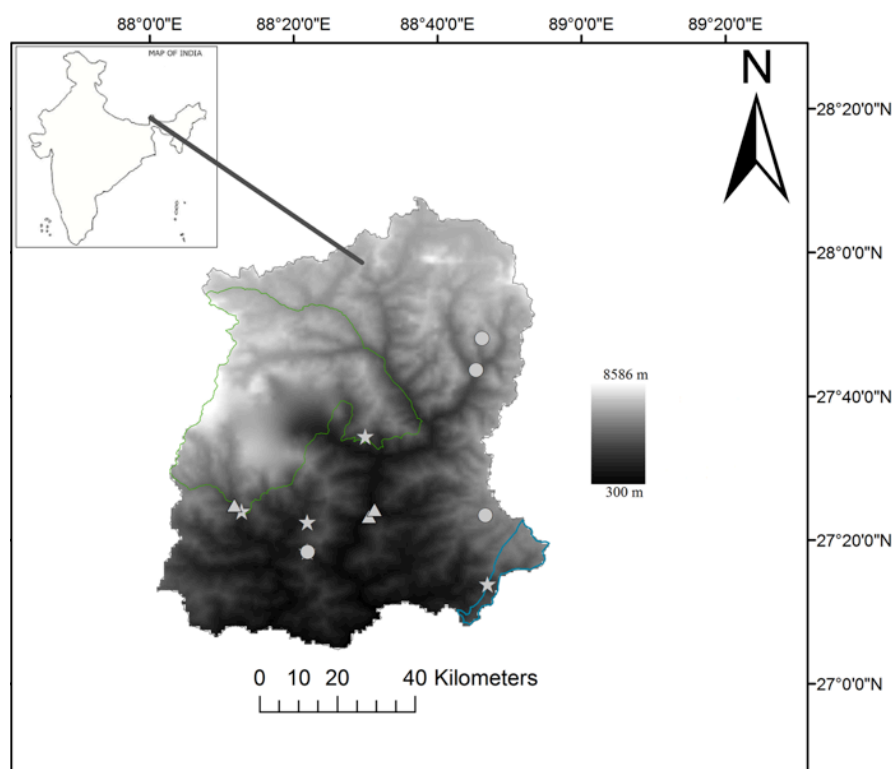
& Rana 2016). Digital media of these specimens are available upon request. The taxonomic designations of Shumei & Murata (2003) were crucial during the identification process, and served as the foundation of the systematic account. Eventually, a digital elevation model for *Balanophora* spp. populations using ArcGIS Version 9.3 was generated (Fig. 1).

## RESULTS AND DISCUSSION

### Systematic Account

*Balanophora polyandra* Griff., Proc. Linn. Soc. London 1: 220. 1844.

Holoparasitic herb, dioecious, tubers clustered in coarse agglomeration, cylindrical, surface covered in stellate protuberances and gray to white haustoria, 2–5 cm in diam., chiffon to bluish. Scapes emerge from apex of root segment, 2.0–10.0 × 0.5–1.5 cm, cream to crimson. Leaves decussate, 4–10, whorled, obovate to broadly oblong, concave, apex rounded, margin entire, base attenuate, 1.5–2 × 1.0–1.2 cm, cream to crimson. Inflorescences emerge endogenously from apex of root segments. Staminate inflorescence terminal, narrowly ellipsoid and spadix-like, racemose, 3–10 cm; pedicelled, bracts truncate, c. 1.0mm, cream to tan. Staminate flowers bisymmetrical to zygomorphic, numerous, spirally arranged in conspicuous vertical rows, c. 1cm



**Figure 1.** Distribution of *Balanophora* spp. in the Sikkim Himalaya (*Balanophora dioica* ▲; *B. polyandra* ★; *B. involucreta* ●) and new populations of *Balanophora polyandra* in Khangchendzonga National Park (area depicted by green line) and Pangolakha Wildlife Sanctuary (area depicted by blue line)



in diam., pedicels 2–4 mm, apex truncate; lateral tepals deltoid to ovate; syndaria subdiscoïd, 4–5 mm in diam., anthers 25–50 locelli, dehiscent, white. Pistillate inflorescence terminal, ellipsoid to oblong-ovoid, 2.0–3.0 x 1.0–2.5 cm, orange to crimson; spadicles clavate, 1.5–2.5 mm; “apical 1/2 to 2/3 ellipsoid to obovoid, cuticular ridges of apical cells short but distinct and congested” (Shumei & Murata 2003). Pistillate flowers zygomorphic, numerous and minute, c. 1.5mm, arranged on main axis of inflorescence and basal stipe of spadicles, white to cream. Flowering period from August to November.

### Distribution and Habitat

*B. polyandra* exhibits a broad distribution throughout the Himalaya, with populations reported in Bhutan, India (Sikkim), Myanmar, Nepal (Kaski, Mustang, Sankhuwasava, Taplejung), and the People’s Republic of China (Guangxi, Hubei, Hunan, Xizang, and Yunnan) between 1,000m and 3,000m (Shumei & Murata 2003; O’Neill & Rana 2016). This species was first reported

in the eastern Himalaya by J.D. Hooker in the mid-19<sup>th</sup> century, and has 11 herbaria records at the Botanical Survey of India in Gangtok (Hooker 1855; Appendix 1). The current study is a first time report of seven new occurrences of the species within two protected areas in the Sikkim Himalaya: namely, the Khangchendzonga National Park (KNP) and Pangolakha Wildlife Sanctuary (PWS). In KNP, five populations comprised of 24 individuals (5 staminate and 19 pistillate inflorescences) were found; in the PWS, two populations comprising of four total individuals (1 staminate and 3 pistillate inflorescences; Image 1) were found. These populations found growing in warm-temperate forests (2,000m and 2,300m) dominated by the following woody taxa: *Acer campbellii* (Sapindaceae), *Alnus nepalensis* (Betulaceae), *Betula utilis* (Betulaceae), *Castanopsis tribuloides* (Fagaceae), *Engelhardia spicata* (Juglandaceae), *Eurya japonica* (Pentaphylacaceae), *Exbucklandia populnea* (Hamamelidaceae), *Juglans regia* (Juglandaceae), *Quercus lamellosa* (Fagaceae), *Q. pachyphylla* (Fagaceae),



Image 1. Pistillate (red colour) and staminate (cream colour) inflorescences of *Balanophora polyandra* Griff. (Balanophoraceae) in Khangchendzonga National Park, Sikkim, India.

and *Viburnum grandiflorum* (Adoxaceae). The preferred habitat of *B. polyandra* is shaded, northeastern slopes (35–55°), in soils with 5–8 cm of humus. This species parasitized seven species belonging to four families: *Castanopsis tribuloides* (Fagaceae), *Quercus lamellosa*, *Q. pachyphylla* (Fagaceae), *Eurya japonica* (Pentaphylacaceae), *Evodia fraxinifolia* (Rutaceae), *Symplocos theifolia*, and *S. spicata* (Symplocaceae). During autumn (October and November 2015), it was observed that *Apis cerana* (Apidae) was pollinating pistillate flowers of *B. polyandra* in KNP.

### Threats

Deforestation threatens *B. polyandra* populations in Sikkim (Chettri et al. 2002; Pandit et al. 2007; Sharma et al. 2007, 2015). A rough estimate projects up to 40% decrease in forest cover by 2100, with transformations driven by road expansion for defense and ecotourism purposes (Sundriyal & Sharma 1996; Maharana et al. 2000; Chettri et al. 2002; Pandit et al. 2007). Herbaria records from the late 1990s suggest that populations of *B. polyandra* and the congeneric *B. dioica* were inundated during the construction of the Rangit Dam between Nauprik and Bey. The Government of Sikkim, however, has taken progressive strides to mitigate potential forest loss and habitat degradation through policies such as Sikkim Forests and Water Courses (Preservation and Protection) Act 2007. Moreover, the 2016 inscription of KNP as a UNESCO World Heritage Site extends additional protection to the *B. polyandra* populations. Agricultural expansion of large Cardamom (*Amomum subulatum*, Zingiberaceae) may also threaten *Balanophora* spp. habitat in Sikkim (Gaira et al. 2016; Sharma et al. 2016). The acute ramifications of forest conversion for agricultural purposes, however, may be overshadowed by chronic environmental changes, including range shifts of host-plant (*Quercus* spp.) populations (Kumar 2012; Telwala et al. 2013). These host plant populations, too, face high extraction pressures in rural Sikkim (Chettri et al. 2002; Tambe et al. 2011). Although *Balanophora* spp. are reported for their medicinal value, including the treatment of skin diseases, internal parasites, and sexually transmitted infections, they face minimal extraction pressure for these purposes in the eastern Himalaya (Venkatarreddi 1969; Podimuang et al. 1971; Ignacimuthu et al. 2006; Tao et al. 2009; Wang et al. 2013; Sharma 2015).

Based on IUCN Red List of Threatened Species criteria, *Balanophora polyandra* is a Least Concern (LC) species both in Sikkim and throughout the eastern Himalaya due to its wider distribution (extent of occurrence EOO

>20,000km<sup>2</sup>) and population stability within several protected areas (O'Neill & Rana 2016). Botanical records suggest that *B. dioica*, *B. harlandii*, and *B. involucrata*, too, are Least Concern (LC) species due to their wider distributions reportedly correlated with host-species ranges (Sharma 2002; Shumei & Murata 2003; Thriveni et al. 2016), and location within the protected areas (Jamir & Pandey 2003; Rai et al. 2014). Agricultural expansion threatens *Balanophora* habitats throughout the eastern Himalaya, as well as Assam and Manipur, where mining has increased in recent decades (Sharma 2002; Bora et al. 2010). Census data for *Balanophora* spp. remains limited. One additional species in the Balanophoraceae, *Rhopalocnemis phalloides*, also has a literature record in Sikkim; however, no herbaria accessions are available as of December 2016. MaxEnt habitat suitability modeling may further clarify the range and status of Balanophoraceae in Eastern Himalaya (Kumar 2012; Chhetri & Badola 2017).

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**Appendix 1. Records of *Balanophora* spp. (Balanophoraceae) in Sikkim Himalaya based on herbarium data, (Sikkim Himalayan Regional Centre, BSI, Gangtok) and present field study (marked with \*)**

Species	District	Locality	Altitude	Coordinates (°N   °E)		Date of Collection /date of study	Collector(s)/ observer(s)	Collection no./Acc. no.	Notes from Herbarium labels
<i>Balanophora dioica</i> Royle	West Sikkim	Sachen (Old Goath Below)	N/A	27.41353	88.19674	2009	S.K. Rai; K. Das	44711	Petals 4, anthers many, flowers white, clustered in dome head, young one pinkish, leafy stem
<i>Balanophora dioica</i> Royle	West Sikkim	Sachen (Old Goath Below)	N/A	27.41353	88.19674	2009	S.K. Rai; K. Das	44712	Petals 4, anthers many, flowers white, clustered in dome head, young one pinkish, leafy
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu (NHPC Dam Site)	750m	27.38785	88.50788	1997	S.K. Jana	33657	Grows on marshy land
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu (NHPC Dam Site); Note: Probably from Nauprik to Bey	720m	27.38785	88.50788	1997	S.K. Jana	33661	Grows on marshy land
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu (NHPC Dam Site)	720m	27.38785	88.50788	1997	S.K. Jana	33660	Grows on marshy land
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu (NHPC Dam Site)	721m	27.40359	88.52144	1997	S.K. Jana	33659	Grows on marshy land
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu, Right Flank	N/A	27.40359	88.52144	19-97	B.K. Shukla	33658	Root parasite, petal coffee colour, herbs up to 20cm tall
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu, Right Flank	N/A	27.40359	88.52144	1997	B.K. Shukle	22604	Root parasite, petal coffee colour, herbs up to 20cm tall
<i>Balanophora dioica</i> Royle	East Sikkim	Dikchu, Right Flank	N/A	27.40359	88.52144	1997	B.K. Shukla	22602	Root parasite, petal coffee colour, herbs up to 20cm tall
<i>Balanophora dioica</i> Royle	West Sikkim	Tshoka to Gumsa	N/A	27.38785	88.50788	2009	S.K. Rai; K. Das	44625	Flowering head pinkish, stem yellow, sheathed; root parasite
<i>Balanophora dioica</i> Royle	West Sikkim	Tshoka to Gumsa	N/A	27.38785	88.50788	2009	S.K. Rai; K. Das	44626	Flowering head pinkish, stem yellow, sheathed; root parasite
<i>Balanophora involuocrata</i> Hook.f.	North Sikkim	Singba 'A'	N/A	27.80109	88.76956	2011	Dr. K Das; S.K. Rai	43891	Root parasite, found in the Rhododendron forest, head pinkish, red, root dotted below
<i>Balanophora involuocrata</i> Hook.f.	North Sikkim	Singba 'A'	N/A	27.80109	88.76956	2011	Dr. K Das; S.K. Rai	43892	Root parasite, found in the Rhododendron forest, head pinkish, red, root dotted below
<i>Balanophora involuocrata</i> Hook.f.	North Sikkim	Lachung to Dombeyang	N/A	27.73649	88.21318	1987	D.C.S. Raju; S. Singh	15918	Roots or stem parasites, whole plant yellow, leaves and flowers yellow
<i>Balanophora involuocrata</i> Hook.f.	North Sikkim	Lachung to Dombeyang	N/A	27.73649	88.21318	1987	D.C.S. Raju; S. Singh	15917	Roots or stem parasites, whole plant yellow, leaves and flowers yellow
<i>Balanophora involuocrata</i> Hook.f.	East Sikkim	Karponang	N/A	27.39104	88.77742	1984	B. Krishna; S. Singh	5636	Root parasite, petals 5, reddish
<i>Balanophora involuocrata</i> Hook.f.	East Sikkim	Karponang	N/A	27.39104	88.77742	1984	B. Krishna; S. Singh	5637	Root parasite, petals 5, reddish
<i>Balanophora involuocrata</i> Hook.f.	East Sikkim	Forest behind Elephant Mansion, Gangtok	N/A	27.30574	88.36578	1980	P. Chakraborty	4345	N/A
<i>Balanophora involuocrata</i> Hook.f.	East Sikkim	Forest behind Elephant Mansion, Gangtok	N/A	27.30574	88.36578	1980	P. Chakraborty	4578	Fleshy leaves with tuberous roots



<i>Balanophora polyandra</i> Griff.	South Sikkim	Rabongla (East Side)	N/A	27.30654	88.3648	2008	S.K. Rai	42932	Herbs, flowers white, powdery, male cone reddish, bracteate, lanceolate
<i>Balanophora polyandra</i> Griff.	South Sikkim	Rabongla (East Side)	N/A	27.30654	88.3648	2008	S.K. Rai	42933	Herbs, flowers white, powdery, male cone reddish, bracteate, lanceolate
<i>Balanophora polyandra</i> Griff.	South Sikkim	Rabongla (East Side)	N/A	27.30654	88.3648	2008	S.K. Rai	42931	Herbs, flowers white, powdery, male cone reddish, bracteate, lanceolate
<i>Balanophora polyandra</i> Griff.	West Sikkim	Karchi R.F.	2,000m	27.37405	88.3648	1999	B.K. Shukla	22603	Root parasite grows in temperate forest up to 15 cm tall
<i>Balanophora polyandra</i> Griff.	West Sikkim	Karchi R.F.	2,000m	27.37405	88.3648	1999	B.K. Shukla	35022	Root parasite grows in temperate forest up to 15 cm tall
<i>Balanophora polyandra</i> Griff.	West Sikkim	Karchi R.F.	2,000m	27.37405	88.3648	1999	B.K. Shukla	35023	Root parasite grows in temperate forest up to 15 cm tall
<i>Balanophora polyandra</i> Griff.	West Sikkim	Karchi R.F.	2,000m	27.37405	88.3648	1999	B.K. Shukla	35024	Root parasite grows in temperate forest up to 15 cm tall
<i>Balanophora polyandra</i> Griff.	West Sikkim	Yuksom; After Karthok Pokhari	N/A	27.37233	88.22231	1992	R.C. Srivastava	35025	Parasitic herbs on hil base in bridge; basal thint yellowish seed stem brown flowers whorled
<i>Balanophora polyandra</i> Griff.	West Sikkim	Yuksom; After Karthok Pokhari	N/A	27.37233	88.22231	1992	R.C. Srivastava	35026	Parasitic herbs on hil base in bridge; basal thint yellowish seed stem brown flowers whorled
<i>Balanophora polyandra</i> Griff.	West Sikkim	Yuksom; After Karthok Pokhari	N/A	27.37233	88.22231	1992	R.C. Srivastava	35027	Parasitic herbs on hil base in bridge; basal thint yellowish seed stem brown flowers whorled
<i>Balanophora polyandra</i> Griff.	West Sikkim	Yuksom-Bakhim Trek (Sachen)	N/A	27.39917	88.21318	2004	S.K. Rai; Arun Kr. Chhetri	43293	Saprophytic, flowers globose white
<i>Balanophora polyandra</i> Griff.	North Sikkim	Khangchend-zonga National Park	2,227m	27.57263	88.49970	2016	P.K.Chhetri, B. Chhetri*	N/A	Herbs, flowers, male cone reddish, female cone cream colour, grows on shady area of sloppy temperate region
<i>Balanophora polyandra</i> Griff.	North Sikkim	Khangchend-zonga National Park	1,991m	27.55239	88.49929	2016	P.K.Chhetri, B. Chhetri*	N/A	Herbs, flowers, male cone reddish, female cone like racemose with cream colour, grows on shady area of sloppy temperate region
<i>Balanophora polyandra</i> Griff.	North Sikkim	Khangchend-zonga National Park	2,183m	27.57242	88.49916	2016	P.K.Chhetri, B. Chhetri*	N/A	Herbs, flowers, male cone reddish, female cone like racemose with cream colour, grows on shady area of sloppy temperate region
<i>Balanophora polyandra</i> Griff.	North Sikkim	Khangchend-zonga National Park	2,376m	27.5765	88.51075	2017	P.K.Chhetri, B. Chhetri*	N/A	Herbs, flowers, male cone reddish, grows on shady area of sloppy temperate region
<i>Balanophora polyandra</i> Griff.	North Sikkim	Khangchend-zonga National Park	1,826m	27.5765	88.51075	2017	P.K.Chhetri, B. Chhetri*	N/A	Herbs, flowers, male cone reddish, grows on shady area of sloppy temperate region
<i>Balanophora polyandra</i> Griff.	East Sikkim	Pangolakha Wildlife Sanctuary	2,044m	27.2378	88.76441	2017	P.K. Chhetri*	N/A	Herbs, flowers, male cone reddish and female cone turned into blackish, grown on shady area of temperate forest
<i>Balanophora polyandra</i> Griff.	East Sikkim	Pangolakha Wildlife Sanctuary	2,152m	27.23868	88.76996	2017	P.K. Chhetri*	N/A	Herbs, flower male cone reddish grown on shady area of temperate forest



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