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Diversity, Distribution and Morphological Characterization of Wild Macro Fungi from Gajni Forest

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Authors' contributions

This work was carried out in collaboration among all authors. Author DRBS collected the samples and conducted the research work. Author FMA designed and supervised the research work, collected the samples, wrote and edited the manuscript. Authors AAJ and MNI collected the samples. Authors JFT and MR managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Survey on macro fungi was made in Gajni forest, Sherpur, Bangladesh which is located in between 24°18' and 25°18' north latitudes and in between 89°53' and 90°91' east longitudes. It is bounded by Meghalaya state of India on the north, Mymensingh and Jamalpur districts on the south with a wide range of ecosystem. The survey was conducted on July to December, 2018 to identify and preserve wood-rot causal macro fungi for future industrial utilization. Morphology of basidiocarp and characteristics of basidiospore were recorded. A total of 20 samples were collected and identified to 12 species belonging 7 families. Dominant species was *Ganoderma* species. The identified four species were from Ganodermataceae family and these were *G. applanatum, G. lucidum*, *G. tropicum* and *G. lobetum*. Other dominant genus was *Russula.* Other recorded genera were *Hebeloma, Boletus, Phlebopus* and *Entoloma*. Among them the highest frequency (85.72%) was recorded for *G. applanatum* and lowest frequency (7.14%) was recorded for *Phlebopus marginatus.*

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Similarly highest density (20.25%) was recorded for *Agaricus* sp. followed by *G. lucidum* (15.85%). The lowest density was (2.14%) was recorded for *Phlebopus marginatus*. Collected specimens were preserved in Sher-e-Bangla Agricultural University Herberium of Macro fungi (SHMF) for further study.

Keywords: Diversity; distribution; morphology; macro fungi; density; frequency; Gajni forest.

1. INTRODUCTION

Macro fungi are macromycetes, they form macroscopic fruiting bodies such as agarics, boletes, coral fungi, stinkhorns, bracket fungi, jelly fungi, puffballs and bird's nest fungi. They are fleshy, sub fleshy or sometimes they are leathery, woody and bear fertile surface either on lamellae or lining the tubes, opening out by means of pores. The tube bearing poroid members, as boletes and polypores and the lamellate members are called agarics. Among macro fungi, Basidiomycotina in particularly they have attracted considerable attention as they have lot of source of new and novel metabolites with antibiotic, antiviral, phytotoxic and cytostatic activities. Macro fungi all alone are represented almost about 41,000 species, where approximately 850 species are already recorded from India [1] and they are mostly belonging to Agaricales, which is also known as gilled macro fungi because of their distinctive gills, or euagarics. The Agaricales has 33 extant families, 413 genera and over 13000 described species [2]. Basidiomycetes macro fungi have been valued as both food and medicine for thousands of years. Basically Macro fungi not only counted as food, but also their wastage can be recycled into fertilizers and additives that utilized for tree plantations and improving soil conditions. They are low calorie food with a very little fat and are highly suitable for grossly fatty persons [3]. They have high nutritive and medicinal values and contribute to a healthy diet, because of their rich source of vitamins, minerals and proteins [4]. Many genera of macro fungi are edible and rich in essential nutrients, such as carbohydrates, proteins, vitamins, mineral, fat, fibers and various amino acids [5]. A major portion of the population consume macro fungi and many mushrooms have been used as food and medicines [6]. The wild macrofungi are greater sources of protein and have a lower amount of fat than commercial macro fungi [7]. Wild macro fungi protein also hold considerable amounts of non-essential amino acids, such as arginine, glycine, glutamic acid, alanine, aspartic acid, proline and serine. These can be used for the food to effectively dealing with the malnutrition problem [8]. Macro fungi generally possess most of the quality of nutritious food as they contain many essential nutrients in good quantity [9]. Several numbers of reviews were published on the nutritional value of macro fungi [10,11,12]. Therefore, it is essential to give efforts to introduce new macro fungi as a source of food and medicinal interest [13].

The species diversity of fungi and their natural beauty occupy prime place in the biological world. The super variation in macro fungi always keeps the earth in an ecological balanced condition and sometimes implies the secret of their survival strategy. This survey was done to get an overview of wild macro fungi diversity, morphology and distribution in Gajni forest.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted in the Laboratory, Department of Plant Pathology, Sher –e- Bangla Agricultural University (SAU), Dhaka.

2.2 Sampling Procedure

A pre-designed collection procedure and data analysis procedure was applied to collect information on biodiversity, distribution, habitat and morphology of macro fungi from the above mentioned regions of Bangladesh.

2.3 Survey Area and Collection of Macro Fungi Samples

Survey was carried out in Gajni forest, Sherpur, Mymensingh, Bangladesh (Fig. 1) during July to December 2018 to determine the morphological variability in the macro fungi population. All of those macro fungi were collected from their natural habitat, minutely inspected, collected and brought to laboratory for detailed analysis. The collected fleshy fungi were studied for their habit, habitat, distribution, morphology and other phenotypic parameter in fresh form.

2.4 Host and Weather of the Collection Sites

Minimum and maximum temperature of the collection sites were 30°C and 34°C during collection.The dominant tree species of this area were Teak/Segun (*Tectona grandis*), Gamari (*Gmelina arborea*), Koroi (*Albizia procera*), Mahogony (*Macrophyla mahogoni*), Sisso (*Dalbergia sissoo*), Rain tree (*Albizia lebbeck*), Akashmoni (*Acacia auriculiformis),* Banyan *(Ficus benghalensis)* and Jackfruit *(Artocarpus heterophyllus*).

2.5 Morphological Observation

Data on the following parameters were recorded after collection of the specimens for identification of macro fungi such as locality, habitat, type of soil, forest type, size of the fructification, carpophores shape, umbo, scale, the gills, color, gills edges, stipes, length, width, color, shape, type of veil, annuls (position), volva, Cap color, cap surface, cap margin, cap diameter, stipe length, gill attachment, gill spacing [14].

2.6 Processing

After collection of macro fungi, photographs were taken in different angle and some morphological data viz. size of fructification, pileus diameter, stipe length, and their color were recorded. Macro fungi were dried and processed [15].

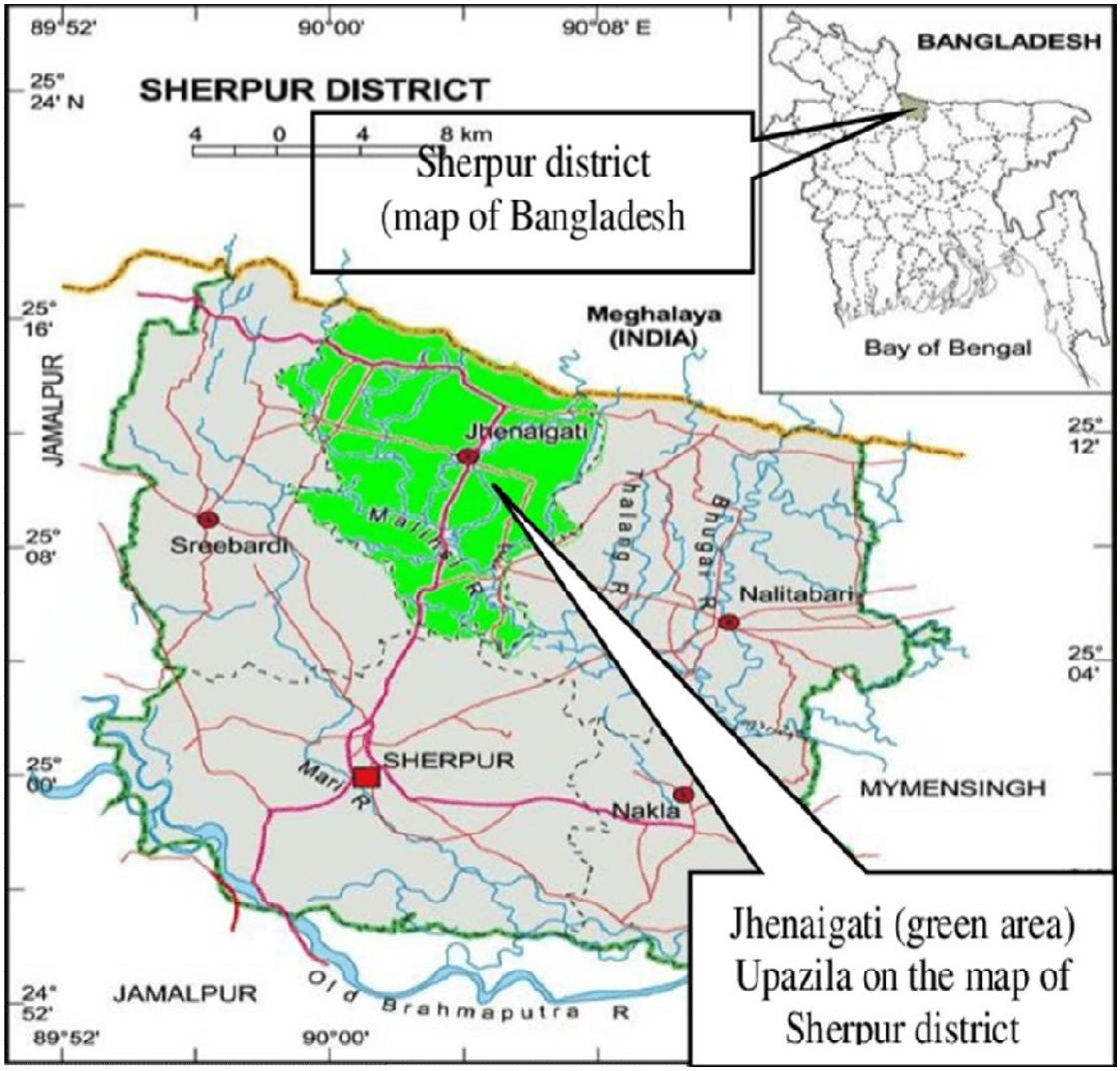

Fig 1. Survey area of macro fungi collection from Gajni forest, Sherpur, Bangladesh

2.7 Drying

Collected samples were cleaned and dried by dryer which easily remove moisture from collected macro fungi within 5-7 days depending on the structure and texture of the species [15].

2.8 Storage

Storage of dried macro fungi specimen was done in Ziploc poly bag during research period for further study. Silica gel was used at the rate of 10% of dry basis during the storage period [15].

2.9 Morphology and Microscopic Characterization

The basidiocarps were rehydrated by soaking in water for few minutes before analyzing their morphology. Qualitative characters such as color, shape and presence of hymenia were evaluated by eye observation while texture was determined by feeling the back and top surfaces using fingers. Most of the morphological data were recorded during collection period that is when the macro fungi was in fresh form [16]. The final identification and classification done by comparing the previously recorded characteristics of macro fungi following the color dictionary of macro fungi written by Dickinson and John [17], the macro fungi guide and identifier by Jorden [18] and the macro fungi identifier by Pegler and Spooner [19].

2.10 Habitat, Distribution and Diversity Analysis

The macro fungi were found in an association with various substrata. The surrounding environment, temperature, soil pH, moisture condition and vegetation were recorded for the biodiversity of macro fungi. The soil pH and moisture were measured by pH meter. On the other hand, the air temperature was measured by thermometer during the collection. Collected samples were wrapped with polybag and brought into the laboratory for further study. The distribution of macro fungi on the locality was also recorded. The frequency and density of different species has been determined by the following formulas [20].

$$\text{Frequency of fungal species (\%)} = \frac{\text{Number of site in which the species is present}}{\text{Total number of sites}} \times 100$$

$$\text{Density (\%)} = \frac{\text{Total number of individual of a particular species}}{\text{Total number of species}} \times 100$$

3. RESULTS

The species name, common name, basidiocarp and basidiospore morphology of collected macro fungi samples were described in tabular form (Table 1). Photographs of basidiocarps and basidiospores were presented in Plate 1 to Plate 3. Family name of identified species and their ecological location of collection, habit, frequency, density, temperature, soil type and weather of collection sites were tabulated (Table 2).

4. DISCUSSION

The survey on wild macro fungi was conducted during July to December, 2018 in Gajni forest in Sherpur, which is bounded on the north by India, on the east by Mymensingh district, on the south and west by Jamalpur district, Bangladesh, to record the morphological variability, habitat, distribution and biodiversity. A total of 20 wild macro fungi samples were collected and identified to twelve species under seven families.

Agaricus sp. was found on humus soil with the frequency of its presence was 70% and density was 20.25%. The genus *Agaricus* was reported in different parts of India [6,21,22]. In another study, three species of *Agaricus* viz. *Agaricus silvicola, Agaricus campestris* and *Agaricus arvensis* were recorded in mangrove forest region of Bangladesh [23].

G. applanatum was found with the frequency of its presence was 85.72% and density was 14.28%. It was associated with *Shorea robusta.* Previously it was found in Kalai, Jaipurhat in an association with *Acacia auriculiformis* [24]. Later then, it was recorded on the bark of Mehogani [25,26]. Four species of *G.* were found during collection time such as- *G. tsugae*, *G. applanatum*, *G. boninense* and *G.* sp. from Sylhet division. The frequencies of collected specimens were 12.5% and densities were 24%. The color of *G. tsugae* was dark brown and white, *G. applanatum* was dark brown and *G. boninense* was brick red. These species were collected from soil, Mehogani (*Swietenia macrophylla*) and Shimul (*Bombax ceiba*) tree, respectively [27]. This species was also reported on *Acacia auriculiformis* [28] and on *Dalbergia sissoo* [29]. *Ganoderma applanatum* was found in National Botanical Garden, Dhanmondi Lake and in National Zoo [30]. *Ganoderma* species was also reported in India [31,22] and China [32].

Plate. 1. Specimen collected from Gajni forest

G. lucidum was found with the frequency of 42.85% and density of 15.85%. It was associated with *Shorea robusta.* This species previously reported from Gazipur, Dhaka, under Tropical Moist Deciduous Forest region, Bangladesh and in association with *Leucaena leucocephala* [24]. It was also recorded in association with *Dalbergia sisso*, *Albizia procera* and *Acacia auriculiformis* [28]. *Ganoderma lucidum* was found in different parks and gardens of Dhaka city associated with *Azadirachta indica* (Neem) [30]. *G. lucidum* also previously reported from Rangamati of Hill tracts area under tropical evergreen and semi-evergreen forest region of Bangladesh [33]. *G. tropicum* was found with the frequency of 50% and density of 8.50%. It was associated with *Acacia auriculiformis.* Previously it was also recorded from National Botanical Garden, Dhaka in association with dead plant wood, Aurjun (*Terminalia arjuna*) [28]. *G. lobetum* was found with the frequency of 50% and density of 10.75%. It was associated with *Shorea robusta.* Previously it was recorded from National Botanical Garden, Dhaka. It was

associated with the root of the Neem (*Azadirachta indica*) plant with the density of 20% [28].

Hebeloma crustuliniforme was found with the frequency of 14.28% and density of 7.14%. This species was common all over the world especially in the Western United States [34].

Phlebopus marginatus was found with the frequency 7.14% and density 2.14%. It was associated with the soil surface. This species was found in Botanical garden, Mirpur, Dhaka in

Plate. 2. Specimen collected from Gajni forest

an association with the stem of Bamboo (Bambuseae) tree [24].

Russula brevipes was found with the frequency 40%and density 10.15%.It was associated with *Shorea robusta*. *Russula nobilis* was found with the frequency 10% and density 3.75%. This species was already reported from Bangladesh in association with the Golden shower tree (*Acacia auriculiformis*) [24] and Kalmegh (*Andrographis paniculata*) [28]. *Russula* sp.was found with the frequency 12.25% and density 3.75%. It was found on soil surface. This species was also recorded in Central India [31].

Boletus edulis was found with the frequency of its presence was 20% and density was 5.5%. Previously one species of *Boletus* was recorded in Modhupur and Patuakhali and that was *Boletus subvelutipes* [35]. This macro fungus was found on the root zone of *Acacia auriculiformis*. A similar *Boletus* sp. viz., *Boletus indoedulis* was collected from East district of Sikkim and occurrences under *Lithocarpus* sp. [36]. *Boletus edulis* was first described in 1782 by the French botanist Pierre Bulliard and still bears its original name [37]. It is common in Europe from northern Scandinavia, south to the extremities of Greece and Italy and North America, where its southern range extends as far south as Mexico [36].

Entoloma vernum was found on top of the hill side with the frequency was 70% and density was 15.25%. This macro fungus was present scatteredly with the soil. Three species of *Entoloma* was reported from the Russian Far East and Vietnum [38]. *Entoloma sinuatum* is fairly common and widespread across North America as far south as Arizona [39]. It also occurs throughout Europe and the British Isles including Ireland though it is more common in southern and central parts of Europe than the northwest. In Asia, it has been recorded in the Black Sea region and Adiyaman Province in Turkey, Iran and Northern Yunnan in China [40].

Plate. 3. Specimen collected from Gajni forest

Table 1. Morphology of basidiocarp and characterization of basidiospore of collected macro fungi from Gajni forest

Sl. no.	Species name	Characterization	
		Basidiocarp	**Spore**
1	*Agaricus* sp.	Cap of the carpophore was depressed. Texture of the fruiting body was soft. Pileus was umbilicate, creamy white in color with no scale. Pileus cuticle was half peeling. Size of the basidiocarp was 2.4×3.4 cm. Flesh odor was farinaceous. Lamellae present. The surface character and zonation was smooth and moist in nature. Margin was regular and round shaped, stipe was present and 1.5 cm in length. Shape was equal, position was central. Spore bearing surface under cap was gills. Gill attachment was adnate, gill color was white, shape and width was moderately broad, gill spacing was close. Lamellulae was present, forking pattern was branched. Firmness fleshy, annulus was absent, volva was absent, scale was absent, umbo was absent.	Light to deep brown in color, thick walled, smooth, irregular, elongated.
2	*G. applanatum*	Cap of the carpophore was fan shaped.Texture of the fruiting body was tough. Pileus was flat, deep brown in color with no scale. Pileus cuticle was not peeling. Size of the basidiocarp was 5-6×6-8 cm. Flesh odor was disagreeable. Lamellae absent. The surface character and zonation was rough and dry in nature. Margin was irregular and wavy. Stipe was absent. Spore bearing surface under cap was ridge.	Hyaline, thick walled, smooth and round in shape.
3	*G. lucidum*	Cap of the carpophore was infundibuliform. Texture of the fruiting body was tough. Pileus was flat, deep brown in color with no scale. Pileus cuticle was not peeling. Size of the basidiocarp was 5-6×6-8 cm. Flesh odor was disagreeable. Lamellae absent. The surface character and zonation was rough and dry in nature. Margin was irregular and wavy. Stipe was absent. Spore bearing surface under cap was gill. Veil was absent, annulus was absent, volva was absent, scale was absent, umbo was absent.	Hyaline in color, thick walled, smooth, elongated.
4	*G. tropicum*	Cap of the carpophore was flat. Texture of the fruiting body was tough. Pileus was flat, dark red in color with no scale. Pileus cuticle was not peeling. Size of the basidiocarp was 14.5×12.5 cm. Flesh odor was disagreeable. Lamellae absent. The surface character and zonation was rough and dry in nature. Margin was irregular and wavy. Stipe was absent. Spore bearing surface under cap was ridge. Veil was absent, annulus was absent, volva was absent, scale was absent, umbo was absent.	Light greenish in color, thick walled, smooth, ellipsoid. Colony growth pattern was irregular.
5	*G. lobetum*	Cap of the carpophore was flat. Texture of the fruiting body was tough. Pileus was flat, dark pinkish in color with no scale. Pileus cuticle was not peeling. Size of the basidiocarp was 12.5×13.5 cm. Flesh odor was disagreeable. Lamellae absent. The surface character and zonation was smooth and dry in nature. Margin was incurved. Stipe was absent. Spore bearing surface under cap was gills. Veil was absent, annulus was absent, volva was absent, scale was absent, umbo was absent.	Dark brown in color, thin walled, unicellular, smooth, ellipsoidal, elongated.

Sl. no.	Species name	Characterization	
		Basidiocarp	**Spore**
6	*Hebeloma crustuliniforme*	Cap of the carpophore was depressed. Texture of the fruiting body was fibrous, soft. Pileus was depressed, creamy white in color with no scale. Pileus cuticle was half peeling. Size of the basidiocarp was 3.2×3.5 cm. Flesh odor was farinaceous. Lamellae present. The surface character and zonation was smooth and moist in nature. Margin was regular and round shaped, stipe was present and 1.4 cm in size. Shape was equal, position was central. Spore bearing surface under cap was gills. Gill attachment was adnate, gill color was white, shape and width was moderately broad, gill spacing was close. Lamellulae was present, forking pattern was branched. Firmness fleshy, annulus was absent, volva was absent, scale was absent, umbo was absent.	Hyaline, thin walled, smooth, round.
7	*Phlebopus marginatus*	Cap of the carpophore shape was uplifted. Texture of the fruiting body was spongy. Pileus was 6 cm in size, greenish (young) and olive (mature) in color with no scale. Pileus cuticle was not peeling. Size of the basidiocarp was 5.5×4 cm. Flesh odor was disagreeable. Lamellae absent. The surface character and zonation was smooth and moist in nature. Pilus margin was incurved. Stipe was present, clavate/cap shaped and 5.5 cm in length.Shapewas equal, position was central. Spore bearing surface under cap was pore.Firmnessfleshyannulus, volva, scale and umbo were absent.	Greenish brown in color, thin walled, smooth, slightly elongated.
8	*Russula brevipes*	Cap of the carpophore was depressed. Texture of the fruiting body was spongy..Pileus was creamy white in color with no scale. Pileus cuticle was half peeling. Size of the basidiocarp was 4×4.5 cm. Flesh odor was farinaceous. Lamellae present. The surface character and zonation was scaly and moist. Pilus margin was incurved, stipe was present and 1.4 cm in length. Shape was equal, position was central. Spore bearing surface under cap was gills. Gill attachment was adnate, gill color was white, shape and width was moderately broad, gill spacing was close. Firmness fleshy, annulus was absent, volva was absent, scale was absent, umbo was absent.	Hyaline to light brown in color, thin walled, smooth, slightly ovoid to round shaped.
9	*Russula nobilis*	Cap of the carpophore shape was infundibuliform. Texture of the fruiting body was spongy. Pileus was, deep pinkish in color with no scale. Pileus cuticle was not peeling. Size of the basidiocarp was 2.2×3.5 cm. Flesh odor was fairnaceous. The surface character and zonation was smooth and moist in nature. Margin was incurved. Stipe was present, clavate shaped and 1.5 cm in length. Shape was equal, position was central. Spore bearing surface under cap was gill. Gill attachment was adnate, gill color was white, shape and width was narrow, gill spacing was crowded. Firmness fleshy, annulus, volva, scale, and umbo were absent..	Hyaline in color, thin walled, smooth, unicellular, round, tiny.
10	*Russula* sp.	Cap of the carpophore shape was uplifted. Texture of the fruiting body was spongy. Pileus was, milky white in color with no scale. Pileus cuticle was not peeling. Size of the basidiocarp was 7×6 cm. Flesh odor was disagreeable. The surface character and zonation was glabrous and moist in nature. Pilus margin was incurved. Stipe was present, clavate/cap shaped and 5.5 cm in length. Shape was equal, position was central. Spore bearing surface under cap was pore. Firmness fleshy, annulus was absent, volva was absent, scale was absent, umbo was absent	Hyaline in color, thin walled, smooth, unicellular, round, tiny.

Sl. no.	Species name	Characterization	
		Basidiocarp	**Spore**
11	*Boletus edulis*	Texture of the fruiting body was corky, brittle and woody. Pileus was irregularly raised, flat shaped, purple in colour. Size of the basidiocarp was 14.5 ×8.4 cm. The surface character and zonation was dry in nature. Margin wavy shaped and stipe was present and 5.0 cm in length. Spore bearing surface under cap was pore. Pore colour was whitish, brown when aged. Pore spacing was moderately crowded.	Hyaline, thin walled, smooth, unicellular, round, tiny.
12	*Entoloma vernum*	Cap of the carpophore shape was convex. Texture of the fruiting body was leathery. Pileus was deep purple in colour with no scale. Pileus cuticle was not peeling. Size of the basidiocarp was 4.2×2.7 cm. Flesh odor was fairnaceous. Lamellae present. Forking pattern was branched. The surface character and zonation was silky and moist in nature. Margin was incurved. Spore bearing surface under cap was gill. Gill attachment was subdecurrent, gill color was brown at mature specimen, shape and width was narrow, gill spacing was crowded. Firmness fleshy, annulus was absent, volva was absent, scale was absent, umbo was slightly present.	Brown in color, thick walled, double membrane, smooth, ovoid, unicellular.

Table 2. Family name and ecological characterization of collected macro fungi from Gajni forest

Sl. no.	Species name	Family name	Occurrence and host/Substratum	Habit	Frequency (%)	Density (%)	Temp. (°c)	Soil	Weather conditions
1	*Agaricus* sp.	Agaricaceae	Abundant	Scattered	70	20.25	34	Clay loam	Moderately moist
2	*G. applanatum*	Ganodermataceae	Abundant, *Shorearobusta*	Caepitose cluster	85.72	14.28	32	Clay loam	More moist
3	*G. lucidum*	Ganodermataceae	Abundant, *Shorea robusta*	Caepitose cluster	42.85	15.85	30	Clay loam	More moist
4	*G. tropicum*	Ganodermataceae	Abundant, *Acacia auriculiformis*	Caepitose cluster	50	8.5	30	Clay loam	More moist
5	*G. lobetum*	Ganodermataceae	Abundant, *Shorea robusta*	Caepitose cluster	50	10.75	30	Clay loam	More moist
6	*Hebeloma crustuliniforme*	Hymenogastraceae	Abundant	Solitary	14.28	7.14	34	Clay loam	Moderately moist
7	*Phlebopus marginatus*	Boletinellaceae	Unabundant, soil	Solitary	7.14	2.14	34	Clay loam	Moderately moist
8	*Russula brevipes*	Russulaceae	Abundant, *Shorea robusta*	Solitary	40	10.15	34	Clay loam	Moderately moist
9	*Russula nobilis*	Russulaceae	Unabundant, on soil surface	Solitary	10	3.75	34	Clay loam	Moderately moist
10	*Russula* sp.	Russulaceae	Unabundant, on soil surface	Solitary	12.25	3.75	34	Clay loam	Moderately moist
11	*Boletus edulis*	Boletaceae	Abundant, dead wood	Scattered	20	5.5	34	Clay loam	Moderately moist
12	*Entoloma vernum*	Entolomataceae	Unabundant, on debris	Scattered	70	15.25	34	Clay loam	Moderately moist

5. CONCLUSION

In this survey 12 species belonging 7 genera and 7 families were collected and identified. Dominant genera were *Ganoderma* and *Russula*. The identified four species of *Ganoderma* were from Ganodermataceae family and these were *G. applanatum, G. lucidum*, *G. tropicum* and *G. lobetum*. Other recorded genera were *Hebeloma, Boletus, Phlebopus* and *Entoloma.* Among them the highest frequency (85.72%) was recorded for *G. applanatum* and lowest frequency (7.14%) was recorded for *Phlebopus marginatus.* Similarly highest density (20.25%) was recorded for *Agaricus* sp. and followed by *G. lucidum* (15.85%). The lowest density was (2.14%) for *Phlebopus marginatus.* This investigation emphasizes further analytical studies to know its survival techniques of macro fungi in the woody plants, their role in forest ecosystem and to search their edible, medicinal and toxic properties for industrial uses.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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