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Research paper

Characteristic Study of *Russula* (Russulaceae) and its Socio-economic value in Respect of Bishnupur Forest of Bankura District, West Bengal, India

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KEYWORDS

Bishnupur forest
Russula
Study of external morphology
Study of anatomy
Socio-economic importance

ABSTRACT

Fungi are playing an important role in forest ecosystem like decomposition of organic matter, cycling of nutrient and transport of minerals. About 1.5 million fungi as reported worldwide belong to different family among which Russulaceae is considered as one of greatest family. It has approximately 2000 species in entire world. Near about 180 species belong to the genus *Russula* and 92 species belong to the genus *Lactarius* under Russulaceae have been reported from India till now. This ectomycorrhiza group is playing a great role in biodiversity conservation. The recent study has been focused on characteristic analysis (morphology & anatomy) of *Russula* and its economical aspect. There were 6 species of *Russula* collected from Bishnupur forest. It was noticed that *Russula* are easily grown in the soil of Bishnupur forest than other adjacent areas especially *Russula aciculocystis* richness was very high around 57.1%. About 50% only edible, 33% inedible and 17% medicinal with edible nature of *Russula* have been reported currently. Monthly distribution in monsoon is also noticed where the population was 31% in July, 52% in August and 17% in September respectively in Bishnupur forest.

1. Introduction

Macro fungi play an important role in forest ecosystem like decomposition of organic matter, cycling of nutrient and transport of minerals. They are called as "The Diamond of the forest by Japanese" (Kothiyal *et al.,* 2022). It is reported that mostly fungi are saprophytic, some are parasitic and very few numbers are ectomycorrhizal in nature. About 1.5 million sporocarp have been enlisted under fungal. community from which one-third are Indian flora but only 50% of them have been known characteristically (Manoharachary *et al.,* 2005). Russulaceae is a one of greatest family among fungal. world which have approximately 2000 species throughout the world and shows cosmopolitan distribution (Ghosh *et al,.* 2021). According to Kirk *et al.* (2008) Russulaceae consists of 1243 species and it shows ectomycorrhizal. association with different plant. At early stage Russulaceae was considered as a part of order Agaricales but after on the basis of its microscopic and molecular data this family finally have been placed into order Russulales (Verma *et al.,* 2019). Roze (1876) has first proposed this family as Russulariees and he has been divided this family into two genera like *Russula*

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and Lactarius. The basic difference between these two genera is that *Russula* does not release any milky fluid from its surface like of *Lactarius*. It is thought that *Russula* is an ancestor of *Lactarius* (Mohanan. 2014) and it evolved approx. 55 million years ago (Kiran *et al.,* 2021). Mohanan (2014) has reported that the genus *Russula* consists of 750 species all over the world. Ghosh *et al.* (2021) have reported that 180 species belong to the genus *Russula* and 92 species belongs to the genus *Lactarius* in India. It is noticed that they have gloeoplerous elements which avoid lactiferous system (Ghosh *et al.,* 2021) and lacking clamp connections mostly. Sarnari (1998) have reported European species of *Russula* which probably considered as the best currently available classification for the genus and he has first proposed the genus into six subgenera like *Amoenula, Compactae, Heterophyllidia, Icnrustatula, Ingratula and Russula.* A new species of *Russula ochrifloridana* from Florida has been reported by Adamcik *et al.* (2010). Berkeley (1851, 1852, 1854, 1876) have reported nine species of *Russula* and five species of *Lactarius*. Atri *et al.* (1994) have reported 67 members of genus *Russula* from India. Verma *et al.* (2019) have documented 35 species under *Russula* from Jammu and Kashmir, India. Approximately 74 members of *Russula* have been reported from Northwestern Himalayas by Atri *et al.* (1997). Das *et al. (2014)* have represented 130 species under the genus *Russula* from India. Tapwal *et al.* (2013) have been recorded 5 members of Russulaceae from Assam of India. Das *et al.* (2013) have reported 3 new species of *Russula* from Sikkim of India. Mohanan (2014) have enlisted 13 members of *Russula* from Western Ghat, Kerala of India. Verma *et al.* (2018) have been represented 6 species of *Russula* from Central India. It is reported that many species of *Russula* are edible in nature (Kalita *et al.,* 2016) and have medicinal properties for that reason researchers are very curious to know about their diversity, habitat, characteristics, uses at present time.

2. Materials and Methods

2.1 Study area

The study area has been visited at monsoon of 2023 (July to September). Mainly survey has been made in tropical Sal forest of Bishnupur of Bankura District (Fig. 1). The Bishnupur is located at latitude 23˚04 48ʺ N to at longitude 87˚ 19 12ʺ E; altitude 59 meters. The climatic conditions of Bishnupur forest are very favorable for fungal growth. The temperature of Bishnupur ranges between 23˚C to 29˚C (26˚C average), gets 2289-6170mm of rain approximately (average 4230mm precipitation) and humidity ranges between 73-96% (85% average) and the common plant are Sal (*Shorea robusta*), Segun (*Tectona grandis*), kendu (*Diospyros melanoxylon*), Akashmoni (*Acacia auriculiformis*) etc (Mukhopadhyay *et al.,* 2024). The soil is full of humus and air containing which help to enormous growth of various fungal species. During survey it was shown that the genus *Russula* have been distributed abundantly in the forest area of Bishnupur.

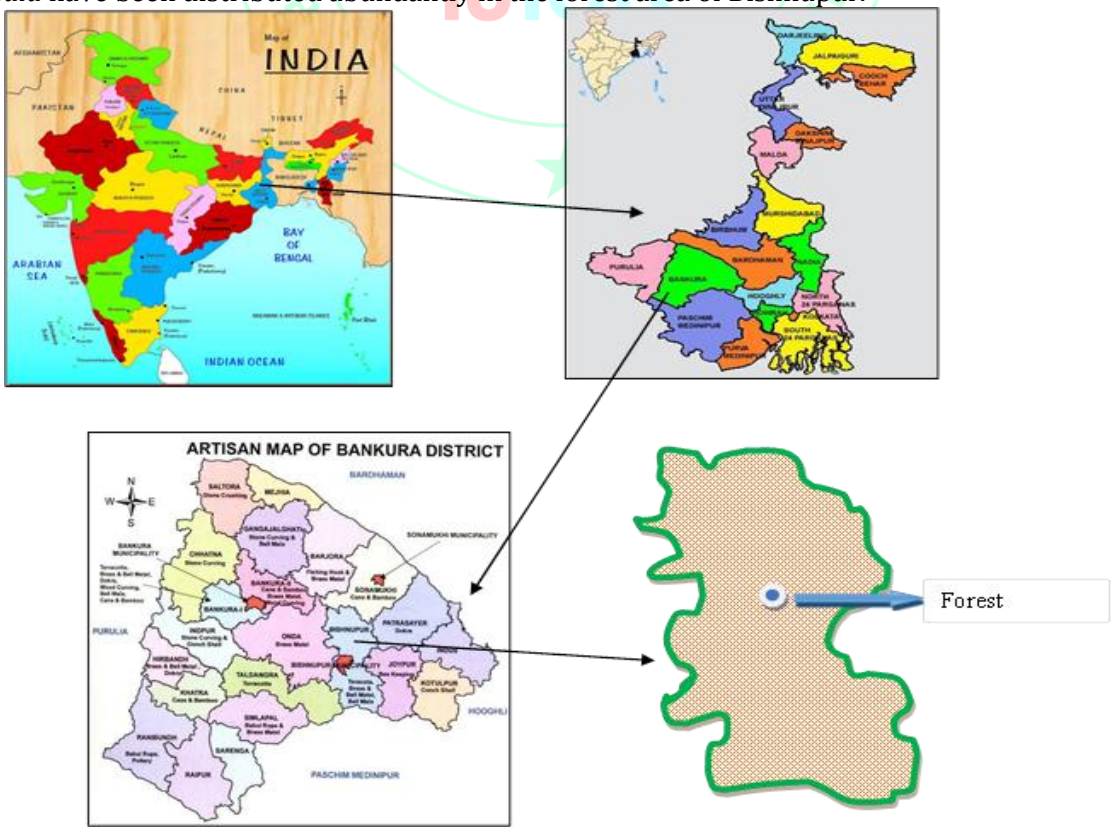


Fig. 1 Study area

2.2 Collection of specimens

The fungi were collected randomly. Healthy species were collected from their habitat with the help of digging tools and photographs were taken at the time of collection. The measurements of pileus and stipe of all collected specimens were taken during survey time and all the macroscopic characters were noted for each species at their natural stage.

2.3 Preservation of specimens

All the collected fungi were wet fungi so sporocarp were preserved with 5% formalin solution (Mukhopadhyay *et al.,* 2024) into plastic jar with proper labelled description for microscopic study. The preservation is treated carefully and entire formalin solution was changed in 3 days interval to maintain the fungal sporocarp.

2.4 Identification of specimens

Identification of collected specimens were performed on the basis of colour of cap, arrangement of gills, length of stipe, structure and colour of spore, presence of ectomycorrhizal. association with the help of standard journal papers.

2.5 Statistical method

The frequency is evaluated with the help of the following formula (Aung *et al.,* 2008)

$$\text{Frequency (\%)} = \frac{\text{presence of total number of a group}}{\text{Total number of all groups}} \times 100$$

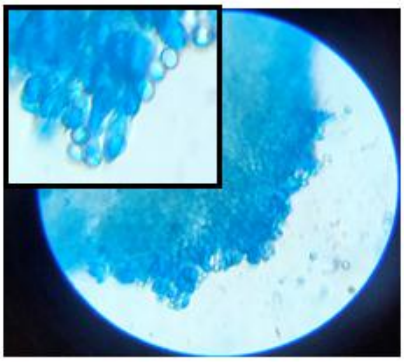
2.6 Characteristic study of collected fungi

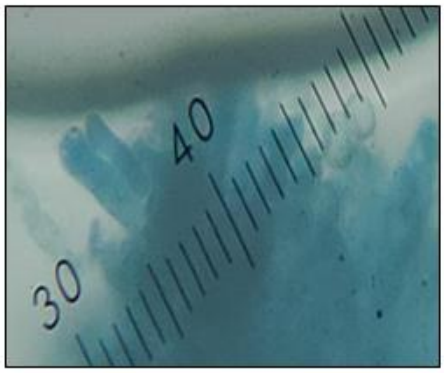
Both external and internal studies were done to know the different characteristic data about the collected species [Fig. 2 (a) – Fig. 3 (b)]. Morphological study was done during collection at their original habitat. Measurement of pileus and stipe, smell, colour of fruiting body, arrangement of gill, number of individuals for each fungus were noted in details. The Anatomical analysis was done in laboratory. Sectional parts were dyed with lactophenol-cotton blue and shown under microscope. In microscopic view the structure of spore, colour of spore, number of spores, arrangement of basidium, structure of basidium, number of basidia and ectomycorrhizal association have been revealed.

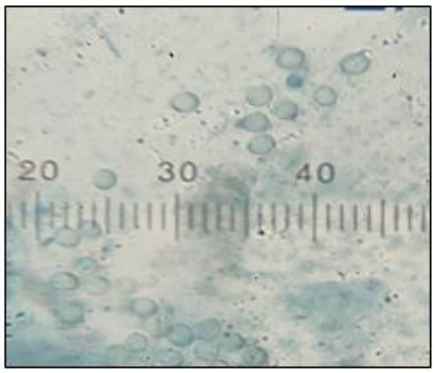
MORPHOLOGICAL AND ANATOMICAL OBSERVATION OF SOME FUNGI OF RUSSULACEAE

Russula cyanoxantha

(a)







Gill Measurement(×400x) Spore Measurement(×400x)

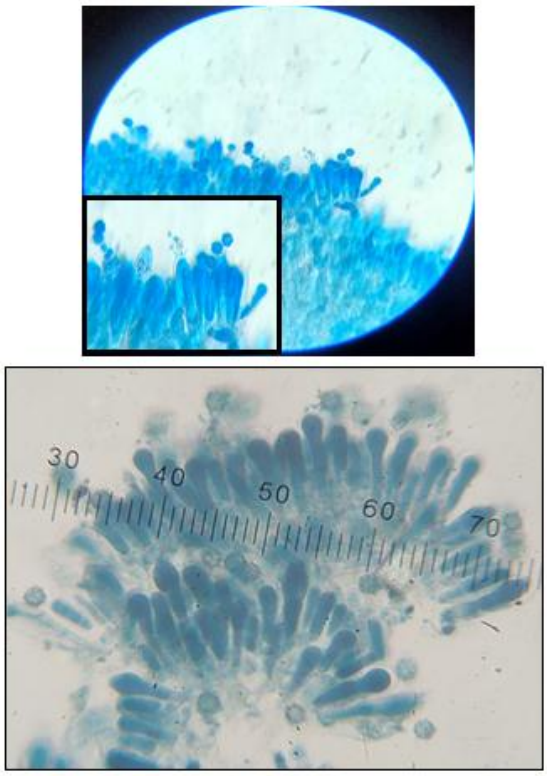
(b)

Fig. 2 (a). Morphological views of *Russula cyanoxantha* (b). Anatomical views of *Russula cyanoxantha* (Magnification Value - 400x)

Morphological Characters *Russula cyanoxantha* :-	Anatomical Characters *Russula cyanoxantha* :-
1. The cap of the fungus is violet in colour, broadly convex. Cap surface is dry, smooth and margin is not striate smooth. 2. Stipe is white in colour and attached at the centre of pileus. Surface is dry, smooth. Compressed type of stipe is present and stipe form rhizoids at base. 3. Volva and annulus are absent. 4. Gills are creamy white in colour, paral.lelly arranged, free in nature and gill margin is even. The length of gill 2.8cm and width is 8mm 5. The whole length of the fungus is 9.5cm. The measurement of only stipe is 3.3cm × 1.2cm and length of pileus is 5 cm.	1. In 400x lense of microscope the gill shows spores like structure, spores are rounded, spore wall is thin. 2. The spores are actually colourless, so it takes the colour of cotton blue. 3. In 400x lense of microscope the sectional view of gill shows the basidium like structure. Basidia are long, club shaped, arise from the hymenial layer. 4. The measurement of basidium is 12-18 µm ×3- 4 µm. 5. The measurement of spore is 4 - 8 µm × 4 -6 µm.

Russula aciculocystis

(a)



Gill and Spore Measurement (×400x)

(b)

Fig. 3 (a). Morphological views of *Russula aciculocystis* (b). Anatomical views of *Russula aciculocystis* (Magnification Value - 400x)

Morphological Characters of *Russula aciculocystis*:-	Anatomical Characters ***Russula aciculocystis***:-
1. The cap of the fungus is red in colour, broadly convex. Cap surface is dry, smooth and margin is not striate smooth. 2. Stipe is white in colour and attached at the centre of pileus. Surface is dry, smooth. Compressed type of stipe is present. Rhizoids are not found at the base of stipe 3. Volva and annulus are absent. 4. Gills are creamy white, regular, thick, parallelly arranged, free in nature and gill margin is even. Length of gill is 2.2 cm and width is 5mm 5. The whole length of the fungus is 3cm. The measurement of only stipe is 1.8cm × 0.5cm and the length of pileus is 2.5 cm.	1. In 400x lense of microscope the gill shows spores like structure, spores are rounded with spiny outer layer, spore wall is thin. 2. The spores are actual.ly colourless, so it takes the colour of cotton blue. 3. In 400x lense of microscope the sectional. view of gill shows the basidium like structure. Basidia are long, broad, club shaped, arise from the hymenial. layer. 4. Sterigma is easily seen in gill section. 5. The measurement of gill is 10 -28µm × 4 – 6 µm. 6. The measurement of spore is 4 – 6 µm × 6 µm

3. Results

Bishnupur forest is rich in Russulaceae. Already many species of *Russula* were reported from different places of west Bengal. (Table 1). But Bankura District is underrated till now and very little fungal flora have been enlisted from this area. Though few researches were performed on fungal diversity of this District. But the present study is the first one that has documented the detailed study of the genus *Russula* from Bishnupur of Bankura District. A survey was made in Bishnupur forest of Bankura district and many species of *Russula* were collected. Their characters, distribution and social values have been brought up in the recent study. From the survey six different species of Russula were collected such as *Russula adusta, Russula michiganensis, Russula cyanoxantha, Russula aciculocystis, Russula fragrantissima, Russula delica* (Table 2). A total number of 42 individual.s under six different species were collected. Those include as follows:- *Russula adusta* - 03, *Russula fragrantissimas* - 05, *Russula cyanoxantha* - 08, *Russula aciculocystis* – 24, *Russula delica* - 01 and *Russula michiganensis* - 01 (Table 2). It was noticed that *Russula aciculocystis* reported highest in number and *Russula michiganensis* and *Russula delica* were found same in number. Morphological studies of these fungi have revealed that they have long, fleshy, white colored stipe showing ectomycorrhizal. association and bright colored pileus with smooth surface. Gills were unbranched, large, thick with milky white colored surface.

Anulus and volva were absent and Anatomical studies have revealed that basidia were long, club shaped and spores were round covered with thin outer layer. Basidiospores were many in number and attached with sterigma which is clearly visible in *Russula aciculocystis*. According to local tribes many members of Russulaceae are used as medicine. Some are consumed as food. Among the collected species *Russula adusta*, *Russula michiganensis*, *Russula cyanoxantha*, *Russula aciculocystis* are used as food by the tribal. people and *Russula cyanoxantha* is only species which is utilised as medicine by local tribal people of this region (Table 3). They take it with soup to compensate their protein deficiency. After the survey it was found that the frequencies of *Russula adusta* was 7.1%, *Russula michiganensis* was 2.4%, *Russula cyanoxantha* was 19%, *Russula aciculocystis* was 57.1%, *Russula fragrantissima* was 12%, *Russula delica* was 2.4% of total. collected fungi (Fig. 4). Among the collected fungi, 50% of these are only edible, 33% inedible and 17% used as food and medicinal. purpose (Fig. 5). The monthly distribution of *Russula* was 31% in July, 52% in August and 17% in September (Fig. 7). The recent study has also documented the frequency of *Russula* of West Bengal. where Jhargram forest shows 14.3% in frequency; Botanical Garden of Ballygang Science College, Paschim Midnapur forest, Balibhasa forest and West Midnapur forest shows 7.1% in frequency separately; Gidhani forest and Derjeeling forest both show 29% respectively in frequencies (Fig. 6).

Table 1 Reported members of *Russula* from different places of West Bengal.

Name	**Area of collection**							**Reference**
	Jhargram	Botanical. Garden of Ballygunge Science College	Darjeeling	Gidhani sal forest	Paschim Midnapur	West Midnapur	Bal.ibhasa sal forest	
Russula albonigra	+	-	-	-	-	-	-	Atri & Saini (1986)
Russula arunii	-	+	-	-	-	-	-	Crous *et al.* (2017)
Russula buyckii	-	-	+	-	-	-	-	Paloi *et al.* (2016)
Russula cyanoxantha	-	-	-	+	-	-	-	Atri & Saini (1986)
Russula emetica	-	-	+	-	-	-	-	Berkeley (1856)
Russula grossa	-	-	+	-	-	-	-	Berkeley (1851)
Russula himalayana	-	-	+	-	-	-	-	Paloi *et al.* (2015)
Russula intervenosa	-	-	-	-	+	-	-	Crous *et al.* (2016)
Russula kanadii	-	-	-	-	-	+	-	Dutta *et al.* (2015)
Russula lepida	+	-	-	-	-	-	-	Berkeley (1851)
Russula pectinata	-	-	-	+	-	-	-	Saini *et al.* (1989)
Russula delica	-	-	-	+	-	-	-	Atri and Saini (1986)
Russula vesca	-	-	-	+	-	-	+	Shajahan & Samajpati (1995)

Table 2 Currently collected species of *Russula* from Bishnupur forest of Bankura District

Name	Family	No of collected members (Monthwise)			Site of collection	Rerferences
		July	August	September		
Russula adusta	Russulaceae	1	2	-	Bishnupur, West Bengal.	Verma *et al.* (2018)
Russula michiganensis	Russulaceae	-	1	-	Bishnupur, West Bengal.	Mohanan (2014)
Russula cyanoxantha	Russulaceae	2	5	1	Bishnupur, West Bengal.	Singha *et al.* (2020)
Russula aciculocystis	Russulaceae	8	11	5	Bishnupur, West Bengal.	Mohanan (2014)
Russula fragrantissima	Russulaceae	2	2	1	Bishnupur, West Bengal.	Kumar *et al.* (2014)
Russula delica	Russulaceae	-	1	-	Bishnupur, West Bengal.	Shajahan and Samajpati (1995)

Table 3 Properties of collected *Russula*

Name	Properties/ uses
Russula adusta	edible
Russula michiganensis	edible
Russula cyanoxantha	Used as food and medicine
Russula aciculocystis	edible
Russula fragrantissima	Not edible
Russula delica	Not edible

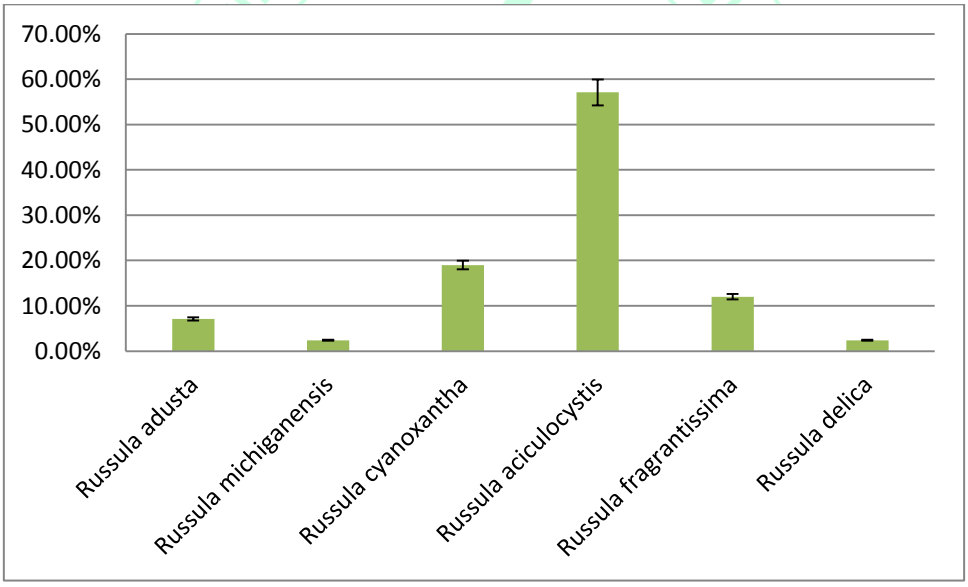


Fig. 4 Percentage of distribution of *Russula spp* in study area

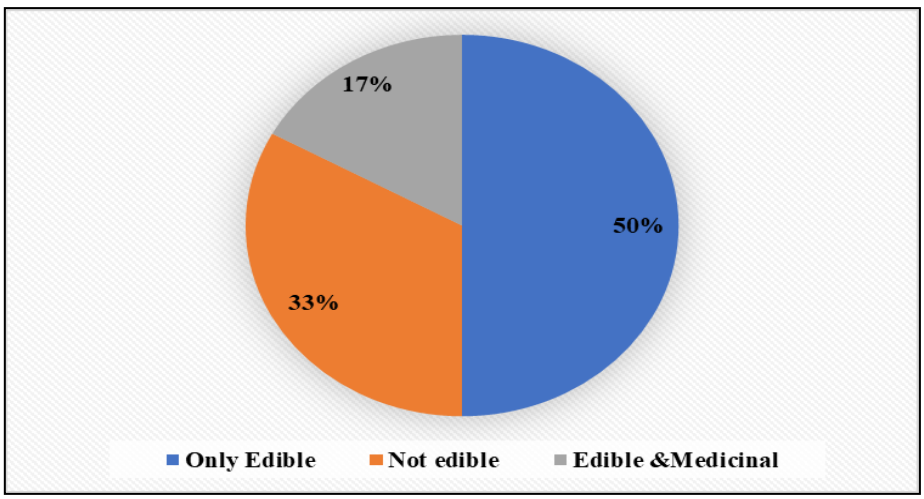


Fig. 5 Percentage of fungal properties

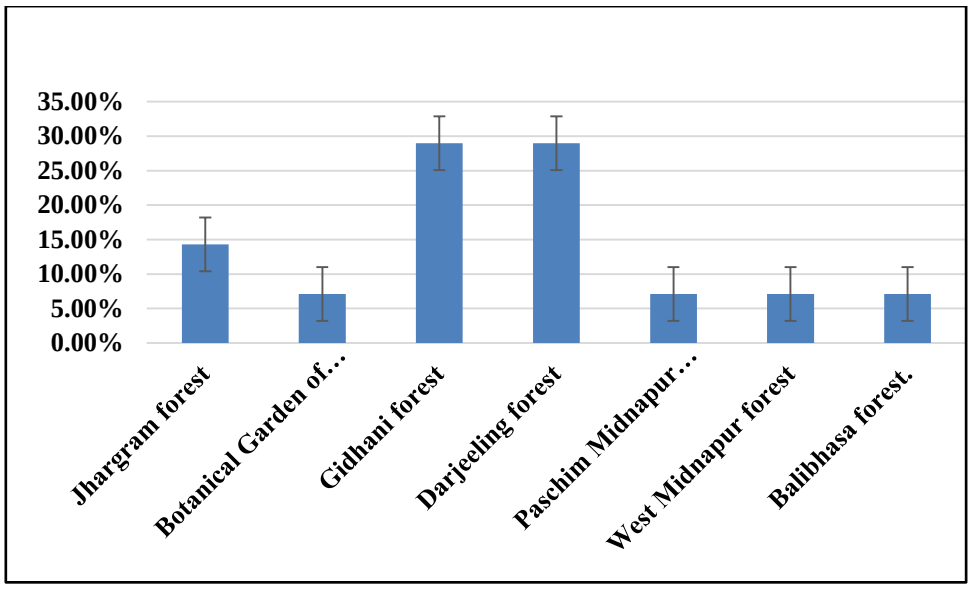


Fig. 6 Frequency of distribution of *Russula* in each area

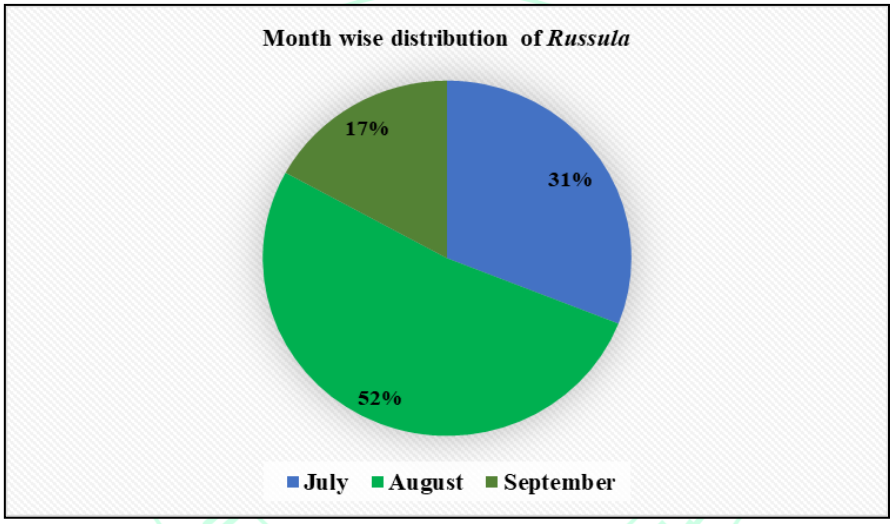


Fig. 7 Monthly growth of *Russula* in Study area

4. Discussion

An estimate of 550 species under 166 genera of 51 families are categorized into Basidiomycota and Ascomycota in India (Mohanan. 2014) and Russulaceae is one of the largest family of this fungal world. Russulaceae represent the most important genus under it namely *Russula* which is coming from the latin word Russulus and this genus have 337 known species all over the world (Atri *et al.,* 1997). Kirk *et al.* (2014) have been recorded 1900 species under the family Russulaceae including 1100 species of *Russula* alone and this genus gets the affiliation of largest genus of Russulaceae. During survey Russulaceae has shown an enormous distribution in the forest of Bishnupur. The climatic conditions of Bishnupur are very suitable for fungal growth, so different types of fungus can easily grow here. It has been noticed that the collected fungi of *Russula* are very attractive for their colourful appearance and all the members are not seen in same number. They do not grow at the same time in the forest but mostly are well distributed. Some members of *Russula* are well known to people because they are sold in local market by the villagers or tribal people. Mostly the abundance of *Russula* have been found after Janmashtami. The distribution became high at the month of August and decreased at the time of September but moderate vegetation was found throughout July. It was noticed that only 3 species namely *Russula cyanoxantha*, *Russula aciculocystis*, *Russula fragrantissima* were grown in all the three months and *Russula abusta* was absent only in September where other two species namely *Russula michiganensis* and *Russula delica* were present only in the month of August. During survey it was also seen that *Russula aciculocystis* have individuals in greater number alone than other five fungi. Detailed study regarding *Russula* is very little in number which is not sufficient to get a proper knowledge. Even Bankura district have not any documentation on morphological and anatomical study of *Russula*. At present, morphological study reveals that all the members of *Rusulla* have colourful, soft and convex pileus, stipe is long, fleshy, spongy in

touch, gills are white, thick, prominent and regularly arranged. It was also found that external appearance of *Russula adusta* among the collected fungi is turning into black after few hours. All the species of *Russula* became colourless after putting them into formalin solution for several days and at that time it was very difficult to identify them. But anatomical. study al.ways acts as key point for identification and it is a very simple procedure. Anatomical data is used to determine similarity or dissimilarity between two species of same genus or two genera under a family and also differentiate two division. In the recent study anatomically fungi were quite dissimilar like *Russula cyanoxantha* have smaller basidia and spores are comparatively larger, rounded with prominent outer layer where *Russula aciculocystis* have larger basidia with broad apex, sterigmata clearly noticed and spore are smaller, bilayered as rounded inner and spiny outer. Comparatively anatomy based identification is not so much expensive and time taking like of molecular technique. Anatomical data may be a revelatory source to detect unknown fungi in future. From anatomical study we can find out different unknown minerals of soil which are uptaked by fungi. The fungi have shown mycorrhizal association with rooting plant playing a role in conservation of forest diversity and acts as nutritional properties for such animal (Ghosh *et al.,* 2021). The ectomycorrhizal fungi of Russulaceae have an enzyme activity to form symbiotic association with plants (Kiran *et al.*, 2021). Many data have been proved that members of *Russula* are associated with both Gymnosperm and Angiosperm namely *Abies*, *Betula*, *Larix*, *Acer*, *Tsuga*, *Rhododendron*, *Taxus*, *Pinus* etc (Verma *et al.,* 2018; Verma *et al.,* 2019) but it was noticed that currently collected fungi of Russulaceae showing the mycorrhizal. association only with Sal. tree in Bishnupur forest, Members of Russulaceae has a special.ized character as sphaerocysts in its stipe which may differ them from other macrofungi and the broken stipe of those mushrooms looks like flesh of apple where other family shows fibres after breaking (Mohanan. 2014).

Socio-economic Values

During survey six species of *Russula* were collected among them four species were edible and two species were inedible but no trace of any poisonous fungi. From interaction with the local people it was revealed that *Russula adusta* and *Russula aciculocystis* are mostly consumed by local. tribes and *Russula cyanoxantha* was only collected fungus which can treat weakness, nutritional disorder, skin disease and wound healing. It also shown that *R. cyanoxantha* lowers high blood pressure (Singha *et al.,* 2020). Different research has revealed that *Russula* produce some compounds being used in medicine and food industry for their potential activity (Kiran *et al.,* 2021). Wang *et al.* (2007) reported that *Russula paludosa* have the inhibition activity against HIV. Gangwar *et al.* (2023) reported that *Russula lakhanpalii* have antibacterial, antioxidant properties. Turkoglu *et al.* (2007) reported that *Russula delica* have the antioxidant and antimicrobial activity. Joshi *et al.* (2014) reported that *Russula lepida* have antibacterial activity. Tian *et al.* (2014) have disclosed that *Russula vinosa* have shown antioxidant and hepatoprotective activity. Singha *et al.* (2020) have repoted that *Russula albonigra* is used for the treatment of cold and cough, *Russula senecis* is treated for microbial infection and cuts. The present study not only focuses on the characteristic nature of *Russula* and their distribution under Bishnupur of Bankura district but also make people aware of the food value of various species of *Russula.* Fungi have been considered as food of gods by romanion people and Chinese called them as Elixir of life (Sarikurkcu *et al.,* 2020). Mushroom contains vitamin, minerals and protein which have same nutritional value like of local legume products (Buyck, 1994). The mushrooms are the only nutritional supplement for poor people and also useful source as baby food in many countries, so now mushrooms are commercially accepted in all over the world. For decades many researchers have improved our economy and also able to fulfill nutritional deficiency by introducing many edible fungi, like Panda *et al.* (2020) have shown the edible potential. of 3 *Russula* species namely *Russula densifolia, Russula violeipes and Russula cyanoxantha* from Northern Odisha, India. Tapwal. *et al. (*2013) have been recorded 4 edible species of *Russula* i.e *Russula amoena, R. delica, R. pectinate, R. nobilis* from the forest of Assam. Ergonul *et al.* (2013) have worked with the edible fungus *Russula anthracina*. Thatoi (2014) have anal.ysed the food value of *Russula delica* and *Russula integra*. Popescu *et al.* (2015) have reported the edible nature and chemical potentiality of *Russula virescens*. Sarikurkcu *et al.* (2020) have recorded 3 species of *Russula* which are edible namely *Russula albonigra, R. delica, R. viscida*. The present study also documented different species of *Russula* which disclose the distribution and richness in West Bengal like two species reported from Jhargram forest, 4 species from both Gidhani forest and Darjeeling Forest, one species from Botanical Garden of Ballygunge Science College, Paschim Mednipur forest, West Midnapur forest, Balibhasa forest each (Table 1). However now we are giving more importance to advance study like molecular study of fungi, fungal biotechnology, DNA informatics etc but we should not forget that these advance study are fully based on fungal flora but diversity and taxonomy related work are currently very limited all over the world. As a result many important fungi being extinct day by day like of *Russula* due to lack of attention as well as many are unknown to us till now due to difficulty in identification and lack of interest. Therefore, the Present study mainly being focused on external and internal

study of the genus *Russula* (Russulaceae) and al.so disclose socio-economic val.ue which may influence others for further study in broad scal.e to enrich our fungal. flora.

5. Conclusions

Russulaceae is one of the most important family of fungal world. Majority of the species of Russulaceae have food value and they are very demanding fungi for their medicinal properties. According to Chinese *Russula* is the most nutritive fungal genus of China (Kiran et al., 2021). It has noticed that the number of poisonous fungi under Russulaceae is very limited. But ethnomedicinal. practices regarding fungi is very rare in India because researchers do not show any interest for the study of medicinal fungi even India have very few mycologists. So mycological study is very limited or irregular and not developed in broad scale in India and people are totally blind about beneficial aspects of fungi.

Russulaceae is a larger family and it contains approximately 750 species under the genus *Russula* throughout the world (Kirk *et al.,* 2008). It shows ectomycorrhizal association with conifers and flowering plants. This ectomycorrhizal group helps to increase the soil fertility even it supplies essential nutrient to the associated plant for recovering deficiency. It has been known that fungal species under the genus *Russula* are able to conserve and protect endangered species (Kiran *et al.,* 2021) but now they are destroyed due to deforestation, overfeeding, disease by infecting agent, infertility, weather change etc. Out of these factors weather change is playing a challenging role in recent days as temperature becomes high day by day and rain fall is irregular. Consequently deficiency of suitable water is there day by day which may stop the fungal growth over time. If such fungi like *Russla* cannot grow in forest system then biodiversity will be lost in future. Therefore immediate attention is required for the conservation of such ectomycorrhizal fungi.

From the survey it was noticed that *Russula* spp grow abundantly in the soil of Bishnupur forest than other adjacent areas specially the richness of *Russula aciculocystis* is very high. Probably high concentration of iron in the soil may be cause for favorable growth of *Russula* in Bishnupur.

The aim of this recent study is to develop knowledge about *Russula* and its prospective which may encourage the researchers for further study. This will help to enrich the fungal diversity in future and thus adding to balance our biodiversity.

Conflicts of Interest

The authors declare no conflicts of interest.

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