

A preliminary study on the vegetative and flowering phenology including diversity of flower visitors in *Rhododendron cinnabarinum* Hook. f. subsp. *cinnabarinum* (Ericaceae Juss.) in and around Singalila National Park of Darjeeling Himalaya (India)

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Summary

During field studies at different places in Singalila National Park in Darjeeling Himalaya since May 2019 under a DST-funded major Research Project, an attempt was made to assess the diversity of insect and avian visitors reflecting the flowering phenology of *Rhododendron cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around the National Park. Besides flowering phenology, variation in different vegetative phenological features for a particular locality are also studied along with identified lichen association with its stem-branch and barks. For insect visitor study, a net sampling method was employed in the field. In net sampling, the number and type of visiting insects were recorded from 08:00 to 16:00 h on sunny days during the flowering season at altitudes ranging from 2900 m – 3636 m at different places of this National Park. The vast array of insects belonging to orders Hemiptera and Diptera is the indicative of flowering phenology of *Rhododendron cinnabarinum* Hook. f. subsp. *cinnabarinum* in Singalila National Park of Darjeeling Himalaya. Of these two orders, Hemiptera were considered the most diverse group. Among the Coleopteran families, notable flower visitors are Staphylinidae, while among the Thysanopterans, notable flower visitors are Phlaeothripidae. Other flower visitors such as three species of birds were also enumerated based on good photographic images taken during field visits, and these images were identified with the help of relevant taxonomic references and consultation with the experts from Zoological Survey of India.

Key words: Ericaceae, *Rhododendron cinnabarinum*, phenology, floral visitors, Darjeeling

1. Introduction

During field studies at different places in Singalila National Park from May 2019 to May 2022 under Department of Science & Technology and Biotechnology-funded major Research Project, an attempt was made to assess the diversity of vegetative phenology, insect and avian visitors reflecting flowering phenology of *Rhododendron cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around Singalila National Park of Darjeeling Himalaya. The species is facing tremendous threat to its existence day by day due to mainly anthropogenic causes. No detailed phenological data are available to date, and when available such data are ambiguous and a few, or species identification is not correct. No data available about flower visitors incl. pollinators of *Rhododendron cinnabarinum* Hook. f. including its subspecies, not only in Darjeeling Himalaya, but also in entire Eastern Himalayan region. Documentation of specific flower visitors/pollinators are urgently required for biodiversity as well as for *Rhododendron* conservation, not only in Darjeeling but also throughout the Himalayas.

Besides flowering phenology, variation in different vegetative phenological features for a particular locality are also studied along with identified lichen association with its stem-branch and barks.

Probably J. D. Hooker was first to explore the present area extensively in April-August, 1848 during his voyage to the Himalayas and he published “The *Rhododendron* of Sikkim Himalayas” in 1849, in which Darjeeling-Kalimpong areas was included under Sikkim. Since Hooker, several other workers like C. B. CLARKE (1882), HARA (1966, 1982), BISWAS (1966), CULLEN & CHAMBERLAIN (1978), CHAMBERLAIN (1982), CHAMBERLAIN et al. (1996), MUKHERJEE (1988), PRADHAN & LACHUNGPA (1990), LONG (1991), DAS (1995, 2004), HANBI & CHAMBERLAIN (2005), CHHETRI et al. (2005), RAI et al. (2013), GIBBS et al. (2011), BHATTACHARYYA & SANJAPPA (2014), GHOSH & MALLICK (2014), MAO et al. (2017),

PANDA (2021) and PANDA et al. (2022) surveyed the area and documented floristic elements in various ways, but very little or no investigations regarding vegetative and floral phenology and flower visitors were made.

2. Materials and Methods

For Phenological Studies: Relevant Taxonomic references and Herbarium specimens consultation were done in CAL (Central National Herbarium), BSIS (Industrial Section Indian Museum, Kolkata) and Lloyd Botanical Garden Herbarium, Darjeeling for preliminary information and species identification purpose. Field visits were carried out at the end of every month at different areas of Singalila National Park of Darjeeling Himalayas except during the animal breeding season (15th June to 15th September). Phenological data include nature of **Stem**-bark, stem-bark-associates like lichens, branch-stem nature, indumentums/scales if any, **leaf** indumentums/scales types, size-range, number of flowers per inflorescence, bracts/bracteoles-nature & number, presence of any mucilage like substances/not, **flowering** (time of beginning, peak & end-duration), flower-buds to flower formation duration, flower colour and colour change, odour if any, flowering time change if any (early or late) if unusually flower in other season, unusual flower nature in detail, floral parts in detail, *calyx*-nature, colour, union, indumentums etc., *corolla*-nature, indumentums, colour, inside colour markings for pollinator path etc., *stamens*-nature, number, size, colour, anther lobes nature, colour, indumentums etc., fruiting (duration, colour, persistent/not) and flower visitors (insects and birds.). Field data were written in specially prepared Field Note Book along with GPS data for each taxon available at different localities/single locality. Live photography was done for different populations using CANON 1500D DSLR Camera along with its Micro lens. Each and every part was also studied using a Dissecting Binocular Microscope for detailed study purpose in the Laboratory of Maulana Azad College, Kolkata.

Descriptive terminology for Phenological-morphology followed LAWRENCE (1951), FEATHERLY (1954), STEARN (1983), RADFORD (1987), VELDKAMP in VOGEL (1987) and Chamberlain et al. (1996) Botanical identity will be confirmed with consulting herbarium specimens in Central National Herbarium (CAL), Online Type images (Kew Herbarium) and relevant Taxonomic References. Important voucher specimens are deposited in the Laboratory of Angiosperm Taxonomy, Botany Dept., Maulana Azad College, Kolkata.

Flower visitors: As variations in the flowering phenology of *Rhododendron* spp. are greatly reflected by the diversity of mostly insect visitors, and major insects (usually belong to orders Diptera and Hemiptera) visiting the flowers also showing temporal variation in the flowering season, one commonly used sampling method was employed for collecting such pollinators-net sampling which was considered to be effective at capturing the most species and highest abundance of pollinators. For avian visitors, such as three species of birds were also enumerated based on good images taken during field study, and these images were identified with the help of relevant taxonomic references and consultation with the experts from Zoological Survey of India. Zoological identities of insects were confirmed up to family level in the Division of Entomology, PG department of Zoology, Maulana Azad College, Kolkata using a Carl Zeiss Trinocular Stereo Zoom Microscope model Stemi 305 and relevant taxonomic references (KJELLSSON 1985, JOHNSON & TRIPLEHORN 2005, GOULET & HUBER 1993, MITRA 2010). Important voucher specimens were deposited in the Entomology Laboratory, PG department of Zoology, Maulana Azad College, Kolkata, also one sample specimen will be deposited in ZSI, Kolkata after completion of the project work. Insect flower visitors were studied in the Entomology Laboratory, Post Graduate Department of Zoology, Maulana Azad College Kolkata. Images of insects were taken from Camera-fitted Carl Zeiss Trinocular Stereo Zoom Microscope (Model no. Stemi 305) set up in the Entomology Laboratory.

Net sampling: Flower-visiting insects were to be sampled along each 100 m 65 m belt transect. Four collectors were deployed among the eight transects at each site: two at each location. Flower-visitors were sampled using nets from all plant species along transects for two hours and fulfilled these conditions: concurrent sampling of crest and swale between collectors. Each transect would be sampled for 30 minutes by each collector. These measures would help to negate any effect of collector's bias. Flower-visitors were then be caught using nets and plastic containers, and were transferred into 5 ml vials for transportation. Net sampling at each site were conducted for three consecutive days in morning and afternoon sessions, the timing of which might be varied to best match the activity patterns of invertebrates. To increase the representation at the transect and above levels, and to minimise any potential effects of weather on captures, sampling were performed during fine weather, and pooled over the three days period. Sites were sampled in random order for each survey.

Overview and history of the study area: Singalila National Park (SNP) is a transboundary protected area with Nepal. Geographically, it is located 27°06'N to 29°19'N and 88°01'E to

97°23'E. It is situated on the north-western part of Darjeeling District. Total area is about 78.6 km². It is well known owing to the Sandakphu trekking route that runs through it. It is bordered on the north by the state of Sikkim, west by the country of Nepal while south & east by the state of West Bengal (Map 1). The Core Area of Singalila National Park is located on the Singalila Ridge at altitudes ranging from 2740 – 3636 m in Darjeeling district of West Bengal, although the average altitude of the Buffer area is about 1830 m Rivers Rammam and Srikhola flow down through the Park. Earlier Singalila Forest was under the control of the Raja of Sikkim. In 1882, the British Government obtained the Singalila forests on lease from the Sikkimese Raja. Later on, after Independence, this forest became the part of Darjeeling District (West Bengal) and in 1992, it was declared as the National Park for the conservation of this forest and it was under the Wildlife Forest Department and named it as "Singalila National Park". SNP is divided into two Ranges: I. North Range (Rimbick) and II. South Range (Maney bhanjyang). Within this two ranges there are four beats namely, a. Gairibas, b. Sandkphu, c. Rammam and d. Gorkhey.

The present study explored Tonglu and part of Tumling which are just outside of Singalila National Park (SNP). Besides, other areas explored such as Kaiakata-Kalipokhri roadside forests, BK Bhanjang, BK Bhanjang-Sandakphu trek route, Sandakphu proper, Sandakphu-Alle village, Sandakphu-Phalut route and Sandakphu-Gurdung roadside forests which fall inside SNP. SNP harbours diverse elements of tropical, subtropical, temperate and alpine vegetation. These nine populations of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* (mentioned above) were mostly observed in temperate to subalpine forests altitudes ranging from 2740 m to 3636 m Mostly observed in and around Sandakphu at altitudes ranging from 3353 m to 3636 m.

3. Results and Discussion

Present work embodies these nine populations of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* based on nine different localities in and around SNP. 12 vegetative, 23 floral and 6 fruiting phenological characters including character-states were observed and documented from these localities (Table 1 - 10) besides documentation of flower visitors (Table 11 - 12). The following 12 tables and 15 plates show comparative vegetative, floral, fruiting and insect and avian visitor diversity in 9 populations of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum*.

Vegetative phenology: Data were collected in respect to leaf indumentum, leaf-size, shape, colour, venation, apical bud scales, petiole nature, stem-colour, bark and branch colour, branches and bark-association, mainly with 3 genera and 6 species of lichens (Plates 1 - 3).

Table 1. Collection no, locality, time, altitude, habit-habitat of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around SNP (Singalila National Park).

Coll No.	Place of Collection	Month of Collection	Altitude (m NN)	Habit	Habitat
112,137, 212, 52, 227, 63, 77, 99, 102	Tonglu	January 2020, February 2021, April 2022, May 2019, May 2022, July 2019, September 2019, November 2019, December 2019.	3061-3070	Treelet up to 3 m high	Loose Rocky sandy soil
113,139, 214, 54, 228, 64, 78, 100, 103	Tumling	January 2020, February 2021, April 2022, May 2019, May 2022, July 2019, September 2019, November 2019, December 2019.	2970-2991	Treelet up to 4 m high	Loose Rocky sandy soil
147, 222, 58, 232, 80, 101, 104	Kaiakata-Kalipokhri roadside forest	February 2021, April 2022, May 2019, May 2022, September 2019, November 2019, December 2019.	3100-3186	Treelet up to 4 m high	Loose Rocky sandy soil
223, 59, 234, 81, 102, 105	BK Bhajang	April 2022, May 2019, May 2022, September 2019, November 2019, December 2019.	3250	Treelet up to 4 m high	Loose Rocky sandy soil
224, 60, 236, 82, 103, 106	BKB-Sandakphu roadside forest	April 2022, May 2019, May 2022, September 2019, November 2019, December 2019.	3250 – 3612	Treelet up to 4 m high	Loose Rocky sandy soil
225, 62, 238, 83, 104, 107	Sandakphu	April 2022, May 2019, May 2022, September 2019, November 2019, December 2019.	3612-3624	Treelet up to 5 m high	Loose Rocky sandy soil
226, 63, 239, 84, 105, 108	Sandakph-Gurdung roadside forest	April 2022, May 2019, May 2022, September 2019, November 2019, December 2019.	3612- 3592	Treelet up to 4 m high	Loose Rocky sandy soil
227, 64, 241, 85, 106, 110	Sandakphu-Alle roadside forest	April 2022, May 2019, May 2022, September 2019, November 2019, December 2019.	3612-3628	Treelet up to 5 m high	Loose Rocky sandy soil
229, 66, 243, 86, 107, 111	Sandakphu-Phalut roadside forest	April 2022, May 2019, May 2022, September 2019, November 2019, December 2019.	3612-3626	Treelet up to 5 m high	Loose Rocky sandy soil

Table 2. Colour of apical bud scales, bark, stem, bark & branch-associates of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around SNP (Singalila National Park).

apical bud scales colour	bark colour	stem colour	bark associates (Lichens)	branch-associates (Lichens)
reddish-brown	silvery-white	silvery-white to dark purple	<i>Usnea</i> spp. (2 different species); <i>Hypotrachyna</i> sp.; <i>H. cirrhata</i> (Fr.) Divakar et al.; <i>Parmotrema thomsonii</i> (Stirt.) Crespo et al.	<i>Usnea</i> spp. (2 different species); <i>Hypotrachyna</i> sp.; <i>H. cirrhata</i> ; <i>Parmotrema thomsonii</i>
yellowish-brown	dull white	dull white to dark purple	<i>Usnea</i> spp. (2 different species); <i>Hypotrachyna</i> sp.; <i>H. cirrhata</i> ; <i>Parmotrema thomsonii</i>	<i>Usnea</i> spp. (2 different species); <i>Hypotrachyna</i> sp.; <i>H. cirrhata</i> ; <i>Parmotrema thomsonii</i>
greenish to greenish with purple tinge toward apex	dull white	dull to silvery white	<i>Usnea</i> sp.; <i>Hypotrachyna</i> sp.; <i>Parmotrema thomsonii</i>	<i>Usnea</i> sp.; <i>Hypotrachyna</i> sp.; <i>Parmotrema thomsonii</i>
greenish to greenish-brown	blackish-brown	green, light brown to greenish-brown	<i>Usnea</i> sp.; <i>Hypotrachyna</i> sp.; <i>Parmotrema thomsonii</i>	<i>Usnea</i> sp.; <i>Hypotrachyna</i> sp.; <i>Parmotrema thomsonii</i>
greenish with purple tinge toward apex and base	blackish-brown	greenish to greenish-brown	<i>Usnea</i> sp.; <i>Hypotrachyna</i> sp.; <i>Parmotrema thomsonii</i>	<i>Usnea</i> sp.; <i>Hypotrachyna</i> sp.; <i>Parmotrema thomsonii</i>
greenish-brown	dull silvery-white	silvery-white	<i>Usnea</i> spp. (2 different species)	<i>Usnea</i> spp. (2 different species)
purple red	dull silvery-white	dull brown	<i>Usnea</i> spp. (2 different species)	<i>Usnea</i> spp. (2 different species)

apical bud scales colour	bark colour	stem colour	bark associates (Lichens)	branch-associates (Lichens)
purple red	dull silvery-white	dull yellow	<i>Usnea</i> spp. (2 different species); <i>Hypotrachyna cirrhata</i>	<i>Usnea</i> spp. (2 different species); <i>Hypotrachyna cirrhata</i>
purple red	dull silvery-white	dull yellow	<i>Usnea</i> sp.; <i>Hypotrachyna</i> sp.; <i>Parmotrema thomsonii</i>	<i>Usnea</i> sp.; <i>Hypotrachyna</i> sp.; <i>Parmotrema thomsonii</i>

BR=Bryophyte; PT=Pteridophyte; LI=Lichen

##Coll. no. and localities like Table 1

Table 3. Leaf apex, margin, surfaces, length & breadth of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around SNP (Singalila National Park).

Lf apex	Lf margin	Lf surface ad	Lf surface ab	Lf length	Lf breadth
mucronate to rarely obtuse	entire-slightly wavy	glabrous	sparsely appressed rounded blackish brown faded scales	3.5-9.0 cm	1.4-3.0 cm
rounded-obtuse to rarely mucronate	entire-slightly wavy	glabrous	densely appressed rounded pale brown scales	5.0-8.5 cm	1.7-3.8 cm
rounded-obtuse	entire to finely winged	glabrous	densely appressed rounded pale brown scales	5.0-7.0 cm	2.8-3.5 cm
Rounded-obtuse to mucronate	entire, slightly rolled toward abaxial side	glabrous	densely appressed rounded pale brown scales	3.6-7.9 cm	1.8-3.7 cm
Mucronate to obtuse	entire-slightly wavy	glabrous	sparsely appressed rounded pale brown scales	5-10 cm	1.6-4 cm
mucronate	entire-wavy	glabrous	few rounded pale brown faded scales	4-11 cm	1.5-4 cm
mucronate	entire-wavy	glabrous	densely appressed rounded pale brown faded scales	5-9 cm	1.6-4 cm
mucronate	entire-wavy	glabrous	densely appressed rounded pale brown faded scales	4.0-11 cm	1.7-4.5 cm
mucronate	entire-wavy	glabrous	densely appressed rounded pale brown faded scales	4.0-10 cm	1.4-4.0 cm

Lf=Leaf; ad=adaxial surface; ab=abaxial surface

##Coll no. & Localities like Table 1

Table 4. Petiole length and indumentum of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around SNP (Singalila National Park).

Adaxial petiole	Abaxial Petiole	Petiole length
purple-brown, glabrous	greenish-purple beset with a few rounded faded blackish brown scales	7-12 mm long
light green (immature), glabrous	light green beset with dense rounded white scales (immature)	4-7 mm long
purple-brown, glabrous	greenish-white beset with dense rounded blackish brown scales	7-19 mm long
light-purple, glabrous	light green beset with dense rounded blackish brown scales	8-16 mm long
purple-brown, glabrous	light green beset with a few rounded blackish brown scales	7-15 mm long
purple-brown, glabrous	light green beset with a few rounded blackish brown scales	8-18 mm long
purple-brown, glabrous	light green beset with a few rounded blackish brown scales	10-18 mm long
purple-brown, glabrous	light green beset with a few rounded blackish brown scales	8-12 mm long
purple-brown, glabrous	light green beset with a few rounded blackish brown scales	7-14 mm long

##Coll no. & Localities like Table 1

Flowering phenology

Data were collected in respect to: flower length, no of flowers per inflorescence, flowering bracts, flowering time, corolla colour, size, shape, corolla indumentum, corolla odour, calyx colour, shape, size, indumentum, stamens-number, filament indumentum, length, colour, anther shape, colour, pistil length, ovary indumentum, length, style length and indumentum, stigma nature (Tables 5 - 9, Plates 4 - 12).

Table 5. Flowering phenology of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around SNP (Singalila National Park): Part A.

Coll No.	Locality	Date of collection	Flower length	Fl bract	No of fl/infl	Flowering time
52, 227, 77, 97	Tonglu	17.05.2019 19.09.2019 21.05.2022 13.11.2018	44-50 mm long incl. pedicel (4-7 mm)	2; 8-9 mm long, narrowly linear	3-4-flowered	May (coll no. 227), September (coll no. 77), November (no.97)
54, 228, 78	Tumling	17.05.2019 18.09.2019 21.05.2022	40-49 mm long incl. pedicel (5-8 mm)	2; 8-10 mm long, narrowly linear	3-5-flowered	May (coll no. 227), September (coll no. 77), November (coll no.97)
58, 238, 80, 101	Kaiakata -Kalipokhri roadside forest	18.05.2019 19.09.2019 18.11.2019 22.05.2022	40-55 mm long incl. pedicel (7-10 mm)	2; 8-10 mm long, narrowly linear	3-flowered	May (coll no. 227), September (coll no. 77), November (coll no.97)
59, 234	BK Bhanjang	18.05.2019 22.05.2022	40-52 mm long incl. pedicel (6-8 mm)	2; 7-9 mm long, narrowly linear	3-5-flowered	May (coll no. 227), September (coll no. 77), November (coll no.97)
60, 236	BKB-Sandakphu roadside forest	18.05.2019 22.05.2022	38-56 mm long incl. pedicel (5-8 mm)	2; 7-9 mm long, narrowly linear	3-5-flowered	May (coll no. 227), September (coll no. 77), November (coll no.97)
62, 238; 06	Sandakphu	18.05.2019 22.05.2022	46 – 50 mm long incl. pedicel (6-8 mm)	2; 7-10 mm long, narrowly linear	4-6-flowered	May (coll no. 227), September (coll no. 77), November (coll no.97)
63, 239	Sandakphu-Gurdung roadside forest	18.05.2019 22.05.2022	42 – 52 mm long incl. pedicel (6-8 mm)	2; 7-10 mm long, narrowly linear	3-5-flowered	May (coll no. 227), September (coll no. 77), November (coll no.97)
64, 241	Sandakphu-Aille village	18.05.2019 22.05.2022	46 – 58 mm long incl. pedicel (6-8 mm)	2; 7-10 mm long, narrowly linear	4-6-flowered	May (coll no. 227), September (coll no. 77), November (coll no.97)
66, 243	Sandakphu-Phalut roadside forest	18.05.2019 22.05.2022	44 – 56 mm long incl. pedicel (6-8 mm)	2; 7-10 mm long, narrowly linear	3-6-flowered	May (coll no. 227), September (coll no. 77), November (coll no.97)
Coll no. = collection number; Fl=flowers; infl=inflorescence						

Table 6. Flowering phenology of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around SNP (Singalila National Park): Part B.

Locality	number of calyx lobes	calyx length & breadth	calyx indumentum	calyx color
Tonglu	5, subequal	2×2 mm to 2×1.5 mm	glabrous inside, appressed with dense lepidote scales outside	dark purple red
Tumling	5, subequal	2×2 mm to 2×1.5 mm	glabrous inside, appressed with dense lepidote scales outside	dark purple red
Kaiakata-Kalipokhri roadside forest	5, subequal	2×1.5 mm to 2×1.0 mm	glabrous inside, appressed with dense lepidote scales outside	dark purple red
BK Bhanjang	5, subequal	2×1.5 mm	glabrous inside, appressed with dense lepidote scales outside	dark purple red
BKB-Sandakphu roadside forest	5, subequal	2×1.5 mm to 2×1.0 mm	glabrous inside, appressed with dense lepidote scales outside	dark purple red
Sandakphu	5, subequal	2×2 mm, 2×1.5 mm to 2×1.0 mm	glabrous inside, appressed with dense lepidote scales outside	dark purple red
Sandakphu-Gurdung roadside forest	5, subequal	2×2 mm 2×1.5 mm to 2×1.0 mm	glabrous inside, appressed with dense lepidote scales outside	dark purple red

Locality	number of calyx lobes	calyx length & breadth	calyx indumentum	calyx color
Sandakphu-Alle village	5, subequal	2×2 mm 2×1.5 mm to 2×1.0 mm	glabrous inside, appressed with dense lepidote scales outside	dark purple red
Sandakphu-Phalut roadside forest	5, subequal	2×2 mm 2×1.5 mm to 2×1.0 mm	glabrous inside, appressed with dense lepidote scales outside	dark purple red

##Coll no. in similar order of sequence like Table 5

Table 7. Flowering phenology of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around SNP (Singalila National Park): Part C.

corolla indumentum	corolla colour	corolla odour	corolla shape	corolla size
glabrous inside, but with a few lepidote scales along basal tube outside	cinnabar-red	mildly aromatic scented	tubulo-campanulate	38-46x35-38mm
glabrous inside, glabrous and slightly glaucous outside	orange-red to cinnabar-red	not-scented	tubulo-campanulate	32-40x28-34mm
glabrous inside, but with a few lepidote scales along basal tube outside	dark purple-red to salmon-red	not-scented	tubulo-campanulate	45x50mm
glabrous inside, but with a few lepidote scales along basal tube outside	dark purple-red to salmon-red	not-scented	tubulo-campanulate	36-44x32-38mm
glabrous inside, glabrous and slightly glaucous outside	cinnabar-red	not scented	tubulo-campanulate	32-42x28-34mm
glabrous inside, glabrous and slightly glaucous outside	orange-red, salmon-red to cinnabar-red	not scented	tubulo-campanulate	38-47x32-39mm
glabrous inside, glabrous and slightly glaucous outside	orange-red to cinnabar-red	not scented	tubulo-campanulate	32-40x28-34mm
glabrous inside, glabrous and slightly glaucous outside	orange-red to cinnabar-red	not scented	tubulo-campanulate	30-40x28-32mm
glabrous inside, glabrous and slightly glaucous outside	orange-red to cinnabar-red	not scented	tubulo-campanulate	32-42x28-34mm

##locality and coll no. in similar order of sequence like Table 5

Table 8. Flowering phenology of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around SNP (Singalila National Park): Part D.

No of stamens	length of stamens	length of filaments	colour of filament	filament indumentum	length of anther lobes	anther colour
10	28-40 mm long	26-38 mm long	purple pink to light pink toward apex	basally with pilose white hairs	1.5-2 mm long	blackish-brown to purple-brown
10 (-8)	22-28 mm	5-6 mm long	purple pink to light pink toward apex	basally with pilose white hairs	1.5-2 mm long	blackish-brown to purple-brown
10	26-37 mm long (April-May); 18-32 mm long (November)	25-36 mm long (April-May); 16.5-30.5 mm long (November)	purple pink to light pink toward apex	basally with pilose white hairs in all	c. 1.5 mm long	blackish-brown to purple-brown
10	21-31 mm	20-29 mm long	purple pink to light pink toward apex	basally with pilose white hairs	1.5-2 mm long	blackish-brown to purple-brown
10 (-8)	22-28 mm long	21-26 mm long	purple pink to light pink toward apex	basally with pilose white hairs	1.5-2 mm long	blackish-brown to purple-brown
10 (-8)	22-35 mm long	20-33 mm long	purple pink to light pink toward apex	glabrous	c. 2 mm long	blackish-brown to purple-brown
10	26-39 mm long	24-37 mm long	purple pink to light pink toward apex	basally beset with pilose white hairs	c. 2 mm long	blackish-brown to purple-brown
10	26-32 mm long	24-30 mm long	purple pink to light pink toward apex	glabrous	1.5-2 m long	blackish-brown to purple-brown
10	28-34 mm long	26-32 mm long	purple pink to light pink toward apex	basally with pilose white hairs	1.5-2 mm long	blackish-brown to purple-brown

##Coll no. & locality similar to Table 5

Table 9. Flowering phenology of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around SNP (Singalila National Park): Part F.

pistil length	ovary size	ovary shape	ovary colour	ovary indumentum	style length & colour	stigma
36-42mm long	5-6x3 mm long	Oblong to oblong-ovoid	light green	beset with dense rounded to oval white lepidote scales	32-37 mm long, purple-pink	c. 1 mm long, capitate to truncate
36-40mm long	6x3 mm long	Oblong to oblong-ovoid	light green	beset with dense rounded to oval white lepidote scales	31-35 mm long, purple-pink	c. 1 mm long, capitate to truncate
34-39mm long (April-May); c. 35 mm long (November)	7-8x3mm (April-May); c.6 mm long	Oblong to oblong-ovoid	light green	beset with dense rounded to oval lepidote scales.	28-32 mm long (April-May); c.29 mm long; dark pink	c. 1 mm long, capitate to truncate (in all time)
35-37 mm long	6-7x3mm	Oblong to oblong-ovoid	light green	beset with dense rounded to oval lepidote scales	28-29 mm long, dark pink	c.1 mm long, capitate to truncate.
38-41 mm long	5-6x3 mm	Oblong to oblong-ovoid	light green	beset with dense rounded to oval lepidote scales	c. 35 mm long, dark pink	c.1 mm long, capitate to truncate.
34-43 mm long	5-7 mm long	Oblong to oblong-ovoid	light green	beset with dense rounded to oval lepidote scales	26-37 mm long, purple pink	c.1 mm long, capitate to truncate.
34-42 mm long	5-6 mm long	Oblong to oblong-ovoid	light green	beset with dense rounded to oval lepidote scales	32-38 mm long, purple pink	c.1 mm long, capitate to truncate.
32-37 mm long	5-7 mm long	Oblong to oblong-ovoid	light green	beset with dense rounded to oval lepidote scales	30-35 mm long, purple-pink	c.1 mm long, capitate to truncate, light green.
35-41 mm long	5-6 mm long	Oblong to oblong-ovoid	light green	beset with dense rounded to oval lepidote scales	30-36 mm long, purple-pink	c.1 mm long, capitate to truncate, light green.

##Coll no. & locality similar to Table 5

Table 10. Fruiting phenology of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around SNP (Singalila National Park).

Coll no.	Fr shape	collection time	Fr colour (mature)	Fr colour (immature)	Fr indum	Fr length	Fr breadth
77	cylindric	September 2019	green-ish-brown	dark green	beset with few rounded to oval lepidote scales	10-12 mm long	4-5 mm broad
78	cylindric	September 2019	green-ish-brown	dark green	beset with few rounded to oval lepidote scales	10-12 mm long	4-6 mm broad
101	cylindric	November 2019	black-ish-brown	dark green	beset with few rounded to oval lepidote scales	8-10 mm long	4-5 mm broad
103	cylindric	November 2019	black-ish-brown	dark green	beset with few rounded to oval lepidote scales	10-13 mm long	4-5 mm broad
82	cylindric	September 2019	green-ish-brown	dark green	beset with few rounded to oval lepidote scales	9-12 mm long	4-5 mm broad
83	cylindric	September 2019	green-ish-brown	dark green	beset with few rounded to oval lepidote scales	8-12 mm long	4-5 mm broad
105	cylindric	November 2019	black-ish-brown	dark green	beset with few rounded to oval lepidote scales	10-12 mm long	4-5 mm broad
85	cylindri	September 2019	Green-ish-brown	dark green	beset with few rounded to oval lepidote scales	10-12 mm long	4-5 mm broad
107	cylindric	November 2019	black-ish-brown	dark green	beset with few rounded to oval lepidote scales	10-12 mm long	4-5 mm broad

Fr=fruit; indum=indumentum;

Flower visitors: Both insect and avian visitors were observed in *Rhododendron cinnabarinum* Hook. f. subsp. *cinnabarinum* in four different populations of Darjeeling Himalaya (Table 11, 12; Plates 13-15). Insect visitors were observed in two distinct populations of Darjeeling Himalaya viz., Tonglu and Tumling based on Net sampling method in May 2019 and 2022, while three different species of avian visitors were observed in three different localities of Darjeeling Himalaya viz., Tonglu, Sandakphu and Sandakphu-Phalut road side forest based on good photographic images taken from CANON 1500D DSLR camera in May 2019 and 2022.

Table 11. Insect Flower Visitors: The following orders, families, tribes and genus observed in *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in two distinct populations viz., Tonglu and Tumling based on Net sampling method. Insect flower visitors were studied in the Entomology Laboratory, Post Graduate Department of Zoology, Maulana Azad College Kolkata. Images of insects were taken from Camera-fitted Carl Zeiss Trinocular Stereo Zoom Microscope (Model No. Stemi 305) set up in the Entomology Laboratory.

Localities	Collection no.	Order	Suborder	Family	Subfamily	Tribe	Genus
Tonglu & Tumling	DKS 1.ii.a	Diptera		Sciaridae			
	DKS 1.iv.a	Diptera		Dolichopodidae			
	DKS 1.iii.a	Hemiptera	Auchenorrhyncha	Cicadellidae			
	DKS 1.v.b	Hemiptera	Heteroptera	Anthocoridae			<i>Anthocoris</i>
	DKS 1.v.c	Hemiptera	Heteroptera	Miridae			
	DKS 1.i.a	Thysanoptera		Phlaeothripidae			
	DKS 1.vii.a	Coleoptera		Staphylinidae	Omalinae	Anthophagini	

#Genus and Species level identification is under process at Zoological Survey of India

Table 12. Avian Flower Visitor (Passeriformes): Following three species of birds observed in *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* in three distinct populations viz., Tonglu, Sandakphu and Sandakphu-Phalut road side forest based on good photographic images.

Localities	Date & time of flower visitation	Family	Genus	species
Tonglu	21/05/2022 at 2.10 PM	Paradoxornithidae	<i>Fulvetta</i>	<i>Fulvetta vinipectus</i> (Hodgson, 1837) [White-browed Fulvetta]
Sandakphu	23/05/2022 at 10.10 AM	Phylloscopidae	<i>Phylloscopus</i>	<i>Phylloscopus subviridis</i> (Brooks, 1872) [Brooks's Leaf Warbler]
Sandakphu-Phalut Road side Forest	19/05/2019 at 9.20 AM	Nectariniidae	<i>Aethopyga</i>	<i>Aethopyga ignicauda</i> (Hodgson, 1837) [Fire-tailed Sunbird]

Species level identification was made by Dr. Dipak Kumar Som and an expert at Zoological Survey of India, Kolkata

Conclusion

The above vegetative, floral and fruiting phenological data of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* including insect and avian visitor data based on nine different natural populations in Darjeeling Himalaya, are unique and mostly new features which may help to understand range of variation as well as to help climate change study when these will compare with past data (if and when available). Documentation of flower visitors including specific pollinators of *R. cinnabarinum* Hook. f. subsp. *cinnabarinum* are urgently required for biodiversity as well as *Rhododendron* conservation purpose, not only in Darjeeling but also throughout Indian Himalayas. This work will be a new raw material cum model for future climate change study not only in *Rhododendron* but also for other plants in respect to biodiversity conservation.

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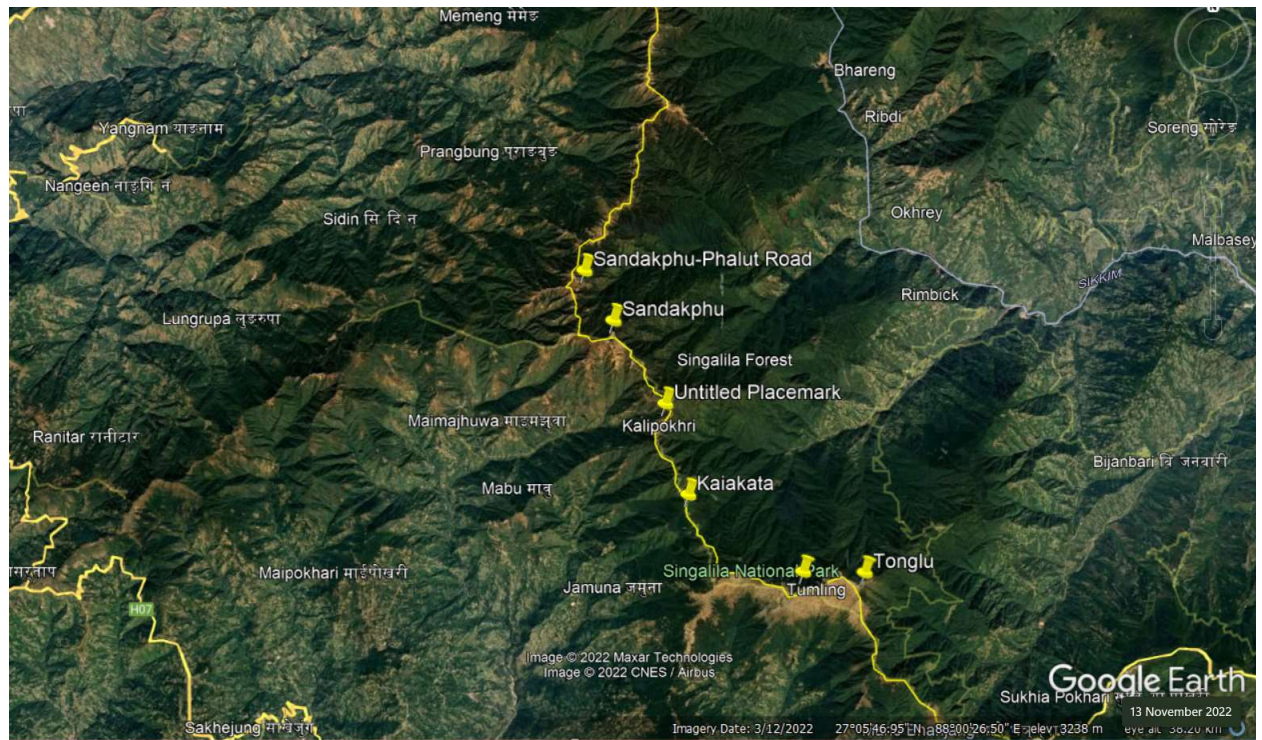
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Map 1. Study area distribution of *Rhododendron cinnabarinum* Hook. f. subsp. *cinnabarinum* in and around Singalila National Park of Darjeeling Himalaya (satellite imagery).

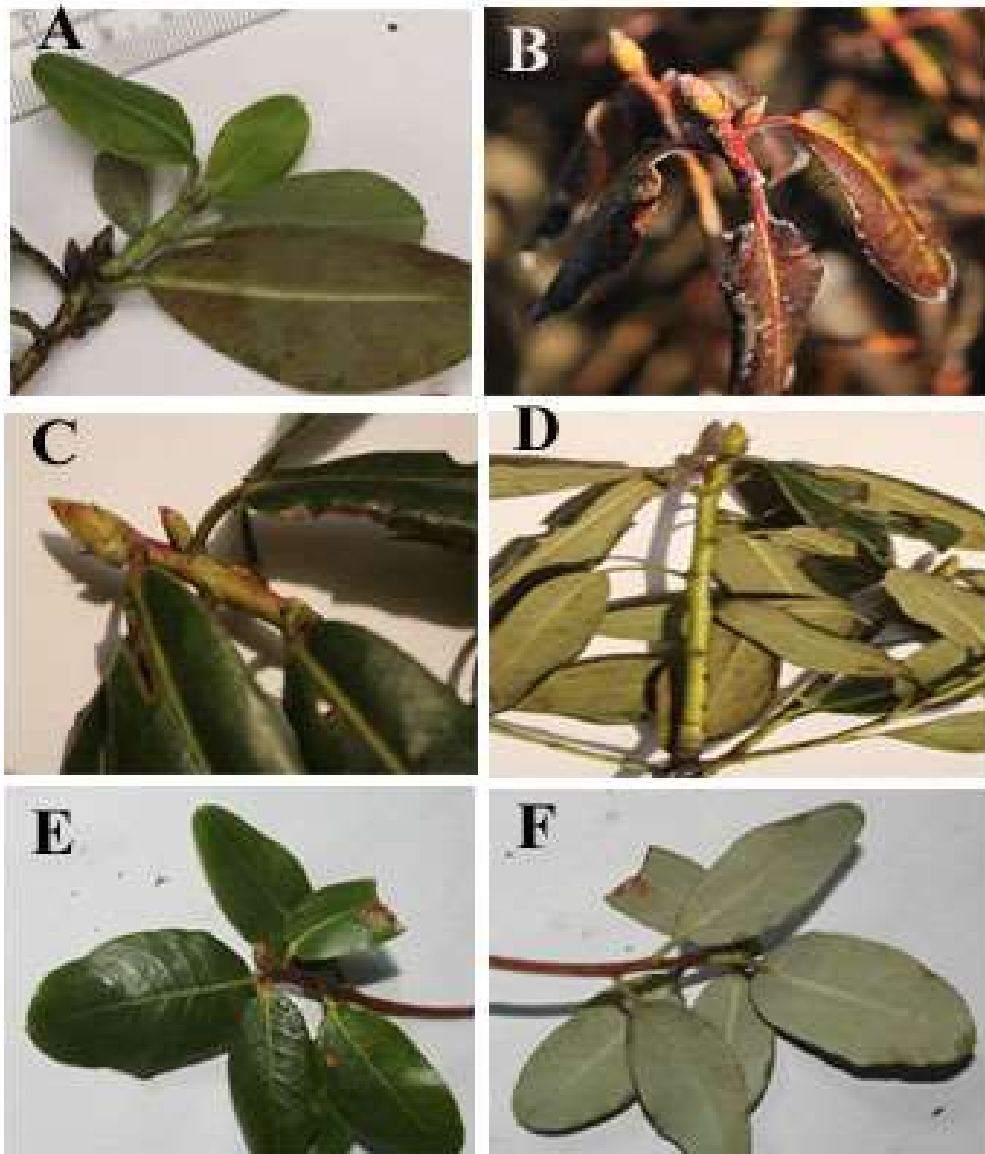


Plate 1. Vegetative phenological features of *Rhododendron cinnabarinum* subsp. *cinnabarinum* in Darjeeling Himalaya: **A.** apical bud scales, abaxial leaves and branches observed at Tumling in September 2019; **B.** Apical bud scales observed at Tumling in Januar 2020; **C-D.** apical bud scales observed at Tumling in July 2019; **E-F.** Adaxial and abaxial leaf surfaces observed at Tumling in July 2019.

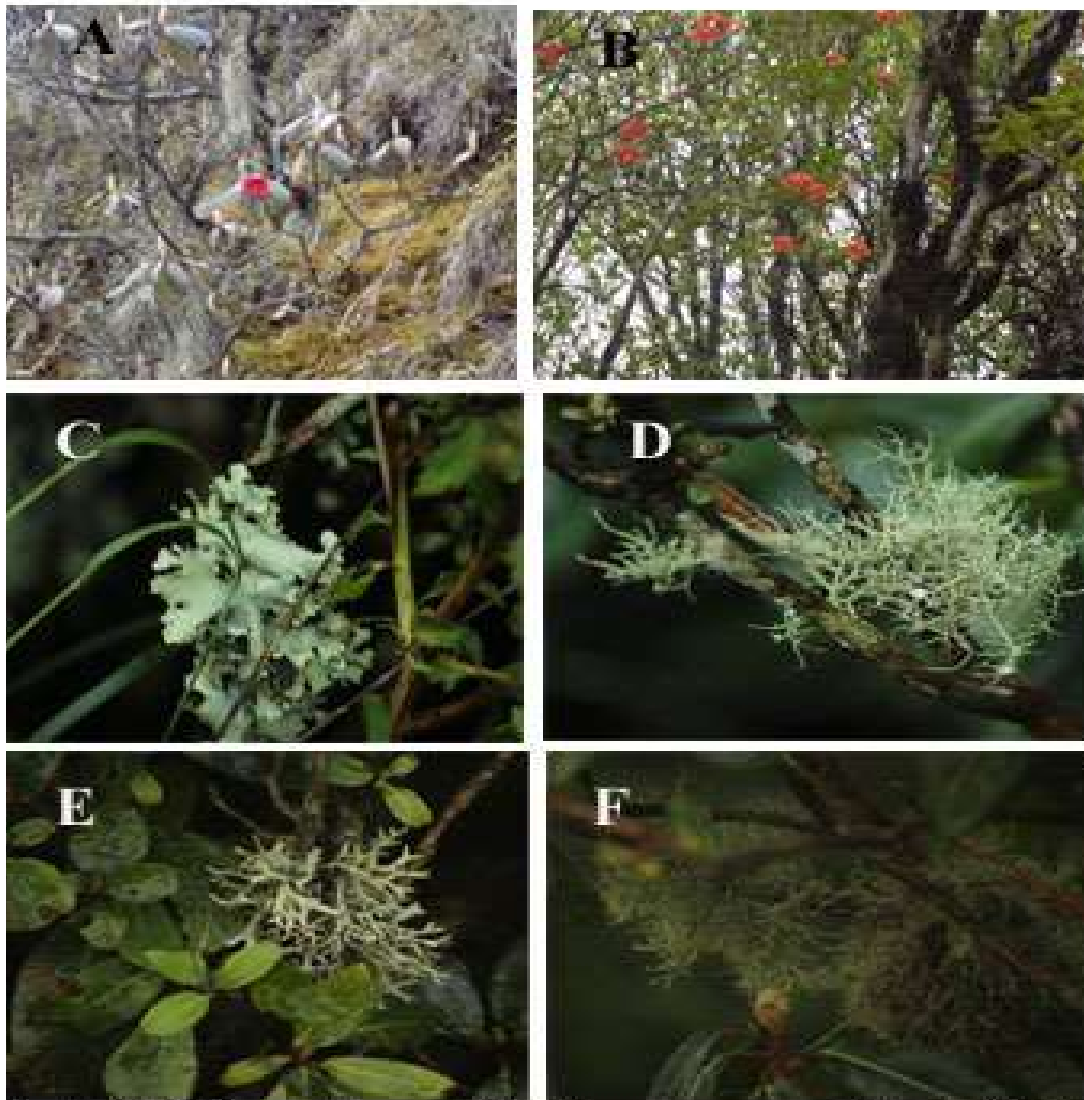


Plate 2. Different types of Lichens are associated with the bark and branches of *Rhododendron cinnabarinum* subsp. *cinnabarinum* in Darjeeling Himalaya: **A.** *Usnea* sp. observed at Sandakphu in May 2022; **B.** *Usnea* sp. observed at Tonglu in May 2019; **C.** *Parmotrema thomsoni* observed on the stem and branches at Tumling in July 2019; **D & F.** *Usnea* sp. observed at Tumling in July and September 2019; **E.** *Hypotrachyna cirrhata* observed at Tumling in September 2019.

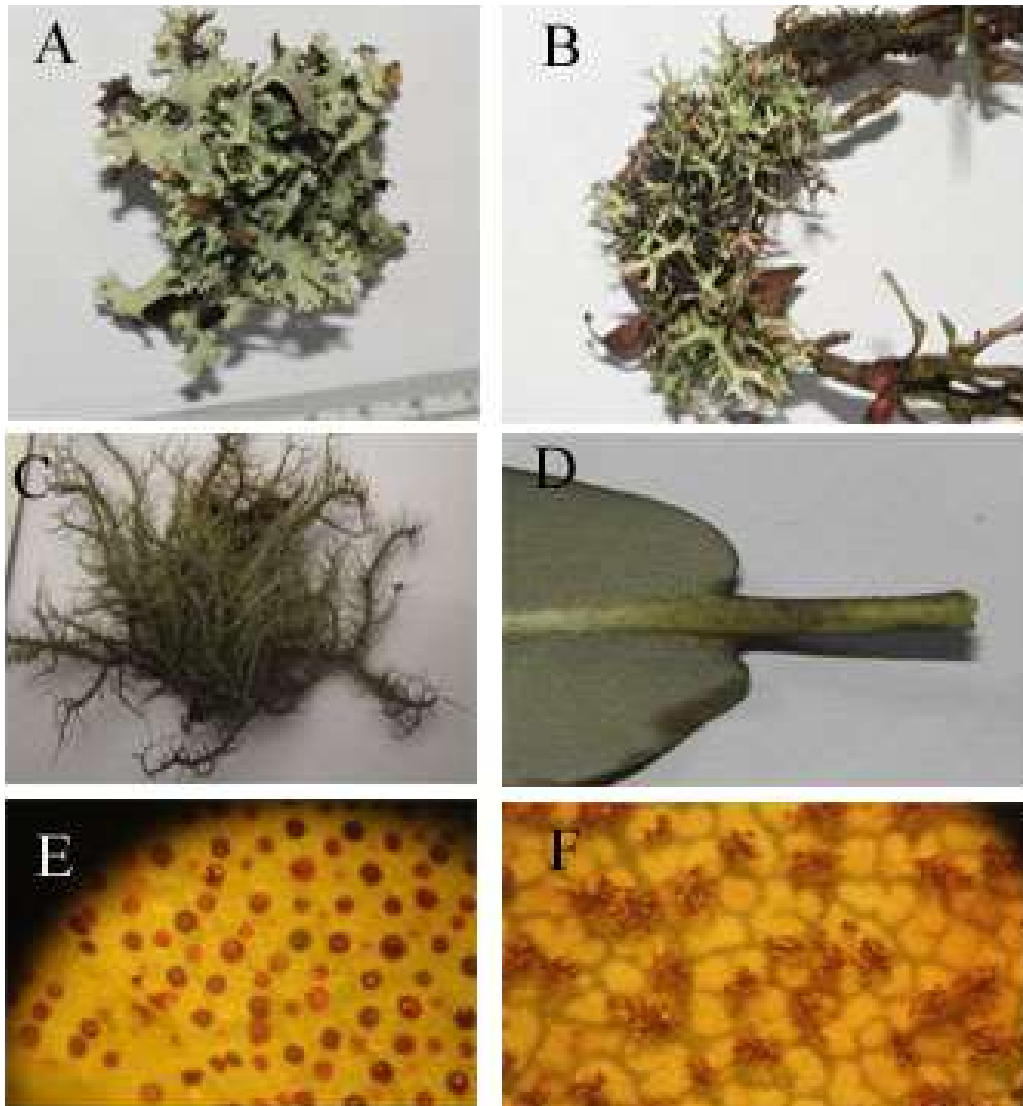


Plate 3. Clear images of Lichens and lepidote scales in *Rhododendron cinnabarinum* subsp. *cinnabarinum* in Darjeeling Himalaya: **A-C.** Lichens observed on the branches at Tumling in July and September 2019 (A. *Parmotrema thomsoni*, B. *Hypotrachyna cirrhata*, C. *Usnea* sp.); **D.** lepidote scales seen on abaxial leaf surface; **E-F.** Microscopic magnified images of lepidote scales of abaxial leaf surface (younger and older leaves respectively).



Plate 4. A-D. Flowering phenology observed in *Rhododendron cinnabarinum* subsp. *cinnabarinum* at Kaikata-Kalipokhri roadside forest approximately 4 km area in May 2019 and May 2022; E. Flowering phenology observed at Sandakphu-Phalut roadside forest in May 2019; F. Flowering phenology observed at Tumling in May 2022.



Plate 5. **A-B.** Flowering phenology observed in *Rhododendron cinnabarinum* subsp. *cinnabarinum* at BK Bhanjang in May 2019; **C.** Flowering phenology observed in between BK Bhanjang and Sandakphu in May 2022; **D-F.** Flowering phenology observed in and around Sandakphu in May 2019.



Plate 6. A-D. Flowering phenology of *Rhododendron cinnabarinum* subsp. *cinnabarinum* observed at Tumling not in flowering time, but in November 2019 [uncommon flowering].



Plate 7. A-F. Flowering phenology of *Rhododendron cinnabarinum* subsp. *cinnabarinum* observed along Sandakphu-Phalut roadside forest in May 2019 and May 2022.

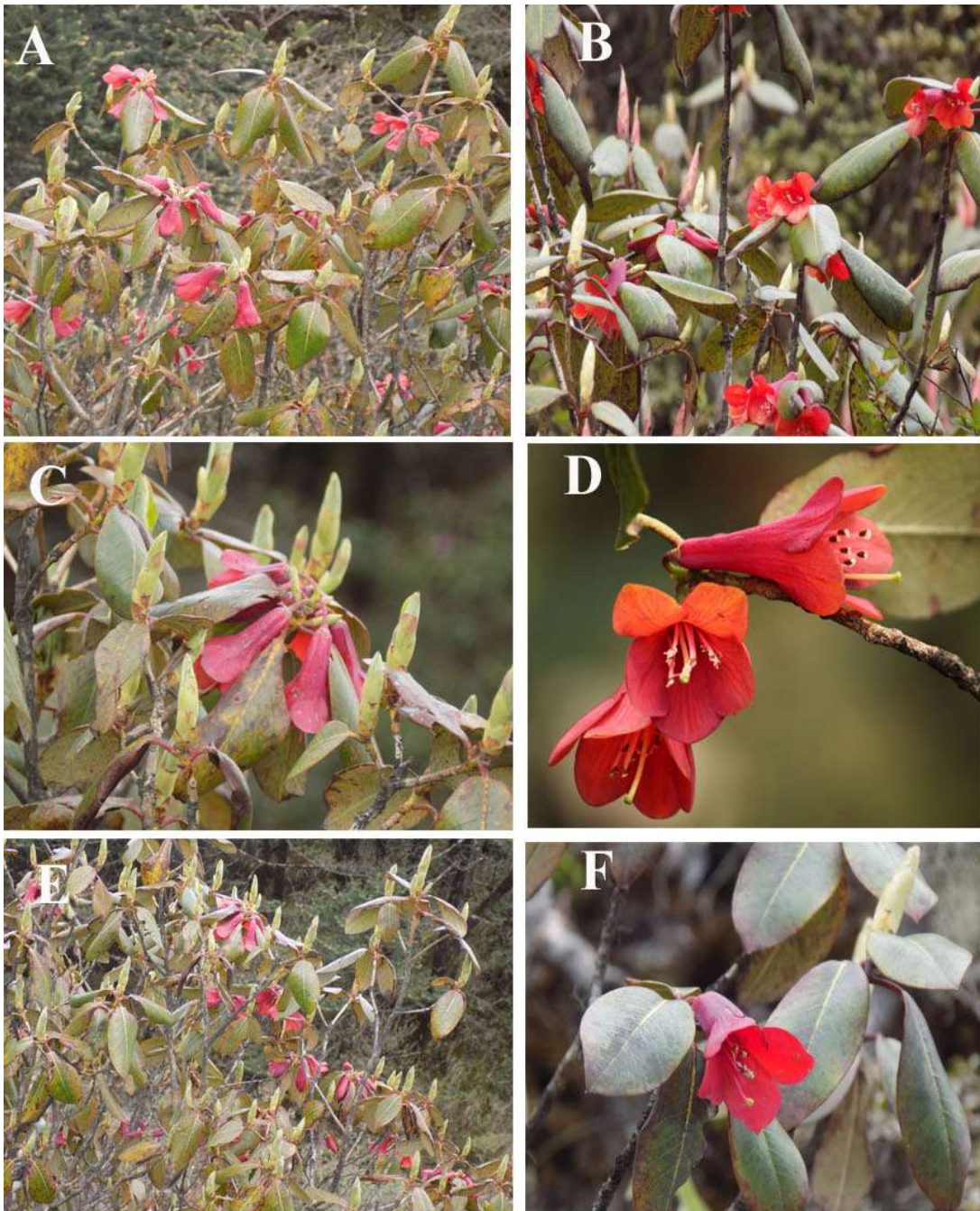


Plate 8. A-F. Flowering phenology of *Rhododendron cinnabarinum* subsp. *cinnabarinum* observed along Sandakphu-Gurdung trek route (approx. 4 km area) in May 2019 and May 2022.



Plate 9. A-C. Uncommon flowering time observed in *Rhododendron cinnabarinum* subsp. *cinnabarinum* at Tonglu (A) and tumling (B & C) in September 2019.



Plate 10. Dissected flower parts of *Rhododendron cinnabarinum* subsp. *cinnabarinum* observed along Kaiakata-Kalipokhri roadside forest in November 2019 (uncommon flowering time).



Plate 11. Dissected flower parts of *Rhododendron cinnabarinum* subsp. *cinnabarinum* observed along Kaiakata-Kalipokhri roadside forest in November 2021 (uncommon flowering time).

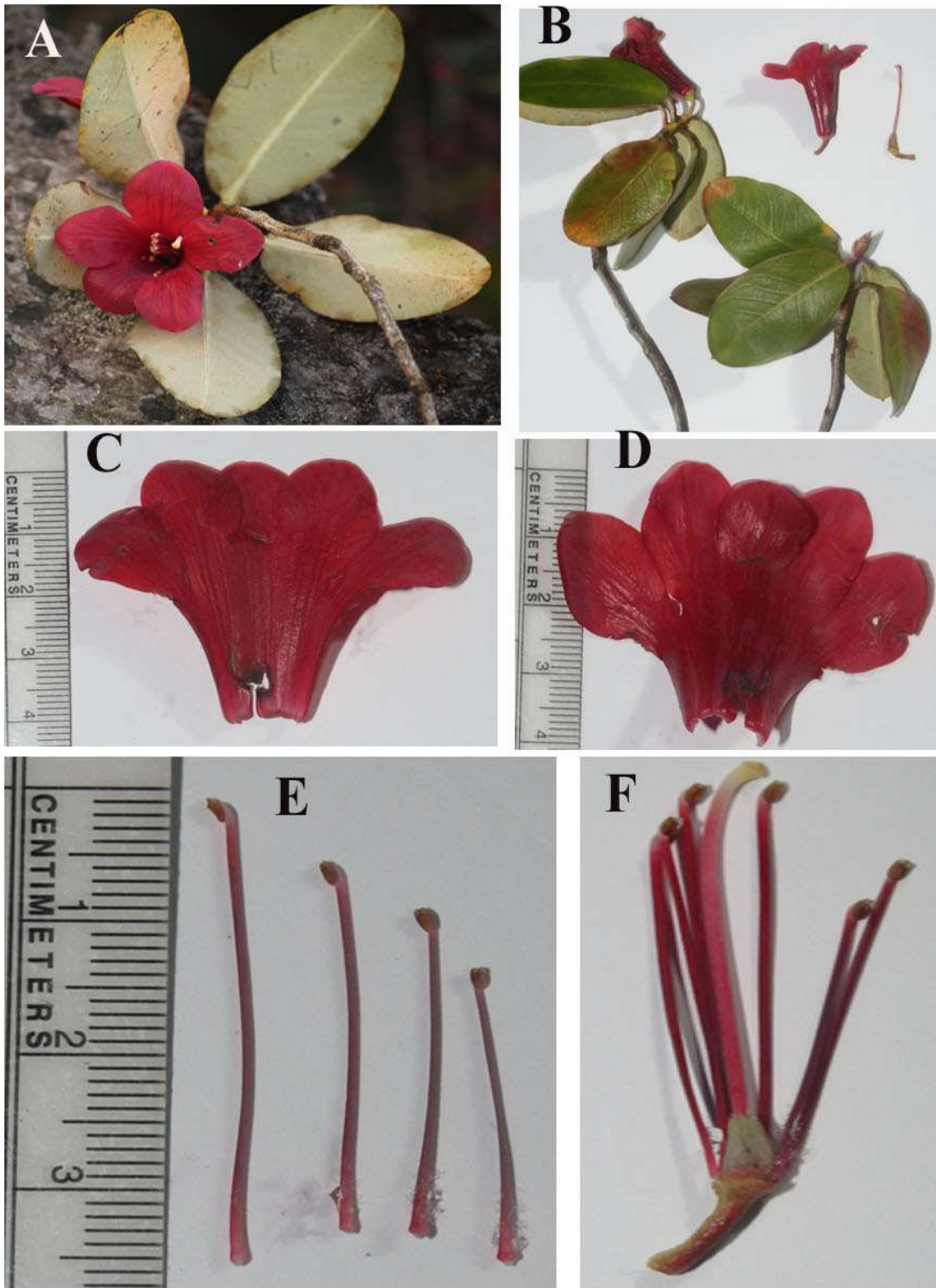


Plate 12. A-F. Dissected flower parts of *Rhododendron cinnabarinum* subsp. *cinnabarinum* observed at BK Bhanjang in November 2019 (uncommon flowering time). A-B. Flowering twigs close up; C-D. Corolla split open showing both sides; E. Showing four separate stamens with scale; F. Eight stamens are encircling the pistil.

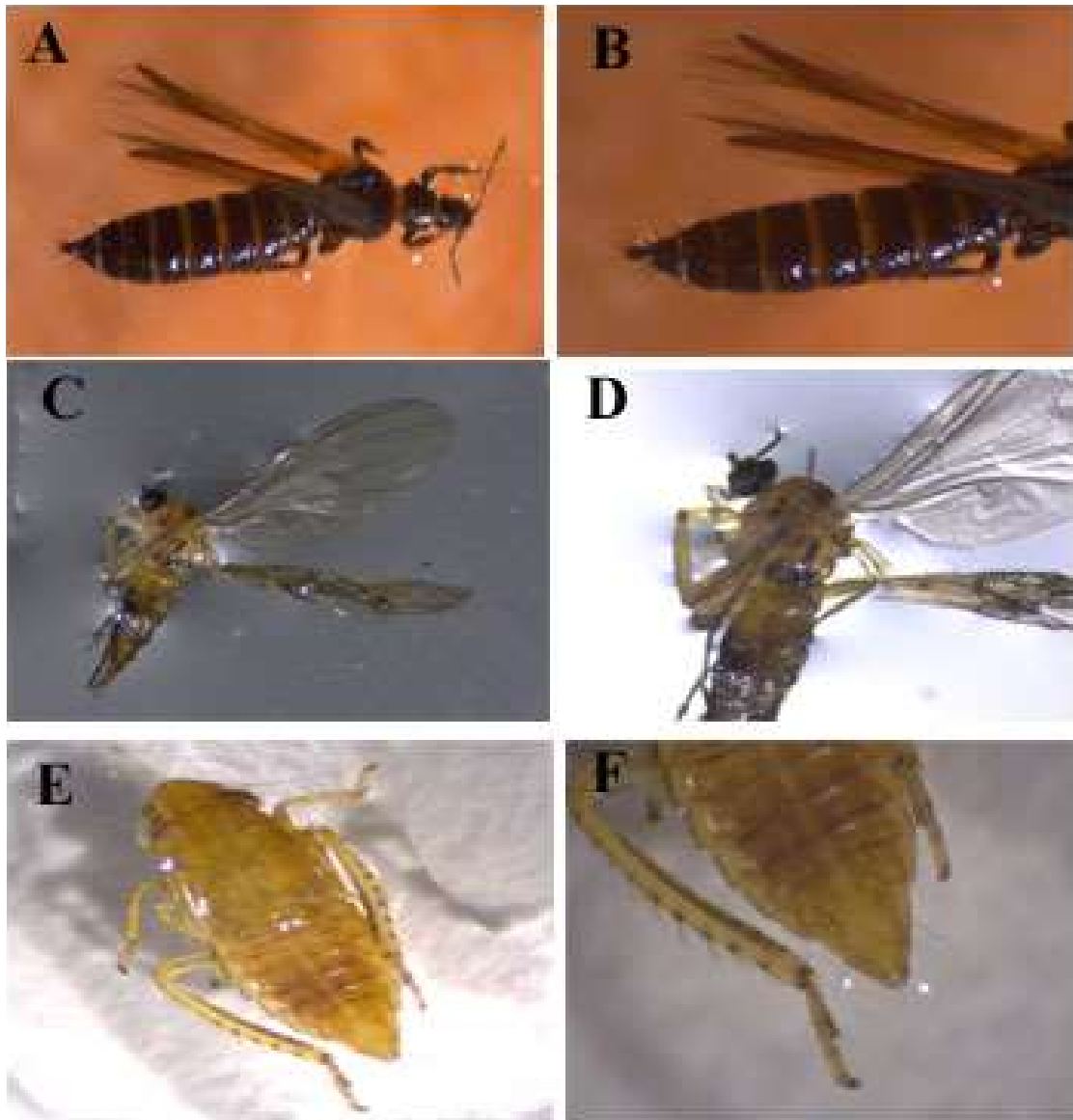


Plate 13. Insect flower visitors observed inside flowers of *Rhododendron cinnabarinum* subsp. *cinnabarinum* at Tonglu-Tumling in Darjeeling Himalaya in May 2019: **A-B.** order Thysanoptera family Phlaeothripidae; **C-D.** order Diptera family Sciaridae; **E-F.** order Hemiptera suborder Auchenorrhyncha - family Cicadellidae [these insect images were taken from camera-fitted Carl-Zeiss Trinocular Stereo Zoom Microscope Model No. Stemi 305].

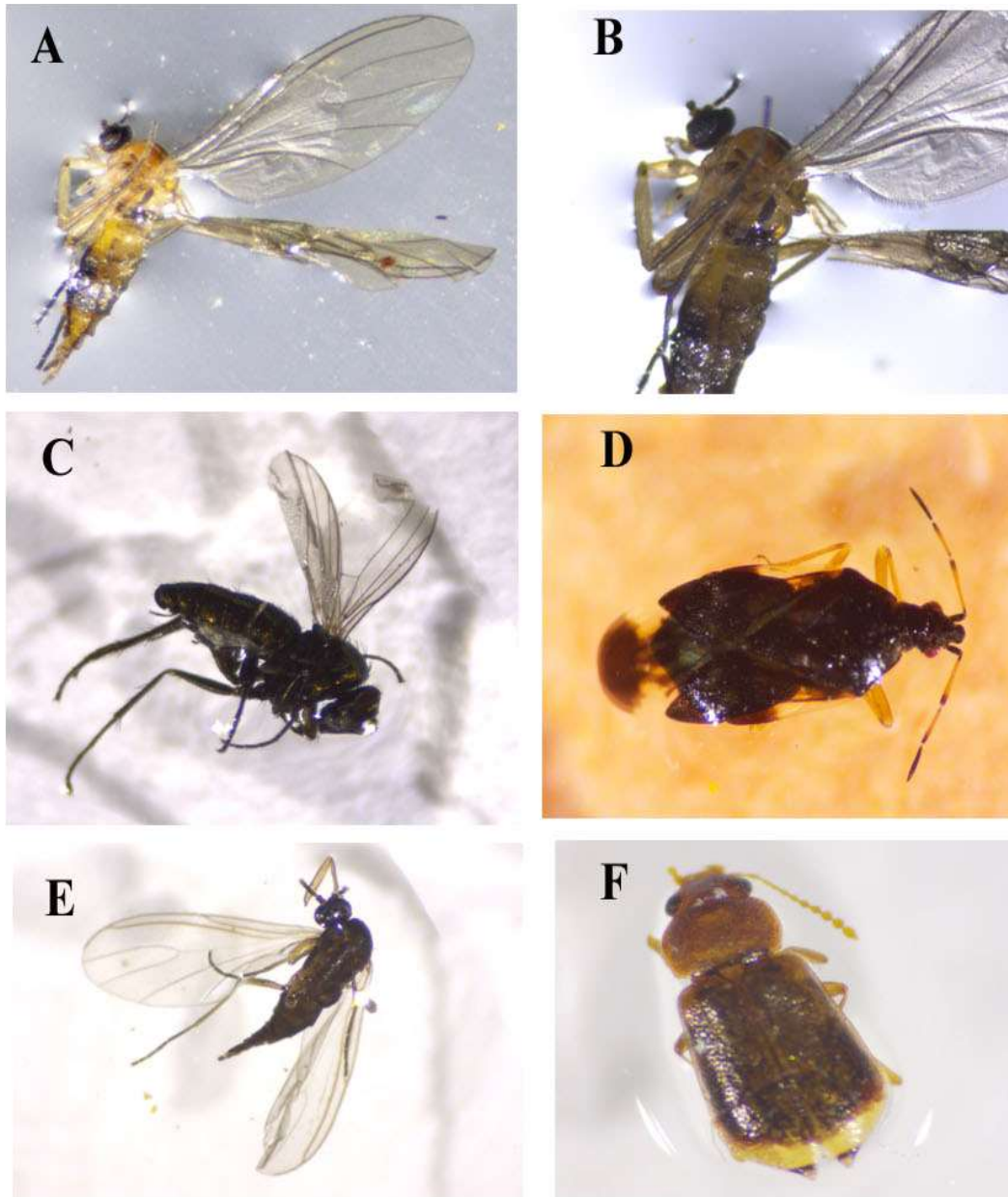


Plate 14. Insect flower visitors observed inside flowers of *Rhododendron cinnabarinum* subsp. *cinnabarinum* at Tonglu-Tumling in Darjeeling Himalaya in May 2019: **A-B.** order Diptera family Sciaridae; **C.** order Diptera family Dolichopodidae; **D.** order Hemiptera suborder Heteroptera family Anthocoridae; **E.** order Diptera family Sciaridae; **F.** order Coleoptera family Staphylinidae - subfamily Omaliinae, tribe Anthophagini [these insect images were taken from camera-fitted Carl-Zeiss Trinocular Stereo Zoom Microscope Model No. Stemi 305].

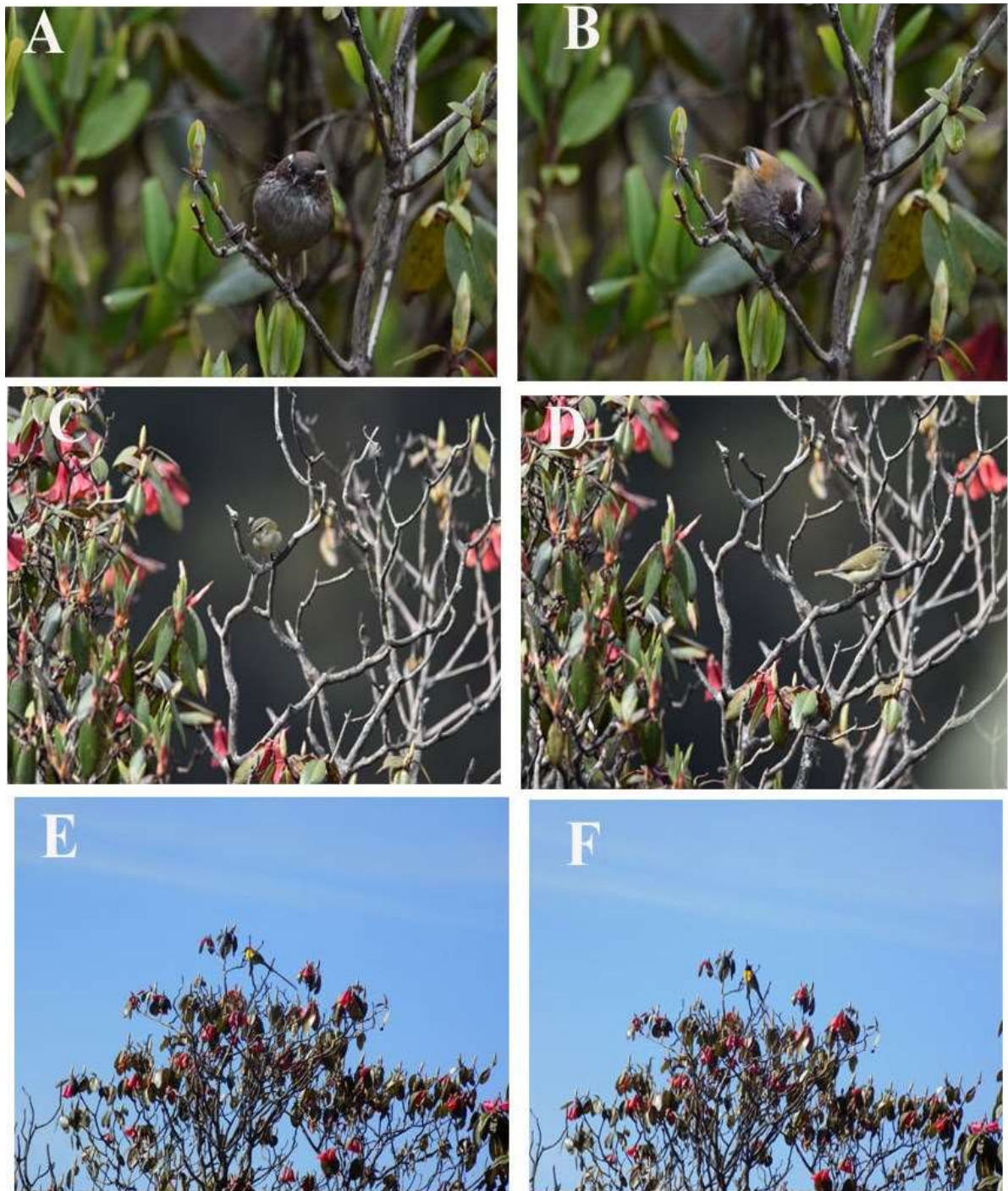


Plate 15. Avian flower visitors observed in *Rhododendron cinnabarinum* subsp. *cinnabarinum* in Darjeeling Himalaya: **A-B.** *Fulvetta vinipectus* (Hodgson, 1837); **C-D.** *Phylloscopus subviridis* (Brooks, 1872); **E-F.** *Aethopyga ignicauda* (Hodgson, 1837).

