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Originals

Altitudinal Distribution and Tree Form of *Rhododendron* in the Jaljale Himal, East Nepal

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東ネパール，ジャルジャレ・ヒマールにおけるシャクナゲ属の垂直分布と樹形

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Altitudinal distribution and tree form of fourteen species of *Rhododendron* growing in the Jaljale Himal are compared based on the field observation and collection in 1991. Species in four types of tree forms have specific upper limit of distribution characteristic to each category: between 3450 and 3670 m in trees, ca. 3750 m in subtrees I, ca. 4000 m in subtrees II, and between 4300 and 4600 m in shrubs. These results are comparable with the results in the Barun Valley, west of the Jaljale Himal: nearly identical in trees and subtrees II, but 150 m lower in subtrees II and 300 to 400 m lower in shrubs. Difference in the latter two reflects limited habitat in the Jaljale Himal without peaks exceeding 6000 m. Tree height reduces along the altitudinal gradient with three steps, ca. 3500 m, 3700 m, and 4000 m, but correspondence with the results of the Barun Valley is obscure due to not enough collection of specimens.

Among arboreal genera distributed in Nepal, none is more diversified than *Rhododendron*. It grows from the montane to the upper limit of the alpine zone, and in various habits from a big tree over 20 m tall to a small shrub a few centimeters tall. Suzuki and Ohba (1988) studied wood anatomical diversity among nine species of *Rhododendron* collected in Central and West Nepal, and clarified structural difference between trees and shrubs. Shakya (1985) plotted altitudinal distribution of 30 species of Nepalese *Rhododendron*, and indicated that the subalpine and the temperate zones harbor largest number of species, 23 and 17 respectively. These studies shed light on the diversity of Nepalese *Rhododedron* species, but were limited in the material, or too general to clarify specific diversification of *Rhododendron* species.

Noshiro and Suzuki (1989) analyzed altitudinal distribution and tree form among the *Rhododendron*

species growing in the Barun Valley, East Nepal. They recognized four types of tree form, Tree, Subtree I, Subtree II, and Shrub, among 14 species growing there. Species in each category had specific ranges of distribution, and their tree height decreased with two distinct steps as altitude increases. Because *Rhododendron* species are the main components of the lower part of the alpine vegetation, these results indicated significant correlation between their diversification and the formation of alpine vegetation. This scheme is however drawn on a limited observation in a small area, and its generality has been obscure.

In the summer of 1991, we had a chance of observing and collecting *Rhododendron* species in the Jaljale Himal, east of the Barun Valley (Ohba 1992), and could compare them with those in the Barun Valley. We could collect 14 species of *Rhododendron*, among which eleven were common with those in the Barun Valley. The Jaljale Himal lies between the Makalu and the Kanchenjunga regions with no peaks exceeding 6000 m, and no extant glaciers exist at present. There are no villages north of Ghupha Pokhari, but many kharkas, i.e., summer pastures in Nepal, are scattered in the alpine zone, and the route is used for transportation to and from Tibet. Even in the subalpine and the alpine zones, human impact against forest vegetation is severer compared with the Barun Valley, and vegetation zones are obscure. The upper limit of *Abies* forests is between 3600 and 3700 m, but accessible forests are usually affected with selective cutting by the villagers.

Material and Method

The collection route runs in the Dhankuta and Sankhuwa Sabha Districts, Koshi Zone, East Nepal, starting from Hile (1890m), and going up north from Ghupha Pokhari (2800m) along Milke Danda and the Jaljale Himal, and coming back via Topke Gola (3570m) and Num (1520m). Once in the Jaljale Himal, this route only traces the alpine zone until the descent into the Arun valley. The surveyed area ranges from 87°10'E to 87°30'E, and from 27°05'N to 27°35'N, and from 420 m to 4630 m in altitude.

Forty-six individuals were measured and collected during this expedition, preferably in 200 m interval (Table 1; black circles in Fig. 1). For the study of altitudinal distribution, data are supplemented with those individuals observed along the route without collecting specimens (black rhombuses in Fig. 1). Collection and observation are not enough between 3100 to 3400 m because of steep ascent and descent in this altitudinal zone. Altitude was measured with a Thomen 6000 m altimeter-barometer TX that was adjusted to 1300 m at Kathmandu. In the following figures, the species are arranged in the same order as in Noshiro and Suzuki (1989).

Tree Form

Among the 46 individuals, 14 species have been recognized (Table 1). Tree form of these species was divided into four categories, Tree, Subtree I, Subtree II, and Shrub, following the division by Noshiro and Suzuki (1989). Their component species and distribution are as follows.

Tree: Species in this category always have a distinct main stem, and three species, *R. arboreum*, *R. barbatum*, and *R. hodgsonii*, belong to it. The upper limit of *R. arboreum* and *R. barbatum* is at ca. 3450 m, and that of *R. hodgsonii* is at ca. 3670 m (Fig. 1). The lower limit is variable, 2440 m in *R. arboreum*, 2840 m in *R. barbatum*, and 2960 m in *R. hodgsonii*. The upper limit of *R. hodgsonii* is higher than the other trees, and is defined by that of *Abies* forests. *Rhododendron arboreum* usually constitutes undergrowth of the montane and lower subalpine forests, especially that of *Quercus semecarpifolia* forests, and *R. hodgsonii* forms characteristic undergrowth of subalpine *Abies* forests. But in Mike Danda, these three species often form *Rhododendron* forests by themselves between 2500 and 3500 m, and attain

Table 1. *Rhododendron* species collected in Jaljal Himal in 1991.

Species	Locality	Alt	Date	H	Coll No
Tree					
R. arboreum	Shidua – Chittre – Basantapur – Tute	2440	13-Jul-91	8	9154019
R. arboreum	Tute – Dor Pani – Tinjure Phedi	2550	14-Jul-91	10	9154038
R. arboreum	Singoa Kharka – Pahakhola	3460	11-Aug-91	3	9154207
R. barbatum	Mangal Bare – Lam Pokhari – Gupha Pokhari	2840	16-Jul-91	6	9154069
R. barbatum	Angare Kharka – Chhippon	3020	18-Jul-91	4	9154097
R. barbatum	Singoa Kharka – Pahakhola	3450	11-Aug-91	5	9154208
R. hodgsonii	Chhippon – Dobati Kharka – Gidde	3220	19-Jul-91	4.5	9154103
R. hodgsonii	Kharka E of Tin Pokhari – a ridge	3670	31-Jul-91	7	9154139
R. hodgsonii	Singoa Kharka – Pahakhola	3440	11-Aug-91	4	9154209
Subtree I					
R. thomsonii	Chhippon – Dobati Kharka – Gidde	3440	19-Jul-91	4	9154107
R. thomsonii	Kharka E of Tin Pokhari – a ridge	3760	31-Jul-91	2.3	9154132
R. thomsonii	Singoa Kharka – Pahakhola	3600	11-Aug-91	2	9154203
R. thomsonii	Singoa Kharka – Pahakhola	3490	11-Aug-91	2.5	9154205
R. campylocarpum	Chhippon – Dobati Kharka – Gidde	3340	19-Jul-91	2	9154105
R. campylocarpum	Kharka E of Tin Pokhari – a ridge	3640	31-Jul-91	1.6	9154135
R. cinnabarinum	Chhippon – Dobati Kharka – Gidde	3220	19-Jul-91	3.5	9154102
R. cinnabarinum	Kharka E of Tin Pokhari – a ridge	3770	31-Jul-91	2.2	9154131
R. cinnabarinum	Singoa Kharka – Pahakhola	3470	11-Aug-91	2.5	9154206
Subtree II					
R. fulgens	Tin Pokhari – Kharka E of Tin Pokhari	4000	30-Jul-91	1.5	9154128
R. fulgens	Kharka E of Tin Pokhari – a ridge	3630	31-Jul-91	1.5	9154136
R. campanulatum	Chhippon – Dobati Kharka – Gidde	3340	19-Jul-91	3.5	9154104
R. campanulatum	Jaljale – a col – Tin Pokhari	4040	22-Jul-91	0.5	9154117
R. campanulatum	Jaljale – a col – Tin Pokhar.	4030	22-Jul-91	0.8	9154118
R. campanulatum	around Banduke.	3970	25-Jul-91	1.6	9154126
R. campanulatum	Kharka E of Tin Pokhari – a ridge	3670	31-Jul-91	2.5	9154138
R. wightii	Tin Pokhari – Banduke	3980	24-Jul-91	1.6	9154125
R. wightii	Shuwan Kharka – a pass – Topke Gola	3720	7-Aug-91	5	9154187
R. wightii	Shuwan Kharka – a pass – Topke Gola	3580	7-Aug-91	2.5	9154191
Shrub					
R. glaucophyllum	Gupha Pokhari – Angare Kharka	2800	17-Jul-91	0.3	9154072
R. camelliiflorum	Chhippon – Dobati Kharka – Gidde	3020	19-Jul-91	0.6	9154099
R. lepidotum	Tute – Dor Pani – Tinjure Phedi	2790	14-Jul-91	0.2	9154043
R. lepidotum	Chhippon – Dobati Kharka – Gidde	3460	19-Jul-91	0.8	9154110
R. lepidotum	Jaljale – a col – Tin Pokhari	4090	22-Jul-91	0.3	9154119
R. lepidotum	Kharka E of Tin Pokhari – a ridge	3700	31-Jul-91	0.9	9154134
R. lepidotum	Goja – a col – Shuwan Kharka	4340	6-Aug-91	0.12	9154180
R. setosum	Khokling – deurali – Jaljale	4050	21-Jul-91	0.1	9154115
R. setosum	Tin Pokhari – Banduke	4460	24-Jul-91	0.1	9154121
R. setosum	Kharka E of Tin Pokhari – a ridge	3720	31-Jul-91	0.2	9154137
R. setosum	Shuwan Kharka – a pass – Topke Gola	4260	7-Aug-91	0.12	9154181
R. setosum	Shuwan Kharka – a pass – Topke Gola	3580	7-Aug-91	0.25	9154190
R. anthopogon	Gidde – Khokling	3420	20-Jul-91	0.5	9154114
R. anthopogon	Jaljale – a col – Tin Pokhari	4040	22-Jul-91	0.3	9154116
R. anthopogon	Tin Pokhari – Banduke	4440	24-Jul-91	0.03	9154122
R. anthopogon	Kharka E of tin Pokhari – a ridge	3730	31-Jul-91	0.3	9154133
R. anthopogon	Shuwan Kharka – a pass – Topke Gola	4260	7-Aug-91	0.25	9154182
R. anthopogon	Bomrang – Pamphule Deurali – Singoa Kharka	4630	10-Aug-91	0.25	9154202

Alt: Altitude (m), H: Height (m).
Collectors: H. Ohba, S. Akiyama, H. Ikeda, T. Kikuchi, S. Noshiro, Y. Omori, M. N. Subedi & M. Wakabayashi.

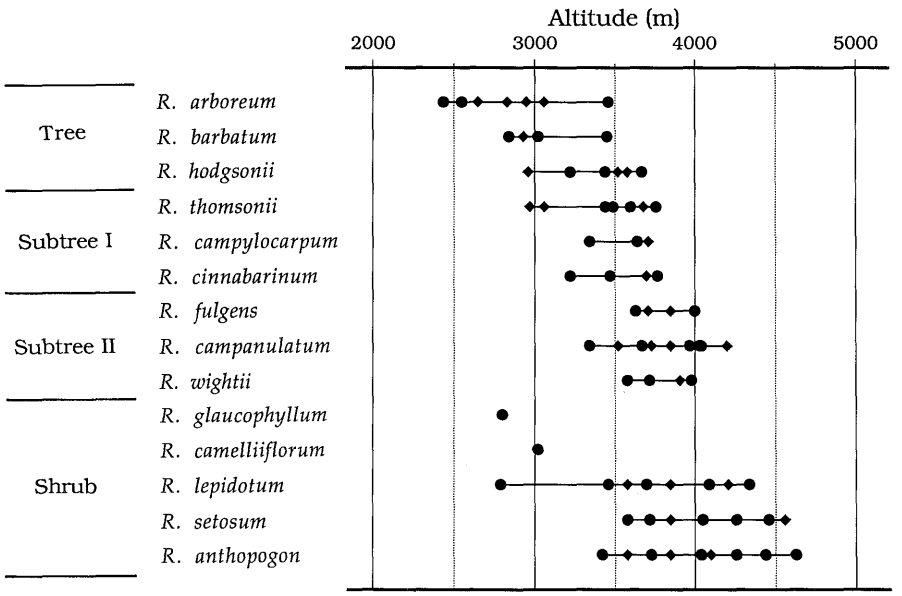

Fig. 1. Altitudinal distribution of *Rhododendron* species in the Jaljale Himal. Black circles: collected specimens, black rhombuses: observed individuals. Division of tree form follows that in Noshiro and Suzuki (1989).

nearly 20 m in height and 1 m in diameter.

Subtree I: Species in this category are in the form of a large shrub, up to 4 m in height, and three species, *R. thomsonii*, *R. campylocarpum*, and *R. cinnabarinum*, belong to it. The upper limit is nearly identical, at ca. 3760 m in *R. thomsonii* and *R. cinnabarinum*, and at 3710 m in *R. campylocarpum* (Fig. 1). The lower limit is variable, 2970 m in *R. thomsonii*, 3340 m in *R. campylocarpum*, and 3220 m in *R. cinnabarinum*. These species usually form the lower part of continuous *Rhododendron* scrubs in the lower part of the alpine zone together with subtrees II, but are occasionally intermingled also in open scattered scrubs within subalpine *Abies* forests.

Subtree II: Species in this category are in the form of a large shrub, same as subtrees I and growing up to 3.5 m in height, and three species, *R. fulgens*, *R. campanulatum*, and *R. wightii*, belong to it. The upper limit is at ca. 3980 to 4040 m, 200 to 300 m above that of subtrees I, except for one isolated individual of *R. campanulatum* at 4200 m (Fig. 1). The lower limit is variable, 3630 m in *R. fulgens*, 3340 m in *R. campanulatum*, and 3580 m *R. wightii*. These species, especially *R. campanulatum*, are the main component of continuous *Rhododendron* scrubs in the lower alpine zone, and grow as low scrubs scattered in the alpine meadow near their upper limit of distribution. *R. campanulatum* grows also in scattered open scrubs within *Abies* forests, but the other two are found only in the alpine scrubs.

Shrub: Species in this category are small shrubs, less than 1 m in height. Some are found in open spaces, on rocks or as epiphytes within the montane or subalpine forests, but most grow as scattered shrubs in continuous alpine *Rhododendron* scrubs, or forming mat-like low scrubs in the alpine meadow. *R. glaucophyllum* and *R. camelliiflorum* are found only at one locality below the alpine zone (Fig. 1). *Rhododendron lepidotum* has the widest range of distribution, covering from 2790 m in the upper montane zone to 4340 m in the alpine zone, but those growing below the alpine zone are rare. *R. setosum* is found from

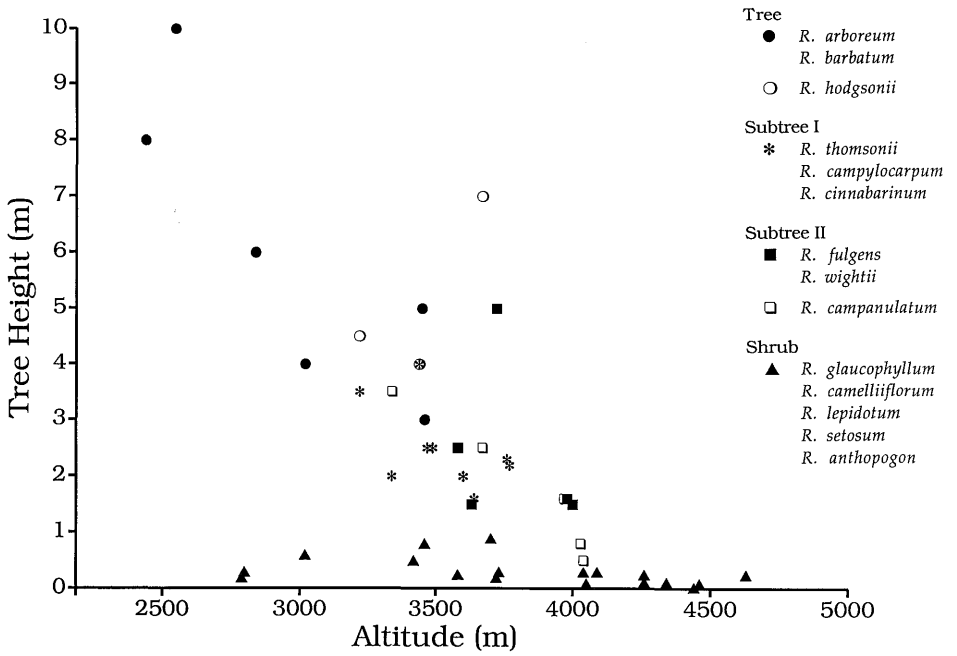

Fig. 2. Altitudinal distribution and tree height of *Rhododendron* species in the Jaljale Himal. Tree height decreases at ca. 3700 m and 4000 m.

3580 m to 4560 m, and *R. anthopogon* from 3420 m to 4630 m. The upper limit of the latter three shrubs is near the top of the ridge, and seems to be defined by the local ecological conditions.

Species in the four tree forms therefore have a certain upper limit characteristic to that category. It differs by 200 to 300 m between the three larger tree forms, and that of shrubs exceeds subtrees II by 300 to 600 m. The lower limit is, on the contrary, very variable in each category, and there are no characteristic value.

Correlation of Tree Form and Tree Height

Above the subalpine zone, tree height of *Rhododendron* usually defines the height of vegetation, especially in the lower part of the alpine zone, and their decrease along the altitudinal gradient usually shows decrease in vegetation height. Tree height of trees ranges from 3 to 8 m and is variable, and does not decrease considerably up to the upper limit (Fig. 2; Table 1). Subtrees I fluctuate between 1.6 and 4 m in height, and become less than 2.5 m at ca. 3500 m. Tree height of subtrees II ranges from 0.5 to 5 m, and goes below 2 m above 3700 m and below 1 m above 4000 m. That of shrubs fluctuates between 0.03 and 0.9 m, but decreases below 0.5 m at ca. 4000 m, above the upper limit of subtrees II. Thus tree height seems to decrease with three steps, at ca. 3500 m in subtrees I, 3700 m in subtrees II, and 4000 m in shrubs.

Discussion

Species in the four types of tree form have specific upper limit of distribution also in the Jaljale Himal as in the Barun Valley. In the Barun Valley, the upper limit of *R. hodgsonii* was at 3750 m, and that of *R. barbatum* was at 3320 m, but *R. arboreum* was found only below 3000 m (Noshiro and Suzuki 1989). The upper limit of subtrees I was at ca. 3800 m, and that of subtrees II at ca. 4150 m. Most shrubs grew higher than 4700 m, up to 5100 m, and altitudinal ranges of three species, i.e., *R. lepidotum, R. setosum,* and *R. anthopogon*, were more than 1000 m. The lower limit

was variable, but fell at ca. 3200 m in three subtrees I and *R. campanulatum*, and at ca. 3750 m in *R. wightii*, *R. campanulatum* var. *wallichii*, and three shrubs. Along the altitudinal gradient, tree height reduced to below 2 m at ca. 3600 m in subtrees I and at ca. 3950 m in subtrees II.

The upper limit of trees and subtrees I is nearly identical in both areas, but that of subtrees II is about 150 m lower and that of shrubs 300 to 400 m lower in the Jaljale Himal. This lowering of the upper limit must be due to the smaller extent of the alpine region in the Jaljale Himal, which has no peaks exceeding 6000 m, and reflects more limited habitat for the alpine *Rhododendron* species in this area. Absence of *R. nivale* must be also due to lack of appropriate habitats over 4500 m. Reduction of tree height within subtrees I and subtrees II is 100 to 250 m lower than in the Barun Valley, but specimen number is too low to confirm and discuss this correspondence and difference.

This study has indicated correlation between tree form and altitudinal distribution. Diversification of *Rhododendron* species as major elements of alpine vegetation should also be considered in relation to speciation. Taxonomically species in Tree, Subtree I, and Subtree II belong to subgen. Hymenanthes sect. Ponticum except for *R. cinnabarinum*, and this species and shrubs to subgen. Rhododendron sect. Rhododendron, excepting *R. anthopogon* in sect. Pogonanthum of the same subgenus (Cullen 1980; Chamberlain 1982). Horticulturally species in each subgenus are known to hybridize easily, and their diversification within a limited altitudinal zone must be maintained by their ecological diversification. In the future field work in the Eastern Himalayas, we have to confirm the generality of the above results, and to clarify mechanism and processes of such diversification while maintaining sympatric existence.

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要旨

東ネパールのヒマラヤ山脈の1支尾根，ジャルジャレ・ヒマールでシャクナゲ属の垂直分布と樹形を調べた．同地には14種が自生し，それらは樹形で，高木，亜高木I，亜高木II，灌木の4つに分けられた．分布上限は樹形ごとに異なり，高木は3450 mから3670 m，亜高木Iは約3750 m，亜高木IIは約4000 m，灌木は4300 mから4600 mであった．これをジャルジャレ・ヒマール西部のバルン谷でのデータと比べると，高木と亜高木Iでは上限はほぼ同じ高度であるが，亜高木IIでは150 m，灌木では300 mから400 m低い．この差は，ジャルジャレ・ヒマールにマカルーのような高度6000 mを超すピークを欠く地形と関連している．また，樹高は高度に従い段階的に減少することが判明した．