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To study biodiversity of mushroom species in Mahabaleshwar, Koyananagar and Gaganbawada forests of Maharashtra

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Abstract
The present investigation entitled "Biodiversity of mushroom flora of Mahabaleshwar, Koyananagar and Gaganbawada forests of Maharashtra" was carried out at Plant Pathology Section, College of Agriculture, Kolhapur. This survey was carried out with the object to study biodiversity of mushrooms in forests of Mahabaleshwar, Koyananagar and Gaganbawada to identify mushroom species on the basis of morphological characteristics. Collection of mushroom specimens was conducted during monsoon season, 2019. The survey was conducted in the forest area of Gaganbawada, Koyananagar and Mahabaleshwar for the collection of mushroom species during July to October (2019). Total 50 mushroom species was collected up to species level. The collected species has showed variations among their morphological characteristics i.e. pileus (diameter, colour, shape), stipe (attachment, colour, size and base), lamellae (gill colour, gill edge) and basal association, edibility and spore prints. Other characteristics include form of mushroom i.e. single, group or connate (united), smell of mushroom (pleasant or odd smell) and mushroom habitat i.e. on soil, grassland, dung, dead tree trunk or wooden stumps or on plant.

Keywords: Biodiversity, mushroom, plant pathology section, agriculture

Introduction
Mushrooms are fleshy, spore-bearing fruiting body of macro fungi. Mushrooms grow in places like fields, woods, forests, water channels, manure heaps, bunds and grassy grounds. It includes edible, medicinal and poisonous species. However, originally, the word "mushroom" was used for the edible members of macro fungi and "toadstools" for poisonous ones of the "gill" macro fungi (Hall *et al*., 2003) [5]. Edible mushrooms once called the "Food of the Gods" and still treated as a garnish or delicacy that can be taken regularly as part of the human diet or be treated as healthy food or as functional food.

Fungi are one of the most prominent and biodiverse organisms to inhabit and influence this planet (Sarbhoy *et al.*, 1996) [12]. Mushroom species are the indicators of the forest life support system (Stamets, 2000) [14]. Mushrooms are considered as 'white vegetables' or 'boneless vegetarian meat'. They are used as a good source for making different tasteful recepies. Mushrooms proteins contain all nine essential amino acids and non-amino acids. Recent studies confirm that they are an important source of food and income in both developing and developed countries. Indigenous peoples are utilizing mushroom for the treatment of different type of diseases and also as an aphrodisiac and tonic. Different types of edible mushrooms are cultivated on large scale for commercial use and many more species of mushrooms grow wildly in nature which has much nutritional and medicinal value. Many of them have been used in food and folk medicine for thousands of years ago (Thatoi and Singdevsachan, 2014) [15]. The species diversity of fungi and their natural beauty occupy prime place in the world and India. The number of fungi on earth has been a point of discussion and several studies have focused on the world's fungal diversity (Crous *et al*., 2006) [1]. The study of mushroom species has been done in many countries. Out of 1.5 million fungi around the globe, only 50% are characterized till now and one third of total fungal diversity of the globe exists in India (Manoharachary *et al*., 2005a) [9]. Only a fraction of total wealth has been subjected to scientific scrutiny and mycologists continue to unravel the unexplored and hidden wealth (Dwivedi *et al*., 2012) [3]. Among the total known mushrooms, approximately 850 species are recorded from India. Himalaya and Western Ghats are the hotspots for a wide range of fungi in a variety of habitats in different altitudinal ranges.

The Western Ghats of India is stretched to about 1600 km with an area about 160,000 km^2. In the forests of Amarkantak several surveys have been conducted by the various workers (Rahi 2001, Upadhyay 2004) [11, 16] to know the biodiversity of mushroom species

The aim of this survey was to collect and study on the biodiversity, distribution, habitat and morphology of wild mushrooms associated with forests of Mahabaleshwar, Koyananagar and Gaganbawada. Therefore, a survey was conducted to explore these areas for mushroom to know the myco treasure in association and on surface of the forest lands. This study adds extra information to the present knowledge on the data of diversity of mushroom.

Material and Methods

The survey was carried out during June to October 2019 in forest areas of Mahabaleshwar, Koyananagar and Gaganbawada.

Material

Equipments and other appliances

The tools like hunting knife with stout blade, pad of paper, scale, pencil, field note book, hand lens, camera, scissors, forceps and secateurs, hand gloves, GPS-GIS app etc. were used for collection of mushroom specimens.

Methodology

Collection of Mushroom Samples A detailed survey was conducted during June to October (2019) in the forest areas of Gaganbawada, Koyananagar and Mahabaleshwar and recorded the morphological variability in the mushrooms population. Spotted mushrooms were inspected in their natural habitats with photographs. The collected fleshy fungi were studied for their macroscopic detail, patterning the habit, habitat, morphology and other phenotypic parameters noted in fresh form.

Morphological observations

Data on the following parameters were recorded for identification of mushrooms specimens

1. Locality
2. Habitat
3. Type of soil
4. Forest type
5. Size of the fructification
6. Umbo
7. Scales
8. Gills: Color, gills edges, gill attachment, gill spacing
9. Stipes : length, width, color, shape
10. Type of veil
11. Annuls (position)
12. Volva
13. Cap color, cap surface, cap margin, cap diameter
14. Spore print color
15. Individual spore characteristics like shape, size and color the final identification and classification were done by comparing recorded characteristics of mushrooms with the help of color dictionary of mushroom [Dickinson and Lucas, 1982] [2].

Dates of collection

The species of wild mushrooms were collected during the rainy season from June to October, 2019.

Locality

The Global Positioning System (GPS) and Geographical Information System (GIS) is a new technology, which provides unequalled accuracy and flexibility of positioning for navigation, surveying. The technology seems to be beneficial to the GPS users in terms of obtaining accurate data up to about 100 meters for navigation, meter-level for mapping and down to millimeter level for geodetic position and which help to determine the exact position of an object on the earth surface in term of geographical coordinates (French, 1996). The GPS technologies have tremendous amount of application in GIS data collection, surveying and mapping. The mobile applications are also available to find correct GPS locations. We also used mobile application to record the exact GPS data.

Habitat

Mushrooms are found in a great variety of habitats, found everywhere, but not all mushrooms are found in all kinds of habitat. Where they grow, such as coniferous forest, oak forest, etc., is the mushrooms' habitat. Some mushrooms develop in only one kind of habitat, such as a bog, a forest, or an open lawn or meadow. Some mushrooms are even more particular than that are associated only with limited number of tree species (sometimes only one type of tree). What they actually emerge from, such as peat, a log, or soil, is the mushrooms' substrate. Forests are an ideal habitat for mushrooms. They also grow along streets, roadsides and rail road. Different terms have been given to signify their habitats. i.e. specimen growing on grasslands are known as “praticolous”, on woodland “silvicolous”, on wood, woody debris, trees, stumps, rotten or burnt wood “lignicolous”, on dung “coprophilous”, amongst moss “muscicolous”, on the site of bonfire “carbonicolous”, in dunes “duensis” and on leaf littre “humicolous”. Some species have tendency to grow in circle on grassy land called “fairy rings”, when a spore falls on suitable substrates under favorable condition and produces a germ tube which gradually develops into mycelium that grows in all direction (Kaul, 1997) [6].

Photography

Finding and shooting mushrooms can be a great challenge both physically and artistically. Mushroom photography can be dirty like a growing in dung kind of dirty and since mushrooms prefer damp, cool places seeking them out can sometimes be a miserable endeavor. But viewed through a camera lens when the light is just right, a mushroom can have beauty that goes far beyond its dirtiness. The photographs of mushrooms were captured by using NIKON camera having high resolution lenses. The photos were taken from every angle (side view, top view, down side) to see Pileus, Lamellae, Stipe, Scales, Volva and Annulus clearly.

Laboratory Study

Morphological studies on size, shape and colour of mushrooms

Pileus

Shape

A pileus is characteristic of agarics, boletes, tooth fungi and some ascomycetes. A mushroom lacking a pileus, that is consisting of just a fertile surface with its back attached to or inter grown with the substrate is said to be resupinate. Pileus can be formed in various shapes and the shapes can change

over the developmental cycle of a fungus. It can be conical, umbonate, convex, funnel shaped (infundibuliform), uplifted, umbilicate, flat or even spherical. The pileus is convex during early stages of development. At maturity the convex pilei usually become plane or expanded, campanulate (bell shaped) or umbilicate when it has an abrupt sharp depression, infundibuliform to cyathiform when margin is raised much higher than the centre so that cap resembles a funnel, depressed when centre is irregularly sunken, umbonate when the centre of the pileus is raised in the center. The umbo may have the form of sharp elevation at the centre or it may be rounded or obtuse, occupying a larger part of the disc. When it is irregular or indistinct the pileus is said to be gibbous. Length of pileus is measured by using scale. The margin of the pileus may be entire, irregular or split with or without radial streaks; thin or thick; curved outwards, straight (acute, obtuse, rounded) or inrolled; in the beginning it is often inrolled and later becomes flat. Surface of the pileus is described as dry, moist or viscid. A viscid pileus surface is also variable according to weather conditions. Under ideal conditions viscidity can be easily ascertain the presence of a glutinous coating. The surface may also be leathery (Lentinus), rugulose, corrugated or may even develop cracking.

Colour

Colour is one of the noticeable characters which if not noted often leads to misidentification because many mushroom pigments are highly sensitive to environmental influence. The colour of the pileus may be white, creamy, yellowish, orange, pinkish, greyish, brownish or even the mixture of any of these. Green and blue are less common. Standard colour notations are required for noting the colour. Methuen Handbook of colours by Kornerup and Wanscher (1963) [8] is a standard colour book which is used in world for this purpose.

Lamellae/ hymenium/ gills

The lamellae are thin blades on the underside of the pileus, radiating from the stipe to the margin. Their colour, shape, width, spacing, attachment, depth, forking pattern, presence or absence of lamellulae, taste, etc. are highly variable. Some mushrooms will have pores instead of gills. These are tiny tubes packed closely together forming a sponge layer, on underside of the cap may be smooth wrinkled or veined. Whichever form it takes, this is where the spores are produced.

Gill attachment

The gills may be free or attached to the stipe and accordingly these are described as adnate, broadly adnate, decurrent, sinuate or adnexed, etc. This character is of taxonomic significance at generic level and also in broad groupings while preparing the taxonomic keys. The lentinoid and pleurotoid mushrooms have decurrent type of gills.

Gill colour

The colour of the lamellae ranges from white, yellowish white, pale, pale yellow, pinkish, yellow to ochraceous or even light brown, etc. Colour of the gills at the developmental stage of carpophore provides handy taxonomic tool for segregation of closely allied taxa. Any colour change when lamellae are cut or bruised is also of significance in the taxonomic categorization of mushrooms at species and variety level. Lentinoid and pleurotoid mushrooms are light spored.

Lamellae edges

These may be smooth, serrate, crenate, dentate or even fimbriate. Mostly Termitomyces species show serrate to dentate gill edges. In some species of Macrolepiota, the gill edges are differently coloured than the faces. This is an additional character which helps in easier identification of such species.

Stipe/stem/stalk

A stipe is the stem or stalk-like feature supporting the cap of a mushroom. The stipe is composed of sterile hyphal tissue. Mushroom that have stipes are said to be stipitate. A mushroom with a cap but no stipe is said to be sessile. Some characters of the stipe include its size, shape, colour, position, texture, surface characteristics, presence or absence of veil, etc.

Shape, size and position

The stipe may be equal in diameter throughout (cylindrical), or it may be broad above (clavate) or broad below (obclavate), having bulb at the base (bulbous) or even swollen in the middle (ventricose). It may even taper down to form a pseudorrhiza whose length and colour may also vary from species to species as in termitophilous mushrooms. The length and width of the stipe should be noted carefully at different levels by using scale. With regard to attachment, the stipe may be central (centre of the pileus), eccentric (slightly away from the centre) and in some cases the pileus is not circular in outline but narrow at one side to a stipe-like point of attachment to the substratum and is called lateral. Many of the lentinoid mushrooms have central to excentric stipe as compared to pleurotoid mushrooms in which the stipe is either excentric or even lateral.

Colour

The colour of stipe varies from white to cream, grey, yellowish, pink, brown to reddish, etc. Some species have same colour as like pileus but in many of them it is different. Any colour change on cutting and bruising is taxonomically important.

Surface

The stipe surface offers a number of valuable taxonomic features. It may be viscid to slimy when moist. If it is dry, it may be glabrous, polished, pruinose, fibrillose or even squamulose. All these characters are needed to be recorded carefully for making proper use in broad taxonomic categorization.

Annulus (veil)

The annulus is basically a skirt-like ring of tissue which encircles the stem of mature mushrooms. The ring is the residue of the veil and the veil is the tissue that joins the stem and the cap before the gills are visible and the fruiting body matures. It should be considered that, all mushrooms do not have a ring. Some mushroom species has a ring or skirt below the cap; this is all that remains of the protective cover for the gills called a veil, which protects the gills when young. As the cap expands or grows, the veil ruptures leaving the skirt like ring on the stem. This can be very obvious in some species

and barely visible in others. This part supports the cap of the mushroom and evolved for the purpose of spore dispersal. It grows fast as it can absorb a lot of water. In mature stage they have lost their protective function. Just like the other parts, this plays an important role in identifying mushrooms. The shape, size, changes in colour when bruised and its texture. There is another type of veil occurring in some species called a universal veil. This covers whole mushroom as it emerges from the ground, and as it grows, the veil breaks leaving behind the Volva.

Cup/base/volva

The volva is a Cup-Shaped structure which is present at the base of the mushroom, either as a cup like structure or as scaly remnants. All mushrooms do not have a Cup or Volva. This macro feature is important in wild mushroom identification because it is an easily observed, taxonomically significant feature that frequently signifies a member of Amanitaceae. A mushroom's volva is often partially or completely buried in the ground and therefore care must be taken to check for its presence when identifying mushrooms. Cutting or pulling mushrooms and attempting to identify them later without having noted this feature could be a fatal error.

Preservation

The specimen that have been drawn, described, labelled and photographed, are to be preserved. Proper preservation is an essential part of the critical study of mushroom flora of any locality. In many cases, identification of the specimen is not immediately possible, but with a preserved specimen this can be achieved at a future date. Preserved specimens are also required if it is to be referred to an expert for final determination. Preservation can be achieved by any of the three methods- drying, freeze-drying (lyophilization) and liquid preservation (alcohol, formalin). The specimens should be dried as quickly as possible to avoid putrefaction. It is suggested that fleshy mushroom should be dried in an air oven at moderate temperature or oven a radiator. Ventilation must be provided during the process of drying. Small and delicate specimens may be sun dried or be dried at room temperature. Dried specimen is usually packed in waxed paper or brown paper packet and stored in box. The specimen for museum may be preserved in a distilled water, alcohol and formalin solution (Purkayastha and Chandra, 1985) [10].

Results and Discussion

The present study was undertaken to know and identify different mushroom flora in the forest. The mushroom samples were collected from the forest area of Gaganbawada, Koyananagar and Mahabaleshwar during rainy season 2019-20. The results of these survey were comapared with those workers who had studied about fungal diversity of different forests.

Collection of mushroom samples collected multiple numbers of specimens of different stages for identifying mushrooms as mushrooms specimens are needed for description, flesh testing, etc. But ensure that minimum specimens required for studies only be collected in view point of in situ mushroom diversity conservation. Recorded essential information on locality, environment, vegetation, weather parameters, habitat and morphological features of the mushroom. Before picking, took a good photograph of mushroom in its natural habitat itself in different aspects. Initially, studied the base of mushroom either it has volva or pseudorhiza. Then, dug the surrounding soil to certain depth before mushroom is removed so that all parts of the mushroom are obtained. Mushroom that was present on wood, collected with wood so that all parts can be observed. The GPS data was recorded by using mobile application. After collection, conducted the preliminary investigation such as aroma as well as presence of latex. The specimen that have been drawn, described, labelled and photographed was preserved. Proper preservation is an essential part of the critical study of mushroom flora of any locality. In many cases, identification of the specimen is not immediately possible, but with a preserved specimen this can be achieved at a future date. The remaining collected specimens were stored in waxed paper bags leaving the top open. Small, tiny and delicate mushrooms were collected in suitable plastic container or glass vials with tight lids. The places of mushroom collection are given in Table 1. From Gaganbawada forest area 17 mushroom spp. has found. Different locations of Gaganbawada are Borbet, Baveli, Katali, Sheloshi, Garivade and Palasambe. Koyananagar forest has rich fungal biodiversity and 17 mushroom spp. was collected from 6 different locations with their GPS data. Different locations of Koyananagar are Humbarli, Helwak, Gokul, Rasati and Gadkhop. Mahabaleshwar forest is very dense and rich in fungal biodiversity. Total 16 mushroom spp. were collected from 7 locations of Mahabaleshwar. Different locations of Mahabaleshwar are Arthur road, Wilson point, Avakali, Sunset point, Old toll plaza and Venna Lake. Total 50 mushroom samples were collected and details of number of mushroom spp. collected from each location is mentioned in Table 1.

Table 1: Collection of mushroom samples from different regions of Gaganbawada, Koyananagar and Mahabaleshwar

Sr. No.	Places	Forest Area	Specimen No. assigned
1	Borbet	Gaganbawada	K-19/01,02,03,05,07,09
2	Baveli	Gaganbawada	K-19/04,11
3	Katali	Gaganbawada	K-19/06,08
4	Palasambe	Gaganbawada	K-19/12,13
5	Gaganbawada	Gaganbawada	K-19/10,48,49
6	Garivade	Gaganbawada	K-19/20
7	Sheloshi	Gaganbawada	K-19/19
8	Koyananagar	Koyananagar	K-19/15,21,25,26,32
9	Gokul	Koyananagar	K-19/14,17
10	Helwak	Koyananagar	K-19/16
11	Rasati	Koyananagar	K-19/18,27,28,30,31
12	Gadkhop	Koyananagar	K-19/29
13	Humbarli	Koyananagar	K-19/22,23,24
14	Avakali	Mahabaleshwar	K-19/45
15	RWRR Station	Mahabaleshwar	K-19/36,38
16	Arthur road	Mahabaleshwar	K-19/40,41,42
17	Wilson point	Mahabaleshwar	K-19/43,44,46
18	Sunset point	Mahabaleshwar	K-19/33,39
19	Old toll plaza	Mahabaleshwar	K-19/34,35,47
20	Venna lake	Mahabaleshwar	K-19/37,50
Total			50

Morphological variations of collected mushroom species

The survey was conducted in the forest area of Gaganbawada, Koyananagar and Mahabaleshwar for the collection of mushroom species during July to October (2019). Total 50 mushroom species were collected and identified up to species level. The collected species have shown variations among their morphological characteristics i.e. pileus (diameter,

colour, shape), stipe (attachment, colour, size and base), lamellae (gill colour, gill edge) and basal association, edibility and spore prints. Other characteristics include form of mushroom i.e. single, group or connate (united), smell of mushroom (pleasant or odd smell) and mushroom habitat i.e. on soil, grassland, dung, dead tree trunk or wooden stumps or on plant. The morphological characters of the collected specimen were compared with those reported by earlier workers. The information of 50 collected mushrooms is summarized in Table 2. Total 50 mushrooms were collected and identified, that belongs to division Basidiomycota, Dacrymycetes, Tremellomycetes, order Agaricales, Tremellales, Russulales, Polyporales, Gloeophyllales and family Agaricomycetes, Agaricaceae, Bolbitiaceae, Clavariaceae, Cortinariaceae, Dacrymycetaceae, Entolomataceae, Gloeophyllaceae, Hygrophoraceae, Hymenogastraceae, Lycoperdaceae, Marasmiaceae, Psathyrellaceae, Pleurotaceae, Schizophyllaceae, Stereacea, Strophariaceae, Tremellaceae, etc.

The mushroom collected from Gaganbawada, Koyananagar and Mahabaleshwar are identified and named as *Temitomyces spp*.- 3, *Leucocoprinus spp*.- 1, *Lepiota spp*.- 3, *Dacryopinax spp*.- 1, *Marasmius spp*.- 4, *Pleurotus spp*.- 5, *Parasola spp*.- 1, *Volvariella spp*.- 1, *Polyporus spp*.- 2, *Psathyrella spp*.- 3, *Coprinopsis spp*.- 2, *Stereum spp*.- 2, *Agrocybe spp*.- 1, *Tremella spp*.- 1, *Ramariopsis spp*.- 1, *Cortinarius spp*.- 2, *Neolentinus spp*.- 1, *Hygrocybe spp*.- 1, *Hygrophorus spp*.- 1, *Chlorophyllum spp*.- 2, *Lentinus spp*.- 1, *Coprinellus spp*.- 1, *Psilocybe spp*.- 2, *Leucoagaricus spp*.- 2, *Chlorophyllum spp*.- 2, *Leptonia spp*.- 1, *Pluteus spp*.-1, *Bolbitius spp*.-1.

Conclusion

This study provides the baseline information on wild edible mushroom diversity. The survey was carried out in forest areas of Gaganbawada, Koyananagar and Mahabaleshwar during July to October (2019). The studied area has rich fungal diversity and it has much scope for scientific communities for further study. The mushrooms were collected and identified according to their morphological characteristics. We have found 50 species of Mushrooms from the families as discussed earlier. The commonly found mushrooms at Gaganbawada, Koyananagar and Mahabaleshwar places are Pleurotus spp., Psythrella spp., Lepiota spp., Marasmius spp., and Termitomyces spp. Some mushrooms like jelly mushroom; puffball mushroom was also been collected and identified.

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