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Ecofriendly Management of Mushroom Flies in edible cultivated Mushroom: A Review

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ABSTRACT

Mushroom farming is an essential aspect of the gardening business and a low-cost food production strategy. Due to a poor agro climate, low-wage labour, and a varied fungal biodiversity, India's mushroom industry has been met with scepticism. Mushrooms are recognized around the world for their nutritional and therapeutic qualities. Several fly pests, such as Phorid, Sciarid, and Cecid flies, damage *Agaricus bisporus*, and these flies create problem to the grower**.** Pesticides are the most significant tool for combating a variety of mushroom pests, there will always be a desire for new and more powerful synthetic chemicals. Different chemical insecticides were used to keep them under control. However, due to food protection and environmental concerns, there are fewer insecticides accessible for mushroom farming. As a result, it's critical to look at alternative pest control tactics that aren't reliant on chemical pesticides and might be employed in a peat management system.

Keywords: *Lycoriella ingenue*, *Megaselia halterata*, chemical control, biological control, insect growth regulator.

INTRODUCTION

Mushroom production has risen quickly in recent years as a result of high demand, market value, and positive effects. Mushroom is regarded as macro fungus with a distinct fruiting body which can either be epigeneous or hypogeneous and large enough to look and be pickled by hand with naked eyes (Gupta et al., 2019). Around 14,000 species of the 1.5 million fungus estimated to exist on the planet develop fruiting bodies large enough to be classified as mushrooms and only 2000 species are being edible (Hawksworth, 2001) and some of them poisonous. The mushrooms have a cells cycle containing the creation of sexual spores and have two periods of growth, i.e. vegetative and reproductive phases. Mushrooms are a part of basmidiomycets and ascomycenes (fruit bodies). The fungal spores are located in a particular structure called basidium or ascus (for Ascomycetes). Vegetative development, growth in the reproduction and sporadic production are the three main stages of mushroom life cycles (Gupta et al., 2019).

Fig.1 Developmental stages of edible mushroom showing inocculaion of spores will germinate into fungal filament which is none as hyphae. Compatible hyphae mate to form fertile mycelium, this mycelium grown into a fruiting body.

The cap of the mushroom opens as it matures, revealing the gills. Since meiosis has occurred in the fruit body, the spores are sexual spores. In the adult gills, these spores are produced in vast quantities (Morell, 1998). Mushroom cultivation has evolved into a commercial and export-oriented endeavor in India. The button mushroom accounts for nearly all of the output and exports. Mushroom study has been aided by a number of research institutes and organizations. Indian Institute of Horticultural Research (IIHR) in Bangalore and the National Research Centre for Mushrooms (NRCM) in Solan are collaborating to develop mushroom cultivation technology (Solomon. P.Wasser, 2010). Thomas and his colleagues in Coimbatore attempted the first mushroom growing attempt in 1943, with the Paddy straw mushroom. In 1961, the Himachal Pradesh government, in collaboration with the Indian Council of Agricultural Research (ICAR), made the first scientific attempt to cultivate the Button mushroom under the scheme "Development of Mushroom Cultivation in Himachal Pradesh," which was later taken up as a business by farmers in Himachal Pradesh and Jammu and Kashmir in the late 1960s (Morell, 1998). The focus was on button mushroom farming in the West and shiitake mushroom cultivation in the East in the first half of the twentieth century. Mushroom production, aside from button mushrooms, has increased in the twenty-first century, particularly in the last ten years (Singh, 2017).

Asian and European countries consume more mushroom kinds than America, Australia, and England. In Asia *Lentinus edodes*, *Volvariella volvacea* (straw mushroom), and Auricularia species are predominant species of cultivated mushroom. The Shiitake has also been cultivated in Europe in recent years. The most popular farmed mushroom is the white button mushroom, which was the first mushroom to be harvested on a big scale for commercial purposes (Badalyan, 2012). The majority of oyster species thrive at temperatures between 20 and 30℃, with relative humidity levels exceeding 85 percent. The paddy straw mushroom is the sixth most common edible fungus on the planet. Orissa currently leads the way in commercial mushroom production (S. Jess & Bingham, 2004). Shiitake mushrooms are one of the most widely consumed edible mushrooms in the planet, because to their nutritional, culinary, and therapeutic properties (Dey et al., 2020).

Mushrooms are prized for their nutritional value and medicinal benefits all over the world. Mushrooms are nutritionally significant since they are high in protein, fibre, and minerals. They contain unsaturated fatty acids, phenolic compounds, tocopherols, and carotenoids. Mushroom is fat free, cholesterol free, gluten free and less in calories (Raman et al., n.d.; V. P. Sharma et al., 2017).

Mushrooms have been used in medicine for centuries to treat everything from simple skin disorders to complex and pandemic diseases like AIDS. *Ganoderma lucidum* is probably the first medicinal mushroom to gain a lot of importance in India (Kumar et al., 2017). Mushrooms have long been used in Traditional Chinese Medicine (TCM). The vast majority of preparations and combinations have positive health impacts and can be taken on a regular basis without causing harm Medicinal mushrooms are thought to have 126 therapeutic effects in total (V. P. Sharma et al., 2017). Antifungal, antibacterial, antioxidant, and antiviral capabilities have been found in biologically active chemicals from mushrooms, which have also been utilized as pesticides and nematicides. Mushrooms have high water content (93-95%) when compared to learn beef (70%) and fresh vegetables (92 %). They positively alter the very upstream of events that may lead to cardiovascular disorders, such as thromboses, diabetes, and obesity, by acting on fundamental risk factors.

Mushroom species are affected by several fly pests and mainly continues threat in mushroom culture. These flies create problem to the grower. Diptera from the families Sciaridae, Phoridae, and Cecidomyiidae are the most common invertebrate pests associated with mushroom cultivation. Other arthropods include mushroom mites from the Tyroglyphidae, Anoetidae, Eupodidae and Tarsonemidae families (Order Acarinae). Nematodes consist of saprophagous and mycophagous species. Rhabditida and Tylenchida are the remaining invertebrate pests for mushroom growing (Morell, 1998).

MUSHROOM FLIES

The button mushroom crop is harmed by three different types of insects. Other mushrooms are infested with sciarid, phorid, and cecid flies. Flies begin to impact the spawning stage, and if sufficient care is not done, crop production may become difficult.

SCIARID FLIES (*Lycoriella ingunea*)

Sciarid flies can be found almost anywhere on the globe. Mushroom sciarids, also called "dark-winged fungus gnats," are 3-6 mm small, slight black gnat-like insects with huge compound eyes and long antennae **Fig.2.**

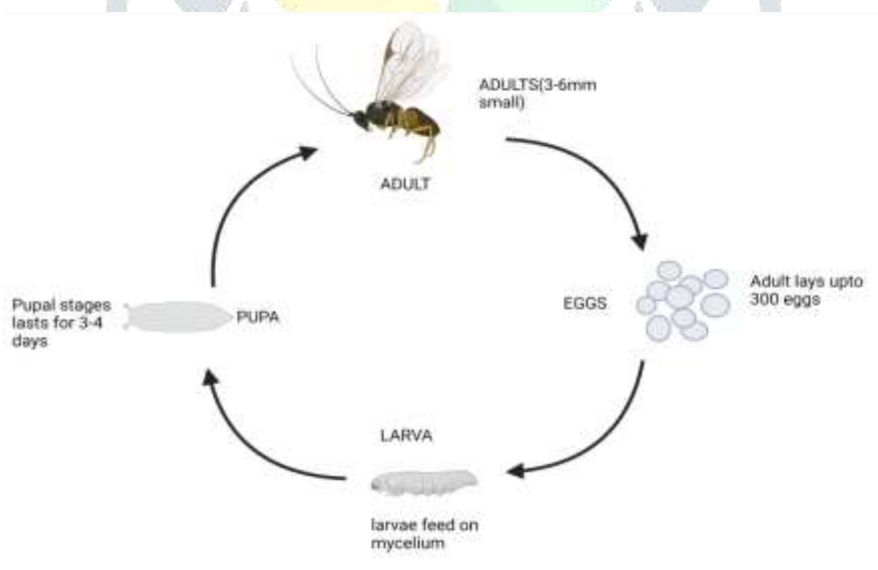

Fig.2 Life cycle of Sciarid Fly undergoes egg, larval instars, pupal instar and the adult. Adults lay up to 300 eggs; eggs are minute, yellowish white and mainly feed on mycelium. Pupae are white, but later become yellow to brown. Pupal stages lasts for 3-4 days and the adults are 3-6 mm small, grey black flies.

Sciarid larvae prefer to eat the compost itself, nibbling on emerging mycelium (Zhang et al., 2005). Adult flies are capable of inflicting crop harm through contamination of repacked mushrooms. They can also transfer Verticillium species spores, and the adults of these flies have been known to spread diseases like cladobotryum. The fly family has been identified as pests in horticulture (Lewandowski et al., 2004). Sciarids are little to medium-sized delicate flies that resemble gnats and midges in appearance. They are found in leaf mould, wild fungus, and decomposing vegetable matter. The biology and behavioral properties of different sciarid genera that infest mushrooms differ slightly (A. Sharma et al., 2019). *Lycoriella auripila, L. mali,* and *L. solani* are the mostly frequent sciarids found in mushroom houses. All three species of sciarid primarily infect mushroom composts, especially as the compost begins to cool after peak heating and spawning (Rijal et al., 2021). Compost, mycelium, and mushrooms are all sources of food for its larvae. Larvae enter mushrooms, begin eating, and form a tunnel within the stipe. They finally reach the pileus and begin to feed heavily. When pinheads are attacked by larvae at the pin head stage, their development is completely halted, and they eventually die (Production, n.d.).

THE PHORID FLY (*Megaselia halterata)*

The phorid flies, sometimes identified as "hump-backed flies," are around 4-6 mm long, white and translucent body with no distinct black head and resemble miniature houseflies. Phorid flies are larger than sciarid flies and have a distinct humpback **FIG.3**.

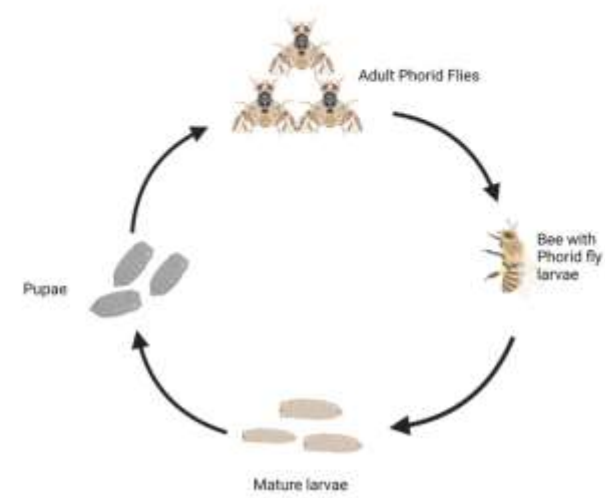

Fig.3 Life Cycle of Phorid Fly: Phorid flies shows complete metamorphosis, developing from egg, larva, pupa, to adult. Eggs are laid inside the bee and these larvae hatch in 24 hours. As they mature, they become whitish. The pupal stages emerge into adults after 20 days.

Their larvae are 1-6 mm long legless creamy-white maggots with a protruding head and flat back end. The larvae of mushroom phorid flies are obligatory mycelial feeders, which reduces productivity. Although phorid larvae do not cause considerable damage to mushroom fields, the adults are vectors of the dry bubble disease *Verticillium fungicola*, which must be avoided. By functioning as fungal vectors, phorid flies provide a far larger impact to the mushroom crop than they do through their own feeding damage. Phorid flies feed on rotting animal or vegetable matter, and they take part in a crucial role in nutrient recycling. *Megaselia* species can be found in a wide range of habitats around the globe. *Megaselia haltrata* (Wood) is a well-known member of this taxon as a cultivated mushroom pest (Journal et al., 1987). Larvae ate mycelia and created holes in mushroom fruiting bodies. They are most prevalent during the growing season in the summer and cause less damage than other flies (A. Sharma et al., 2019). *Megaselia halterata*, a phorid fly, causes direct damage to crops by feeding on mushrooms and indirectly by transmitting fungal infections. Although phorid flies are less damaging than sciarid flies, they chew through mushrooms as well (Production, n.d.).

MANAGEMENT OF MUSHROOM FLIES

Growing high-yielding, high-quality mushrooms necessitate the control of mushroom flies. Unfortunately, pesticide resistance in insect populations, pesticide toxicity to mushroom mycelium, pesticide residues in compost casing material, and worker exposure to hazardous pesticides have all hampered reliable pest control of these pests. As a result, new or alternative pesticides and/or application methods are required for commercial mushroom cultivation to continue.

CHEMICAL CONTROL

Chemical insecticides were ineffectual in preventing flies from attacking commercial mushroom farms. The response of the mushroom cultivation to pesticides is determined by the chemical control. Chemical control is the most efficient and time-saving technique employed by our farmers. As a result, Commercial pesticides were urgently needed to be tested against this pest. Furthermore, different mushroom strains have distinct reactions to specific chemicals. Chlorfenvinphos, diazinon, fenitrothion, and thionazin were all completely effective, but only chlorfenvinphos and diazinon were given further consideration due to potential toxicity concerns. Diazinon in emulsifiable concentrations of 50ppm and 100ppm reduces the number of larval stages of sciarid flies by 100%. Diazinon at 10ppm at spawning resulted in yields of 1.90 and 1-66 Ib/ft^2 after 45 days (Shirvani-Farsani et al., 2013). Chlorfenvinphos is used to reduce larval stages of sciarid larvae by up to 100 percent. It can be applied in granule form or as an emulsified concentration. The results are comparable to those achieved when it is applied in a spawning machine (Badalyan, 2012). Permethrin was originally used to control flies in the mushroom industry in 1980. Permethrin is used as an adulticides in the mushroom industry as part of an integrated pest management approach (Sciaridae & Brewer, 1990). Permethrin is most commonly employed as a 2 percent dust, an emulsifiable concentrate in water, or a fogging solution. Except when mushrooms are present, it is utilized at the end of compost pasteurization and throughout the crop cycle. Permethrin applications at the farms studied ranged from none to several per week in the months leading up to the sampling (Brewer & Keil, 1989). Spinosad is a new insecticide with a new chemical. It was originally registered against dipterous insects in the in 2005. Spinosad has been used in mushroom house conditions for three consecutive growing periods (Muhammad Hussnain Babar, 2012). Trichlorphon deltamethrin and spintoram were determined to be the most efficient pesticides for controlling the mushroom phorid fly. Fly emergence was reduced by 71.9 percent with Spinosad and 72.4 percent with Chlorpyrifos ethyl (Shamshad et al., 2008).

ENTAMOPATHOGENIC NEMATODES

Heterorhabditidae and *Steinernematidae* nematodes are parasitic nematodes that infect a wide range of insect species. All around the world, *Heterorhabditidae* and *Steinernematidae* nematodes have been used as biological control agents (Shamshad, 2010). These two species also provide better or 90% control with a density≥56 nematodes per cm^{-2} (Olthof et al., 1995)· These are four identified species in the Steinernematidae family, for removing sciarid species. When applied at a value of 620 nematodes cm^{-2} to second to fourth-instar larvae of *L. mali*, *S. feltiae* produced 72–81 percent mortality (Lewandowski et al., 2004). The allantonematid nematode *Howardula husseyi's* natural prevalence in mushroom flies initially provided hope for biological control. However, large-scale in vitro generation of *H. husseyi*, as well as the release of mass-reared parasitized flies into spawn-running rooms, was ruled out. *Steinernema feltiae* (Rhabditida: Steinernematidae) had previously been shown to be effective against the mushroom pest *Lycoriella auripila.* The most dangerous nematode against *L. solani* was *S. feltiae*. Uneconomic concentrations of 15 106 nematodes m^{-2} were required to control phorid flies larvae in infested casing soil, resulting in 52 percent and 73 percent decreases for *S. feltiae* and *S. carpocapsae*, respectively. The lowest dose of 30 IJs per sciarid larva resulted in 78 percent control. The phorid mortality rate increased just slightly when the dosage was increased from 30 to 1000. A considerable mortality of 18% was obtained using 1000 IJs per larva. The second-instar to fourth-instar larvae were killed in 72-81 percent of cases by the *S. feltiae*. The mortality of the more mature fourth instars of *L. mali* was significantly lower than that of the younger fourth instars (Brookes, 1985). The parasitization rates were unaffected by the type of substrate, compost, or casing used. The nematode sex ratio that was able to penetrate and develop in the phorid larvae appeared to be skewed toward females. Males made up only 19 percent of the population. The phorid larva's low susceptibility has been attributed to the inaccessibility of its small mouth opening (HUSSEY & GURNEY, 1968). *S. feltiae* and *S. carpocapsae* were the most widespread nematodes in Bradysia paupera at 22°C, according to Gouge and Hague, although *S. feltida* showed 100% mortality. At 30°C, the efficacy of *S. feltida* and *S. carpocapsae* decreased (Gouge & Hague, 1995). Sciarids and phorids were controlled using *Hypoaspis aculeifer* and *H. miles* mites at 700 mites m^{-2} and the entamopathogenic nematode *Steinernema feltiae* at 3 – 10^{-6} nematodes m^{-2} in mushroom compost and casing substrates (S. Jess & Bingham, 2004). Sciarid emergence was minimized in both mite species when the growing substrate was applied as soon as possible after the sciarid infection. Because of its greater diffusion inside compost and casing, as well as its ability to kill larvae of varied ages, *H. aculeifer* had a greater control over sciarids and phorids than any of the other biological agents studied. *Hypoaspips miles* suppresses the first and second generations of sciarid flies. Sciarids in glasshouses were efficiently managed at rates of 55 or more mites per pot, with no recurrence of the pest. Mites remained atop the pots until the end of the experiment, most likely feeding on a lingering population of sciarids (Chambers et al., 1993). When *Hypoaspis miles* (Berlese) was introduced to the compost, adult sciarids were reduced by 87 percent (P0.05). *Hypoaspis miles* were introduced later in the case-run era and had a lower success rate than when they were first introduced (Stephen Jess & Kilpatrick, 2000). *Megaselia halterata*, a mushroom phorid, is resistant to Heterorhabditis and Steinernema species. At a dosage of 1500 infective juveniles (IJs) per 30 larvae, control rates of 61 to 70% were attained. The nematode sex ratio that was able to enter and settle in the larva appeared to be skewed toward females (Zaremba & Smoleński, 2000).

All densities of *L. mali* are reduced by *Hypoaspis heliothidis* and *S.feltiae*. With a density of 56 nematodes cm^{-2}, *S. feltiae* provided 90 percent or better larval control; however, three times that density was required for equivalent control of *H. heliothidis* (Journal et al., 1987). P.N. Richardson showed that heliothidis had no influence when treated during spawning, but that a consistent fall in sciarid populations with increasing amounts of nematode application indicates that nematodes can be used at casing to produce a significant reduction in fly emergence (*Diazinon Compost Treatment*, n.d.).

Tetradonema plicans met several of the requirements for being a successful biological control agent (Tetradonematidae). It was extremely pathogenic and only affected sciarid flies as a target host (Shirvani-Farsani et al., 2013). Tetradonematidae decreases sciarid population within four weeks of introduction (Invertebrate, 1974). *S. feltiae, S. carpocapsae, H. megidis,* and *H. bacteriophora*, the four nematode species investigated, all had similar mortality rates of third instar phorid larvae, ranging from 61 to 70%. With *S. feltiae*, the maximum mortality rate of 20% was achieved (Shamshad et al., 2008)At the largest dose ever recorded of 610 313 nematodes/m^2, S. feltiae killed 93.33 percent of the third instar larvae of *L. ingenua*, which is greater than the recommended rate. Similarly, at the measured amount of 312.5 mg a.i./m^2, Bti gave 46.67 percent control (HUSSEY & GURNEY, 1968). *Bti (bacillus thruingenesis)* reduced adult emergence by 76.9% on average, whereas S. feltiae reduced emergence by 71 percent on average. This also decreases the likelihood of larval damage to mushrooms (Sciaridae & Brewer, 1990). In controlled conditions, two mushroom cultivation studies were conducted. Immature sciarids, *Lycoriella ingenua* (Dufour), as well as adult activity, were inhibited in the developing substrate by the mite *Hypoaspis miles* Berlese near the conclusion of cropping (M.J Navarro et al., 2014). Following the administration of *Steinernema feltiae* (1.5 106 nematodesm^2) at casing, there was a decrease in mature sciarid activity and a decrease in sciarid emergence from substrates. There were no substantial treatment impacts on mushroom yield. In untreated controls, however, adult sciarid infectivity of the mushroom crop increased (Brewer & Keil, 1989). With nematode or pesticide treatment, no reduction in the population of *M. halterata* was observed (Muhammad Hussnain Babar, 2012). In a second experiment, there were no significant changes in the number of phorid flies trapped in the treatments Infested Control try, *S.feltiae*, and *S.feltiae* + *S.carpocapsae*. In addition, the treatments Sf and Sf+Sc had no effect on the emergence of phorid flies (María Jesús Navarro & Gea, 2014). The study found that a dose of 973 nematodes/cm^2 will kill 95 percent of the nematodes, with 95 percent fiducial limits of 861 and 1,131. To achieve 99 percent death, 1,376 nematodes/cm are required (Shamshad, 2010).

BY PLANT EXTRACT

Plant extracts may reduce adult emergence and so lower mushroom fly populations, making them a viable alternative to traditional insecticides. The number of *L. ingenue* and *M. halterata* was dramatically reduced by all of the natural plant extracts used. These plant extracts were proven to be especially powerful against newly emerged insect pests when compared to alternative management measures in mushroom cultivation. Mushroom sciarids are mostly located in the casing; hence the most frequent chemical treatment is to spray the covering with insecticides like Dimilin (diflubenzuron). Adults are kept at bay by inhaling insecticidal smokes or fogs. In the case of phorid flies, however, no pesticides are currently available to control them. In recent years, government rules on pesticides have become more stringent, and consumer pressure organizations have advocated against their use due to the related human health risk, implying that alternate fly control is necessary. In order to build proactive strategies for eradicating mushroom flies, new control agents that are safe for non-target species must be researched. Several studies has in order to build proactive strategies for eradicating mushroom flies, new control agents that are safe for non-target species must be researched.ve looked into plant components as a possible source for reducing mushroom flies. Adults are kept at bay by inhaling insecticidal smokes or fogs. However, there are no pesticides available to control phorid flies at this time. Pesticide restrictions have become more stringent in recent years, and consumer pressure organizations have pushed against their usage because of the risk to human health, suggesting the need for alternative fly control. Innovative control agents that are safe for non-target creatures must be studied in order to find sustainable approaches to manage mushroom flies. Several studies have looked into plant compounds as a potential source for reducing mushroom flies (Olthof et al., 1995). All of the botanical treatments resulted in significant reductions in the mean number of emerging adults and larval damage rates when compared to the negative control. Adult emergence was prevented more by both neem treatments than by the positive control. While the Neemazal and O. treatments were effective, there were no significant differences in larval damage rates between the treatments with Chlorpyrifos-ethyl, Greeneem oil, and *P. anisum* (Zaremba & Smoleński, 2000), The treatment methods with Chlorpyrifos-ethyl, Greeneem oil, and *P. anisum* had no significant changes in larval damage rates. The fumigant activity of four essential oils and their primary components against adult scatopsid flies was investigated. During a 4-hour exposure period, both the oil and its main component caused 100% mortality at all concentrations. *M. pulegium* was found to be the most toxic (Fedai Erler & Polat, 2015). Semi plant extracts may also operate as contact larvicides, implying that they could be a viable alternative to synthetic pesticides used on the casing layer to keep mushroom fly larvae at bay (Brookes, 1985). In the 5th week of production, adult emergence by treatment and sampling week treatment with water alone shows emergence for uncontrolled mushroom production growing to approximately 1000 flies per m^2. Except for the S. feltiae therapy, the three microbial product treatments showed no significant differences. (Fedai Erler et al., 2009). Glasshouse sciarids were effectively controlled at rates of 55 mites per pot and above, with no subsequent return of the pest. Mites remained atop the pots until the end of the experiment, most likely feeding on a lingering colony of sciarids. The azadirachtin-based product tested suppressed populations of the sciarid fly *L. ingenua* and could be used instead of the chemical insecticide malathion (Gouge & Hague, 1995). When compared to the usual insecticide based on malathion, the azadirachtin-based bioinsecticide (1%) applied four times at a rate of 4 x 0.5 ml/m^2 considerably decrease the density of sciarid fly *L. ingenua*. Kashif Badshah, Farman Ullah, Bashir Ahmad, Shakil Ahmad, Sartaj Alam, Mehran Ullah, Momana Jamil, and Sapna Sardar show that among all the treatments, Neem aqueous extract at a concentration of 5% was shown to be the most effective against *L. ingenua*. Because of the presence of azadirachtin, the effect of neem aqueous extract was found to be superior to that of other natural plant extracts (Badshah et al., 2021). Azadirachtin causes male sterility, has antifeedant qualities, and disrupts the hormone systems of a variety of insects, as well as their growth and development. Extracts from oyster mushroom bags treated with 4% garlic bulbs, 4% onion bulbs, and 6% eucalyptus leaf showed significantly reduced quantities of *Lycoriellia* adults were followed by extracts from 4% garlic bulbs, 4% onion bulbs, and 6% eucalyptus leaves, respectively (Chambers et al., 1993). The azadirachtin-based product was tested on *L. sciaridae* populations that had been repressed. *L. ingenua* is a natural insecticide that can be used instead of the chemical pesticide malathion (Gouge & Hague, 1995). In one study, in vitro administration of Neemazal (1%) or Nimbecidine (0.03%) at 4–6 mLL^1 and in vivo application of neem seed kernel powder at 4 gkg^1 compost resulted in >50% mortality in the *A. composticola* population and improved mushroom output by 2%–33% (Gahukar, 2014). *Nicotiana tobacum* and *Eucalyptus globulus* were evaluated against second instar larvae of *Lycoriella auripila*, one of the most significant pests of button mushrooms, using the agar dilution technique. Second-instar larvae were given seven doses of both plant aqueous extracts, and their mortality was assessed after 24, 48, and 72 hours. Aqueous extracts of *N. tabacum* and *E. globulus* killed 77.55 percent and 72.5 percent of *L. auripila* larvae after 72 hours, respectively, at a concentration of 4000 ppm. At 12.5 g/ml air concentration, *Schizonepeta tenuifolia* oil caused 96.6 percent mortality, but at 3.125 g/ml air concentration, mortality dropped to 60%. Static olfactorometers were used to test *Lycoriella ingenua* and *Megaselia halterata*. Garlic solutions repelled adult female *M. Halterata* at concentrations as low as 0.1 percent (v/v) for both pest species.

INSECT GROWTH REGULATOR

To combat mushroom fly, man-made pesticides like as chlorpyrifos, diazinon, Malathion, methidathion, and methomyl are commonly used, posing a risk to human health and the environment. Because insect growth regulators directly affect the target pest and closely related species, these synthetic pesticides could be substituted with insect growth regulators, which could give possible alternatives to currently employed mushroom fly control treatments (F Erler et al., 2011). Insect growth regulators (IGRs) have been one of the most rapidly increasing groups of pesticides since the 1960s. Because of the granularity of their objective, and minimal environmental toxicity, most IGRs are classified as "reduced risk." Insect larvae and pupae are frequently targeted by these chemicals. Insect growth regulators are classified as juvenile hormone mimics, ecdysone agonists, or chitin synthesis inhibitors, depending on how they function. The first benzyoyl urea chemical utilized against organophosphorus pesticide drug resistance of *L. auripila* was diflubenzuron, a chitin synthesis inhibitor, in 1975. Methoprene, a juvenile hormone, was the first insect growth regulator licenced in 1986. It is the sole registered benzoyl urea in the United States, sold as Dimilin, and was first approved for use against mushroom flies in 1982. At 100 µg g^{-1}, methoprene provided long-term control of *L. auripila*. Effective control against *L. auripila* was established when 30 gg^{-1} of gamma-HCH, methoprene, and diflubenzuron were included into the casing. When diflubenzuron was combined into or drenched into the casing at the commercial rate of 30 µg g^{-1}, the yield and size of the mushrooms increased without influencing the timing of the IPM for sciarid fly control in mushrooms. However, at higher rates of 180 and 1080 µg g^{-1}, there was a rise in size as well as a decrease in number and yield. Diflubenzuron was used against resistant sciarid populations by White and Gribben, who suggested it as a regular control technique for this pest. Insect growth regulators may be more effective than sciarid flies first generation larval stages (Keil, 2019). In two successive growth periods (negative control and positive control group), F. erler, e. polat, h. demir, m. catal, and g. tuna choose eight insect growth regulators: dibubenzuron, bufenoxuron, lufenuron, methoprene, novaluron, pyriproxyfen, tebubenzuron, and tribumuron. During the two growing phases, IGR treatments resulted in significant reductions in emerging adult numbers and sporophore damage rates when compared to the water-treated control. Novaluron, dibubenzuron, and tebubenzuron had considerably fewer emerging adults in both periods than the other IGRs and the chlorpyrifos ethyl-treated control. Tebubenzuron, pyriproxyfen, novaluron, and dibubenzuron treatments caused much less sporophore damage than all other treatments. There were no significant yield reductions due to the application of chosen IGRs when compared to the negative control (Stephen Jess & Kilpatrick, 2000). In a comparative analysis of five different insect growth regulators, methoprene, cyromazine, diflubenzuron, flufenoxuron, and teflubenzuron, methoprene and cyromazine were found to be effective against sciarid larvae in French mushroom crops. On diverse mushroom strains, the IGRs had no apparent phytotoxic effect Clift and Terras (1992) examined triflumuron and diflubenzuron as insect growth regulators (IGRs) for application in casing and compost against the mushroom sciarid *Lycoriella mali* and the white cecid *Heteropeza pygmaea*. When employed at 35 mg Kg^{-1} in casing and 10 mg Kg^{-1} in compost, both IGRs exhibited significant efficacy against sciarids, leading in better yields and less damage. Unless paired with 0.01 percent maldison watered on weekly, neither demonstrated enough activity against cecids. When compared to an uninfected control, the use of triflumuron, either alone or in combination with maldison, resulted in the least yield loss. In their trial, A.D. Clift and M.A. Terras found that both IGRs, triflumuron and diflubenzuron, are particularly efficient against larvae of *L. mali*, resulting in better marketable yields and less damage. Maldison watered onto triflumuron in the casing was shown to be equally effective as a compost and diazinon casing treatment (Fedai Erler et al., 2009).

FUTURE PERSPECTIVES

Mushrooms are well-known throughout the world for their nutritional and therapeutic benefits. Several fly pests damage mushroom cultivation, and these flies create problem to the grower. Growing high-yielding mushroom farms necessitates the control of mushroom flies. Due to the powerful selection of pesticides imposed on pests over the last few decades, a number of insect species have acquired resistance to various pesticides. Because pesticides are the most important weapon for controlling various types of mushroom pests, there will always be a demand for new and effective synthetic chemicals. However, due to high production costs and opposition from environmental groups, this may not be generally available. As a result, adopting ecologically oriented techniques to reduce mushrooms-related pests will become more critical. Ecological pest control solutions are effective in keeping pest populations below economic thresholds because they are appropriate, environmentally sound, long-term, and cost-effective. Adoption of all parts of Insect

Pest Management, as well as the use of information and communication technology in mushroom production firms, could have a substantial impact on mushrooms resistance to biotic and abiotic stresses in the future. In order to meet the difficulties ahead, it will be critical to focus on research facilities and training of farmers, scientists, and extension workers in the future. As a result, these steps may have the potential to boost mushroom production.

CONCLUSION

Mushroom farming is an essential aspect of the gardening business and a low-cost food production strategy. Due to a poor agro climate, low-wage labour, and a varied fungal biodiversity, India's mushroom industry has been met with scepticism. Mushrooms are recognized around the world for their nutritional and therapeutic qualities. One of the most serious hazards to mushroom production is severe infestation by a variety of pests, which can cause massive damage to the mushrooms and result in significant financial loss. IPM is an ecological tool that includes preventive and restorative actions to keep crops free of pests with minimal risk to the ecosystem for effective and efficient pest management. Excessive use of chemicals has long-term harmful consequences on natural ecosystems, as well as adverse effects on both helpful and non-beneficial living organisms and humans.

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Sunil Kumar conceptualization, Methodology; Kumari Ruchika, Kanika Choudhary, Jigmet Yangchan, Dixit Sharma: Data curation, analysis, Validation; Sunil Kumar, Dixit Sharma,:Visualization; Kumari Ruchika:

Writing- Original draft preparation; Sunil Kumar, Dixit Sharma: Writing- Reviewing; Sunil Kumar: Supervision; Dixit Sharma: Editing and suggestions.

Conflict of interests

The authors declare that have no conflict of interest. The manuscript has not been submitted to any other journal.

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