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Mycovores and entomo-associates of commercially cultivated *Pleurotus florida*

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Abstract

Mycovory is feeding on mycelia, fruiting bodies, or even spores of fungi particularly mushrooms. This paper reported the mycovorous insects and entomo-associates in the different developmental stages of fruiting bodies of commercially cultivated mushroom *Pleurotus florida*. A total of 675 specimens were collected and they were classified under 7 Orders and 15 Families. Majority of the collected insects were under Collembola (542), in which 412 of these insects belong to Poduroidea and the remaining 130 belongs to Entomobryidae. This was followed by Coleoptera (61) dominated by Staphylinidae (60), and Diptera (42) dominated by Ceratopogonidae (25) and Sciaridae (12). Collembola was found in all development stages (except Stage 2 - primordial initiation), but the highest number of this group was noted in Stage 3 - pinhead formation. However, most of the insect orders were collected in complete mycelial ramification (Stage 1), pinhead formation (Stage 3), and maturation (Stage 5) stages of the mushroom.

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Introduction

Mushroom production is profitable and is considered as an important industry in the Philippines. The cultivation of mushroom by either small or large scale growers is based on the developed production technologies using various agro-industrial materials and cellulosic residues (Dulay *et al.*, 2012a; Dulay *et al.*, 2012b; Magday *et al.*, 2014; Dulay *et al.*, 2014). One of the most widely cultivated mushrooms is *Pleurotus* species. This mushroom group is commonly called as oyster mushroom due to white shell-like appearance of the fruiting body. They can be found growing naturally on dead and decaying wooden logs (Ahmad *et al.*, 2011) and in artificial cultivation (Khan *et al.*, 2012; Chukwurah *et al.*, 2012). *Pleurotus* species are efficient degraders of complex organic compounds present in agro-industrial waste materials due to their extensive enzyme systems and have broad adaptability to wide range of climatic conditions (Khan *et al.*, 2012).

In Central Luzon, Philippines, exotic strains of *Pleurotus* such as *P. florida, P. sajor-caju,* and *P. ostreatus* are introduced and are now being cultivated in fruiting bags containing substrate formulation of rice straw, sawdust and rice bran. Among the three species, *P. florida* is the most widely and commercially cultivated in simple, low cost, and practical production technology. However, production of fruiting bodies of *P. florida* is a challenging task because of the different important factors to be considered. Aside from the formulation of lignocellulosic residues as substrate for the production, cultivation of this mushroom also requires environmental conditions (aeration, illumination, moisture, humidity, and temperature) and cultural management. As a crop, it is also normally infected by diseases and attacked by insect pests causing the poor quality of fruiting bodies and very low yield. Mycovores are those organisms that feed on mycelia, fruiting bodies, or even spores of fungi particularly mushrooms.

Therefore, this present work investigated the different insects associated with the commercially cultivated mushroom *P. florida*. Insects were collected in five different stages of mushroom growth from mycelial ramification to fully grown fruiting bodies. They were classified and identified using morphological approach.

Materials and method

Mushroom Cultivation

The preparation of fruiting bags and the growing of fruiting bodies of *P. florida* were done in one of the mushroom farms located in San Jose, Nueva Ecija, Philippines. The grain spawns were inoculated into the fruiting bags containing 7 parts of rice straw and 3 parts of sawdust (by volume) pasteurized for 4 hours. Inoculated bags were incubated at 30°C until the full ramification of mycelia. After incubation for 25 days, fruiting bags were opened and watered 2-3 times a day to allow the emergence of fruiting bodies.

Collection and Identification of Insects

Insects were collected from the five stages of fruiting body development of *P. florida* namely; complete mycelial ramification (Stage 1), primordial initiation (Stage 2), pinhead formation (Stage 3), pileus expansion and stipe elongation (Stage 4), and maturation (Stage 5) as shown in Figure 1. Traps were made up of container with 70% ethanol placed under the fruiting bodies for 24 hours. Insects were collected in the morning and placed into the vials containing ethanol. The collected insects were brought in the laboratory and were microscopically examined for taxonomic classification and identification. They were classified and identified according to their order based on the taxonomic key of insect identification (Janssens, 2006; Yossi, 1959).

Results and discussion

A total of 675 specimens were collected from the five stages of fruiting body development of mushroom and they were classified under 7 Orders and 15 Families. The distribution of the collected insects under Order taxa is presented in Figure 2. Apparently, regardless of mushroom developmental stages, majority of the collected insects were under Collembola (542), in which 412 of these insects belong to Poduroidea and the remaining 130 belongs to Entomobryidae. This was followed by Coleoptera (61) dominated by Staphylinidae (60), and Diptera (42) dominated by Ceratopogonidae (25) and Sciaridae (12).

The occurrence and population of insects in different stages of fruiting body development of *P. florida* were monitored and the results are shown in Figure 3. Apparently, Collembola was observed in all development stages except Stage 2, but the highest number of this group was noted in Stage 3.

However, most of the insect orders were collected in Stage 1, 3, and 5 of mushroom.

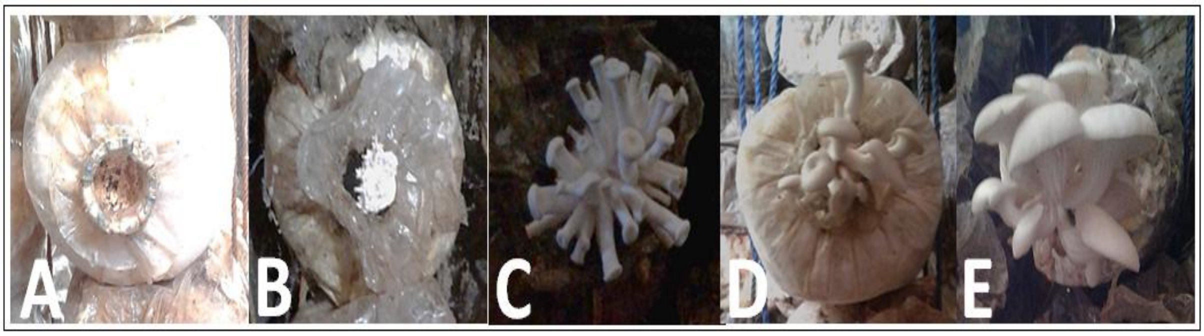

Fig. 1. Fruiting body development of *P. florida* (A) complete mycelial ramification, (B) primordial initiation, (C) pinhead formation, (D) pileus expansion and stipe elongation, and (E) maturation.

These results clearly indicate that *P. florida* mushroom is a natural habitat of various types of insects. This could be attributed to the benefits of mushrooms as food source, which contain carbohydrates, proteins, fibers, minerals and vitamins necessary for the growth and development of insects.

Mycovores are those organisms that feed on mycelia, fruiting bodies, or even spores of fungi particularly mushrooms. However, the most representative taxa among these are Diptera, Coleoptera, and Collembola. According to Valer *et al.* (2016), Schigel (2012b), and Parimuchova *et al.,* (2018), these taxa primarily used fruiting bodies for feeding and development.

Mycovory of Diptera is mostly associated with their detritivorous feeding mechanism (Valer *et al.,* 2016).

Mycovorous species are widely distributed within these taxa that include Family Drosophilidae, Sciaroidea, Bolitophilidae, Diadocidiidae, Ditomyiidae, Keroplatidae, and Mycetophilidae (Valer *et al.,* 2016; Jakovlev, 2012).

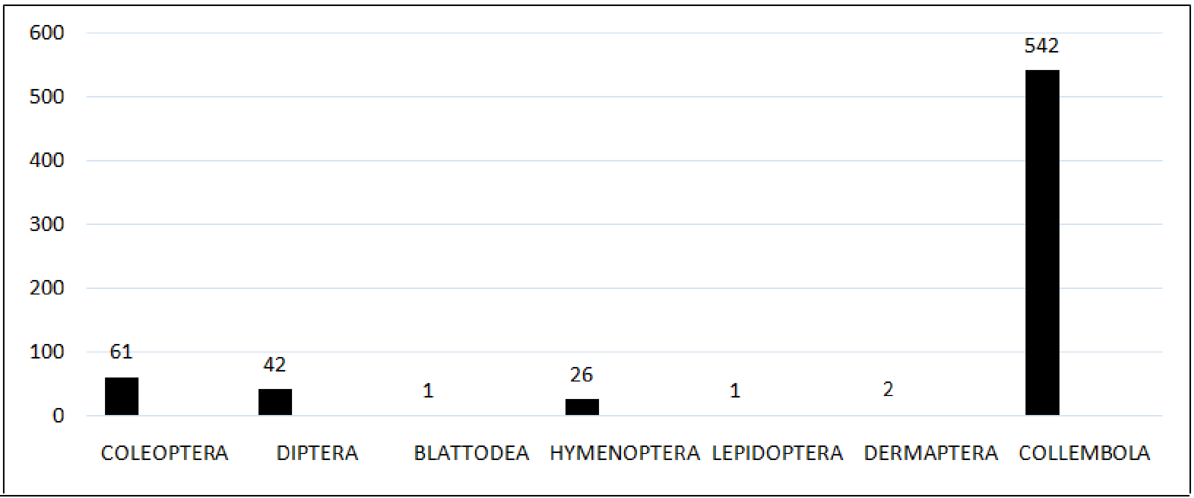

Fig. 2. Distribution of collected insects in seven Order taxa.

Most of the mycovorous Diptera thrive primarily in moist or decaying fruiting bodies or with mycelia in decaying wood or soil litters (Jakovlev, 2012; Komonen, 2003). They mostly colonize Agaricales mushrooms and boletes (Valer *et al.,* 2016; Jakovlev, 2012). Moreover, in the study of Komonen (2003), there are some Diptera species (like *Cis glabratus* and *C. quadridens*) colonizing polypores.

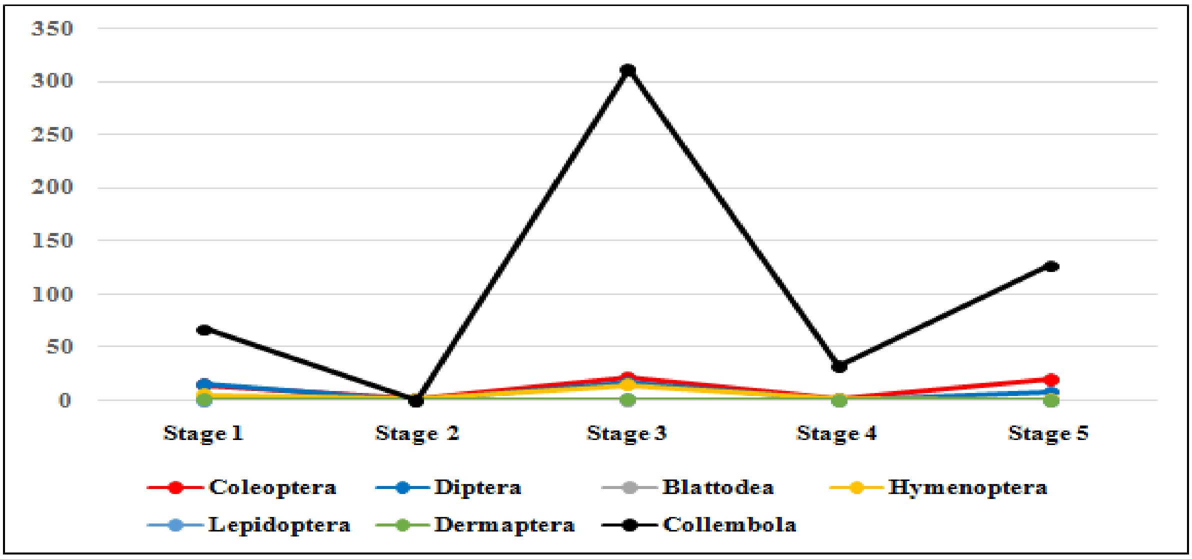

Fig. 3. Occurrence and population of insects in different stages of fruiting body development of *P. florida*.

On the other hand, mycovory in Coleoptera is an ancestral type of feeding (Schigel, 2012a). This is found in Ptiliidae species, as well as in Leiodidae species. The latter's adult form are spore-feeders, while their larvae feed on myxomycetes.

This change in food source is also observable in other spore-feeders like Sphindidae, Nitidulidae, and Latridiidae species. Most Coleoptera species are saproxylic and feed on decaying fungi (Schigel, 2012b). Some of these saproxylic beetles include Silphidae, Hydrophilidae, Scarabaeidae, and Staphylinidae (Schigel, 2012a). Only minority of the Staphylinidae species are mycovorous including subtribe Gyrophaenina, tribe Homalotini, and subfamily Aleocharinae (Frank & Stansly, 2004).

Nevertheless, Collembola are abundant in soil litter (Scheu and Brose, 2010). They promote mycelial growth enhancing fungal dispersal. But since these are soil organisms responsible for decomposing organic matter and nutrient mineralization, feeding might eliminate certain fungal species from the community. In other words, Collembola play a crucial role in regulation of fungal populations affecting their dispersions.

According to Meneses *et al.,* (2004), Collembola species associated with fungal fruiting bodies are Hypogastruridae primarily because of the presence of molar plates. Collembola can only feed on fungal hyphae with the presence of this mouth part.

Among these Hypogastruridae, species of Odentellidae and Isotomidae are associated with fruiting bodies. In the study in Australia, however, the native Brachistomellidae are found dominant in fungal fruiting bodies instead of the hypogastrurids (Meneses *et al.,* 2004).

Conclusion

It can be concluded that the different phases of fruiting body development of commercially cultivated *P. florida* serve as natural habitat and food source of many mycovorous insects. Among the insects attracted to this mushroom, the most species-rich taxa are Collembola, Coleoptera and Diptera. Stage 3 - pinhead formation of mushroom recorded the highest number of Collembola.

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