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PLATINUM OPEN ACCESS

Multivariate analysis of elements from the microhabitats of selected plateaus in the Western Ghats, Maharashtra, India

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Abstract: The Western Ghats represents a small part of the Deccan Traps continental flood basalt province that erupted about 65 million years ago. It is an area of outstanding scenic beauty and has attracted the attention of geologists, naturalists and geomorphologists for over a century. One of the unique habitats in the Western Ghats are the rocky plateaus. Previous studies have covered plant species composition, geological and geomorphological status of the rocky plateaus. An analytical study of microhabitats and associated therophytes of four rocky plateau sites was conducted. The study sites were Durgawadi Plateau, Naneghat Plateau which are basalt outcrops and Zenda plateau and Amba Plateau, which are laterite outcrops on the escarpment of the northern Western Ghats. The results revealed a correlation between basalt and lateritic rock outcrops as well as ephemeral plant elements. All four outcrops are similar in their nutrient status but the microhabitats of these plateaus are extremely different from each other.

Keywords: Basalt, ephemeral, geology, laterite, Rock outcrop, therophytes.

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Author details: Ms. Priti Vinayak Aphale—associated with Department of Environmental Science, Fergusson College, Pune. Interested in habitat ecology studies and conservation related research. Baseline data collected for sacred groves of Maval Tahsil, Pune since 2012 with special reference to community participation in conservation. Current studies include impact assessment of developmental activities on plateaus and geomrphological and geochemical characterization of plateaus in Western Ghats. Dr. Dhananjay Chintaman Meshram—Professor in Geology, associated with Department of Geology, SPPU, Pune. Interested in Geochemistry, characterization of river sediments, characterization of Basalt. Dr. Dnyaneshwar Maruti Mahajan—Associate Professor with over 24 years of teaching experience and 27 years of research experience. Interested in plant diversity, wetland Ecology, phytoremediation ,ecological restoration, habitat modification and its impact, urban ecology, biomass carbon sequestration and exotic and invasive species. Dr. Prasad Anil Kulkarni—associated with Post Graduate Research Center in Environmental Sciences Department of Applied Sciences, College of Engineering, Pune. Interested in change detection mapping of Mangrove Ecosystem of Raigad Coast, Maharashtra and in ecosystem monitoring and its conservation related research. Dr. Shraddha Prasad Kulkarni—associated with Department of Environmental Science, Fergusson College, Pune. Interested in ecosystem monitoring and its conservation related research. Baseline data collected for Ujjani Wetland, Maharashtra, India since 2010 with special reference to preferential habitat utilization of wetland by bird communities. Habitat monitoring and association of communities were analysed by applying various statistical models.

Author contribution: PVA—contributed in research idea development and experiment design as well as implementation on field, sample collection and analysis; DCM—suggested and contributed in geochemical and geomrphological characterization of plateaus and interpretation of the data; DMM—contributed in identification of species and microhabitats from the plateau ecosystem; PAK—supported in plateau Ecosystem monitoring, field data collection and technical aspects; SPK—supported in statistical analysis for various tests applied to the data and result interepretaion.

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INTRODUCTION

The Sahyadri Range is one of the spectacular geographic features of the Indian subcontinent. Documenting the plant species was necessary to understand the nature of vegetation (Sambhaji 2015). A compilation with commentary of landmark papers by the Geological Society of India's (Gunnell & Radhakrishna 2001) findings till date gives us an idea about its uniqueness. One of the distinctive aspects of the geomorphology of the Sahyadri Range is the presence and preservation of two "paleosurfaces" indicated by laterite (Fox 1923; Widdowson & Cox 1996; Widdowson 1997). Cliffs, isolated hills, and platforms of rocks formed due to landscape level activities of weathering are the types of outcrops seen commonly in India, whereas "rock outcrops" is the term recognized by IUCN as a category of habitats wherein some portions of freely exposed bedrock project above the soil level due to natural reasons (Porembski & Watve 2005). According to Porembski (2007) well-known rocky outcrops in the world are inselbergs, barrens, cedar glades, cliffs, serpentine, ultramafic, limestone, and gypsum outcrops. He also suggested that each of these are known to harbor highly specialized vegetation rich in microhabitat-specific and endemic plants. Rock outcrop habitats are generally of small extent within a region and present particular habitat limitations, e.g., greater exposure to sun and scarcity of soil. The microenvironment at the rock surface ranges from very hot and arid in dry season to water logged in the wet season. Hence edaphically controlled herbaceous plant communities are characteristic of rock outcrops. Rock outcrops are very well known throughout the world for their uniqueness, but are less studied habitats. Most studies are from African, American and Australian outcrops (Porembski et al. 1994, 2000; Burke 2005a,b; Jacobi et al. 2007) describing the habitat types and associated vegetation composition. In India, relatively very few reports exist about vegetation on these special habitats (Porembski & Watve 2005; Watve 2008, 2013; Lekhak & Yadav 2012; Bhattarai et al. 2012).

The rock outcrops in the Western Ghats of Maharashtra are of two types based on the rock formation and soil type developed from it: (i) Lateritic—lateritic rock cover is well preserved over the parent basalt rock and soil rich in iron, and (ii) Basaltic—having black hard rock and soil. Durgawadi and Naneghat plateaus from the northwestern corner of Pune District are entirely basaltic but have some lateritic soil due to weathering. They have a diversity of micro-habitats and are rich in flora and fauna. Trees or shrubs are less in number, but herbaceous angiosperms, algae, mosses, ferns and lichens are generally abundant in these habitats. Many of the endemic ephemerals, herbaceous angiosperms, pteridophytes and lichens, however, are restricted to these special habitats (Watve 2008). Species composition patterns and outcrop communities are influenced by multiple environmental factors like soil type, elevation, aspect of that rock outcrop and micro-environments (Watve 2013). Moreover, transect studies of plateaus in northern Western Ghats region conducted by Watve (2008 & 2013) discuss the vegetation composition and pattern of some microhabitats on the plateaus. A comprehensive botanical study of two rock outcrops, Durgawadi Plateau (DP) and Naneghat Plateau (NP), on the escarpment of northern Western Ghats revealed a very high plant diversity within the sites and between the sites (Rahangdale & Rahangdale 2014). Herbaceous vegetation of high-level lateritic plateaus of southwestern Maharashtra have been studied by Lekhak & Yadav (2012). These studies have revealed the importance of microhabitats as this plateau vegetation has unique microhabitats that support distinct plant communities depending primarily on soil, depth of the soil and moisture availability. None of these studies describe the interrelationship between nutrient status and plant communities. Hence, the present study was carried out to find out the correlation between nutrient status of selected microhabitats and associated plant communities with the following objectives.

1. Identification and RS & GIS based mapping of microhabitats at plateau ecosystem
2. Sampling and analysis of trace and major elements of rock as well as soil from microhabitats
3. Identification and selection of ephemerals in plateau ecosystem
4. Sampling and analysis of trace and major elements of selected plant communities
5. Understanding correlation among elements, microhabitats and plant communities as well as plateaus using statistical methods

STUDY AREA

Durgawadi Plateau (Image 1): It is located 60km from Junnar Town at 1,200m altitude. The plateau top can be reached after a steep climb from Inglun Village at 19.193^{0}N, 73.695^{0}E & 19.217^{0}N, 73.642^{0}E. The road passes through the villages of Ambe, Hatwij, and Kathewadi and ends at the sacred grove of Durgawadi, which overlooks the Konkan area. Adjacent to it is the

Image 1. Durgawadi Plateau.

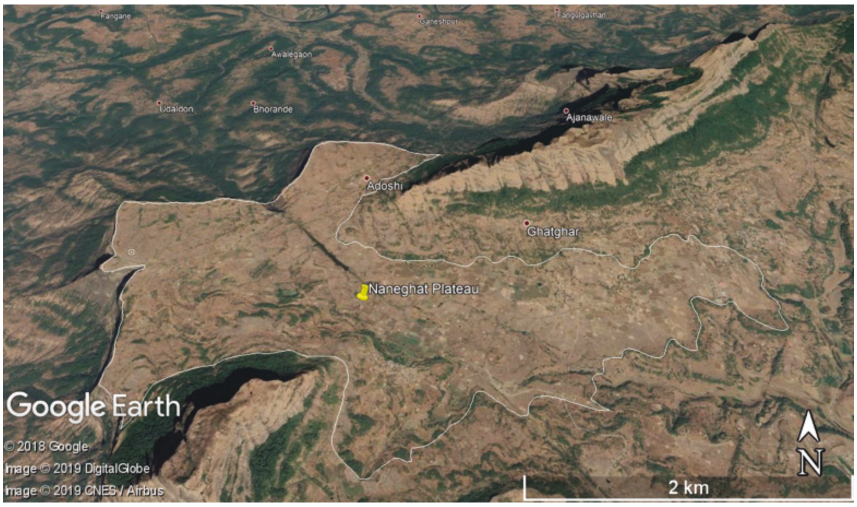

Image 2. Naneghat Plateau.

plateau of Warsubai Temple. The Durgawadi Plateau is floristically very important because a number of new taxa are described from this region or adjacent region. According to Rahangdale (2009), Yadav (2010), Aitawade & Yadav (2012), and Rahangdale & Rahangdale (2012) all new taxa described from the location are endemic to Durgawadi.

Naneghat Plateau (Image 2): It is located 26km away from Junnar Town at 19.271^{0}N,73.720^{0}E & 19.298^{0}N,73.672^{0}E, 700m. The rocky hills of this region are well known forts. There is a tar road from Junnar to Naneghat (Ghatghar Village). The basalt is exposed as a broad expanse at a low altitude and bounded by sacred groves, reserve forest patches, rice fields and vertical slopes. The outcrop and its surroundings are affected by biotic pressures. Hemadri (1980) and Rahangdale (2009) denoted that Naneghat Plateau area is rich in plant diversity.

Amba Plateau (Image 3): Amba plateau is located at 16.985^{0}N, 73.784^{0}E & 16.987^{0}N, 73.797^{0}E, 740m, and overlooks the Amba Ghat which is a famous monsoon tourist destination. The plateau top can be reached from a forested path through Amba village.

Zenda plateau (Image 4): Zenda-Dhangarwada Plateau is a least disturbed outcrop located at 16°55'5.50"N, 16.918^{0}N, 73.797^{0}E & 16.904^{0}N, 73.849^{0}E, 1025m. The plateau is known as Zenda Hill and is located between Manoli-Gajapur-Dhangarwada villages near Amba Ghat. The plateau top on Manoli side can be approached from a forested footpath branching from Amba to Vishalgad road (Images 5 & 6).

Image 3. Amba Plateau.

Image 4. Zenda Plateau.


Image 5. Zenda Plateau during the monsoon season.


Image 6. During the eight months plateaus are dry, but possess therophytic communities of endemic plants which are less studied. (Zenda Plateau, Kolhapur) during dry conditions.

METHODS

Maharashtra possesses characteristic habitats called high level plateaus (Watve 2007). Many of them represent lateritic, basaltic as well as sandy characteristics. Of the four plateaus which were found least disturbed, the ones representing basalt and laterite were selected for the said research. All of these are located in the Western Ghats at Pune and Kolhapur regions. These were specifically selected after referencing existing literature and after conducting several field surveys.

GIS mapping – tools and techniques

The research area was surveyed extensively to mark the boundaries of the plateaus. Exact latitudes and longitudes were recorded and marked by using Garmin 5 handheld GPS. These lat-longs were then calibrated with Google Earth version 6.2 (http://www.Google.com/earth/index.html) to get .kmz images as a reference database. For freshly captured images, satellite data was procured from NRSC, Hyderabad. The data was further used to mark each microhabitat at each plateau (Table 1) on ArcGIS … and ERDAS 9.1 platform. Each plateau as well as each microhabitat was GPS marked.

In all, three field study visits were carried out during different seasons: pre-monsoon (March–May), monsoon (June–October), and winter (November–February) to understand the seasonal variations from 2013 to 2017.

Sampling and analysis of soil and rock

Rock and soil sampling was done from the microhabitats marked using GIS; wherever soil was accumulated in microhabitats soil samples were collected from 100cm depth. For habitats like boulders and exposed rock surfaces, the intact rocks were broken and samples were collected. These samples were analyzed using x-ray fluorescence spectrophotometry (XRF). It is a non-destructive analytical technique used to determine the elemental composition of materials. XRF analyzers determine the chemistry of a sample by measuring the fluorescent (or secondary) x-ray emitted from a sample when it is excited by a primary x-ray source. The method is used extensively to analyze trace and major elements of rock as well as soil in a powdered form. Nutrients, Nitrogen by Kjeldahl's method and organic Carbon by Walkley & Black method. The data of XRF analysis is heterogenously distributed over 50 elements around two rock types from four locations distributed over 10–11 microhabitats. Dimensions of which are 2*4*11*50 and types of measurements are percentage and part-per-million.

The statistical analysis was carried out using R $v_{3.3.3}$ and ggplot2 $v_{2.2.0}$ package

Identification of micro habitats at plateau ecosystem

Plants on the plateaus are adapted to various microhabitats and each of these is unique in its edaphic properties, water availability and species composition (Porembski & Barthlott 2000). According to Jacobi et al. (2007) and Watve & Thakur (2006) the most common habitat types observed on plateaus have been identified by following an established categorization for rock outcrops.

Identification and selection of ephemerals at plateau ecosystem

A comprehensive list of plants has been prepared for each microhabitat classified as per Raunkiaer (1934). Phenology was recorded and all the specimens collected were therophytes. An analysis reveals that nearly 70% of the species associated with plateau ecosystem are therophytes (Porembski 2000). The species found in abundance were collected by direct uprooting method along with all parts including roots to flowers. Care was taken to avoid disturbing species nearby. Identification of species was done using regional flora of Kolhapur and Pune and the literature available. Collected plant specimens were processed at the herbarium using standard techniques. All herbarium specimens were deposited in Agharkar Research Institute, Pune for authentication. This was recorded as a first set of samples. The second set of samples were carefully dried in shade. Soil particles from the roots were carefully removed from the plants, and the sample plants were powdered with mortar and pestle. Further, these set of samples were analyzed by XRF to understand trace

Table 1. Samples collected from microhabitats across the plateaus.

Microhabitat	Durgawadi	Naneghat	Amba	Zenda
Cliffs	Rock	Rock	Rock	Rock
Exposed rock surfaces	Rock	Rock	Rock	Rock
Ephemeral pools	Soil	Soil	Soil	Soil
Sacred groves	Soil	Soil	NA	NA
Soil covered areas	Soil	Soil	Soil	Soil
Seasonal ponds	Soil	Soil	Soil	Soil
Rock crevices	Rock	Rock	Rock	Rock
Boulders	Rock	NA	Rock	Rock
Soil richareas	Soil	Soil	Soil	Soil
Soil filled depressions	Soil	Soil	Soil	Soil
Plateau tree cover	Soil	Soil	Soil	Soil

and major elements (Table 2). Kjeldahl's and Walkley & Black methods were used for nutrients like Nitrogen and organic Carbon, respectively. Multivariate statistical analysis was done using software like PAST and R. This was done to understand correlation among elements, microhabitats and plant communities as well as plateaus (Shtangeeva & Alber 2009). Interrelationship among elements was also identified. Table 1 shows the details of the samples collected and processed.

RESULTS AND DISCUSSION

The multivariate analysis of variance (MANOVA) was carried out between the selected elements of plants and rocks across four regions (Durgawadi, Naneghat, Amba, and Zenda) for 10 nutrient elements. The p-values were estimated using multivariate Pillai–Bartlett test statistic.

The overall MANOVA, carried out across all the regions, indicated a significant difference in the content of all the nutrient elements between rocks and plants (p-value = 2.2e-16; <0.001) (Fig. 1).

In the case of Durgawadi region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 1.795e-12; <0.001). Further investigations revealed that except Zinc, all other elements were significantly contributing towards the differences in nutrients of rocks and plants in the Durgawadi (Fig. 2) plateau.

Similar to Durgawadi, the Naneghat region also showed a significant difference in the content of nutrient elements between rocks and plants (p-value = 4.761e-09; < 0.001). Copper, however, did not contribute significantly towards the differences between rocks and plants in the Naneghat (Fig. 3) region.

When Amba region was analysed using MANOVA it revealed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 5.667e-10; <0.001). Further investigation revealed that except Zinc, all other elements significantly contributed towards the differences in nutrients of rocks and plants in the Amba region, which is similar to Durgawadi (Fig. 4)

In case of Zenda region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 1.31e-06; <0.001). Closer inspection showed that the elements Calcium, Manganese, Zinc and Copper did not contribute towards the significant differences in plants and rocks of Zenda region (Fig. 5). It shows that the nutrient profiles of plant and rocks in Zenda region is characteristically different from other regions.

MANOVA between Plants and Rocks

The Multivariate Analysis of Variance (MANOVA) was carried out between plants and rocks across four regions (Durgawadi, Naneghat, Amba and Zenda) for ten nutrient elements. The p-values were estimated using multivariate Pillai–Bartlett test statistic.

In case of the Durgawadi region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (*p*-value = 1.795e-12; <0.001). Further investigation revealed that except Zinc, all other elements were significantly contributing towards the differences in nutrients of rocks and plants in the Durgawadi (Fig. 1: Durgwadi_manova_boxplot.png) region.

Similar to Durgawadi, the Naneghat region also showed significant difference in the content of nutrient elements between rocks and plants (p-value = 4.761e-09; <0.001). However, Copper did not contribute significantly towards the differences between rocks and plants in the Naneghat (Fig. 2: Naneghat_manova_boxplot.png) region.

When Amba region was analyzed using MANOVA it revealed that there was significant difference in the content of nutrient elements between rocks and plants (p-value = 5.667e-10; <0.001). Further investigation revealed that except Zinc, all other elements were significantly contributing towards the differences in nutrients of rocks and plants in the Amba region, which

Table 2. Selection of elements for XRF and nutrient analysis of ephemeral plants.

Type of element	Name of the element	Reason for selection	Method of estimation
Nutrients	Organic Carbon, Nitrogen, Phosphorous, Potassium	Essential nutrients	OC (Walkley & Black), Nitrogen (Kjeldahl's), Phosphorous & Potassium (XRF)
Major elements	Calcium, Magnesium, Iron, Manganese	Selected as per t-test results across the regions	XRF method
Trace elements	Zinc, Copper	Selected as per t-test results across the regions	XRF method

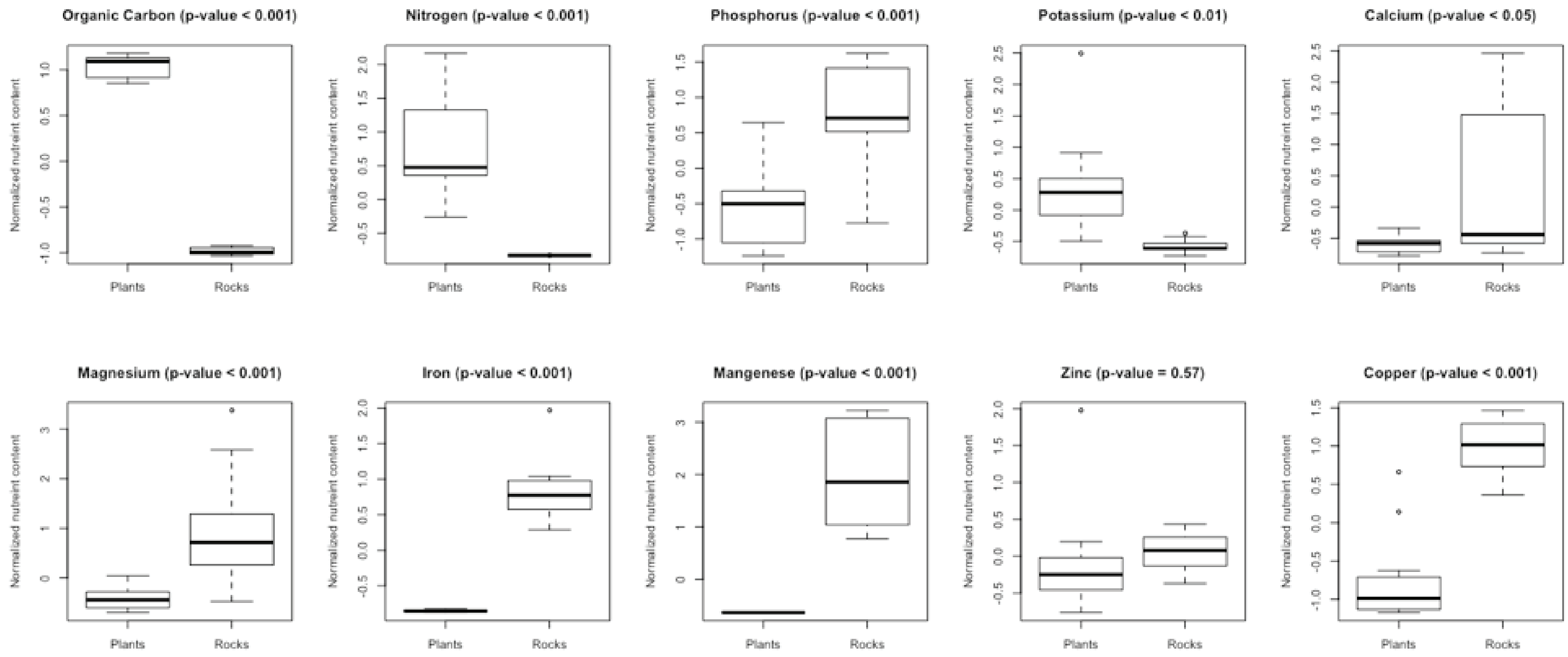

Figure 1. The variation of nutrient elements between rocks and plants in the Durgawadi region. The p-values were estimated using the multivariate Pillai–Bartlett test statistic (MANOVA).

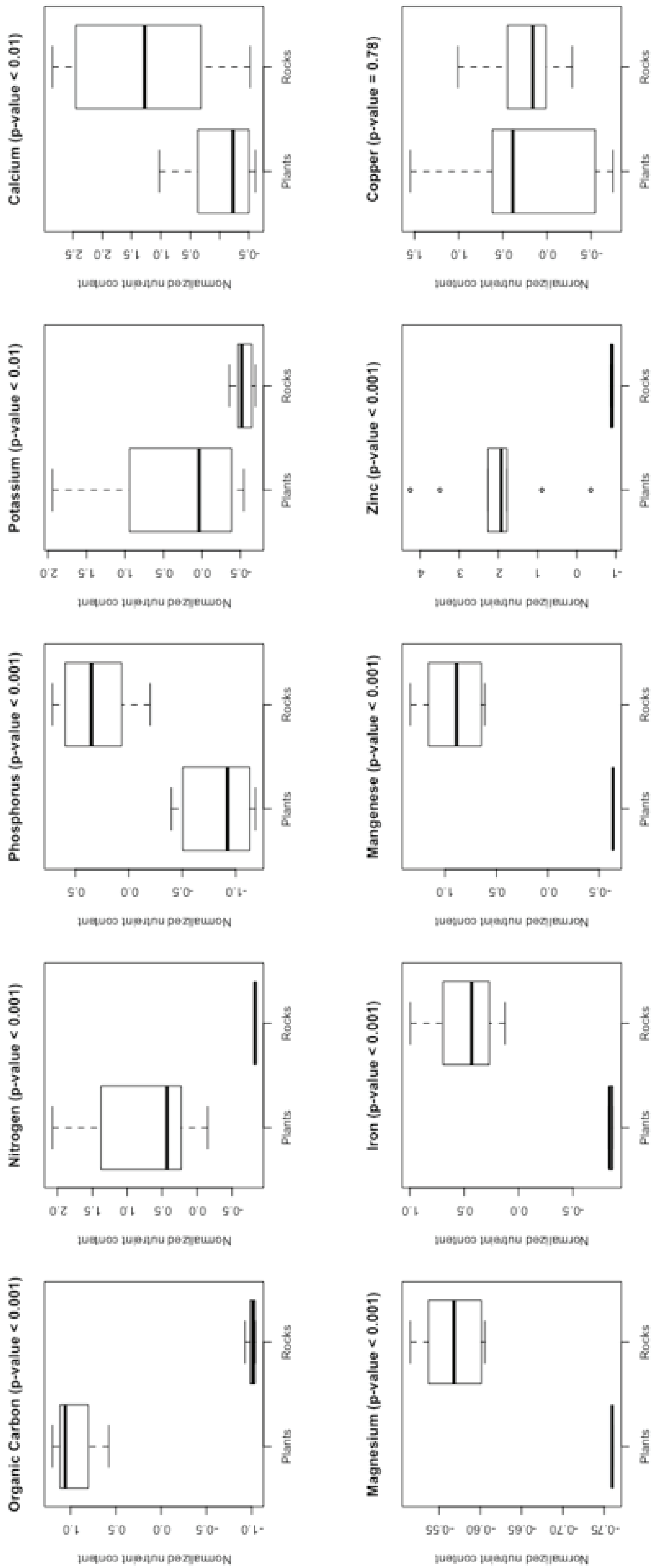

Figure 2. The variation of nutrient elements between rocks and plants in the Naneghat region. The p-values were estimated using the multivariate Pillai–Bartlett test statistic (MANOVA).

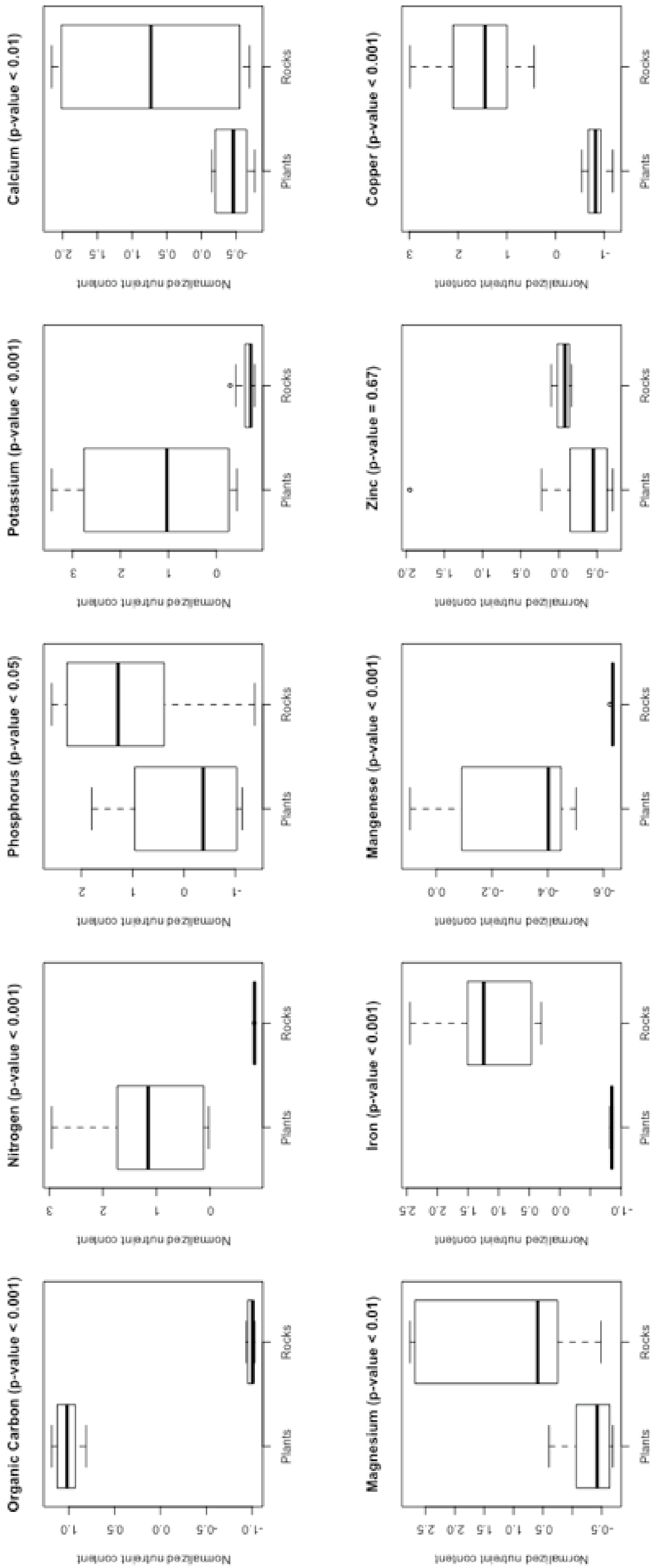

Figure 3. The variation of nutrient elements between rocks and plants in Amba region. The p-values were estimated using the multivariate Pillai–Bartlett test statistic (MANOVA).

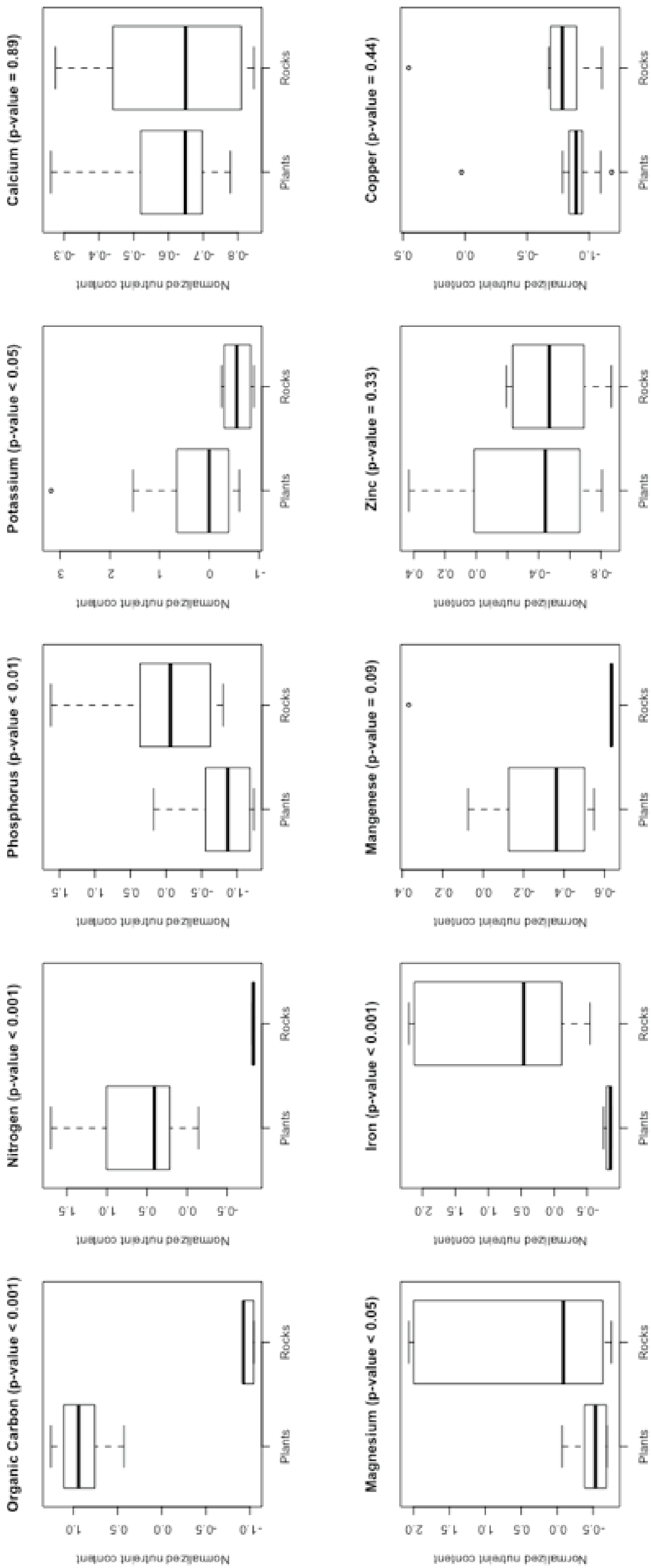

Figure 4. The variation of nutrient elements between rocks and plants in Zenda region. The p-values were estimated using multivariate Pillai–Bartlett test statistic (MANOVA).

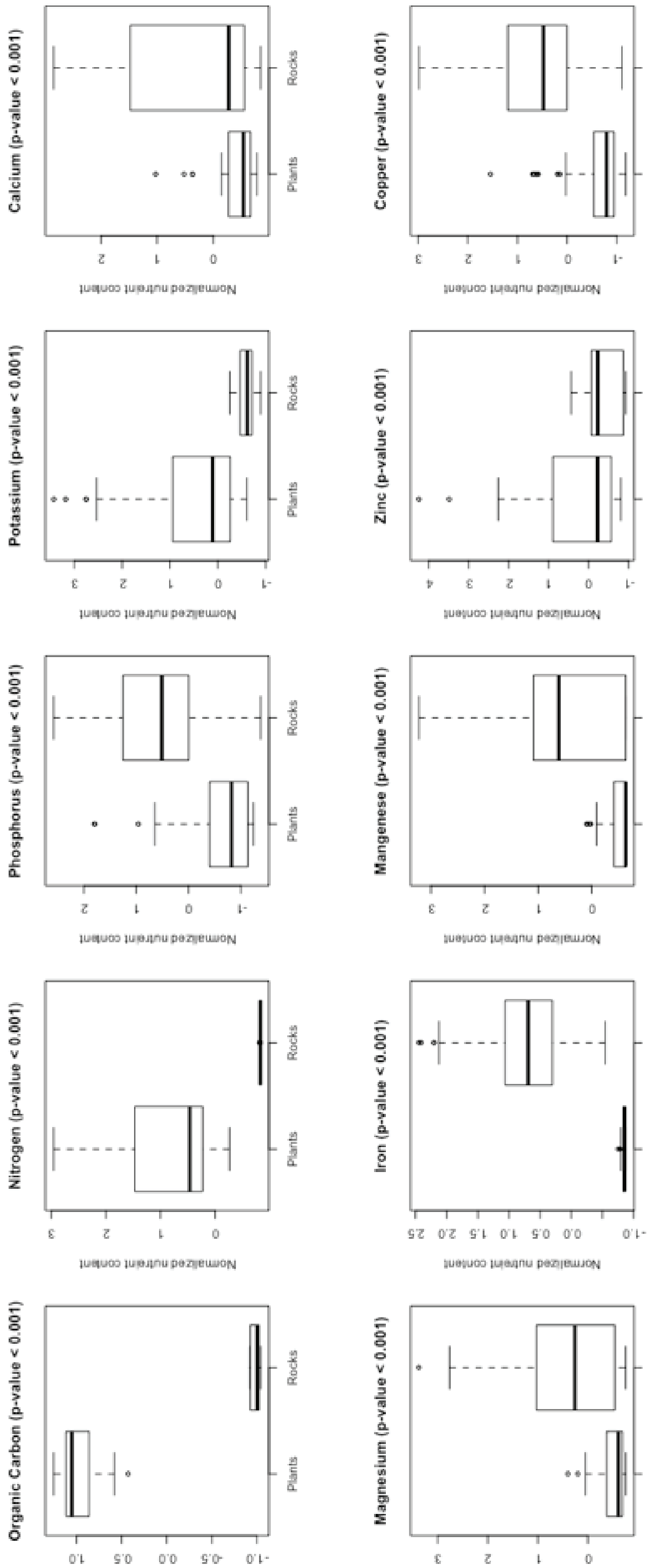

Figure 5. The overall variation of nutrient elements between rocks and plants in all the regions (Durgawadi, Naneghat, Amba Zenda). The p-values were estimated using multivariate Pillai–Bartlett test statistic (MANOVA).

is similar to Durgawadi (Fig. 3: Amba_manova_boxplot.png).

In case of Zenda region, based on the MANOVA it was observed that there was significant difference in the content of nutrient elements between rocks and plants (*p*-value = 1.31e-06; <0.001). Closer inspection shows that the elements Calcium, Manganese, Zinc and Copper do not contribute towards the significant differences in plants and rocks of Zenda region (Fig. 4: Zenda_manova_boxplot.png). It shows that the nutrient profiles of plant and rocks in Zenda region is characteristically different from the other regions.

The overall MANOVA, carried out across all the regions, also indicated the significant difference in the content of all the nutrient elements between rocks and plants (*p*-value = 2.2e-16; < 0.001) (Fig. 5: Combined_manova_boxplot.png).

CONCLUSION

The overall results show that nutrients, trace and major elements under study in all four selected plateaus are significantly different. The Zenda Plateau, the least disturbed plateau in all four plateaus, shows characteristically different nutrient and element content. As Calcium, Manganese, Zinc, and Copper do not contribute towards significant differences in plants and rocks of Zenda region. Each of these areas is different and needs to be studied in detail to understand the dynamics of the ecosystem. Except Zinc, similarity was observed in all elements when samples were analyzed from rocks as well as plants at Durgawadi- Basalt and Amba-Lateritic plateaus. For understanding the causes of such similarities more such studies are needed. The environmental exceptionality, high diversity, lack of studies and speedy destruction of these ecosystems pose an abrupt challenge for their conservation. These should not be considered as wastelands as they are ecologically significant and a hold scientifically unknown facts.

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Appendix 1. Species recorded from four plateaus.

	Species	Family	Durgawadi microhabitat	Naneghat microhabitat	Amba microhabitat	Zenda microhabitat
1	*Acanthospermum hispidum* DC.	Asteraceae	-	CE	-	-
2	*Acmella paniculata* (Wall. ex DC.) R.K. Jansen	Asteraceae	-	-	SCA	-
3	*Adenocaryum coelestium* (Lindl.) Brand	Commelinaceae	+	SCA	-	SCA
4	*Adenoon indicum* Dalzell	Asteraceae	-	-	-	SFD
5	*Adiantum* sp.	Adiantaceae	-	-	-	B
6	*Alysicarpus belgaumensis* Wight	Fabaceae	-	-	-	SFD
7	*Antraxon jubatus* Hack	Poaceae	CE, SCA, PTC	CE, SCA, PTC	-	CE, SCA, PTC
8	*Antraxon lanceolatus* var *meeboldi (stapf) welzen*	Poaceae	-	-	-	SFD
9	*Argemone mexicana* L.	Papaveraceae	SFD	-	-	-
10	*Argyreia cuneata* Ker Gawl.	Convolvulaceae	SG	-	PTC	-
11	*Argyreia sericea* Dalzell	Convolvulaceae	SG	SG	-	PTC
12	*Arisaema murrayi* (Graham) Hook.	Araceae	SRA,B	SRA,B	SRA,B	SRA,B
13	*Arundinella ciliata*	Poaceae	-	SFD	-	
14	*Arundinella pumila* (Hochst. ex A. Rich.) Steud	Poaceae	-	-	SRA	-
15	*Asystasia dalzelliana* Sant.	Acanthaceae	CE, RC, SG	CE, RC, SG	CE, RC	CE, RC
16	*Begonia crenata* Dryand.	Begoniaceae	CE, B	CE	CE, B	CE, B
17	*Bidens biternata* (Lour.) Merr. & Sherff.	Asteraceae	-	ERS	-	-
18	*Biophytum sensitivum* (L.) DC.	Oxalidaceae	SRA	-	-	-
19	*Blepharis maderaspatensis* B. Heyne ex Roth	Acanthaceae	-	ERS, RC	-	-
20	*Blumea malcolmii* Hook.f.	Asteraceae	CE, RC	CE, RC		CE, RC
21	*Buchnera hispida* Buch.-Ham.	Scrophulariaceae	SCA	-	-	-
22	*Burmannia coelestis*	Burmanniaceae	-	-	SRA	-
23	*Canscora diffusa* (Vahl) R. Br. ex Roem. & Schult.	Gentianaceae	CE, RC	CE, RC	CE, RC	CE, RC
24	*Carvia callosa* (Nees) Bremek.	Acanthaceae	-	B, SG, SCA	-	-
25	*Catharanthus pusillus* (Murr.) G.Don	Apocynaceae	-	ERS,SRA	-	-
26	*Celosia argentea* L	Amaranthaceae	B, CE	CE	B, CE	-
27	*Ceropegia rollae* Hemadri	Asclepiadaceae	RC, SFD	-	-	RC, SFD
28	*Chlorophytum glaucoides* Blatt.	Anthericaceae	SRA	-	-	SRA
29	*Chlorophytum laxum* R.Br.	Anthericaceae	-	SCA	-	-
30	*Chrysopogon polyphyllus* Blatt. & McC.	poaceae	SCA	SCA	-	-
31	*Commelina benghalensis* L.	Commelinaceae	SCA, RC, SFD	SCA, RC, SFD	-	SCA, RC, SFD
32	*Commelina maculata* Edgew.	Commelinaceae	-	-	SCA	-
33	*Commelina paludosa* Blume	Commelinaceae	-	-	SCA	-
34	*Commelina suffruticosa* Blume	Commelinaceae	-	SCA	-	-
35	*Conyza stricta* Willd.	Asteraceae	-	-	SRA	-
36	*Cosmos bipinnatus* Cav.	Asteraceae	ERS	-	-	-
37	*Crinum latifolium L.* var. *latifolium*	Amaryllidaceae	SRA	-	SFD	SFD
38	*Crinum pratense* Herb.	Amaryllidaceae	-	-	SCA, SFD, RC	-
39	*Crotolaria filipes* Benth.	Fabaceae	-	SFD	-	-
40	*Curcuma pseudomontana* Grah.	Zingiberaceae	SG,SRA	SG,SRA	,SRA	SRA
41	*Cyanotis fasciculata* (Heyne ex Roth) Schult.f.	Commelinaceae	RC, SCA	RC, SCA	RC, SCA	-
42	*Cyanotis tuberosa* (Roxb.) Schult.f. var. *tuberosa*	Commelinaceae	SRA	SRA	-	SRA
43	*Cyathocline lutea* Law ex Wight	Asteraceae	SEP, SCA	-	-	-
44	*Cynodon dactylon* (L.) Pers.	poaceae	SRA	-	-	-
45	*Cyperus difformis* L.	Cyperaceae	SEP, SP	-	-	-
46	*Cyperus rotundus* L.	Cyperaceae	SRA	-	SRA	SRA
47	*Cyperus tenuispica* Steud.	Cyperaceae	SEP, SP	-	-	SEP, SP

	Species	Family	Durgawadi microhabitat	Naneghat microhabitat	Amba microhabitat	Zenda microhabitat
48	*Delphinium malabaricum* (Huth) Munz.	Ranunculaceae	CE,SG	CE,SG	-	CE
49	*Desmodium triflorum* (L.) DC.	Fabaceae	-	-	SCA	-
50	*Digitaria stricta*	poaceae	-	-	SFD	-
51	*Drimia indica* (Roxb.) Jessop	Hyacinthaceae	ERS	ERS	-	-
52	*Drosera indica* L.	Droseraceae	SCA, SEP	-	SCA, SEP	SCA, SEP
53	*Elephantopus scaber* L.	Asteraceae	-	PTC	PTC	PTC
54	*Emilia sonchifolia* (L.) DC.	Asteraceae	-	SFD	-	-
55	*Eragrostis unioloides* (Retz.) Steud.	Poaceae	SCA	SCA	SCA	SCA
56	*Eriocaulon achiton* Korn	Eriocaulaceae	ERS	-	-	ERS
57	*Eriocaulon eurypeplon* Körn	Eriocaulaceae	-	-	-	-
58	*Eriocaulon sedgwikii* Fyson	Eriocaulaceae	SEP, SP	SEP, SP	-	SEP, SP
59	*Euphorbia thymifolia* L.	Euphorbiaceae	-	ERS	-	-
60	*Evolvulous alsinoides* L.	Poaceae	-	ERS, SCA	-	SRA
61	*Exacum lawii* C.B. Clarke	Gentianaceae	SCA, SFD		SCA, SFD	SCA, SFD
62	*Fimbristylis lawiana* (Boeckeler) J.Kern	Cyperaceae	SRA	SRA	SRA	SRA
63	*Fimbristylis tenera* Schult	Cyperaceae	-	-	-	CR,SFD
64	*Gloriosa superba* L.	Colchicaceae	SCA,SG	-	-	-
65	*Glyphochloa forticulata* (C.E.C.Fischer) W.D.Clayton	Poaceae	SFD	SFD	-	SFD
66	*Gynura bicolor* (Roxb. ex Willd.) DC.	Asteraceae	-	SFD, CE	SFD, CE	-
67	*Habenaria foliosa* A. Rich var. *foliosa*	Orchidaceae	SRA	SRA	-	SRA
68	*Habenaria grandifloriformis* Blatt. & McC.	Orchidaceae	SCA	SCA	-	SCA
69	*Habenaria heyneana* Lindl.	Orchidaceae	SCA	SCA	SCA	SCA
70	*Habenaria longicorniculata* J.Graham	Orchidaceae	-	-	SRA	-
71	*Habenaria panchganensis* Santapau & Kapadia	Orchidaceae	-	-	-	RC
72	*Habenaria rariflora* A.Rich	Orchidaceae	SCA	SCA	SCA	SCA
73	*Hedyotis aspera* Heyne ex Roth	Rubiaceae	SCA	-	-	-
74	*Hedyotis stocksii* (Hook.f. & Thomson) R.S.Rao & Hemadri	Rubiaceae	-	Naneghat	-	ERS,B
75	*Heliotropium indicum* L.	Boraginaceae	-	SRA	-	-
76	*Hypoxis aurea* Lour	Hypoxidaceae	SRA	SRA	SRA	SRA
77	*Impatiens acaulis* Arn.	Balsaminaceae			CE	
78	*Impatiens balsamina* L.	Balsaminaceae	SRA, SFD	SRA, SFD	SRA, SFD	SRA, SFD
79	*Impatiens lawii* Hook. f. & Thomson	Balsaminaceae	SFD, RC	-	SFD, RC	SFD, RC
80	*Impatiens minor* (DC.) Bennet	Balsaminaceae	RC,SG	-	RC	RC
81	*Impatiens oppositifolia* L.	Balsaminaceae	SFD	SFD	SFD	SFD
82	*Indigofera dalzelli* T. Cooke	Fabaceae	-	-	SFD,CR	SFD,CR
83	*Iphigenia indica* (L.) A.Gray ex Kunth	Colchicaceae	SCA	-	-	-
84	*Iphigenia stellata* Blatt.	Colchicaceae	SCA	SCA	SCA	-
85	*Isachne elegans* Dalz. ex Hook.f.	Poaceae	SCA	-	-	SCA
86	*Jansenella grafithiana* (M.II.Hal) Bor	Poaceae	-	-	SFD	SFD
87	*Jansenella neglecta* Yadav, Chivalkar & Gosavi	Poaceae	SCA	-	-	SCA
88	*Justicia betonica* L.	Acanthaceae	SRA, SG	SRA, SG	-	SRA
89	*Justicia glaucea* Rottl.	Acanthaceae	SRA, SG	SRA, SG	-	SRA
90	*Lavandula bipinnata* Kuntze	Lamiaceae	ERS	ERS	-	ERS
91	*Linum mysurense* B. Heyne ex Benth.	Linaceae	SCA	-	SFD	SFD
92	*Momordica dioica* Wall.	Cucurbitaceae	RC, SFD	RC, SFD	-	RC, SFD
93	*Murdannia lanuginosa* G. Brückn	Commelinaceae	-	-	-	RC
94	*Murdannia semiteres* (Dalzell) Santapau	Commelinaceae	ERS	ERS	ERS	ERS

	Species	Family	Durgawadi microhabitat	Naneghat microhabitat	Amba microhabitat	Zenda microhabitat
95	*Murdannia simplex* (Vahl) Brenan	Commelinaceae	-	-	SFD	-
96	*Murdannia spirata* L.	Commelinaceae	-	ERS	-	ERS
97	*Murdannia versicolor* G. Brückn.	Commelinaceae	-	-	SEP, SCA	RC
98	*Neanotis calycina* (Wall. ex Hook.f.) W.H. Lewis	Rubiaceae	SRA, RC, SFD	SRA, RC, SFD	SRA, RC, SFD	SRA, RC, SFD
99	*Neonatis foeitida* (Dalzell) W.H. Lewis	Fabaceae	SCA	SCA	SCA	SCA,SRA
100	*Nervilia aragoana* Gaudich.	Orchidaceae	-	-	Amba	-
101	*Nicandra physalodes* (L.) Gaertn.	Solanaceae	SRA	SRA	-	SRA
102	*Nilgirianthus reticulatus* (Stapf) Bremek.	Acanthaceae	CE, SRA	CE, SRA	-	CE, SRA
103	*Nilgirianthus reticulatus* (Stapf) Bremek.	Acanthaceae				
104	*Nymphoides indica* (L.) Kuntze	Menyanthaceae	SP	-	-	SP
105	*Panicum antidotale* Retz.	poaceae	SRA	SRA	SRA	SRA
106	*Paspalum canarae* (Steud.) Veldk. var. *canarae*	Poaceae	ERS,SFD	ERS	ERS	SFD
107	*Pimpinella adscendens* Dalzell	Apiaceae	RC, CE	RC, CE	RC, CE	RC, CE
108	*Pinda concanensis* (Dalzell) P.K.Mukh. & Constance	Apiaceae	SFD, SCA	SFD, SCA	-	SFD, SCA
109	*Pogostemon deccanensis* (Panigrahi)	Lamiaceae	SP	SP	SP	SP
110	*Remusatia vivipara* (Roxb) Schott	Araceae	SFD, SG	-	SFD	SFD
111	*Rhamphicarpa longiflora* Benth.	Scrophulariaceae	SP, SEP	SP, SEP	SP, SEP	-
112	*Rostellularia diffusa* (Nees.) Nees	Acanthaceae	-	CE	-	-
113	*Rotala densiflora* Koehne	Lythraceae	SP, SEP	SP, SEP	SP, SEP	SP, SEP
114	*Senecio bombayensis* N.P. Balakr.	Asteraceae	CE, RC, SFD	CE, RC, SFD	CE, RC, SFD	CE, RC, SFD
115	*Senecio dalzellii* C.B. Cl.	Fabaceae		SFD,SEP		
116	*Smithia bigemina* Dalzell	Fabaceae	SCA, SFD, RC	SCA, SFD, RC	SCA, SFD, RC	SCA, SFD, RC
117	*Smithia hirsuta* Dalzell	Fabaceae	SCA	SCA	SCA	SCA
118	*Smithia purpurea* Hook	Fabaceae	SRA, SEP, RC,	SRA, SEP, RC,	-	-
119	*Smithia racemosa* B. Heyne	Fabaceae	SRA	SRA	SRA	SRA
120	*Smithia sensitiva* Aiton	Fabaceae	SRA	SRA	-	SRA
121	*Solanum anguivi* Lam.	Solanaceae	SCA	-	SCA	SCA
122	*Sonerila scapigera* Dalzell	Melastomataceae	B,RC	B,RC	B,RC	B,RC
123	*Sopubia delphinifolia* G. Don	Scrophulariaceae	SP, SEP, SCA	SP, SEP, SCA	SP, SEP, SCA	SP, SEP, SCA
124	*Sphaeranthus indicus* L	Asteraceae	-	SCA	-	-
125	*Striga gesnerioides* (Willd.) Vatke	Scrophulariaceae	SCA	-	-	SCA
126	*Swertia densifolia* (Griseb.) Kashyapa	Gentianaceae			SRA, SFD	
127	*Swertia minor* Knobl.	Gentianaceae	SCA, SEP	SCA, SEP	SCA, SEP	SCA, SEP
128	*Thunbergia laevis* Wall. & Nees	Acanthaceae	SRA, SG	SRA, SG	-	SRA, SG
129	*Torenia indica* C.J. Saldanha	Scrophulariaceae	PTC	-	-	PTC
130	*Utricularia graminifolia* Vahl	Lentibulariaceae	SP, SEP	-	SEP	-
131	*Utricularia praeteria* P. Taylor	Lentibulariaceae	-	-	-	SP, SEP
132	*Utricularia purpurescens* Grah.	Lentibulariaceae	SP, SEP, B,	SP, SEP, B,	SP, SEP, B,	SP, SEP, B,
133	*Utricularia striatula* J.E. Sm.	Lentibulariaceae	SP,SEP	SP,SEP	SP,SEP	SP,SEP
134	*Vigna vexillata* (L.) A.Rich	Fabaceae	SFD, RC, SCA	SFD, RC, SCA	SFD, RC, SCA	SFD, RC, SCA

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