

Taxonomic Documentation and Statistical Analysis of Soil Mycoflora of Sanjay Gandhi National Park, Maharashtra, India

ABSTRACT

Aims: The present paper deals with documentation of diversity and analysis of ecological aspects of soil microfungial flora of Sanjay Gandhi National Park (SGNP).

Study design: The study area was divided into five zones, defined over span of three ranges and 10% peripheral area.

Place and Duration of Study: SGNP, Maharashtra, India between September 2016 and September 2020.

Methodology: A total of 43 soil samples were collected from 5 zones. Microscopic and molecular methods were used for identification of species. We examine dissimilarity in species composition by pairwise Jaccard Dissimilarity Index. We examine diversity of microfungi using diversity indices of Gini-Simpson's and Shannon's, true diversity (Shannon's effective number of species) and equitability of species with Pielou's evenness index.

Results: The study resulted in a total of 77 isolates of 77 soil fungi obtained from 43 soil samples. A total of 36 species were documented under 15 genera. *Aspergillus* was dominant genus with 16 species, whereas *Aspergillus niger* was dominant species representing maximum 12 isolates. Pairwise Jaccard Dissimilarity Index was found to be above 66% in all cases, with only one species common in all the zones. In diversity indices, Gini-Simpson's was 0.9347, and Shannon's, was 3.1450. Pielou's evenness index was 0.8776, causing true diversity, calculated as effective number of species (23), to be less than observed species richness (36).

Conclusion: Thus, based on systematics and statistical analysis, it can be concluded that SGNP exhibits rich diversity of soil microfungi.

Keywords: Diversity indices; Jaccard's dissimilarity index; Maharashtra; soil fungi; true diversity

1. INTRODUCTION

Sanjay Gandhi National Park (SGNP), Borivali, commonly known as Borivali National Park (BNP) or "Krishnagiri Upwan" is situated at the extreme north of Mumbai. The National Park lies between longitude 72°53' E to 72°58' E and latitude 19°8' to 19°21' N (Khawarey 2000), and covers 103.09 km² of area spanning over three districts viz., Mumbai Suburbs (towards the south and west), Thane (towards the east) and Palghar (towards the north). Located in Mumbai Metropolitan Region, it is one of the few national parks in the world entirely lying within the limits of a bustling metropolis, apart from being one of the most visited national parks. SGNP consists of three forest ranges viz., Tulsi, Krishangiri, and Yeoor. Vasai creek flows through the Yeoor Range, dividing SGNP in two unequal halves. Most dominant forest type in SGNP is southern moist mixed deciduous forest, with patches of mangrove

vegetation along the Vasai creek shores (Pradhan et al 2005). The national park lying between Arabian Sea and Sahyadri Hills of Western Ghats, and with its varied topography, provides favourable environment for growth of fungi. However, only sporadic publications are available on certain aspects of microfungal flora of SGNP, viz., keratinophilic fungi from selected soils of SGNP were documented by Deshmukh & Verekar (2014); fungal diversity of regions with anthropogenic activity in some green zones of Mumbai Metropolitan Region, which included some areas of SGNP, was studied by Sharda et al (2015); diversity and distribution of Arbuscular Mycorrhizal Fungi (AMF) of five trees of medicinal importance from Thane region of SGNP was reported by Chahar & Belose (2018); Dubey & Pandey (2017 & 2019) documented foliicolous fungi of SGNP as a part of larger project of foliicolous fungi of Maharashtra. Thus, there was a huge gap to be filled with regards to the comprehensive study of soil micro-fungal flora of such a rich region. To fulfil this gap, microfungal explorations were carried out in this unexplored area for the period of four years, from 2016 to 2020. The three forest ranges (Tulsi, Krishangiri, and Yoor) and 10% adjoining areas of the National Park were thoroughly explored and investigated during the field tours.

2. MATERIAL AND METHODS

A total of six field tours were carried out during 2016–2020 to SGNP and its 10% peripheral areas. All major forest areas along with core and buffer areas were surveyed in different seasons viz., monsoon, post monsoon, winter and summer, to study the diversity of soil microfungal flora of the National Park. GPS coordinates of collection locations were also recorded. QGIS 2.8 Wien version was used for plotting GPS data to prepare survey map showing collection sites visited during the field tours. The survey map, alongside range map of SGNP (source: forest authorities), is shown in Fig. 1. The field tours resulted in collection of a total of 43 soil samples from the study area. Rhizospheric soil samples were collected in paper bags, dried at room temperature to remove moisture, and then transferred to new paper bags. The isolation of soil fungi was done by dilution plating method (Waksman 1922). The Slides of fungi were prepared under aseptic conditions, observed under Olympus compound microscope model CX-41, and microphotographs were captured with the attached DP22 and DP27 camera. Identification of fungi was done based on morphological characteristics, for which, Gilman (1945), Nagmani, et al. (2006), and Guarro et al. (2012) were consulted. DNA extraction, PCR amplification, and DNA sequencing and Phylogenetic analysis were carried out for selected species as per the standard protocol. The isolates were assigned to respective genera and species using aforementioned approaches based on morphology, SEM and molecular phylogeny. The recent taxonomic position of fungal taxa was verified from the online databases such as Index fungorum (<http://www.indexfungorum.org>) and Mycobank (<http://www.mycobank.org>)

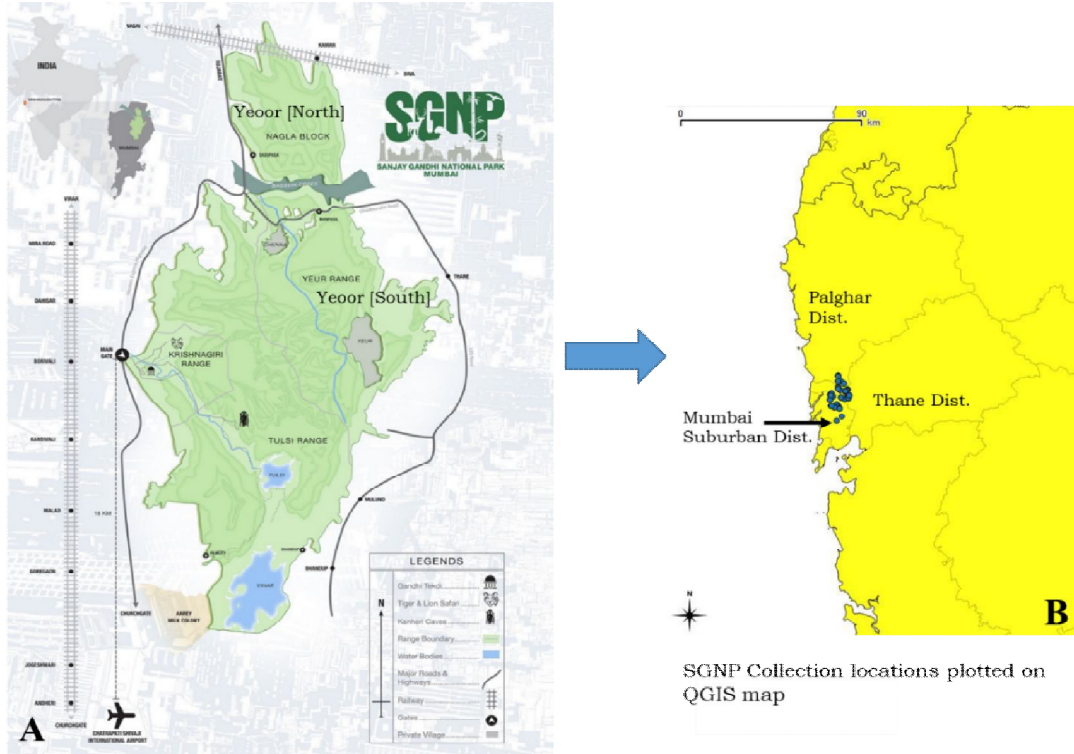


Fig. 1. Map of SGNP showing collection locations. A. Map of SGNP ranges provided by forest authorities. B. Survey map prepared by plotting GPS of collection locations using QGIS 2.8 Wien version.

Statistical Methodology

We analyse different aspects of microfungal ecology at two levels, viz., species richness and diversity indices, consistent with, for instance Dubey & Pandey (2019, 2022a, 2022b). At the level of species richness, defined as number of observed species, we calculate pairwise dissimilarity in species composition between zones, as well as the number of species common in all the zones as percentage of the total. At the level of diversity indices, we combine information on number of species and number of isolates to calculate two widely used measures of fungal diversity, we then calculate a measure of evenness, and finally, to allow for comparison among zones, we calculate true diversity by converting respective Shannon's index into effective number of species.

At the level of species richness, we first calculate observed species richness, defined as observed number of species. In order to examine dissimilarity in species composition among the zones, we first compute Jaccard Similarity Index (Gotelli & Ellison 2004). Jaccard Similarity Index (JSI), between any two locations (X & Y), is given by:

$$JSI = \frac{n(X \cap Y)}{n(X \cup Y)} = \frac{n(X \cap Y)}{n(X) + n(Y) - n(X \cap Y)} \dots (1)$$

Where $n(X \cap Y)$ is number of species common to both ranges (or zones), $n(X \cup Y)$ is total number of species, and $n(X)$ and $n(Y)$ are number of species in ranges (or zones) X and Y respectively. This index (JSI) gives the similarity of species composition between two locations, taking values from 0 to 1. Therefore, the index is subtracted from one (1-JSI) to give a measure of dissimilarity, Jaccard Dissimilarity Index (JDI). For this, we divide SGNP in 5 zones viz., Yeoor [South], Yeoor [North], Krishnagiri Range, Tulsi Range, Peripheral,

roughly corresponding to ranges of SGNP. However, two exceptions have been made – first, peripheral area is defined as a separate unit to include areas outside the national park often with scarce or no vegetation; second, areas falling within Yeoor Range to the north of Vasai Creek are defined as Yeoor [North], as they form a separate natural ecological unit in contrast with those lying in south of the creek, defined as Yeoor [South].

Then, at the level of diversity indices, we calculate two diversity indices for the study area, viz., Simpson's index and Shannon's index (Jost 2006).

Simpson's index measures the probability of two randomly selected isolates belonging to the same species. It takes values from 0 to 1. It is given by the formula –

$$D = \sum_{i=1}^S p_i^2 = \sum_{i=1}^S (n_i / N)^2 \quad \dots\dots (2)$$

Where, p_i is proportion of i th species, n_i = number of isolates of i th species, N = total number of isolates of all species, S = number of distinct species. Thus, lower the value of the index, lower the probability of two isolates belonging to the same species, thus higher the diversity, and vice versa. However, such interpretation tends to be counter-intuitive. Hence, its complement ($1-D$), known as Gini-Simpson's index (Jost 2006), which follows naturally from the laws of probability, has been used which is easy and intuitive in terms of interpretability, as higher values correspond to higher diversity.

The Shannon's index quantifies the uncertainty (or entropy) associated with correctly predicting species to which next isolate belongs to. Therefore, higher the value, more the uncertainty, thereby higher the diversity. It is calculated as follows:

$$H = \sum_{i=1}^S p_i \ln(1 / p_i) \quad \dots\dots\dots (4)$$

Where \ln = natural logarithm, while others are same as in Simpson's index.

Pielou's evenness index J' (Pielou 1995) is a measure of species evenness. It is essentially a normalized Shannon's index, bounded by zero and one. Higher values correspond to more equitable distribution, with $J'=1$ representing perfectly equitable distribution where all species are equally abundant.

$$\text{Pielou's evenness index } (J') = \frac{H}{\ln(S)} \quad \dots\dots\dots (5)$$

Next, we examine true diversity by calculating effective number of species obtained by *correcting* species richness (observed number of species) by incorporating evenness (number of isolates). Effective number of species, calculated from a diversity index, is equivalent number of equally abundant species in a hypothetical assemblage for the same value of the given diversity index (Gotelli & Ellison 2004). True diversity is obtained by transforming Shannon's index as follows (Jost 2006):

$$ENS_H = e^H \quad \dots\dots\dots (6)$$

Where ENS_H is effective number of species, and 'e' is Euler's number or natural base. ENS_H is usually rounded down to nearest integer so as to have meaningful interpretation. We use Shannon's index for calculation as it weighs both common and rare species equally, unlike Simpson's index and species richness which overweigh common species rare species, respectively (Gotelli & Ellison 2004).

3. RESULTS AND DISCUSSION

Results

A total of 36 species of soil fungi were identified from 77 isolates obtained from 43 soil samples, detailed in Table 1 along with associated taxonomic and collection details. Fig. 2 shows microscopic images of some of the fungi isolated from the soils of SGNP. The

molecular phylogeny of some selected fungi is depicted in fig.3. As shown in Fig. 4, *Aspergillus* was dominant genus with 16 species, followed by *Emericella*, *Eurotium*, *Fusarium*, *Penicillium*, *Rhizopus*, *Trichoderma* (each 2). As Fig. 5 shows, *Aspergillus niger* was dominant species, accounting for maximum of 12 isolates, followed by *Aspergillus nidulans* (9), *Aspergillus fumigatus* (7), *Emericella rugulosa* and *Trichoderma harzianum* (each 5), *Aspergillus flavipes* (4).

In examining dissimilarity in species composition, pairwise Jaccard Dissimilarity Index (JDI) was calculated for each pair (Table 2). Highest dissimilarity was between Yeoor [North] and Krishnagiri ranges (JDI = 0.9231), and lowest between Tulsi range and peripheral areas (0.6667). Only one species viz., *Aspergillus nidulans* was common in all the ranges, representing 2.78% of the total.

Diversity measures (Table 3) were calculated by combining species richness with evenness (Table 2). Gini Simpson's index ($1-D$) was 0.9347, Shannon's index (H) was 3.1450, Pielou's evenness index (J) was 0.8776, whereas effective number of species was 23.

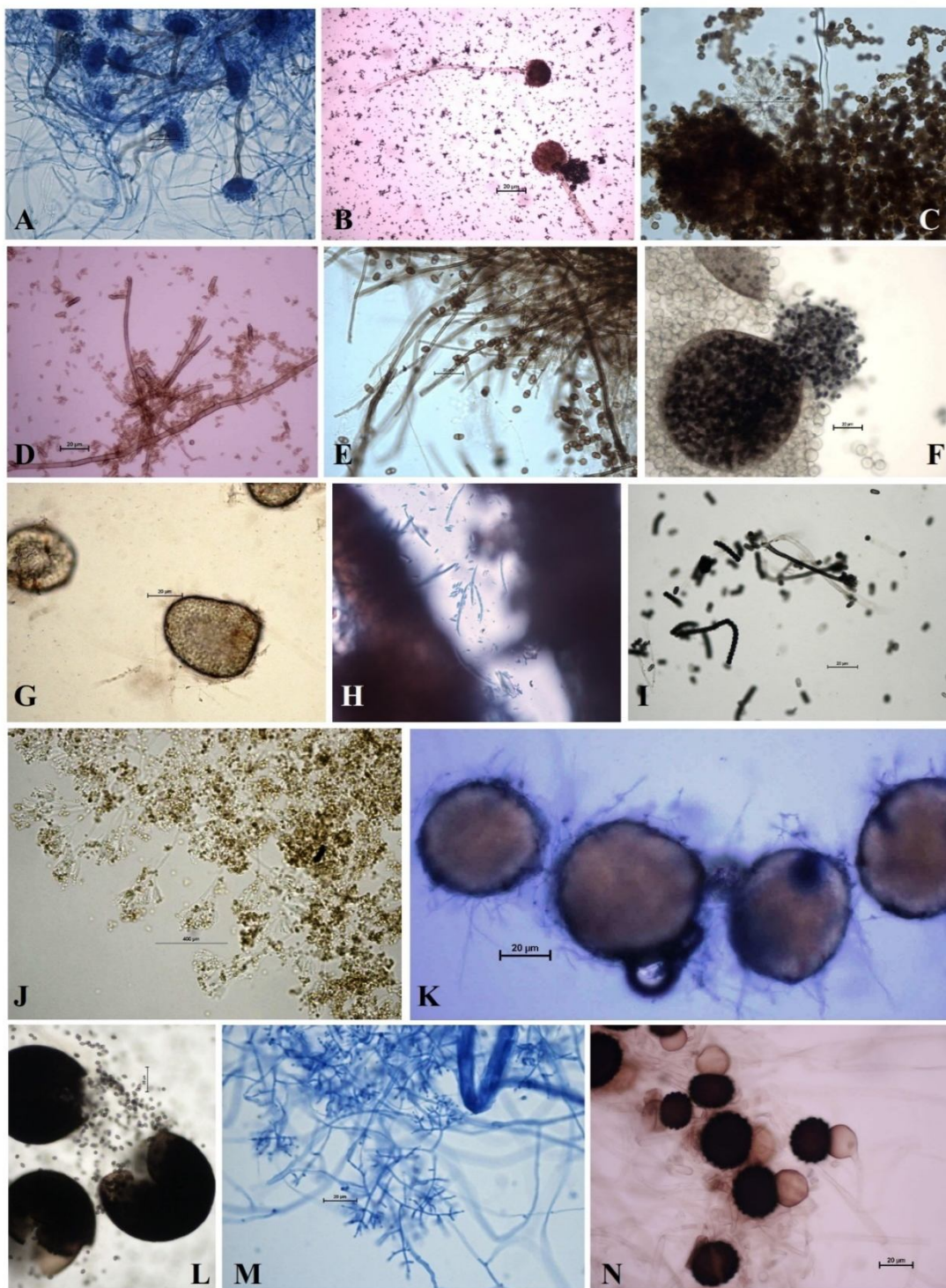


Fig. 2. Some of the soil fungi isolated from the soils of Sanjay Gandhi National Park. A *Aspergillus nidulans*. B *Aspergillus niger*. C spores of *Aspergillus niger*. D *Cladosporium cladosporioides*. E *Diplodia caffer*. F *Emericella rugulosa*. G *Eurotium* sp. H *Fusarium concentricum*. I *Memnoniella echinata*. J *Penicillium chrysogenum*. K

Talaromyces pinophilus. L. *Thielavia* sp. M *Trichoderma harzianum*. N *Zygorhynchus* sp. (Scale Bars: A, B, D, F, G, I, K–N = 20 µm; C = 500 µm; J = 400 µm).

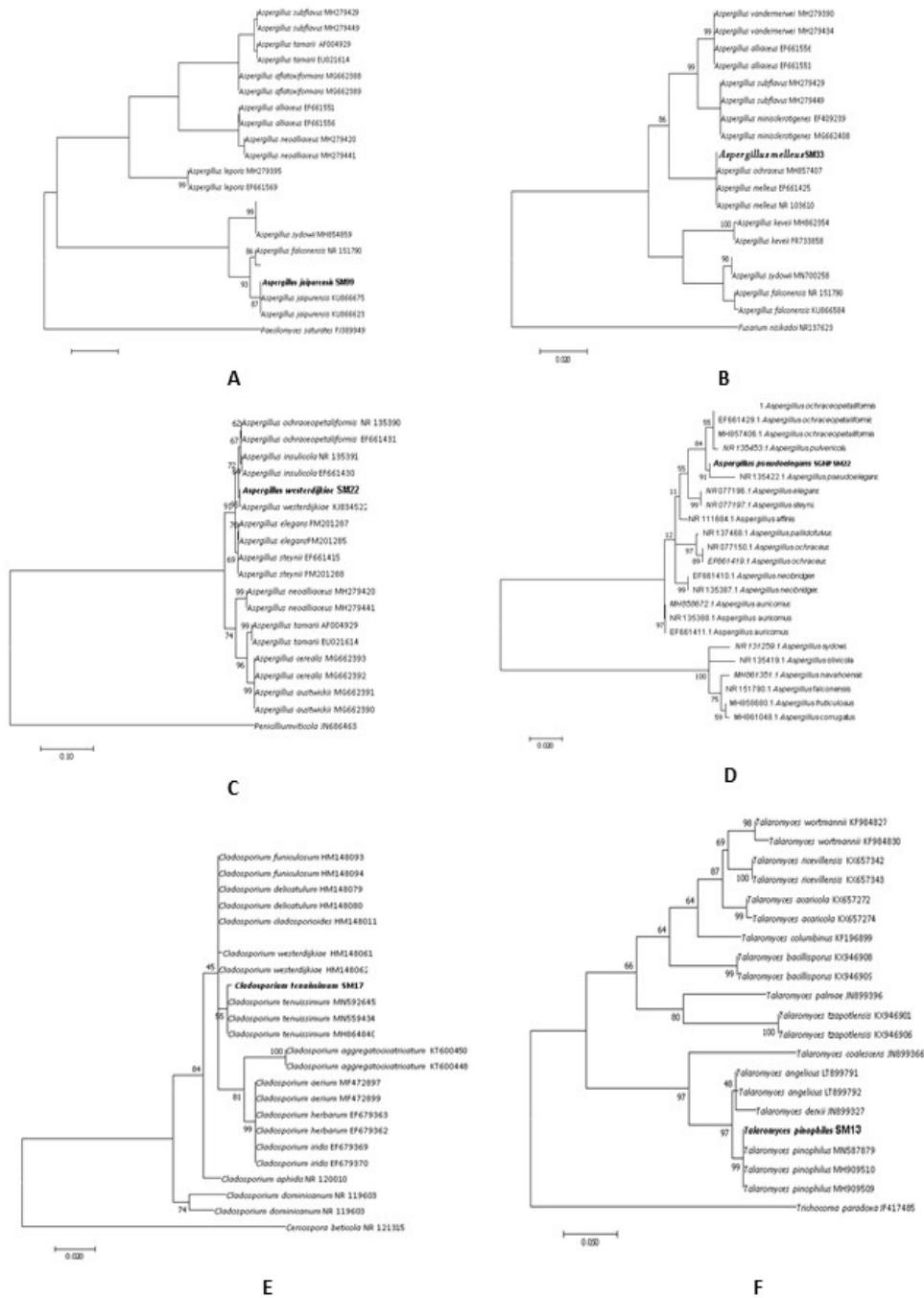


Fig. 3. Molecular phylogenetic analysis by maximum-likelihood (ML) method based on ITS sequence data (Bootstrap =1000 times). A. *Aspergillus jaipurensis*, B. *Aspergillus melleus*, C. *Aspergillus pseudoelegans*, D. *Aspergillus westerdijkiae*, E. *Cladosporium tenuissimum*, F. *Talaromyces pinophilus*

Fig. 4. Top genera having highest number of species

Fig. 5. Top species, in terms of having been isolated from maximum number of collections.

Table 1. Checklist of soil fungi of SGNP

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
1	<i>Aspergillus</i> <i>brasiliensis</i> Varga, Frisvad & Samson	Aspergillaceae	205539	23/10/2 018	Pankhand, Ovale, Yeoor Range [South],	N 19° 16' 16.80"	E 72° 56' 45.92"

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
	2007				SGNP, Thane		
2	<i>Aspergillus brasiliensis</i> Varga, Frisvad & Samson 2007	Aspergillaceae	205537	21/10/2018	Kavesar, Yeoor Range [South], SGNP, Thane	N 19° 14' 42.96"	E 72° 57' 09.18"
3	<i>Aspergillus candidus</i> Link 1809	Aspergillaceae	205535	20/10/2018	Panchpakhadi, Yeoor Range [South], SGNP, Thane	N 19° 14' 01.97"	E 72° 57' 06.90"
4	<i>Aspergillus flavipes</i> (Bainier & R. Sartory) Thom & Church 1926	Aspergillaceae	205364A	19/08/2017	Ramgad Nursery, Peripheral of SGNP, Mumbai	N 19° 15' 31.49"	E 72° 52' 41.81"
5	<i>Aspergillus flavipes</i> (Bainier & R. Sartory) Thom & Church 1926	Aspergillaceae	205453	25/01/2017	Yeoor Range [South], SGNP, Thane	N 19° 13' 54.51"	E 72° 56' 14.87"
6	<i>Aspergillus flavipes</i> (Bainier & R. Sartory) Thom & Church 1926	Aspergillaceae	205386A	20/12/2017	Karnal Pada, Sarjamori, North of Vasai Creek, Yeoor Range [North],	N 19° 20' 10.20"	E 72° 54' 28.19"

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
					SGNP, Palghar Dist.		
7	<i>Aspergillus flavipes</i> (Bainier & R. Sartory) Thom & Church 1926	Aspergillaceae	205536A	21/10/2 018	Kavesar, Yeoor Range [South], SGNP, Thane	N 19° 14' 50.46"	E 72° 57' 19.44"
8	<i>Aspergillus fumigatus</i> Fresen. 1863	Aspergillaceae	205542	23/10/2 018	Pankhand, Ovale, Yeoor Range [South], SGNP, Thane	N 19° 16' 32.11"	E 72° 56' 51.78"
9	<i>Aspergillus fumigatus</i> Fresen. 1863	Aspergillaceae	205362A	19/08/2 017	MLDC Quarry, Peripheral of SGNP, Mumbai	N 19° 15' 08.03"	E 72° 52' 18.36"
10	<i>Aspergillus fumigatus</i> Fresen. 1863	Aspergillaceae	205374A	21/08/2 017	Chena Lake, Yeoor Range [South], SGNP, Thane	N 19° 16' 17.69"	E 72° 55' 01.21"
11	<i>Aspergillus fumigatus</i> Fresen. 1863	Aspergillaceae	205538	22/10/2 018	1140, Kavesar, Yeoor Range [South], SGNP, Thane	N 19° 14' 24.85"	E 72° 55' 05.66"

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
12	<i>Aspergillus fumigatus</i> Fresen. 1863	Aspergillaceae	205496A	20/12/2 017	Karnal Pada, Sarjamori, North of Vasai Creek, Yeoor Range [North], SGNP, Palghar Dist.	N 19° 20' 10.20"	E 72° 54' 28.19"
13	<i>Aspergillus fumigatus</i> Fresen. 1863	Aspergillaceae	205522A	20/10/2 018	Near Tulsi lake, Tulsi Range, SGNP, Mumbai	N 19° 11' 05.96"	E 72° 54' 41.04"
14	<i>Aspergillus fumigatus</i> Fresen. 1863	Aspergillaceae	205536A	21/10/2 018	Kavesar, Yeoor Range [South], SGNP, Thane	N 19° 14' 50.46"	E 72° 57' 19.44"
15	<i>Aspergillus</i> <i>jaipurensis</i> Samson, Visagie & Houbraken 2014	Aspergillaceae	210065	20/10/2 018	Panchpakhadi, Yeoor Range [South], SGNP, Thane	N 19° 14' 01.97"	E 72° 57' 06.90"
16	<i>Aspergillus nidulans</i> (Eidam) G. Winter 1884	Aspergillaceae	205540	23/10/2 018	Pankhand, Ovale, Yeoor Range [South], SGNP, Thane	N 19° 16' 32.11"	E 72° 56' 51.78"
17	<i>Aspergillus nidulans</i> (Eidam) G. Winter	Aspergillaceae	205363A	19/08/2 017	K.N. Shaikh Quarry,	N 19° 15' 34.49"	E 72° 52' 35.57"

<u>Sr. No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collection Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
	1884				Peripheral of SGNP, Mumbai		
18	<i>Aspergillus nidulans</i> (Eidam) G. Winter 1884	Aspergillaceae	205371A	20/08/2017	Powai lake, Peripheral to SGNP, Mumbai	N 19° 07' 45.21"	E 72° 53' 56.62"
19	<i>Aspergillus nidulans</i> (Eidam) G. Winter 1884	Aspergillaceae	205495	21/12/2017	Sasunavaghar Foothills, Near Stream, North of Vasai Creek, Yeoor Range [North], SGNP, Palghar Dist.	N 19° 18' 40.43"	E 72° 54' 29.16"
20	<i>Aspergillus nidulans</i> (Eidam) G. Winter 1884	Aspergillaceae	205509	23/12/2017	Tulsi road, Tulsi Range, SGNP, Mumbai	N 19° 11' 34.36"	E 72° 53' 29.86"
21	<i>Aspergillus nidulans</i> (Eidam) G. Winter 1884	Aspergillaceae	205513	23/12/2017	Upwan, Near boating lake, Krishnagiri Range, SGNP, Mumbai	N 19° 13' 44.75"	E 72° 52' 08.43"

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
22	<i>Aspergillus nidulans</i> (Eidam) G. Winter 1884	Aspergillaceae	205374A	21/08/2 017	Chena Lake, Yoor Range [South], SGNP, Thane	N 19° 16' 17.69"	E 72° 55' 01.21"
23	<i>Aspergillus nidulans</i> (Eidam) G. Winter 1884	Aspergillaceae	205513	23/12/2 017	Upwan, Near boating lake, Krishnagiri Range, SGNP, Mumbai	N 19° 13' 44.75"	E 72° 52' 08.43"
24	<i>Aspergillus nidulans</i> (Eidam) G. Winter 1884	Aspergillaceae	205536A	21/10/2 018	Kavesar, Yoor Range [South], SGNP, Thane	N 19° 14' 50.46"	E 72° 57' 19.44"
25	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205535	20/10/2 018	Panchpakhadi, Yoor Range [South], SGNP, Thane	N 19° 14' 01.97"	E 72° 57' 06.90"
26	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205534	23/10/2 018	Pankhand, Ovale, Yoor Range [South], SGNP, Thane	N 19° 16' 16.80"	E 72° 56' 45.92"
27	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205539	23/10/2 018	Pankhand, Ovale, Yoor Range [South],	N 19° 16' 16.80"	E 72° 56' 45.92"

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
					SGNP, Thane		
28	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205541	23/10/2 018	Pankhand, Ovale, Yeoor Range [South], SGNP, Thane	N 19° 16' 32.11"	E 72° 56' 51.78"
29	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205542	23/10/2 018	Pankhand, Ovale, Yeoor Range [South], SGNP, Thane	N 19° 15' 59.84"	E 72° 56' 23.70"
30	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205365	19/08/2 017	Ramgad Plantation, Peripheral of SGNP, Mumbai	N 19° 15' 31.49"	E 72° 52' 41.81"
31	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205376A	21/08/2 018	Upwan, Krishnagiri Range, SGNP, Mumbai	N 19° 14' 28.08"	E 72° 52' 59.33"
32	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205453	25/01/2 017	Yeoor Range [South], SGNP, Thane	N 19° 15' 32.32"	E 72° 56' 28.94"

<u>Sr. No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collection Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
33	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205538	22/10/2018	1140, Kavesar, Yeoor Range [South], SGNP, Thane	N 19° 14' 24.85"	E 72° 55' 05.66"
34	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205537	21/10/2018	Kavesar, Yeoor Range [South], SGNP, Thane	N 19° 14' 42.96"	E 72° 57' 09.18"
35	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205536A	21/10/2018	Kavesar, Yeoor Range [South], SGNP, Thane	N 19° 14' 50.46"	E 72° 57' 19.44"
36	<i>Aspergillus niger</i> Tiegh. 1867	Aspergillaceae	205369A	20/08/2017	No. 53, Tulsi Lake Road, Tulsi Range, SGNP, Mumbai	N 19° 11' 59.52"	E 72° 54' 23.93"
37	<i>Aspergillus pseudoelegans</i> Frisvad & Samson 2004	Aspergillaceae	205541	23/10/2018	Pankhand, Ovale, Yeoor Range [South], SGNP, Thane	N 19° 16' 32.11"	E 72° 56' 51.78"
38	<i>Aspergillus</i> sp. 1	Aspergillaceae	205372A	07/09/2016	On the way to Kanheri Caves, Tulsi Range, SGNP, Mumbai	N 19° 12' 28.62"	E 72° 53' 54.89"

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
39	<i>Aspergillus</i> sp. 2	Aspergillaceae	205534	23/10/2 018	Pankhand, Ovale, Yeoor Range [South], SGNP, Thane	N 19° 16' 16.80"	E 72° 56' 45.92"
40	<i>Aspergillus</i> sp. 3	Aspergillaceae	205542	23/10/2 018	Pankhand, Ovale, Yeoor Range [South], SGNP, Thane	N 19° 15' 59.84"	E 72° 56' 23.70"
41	<i>Aspergillus</i> sp. 4	Aspergillaceae	205387A	10/09/2 016	Nagla Block, North of Vasai Creek, Yeoor Range [North], SGNP, Palghar Dist.	N 19° 18' 47.43"	E 72° 54' 58.84"
42	<i>Aspergillus</i> sp. 5	Aspergillaceae	205511	23/12/2 017	Near Tulsi lake, Tulsi Range, SGNP, Mumbai	N 19° 11' 34.36"	E 72° 53' 29.86"
43	<i>Aspergillus</i> sp. 6	Aspergillaceae	205386A	20/12/2 017	Karnal Pada, Sarjamori, North of Vasai Creek, Yeoor Range [North], SGNP, Palghar	N 19° 20' 10.20"	E 72° 54' 28.19"

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
					Dist.		
44	<i>Aspergillus sydowii</i> (Bainier & Sartory) Thom & Church 1926	Aspergillaceae	205360A	21/08/2 017	Shingte Quarry, Peripheral of SGNP, Mumbai	N 19° 14' 41.93"	E 72° 52' 26.28"
45	<i>Aspergillus</i> <i>westerdijkia</i> Frisvad & Samson 2004	Aspergillaceae	205554	23/10/2 018	Pankhand, Ovale, Yeoor Range [South], SGNP, Thane	N 19° 15' 59.84"	E 72° 56' 23.70"
46	<i>Aspergillus</i> <i>westerdijkia</i> Frisvad & Samson 2004	Aspergillaceae	205370A	20/08/2 017	Near to Vihar lake, Tulsi Range, SGNP, Mumbai	N 19° 09' 04.43"	E 72° 55' 21.36"
47	<i>Chaetomium</i> <i>globosum</i> Kunze 1817	Chaetomiaceae	205373	21/08/2 017	Chena Lake, Yeoor Range [South], SGNP, Thane	N 19° 16' 17.69"	E 72° 55' 01.21"
48	<i>Cladosporium</i> <i>cladosporioides</i> (Fresen.) G.A. de Vries 1952	Cladosporiaceae	205495	22/12/2 017	Sasunavaghar Foothills, Near Stream, North of Vasai Creek,	N 19° 18' 40.43"	E 72° 54' 29.16"

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
					Yoor Range [North], SGNP, Palghar Dist.		
49	<i>Diplodia caffer</i> Matsush. 1996	Botryosphaeriaceae	205534	23/10/2 018	Pankhand, Ovale, Yoor Range [South], SGNP, Thane	N 19° 16' 16.80"	E 72° 56' 45.92"
50	<i>Emericella nidulans</i> (Eidam) Vuill. 1927	Aspergillaceae	205543	23/10/2 018	Pankhand, Ovale, Yoor Range [South], SGNP, Thane	N 19° 15' 59.84"	E 72° 56' 23.70"
51	<i>Emericella rugulosa</i> (Thom & Raper) C.R. Benj. 1955	Aspergillaceae	205542	23/10/2 018	Pankhand, Ovale, Yoor Range [South], SGNP, Thane	N 19° 15' 59.84"	E 72° 56' 23.70"
52	<i>Emericella rugulosa</i> (Thom & Raper) C.R. Benj. 1955	Aspergillaceae	205375A	21/08/2 017	Vasai (Creek) Bridge, Peripheral of SGNP, Thane	N 19° 17' 12.50"	E 72° 54' 20.40"
53	<i>Emericella rugulosa</i> (Thom & Raper) C.R. Benj. 1955	Aspergillaceae	205513	23/12/2 017	Upwan, Near boating lake, Krishnagiri	N 19° 13' 44.75"	E 72° 52' 08.43"

<u>Sr. No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collection Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
					Range, SGNP, Mumbai		
54	<i>Emericella rugulosa</i> (Thom & Raper) C.R. Benj. 1955	Aspergillaceae	205522B	19/10/2018	Tulsi road, Tulsi Range, SGNP, Mumbai	N 19° 11' 49.128"	E 72° 54' 28.98"
55	<i>Emericella rugulosa</i> (Thom & Raper) C.R. Benj. 1955	Aspergillaceae	205522B	19/10/2018	Tulsi road, Tulsi Range, SGNP, Mumbai	N 19° 11' 49.128"	E 72° 54' 28.98"
56	<i>Eurotium</i> sp. 1	Aspergillaceae	205377A	19/08/2017	Upwan, Krishnagiri Range, SGNP, Mumbai	N 19° 13' 43.59"	E 72° 52' 12.57"
57	<i>Eurotium</i> sp. 2	Aspergillaceae	205495	19/08/2017	Sasunavaghar Foothills, Near Stream, North of Vasai Creek, Yoor Range [North], SGNP, Palghar Dist.	N 19° 18' 40.43"	E 72° 54' 29.16"
58	<i>Fusarium concentricum</i> Nirenberg &	Nectriaceae	210066A	19/08/2017	Krishnagiri Range, SGNP, Mumbai	N 19° 13' 43.59"	E 72° 52' 12.57"

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
	O'Donnell 1998						
59	<i>Fusarium</i> sp.	Nectriaceae	205543	23/10/2 018	Pankhand, Ovale, Yoor Range [South], SGNP, Thane	N 19° 15' 59.84"	E 72° 56' 23.70"
60	<i>Memnoniella</i> <i>echinata</i> (Rivolta) Galloway 1933	Stachybotryace ae	205539	23/10/2 018	Pankhand, Ovale, Yoor Range [South], SGNP, Thane	N 19° 16' 16.80"	E 72° 56' 45.92"
61	<i>Penicillium</i> <i>chrysogenum</i> Thom 1910	Aspergillaceae	205535	20/10/2 018	Panchpakhadi, Yoor Range [South], SGNP, Thane	N 19° 14' 01.97"	E 72° 57' 06.90"
62	<i>Penicillium</i> <i>chrysogenum</i> Thom 1910	Aspergillaceae	205536	21/10/2 018	Kavesar, Yoor Range [South], SGNP, Thane	N 19° 14' 50.46"	E 72° 57' 19.44"
63	<i>Penicillium</i> <i>chrysogenum</i> Thom 1910	Aspergillaceae	205536	21/10/2 018	Kavesar, Yoor Range [South], SGNP, Thane	N 19° 14' 50.46"	E 72° 57' 19.44"
64	<i>Penicillium</i> sp.	Aspergillaceae	205368	20/08/2 017	No. 37, Tulsi Lake Road, Tulsi Range	N 19° 11' 19.51"	E 72° 54' 46.34"

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
65	<i>Rhizopus</i> <i>microsporus</i> Tiegh. 1875	Rhizopodaceae	205515A	20/08/2 017	Vasai (Creek) Bridge, Peripheral of SGNP, Thane	N 19° 17' 9.92"	E 72° 54' 22.57"
66	<i>Rhizopus nigricans</i> <i>Ehrenb.</i> 1821	Rhizopodaceae	205367A	19/08/2 017	Outside Mahindra & Mahindra, Thakur Village, Peripheral of SGNP, Mumbai	N 19° 12' 02.088"	E 72° 52' 21.72"
67	<i>Talaromyces</i> <i>pinophilus</i> (Hedgc.) Samson, N. Yilmaz, Frisvad & Seifert 2011	Aspergillaceae	205511	23/12/2 017	Near Tulsi lake, Tulsi Range, SGNP, Mumbai	N 19° 11' 34.36"	E 72° 53' 29.86"
68	<i>Thielavia</i> sp.	Chaetomiaceae	205386A	20/12/2 017	Karnal Pada, Sarjamori, North of Vasai Creek, Yeoor Range [North], SGNP, Palghar Dist.	N 19° 20' 05.21"	E 72° 54' 22.07"
69	<i>Thielavia</i> sp.	Chaetomiaceae	205522A	20/10/2	Near Tulsi lake,	N 19° 11'	E 72° 54'

<u>Sr.</u> <u>No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collectio</u> <u>n</u> <u>Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
				018	Tulsi Range, SGNP, Mumbai	5.96"	41.04"
70	<i>Trichocladium</i> <i>asperum</i> Harz 1871	Chaetomiaceae	205543	23/10/2 018	Pankhand, Ovale, Yeoor Range [South], SGNP, Thane	N 19° 15' 59.84"	E 72° 56' 23.70"
71	<i>Trichoderma</i> <i>asperellum</i> Samuels, Lieckf. & Nirenberg 1999	Hypoceraceae	205543	23/10/2 018	Pankhand, Ovale, Yeoor Range [South], SGNP, Thane	N 19° 15' 59.84"	E 72° 56' 23.70"
72	<i>Trichoderma</i> <i>harzianum</i> Rifai 1969	Hypoceraceae	205511	23/12/2 017	Near Tulsi lake, Tulsi Range, SGNP, Mumbai	N 19° 11' 34.36"	E 72° 53' 29.86"
73	<i>Trichoderma</i> <i>harzianum</i> Rifai 1969	Hypoceraceae	205374A	21/08/2 017	Chena Lake, Yeoor Range [South], Outside SGNP, Thane	N 19° 16' 41.016"	E 72° 54' 27.396"
74	<i>Trichoderma</i> <i>harzianum</i> Rifai 1969	Hypoceraceae	205387A	10/09/2 016	Nagla Block, North of Vasai Creek, Yeoor Range [North], SGNP, Palghar	N 19° 18' 08.46"	E 72° 55' 52.98"

<u>Sr. No.</u>	<u>Sps</u>	<u>Family</u>	<u>Collection Number</u>	<u>Date</u>	<u>Locality</u>	<u>Latitude</u>	<u>Longitude</u>
					Dist.		
75	<i>Trichoderma harzianum</i> Rifai 1969	Hypoceraeae	205366	19/08/2017	Plantation, Near Akurli, Peripheral of SGNP, Mumbai	N 19° 12' 0.432"	E 72° 52' 33.528"
76	<i>Trichoderma harzianum</i> Rifai 1969	Hypoceraeae	205361A	19/08/2017	Keshav Nagar, Peripheral of SGNP, Mumbai	N 19° 14' 59.064"	E 72° 52' 23.52"
77	<i>Zygorhynchus</i> sp.	Mucoraceae	205538	22/10/2018	1140, Kavesar, Yeoor Range [South], SGNP, Thane	N 19° 14' 24.85"	E 72° 55' 05.66"

Table 2. Jaccard Dissimilarity Index

	Yeoor [South]	Yeoor [North]	Krishnagiri Range	Tulsi Range	Peripheral
Yeoor [South]	0.0000				
Yeoor [North]	0.8519	0.0000			
Krishnagiri Range	0.8750	0.9231	0.0000		
Tulsi Range	0.7778	0.7500	0.7692	0.0000	

Peripheral	0.7600	0.7143	0.7273	0.6667	0.0000
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Aspergillus nidulans was common in all the ranges, representing 2.78% of the total

Table 3. Diversity Measures

Species Richness = Observed number of species	36
Simpson's Index (D)	0.0653
Gini-Simpson's Index ($1-D$)	0.9347
Shannon's Index (H)	3.1450
Pielou's evenness index (J)	0.8776
True Diversity = Effective number of Species = e^H	23

Discussion

In the present paper we have examined the diversity of soil fungi of SGNP from taxonomic and ecological perspectives. We present the checklist of 36 species of soil fungi documented along with their taxonomic and collection details. We also calculated dissimilarity and diversity measures to study the ecology of the soil fungi. Values of JDI ranged from 0.6667 to 0.9231, with only one species common in all ranges. It, thus, shows high dissimilarity in species composition¹, if we define high dissimilarity as $JDI > 0.5$. The study area shows high diversity as evidenced by high values of Gini-Simpson's Index ($=0.9347$) and Shannon's index ($=3.1450$). Pielou's evenness index ($J = 0.8776$) shows presence of some unevenness, despite high equitability in species distribution. In order to correct species richness for observed evenness, we examine true diversity, a measure of which is Effective number of Species, calculated from Shannon's index. True diversity or effective number of species for the study area (23) is less than species richness or observed number of species (36) due to the absence of perfectly equitable distribution of species ($J \neq 1$). The present study thus provides important insights into taxonomy, distribution and ecology of soil fungi of SGNP.

4. CONCLUSION

[This should briefly state the major findings of the study. If you are using copy-paste option then select 'match destination formatting' in paste option OR use 'paste special' option and select 'unformatted Unicode text' option] The study resulted in a total of 77 isolates of 77 soil fungi obtained from 43 soil samples. A total of 36 species were documented under 15 genera. *Aspergillus* was dominant genus, whereas *Aspergillus niger* was dominant species. Pairwise Jaccard Dissimilarity Index was found to be above 66% in all cases, with only one

¹ Since there is not much discussion and consensus in literature about what values constitute low, moderate and high range, and the indices are usually interpreted in relative terms, therefore we chose 0.5 as reasonable cut-off, above which values are treated as high, and below 0.5 as low.

species common in all the zones. The diversity and evenness were quantified by calculating various indices and true diversity.

CONSENT (WHERE EVER APPLICABLE)

Not Applicable

ETHICAL APPROVAL

Not Applicable

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