Chapter 3
Orchid Diversity in the Chitwan District

Iva Traxmandlová, Bishnu Prasad Bhattarai, and Pavel Kindlmann

Abstract Although the orchids in the Himalayan region are generally well known, there is little or no information on the orchids in the lowlands of Nepal. The aim of this paper is to shed light on the general status and distribution of orchids in one important lowland region, the Chitwan district. The study area included the Chitwan National Park (CNP), Barandabhar corridor forest (BCF) and the Mahabharat range (MR). The orchids in the trees, on rocks and on the ground were recorded along a total of 200 line transects: 40 in the BCF, 105 in the CNP and 55 in the MR. From the beginning of each transect, the first 50 trees within 10 m of the transect line were sampled. In addition, all terrestrial orchids and species of trees within 10 m of the transect line were also recorded. There was no association between the orchid and specific species of trees. There were nine orchid species in the MR that did not occur in the CNP and BCF, and seven in the CNP and BCF that did not occur in the MR. In the BCF, the orchids occurred on average on four different trees. In contrast, in the CNP the orchids occurred on average on eight different trees.

Keywords Orchids • Species-abundance • Nepal

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3.1 Introduction

Orchids in the Himalayan region have been studied for a long time (Duthie 1906; Amatya 1982; Paudyal 1982). In his three reports on the flora of the eastern Himalayas, Hara and Hohashi 1966, 1971 and 1974 mention 139 species belonging to 48 genera. According to recent records in the British Museum, there are 90 genera and over 300 species of orchids in Nepal (Hara and Williams 1979: Hara et al. 1978, 1982). Willis (1979) referred to in Sharma (1999) reported 735 genera and 17 000 species of orchids in the world. They are found in abundance in the tropics but are rare in arctic regions (Majupuria and Majupuria 1999). In the eastern part of Nepal, epiphytic species abound, while in the western part there are mainly terrestrial orchids (Majupuria and Majupuria 1999). The geographical distribution of orchids is mainly determined by the north-south orientation of a site, with species that prefer moisture living mainly on the northern slopes in hilly areas (Duthie 1906), and by altitude (Amatya 1982). Most orchid species are found at low altitudes (below 1500 m), with very few species above 2300 m (Duthie 1906; Amatya 1982; Paudyal 1982). However, there is no data, or any other information on orchids in the lowlands of Nepal, where most of the studies have focused on vertebrates and other plants. Thus the aim of this study was to shed light on the general status and distribution of orchids in one important region, the Chitwan district.

3.2 Methods

3.2.1 Study Area

The Chitwan district, also called "inner Tarai region", is mainly tropical and subtropical lowland, surrounded by temperate regions, the Churia hills (150–800 m) in the south and Mahabharat hills (1200–1947 m) in the north. Politically, the Chitwan district consists of 36 village development committees (VDCs) and two municipalities. Of the 36 VDCs, nine are located in the hilly region Korak, Siddi, Saktikhor, Kaule, Kabilas, Dahakhani, Chandibhanjyang, Darechowk and Lothar, and the rest are in the lowlands. The population in this district was 472,048 in 2001 of which 90% lived in the lowlands (plain) and 10% in the hills (DDC Chitwan 2006).

The Chitwan district includes several ethnic communities, the Chepang (mainly in the hills), Bote, Mushahar and Tharu (PDDP 2002). As these people have very little agricultural land and are not allowed to fell trees for timber and collection of non-timber forest products, they find it difficult to earn enough money for their survival. Illegal dealers in wildlife products exploit the people in the poorer ethnic communities, such as Chepang, Bote and Tharu. Because of poverty and lack of

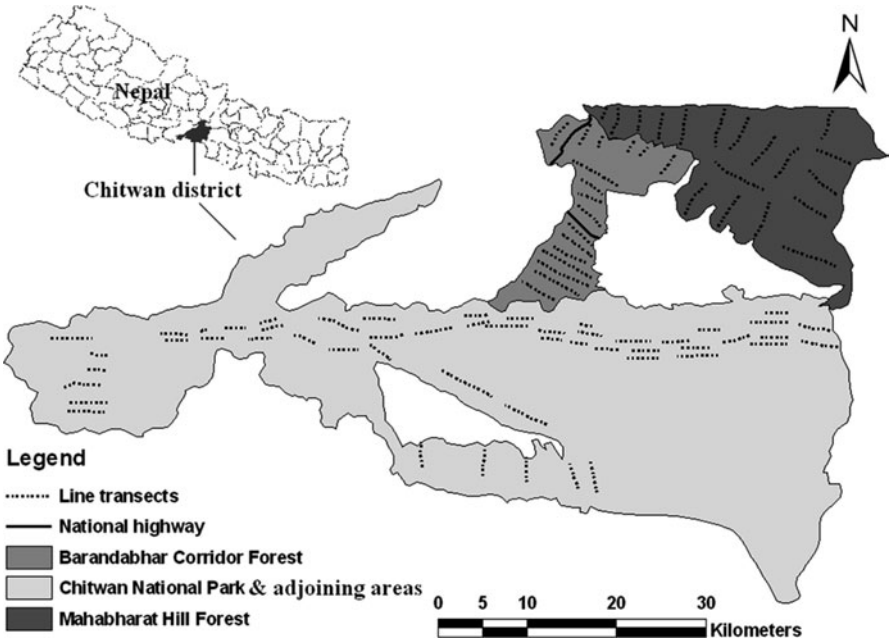

Fig. 3.1 Study area and locations of transects

education, these people become involved in illegal activities. The government is unable to provide basic amenities like healthcare, education, power and water. The increase in the local population has resulted in conflicts between the interests and socio-economic welfare of the people.

The study area (83°55′–84°48’ N; 27°21′–27°46′ E; 126–1947 m above sea level, total size 2238 km^2) consisted of the Chitwan National Park (CNP), Barandabhar corridor forest (BCF) and Mahabharat range (MR) (Fig. 3.1). Forest covers 58.7%, while agricultural land, cities and others cover 41.3% of the area this district. The national forest consists of productive forest (12.5%), community forest (21%), leasehold forest (2.1%) and protected forest (53.9%). The community and leasehold forest make up 4% and 5.9% of the area, respectively (DDC Chitwan 2006). All the areas in the national forest are governed by the district forest office, except the protected area and its buffer zone. The main habitats in the study area include sal forests (SF), mixed forests (MF), riverine forests (RF), wetlands and grasslands (Table 3.1).

The Chitwan National Park today is a successful testimony of nature conservation in south Asia. It is the first national park of Nepal, covers an area of 932 km^2 and preserves a unique ecosystem of great value for the entire world. The park consists mainly of lowland, but it also contains the Churia hills, which rise gradually towards the east. With the variation in the climate and altitude there is variation in

Table 3.1 Habitats and their abundance in the different parts of the Chitwan district

Habitat type	Dominant plant species	BCF	CNP	MR
Sal forest	*Shorea robusta, Terminalia alata, Dillenia pentagyna, Cleistocalyx operculatus, Adina cordifolia, Emblica officinalis, Lagerstroemia parviflora*	[a]	[a]	[b]
Mixed hardwood forest	*Terminalia bellarica, Cleistocalyx operculata, Dillenia pentagyna, Adina cordifolia, Syzygium cumini, Gmelina arborea, Garuga pillata, Derris elliptica, Lagerstroemia parviflora*	[b]	[b]	[c]
Riverine forest	*Trewia nudiflora, Bombax ceiba, Dalbergia sissoo, Gaultheria fragrantissima, Litsea monopelata*	[b]	[d]	[c]
Mixed rhododendron forest	*Rhododendron arboreum, Butea monosperma, Castanopsis tribuloides, Micenia champaca, Schima wallichii*	[c]	[c]	[d]
Mixed deciduous forest	*Schima wallichii, Aesandra butyracea, Micenia champaca, Terminalia alata, Castanopsis tribuloides, Shorea robusta*	[c]	[c]	[d]
Short grassland	*Imperata cylindrica, Ageratum conyzoides, Commelina benghalensis, Polygonum barbaratum, Hedyotis diffusa, Oplismenus compositus*	[a]	[b]	[c]
Tall grassland	*Themeda arundinacea, Saccharum spontaneum, Daphne papyracea, Phragmites karka*	[b]	[a]	[c]
Wetland	*Eichhornia crassipes, Cyperus rotundus, Ipomoea aquatica, Leersia hexandra*	[b]	[b]	[c]

[a]dominant
[b]present
[c]absent
[d]common

The Mahabharat range (Photo by BP Bhattarai)

Churia hills covered with sal forest in the Chitwan National Park (Photo by BP Bhattarai)

Sal forest and associated short grassland: a typical habitat in the Tarai region (Photo by BP Bhattarai)

Regeneration of the tropical riverine forest (Photo by BP Bhattarai)

wild fauna and flora (BPP 1995). The diverse geography of the Chitwan district has resulted in a rich biodiversity, both in plants and animals and ethnic and cultural diversity, which lures more than 70,000 tourists per year to the area (UNESCO/EoH 2003). However, most of the tourists visit the CNP and its adjacent buffer zone (BZ). As a consequence, it is reported that the spatial concentration of tourists is having a detrimental affect on the environment in the CNP. Several studies report that the effect of tourism ranges from habitat disturbance to vegetation damage and pollution (Curry et al. 2001).

The Chitwan National Park is an important rhino and tiger conservation area and was made a World Heritage Site by UNESCO in 1984 because of its unique ecosystems, which are of international importance (UNESCO/EoH 2003). To reduce the numbers of people living inside the core area of the CNP, the government of Nepal in 1996 declared an area of 750 km^2, made up of forests and private lands, including cultivated land surrounding the park, a buffer zone. The CNP has one of the highest densities of large mammals, including tigers and rhinos, in southern Asia.

Potential threats to the long-term conservation of wildlife in the CNP are habitat fragmentation, poaching and illegal collecting of forest products and livestock grazing. Local people collect various forest products for their subsistence. The local ethnic people are mostly poor, landless and socially dominated by

other caste groups. Intentional and accidental forest fires, encroachments, cattle grazing, etc. are all long-term threats to the quality of the habitat and biodiversity of the area.

The second part of the study area, the Barandabhar corridor forest (BCF) is dominated by sal forest, which is rich in plants and animals. The conservation and management of the BCF is a priority for Nepal, as it links the Churia hills, Chitwan National Park and Mahabharat hill forest (KMTNC/BCC 2003). It is important for the long-term survival and mobility of the megafauna in the CNP and other migratory animals. Basic information on the BCF, its flora and fauna is lacking or scarce. BCF is part of a larger forest, which divides the Chitwan district into two parts: east and west Chitwan. The encroachment of people from both sides is the main threat to this area. Because of different conservation practices, more people collect forest products in the district forest area than in the buffer zone. The government declared an area up to 300 m from a village into the forest as the community's forest, where people from the village are allowed to fell the trees for their use, but nowhere else. Illegal logging of trees is a serious problem, as it results in the loss of many rare and endangered orchids, and other flora and fauna.

The east-west national highway divides the forest into the southern Barandabhar corridor forest of 57 km^2, which is a buffer zone for the CNP, and the northern Tikauli forest of 31 km^2, which is under district forest management. The incorporation of the BCF into the Chitwan National Park resulted in a major conflict between the communities around the BCF and the park authorities. The traditional practice of livestock grazing and collecting firewood and fodder was strictly limited inside the national park. In addition, conservation measures had a positive effect upon the numbers of wild animals, many of which moved into the BCF. However, people prevented from using natural resources inside the park were using those available in the BCF at an alarming rate. Therefore, in order to stop any further degradation of one of the few remaining Mahabharat forests, there is an urgent need to introduce an integrated conservation and development program for the BCF area (KMTNC/BCC 2003).

The conservation practices in the Mahabharat range (MR) differ from those in the CNP and BCF, as the MR is not a protected area. It is a government forest, managed by the district forest office of Chitwan. From the conservation and protection point of view, the people in this area manage the community forest areas, but there are many other large forests, mainly in hilly areas, where there are no people and the forest is in good condition. The higher humidity and better habitat in these areas support more orchid species. Because of the higher humidity on the north-facing slopes in hilly areas (Amatya 1982), the numbers of orchid species in these areas are also higher, even though they are not protected. The hilly regions of Chitwan are occupied by ethnic and low caste communities (e.g., Chepang, Magar) with a few settlements of high caste people (e.g., Brahmin, Chhetri). The people of low caste and ethnic communities are mainly traditional healers, i.e., they use plants (mainly orchids, ferns and some herbs) and animals (mainly small mammals and birds) to

treat diseases. Because of the lack of good quality agricultural land in hilly areas the people there collect plants and animals of medicinal importance and make handicrafts for domestic use.

3.2.2 Sampling Methods

The field studies consisted of walking along transects walks in the study area and recording orchids growing in the trees, on rocks and on the ground. There were a total of 200 transects: 40 in the BCF, 105 in the CNP and 55 in the MR. Transects were chosen to include the main habitats in the region. The first 50 trees along and within 10 m of the transect line were sampled. Thus the length of the transect was not fixed: where the density of trees was low, the transect was long and vice versa. The species of each tree and all the orchids on each tree were noted. Along each transect, all the species of terrestrial orchids within a distance of 10 m from the transect line were also noted. The trees and associated orchids were identified using standard taxonomic keys (White and Sharma 2000; Rajbhandari and Bhattarai 2001). All the orchids were photographed for easier identification and later documentation.

3.2.3 Analyses

A canonical correspondence analysis (CCA) of orchid species preferences was done using CANOCO software (Version 4.5; ter Braak and Šmilauer 2002). The resulting ordination diagrams express both the variation in species composition and the principal relationships between species and environmental variables. Including tree species identity as dummy variables, differences in the epiphyte assemblages on trees were analyzed using Monte Carlo permutation tests (999 permutations). Infrequent tree species (less than 10 individuals in the whole data set) were excluded from the analyses.

3.3 Results

Results of the CCA analysis are shown in Figs. 3.1–3.9. Only those orchid species that showed a relationship with a particular tree species are displayed. Table 3.2 shows the presence/absence of the orchid species at specific sites and the abbreviations used in CANOCO.

Table 3.3 shows a list of the trees and their numbers as used in CANOCO.

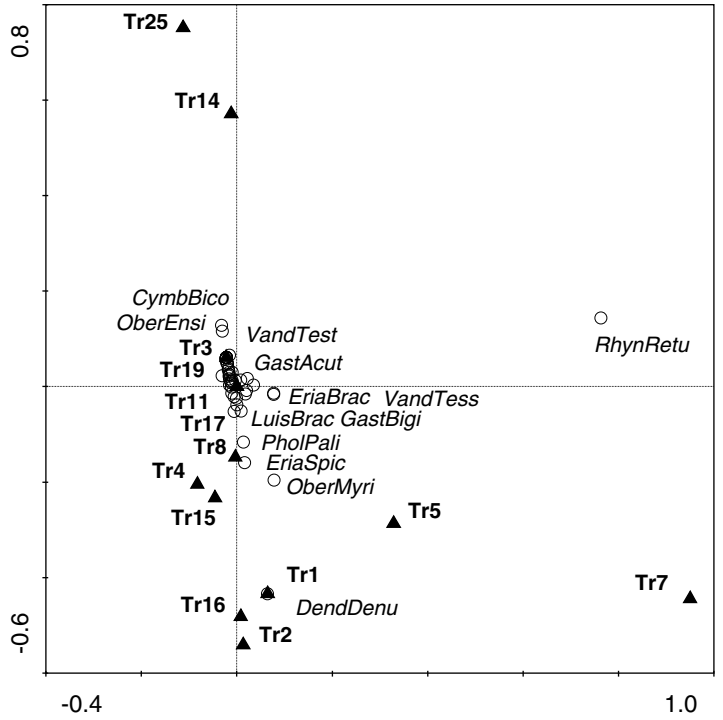

Fig. 3.2 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the sal forest in the Barandabhar corridor forest (*BCF-SF*). Monte- Carlo permutation test of significance of all canonical axes: F = 1.279, P = 0.122 (with 999 permutations). First two axes are displayed. The first axis explains 9.6% and second 6% of the variability

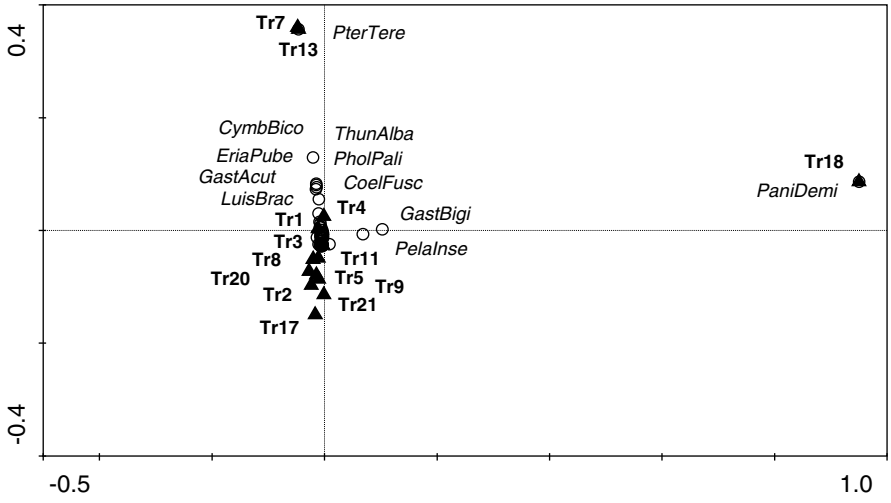

Fig. 3.3 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the mixed hardwood forest in the Barandabhar corridor forest (*BCF-MF*). First two axes are displayed. The first axis explains 25.9% and the second 13.8% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.197, P = 0.145 (with 999 permutations)

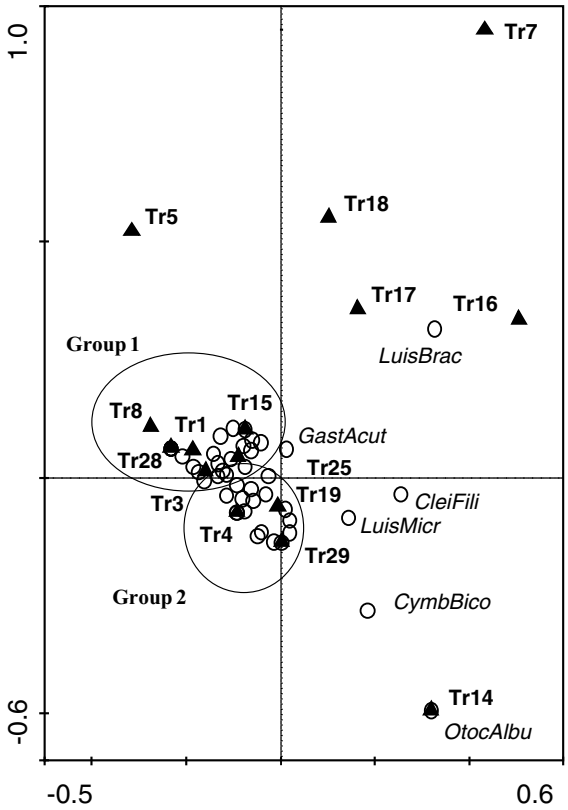

Fig. 3.4 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the riverine forest in the Barandabhar corridor forest (*BCF-RF*). First two axes are displayed. The first axis explains 31.7% and the second 20.2% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.534, P = 0.043 (with 999 permutations). In Group 1 there are: AcamPapi, AcamRigi, AeriOdor, AscoAmpu, BulbAffi, BulbLeop, CoelFlac, CoelFusc, CrypLute, CymbAloi, DendAphy, DendFimb, DendMosc, DendPunc, EchiSimo, EriaPube, GastCalc, LipaViri, OberEnsi, OberFalc, PaniDemi, PholImbr and VandTest, and in Group 2: AeriMult, BublCare, BulbGutt, BulbPoly, DendAnce, DendPrim, EriaBrac, EriaSpic, FlicFuxa, GastBigi, OberMyri, PelaInse, PholPali, ThunAlba, RhynRetu and VandTess

3.3.1 Barandabhar Corridor Forest

In the sal forest (Fig. 3.2) no association between orchid species and the different trees was recorded. Ten orchid species: *Agrostophyllum callosum, Bulbophyllum affine, Coelogyne cristata, Coelogyne flaccida, Coelogyne fuscescens, Cryptochilus lutea, Cymbidium elegans, Dendrobium anceps, Liparis viridiflora* and *Panisea demissa* were found only on *Shorea robusta. Dendrobium denudans* was observed

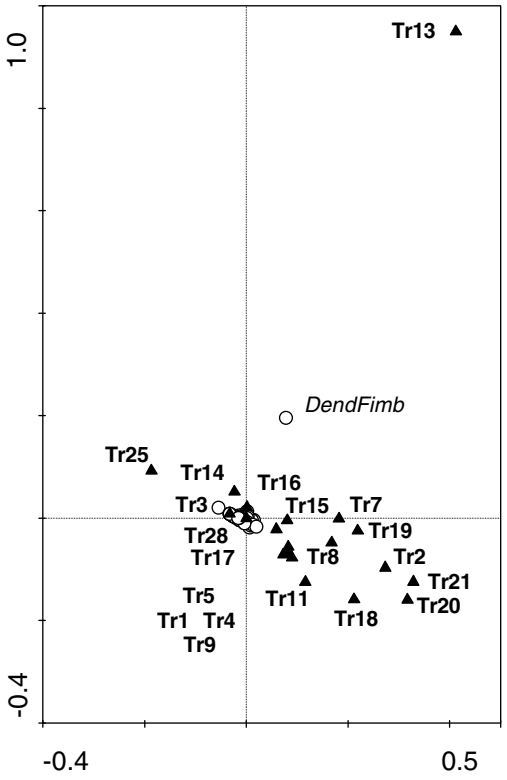

Fig. 3.5 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the sal forest in the Chitwan National Park (*CNP-SF*). First two axes are displayed. The first axis explains only 2% and the second 1.4% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 0.898, P = 0.694 (with 999 permutations)

only once, on *Cleistocalyx operculata.* The most common tree in this region is *Shorea robusta*, with which 48 orchid species are associated and *Cleistocalyx operculata*, with 34 orchid species. In the mixed hardwood forest (Fig. 3.3), a positive association was observed between *Panisea demissa* and *Bauhinia purpurea*, and between *Pteroceras teres* and *Dillenia pentagyna. Agrostophyllum callosum, Cymbidium elegans, Oberonia ensiformis* and *Oberonia falconeri* were found only on *Shorea robusta*. The most common tree in this forest was again *Shorea robusta* with 42 orchid species and *Lagerstroemia parviflora* with 36. In the riverine forest (Fig. 3.4) there were two groups of associations between trees and orchid species ($p < 0.05$): orchids in group one mostly grew on *Cleistocalyx operculata, Shorea robusta, Bombax ceiba* and *Careya arborea*, while those in group 2 mostly on *Lagerstroemia parviflora, Adina cordifolia* and *Gaultheria fragrantissima. Luisia brachystachys* was recorded mostly on *Trewia nudiflora* and *Otochilus albus* only on *Dalbergia sissoo.* The most common trees in the riverine forest were *Bombax ceiba* and *Gaultheria fragrantissima*, both with 28 orchid species, but more orchid species were recorded on *Cleistocalyx operculata*, 35.

Cymbidium aloifolium: one of the dominant epiphytic orchid species in the Tarai (Photo by BP Bhattarai)

Rhynchostylis retusa (Photo by BP Bhattarai)

Eria pubescens in the lowlands (Photo by BP Bhattarai)

Oberonia ensiformis in the Mahabharat range (Photo by BP Bhattarai)

Trudelia cristata in the Churia range (Photo by BP Bhattarai)

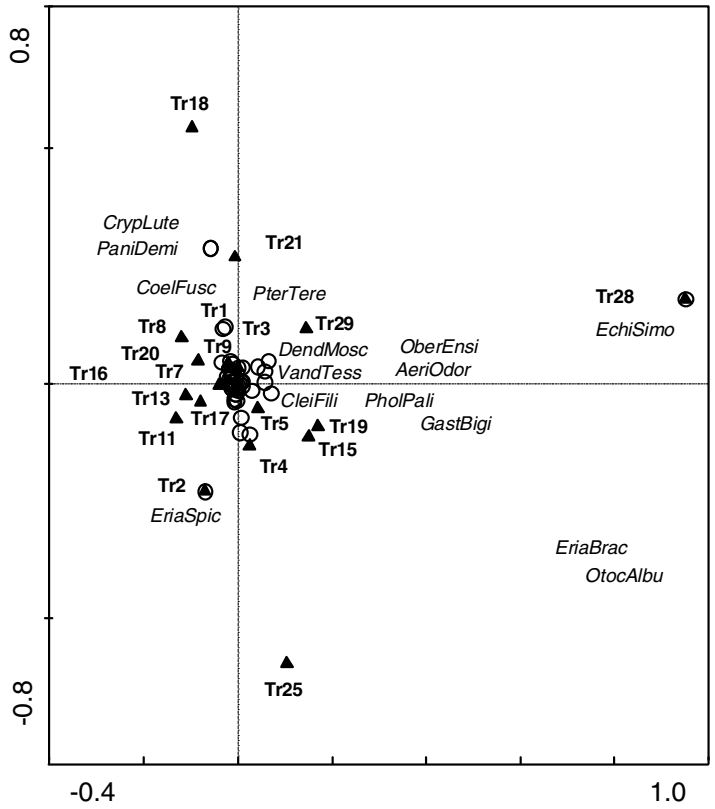

Fig. 3.6 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the mixed hardwood forest in the Chitwan National Park (*CNP-MF*). First two axes are displayed. The first axis explains 4.2% and the second 3.9% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.297, P = 0.052 (with 999 permutations)

3.3.2 Chitwan National Park

In the Chitwan National Park, there is also no association between orchid species and particular species of trees (Figs. 3.5 and 3.6, $p > 0.05$ in all cases). *Dendrobium fimbriatum* mostly occurred in the sal forest (Fig. 3.5) on *Shorea robusta*, but also on *Terminalia chebula. Cryptochilus lutea, Dendrobium bicameratum, Eria spicata* and *Otochilus albus* were recorded only on *Shorea robusta.* Other orchid species show no association with particular trees. The most frequently occurring tree in the sal forest was *Shorea robusta* with 45 orchid species and *Cleistocalyx operculata* with 36. In the mixed hardwood forest (Fig. 3.6) *Dendrobium nobile* occurred only on *Shorea* robusta, *Echioglossum simondii* only on *Careya arborea* and *Eria spicata* on *Syzygium cumini. Cryptochilus lutea* and *Panisea demissa* were recorded once on *Shorea robusta* and once on *Bauhinia purpurea.* The most common tree in this forest

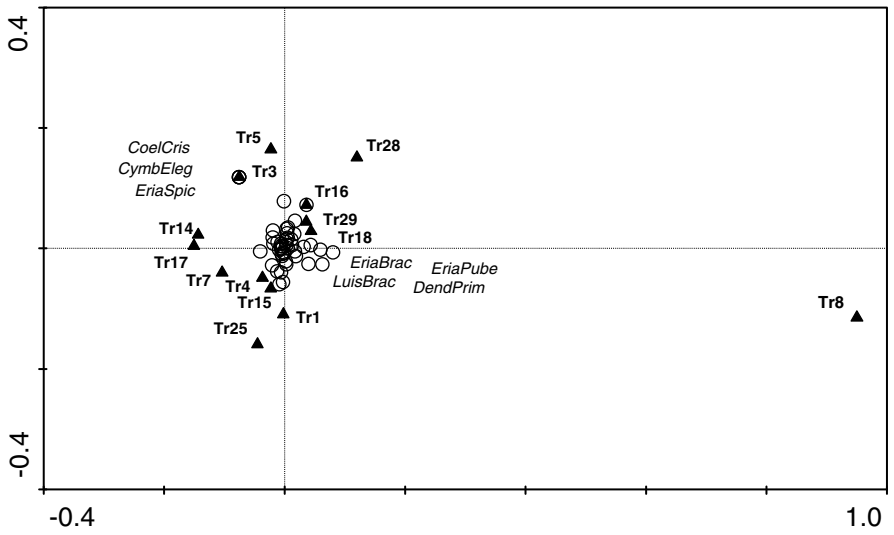

Fig. 3.7 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the riverine forest in the Chitwan National Park (*CNP-RF*). First two axes are displayed. The first axis explains 4.5% and the second 3.6% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.2, P = 0.114 (with 999 permutations)

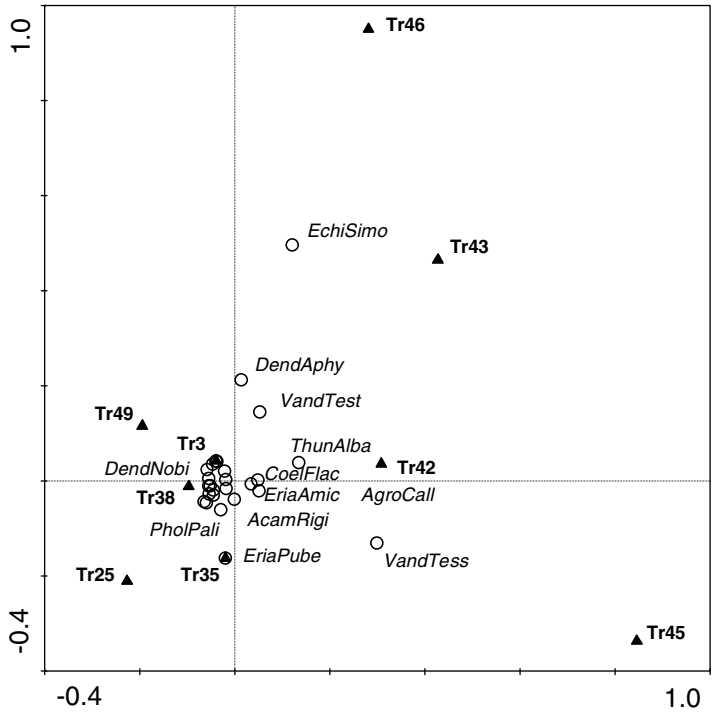

Fig. 3.8 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the hill sal forest in the Mahabharat range (*MR-HSF*). First two axes are displayed. The first axis explains 10.5% and the second 10.1% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 0.909, P = 0.458 (with 999 permutations)

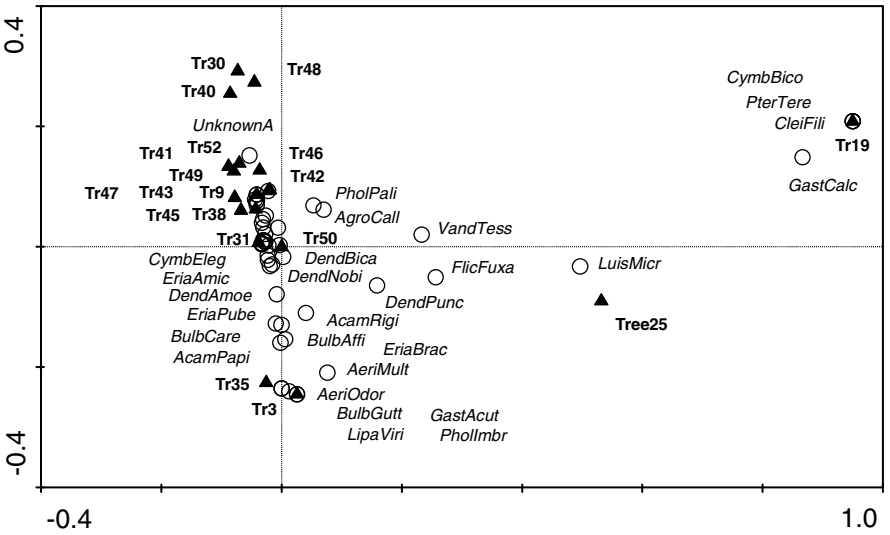

Fig. 3.9 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the mixed deciduous forest in the Mahabharat range (MR-MF). First two axes are displayed. The first axis explains 35.2% and the second 13.3% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.841, P = 0.006 (with 999 permutations)

was *Shorea robusta* with 43 orchid species and *Lagerstroemia parviflora* with 37. In the riverine forest (Fig. 3.7) *Coelogyne cristata*, *Cryptochilus lutea*, *Cymbidium elegans* and *Eria spicata* occurred mostly on *Shorea robusta* and *Dendrobium ochreatum* on *Trewia nudiflora.* However, most of the orchid species were found on *Bombax ceiba* (42 orchid species) and on *Trewia nudiflora* (41).

3.3.3 Mahabharat Range

In the Mahabharat range, several orchid species were clearly associated with particular trees. In the hill sal forest (Fig. 3.8) *Eria pubescens* was recorded only on *Aesandra butyracea* and *Gastrochilus acutifolium* on *Shorea robusta.* The most common trees in this type of forest were *Shorea robusta* with 26 orchid species and *Schima wallichii* with 20. In the mixed deciduous forest (Fig. 3.9) there was a statistically significant association ($p < 0.05$) between orchids and trees. For example, *Cymbidium bicolor, Pteroceras teres* and *Cleisostoma filiforme* were recorded only on *Adina cordifolia. Gastrochilus calceolaris* was recorded mostly on *Adina cordifolia* but also on *Terminalia alata. Aerides odorata* grew only on *Shorea robusta.* The most frequent tree in this forest was *Schima wallichii* with 34 orchid species, but more species were recorded on *Shorea robusta* (41 orchid species). In the rhododendron forest (Fig. 3.10) there was also a significant association between orchids

Table 3.2 List of orchid species with the abbreviation used in analysis and the presence/absence of these orchids in sal forests (*SF*), mixed forests (*MF*), and riverine forests (*RF*)

Scientific name	Abbreviation	BCF-SF	BCF-MF	BCF-RF	CNP-SF	CNP-MF	CNP-RF	MR-HSF	MR-MF	MR-RhF
Acampe papillosa	AcamPapi	+	+	+	+	+	+	–	+	–
Acampe rigida	AcamRigi	+	+	+	+	+	+	+	+	+
Aerides multiflora	AeriMult	+	+	+	+	+	+	+	+	+
Aerides odorata	AeriOdor	+	+	+	+	+	+	–	+	+
Agrostophyllum callosum	AgroCall	+	+	–	–	–	–	+	+	+
Ascocentrum ampullaceum	AscoAmpu	+	–	+	+	+	+	–	–	+
Bulbophyllum affine	BulbAffi	+	+	+	+	+	+	+	+	+
Bulbophyllum careyanum	BulbCare	+	+	+	+	+	+	–	+	+
Bulbophyllum guttulatum	BulbGutt	+	+	+	+	+	+	–	+	+
Bulbophyllum leopardinum	BulbLeop	+	+	+	+	+	+	–	+	+
Bulbophyllum polyrhizum	BulbPoly	+	+	+	+	+	+	–	–	+
Bulbophyllum secundum	BulbSecu	–	–	–	–	–	–	+	+	+
Cleisostoma filiforme	CleiFili	+	+	+	+	+	+	–	+	–
Coelogyne cristata	CoelCris	+	–	–	–	–	+	+	+	+
Coelogyne flaccida	CoelFlac	+	–	+	–	–	–	+	+	+
Coelogyne fuscescens	CoelFusc	+	+	+	+	+	+	–	+	+
Coelogyne nitida	CoelNiti	–	–	–	–	–	–	+	+	+
Cryptochilus lutea	CrypLute	+	–	+	+	+	+	–	–	+
Cymbidium aloifolium	CymbAloi	+	+	+	+	+	+	–	+	+
Cymbidium bicolor	CymbBico	+	+	+	+	+	+	–	+	–
Cymbidium elegans	CymbEleg	+	+	–	–	–	+	+	+	+
Cymbidium iridioides	CymbIrid	–	–	–	–	–	–	–	+	+
Dendrobium amoenum	DendAmoe	–	–	–	–	–	–	+	+	+
Dendrobium anceps	DendAnce	+	+	+	+	+	+	–	–	–
Dendrobium aphyllum	DendAphy	+	+	+	+	+	+	+	+	+
Dendrobium bicameratum	DendBica	–	+	–	+	–	–	+	+	+

Dendrobium denudans	DendDenu	+	+	–	–	–	–	+	+	+
Dendrobium fimbriatum	DendFimb	+	+	+	+	+	+	–	+	+
Dendrobium moschatum	DendMosc	+	+	+	+	+	+	–	–	+
Dendrobium nobile	DendNobi	–	–	–	–	+	–	+	+	+
Dendrobium ochreatum	DendOchr	–	–	–	–	–	+	+	+	+
Dendrobium primulinum	DendPrim	+	+	+	+	+	+	–	–	–
Dendrobium pulchellum	DendPulc	+	+	+	+	+	+	–	+	–
Echioglossum simondii	EchiSimo	+	–	+	+	+	+	+	+	+
Epigeneium amphum	EpigAmph	+	+	–	+	+	+	–	–	+
Eria amica	EriaAmic	–	–	–	–	–	–	+	+	+
Eria bractescens	EriaBrac	+	+	+	+	+	+	–	+	+
Eria pubescens	EriaPube	+	+	+	+	+	+	+	+	+
Eria spicata	EriaSpic	+	–	+	+	+	+	–	+	+
Flickingeria fugax	FlicFuxa	+	+	+	+	+	+	–	+	+
Gastrochilus acutifolium	GastAcut	+	+	+	+	+	+	+	+	–
Gastrochilus bigibbus	GastBigi	+	+	+	+	+	+	–	–	–
Gastrochilus calceolaris	GastCalc	+	+	+	+	+	+	–	+	–
Liparis viridiflora	LipaViri	+	–	+	+	+	+	–	+	–
Luisia brachystachys	LuisBrac	+	+	+	+	+	+	–	–	–
Luisia micrantha	LuisMicr	+	+	+	+	+	+	–	+	–
Oberonia ensiformis	OberEnsi	+	+	+	+	+	+	–	–	–
Oberonia falconeri	OberFalc	+	+	+	+	+	+	–	–	–
Oberonia myriantha	OberMyri	+	+	+	+	+	+	–	–	–
Otochilus albus	OtocAlbu	–	+	+	+	+	+	–	–	+
Otochilus porrecta	OtocPorr	–	–	–	–	–	–	–	+	+
Panisea demissa	PaniDemi	+	+	+	+	+	+	–	+	+
Pelatantheria insectifera	PelaInse	+	+	+	+	+	+	+	+	+
Pholidota imbricata	PholImbr	+	+	+	+	+	+	+	+	+
Pholidota pallida	PholPali	+	+	+	+	+	+	+	+	+

(continued)

Table 3.2 (continued)

Scientific name	Abbreviation	BCF-SF	BCF-MF	BCF-RF	CNP-SF	CNP-MF	CNP-RF	MR-HSF	MR-MF	MR-RhF
Pteroceras teres	PterTere	+	+	–	+	+	+	–	+	+
Rhynchostylis retusa	RhynRetu	+	+	+	–	–	–	+	+	+
Sunipia bicolor	SuniBico	–	–	–	–	–	–	+	+	+
Thunia alba	ThunAlba	–	+	+	–	–	–	+	+	+
Trudelia cristata	TrudCris	–	–	–	–	–	–	–	+	+
Unknown A	UnknownA	–	–	–	–	–	–	–	+	+
Vanda tessellata	VandTess	+	+	+	+	+	+	+	+	+
Vanda testacea	VandTest	+	+	+	+	+	+	+	+	+

Table 3.3 A list of the trees and their numbers as used in CANOCO

Number of tree	Scientific name	Number of tree	Scientific name
1	*Cleistocalyx operculatus*	25	*Terminalia alata*
2	*Syzygium cumini*	28	*Careya arborea*
3	*Shorea robusta*	29	*Gaultheria fragrantissima*
4	*Lagerstroemia parviflora*	30	*Saurauia napaulensis*
5	*Terminalia bellirica*	31	*Betula alnoides*
7	*Dillenia pentagyna*	35	*Aesandra butyracea*
8	*Litsea monopelata*	38	*Schima wallichii*
9	*Sapium insigne*	40	*Alnus nepalensis*
11	*Rhus javanica*	41	*Rhus succedanea*
13	*Terminalia chebula*	42	*Castanopsis tribuloides*
14	*Dalbergia sissoo*	43	*Michelia champaca*
15	*Bombax ceiba*	45	*Castanopsis indica*
16	*Trewia nudiflora*	46	*Butea monosperma*
17	*Garuga pinnata*	47	*Debregeasia salicifolia*
18	*Bauhinia purpurea*	48	*Cedrus deodara*
19	*Adina cordifolia*	49	*Rhododendron arboreum*
20	*Gmelina arborea*	50	*Quercus lanata*
21	*Comus oblonga*	52	*Rhus wallichii*

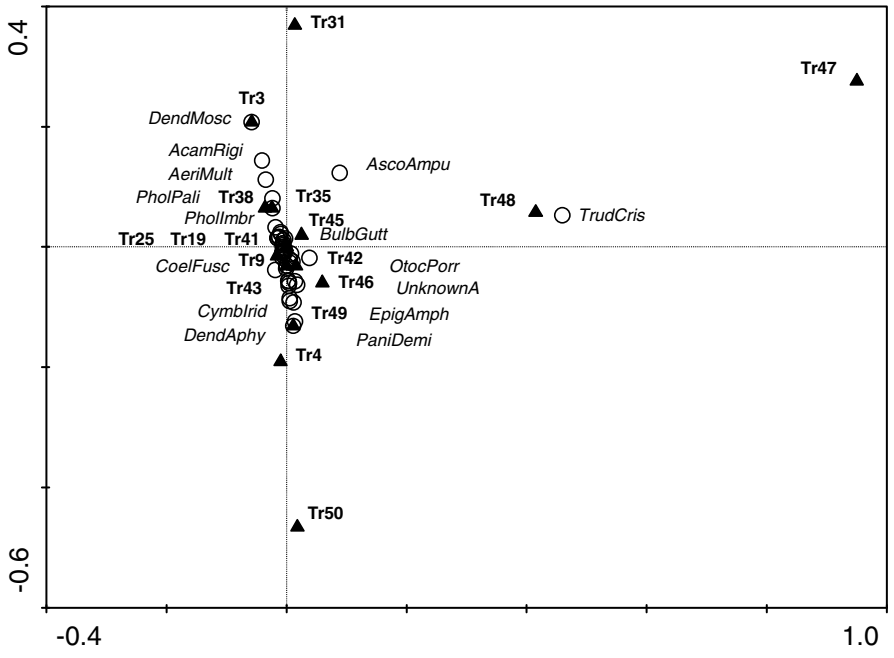

Fig. 3.10 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the rhododendron forest in the Mahabharat range (MR-RhF). First two axes are displayed. The first axis explains 13.8% and the second 8.4% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.95, P = 0.003 (with 999 permutations)

and the trees ($p < 0.05$). *Dendrobium aphyllum* was recorded only on *Rhododendron arboretum*, *Aerides odorata* and *Otochilus albus* only on *Castanopsis tribuloides* and *Dendrobium moschatum* only on *Shorea robusta.* Most orchid species were recorded on *Castanopsis tribuloides* (42 orchid species) and *Rhododendron arboretum* (35).

Figures 3.11–3.13 show orchid species-abundance relationships for the different regions. In the Barandabhar corridor forest, the orchids were most closely associated with particular trees and were recorded only on four different tree species. In contrast, in the Chitwan National Park, the orchids were recorded on average on eight different trees and in the Mahabharat range on five different tree species (Table 3.4). Between 45 and 50 orchid species were recorded in most regions, but only 27 orchid species in the hill sal forest in the Mahabharat range (Table 3.2).

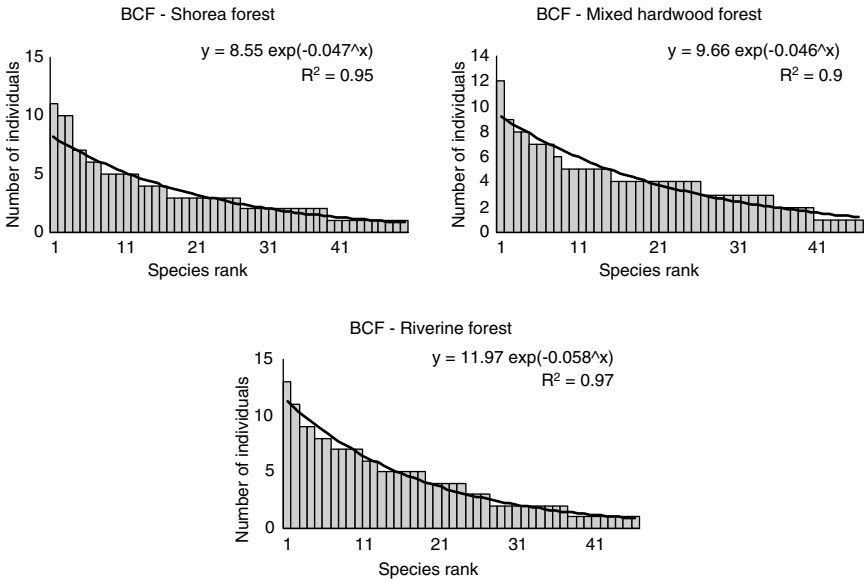

Fig. 3.11 Orchid species abundance relationships for the different types of forest in the Barandabhar corridor forest

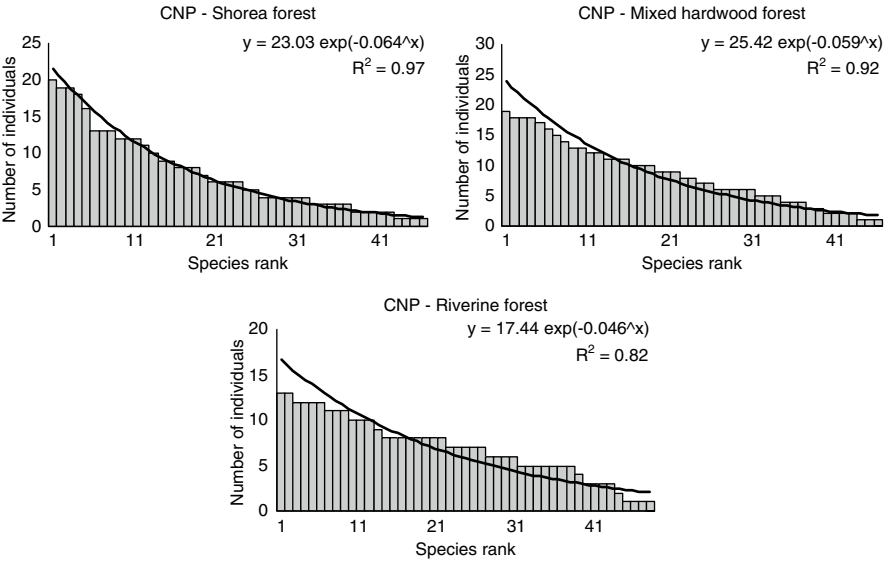

Fig. 3.12 Orchid species abundance relationships for the different types of forest in the Chitwan National Park

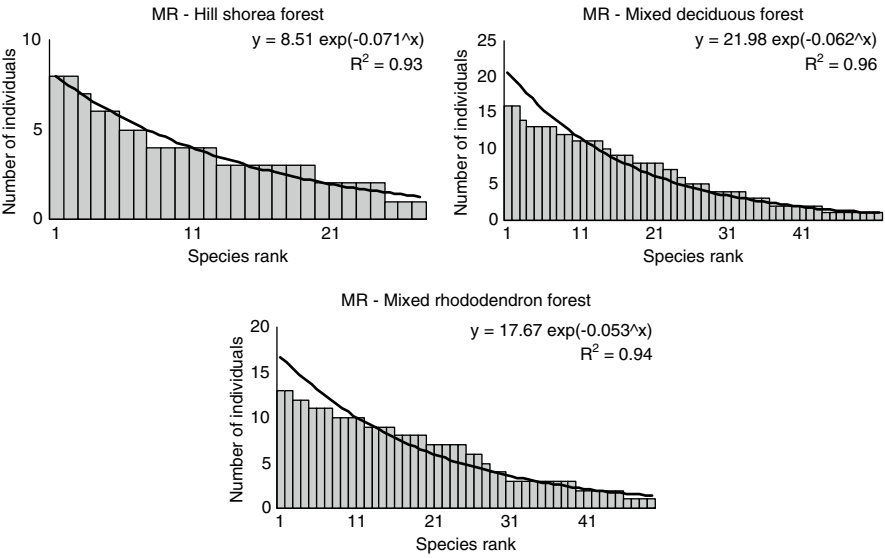

Fig. 3.13 Orchid species abundance relationships for the different types of forest in the Mahabharat range

Table 3.4 Descriptive statistics of the number of orchids per tree

	Number of orchid species	Minimum	Maximum	Median	Mean number of orchids per tree	SE
BCF-SF	49	1	11	3.0	3.33	0.35
BCF-MHF	45	1	12	4.0	4.02	0.35
BCF-RF	45	1	13	4.0	4.13	0.44
CNP-SF	45	1	20	6.0	7.20	0.81
CNP-MHF	45	1	19	8.0	8.42	0.78
CNP-RF	47	1	13	7.0	6.94	0.50
MR-HSF	27	1	8	3.0	3.67	0.38
MR-MDF	50	1	16	5.0	6.42	0.65
MR-RhF	48	1	13	6.5	6.13	0.54

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