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Insights and Prospects Toward the Undergraduate Mycological Researches of Bicol University

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Mycology is a diverse field of study and yet relatively few mycological researches are published in the Philippines. This stems from a variety of problems such as limited number of experts, fewer mycological training, lack of financial and institutional support, and low preference for mycological researches. Unpublished undergraduate researches archived in educational institutions may mirror these research realities. This research was conducted to document the mycological researches of the Biology Department of Bicol University. Mycological researches were categorized into major themes. Highlights, focus, gaps, and challenges were reported. Results showed that only 76 of the 865 archived undergraduate research papers in the span of 33 years are mycological in nature, with only one published in a scientific journal. The 76 theses can be categorized into one of the following common themes: agricultural, biodiversity, food, industrial, and medical mycology. Among the agricultural-themed researches, most were on post-harvest pathology or plant pathology. In medical mycology, the majority merely used fungal species as test organisms for antifungal activities of plant extracts. To increase interests in fungi, three strategies are recommended: (1) increase exposure of students to mycological researches, (2) provide infrastructure and policy support for the actual conduct of experiments, and (3) encourage publication of results in peer-reviewed scientific journals. New research areas are also proposed that may be responsive to regional and national needs.

Keywords: agriculture, fungal biology, mycological herbaria, plant pathology, undergraduate research

INTRODUCTION

Mycology is a diverse field of study. In the past, mycological literature in the Philippines was dominated by taxonomy (Roldan 1937; Quimio 1986; Teodoro 1937). Most of the fungal taxonomists working in Asia, including the Philippines, were visiting scientists (Hyde 2003; Tadiosa 2012). Two of the country's earliest Filipino mycologists, Dr. Irineo J. Dogma Jr. of the University of Santo Tomas in Manila and Dr. Tricita H. Quimio of the University of the Philippines in Los Baños, have contributed well to Philippine fungal taxonomy. Dr. Quimio has published numerous papers on Philippine fungi (Quimio 1986), fungal endophytes (Umali *et al.* 1999), fungal pathogens (Quimio 1973), Agaricales species (Quimio 1983), and specific genus such as *Termitomyces* (Quimio 1977). Dr. Dogma has published papers on chytrids (Dogma 1969), phycomycetes (Sparrow and Dogma 1973), and Blyttiomyces (Dogma and Sparrow 1969), among others. Dr. Dogma Jr. is honored with a fungal genus named after him, *Ireneochytrium* (Letcher *et al.* 2014). Eventually, fungal taxonomy has gained momentum through the works of Dr. Resurreccion B. Sadaba of the University of the Philippines Visayas on his works on mangrove-associated fungi (Calabon *et al.* 2019; Sadaba *et al.* 1995), Dr. Edwin R. Tadiosa

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of the National Museum of the Philippines on fungi in terrestrial landscapes (Tadiosa *et al.* 2012; Tadiosa and Briones 2013), and the ethnomycological surveys of Dr. Angeles de Leon of Central Luzon State University (Lazo *et al.* 2015; de Leon *et al.* 2016). Dr. Thomas Edison E. dela Cruz of the University of Santo Tomas provided an in-depth review of Philippine mycology that tackles the current trend and challenges to fungal taxonomy and biodiversity in the country (dela Cruz *et al.* 2013).

Along with taxonomy, the study of fungi is well established in agriculture, specifically in the study of plant pathologists Dr. Teresita U. Dalisay on gall rust (Doungsa-ard *et al*. 2015), Dr. Christian J. Cumagun on sugarcane smut (Luzaran *et al*. 2012), and Dr. Mark Angelo O. Balendres on *Spongospora subterranea* (Balendres *et al*. 2017) among others. It has been reported that at least 60% of crop diseases in the Philippines are caused by fungi (Tangonan 1993). Among them are the economic and epidemiologic challenges brought by *Colletotrichum gloeosporioides* causing mango anthracnose (Dodd *et al.* 1991) and *Mycosphaerella fijiensis* causing black sigatoka of banana (Juan 1985). In medical mycology, the Philippine fungal research includes common opportunistic fungal pathogens such as *Candida albicans* and dermatophytes (Handog and Dayrit 2005).

Despite the diverse researchable areas and its contributions to science and society, there is a dearth of mycological research in the Philippines. This is in part due to the limited number of experts – especially on systematics and ecology (dela Cruz *et al*. 2013) – the waning interest in agriculture especially among the youth, and the lack of infrastructure and policy support. Education institutions especially universities can bridge these gaps in mycological researches. Expertise is concentrated in the university and more students can be enticed to work on fungi when given the proper exposure and guidance in research. More so, universities are repositories of valuable data that may be tapped for research directions.

Many works of mycological literature can be found in archives as unpublished researches in educational institutions. These documents may potentially be sources of data with economic, medical, industrial, and ecological values. When properly selected and curated, these are vital in providing good evidence for biodiversity conservation (Haddaway and Bayliss 2015) and other important policy formulations. These works can provide valuable insights into the study of mycology at a local level, one aspect that may not be captured in reviews of national scope.

This article, therefore, aimed to document the mycological researches of the Biology Department at Bicol University from 1985–2018 and provide insights into the research areas, trends, highlights, and focus. This paper specifically looked into which researches were common and responsive to challenges facing the region and country during the time the researches were conducted. Finally, this paper aimed to provide recommendations on mycological researches in the future.

METHODOLOGY

Profile of the Biology Department of the Bicol University

Bicol University is a state-funded higher education institution (HEI) in the Bicol Region. Its main campus is in the province of Albay where the College of Science is located. The Biology Department is one of the five academic departments of the College of Science along with Chemistry, Physics and Meteorology, Mathematics, and Computer Science and Information Technology. The department is now in its 42 years of existence and offers a Bachelor of Science in Biology program. The department is also involved in the offering of courses for the Master of Science in Biology program at the Graduate School. There are 13 full-time faculty members of the department with at least three faculty members specializing in fungal research, *i.e.* on fungal endophytes and plant pathology, macrofungi and forest mycology, and myxomycetes or slime molds.

Undergraduate Researches

Titles of researches were obtained from the updated list of undergraduate researches of the biology department. This list contains 865 theses titles from 1985–2019. From this list, all titles that were focused on mycology were filtered. All titles from the list were individually checked and transferred to a mycological research database. When titles were not clear about the subject matter, the abstracts of the research were consulted in the hardbound copies in the department library. When copies were not available at the department level, copies at the university library were consulted. Because the results of the research remained a copyrighted material of the student author and to avoid preempting them in case they opt to publish, no results of the undergraduate thesis were included in the analysis.

Categorization of Mycological Researches

A summary of researches per year was done. After this, an initial cursory evaluation of the research titles was done to determine the commonalities. Based on the intent of the research, they were categorized along the following: Agricultural Mycology, Biodiversity, Food Mycology, Industrial Mycology, and Medical Mycology. Sub-disciplines were determined for each of the major groups. Other parameters were included

such as commodities studied, location of sampling, and bioactivities determined. Researches were likewise categorized whether they were basic or applied researches. Organisms discussed were also noted. Grouped data were indicated in percentages.

RESULTS

Research Works by Year

There is a total of 76 mycological research works in the department from 1985–2018 (Figure 1). This is 8.79% of the total 865 undergraduate research works produced throughout the 33 years. This translates to an average of two to three mycological researches per year. This number is rather low compared to other research disciplines. For example, medicinal plant research is twice as many, comprising 14.85% of the total undergraduate researches, while biodiversity researches are four times as many with over 272 biodiversity surveys or 31.81% of the entire thesis archives. There were 194 studies on agriculture and fisheries. Other research areas are on parasitology, bacteriology, ecology, and genetics while many are interdisciplinary.

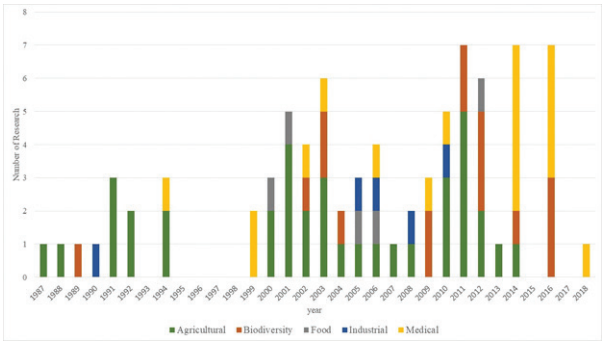

Figure 1. Number of mycological researches from 1987–2018 and the proportion of researches in each of the disciplines.

The first mycological research of the department was on the damping-off disease of *Brassica chinensis* Linn. caused by species of *Pythium*. This was completed in 1987 and is the only research on oomycetes in Bicol University to date. The research compared three methods to fertilize soils infected with *Pythium* species. The methods were not effective and, thus, were not recommended for use.

The peak years of mycology were 2011, 2014, and 2016 with seven mycological research works each but with different focus. In 2011, Agricultural Mycology was the most common because of both the early research mandate of the university and the expertise of the former professors of the department. In its early years, Bicol University's line of research was on agriculture and, therefore, most faculty members were experts in its various fields. In fact, up until 2001, the proportion of undergraduate researches focused on agriculture ranged from 50–100% per year. Plant pathology and post-harvest pathology were interestingly the closest to mycology while compost production relied greatly on fungi, particularly *T. harzianum*, as its activator. This has waned through the years and, since 2015, there has been no research along agricultural mycology. There was a shift towards medical mycology since then.

The rise in mycological research in 2014 and 2016 may be an offshoot of the offering of a specialty course in Mycology. For the first time, Mycology was offered as a separate undergraduate subject from Microbiology and, therefore, was discussed more thoroughly and no longer in passing. Most of the researches during this year was in medical mycology, also partly due to the opening of the College of Medicine of Bicol University. These potentially inclined students to research on plant natural products using fungi as test organisms.

Research Works by Discipline

Among the 76 research works, 43 are applied researches while 34 are basic researches. Agricultural Mycology was the most studied among the disciplines (Figure 2). Almost half of the mycological theses, 46.67%, were agricultural. This was followed by medical mycology and biodiversity studies with 24.00% and 21.33% of the researches, respectively. Only two researches fall under two disciplines because their objectives were both to assess biodiversity and to determine the bioactivities of the isolates (medical mycology).

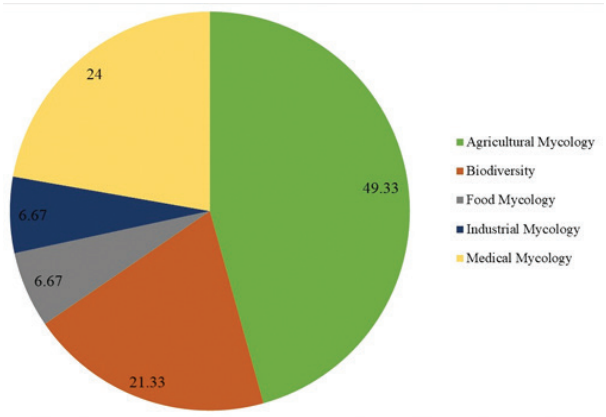

Figure 2. Percentage of researches per discipline.

Twelve research works under agricultural mycology were post-harvest studies dedicated to fungal pathogens in stored grains and agricultural products (Figure 3). Nine (9) were on plant pathology researches, elucidating plant

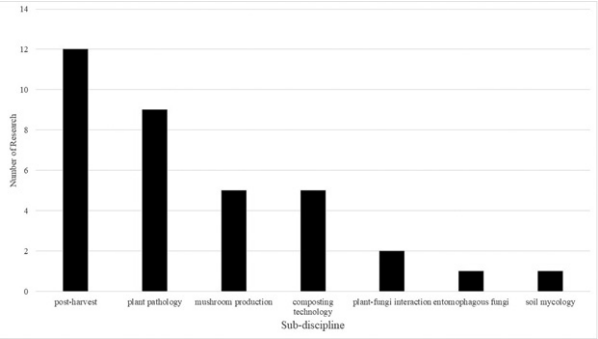

Figure 3. Researches along agricultural mycology.

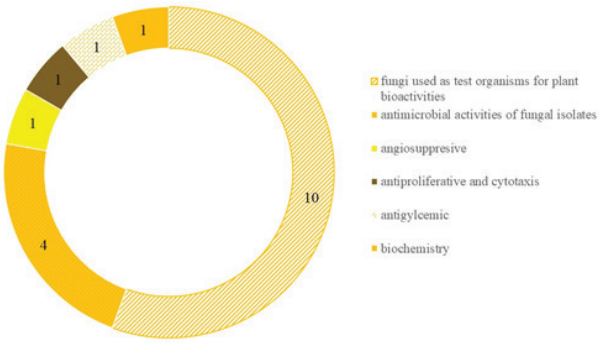

Figure 4. Researches along medical mycology.

pathogens of important regional crops such as abaca (*Musa textilis* Nee) and pili (*Canarium ovatum* L.). Ten (10) researches tried to utilize fungi in either production of edible mushrooms or of better compost products. Edible mushrooms included only three Basidiomycete species: *Volvariella volvacea* (Bul.) Singer (straw mushroom), *Pleurotus flabellatus* Sacc. (oyster mushroom), and *Agaricus bisporus* (J.E. Lange) Imbach (button mushroom). Researches on compost production, on the other hand, utilized either *T. harzianum* Rifai or screening of potential compost activators isolated from different soils. These soils were from a dumpsite, a rice paddy, and an area around Mayon Volcano Natural Park.

In terms of commodities, agricultural mycology researches were concerned about at least 15 crops. Abaca (*M. textilis*) and pili (*C. ovatum*) were top priority, as they are also the main products of the Bicol region in which the province of Albay is part of. One research is on sili (*Capsicum* sp.), another major crop of the province. Other crops include grains such as corn (*Zea mays* L.) and rice (*Oryza sativa* L.), cash crops such as coconut (*Cocos nucifera* L.) and banana (*Musa* sp.), and important vegetables and root crops: tomato (*Solanum lycopersicum* L.), cabbage (*Brassica oleracea* L.), and cassava (*Manihot esculenta* Crantz).

Most of the researches under medical mycology only used fungal species as test organisms for plant antifungal activities (Figure 4). Among the test organisms were the yeast *Candida albicans* (C.-P. Robin) Berkhout, dermatophytes, and the common opportunistic molds *Aspergillus flavus* Link and *Rhizopus nigricans* Vuillemin. Only eight researches made use of fungi as potential sources of bioactive compounds for the following activities: angiosuppresive, antiproliferative, cytotactic, and antiglycemic. Five of the eight studies investigated activities of fungal endophytes or associates of pili (*C. ovatum*), the seagrasses *Thalassia hemprichii* (Ehrenb.) Asch., *Enhalus acoroides* (L.f.) Royle, *Cymodocea serrulata* (R. Br.) Asch., and *Halodule uninervis* (Forssk.) Asch., mangrove species, and a jellyfish. The two others used macrofungi from Mount Malinao, Albay.

Fourteen (14) of the 16 biodiversity research works were conducted in the province of Albay while the two others were in the adjacent province of Sorsogon. Fourteen were terrestrial surveys while two were marine. A survey of lichens was among the most common research on biodiversity. These lichens were surveyed in the following ecological sites: Mt. Mayon Natural Park (Albay), Mt. Bulusan Natural Park (Sorsogon), Mt. Malinao (Albay), and along the Sagumayon River (Albay) – an important river system that traverses the city of Legazpi and the adjacent municipality of Daraga. Lichenology studies were mostly correlated with sulfur dioxide concentration of the atmosphere because all these sites are within volcanic areas. The rest of the researches were surveys of mushrooms (six research works). Studies on fungal endophytes were first done in *C. ovatum* in 2014 and a few others in seagrasses and mangroves in 2018. They were new at the department level but may be considered late addition to mycological research in general. These researches, nonetheless, opened new thematic areas for students to venture into.

Industrial and food mycology researches combined comprise only 13.34% of all mycological researches of the Department. Industrial mycology researches were mainly on the use of mushrooms on improving the quality of abaca and pulp fibers while food mycology researches were focused on the identification of fungal load of salted egg, dried fish, gulaman, and puto de Oas – a native rice cake in the province.

DISCUSSION

Responsiveness and Gaps of Mycological Researches to Regional and National Needs

Researches were somehow responsive to the needs of the region. Abaca and pili, the two major crops of the

region, were the most studied mycologically. Mushroom production and compost production were long been encouraged by the Philippine Department of Agriculture. The use of *Trichoderma harzianum* in the production of compost has many researchable topics such as the biocontrol of diseases (Singh *et al.* 2007; Gava and Pinto 2016) and fortification of composts (Siddiqui *et al.* 2008). In terms of drug discovery, fungi were used as test organisms and are, therefore, accessory to finding plants with potential medicinal values. All of these were undertaken by the Department in terms of undergraduate research. However, there is no data to support that these researches actually contributed to regional needs because none of these were published or utilized. The responsiveness of the research, therefore, was not translated to any utilizable contribution to the region.

Responsiveness was translated to important policy contributions, however, on biodiversity conservation. Important ecological sites such as Mayon Volcano Natural Park and Bulusan Natural Park, both of which are protected areas, were surveyed for both macrofungi and soil microfungi. Research on lichens within the Mayon Volcano Natural Park formed part of the document submitted by the Provincial Government of Albay to UNESCO in its bid to become a Biosphere Reserve in 2016. Mt. Mayon is an important protected site for biodiversity conservation (Bagarinao 1999) and has already been surveyed for its botanical diversity (Buot 2009). Currently, undergraduate researches by the biology department are the only record of fungal diversity within these protected areas. Currently, the Sagumayon River Management Council is collating researches conducted along the Sagumayon river and at one fungal research is included in the list.

Along agricultural mycology, the sili (*Capsicum* sp.) remained understudied even at a plant pathology level. Similarly, no studies were done on the fungal pathogens of important crops such as taro or gabi (*Colocassia esculenta* (L.) Schott), an economically valuable plant used to make the famous pinangat and laing in the town of Camalig in the province of Albay. Taro (*C. esculenta*) is an important commodity in the Bicol region, with the province of Albay as one of the centers of its utilization. Culinary demand is high in this part of the country, and most of the taro is produced in wet or lowland culture. Taro leaves is a staple diet in the form of pinangat and laing, while the corm is served as extenders to traditional viands or processed into chips and flour for pastries. Many small to medium scale enterprises rely on taro for income and in the provision of daily sustenance. The tropical climate, being warm and wet, is conducive for taro to be grown throughout the year making it available for the pathogen to colonize. *Phytophthora colocasiae* Racib., the causative agent of the taro leaf blight, spreads from field to field and over long distances with diseased planting material (Nath *et al.* 2013).

Further, fungal diversity is an area that needs sustained research interest. Fungal diversity is estimated to be 1.5–3 M species (Hawksworth 2012). Of this, global macrofungal diversity is estimated to be within 50,000–110,000 species (Mueller *et al.* 2007). An ethnomycological aspect may be incorporated as a value-adding component. Fungi are known for many direct benefits to man including medicine (Badalyan 2003) and food (Chang and Lee 2004).

Conservation of historical sites, especially of churches, is a researchable area. Fungi are the main cause of deterioration of cultural heritage (Sterflinger 2010), including murals and paintings (Unković *et al.* 2016), and books and parchments (Sterflinger and Pinzari 2012). In many countries like Chile, fungi are among the chief cause of wood deterioration in heritage sites (Ortiz *et al.* 2014). At least one church in each of the 16 municipalities and cities of the province of Albay has a part or artifacts made of wood. These may be prone to degradation by wood-rotting fungi. Identification of wood-rotting fungi and developing a technology that will help maintain wood integrity may be vital themes to explore.

The presence of mining sites in the Bicol region may open interest along mycoremediation. At least two mining corporations are in the process of decommissioning (Gonzales 2018). Heavy metal contamination of both soil and water can be of interest, especially among students and faculty willing to collaborate with chemistry and environmental science researchers. Fungi may be isolated from contaminated soils. The use of soil fungi, especially when in consortia, can be advantageous for higher metal scavenging and more stability against environmental fluctuations (Mishra and Malik 2014) and can rely on the different mechanisms by which fungi detoxify metal contaminants (Pan *et al.* 2010).

As there are many plant hosts that remain unstudied for fungal endophytes, there is still a diverse niche to fill in fungal endophytism research. Medical mycology may come up with researches on endophytism because fungi mirror their hosts' biochemical activities. Microfungal secondary metabolites present a wide range of possibilities. They have already proven their vast contribution to health and agriculture such as penicillin, cyclosporine A, and many more (Gamboa-Angulo *et al.* 2012). The challenge is to find ways to recreate the interaction, preferably in an *in planta* setup, so that the production of important bioactive compounds is not hampered (Kusari *et al.* 2012). In conjunction with this is the continued search for unique biotopes, utilizing both creativity and logical reasoning, in the process of bioprospecting. These could be mangroves,

seaweeds and seagrass beds, marine organisms, as well among medicinal plants (Tejesvi *et al.* 2007).

While plant pathology was present in the early years of the department, they were not highly focused on a particular disease. A future direction can be to specialize in diseases of important plants of the region, not mainly on what these fungal pathogens are but their control, transport, and management. This will incorporate plant disease epidemiology, as well as statistics necessary, to perform analysis. As a global phenomenon, it may also be interesting to shift researches into the effects of climate change or its drivers to fungal diversity and plant fungal disease epidemiology. Mascariñas and colleagues (2013) have made efforts to mainstream disaster risk reduction into agriculture but have not included the effects of extreme weather conditions on the epidemiology of diseases.

The soil, partially a missed opportunity during the 33 years, maybe a source of many mycological research works. The volcanic soil of the province may hold the potential for isolation of new species. The soil houses both pathogens and beneficial fungi. Soil amendments also affect soil mycoflora in various ways. Their diversity, physiology, and genetics may be altered by biochemicals incorporated into the soil matrix (Navarro *et al.* 2008). This is important because volcanic soils may harbor new species due to the unique characteristics of the soil. An archaean was already isolated from the surrounding soils of Mayon Volcano (Yim *et al.* 2015) and fungi with unique characteristics may follow.

On biodiversity, other groups of fungi were not studied by the department. Myxomycetes and chytrids remain an unstudied area. There are published researches on myxomycetes in the Bicol region, including the works of Dagamac and colleagues (2010, 2017), which may be used by students and faculty as a springboard to exploration. New niches such as marine ecosystems may also be explored. Currently, there are several islands in the region that are left unexplored in terms of biodiversity. Also, the identification of fungi should already incorporate internal transcribed spacer sequencing as a basic method in all undergraduate mycological researches. This, however, should always be polyphased with the traditional way of using morpho-cultural characterization so that this skill will not be lost (Silva *et al.* 2011). It should also be required for isolates to be deposited in reputable mycological herbaria so that new thesis students may go back to them rather than isolating new ones.

Challenges of the Next Decade of Mycological Research

At least three things are needed to sustain this shift in the next decade and may be applicable to all universities in the Philippines. One, there is a need to increase the exposure of students to mycological researches. This may include attendance to lectures, conferences, and symposia that tackle different aspects of fungal biology. Guest lecturers may be invited to discuss research trends in mycology and how it is shaping modern medicine, industry, and agriculture. Collaborative advising may complement the faculty expertise needed to guide students in mycological researches. Faculty expertise is a crucial component of undergraduate research (Lopatto 2003). Leading universities in the Philippines have fungal research labs such as the Mycology Research laboratory of the University of Santo Tomas in Manila and the University of the Philippines in Los Baños. In the process of collaborative work at the undergraduate level, young mycologists may join the roster of people working with fungi in the country.

The second challenge is to build infrastructures and policies to support actual mycological researches. As of this writing, mycology shares a laboratory with bacteriology within Bicol University, a reality that most HEIs may be experiencing. A separate and dedicated laboratory is needed to provide focus. Laboratory space and the accompanying equipment are necessary to foster a thriving mycological research environment. Faculty researches on fungi may also involve students so that inclination towards the subject matter is heightened and provide students with resources necessary to carry out their own undergraduate theses. The master's program of the Department may open collaborative work between undergraduate and graduate students.

Policy support includes the requirement for deposits of fungal isolates in a museum, preferably at the University of the Philippines Los Baños Museum of Natural History or the University of Santo Tomas Mycological Culture Collection. Along this line, the department may ink a memorandum of agreement to ensure seamless transfer and storage of cultures between institutions. In the long run, Bicol University may put up its own mycological herbaria to cater to the growing needs of student and faculty research. The role of mycological herbaria is vital, especially in archiving environmental samples, as it becomes a repository of unidentified species or those that require confirmation and further studies (Brock *et al.* 2009).

Likewise, the incorporation of mycological researches into the biorisk management system of the university will ensure that there are existing protocols to ensure the safety of the faculty and students and security of cultures and data within the university complex. Many fungi produce spores that may be inhaled by laboratory workers, putting them at risk of opportunistic infections. A biosafety protocol in handling mycological specimens,

especially from environmental samples, ensures the safety of the workers and the community in general (Padhye *et al.* 1998). Bicol University has already conducted a biorisk assessment of the natural science laboratories (Guerrero and Serrano 2018) but the focus was on bacterial assets.

Third, there is a need to increase the publication of undergraduate research. While this article only tackles the subject of the research, many undergraduate theses may be of high value. Thorough editing by the student author and adviser may qualify a number for publication, especially those within the last five years. Publication completes the research cycle and ensures that the work contributes to existing knowledge, no matter how small. In the long run, it stimulates new questions that become scaffolding for new research topics. While they have not undergone the rigors of peer review, as the main critique of using these unpublished materials as sources of valuable data, they have nonetheless undergone screening by experts or other qualified academic reviewers who checked the veracity of the scholarly work. Much caution, however, is needed to utilize them as valid sources of data because of issues such as plagiarism, depth and breadth of work, and the methodological and statistical analyses to arrive at the conclusions stated in the paper.

CONCLUSION

From 1985–2019, only 76 mycological research works were conducted in the Department of Biology. While mycology offers many opportunities for research and development, mycological researches are limited in the university, a fact that may be true to most HEIs in the country. This article highlights the need for undergraduate researches in mycology to be fully utilized as an input to crafting new research directions. It is, therefore, recommended that strategies be developed to engage the young generations into mycological researches, provide ample infrastructure and policy support, and increase publication of research findings.

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CONFLICT OF INTEREST

The author declares no conflict of interest in publishing this research article.

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