

GROWING *Pleurotus ostreatus* (ex. Fr) Kummer USING GAMMA RADIATION IN SOUTHERN GHANA AND ITS ASSOCIATED PESTS

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ABSTRACT

Pests have been implicated in causing severe damage to food crops including mushrooms, thereby increasing the incidence of postharvest loss. This study investigated the various pests involved in the cultivation of gamma radiation aided cultivated *Pleurotus ostreatus*. Pests were isolated and identified by the procedure described by the Entomological Society of Canada. Cultivation of *Pleurotus ostreatus* was achieved by pre-treating composted sawdust substrates and spawn preparation with a gamma radiation dose of 15 kGy from a Cobalt 60 source (SLL 515, Hungary) at a dose rate of 1.7 kGyh⁻¹ in air. A total of five pests were recorded while cropping, namely; *Drosophila melanogaster* (Fruit fly), *Blatta germanica* (cockroach), *Archachatina marginata* (giant snail), and *Doratogonus meridionalis* (millipede) and *Cryptophlebia leucotreta* (False codling moth). The predominant pest was *Drosophila melanogaster* (Fruit fly) (97%). Results recorded over four flush periods were 378g, 0.63, and 63% for Total yield, biological yield, Biological Efficiency (%), respectively. The average stipe length and pileus diameter were recorded and showed no statistical differences ($p>0.05$) observed in the different weeks. Other growth parameters (mushroom size, total number of primordia, total number of fruitbodies etc.) recorded showed some significant differences ($p<0.05$). Pests identified contributed to yield reduction and product quality.

Keywords: Pests, insects, oyster mushrooms, *Pleurotus ostreatus*, gamma radiation.

Introduction

For almost 300 or more years, mushroom cultivation has been trendy (Singh & Sharma, 2016). Nevertheless, commercial cultivation in Ghana started only recently and so has contributed to its high demand and fame. It is currently a growing industry and evolving into a serious agribusiness which is largely export-oriented (Kortei *et al.*, 2018a). Mushroom is a good reservoir of protein, vitamins, minerals, folic acid and is a good source of iron for

anaemic patients (Kim *et al.*, 2015; Tolera & Abera, 2017; Kortei *et al.*, 2017b; Kortei *et al.*, 2017c). Additionally, mushrooms digest easily and have very low to no cholesterol content (Oei, 2016).

The main focus of interest of mushrooms as food value is their high protein content. Mushroom offers greater potential in producing more protein per unit area of land, which is not possible with any other form of agriculture and technology available at present

(UNDP, 2022). The FAO has recognized the rich food value of mushrooms contributing to the protein nutrition of the country depending on cereals and other staples.

Different biodegradable substrates which entangle with innumerable mushroom threads (collectively referred to as mycelia) together with the spent substrate left after harvesting the mushrooms, can also be used as animal feed (more palatable), bio-fertilizer (Wiafe-Kwagyan, 2014; Wiafe-Kwagyan & Odamtten, 2018) for soil fertility enrichment and biogas production (Beetz & Greer, 2004).

Cultivation can be done at the cottage and small-scale levels besides large-scale farming. Mushroom cultivation is one of the fastest growing and most technologically erudite horticultural industries in the world. Several pieces of research to improve upon mushroom (*Pleurotus ostreatus*) yield have been conducted on different lignocellulosic with the use of numerous substrate pre-treatment methods such as chemicals, hot water at different temperatures, etc. have been reported (Oseni *et al.*, 2012). Some researchers (Gbedemah *et al.*, 1998; Kortei & Wiafe-Kwagyan, 2014; Kortei *et al.*, 2017a; Kortei, 2015; Kortei *et al.*, 2018b) have reported successful mushroom cultivation on gamma radiation pre-treated substrates which promise to be potential in this field since it can sterilize more compost bags per unit time, it is less laborious and makes the process more interesting (Kortei *et al.*, 2018a).

Several factors interact to affect mushroom survival and multiplication (Kim *et al.*, 2011; Bellettini *et al.*, 2019). At the initial phase of the development of this industry, there were no major attendant pest problems. However, a wider expansion of the production of mushrooms during the recent past has led to the development of new problems. One of the main constraints in the commercialization

of mushroom production is the damage caused by insect pests (Gnanesan & Wijayagunasekara, 1999; Johal & Disney, 1994). Globally, mushroom cultivations were adversely affected by other biotic stresses such as bacteria, fungi, insects, nematodes, and some other pests leading to complete closure of some farms.

Fletcher & Gaze (2007) and Shamshad (2010) emphasized that mushrooms are affected by all kinds of insect pests and diseases in several ways such as keeping the spawn from colonizing the substrate, by colonizing the substrate faster than the mycelium of the spawned mushroom, destroying the mycelium of the spawned mushroom and by destroying the mushroom itself. Some factors such as unsuitable substrates, poor strain, microbial contamination of the substrates, and unsuitable climatic conditions can adversely affect the yield of the mushrooms (Kortei *et al.*, 2015; Bellettini *et al.*, 2018). Fletcher & Gaze (2007), implicated some organisms as pests and diseases in mushroom cultivation including insects, termites, mites, nematodes, snails and rodents, parasitic fungi, saprophytic fungi, bacteria, and viruses. According to the published findings of Australian Mushroom Growers Association (AMGA, 2010), a range of mite species may also affect the mushroom crop. Some directly damage the fruiting bodies, some may attack the mycelium, and some mites are predatory with other mites, fly eggs, nematodes, or bacteria. Mite damage to the fruiting bodies often shows up as small cavities in the stem and cap similar in appearance to bacterial pit disease. Oei (2016) further suggests the best way to fight these organisms is to prevent them.

Given this, there are no reports on the systematic study of these pests up to date in Ghana. Therefore, this study was conducted to investigate the pest spectrum of oyster

mushrooms cultivated with gamma radiation to ascertain the occurrence and abundance of these pests on cultivated mushrooms.

Experimental

This research was conducted at the Mycology unit (CSIR- Food Research Institute) and Radiation Entomology and Pest Management Centre of the Biotechnology and Nuclear Agricultural Research Institute (Ghana Atomic Energy Commission) respectively in Accra, Ghana from November 2016 to February 2017.

Pure culture

Pure tissue cultures of *Pleurotus ostreatus* (Jac.Ex.Fr.) Kummer strain EM-1 (One-week-old) were obtained from the National Mycelium Bank at the CSIR- Food Research Institute in Ghana. Aseptic inoculation of bottles was done with 1cm² of the one-week-old tissue culture of the experimental strain grown on Malt Extract Agar (OXOID™ Ltd., Basingstoke Hampshire, England) using a flamed and cooled scalpel in a laminar flow hood. Thereafter, incubation of the spawns was done for 16-21 days without illumination in an incubator (Tuttlington™ WTC Binder, Germany) set at 28°C.

Spawn preparation

Modified methods outlined by Narh *et al.* (2011) and Kortei *et al.* (2015) were used to prepare the spawns. The cereal grains used were sorghum obtained from the Madina Market in Accra, Ghana. The grains were separately washed and steeped overnight in water. They were then thoroughly washed separately with tap water to ensure that all debris as well as dust were removed, drained, and tied to a wire mesh.

Thereafter, they were air-dried to cool on a wooden frame with a wire mesh. To each grain, 3 percent (w/w) of calcium carbonate (CaCO₃) was added and thoroughly mixed

manually. They were then packaged into heat resistant polythene bags of dimensions of 24 x 38 cm².

Substrate preparation and spawning

Sawdust substrates were prepared as described by Kortei *et al.* (2014) with modifications. Thorough mixing was done for each sample by mixing 11.5 parts of rice bran and 0.5 part of calcium oxide. Each substrate attained an average moisture content of 30% (w/w) (88 parts). Water was sprinkled on the mixture until its moisture content was about 70% (w/w). The mixture was piled up into a pyramidal heap and allowed to ferment for 14 days. It was turned every four days to ensure proper aeration and homogeneity. Aliquots of composted substrates (1 kg) were bagged into 33 x 18 cm² heat-resistant, 0.1 /m polypropylene bags (Auetrugal, 1984). Sawdust substrate was prepared by composting for 28 days and bagged as described above.

Determination of moisture content

The moisture content of the sawdust substrates was determined according to the method described by AOAC (1995) as follows;

$$= \frac{W2-W3}{W2-W1} \times 100$$

Where; W1 is the weight of empty Petri dish
W2 is the weight of sample + petri dish before drying

W3 is the weight of sample + petri dish drying

Gamma irradiation of spawn and compost bags

Sorghum grains were soaked overnight and about 265g of grains were packed into bottles and then transferred into transparent heat-resistant polypropylene bags (24cm x 38

cm) and then plugged with cotton wool and covered with plain sheets. The sheets were held in place with rubber bands. Irradiation was done using a dose of 15 kGy at a dose rate of 1.7 kGy per hour in air from a Cobalt-60 source (SLL 515, Hungary). This selected dose was the most appropriate dose from earlier experiments by Kortei (2015) and Kortei & Wiafe-Kwagyan (2014) for cultivation of mushrooms on sawdust as well as other lingo-cellulosic substrates. Absorbed doses were confirmed using the ethanol-chlorobenzene (ECB) dosimetry system at the Radiation Technology Centre of the Ghana Atomic Energy Commission, Accra, Ghana. Each treatment was replicated four (4) times. One kilogram (1kg) of sawdust (*Triplochiton scleroxylon*) substrate type was packed into 33 x 18cm heat resistant polypropylene bags and irradiation was done as described above.

Inoculation and incubation

Five grams (5g) sorghum spawn was used to inoculate the compost bags. The procedure was carried out in a well-ventilated, semi-dark room, where each bag was closed with a plastic neck and. The bags were then incubated at 26–28°C and 60–65% RH for 20–35 days. The mean radial growth per week and the spawn run period to total colonization (i.e., the number of days from inoculation to complete colonization of the compost bag by the mycelium) were recorded by using a string and a centimetre rule according to the method prescribed by Musanze, (2013).

Fructifications and harvesting

Primordia (young developing mushrooms) were allowed to develop to mature fruiting bodies and harvested. Mushrooms were harvested by holding and twisting the base of the stalk and pulling them by hand from the substrate, then were taken away and weighed

the same day. The oyster mushrooms were harvested when the in rolled margins of the basidiospores began to flatten (Tisdale *et al.*, 2006). Humidity was kept as high as possible 80-85% by spray watering twice daily with a water hose connected to a tap.

Stipe lengths were measured by taking readings of the length of the cap base to end of the stalk.

$$\text{Average cap diameter} = \frac{\text{longest} + \text{shortest cap diameter}}{2}$$

Dates of each harvest were noted.

The total number of flushes (flush number) produced per each bag was noted at the end of the six weeks. The distribution of yield per flush was tabulated to observe changes in yield throughout multiple flushes. Seven aspects of crop yield were evaluated according to some researchers (Tisdale *et al.*, 2006, Amin *et al.*, 2008, Kortei & Wiafe-Kwagyan, 2014, Morais *et al.*, 2000) as follows:

- (i) Mushroom size (MS)
- (ii) Biological efficiency (BE)

$$= \frac{\text{Weight of fresh mushrooms harvested (g)}}{\text{Dry substrate weight (g)}} \times 100$$
- (iii) flush number
- (iv) Flush period (sum of incubation and fruiting periods)
- (v) Fresh weight.
- (vi) Biological yield (BY)

$$= \frac{\text{Weight of fresh mushrooms harvested (g)}}{\text{dry substrate weight}}$$

*was expressed as kg fresh mushrooms/ kg dry substrate weight.
- (vii) Economical or mushroom yield values were calculated as previously reported by (Morais *et al.*, 2000) as:

Economic Yield

$$= \frac{\text{weight of fresh mushrooms harvested (g)}}{\text{Fresh substrate weight.}}$$
- (viii) The average MS was calculated as the total fresh weight of mushrooms

harvested divided by their total number of mushrooms.

BY= [Weight of fresh mushrooms harvested (g) per dry substrate weight] and was expressed as g fresh mushrooms/kg dry substrate weight (Amin *et al.*, 2008).

The average weight of individual mushrooms was determined as a quotient of the total fresh weight mushrooms harvested by their total numbers (Philippoussis *et al.*, 2001).

Economical Yield (g/kg wet sawdust) = Total fresh weight of mushrooms.

N. B. - Dry weight of substrate- 600g

Wet weight of substrate- 1000 g = 1 kg.

A Digital Computing Scale (Hana Electronics Company Limited, Korea) was used to take all weight measurements and the unit of measurement was in grams (g).

The cropping house was monitored by making daily visits throughout one and a half months. An appropriate sampling procedure was developed using the guidelines suggested by the Entomology Society of Canada (1994) and was used during the study. Water filled pit traps (plastic Petri dishes) were used to obtain a relative estimate of the adult fly population. These traps were changed at each visit. A plate smeared with a layer of coconut oil as a sticky trap was used to take samples of flies and small beetles. A sample of compost and fruiting bodies were collected at monthly intervals from the farmers. The insects and their post-embryonic stages present were separated using the Berlese funnel method. Marketed samples of fruiting bodies were also purchased and brought to the laboratory for the detection of any insects present in such samples.

Statistical analysis

Data on pest occurrence were analysed using Excel for Microsoft Windows 10. Growth (number of primordia, total fruitbodies, av. Stipe length, av. Cap diameter, mushroom size, and the interval between flushes) and yield (mushroom size, mushroom yield, and biological efficiency) parameters of *Pleurotus ostreatus*, cultivated on pre-treated gamma radiation substrates were replicated 5 times and subjected to analyses of variance (one-way ANOVA) when significant differences were determined post-hoc test was made using Duncan's multiple range test i.e. DMRT (Gomez & Gomez, 1984) with SPSS 16 (Chicago, USA).

Results

Table 1 summarizes all types of pests identified, habitats, and their associated damage caused to the mushroom crops. The giant snail (*Archachatina marginata*) was observed to be hydrophilic creatures whom upon discovery of water, heightened their activities. The fruit fly (*Drosophila melanogaster*) was identified as the most prevalent insect pest.

Mushroom cultivators have recognized that the presence of crustaceans, mites, insects, and other mycetophagous arthropods and synthetic or wood substrate decomposers as detrimental and therefore restrained proper development of the mushrooms (Table 1). Giant African snails belonging to the Mollusca, which were noticed as pests which had a penchant for moist environments were found feeding on the mycelia and primordia of the mushrooms.

TABLE 1
Pests identified on gamma radiation aided cultivated Pleurotus ostreatus

Scientific Name of Pest	Common Name	Order/Family	Habitat of larvae	Damage
<i>Drosophila melanogaster</i>	Fruit fly	Drosophilidae	Lays eggs in the gill pores underneath the pileus	Larvae are seen in groups and are likely to feed on organic decomposed matter and mycelial growth but rarely seen feeding on mushroom
<i>Cryptophlebia leucotreta</i>	False codling moth	Totricidae	In the corners of the cropping house	Destroys the stipe
<i>Archachatina marginata</i>	Giant African snail	Archachatina	Moist environments of the cropping house	Destroys both pileus and stipes Eats up the mycelia of the mushrooms
<i>Doratogonus meridionalis</i>	Millipede	Spirostreptidae	Thatch roofs and crevices of wood	Destroy both pileus and stipe
<i>Blatta germanica</i>	Cockroach	Blatellidae	Compost bags and crevices of wood in cropping house	Found on compost bags with new and old primordia Secondary importance causing little damage to the fruiting bodies but act as vector of other fungal diseases They are vectors of food borne diseases such as dysentery, cholera, etc.

Yield parameters

The results of the various yield and growth parameters have been represented in Table 2. For yield, a total of 4 flushes were recorded. Values ranged between 79-110g. The total

yield recorded was 378g. Biological yield and Biological Efficiency recorded were 0.63 g/g dry substrate and 63.0%, respectively. There was an observed decrease in yield with increasing flush numbers.

Growth parameters

The total number of primordia investigated ranged between 12-19. showed some significant differences ($p < 0.05$). The total number of primordia for the flushes ranged from 12 ± 3.09 - 19 ± 3.09 (Table 3). Values obtained were statistically not comparable ($p < 0.05$). The total number of fruitbodies for the flushes ranged between 10 ± 3.16 - 17 ± 3.16 (Table 3). Results of flush 1 was significantly ($p < 0.05$) greater

than all flushes, while flushes 3 and 4 were comparable ($p > 0.05$). The average stipe length and pileus diameter ranged 58 ± 0.95 - 60 ± 0.95 mm and 61 ± 1.89 - 65 ± 1.89 mm, respectively. Statistically, there were no significant ($p > 0.05$) differences observed. Mushroom size also ranged from 6.4 ± 1.16 - 9.1 ± 1.16 . Lastly, the average time between flushes was 11 days. The time intervals between the appearance of flush also significantly differed ($p < 0.05$).

TABLE 2

Yield parameters of gamma radiation aided P. ostreatus as affected by pests

Flush	Total Yield /Mushroom yield (g)	Biological Yield (g/g dry substrate)	Biological Efficiency (%)
1	110 ^{bc}	0.1833 ^{bc}	18.33
2	98 ^b	0.163 ^b	16.3
3	91 ^b	0.152 ^b	15.2
4	79 ^a	0.132 ^a	13.2

Means with same letters in a column are not significantly different ($P > 0.05$)

TABLE 3

Growth parameters of mushrooms (P. ostreatus) as affected by pests

Flush	Total no. of primordia	Total no. of fruitbodies	Av. Stipe length (mm)	Av. Pileus diameter (mm)	Mushroom size (mm ²)	Time between flushes (days)
1	19 ± 3.09 ^a	17 ± 3.16 ^a	59 ± 0.95 ^a	65 ± 1.89 ^a	6.4 ± 1.16 ^a	0 ± 0.00 ^a
2	15 ± 3.09 ^{ab}	14 ± 3.16 ^{ab}	60 ± 0.95 ^a	65 ± 1.89 ^a	7 ± 1.16 ^a	8 ± 1.1 ^b
3	12 ± 3.09 ^c	10 ± 3.16 ^c	58 ± 0.95 ^a	61 ± 1.89 ^a	9.1 ± 1.16 ^{ab}	11 ± 1.17 ^c
4	13 ± 3.09 ^{bc}	11 ± 3.16 ^c	58 ± 0.95 ^a	64 ± 1.89 ^a	7.2 ± 1.16 ^a	14 ± 1.18 ^d

Means with same letters in a column are not significantly different ($P > 0.05$)

The array percentage occurrence, number, as well as the influence of the various pests on the growth and yield of gamma radiation aided cultivated *P. ostreatus* over 6 weeks of cropping are shown in Figures 1-5.

At the initial stage of cropping (week 1), only one (1), *Archachatina marginata* (giant

snail) was observed and this represented 100% occurrence.

However, in week 2, pests such as *Cryptophlebia leucotreta* (False codling moth) (8%), *Doratomyza meridionalis* (millipede) (2.7%), *Archachatina marginata* (giant snail) (5.4%) and *Drosophila melanogaster* (Fruit

fly) (83.8%) were recorded. *Drosophila sp.* recorded the greatest number ($P < 0.05$).

In week 3, *Drosophila melanogaster* (Fruit fly) (95%), *Blatta germanica* (cockroach) (2.29%), *Archachatina marginata* (giant snail) (0.76%) and *Dorotogonus meridionalis* (millipede) (1.53%). There was an observed a significant increase in the number of *Drosophila melanogaster* ($P < 0.05$). There was, however, no significant difference in the number of the other pests ($P > 0.05$).

There was an observed decrease in the kinds as well as the number of pests in the cropping house in week 4. Only *Drosophila melanogaster* (Fruit fly) (97.5%) and *Archachatina marginata* (giant snail) (2.5%) were recorded.

A similar trend of pest type and population was recorded at week 5. At week 6, there was a general decrease in type of pests and number again as observed in week 4. *Drosophila melanogaster* (Fruit fly) (96.2%) and *Archachatina marginata* (giant snail) (2.86%) and *Cryptophlebia leucotreta* (False codling moth) (0.95%) were recorded. *Drosophila melanogaster* predominated.

At the end of the cropping period, there was an observed pest increase (*Drosophila melanogaster* (Fruit fly) (97%), *Blatta germanica* (cockroach) (0.46%), *Archachatina marginata* (giant snail) (0.91%) and *Dorotogonus meridionalis* (millipede) (0.46%) and *Cryptophlebia leucotreta* (False codling moth) (0.91%) while the quantity remained low except for *Drosophila melanogaster* which increased about a two-fold ($P < 0.05$).

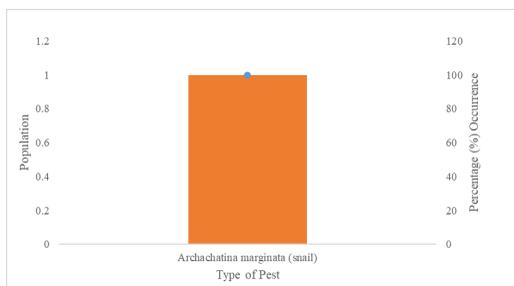


Fig. 1. Population and percentage occurrence of pests in the cropping house at end of week one

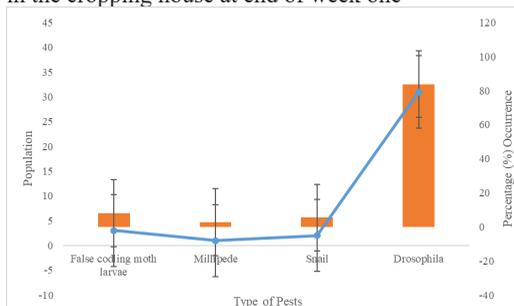


Fig. 2. Population and percentage occurrence of pests in the cropping house at end of week two

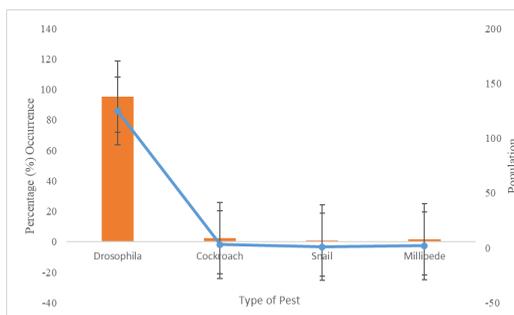


Fig. 3. Population and percentage occurrence of pests in the cropping house at end of week three

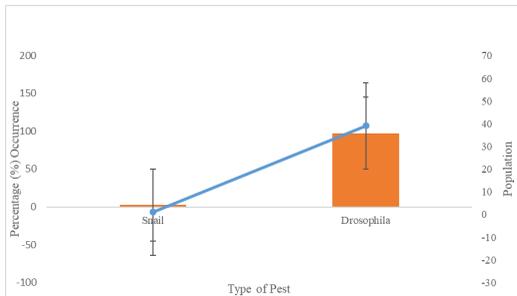


Fig. 4. Population and percentage occurrence of pests in the cropping house at week four

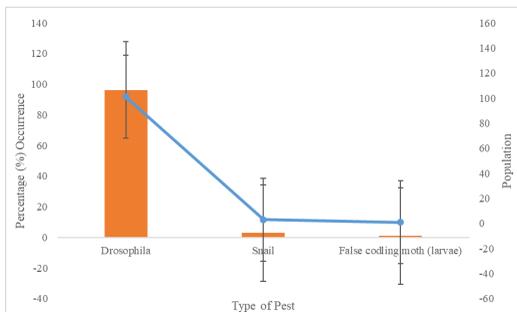


Fig. 5. Population and percentage occurrence of pests in the cropping house at week five

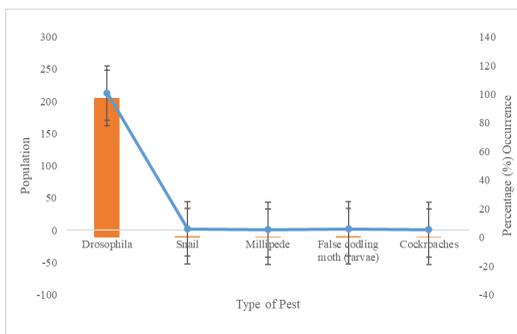


Fig. 6. Population and percentage occurrence of pests in the cropping house at week six

Discussion

Pests isolated

A perusal of the pertinent literature reveals not much information regarding pests of mushrooms and their substrates. Mushrooms are usually cultivated commercially in an enclosed controlled environment and its production is therefore largely dependent on the environment. A moist environment usually becomes conducive to support the activities of some pests. The unhygienic conditions of mushroom cultivation provide a congenial atmosphere for many pests and diseases. Biological cycles of these pests are not well known.

Several types of insect pests can attack mushrooms, but the major pests belong to three families of flies (Family: Trypetidae; Order: Diptera) (Bellitini *et al.*, 2019). Some mites, springtails, beetles, and moths also infest the crop. *Drosophila melanogaster* (Fruit fly) preponderated the entire pest in this study. Flies, especially in their immature stage (larvae) according to Bellettini *et al.* (2019) perforate the stipe and pileus of mushrooms, opening inside the galleries, causing its overall depreciation. Bellettini *et al.* (2019) attributed this association to the ability of fruit flies to get attracted to fungi resulting from the initial decomposition of plant materials. Mushrooms, sap flow, and overripe produce and are the foods of choice for fruit flies. They attack and puncture the skin of overripe fruit, vegetables, and mushrooms to lay eggs and feed. During the pre-oviposition feeding stage, adult fruit flies spend time feeding on fruits, vegetables, and other decaying materials. After this period, the female fruit fly places

her eggs beneath the skin of the fruits (Orkin, 2021). Belletini *et al.* (2019) explained their larvae feed on the surface of decaying masses within which they are laid and so are often present in the blemished and over-ripened areas of fruitbodies. Basidiomycetes possess fruitbodies which provide insects with an assortment of hiding places or habitats ranging from the stipe cap as well as their hymenial layer. Furthermore, protection is offered from desiccation and predation as they are a potential source of food.

African giant snails were recorded as pests in this study, which corroborated with published findings of Dias *et al.* (2020) and Bellettini *et al.* (2018). Their presence could be attributed to the cold and moist environment due to the irrigation or supply of moisture which triggers primordia formation in the mushroom cropping house.

Millipedes on the contrary were not numerous although it has been reported by Australian Mushroom Growers Association (AMGA) to be in outdoor cultivated areas because they prefer to inhabit partially decomposed straw and swampy areas. Species such as *Microdispus lambi* (Krozol) is reported to cause severe yield loss of about 10-20% by feeding directly upon the mycelium of crop mushrooms and occasionally even total crop loss on some farms in China (Gao & Zou, 2001) and in Australia up to 30% yield loss has been reported (Ferragut *et al.*, 1997). Moreover, *Pediculaster fletcheri* was reported to be a cosmopolitan pest that caused a nuisance in the cultivation of *Agaricus bisporus* (Kheradmand *et al.*, 2006).

In another study, Singh & Sharma (2016) in India, identified several types of insect pests' attack of *P. ostreatus*, but the major pests belong to three families of flies (Oestridae, Sarcophagidae, and Calliphoridae). Some mites, springtails, beetles, and moths also infest the crop. They named nematodes

as the main pests of *P. ostreatus* and further implicated *Iotonchium unguate* as the causal agent of gill-knot disease of the oyster mushroom (*Pleurotus ostreatus*). Ahlawat *et al.* (2011) reported nematodes and mites as major pests of *Volvariella volvacea* grown on composted substrates of paddy straw and cotton mill wastes. Strict hygienic measures and physical barriers are most important (Cha, 2004) to largely keep these pests reduced.

The presence of these pests presumably caused some adverse effects by feeding (by biting and chewing as well as piercing and sucking some fluids from the mushrooms) on the fruit bodies, thereby reducing the yields and causing some economic loss.

In other related studies, beetles (Eira & Minhoni, 1997; Bellettini *et al.*, 2015), termites (Van Nieuwenhuijzen & Oei, 2005), rodents (Bellettini & Fiorda, 2016) have been reported as pests that feed on mycelia and mushrooms to cause a reduction in yield.

Mushroom yield

Factors such as growth substrate type, pileus size, harvest time, and species of mushrooms influence mushroom nutritional composition, including protein content, and other biochemical characteristics. The highest yield of 110g was recorded in the first flush and gradually decreased in subsequent flushes. There was an observed decrease in yield, biological yield, and biological efficiency with increasing flush periods. Upadhyay *et al.* (2002) suggested that this observation could be a result of depletion of nutrients and accumulation of some toxic metabolites in the substrates of the compost bag, which may slow down the growth process to affect yield. Results obtained in this study agreed with published findings of Girmay *et al.* (2016) who investigated the growth and yield performance of *P. ostreatus* on different substrates in Ethiopia. Kortei and Wiafe-Kwagyan (2014) & Mshandete (2011) also

reported similar values as they evaluated the effect of gamma radiation on eight different agro-lignocellulose wastes materials for the production of *Pleurotus eous* (Berk.) sac. Strain P-31 in Ghana and Cultivated *Pleurotus* HK-37 and *Pleurotus sapidus* (oyster mushrooms) on cattail weed (*Typha domingensis*) substrate in Tanzania respectively.

Growth

The mushroom weight (g/flush) of oyster mushrooms depends on the cap diameter, the length and thickness of the stipe, the number of effective fruiting bodies per flush, and the thickness of the cap (Hoa *et al.*, 2015). Stipe lengths recorded in this study were within the range of values reported by Hoa *et al.*, (2015) for *Pleurotus cystidiosus* (46.06 - 57.84 mm), Kortei *et al.* (2014) for *Pleurotus ostreatus* EM-1 (40-55mm), Mshandete, (2011) for *Pleurotus High King* but higher than *P. ostreatus* (35.28 - 39.21 mm) reported by Hoa *et al.* (2015). Averagely, the ranges obtained in this work were in agreement with the values reported by some previous researchers (Owusu-Boateng & Dzogbefia, 2005; Mshandete *et al.*, 2013; Nurudeen *et al.*, 2013).

Samuel & Eugene (2012) reported that the size of the stalk and pileus is positively correlated with yield and with carbohydrate and protein, respectively. The length of the stipe, the diameter of the pileus, etc are some unique characters of the mushroom which vary from species to species. In this research, the pileus diameters recorded were also within the range of the values reported by the same authors mentioned above. Ahmed *et al.* (2013) suggested that in the case of yield, the larger the pileus size, the higher the yield. Fruiting body weight is to a large extent influenced by the thickness and diameter of the pileus. Undamaged (good looking) fruit bodies are widely perceived to be of superior quality,

highly ranked, and a good criterion for grading and pricing in mushroom cultivation (Kortei *et al.*, 2018a; Kortei *et al.*, 2018b). It will, therefore, be damaging to the mushroom crop if these pests invade and ultimately reduce the yields

Conclusion

A total of five pests were recorded while cropping, namely; *Drosophila melanogaster* (Fruit fly), *Blatta germanica* (cockroach), *Archachatina marginata* (giant snail) and *Doratomyces meridionalis* (millipede) and *Cryptophlebia leucotreta* (False codling moth) with *Drosophila melanogaster* (Fruit fly) adjudged the most predominant pest.

These identified pests can cause defective and unattractive effects (economic loss) to the mushroom fruitbodies (agronomic data) as a result of biting and chewing, piercing and sucking, etc., which may have an adverse effect on the physical quality (colour, texture, structure, aroma) which serves as important criteria for the selection of a food product on the market.

Unhygienic conditions in a mushroom cropping house provide a congenial atmosphere for many diseases and pests. Therefore, a clean environment is essential to mushroom production. The important considerations include previously cleaned implements and maintaining overall hygiene.

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