PESTS OF TROPICAL MUSHROOM AND THEIR MANAGEMENT

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DECLARATION

I hereby declare that this thesis entitled "**Pests of tropical mushroom and their management**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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DEDICATED TO
MY EVER LOVING DADDY
WHO GUIDE ME FROM HEAVEN

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INTRODUCTION

1. INTRODUCTION

Mushrooms often mentioned as "Queen of vegetables" are table delicacies since time immemorial. The word 'mushroom' has always been fascinating and mystic to man, owing to their sudden appearance in numbers, groups, rings, bunches, and also in isolation as a single attractive structure. References about mushrooms are available in most ancient literature like the Vedas and the Bible. The rate of expansion of knowledge on mushroom cultivation in the past few decades has been massive because of its nutritive and medicinal values.

Mushrooms being an indoor crop provide a very congenial habitat for insect pests due to which they remain protected from the vagaries of the weather. Moreover, maintenance of optimum temperature and humidity in the cropping rooms provide ideal conditions for the maximum activity and population build up of the pests. The crop throughout its growth period is ravaged by a wide array of insect pests which include springtails, mushroom flies and beetle pests. Majority of the mushroom growers lack proper compost and pasteurization facilities. Use of unpasteurized compost coupled with unhygienic conditions helps in the perpetuation of pests and pathogens besides resulting in reduced level of production (Sharma and Suman, 2006). One of the major limiting factors in mushroom cultivation is the lack of sustainability due to pests and diseases (Verma, 2002).

Infestation of pests on mushroom necessitates application of plant protection chemicals for their management. Mushrooms are unique as these are short duration crops and are consumed shortly after harvest. Hence application of chemicals may lead to the presence of pesticide residues. Moreover, continuous application of pesticides may causes pest flare up due to development of insecticide resistance in pests and resurgence of the target pests leading to crop failure. Hence safer and effective insecticides have to be identified for the control of these pests.

In this context, studying the bioefficacy of botanicals and synthetic insecticides against major pests of mushroom assumes greater importance. Further, to assess the pesticide residue status in mushrooms is very important as this commodity is consumed directly without much processing. Hence the present study was undertaken with the following objectives, viz.,

- To assess the occurrence and to study the distribution of various pests attacking mushroom
- To record the nature and extent of damage caused by the pests
- To correlate weather parameters with occurrence of the pests and the extent of damage caused by the pests
- To identify suitable botanicals or chemical insecticides for the management of major pests
- To estimate the terminal pesticide residues if any, in the harvested sporocarp.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The literature relating to the pest of tropical mushroom and their biology, nature and extent of damage, seasonal occurrence, and integrated management strategies, effect of pesticides on the mycelial growth and yield and persistence of pesticide residues in mushroom is reviewed below.

2.1 PESTS OF TROPICAL MUSHROOM

Mushrooms are attacked by a number of pests right from spawning to harvest. Of these, springtails, sciarid flies, phorid flies and mites are the important arthropod pests of cultivated mushroom in India (Sandhu, 1995). Some coleopteran species also inflict damage to mushrooms under certain situations (Deepthi et al., 2003).

2.1.1 Springtails

Occurrence

Atkins (1972) reported that several species of springtails *viz*., *Lepidocyrtus* sp., *Xenylla* sp. and *Seira iricolor* Yosii and Ashraf infest oyster mushroom. Bahl et al. (1981) reported the occurrence of *Lepidocyrtus* sp. and *Xenylla* sp. in mushroom from Delhi. *Lepidocyrtus* sp. has been reported to damage button and oyster mushroom grown in Himachal Pradesh (Thapa and Seth, 1983). *Lepidocyrtus cyaneus* Tulb has been reported to cause serious damage to oyster mushroom in Rajasthan (Bhandari and Singh, 1983). Under Punjab conditions, *S. iricolor* was found damaging mycelium and sporophore of button mushroom (Gill and Sandhu, 1994). The springtail *Achorutes armatus* Nicolet was found to damage button mushroom in Himachal Pradesh (Kumar and Sharma, 1997). Balakrishnan (1994) first reported occurrence of springtails in oyster mushroom beds of Kerala. Later Deepthi et al. (2003) also observed the predominance of springtails in oyster mushroom beds in Kerala.

Biology

Gill and Sandhu (1994) studied the biology of springtail and found that freshly laid eggs were smooth, spherical, white and measure 0.19 mm. Mean incubation period was 4.9 and 3.2 days at 22.5 ^{0}C and 30 ^{0}C respectively. Sharma and Suman (2006) reported that the newly hatched insects were white except for an area of dark pigments surrounding the ocelli and the size of the insect increases at each moult. They also observed that the adults lived up to 78 days at 26 ^{0}C and remained active throughout the year on different mushrooms except in severe winter its population declines considerably.

Nature and extent of damage

In oyster and shiitake mushroom, springtails fed on gills resulting in destruction of gill linings and formation of webby structure. (Thapa and Seth, 1983; Balakrishnan, 1994; Kim and Hwang, 1996). *S. iricolor* scrap the spawn grains made them naked (Gill and Sandhu, 1994). Gill and Sandhu (1995) reported that springtails fed mostly on the lower surface of the sporophores, while feeding on upper side was more on beds placed at ground level. They also observed that the population of springtail was more in lower surface of the sporocarp. Similar findings were reported by Deepthi et al. (2003). They also found that continuous feeding resulted in discoloration and deformation of sporocarp resulting in substantial reduction in yield. Sharma and Suman (2006) reported that the springtails fed on mycelium in compost resulting in disappearance of mycelium from spawned compost. Springtails also attacked fruit bodies of button mushroom and caused slight pitting or browning at feeding sites.

2.1.2 Phorid Flies

Occurrence

The Phorid flies have been known by various other common names, such as scuttle flies, humpbacked flies, manure flies, coffin flies etc. but scuttle flies is the name commonly adopted. Atkins (1972) listed the various species of phorids attacking mushroom which include, *Megaselia nigra* Meigen, *Megaselia agarici* Lintner, *Megaselia flavinervis* Malloch *and Megaselia halterata* Wood. Shandilya et al. (1975) described phorid flies as one of the most important pests of mushrooms in India. Disney (1981) collected phorid fly from Punjab and described for the first time under the name *Megaselia sandhui* Disney which was later correctly identified as *M. agarici*. *M.sandhui, M. halterata, M. nigra, M. agarici* and *M. flavinervis* have been earlier reported on *Agaricus* spp. from India (Sandhu and Bhattal, 1987; Sandhu and Bhattal, 1989)

The occurrence of phorid fly *Megaselia* sp. was reported for the first time in India on oyster mushroom beds by Krishnamoorthy et al. (1991). According to Johal and Disney (1994), the larvae of two species of phorids *viz., Megaselia pleurota* Johal & Disney and *Megaselia scalaris* Loew attacked cultivated mushroom. The occurrence of phorid flies in oyster mushroom beds of Kerala was first reported by Balakrishnan (1994). The occurrence of phorid fly *M. agarici* in Haryana was reported by Mrig et al. (1997).

Kumar and Sharma (2000) reported that phorids have wide range of habitat and were the major pests of mushroom throughout the world. They had listed the different species of phorid flies infesting cultivated mushroom as below.

Group	Host	Phorid species
Agaricaceae	*Agaricus* sp.	*Dohrniphora perplexa* Brues
	Agaricus bisporus (Lge.)	*M. agarici* *Megaselia bovista* Gimmerthal *M.halterata* *Megaselia iroquoiana* Malloch *Megaselia longipennis* Malloch, *M. nigra*
	Agaricus bitorquis (Quél.)	*M.halterata*
	Agaricus campestris L.	*M.agarici* *M.bovista* *M.halterata* *Megaselia hirtiventris* Wood *M. nigra*

		Megaselia rubella Schmitz
		Megaselia rufipes Meigen
Pleurotaceae	*Lentinus lepideus* Nagasawa Eiji	*M.rubella*
	Pleurotus sp.	*Megaselia chaetoneura* Malloch
	Pleurotus cornucopiae (Paulet)	*Megaselia frameata* Schmitz
		Megaselia giraudii Egger
		Megaselia plurispinulosa Zett.
	Pleurotus ostreatus (Jacq.)	*Megaselia rubescens* (Wood)
	Pleurotus sajor- caju (Fr.) Sing	*Megaselia* sp.

Biology

The biology of phorid fly, *M. agarici* was studied by Mrig et al. (2006) on white button mushroom and found that eggs were cylindrical, whitish and measured 0.37 mm. Newly hatched maggot measured 0.56 mm and was transparent with black mouth hooks and dirty white in colour. Pupa measured 2.37 mm with full developed respiratory horns on thorax and was yellowish brown in colour. The adult flies were small, humpbacked and light to dark brown in colour. The spawned compost was preferred for egg laying. The life cycle including the period from egg to adult emergence was found to be of 13-17 days.

Nature and Extent of damage

According to Atkins (1972), phorid larvae were known to cause damage by feeding mainly on mycelium and occasionally tunneling into the mushrooms. Sandhu and Bhattal (1987) noticed the infestation of phorid flies ranging from 11-74% during March-April. In the early stage of spawn running, they decayed the compost completely. The beds were also found contaminated with moulds like, *Trichoderma* sp., *Pencillium* sp. and *Aspergillus* spp. In latter stages of infestation a clear wet zone localized around the vent was noticed. Krishnamoorthy et al. (1991) reported that infestation by phorid flies resulted in rotting of the bed and emission of fowl smell.

2.1.3 Sciarid Flies

Occurrence

Shandilya et al. (1975) reported the damage to white button mushroom by *Bradysia paupera* Tuomikoski from Himachal Pradesh. White (1982) reported sciarid flies, *Lycoriella auripila* Winnertz and *Lycoriella solani* Winnertz as major pests of mushrooms. The attack of sciarid flies on cultivated mushroom was recorded by Fletcher et al. (1986). Chakravarthy et al. (1987) reported *L. auripila* damaging oyster mushroom in West Bengal. Occurrence of *Bradysia tritici* Coquillett on white button mushroom from Punjab was recorded by Sandhu and Brar (1980) and from Haryana (Mrig et al., 1997). Occurrence of *B. paupera* on *P. osteratus* in central province of Sri lanka was reported by Gnaneswaran and Wijayagunasekara (1999). *L. solani* was found to attack the oyster mushroom *P.ostreatus* (Lewandowski et al., 1999). The occurrence of sciarid as a pest of oyster mushroom in Kerala was reported by Balakrishnan (1994).

Biology

Sandhu and Brar (1980) recorded the mean fecundity of *B. tritici* to be 14.07 eggs/ female. Shivanna et al. (2003) described sciarid fly, *B. tritici* on white button mushroom, *A. bisporus* that eggs were cylindrical, whitish with 0.2 mm in length. Newly hatched maggot had a distinct black head with 0.55 mm length and dirty white in colour. Pupa measured 2.39 mm and yellowish brown in colour. Developmental period including the period from egg to adult emergence varied from 19-26 days.

Nature and extent of damage

The yield loss due to infestation by *L. auripila* varied from 30.0 to 34.5 % in oyster mushroom (Chakravarthy et al., 1987). In white button mushrooms it ranged from 14 – 78 per cent (Goltapeh and Kapoor, 1990). Brar and Sandhu

(1990) observed that the most serious type of injury is caused to the developing primordial or pinheads by which became brown, leathery and stopped further development. Larvae also entered into the pinheads, made them hollow, spongy and tunneled into the stipes of pickable mushrooms. Goltapeh (1991) reported that when larvae attack pinheads, further development of pins stopped resulting in the death of pin. Balakrishnan (1994) reported that the sciarid larvae feeding on growing mushroom mycelium arrested its growth and the substrate decaying started within 7-12 days. Kumar and Sharma (1998a) found that sciarid flies acted as vectors or carriers of many diseases, mites and nematodes. Kumar et al. (2001) reported that the damaging stage of the pest was the larvae, which fed extensively on mushroom mycelium and sporocarps.

2.1.4 Red eyed flies

Occurrence

Gnaneswaran and Wijayagunasekara (1999) identified *Drosophila funebris* Fabricius as a pest of oyster mushroom. Deepthi et al. (2003) recorded for the first time another devastating pest of *Mycodrosophila* sp. in oyster mushroom from Kerala.

Nature and Extent of damage

According to Deepthi et al. (2003) the growth of mycelium in the substrate was reduced due to the attack by *Mycodrosophila* sp. Slight discolouration and reduction in the sporocarp size was also observed in oyster mushroom.

2.1.5 Staphylinid Beetle

Occurrence

According to Ashe (1990) the adults of staphylinid beetle, *Pleurotobia tristigmata* Erichson fed only on *Pleurotus*.spp among gilled mushrooms. Occurrence of *Staphylinus* sp. was first reported on oyster mushroom from Kerala by Asari et al. (1991). Later Balakrishnan (1994) reported severe attack of staphylinid beetle in oyster mushroom sporocarps. Mazumdar et al. (2001) reported that the adults and grubs of the beetle, *Scaphisoma tetrastictum* Champ infested the fruit bodies of oyster mushroom and the loss reached up to 32-94 per cent. Deepthi et al. (2003) reported that both the grubs and adults of *Scaphisoma nigrofasciatum*

Pic. fed on the sporocarps and caused severe damage to oyster mushroom, *Pleurotus florida*. In advanced stage of infestation 2-3 beetles/ sq.cm were observed resulting in abandment of mushroom cultivation by many growers.

Biology

Mazumdar et al. (2001) observed that the grubs of *S. tetrasticum* was dirty white, elongate (0.6-1.2 cm), campodeiform with prognathus head, lightly sclerotized and blackish body colour with creamy white intersegmental segments. Pupa was creamy, 2-3 mm long and became brown as the beetle developed. The body colour of the adult beetle was deep amber, head hypognathus, tip of the abdomen not fully covered by elytra, legs long and light brown in colour.

According to Deepthi et al. (2003) the grub of *S.nigrofasciatum* was dirty white with small black lines all over the body. Adult was deep brown with hypognathus head, short elytra, light brown and long legs. *Staphylinus* sp. was dark brown in colour with short elytra and large membranous hind wing, the tip of abdomen curled dorsal wards. The larva was whitish, long and cylindrical with tubular terminal segments (Asari et al., 1991; Deepthi et al., 2004).

Nature and Extent of damage

Asari et al.(1991) reported that the emerging grubs of *Staphylinus* sp. fed on the soft gills and crawled over the beds and made irregular holes in the hymenium and even in the stipe. Balakrishnan (1994) found that the grubs made injuries beneath the pileus and fed on gills. The adults were found to make holes on the stipe and pileus surface and caused rotting.

Mazumdar et al. (2001) reported that the grubs of *S. tetrastictum* produced characteristic visible symptom of small irregular holes in the hymenium and stipe. The infested fruit body showed poor growth and adults fed on the softer tissues of the stipes, gills and pileus as well as mycelium during the mycelium running period. Deepthi et al. (2004) observed that the grubs as well as adults voraciously fed on the edges of the sporocarps. The heavily infested fruiting bodies were totally deformed.

2.1.6 Cucujoid Beetle

Occurrence

The occurrence of cucujoid beetle *Cyllodes whiteii* Johal, Kaushal & Mann, larvae on the fruit bodies of *P. sajor-caju* was first reported by Johal et al.(1992). Gnaneswaran and Wijayagunasekara (1999) reported severe infestation of *Cyllodes bifacies* Walker in mushroom farms of Sri Lanka.

Nature and Extent of damage

According to Johal et al. (1992), there were no visible symptoms on the fruit bodies but were observed to collapse or droop 3-5 days after sporophore initiation. At this stage, larvae were found on the lower surface of the fruit bodies in between the gills.

2.1.7 Other Beetles

Johal and Kaushal (1993) reported *Alphitobius laevigatus* (Fabricius) as a pest of oyster mushroom (*P. sajor caju*). Adults fed on the softer tissues of the stipes, gills and pileus and gave a fringed appearance to the fruit bodies. In severe cases, adults bored windows in the pileus. Hanley and Goodrich (1994) reported that the adults of *Oxyporus stygicus* Say inhabited mature fruiting bodies of a variety of fungi including *P. ostreatus*. Kumar et al. (2004 b) observed the incidence of cigaratte beetle, *Lasioderma serricorne* Fabricius on mushroom in storage, which created holes all over the fruit body and finally turned in to a powdery mass.

2.1.8 Noctuid Moth

Thapa (1975) reported for the first time the occurrence of the noctuid moth as a pest of mushroom. The damage was solely by the light brown caterpillars, which are semi- loopers. The last instar larvae caused the maximum damage. The peculiar damage comprised of voracious feeding by caterpillars there by making tunnels and pits on the surface, gills and stem portions of the mushroom.

2.1.9 Mites

Occurrence

According to Kannaiyan and Ramaswamy (1980), among the arthropod pests, mites have been found to damage mushroom right from spawning to harvest of the crop. Fifty four species of mites have been found associated with the mushrooms throughout the world. Shandilya et al. (1975) reported the occurrence of *Parasitus* spp. on mushroom beds in Solan. Das (1986) reported *Rhizoglyphus echinopus* Fumouze & Robin, *Tyroglyphus dimidiatus* Herm. *Histiostoma heinemanni* Hill & Deahl and *Hypoaspis miles* Berlese damaging mushroom in West Bengal.

Straw mite, *Tyrophagus dimidiatus* Herm. was the most serious problem for paddy straw mushroom and the mites multiplied after spawning of beds (Rathaiah et al.,1996). Kumar and Sharma (1998c) recorded that species of *Histiostoma, Tyrophagus, Neoseilus* and *Leiodonychus* were associated with mushroom produced in a diverse habitat. They also observed that the mites were carried by dipteran flies.

Kumar et al. (2004 a) reviewed the infestation and association of different groups of mites with mushrooms throughout the world, the details of which are furnished below.

Family	Mites associated with mushrooms
Acaridae	*Tyrophagus fungivorus* Oudemans
	Tyrophagus longior Gervies
	Tyrophagus oudemansi Robertson
	Tyrophagus putrescentiae Scharnk
	Tyroglyphus berlesei Michael
	Tyroglyphus lintneri Osb.
	Tyroglyphus mycophagous Megnin
	Caloglyphus Berlese Michael
	Caloglyphus mycophagus Megnin
	Caloglyphus krameri Berlese
	Aeroglyphus rofustus Banks
	Blattisocius kegani Fox
	Oppia nitons Koch

	R. echinopus
	Rhizoglyphus phylloxerae Riley
	Eberherdia sp.
Anoetidae	*Glyphanoetus fulmeki* Oudemans
	Histiostoma gracilipes Banks
	Histiostoma feroniarum Dufour
	Histiostoma rostroserratum Megnin
	Histiostoma heinemanni Hill & Deahl
	Histiostoma miles Banks
Glycyphagidae	*Glycyphagus phylloxerae* Riley
Tarsonemidae	*Tarsonemus tarsalis* Ewing
	Tarsonemus waitei Banks
	Tarsonemus randsi Ewing
	Tarsonemus confuses Ewing
	Tarsonemus floricolus Canestrine
	Tarsonemus myceliophagus Hussey
	Tarsonemus mercedesae Hill & Deahl
	Tarsonemus linteri Ewing
	Tarsonemus mycophagus Banks
Pyemotidae	*Pygmephorus americanus* Banks
	Pygmephorus mesembrinae Canestrini
	Pygmephorus guadratus Ewing
	Pygmephorus sellinicki Krazel
	Dolichocyle keiferi Krantz
	Macrodispodides fungorum Lombardini
	Macrodispodides bua Lombardini
	Pygmephorus flechtmanni Wicht
	Pygmephorus kneeboni Wicht

Pygmephorus althiasae Wicht
Pygmephorus lambi Wicht
Pygmephorus allamni Wicht
Pseudopygmephorus smileyi Hill& Deahl

Eupodidae	*Linopodes antennaepes* Banks
Ascidae	*Arctoseius cetratus* Sellnick
Digamasellidae	*Digamasellus fallux* Leitner
Scutacaridae	*Scutacarus baculitarsus agaricus* Norton and Ide
Tydeidae	*Pronematus bonatii* Bertlese
Macrochelidae	*Macrochelus merdarius* Koch
Laelapidae	*Hypoaspis miles* Berlese

Biology

Ramaraju and Madanlar (1998) identified and described four new species *Poecilochirus* on mushroom compost from Turkey. Kumar et al. (2004 a) reported that developmental stages of mites include egg, prelarva, larva, protonymph, deutonymph, tritonymph and adults. Eggs were laid in batches and environmental conditions were found to greatly influence the duration of development.

Nature and Extent of damage

According to Ramaraju and Madanlar (1998) parasitic mites were attracted by the weed moulds on which they fed and multiplied. Kumar et al. (2004 a) reported that mites fed on the mycelium and infestation after spawning destroyed the grain spawn before the impregnation of the compost.

2.1.10 Snail and Slugs

Occurrence

Worthen (1988) observed that slugs (*Arion* spp.) frequently consumed mushrooms, those are preferred by the mycophagous flies. A positive curvilinear trend between slug visitation and fly production suggested that intermediate levels of slug activity facilitated the production of flies from mushroom. Heera et al. (2006) reported snail as a new major devastating pest of milky mushroom responsible for severe yield loss in Kerala in recent years. Kumar and Sharma (2006) observed slugs as a new pest of shiitake mushroom from Solan.

Extent of damage

The damage by slug was equally severe on stipe, gills and pileus. Loss in yield ranged from 40-60 per cent.

2.2 SEASONAL ABUNDANCE OF PESTS OF MUSHROOM

Gill and Sandhu (1994) reported that maximum activity of springtail *S. iricolor* was during hot and humid conditions in July – August on tropical mushrooms.

Kumar and Sharma (2001) recorded that phorids showed positive correlation with temperature whereas sciarids showed a negative correlation. A negative correlation was observed between evening relative humidity and phorid population.

On the other hand, a positive correlation was reported between the maximum temperature and *Staphylinus* sp. by Deepthi et al. (2004). Kumar et al. (2004 a) reported that the mite was unable to withstand high temperature beyond 35°C.

2.3 INTEGRATED PEST MANAGEMENT IN MUSHROOM

The steps involved in the execution of mushroom Integrated Pest Management (IPM) include selection, integration and implementation of several individual control techniques into a whole system. Different techniques like cultural, physical, biological, behavioral, genetic, botanical and chemical control methods were integrated in a suitable manner and utilized harmoniously to tackle the problems.

2.3.1 Cultural Control

Khanna (1991) reported that the most practical approach for pest control was through proper hygiene maintained in and around mushroom farms and composting platform must be cemented so that the compost does not come in contact with soil. Sharma and Suman (2006) opained that hygiene programme include exclusion, elimination and destruction of pests present in a crop at its termination and dumping of spent compost in a pit far off from the cropping area and covered by soil

2.3.2 Physical Control

Significant reduction in pest population was observed when, the appliances used for mushroom production were dipped in boiling water for 1-2 minutes (Seth, 1984)

Sandhu and Arora (1990) reported that screening of doors and ventilators with nylon nets of 14 mesh/cm effectively checked the entry of mushroom flies in the cropping rooms.

Light trap consisting of 15W yellow bulbs and polythene sheets coated with sticky material placed in cropping rooms helped in controlling adult flies and the insects were attracted to yellow light and were trapped on the sticky material (Kumar and Sharma, 1999). Sharma and Suman (2006) reported that efficient pasteurization of compost and casing soil and proper cook out of cropping rooms after the crop period was the best and most practical approach for pest elimination from the mushroom house.

2.3.3 Biological Control

Parasitic nematode

Three parasitic nematodes *viz.*, *Howardula* sp. *Steinernema* sp. and *Heterorhabditis* sp. had been reported parasitic on a large number of insect pests of mushrooms (Richardson and Grewal, 1991). Grewal et al. (1993) also reported that application of strains Sc and SN of *Steinernema feltiae* (Filipjev) (0.5 x 10 and 1.0 x10) infective juveniles/ m^2 cropping area effectively checked the larval population. Brandl (1994) observed that *S. feltiae* at a concentration of 5, 00,000/ m^2 was effective against *L. solani* and *L. auripila.*

Predatory mite

Predatory mites reported on different pests of mushrooms are listed below,

Mite	Host	Reference
Parasitus fimetorum Berlese	Sciarids,Phorids Cecids,	Binns,1973
Macrocheles merdarius Berlese	Dipteran pests Tyroglyphid mites *Bradysia* spp.	Binns,1973
Hypoaspsis miles Berlese	*L.auripila*	Lind, 1993

Microbial Pathogens

A bioagent, Delfin WG (*Bacillus thuringiensis*) had been reported to be effective in controlling various coleopteran and dipteran pests of mushroom. (Cantwell and Cantelo, 1984; Keil, 1991).

Mazumder et al. (2005) reported that Delfin WG (Bt formulations at 0.06 per cent) resulted in the lower mean fruit body infestation of 9.14 per cent of *S. tetrastictum* in oyster mushroom. Observation on the population dynamics of *S .tetrastictum* indicated no incidence of both the adult and grubs in the Delfin WG treated beds during the first flush crop.

The bacterium *Bacillus thuringiensis* sub sp. *israelensis* had been reported to suppress the nematode population of *Ditylenchus myceliophagous* Filipjev in mushroom (Cayrol, 1974). Keil (1991) revealed that mushroom pests were controlled by *Bacillus thuringiensis* sub sp. *israelensis.*

The bacterium, *Serratia marcescens* Bizia (MTCC 3124) had been observed as a potential bio control agent for insect pests in mushroom particularly against beetles. Forty eight hours after the bacterial suspension applied in the beetle rearing medium. 10- 15 per cent of the grubs were observed morbid with soft body that turned red in colour and afterwards died. (Kumar and Sharma, 1998b).

The most important species of fungi used for the control of mushroom flies were; *Verticillium lecanii* Viegas against *L. auripila* and *Pandora gloeospora* (Vuill.) against *L. mali* (White, 1995) The fungi used for the control of mushroom nematodes were *Arthrobotrys irregularis* Matr. and *Candelalrella* sp. (Khanna and Sharma,1990), *P. sajor caju* (Sharma, 1994), *P. citrinopileatus* (Sharma et al., 2002) and *P. ostreatus* (Sharma et al., 2003).

Sharma et al. (2002) reported that species of *Pleurotus viz., P. ostreatus, P. citrinopileatus, P. cornucopiae* and *P. ostreatus* (Strain from Belgium) were found to have nematophagous activity against two mushroom nematodes *viz.*, *Aphelenchoides composticola* Franklin and *D. mycellophagus* under *in vitro* conditions.

2.3.4 Use of Botanicals

Das (1986) recommended the use of citronella oil for the management of mushroom mites. According to Rao and Pandey (1991), numerous plants like neem, castor, groundnut and karanji in different forms had been known for their antagonistic properties against mushroom nematodes.

Khanna and Sharma (1994) reported that dry neem leaf powder @ 2 per cent w/w basis when mixed in compost at spawning not only kept the nematode population under check but also improved button production. Addition of oil cakes like neem, karanj, coconut, caster and ground nut had been reported to increase button production better than nematicides in mushroom(Rao and Pandey, 1991).

Khanna and Sharma (1996) reported that neem cake @ 5 per cent when mixed in nematode infested compost at spawning, hindered *A. composticola* multiplication and enhanced the sporophore production significantly.

Bhat et al. (1998) reported that the two neem based products Rakshak (Azadirachtin 0.15 EC) at 0.3 per cent and Neem mark (Azadirachtin 0.03 EC) at 0.2 per cent reduced pest population by 77 per cent and fruit body infestation by 78 per cent.

Reddy et al. (1999) reported that Karanj cake @ 2 per cent , coconut, niger and neem cake @ 4 per cent were as effective as chemical treatment of dichlorvos against *A. composticola*.

The garlic extract at 2 per cent was effective against mushroom pests. (Deepthi, 2003).

Mazumder et al. (2005) indicated that there was no incidence of both the adult and grubs of *S.tetrastictum* in Achook (Azadirachtin 0.15 % EC AT 0.3 %) treated beds during the first flush crop.

2.3.5 Chemical Control

Springtails

Sandhu (1995) recommended the use of dichlorvos @ 76 EC 30 ml/ 100 m^2 in mushroom house and ceiling but pointed out that direct spraying on bed should be avoided. Dichlorvos both at 0.01 and 0.02 per cent in the spray schedule of three day interval in incubation room and 10 day interval in cropping room could be significantly reduce the pest population (Deepthi, 2003).

Control of springtails by the use of malathion at 0.01 to 0.025 per cent had been reported by different workers (Bhandari and Singh, 1983; Thapa and Seth, 1983; Sandhu, 1995; Deepthi, 2003). Sharma and Suman (2006) suggested spraying of malathion or dichlorvos at 0.025 – 0.05 per cent for controlling the infestation of springtails during spawn run and cropping period and recommended the waiting period of 2 and 5 days for dichlorvos and malathion respectively.

Mushroom flies

Arora and Sandhu (1991) reported that dichlorvos 30 ml/100 lit of water in fine droplets was effective in controlling the mushroom flies.

Malathion (0.01 per cent) spray on beds on seventh day after spawning was effective for controlling sciarid fly, *L. auripila* maggots infesting *Pleurotus* beds (Chakravarty et al., 1987).

Sharma and Suman (2006) recorded that chlorpyriphos at 50 ppm in compost and at 25 ppm dosage in casing soil had good potential for fly control.

Sandhu and Arora (1990) recommended the treatment of compost with lindane 20 EC @ 200 ml per 1000 kg of straw after dilution in water at the final stage of compost preparation.

Mushroom mites

Szudyga (1978) recommended the use of DDVP aerosol sprays against the mites attacking *Stropharia rugosa- annulata.*

Delmas (1978) recommended addition of lindane dust at first turning of compost and on the beds before or after casing.

2.4 EFFECT OF PESTICIDES ON MYCELIAL GROWTH AND YIELD OF MUSHROOMS

According to Bhandari and Singh (1983) malathion, carbaryl, endosulfan and dichlorvos reduced the yield at 5 -15, 5-15, 10-15 and 15ppm dosages respectively. The yield decreased with the increase in the concentration of the insecticides. They also reported that the yield of oyster mushroom was reduced when the dosage of malathion was increased from 5 to 10 ppm for soaking maize straw. Bhandall and Mehta (1987) reported that malathion showed no inhibition of mycelial growth of *Auricularia polytricha* (Mont.) Sacc. at 50 ppm, while 500 ppm resulted in inhibition. Grewal and Sohi (1987) reported that dichlorvos 40 ppm inhibited the mycelial growth and yield of *P. sajor-caju.*

Sandhu et al. (1987) opained that incorporation of chlorpýriphos and carbofuran from 50 to 100 ppm and from 25 to 50 ppm respectively in the compost reduced the spawn run and yield of mushrooms to great extent. Katyal et al. (2006) reported that chlorpyriphos @ 25- 75 ppm had adversely affected the yield as shown by 19- 60 per cent reduction in yield of *A. bisporus* strain P-1 and no fructification in strain U-3.

Brar and Sandhu (1991) recorded that incorporation of insecticides in the casing soil caused more adverse effect on yield than the incorporation in compost.

2.4 PERSISTENCE OF PESTICIDE RESIDUES IN MUSHROOM

Residues of malathion at 0.1 and 0.15 per cent concentrations after 7 days and dichlorvos at 0.03 and 0.05 per cent concentrations after 8 days when sprayed at opening (mycelial) stage of oyster mushroom were found to be below the maximum residue limit of 0.5 ppm (FAO, 1982).These periods coincided with the normal harvest time after mycelial stage (Sarode et al., 1982). Bhandari and Singh (1983) reported that the residues of malathion, dichlorvos, endosulfan and carbaryl were 1.0 ppm (after 33 days), 1.2-0.4 ppm (after 15-23 days), 1.8 ppm (after 17 days) and 4.0-1.0 ppm (after 12- 21days) respectively. Residues of dichlorvos after use as adulticide mushroom flies at 22.5, 30.00 and 60.0 g a.i/100 m^3 were below the mean residue limit of 0.5 ppm on one day after application (FAO/WHO, 1986). Arora et al. (1989) reported that initial residues of dichlorvos reached below the maximum residue limit of 0.5 ppm after 24 hours at 22.5 and 30.3 g ai per 100^3 treatment and after 48 hours at 60 g ai per 100^3 treatment in white button mushrooms. When dichlorvos was sprayed at 22.5 g/100m^3, the residues in mushroom dropped below the prescribed residue limit of 0.5 ppm after 24 hours of its application (Arora and Sandhu, 1991). Nath et al. (1996) studied the persistence of dichlorvos sprayed at 0.05 and 0.1 per cent concentrations at the primordial stage of white button mushroom, *A. bisporus* and found that residues were below detectable level after 42 hours of spraying in both lower and higher concentrations. Sharma et al. (1997) reported that dichlorvos @ 0.1 per cent and 0.2 per cent concentrations sprayed at the pinning stage resulted in initial deposits of 1.34 and 1.65 mg kg^{-1}respectively on mushroom which dissipated fast to reduce down to non detectable limit within another two days. Due to fast dissipation and low persistence of dichlorvos, it is being used all over the world as aerosol sprays in mushroom houses for controlling flies.

Katyal et al. (2006) reported that uptake of chlorpyriphos in fruit bodies at first flush was below detectable limit (0.05 mg kg^{-1}) when mixed in casing @ 25-75 ppm and was 0.08 mg kg^{-1} when used @ 100 ppm which declined further to below detectable level at second flush.

The residues of the synthetic pyrethroides, cypermethrin (0.02 per cent) and fenvalerate (0.02 per cent) in mushroom at 48 h after spraying were 0.75 ppm and 1.24 ppm respectively. (Balakrishnan, 1994).

Sharma et al. (1997) reported the application of lindane @ 100 and 200 mg kg^{-1} in compost at its final turning state resulted in uptake of 0.065 mg kg^{-1} and 0.088 mg kg^{-1} at first flush of mushroom and that persisted to 0.018 mg kg^{-1} and 0.030 mg kg^{-1} at second flush after 10 days.

Sandhu et al. (1987) recorded that residues were more in casing treatment than in compost treatment, residues were slightly more than double in compost + casing treatment than in the single compost treatment.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A survey was conducted to record the incidence of pests infesting mushroom in different locations of Thiruvananthapuram district and to assess their seasonal occurrence during 2006-2007. An experiment was also conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram to identify suitable botanicals /synthetic insecticides for the management of the pests. The terminal residues at the time of harvest in mushroom beds sprayed with synthetic insecticides at different intervals after bed preparation were also determined. The materials used and the various methods adopted are given here under.

3.1 SURVEY ON PESTS OF MUSHROOM

The survey was conducted for a period of one year (April 2006 to March 2007) at monthly intervals in five different commercial mushroom houses / and those of progressive mushroom growers in Thiruvananthapuram District namely, (1) The Instructional Farm, College of Agriculture, Vellayani (2) Krishi Vigyan Kendra, Mitraniketan, Vellanad (3) Swathishta Mushrooms, PTP Nagar (4) Mrs. Sosamma, Mushroom garden, Manacaud (5) Mrs. Reeja's mushroom house at Chemmanvilla puthanveedu, Thiruvallam to assess the population of pests infesting mushroom. From each location, five mushroom beds were selected at random and population of pests were recorded following standard techniques.

3.1.1 Population Assessment

The methodology applied for recording the population of pests and extent of damage in mushroom is furnished below.

Springtails

An area of 225 cm^2 was marked on the outer surface of the polythene tubes of the mushroom bed with a marker pen. From the marked area, springtails were collected by tapping using camel hair brush and hand lens into a petri dish and their number was counted after anaesthetizing. The population was expressed as number /225 cm^2.

Flies

The number of adult flies present in an individual bed was counted by visual counting method and population expressed as number/ bed.

Beetles

Five well developed fruiting bodies per bed were selected for assessing the population of beetles. From each fruit body, number of beetles was recorded and the population was expressed as number/ 5 sporocarp / bed.

Mites

Population of mites were assessed using the floatation technique suggested by Kumar and Sharma (1998c). Two hundred and fifty grams of the compost was taken in a one litre vessel and 500 ml of water added to it. Floating mites were isolated using camel hair brush and then counted using a hand lens. The population of mites were expressed as the number / 250 g compost.

Noctuid Moth

The population of the pest was recorded by counting the number of larvae / bed.

Slug

The total number of slugs / mushroom bed was recorded in the morning at 6 am.

3.1.2 Damage Assessment

Springtail

To record the extent of damage by springtails on mushroom beds, the area damaged by the pest was marked on polythene tubes with a marker pen. Then the polythene tubes were carefully removed and the marked area in each bed was measured using graph paper. Then the percentage of area damage by springtails in each mushroom bed was determined.

Based on the percentage of damage, a damage intensity score (0-5 scale) was used for assessing the extent of damage as follows (Plate-1)

5 >80 % damage

4 61-80 % damage

3 41-60 % damage

2 21-40 % damage

Plate 1. Damage intensity score of springtails on oyster mushroom (0-5)

1 1-20 % damage

0 Undamaged beds (Bed fully covered with mycelium)

Beetles

To study the extent of damage by beetles, the beds were randomly selected and the total number of healthy and infested sporocarp per bed were counted. The extent of damage was assessed from the percentage of sporocarps damaged.

3.1.3 Assessment of damage by pests

The technique developed by All India Coordinated Mushroom Improvement Project, National Research Centre for Mushroom, Solan was followed for assessment of loss.

Springtails

0 No damage

1 Browning of pin heads

2 Pits on fruit bodies and browning of caps

3 Infestation on gill tissue

4 10 per cent of mushroom infested

5 20 per cent of mushroom infested

6 30 per cent of mushroom infested

7 40 per cent of mushroom infested

8 50 per cent of mushroom infested

Beetles

0 No damage

1 Infestation during spawn run

2 Infestation in gill tissue

3 Damaged pileus

4 10 per cent of mushroom infested

5 20 per cent of mushroom infested

6 30 per cent of mushroom infested

7 40 per cent of mushroom infested

8 50 per cent mushroom infested

Phorid fly

0	No damage
1	Browning of pin heads
2	Gills infested larvae / tunneling of stipe
3	Number of adults trapped / week (15-20 adults)
4	10 per cent of mushroom infested
5	20 per cent of mushroom infested
6	30 per cent of mushroom infested
7	40 per cent of mushroom infested
8	50 per cent of mushroom infested

3.2 INFLUENCE OF WEATHER FACTORS ON THE INCIDENCE OF PEST POPULATION ON MUSHROOM

The data on meteorological parameters recorded by India Meteorology Department, Thiruvananthapuram and Department of Agricultural Meteorology, College of Agriculture, Vellayani were used for the correlation with population of pests and extent of damage by mushroom pests in different locations. The impact of different abiotic factors such as temperature, relative humidity and rainfall on the incidence of different mushroom pests in different locations were studied. The data on weather parameters from India Meteorology Department, Thiruvananthapuram was correlated with pest population collected from Krishi Vigyan Kendra, Mitraniketan and Swathista mushrooms, PTP Nagar and weather parameters recorded by the Department of Agricultural Meteorology, College of Agriculture, Vellayani were correlated with the pest population collected from other three sites namely, Mrs. Sosamma, Mushroom garden, Manacaud, Mrs. Reeja's mushroom house at Chemmanvilla puthanveedu, Thiruvallam and The Instructional Farm, College of Agriculture, Vellayani.

3.3 EVALUATION OF BOTANICALS AND SYNTHETIC INSECTICIDES FOR THE MANAGEMENT OF PESTS OF MUSHROOM

An experiment was conducted to evaluate the efficacy of two neem-based botanicals and seven chemical insecticides against the pests attacking mushroom at Instructional Farm, Vellayani (Plate -2)

3.3.1 Details of the Experiment

Design : CRD

Number of treatments : 10

Number of replications : 3 (A cluster of six beds per replication)

Treatments

T_1	-	Neem Azal 1 per cent TS	4ml/lit
T_2	-	Neem oil - Garlic	2 per cent
T_3	-	Dichlorvos	0.02 per cent
T_4	-	Malathion	0.05 per cent
T_5	-	Dimethoate	0.05 per cent
T_6	-	Chlorpyriphos	0.02 per cent
T_7	-	Fenvalerate	0.03 per cent
T_8	-	Lambda cyhalothrin	0.05 per cent
T_9	-	Floor treatment (prior to bedding) Lindane	0.05 per cent
T_{10}	-	control	

Observations on the population of the pests were recorded one day prior to application of insecticides and one, three, five, seven, fifteen and twenty days after each application.

Time of pesticide application except treatment nine:

- At the time of bed preparation
- 5 days after bed preparation
- 10 days after bed preparation
- 15 days after bed preparation

Plate 2. A View of the beds in the mushroom house

3.3.2 Preparation of mushroom beds for *Pleurotus* spp.

Mushroom beds were prepared in the mushroom house of Instructional Farm, Vellayani using the following the standard compact poly bag method of mushroom cultivation (Bhaskaran et al., 1978) using paddy straw as the substrate. The paddy straw was chemically sterilized using a mixture of carbendazim (75 ppm) and formaldehyde (500 ppm) as described by Gokulapalan *et al.* (1987). The spawn, seed material used for the mushroom cultivation was procured from the Instructional Farm, Vellayani.

The substrate for mushroom cultivation was pre-soaked over night in water containing the above chemicals and made into small twists after draining excess water. The processed substrate was laid out into beds using 150-200 gauge polythene bags of 30 x 60 cm size. About seven to eight holes of 0.5 – 1.0 cm diameter were made all over the polythene tube for aeration and the free end was tied with a string. Treated straw was then placed inside the cover up to a height of 10 cm. This layer was spawned using rice grain spawn and the second layer of straw was placed over it and spawned. In this way, the whole cover was filled layer by layer and cover was made as compact as possible and tightly tied to a compact mass. The beds were then kept on bricks laid on a 10 cm high layer of river sand and incubated at room temperature for a spawn run period of 12-15 days. In order to maintain 80 per cent relative humidity in the mushroom house, water was sprinkled on the sand during morning and evening hours. After attaining full spawn run they were transferred to the cropping rooms of the mushroom house.

3.3.3 Assessment of Population and Extent of damage by springtails

Pest population

During the spawn run period the population of springtails was recorded on the mushroom beds while at cropping period it was recorded on the fruit bodies of mushroom. The population of springtails was assessed as per the method described in item 3.1.1.

Extent of damage

The nature and extent of damage in mushroom beds were recorded and quantified during the spawn run period. For this, the area damaged by pests was marked on the polythene tubes of the bed with a marker pen. The polythene tubes were then carefully removed and the area damaged in each bed was measured using graph paper and the percentage area damaged was worked out.

3.4 ESTIMATION OF TERMINAL RESIDUES IN MUSHROOM

The terminal residues present in mushroom at first harvest from the pesticide treated beds were estimated following standard protocols.

3.4.1 Procedure for Pesticide Residue Analysis

3.4.1.1 Recovery studies

The samples 25g were fortified with a mixture of organochlorine insecticide (lindane), organ phosphorus insecticides *viz.*, chlorpyriphos, malathion, dimethoate and dichlorvos and synthetic pyrethroid insecticides *viz.*, lambda cyhalothrin and fenvalerate at 0.05 ppm, 0.10 ppm, 1.00 ppm levels.

Extraction and Partitioning

The samples were blended with 200 ml acetone for two minutes at high speed. The extract was passed through a Buchner funnel fitted with filter paper and extraction was completed with in one minute. From the extract, an aliquot of 80 ml was transferred to a one litre separatory funnel and extracted with 20 ml portion of hexane: dichloromethane (1:1, v/v) by vigorous shaking for one minute. The lower aqueous phase was transferred to another one litre separtaoty funnel. The organic phase of the first separatory funnel was dried by passing through approximately 30g a 1.5" anhydrous sodium sulphate supported on pre washed with hexane cotton in 4" funnel. Ten ml saturated sodium chloride solution was added to the aqueous phase in the separatory funnel and shaken vigorously for thirty seconds. To this, added 100 ml dichloromethane, shaken vigorously and collected the lower organic phase through the same sodium sulphate that was used for drying the organic extract of the first separataory funnel. The extraction was repeated once more with 100 ml portions of dichloromethane and dried as mentioned above. The sodium sulphate was further rinsed with 50 ml dichloromethane. The whole extract was concentrated using vacuum flash rotary evaporator without allowing the solution to go to dryness. The concentration step was repeated in the presence of hexane to remove all traces of dichloromethane and then repeated again to produce final extract in acetone solution. The volume was made up to seven ml with acetone.

Clean up for Organo chlorine and Synthetic Pyrethroid

To a sintered chromatographic column (22mm i.d.) added 50 ml hexane and then poured slowly 4 g of activated Florisil 60 - 100 mesh size, followed by 2g sodium sulphate. One ml of the extract was diluted to 10 ml with 10 per cent acetone in hexane and transferred the solution to the florisil column. The container was rinsed with 2x3 ml portions of hexane. The column was eluted with 50 ml of 50 per cent dichloromethane 1.5 per cent: acetonitrile : 48.5 per cent hexane v/v/v at about 5 ml/min. The florisil eluate was concentrated to 1ml. The extract was used for further determination of organochlorine and synthetic pyrethroid residues using gas chromatograph (GC –Shimadzu 2010 A) equipped with Ni ^{63}ECD .

Clean up for Organo Phosphorous

Two ml of the extract was subjected to clean up and for further estimation. To a sintered chromatographic column, placed about 1" celite 545, 6g adsorbant mixture (1:4w/w charcoal / celite 545), and topped with 2g sodium sulphate. The column was prewashed with 25ml dichloromethane and the solvent was discarded. 2ml of the extract was transferred to the column with small portions of dichloromethane and forced the solvent through, and collected the solvent in a conical flask. Eluted with 200 ml 2:1 acetone: dichloromethane (v/v). The eluate was evaporated using vacuum flash rotary evaporator. The extract was used for further determination of organophosphate residues using gas chromatograph (GC – Shimadzu 2010 A) equipped with FPD.

GLC parameters

Parameters	Organophosphorous insecticides	OC and SP insecticides
Injector temperature	250 °C	250°C
Column flow	1.50 ML /min	1.87 ML /min

Column temperature program	100 °C - 15 °C -160 °C - 8 °C -250 °C (20 min hold)	160 °C - 3 °C -270 °C (10 min hold)
Detector temperature	290 °C	300 °C
Injection volume	2 µl	1 µl

The mushroom at first flush from the different pesticide treated beds were analysed for the presence of terminal residues following the methods described above.

3.5 STATISTICAL ANALYSIS

The data obtained on pest population and extent of damage by mushroom pests were subjected to statistical analysis as per the method given by Panse and Sukhatme (1985)

RESULTS

4. RESULTS

The information gathered on the occurrence of pests on mushroom beds, their nature and extent of damage, relationship between weather parameters and the incidence of pest during the survey for the period from April 2006 to March 2007, efficacy of botanicals and synthetic insecticides against the pests of mushroom and the persistence of pesticide residues in the harvested mushroom following application at different interval after bedding are presented in this chapter.

4.1 PESTS INFESTING THE TROPICAL MUSHROOMS IN THIRUVANANTHAPURAM DISTRICT

Different pests observed in mushroom at various locations in April 2006 to March 2007 during the survey are presented in Table 1. The pests observed during the incubation period and cropping period comprised of springtails, phorid flies, beetles, mites, slugs and snails.

The dominant pest observed in mushroom during the survey was springtail *Seira* sp. it was followed by mushroom flies belonging to the families, phoridae and sciaridae, Staphylinid beetles *viz.*, *Staphylinus* sp. and *S. nigrofasciatum* and non- insect pests, snails and these pests are already known pests of mushroom in Kerala.

The infestation of cucujoid beetle *Cyllodes* sp., noctuid moth, mite *P. necrophori*, slug and snail in oyster mushroom is reported for the first time in Kerala from this study.

4.1.1 Description of Pests Infesting Mushroom and Their Nature and Extent of Damage

4.1.1.1 Collembola

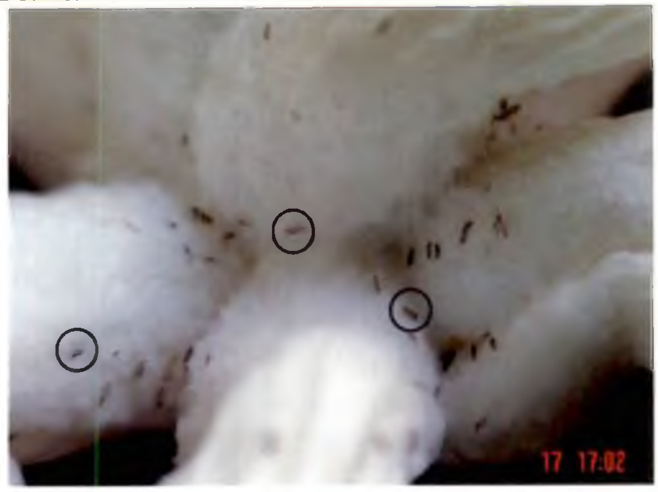
Springtails

Adults are silvery grey to ground colour with bands along the sides of the body. Newly hatched insects are white in colour. Juveniles and adults exhibited the characteristic jumping movement using the springing organ when disturbed. The insect remained active throughout the year (Plate 3).

Table 1. Pests of mushroom recorded in Thiruvananthapuram District from April 2006 to March 2007

Order	Family	Common name	Scientific name
Collembola	Entomobryidae	Springtails	*Seira* sp.
Diptera	Phoridae	Phorid flies	*Megaselia* sp.
	Sciaridae	Sciarid flies	Unidentified
Coleoptera	Staphylinidae	Staphylinid beetle	*Staphylinus* sp.
			Scaphisoma nigrofasciatum Champ
	Nitidulidae	Cucujoid beetle	*Cyllodes* sp.
Lepidoptera	Noctuidae	Noctuid moth	Unidentified
Acari	Parasitidae	Mite	*Poecilochirus necrophori* Vitzthum
Archaeogastropoda	Acmaeidae	Slugs	Unidentified
Archaeogastropoda	Acmaeidae	Snails	Unidentified

Adult of Springtail



Juveniles of Springtail

Disappearance of mycelium

Browning of pin head

Destruction of gill linings

Discoloration and deformation of Sporocarp

Plate 3. Life stages of *Seira* sp. and their damage

Nature and Extent of damage

Numerous springtails were seen inside the mushroom beds during incubation period. The feeding by these insects resulted in disappearance of mycelium from spawned compost. They also attacked fruit bodies of mushroom and caused slight pitting or browning at feeding sites. The insects were mainly seen crowded on the lower portion of the sporocarps and they fed on gills resulting in destruction of gill linings. This in turn reduced the market value of the mushrooms. When the sporocarps were severely infested they became discolored and deformed (Plate 3).

4.1.1.2 Dipterans

Phorid flies

The adults of *Megaselia* sp. are hump backed, light to dark brown in color and 2-3 mm long. They have inconspicuous antennae. Full grown larva is dirty white and 3 mm long with pointed head and blunt rear end (Plate 4).

Nature and Extent of damage

The attack of mushroom flies started at the early spawn run stage. The larvae were found feeding on mycelium arresting its growth. This resulted in the decaying of the substrate and in the later stages of infestation the rotten beds emitted foul smell. The beds were also found contaminated with weed moulds like, *Trichoderma* sp. and *Coprinus* sp.

During pin head stage the larvae made tunnels in the stipe resulting in discoloration and decay of the fruit bodies. When they attacked at pinheads, further development of pins stopped and eventually died. The larvae were observed to hide inside the pileus and gills and they crawled out when the fruiting bodies were harvested (Plate 4).

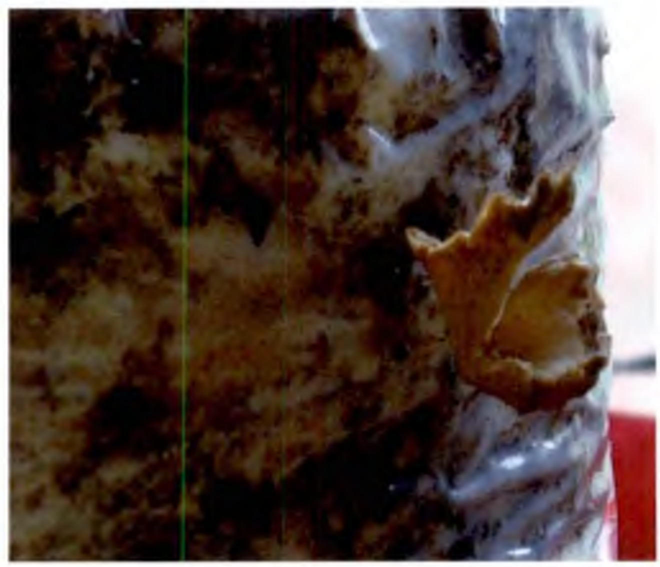
Sciarid flies

These are small flies and the colour of these flies varies from brown black to black. Its body length varies from 2-5 mm with prominent antennae. Larvae 6-8 mm long dirty white with visible longitudinal black streaks.

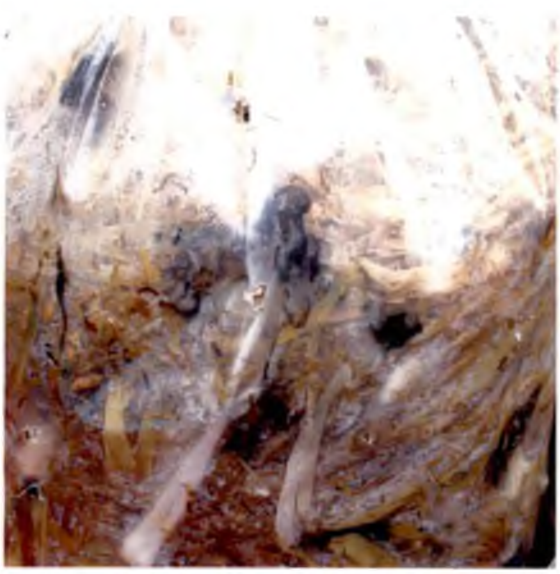
Adult of Phorid fly

Maggot of Phorid fly

Decaying of substrate



Weed mould-*Trichoderma* sp.



Weed mould-*Coprinus* sp.

Discoloration and decay of fruit bodies

Plate.4.Life stages of *Megaselia* sp. and their damage

4.1.1.3 Coleopterans

***Staphylinus* sp.**

Adults 3-5 mm in size, brown with short elytra and with large membranous hind wing and the tip of the back curled dorsally. Grubs are long whitish cylindrical with tubular terminal segment (Plate 5).

***Scaphisoma nigrofasciatum* Champ**

Adults are deep brown with hypognathous head. Abdomen not fully covered by elytra (Plate 5).

Cucujoid beetle

Cyllodes sp. is slightly broadened in the middle, some what depressed (Plate 5).

Nature and Extent of damage

The infestation of beetle pests was not prominent during incubation. The grubs crawled into the surface of fruiting beds and sporocarps. They were found to feed voraciously, making tunnels on the sporocarps. The adults, made holes all over the fruiting bodies and caused rotting. The grubs as well as the adults voraciously fed on the edges of the sporocarps. The heavily infested fruit bodies were totally deformed (Plate 5).

4.1.1.4 Lepidopteran

Noctuid moth

The caterpillar is light brown in color, which it is a semi-looper (Plate 6).

Nature and Extent of damage

The damage was solely done by caterpillars particularly, the last instar caused maximum damage. The caterpillars voraciously fed on the stipe and pileus and made tunnels and pits on the surface, gills and stem portions of the fruiting body (Plate 6).

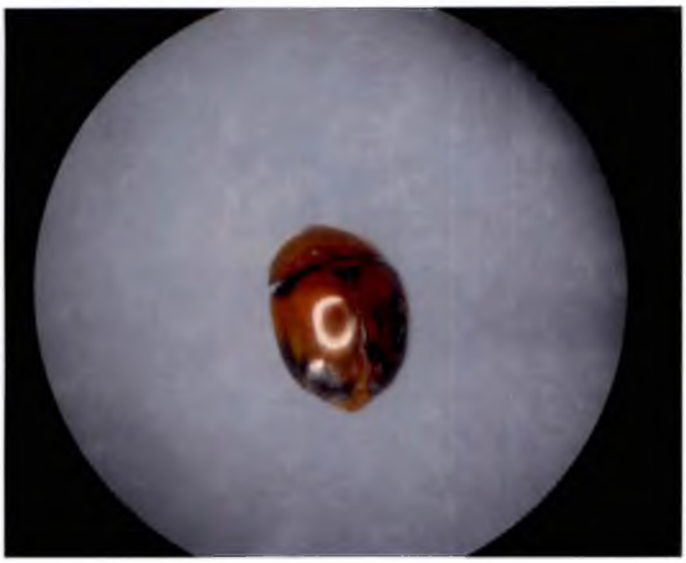
4.1.1.5 Non insect pests

Mites

The juveniles and adults of parasitic mites are light brown in colour and fast moving, body oval with slightly narrow anteriorly and all the four pairs of legs long with simple setae. Pre tarsi of all legs ending with a pair of claws and an empodium distally.

Adult of *Staphylinus* sp.

S. nigrofasciatum



Cyllodes sp.

Holes on the fruit bodies

Total deformation of sporocarps

Plate 5. Beetle pests and their damage

terpillar of Noctuid moth (Semilooper)

Damage by Noctuid caterpillar

Damage by mites

Disappearance of mycelium and decay of substrate

Plate 6. Damage by noctuid caterpillar and mites

Nature and Extent of damage

The feeding of these insects resulted in the disappearance of mycelium from spawned compost and resulted in the rotting of beds. Parasitic mites were attracted by the weed moulds on which they fed and multiplied (Plate 6).

Slugs and Snails

The slug was green in colour and body asymmetrical and spirally coiled when disturbed. They are found to feed voraciously, making tunnels in the stipe as well as on the gills and lower portion of pileus (Plate 7).

4.2 OCCURRENCE OF PESTS AND THEIR EXTENT OF DAMAGE IN MUSHROOM

4.2.1 Occurrence of Pests

The data on the population of mushroom pests recorded from five different locations during the period from April 2006 to March 2007 are presented in Tables 2 to 10.

***Seira* sp.**

Wide variation in the population was observed during the period under study, the range being 47.48 to 241.60 (Table 2). The population of the pest was significantly lower during March 2007 (47.48).This was followed by April 2006 (60.64), February 2007 (62.96) which were on par. An increasing trend in the population was observed from the month of May 2006, reaching the highest during October-November 2006 and were at par. The population recorded during the period being, May 2006 (107.08), June 2006 (98.04), July 2006 (218.60), August 2006 (222.40), September 2006 (231.28), October 2006 (241.60) and November 2006 (241.52).

Perusal of the data on the population in the five different locations it could be seen that, the lowest population was in the first location (Instructional Farm, Vellayani; 149.05). Significantly higher population was observed in the fifth location (Thiruvallam; 155.31) as compared to other locations.

There was significant difference in the population of the pest in different locations during various months. In all the locations, the population of *Seira* sp.

Slug

Snail

Tunnels in the stipe

Tunnels in the gills

Plate 7. Damage by slugs and snails

Table 2. Population of *Seira* sp. on mushroom in five locations in Thiruvananthapuram District

Month	Location 1	Location 2	Location 3	Location 4	Location 5	Mean
April 06'	50.20	74.20	57.00	63.60	58.20	60.64
May 06'	118.80	89.80	103.60	102.80	120.40	107.08
June 06'	197.00	199.00	199.40	198.40	196.40	198.04
July 06'	203.60	232.00	215.60	225.60	216.20	218.60
Aug. 06'	216.60	220.00	217.80	222.60	235.00	222.40
Sept. 06'	233.00	228.60	226.00	231.80	237.00	231.28
Oct. 06'	241.60	239.80	240.40	242.20	244.00	241.60
Nov. 06'	240.60	239.60	242.20	238.60	246.60	241.52
Dec. 06'	108.00	107.80	108.60	108.60	136.40	113.88
Jan. 07'	70.80	83.40	66.20	68.00	65.60	70.80
Feb. 07'	65.80	59.60	66.40	67.00	56.00	62.96
Mar. 07'	42.60	47.20	47.60	48.00	52.00	47.48
Mean	149.05	151.75	149.23	151.43	155.31	

CD (0.05)
Location: 3.45
Month : 5.04
Location x month: 11.27

Table 3. Population of *Cyllodes* sp. on mushroom in five locations in Thiruvananthapuram District

Month	Location 1	Location 2	Location 3	Location 4	Location 5	Mean
April 06'	7.60	6.80	6.60	6.20	6.20	6.68
May 06'	6.80	5.80	5.80	6.00	5.00	5.88
June 06'	3.80	4.20	4.00	4.80	2.80	3.92
July 06'	2.40	2.00	1.80	1.80	1.80	1.96
Aug. 06'	1.20	1.20	0.80	1.20	1.20	1.12
Sept. 06'	1.80	1.60	1.80	1.20	1.20	1.52
Oct. 06'	1.40	1.20	1.20	0.80	0.80	1.08
Nov. 06'	1.60	1.20	1.20	1.00	1.40	1.28
Dec. 06'	4.20	3.20	2.80	3.20	2.40	3.16
Jan. 07'	5.40	5.00	3.80	3.60	3.20	4.20
Feb. 07'	6.40	6.40	6.40	6.00	4.40	5.92
Mar. 07'	6.00	6.00	5.40	6.20	5.40	5.80
Mean	4.05	3.71	3.46	3.50	2.98	

CD (0.05)
Location: 0.44
Month : 0.57
Location x month: NS

was the lowest during March 2007. However, population did not vary significantly and it ranged from 42.60 to 52.00 in the different locations.

Location wise comparison of the data indicated that, in the first location, there was no significant difference in the population of the pest from September 2006 to November 2006 and the population ranged from 233 to 241.60.The lowest population of the pest was observed during March 2007 (42.60) and this was on par with the population during April 2006 (50.20).

In the second location, highest population was recorded during October 2006 (239.80) which was on par with November 2006 (239.60), July 2006 (232.00) and September 2006 (228.60).

The population observed during October 2006 (240.40) and November 2006 (242.20) were on par and significantly higher than other months in the third location.

Highest population in the fourth location was recorded during October 2006 (242.20).The population during September 2006 (231.80) and November 2006 (238.60) were statistically similar with that of October 2006 (242.20). Significantly, lower population was observed during March 2007 (48.00).

In the fifth location, the population of *Seira* sp. was the highest during November 2006 (246.60). The population of the pest from September 2006 to November 2006 was on par and the population ranged from 237.00 to 246.60.The lowest population was observed during March 2007(52.00) and was at par with February 2007 (56.00) and April 2006 (58.20).

***Cyllodes* sp.**

The incidence of the *Cyllodes* sp. was observed in all the five locations throughout the period of observation from April 2006 to March 2007 (Table 3).

The mean population of *Cyllodes* sp. ranged from 1.08 to 6.68. The lowest population was recorded in October 2006 (1.08) which was at par with those recorded during August 2006 (1.12), November 2006 (1.28) and September 2006 (1.52). The population of *Cyllodes* sp. was the highest during April 2006 (6.68) and was significantly higher than the population recorded till March 2007 (5.80).The population showed a declining trend until November 2006 and the population recorded during the period being 5.88 (May 2006), 3.92(June 2006), 1.96 (July 2006), 1.12 (August 2006), 1.52 (September 2006), 1.08 (October 2006) and 1.28 (November 2006).Thereafter an increase in population was observed the mean being 3.16 (December 2006), 4.20 (January 2007), 5.92 (February 2007) and 5.80 (March 2007).

The comparison of the mean population in different locations showed significant difference. The highest incidence of cucujoid beetle was observed in the first location (4.05) and was on par with second location (KVK, Mitraniketan, Vellanad ; 3.71).However, the population in second location (3.71) was at par with third (Swathishta mushrooms, PTP Nagar ; 3.46) and fourth (Manacaud; 3.50) locations. Population at fifth location (Thiruvallam ; 2.98) was significantly lower.

The population recorded from the five locations during different months did not show any significant difference.

Megaselia. **sp**

The population of *Megaselia* sp. was observed throughout the year and ranged from 1.00 to 7.92 (Table.4). The population declined significantly during June 2006 (2.52) after recording higher population during April 2006 (7.92) and May 2006 (5.60). The population recorded during July 2006 (1.20), August 2006 (1.00), September 2006 (1.04) October 2006 (1.00) and November 2006 (1.12) was statistically similar. The population increased still further during January 2007 (2.04) to March 2007 (6.20).

Location wise comparison of the data revealed that the mean population did not show significant variation. Similarly, there was no significant difference when the population of *Megaselia* sp. and the interaction between the different months and locations were considered.

S. nigrofasciatum

The data on population of *S. nigrofasciatum* recorded from the five locations during the period of one year are presented in Table 5.

The mean population of the beetle recorded during the period under study ranged from 0.96 to 4.76. The mean population recorded during April 2006 (3.84) and May 2006 (3.92) which were on par were significantly higher than those

Table 4. Population of *Megaselia* sp. on mushroom in five locations in Thiruvananthapuram District

Month	Location 1	Location 2	Location 3	Location 4	Location 5	Mean
April 06'	7.80	9.80	6.80	8.60	6.60	7.92
May 06'	6.20	5.60	5.40	5.20	5.60	5.60
June 06'	3.00	2.80	2.00	2.20	2.60	2.52
July 06'	1.40	1.00	1.20	1.20	1.20	1.20
Aug. 06'	0.80	1.20	0.80	1.20	1.00	1.00
Sept. 06'	0.80	0.80	1.20	1.20	1.20	1.04
Oct. 06'	0.80	0.80	1.20	1.20	1.00	1.00
Nov. 06'	0.80	0.80	1.20	1.20	1.60	1.12
Dec. 06'	1.80	1.60	1.60	1.60	2.20	1.76
Jan. 07'	1.80	1.80	2.20	2.20	2.20	2.04
Feb. 07'	3.80	3.60	3.20	3.40	5.20	3.84
Mar. 07'	6.60	6.20	6.20	5.60	6.40	6.20
Mean	2.96	3.00	2.75	2.90	3.06	

CD (0.05)
Location: NS
Month : 0.67
Location x month: NS

Table 5. Population of *S. nigrofasciatum* on mushroom in five locations in Thiruvananthapuram District

Month	Location 1	Location 2	Location 3	Location 4	Location 5	Mean
April 06'	3.80	3.80	3.80	3.60	4.20	3.84
May 06'	4.20	4.40	3.80	3.40	3.80	3.92
June 06'	3.20	2.80	3.40	3.40	3.20	3.20
July 06'	1.20	1.60	1.60	1.60	1.20	1.44
Aug. 06'	0.80	1.20	1.00	1.00	0.80	0.96
Sept. 06'	1.00	1.60	1.20	0.80	0.80	1.08
Oct. 06'	1.00	1.20	1.20	1.20	1.20	1.16
Nov. 06'	0.80	1.20	1.00	1.20	0.80	1.00
Dec. 06'	1.80	1.60	1.60	1.60	2.00	1.72
Jan. 07'	3.80	2.80	2.80	3.00	2.80	3.04
Feb. 07'	5.00	4.00	3.80	4.00	3.80	4.12
Mar. 07	5.80	5.00	3.80	4.20	5.00	4.76
Mean'	2.70	2.60	2.41	2.41	2.46	

CD (0.05)
Location: NS
Month : 0.50
Location x month: NS

observed during the consecutive months namely, June 2006, July 2006 , August 2006, September 2006, October 2006, November 2006, December 2006 and January 2007, the population being 3.20,1.44,0.96,1.08,1.16,1.00,1.72 and 3.04 respectively. On the other hand the population observed during February 2007 (4.12) and March 2007 (4.76) were significantly higher than those observed in all the other months.

The data indicated that there were no significant difference in the mean population of the pest in different locations and the population of *S. nigrofasciatum* had no significant difference when the populations at different locations and months were considered.

***Staphylinus* sp.**

The data on the population of *Staphylinus* sp. observed during the study period. *Staphylinus* sp. population was seen only in three locations *viz*., Instructional Farm, Vellayani, KVK, Mitraniketan, Vellanad and Swathishta Mushrooms, PTP Nagar are depicted in Table 6.

The mean population of the pest during the different periods ranged from 1.13 to 5.00. The lowest population was recorded during November 2006 (1.13) and was on par with those recorded during July 2006 to October 2006 and the population ranged from 1.20 to 1.73. The highest population was recorded during April 2006 (5.00) which was statistically similar with that of March 2007 (4.80). There was a significant decline in the population from June 2006 (1.86) to November 2006 (1.13) after recording higher population during December 2006 (2.33) to March 2007 (4.80).

There was no significant difference in the mean population of *Staphylinus* sp. observed in all the locations. Similarly, there was no significant variation in the population when the interaction with the locations and periods under study was considered.

P. necrophori

Unlike other pests, the population of *P. necrophori* is observed only in one location (Instructional Farm, Vellayani) during the period from September 2006 to March 2007 (Table 7).

Table 6. Population of *Staphylinus* sp. on mushroom in three locations in Thiruvananthapuram District

Month	Location 1	Location 2	Location 3	Mean
April 06'	5.20	4.80	5.00	5.00
May 06'	3.20	3.80	3.60	3.53
June 06'	2.20	1.80	1.60	1.86
July 06'	2.20	1.60	1.40	1.73
Aug. 06'	1.80	1.80	1.40	1.66
Sept. 06'	1.20	1.00	1.60	1.26
Oct. 06'	1.20	1.20	1.20	1.20
Nov. 06'	1.40	1.00	1.00	1.13
Dec. 06'	2.80	2.00	2.20	2.33
Jan. 07'	4.20	3.00	3.20	3.46
Feb. 07'	4.40	3.80	4.00	4.06
Mar. 07'	4.80	4.80	4.80	4.80
Mean	2.88	2.55	2.58	

CD (0.05)

Location: NS

Month : 0.66

Location x month: NS

Table 7. Population of non-insect pests on mushroom in the Instructional Farm, Vellayani.

Month	Population of	
	P. necrophori	Slug
Sept. 06'	244.80	1.40
Oct. 06'	242.80	1.20
Nov. 06'	229.00	1.00
Dec. 06'	189.60	1.20
Jan. 07'	186.40	0.40
Feb. 07'	180.60	0.20
Mar. 07'	100.60	0.00
Mean	**196.25**	**0.77**
CD (0.05)	10.39	0.80

The populations observed during September 2006 (244.80) and October 2006 (242.80) which were on par were significantly higher than rest of the periods. The lowest population of mite was observed during March 2007 (100.60).

Slug

Unlike other pests, the population of slug was also observed only in one location (Instructional Farm, Vellayani) during the period from September 2006 to March 2007 (Table 7).

The mean population of slug recorded during the period ranged from 0 to 1.40. The population observed during September 2006 (1.40) was significantly higher than the rest of the periods and it was at par with October 2006 (1.20), November 2006 (1.00), and December 2006 (1.20). Thereafter, the population showed a declining trend till March 2007 (0).

4.2.2 Extent of Damage by Mushroom Pests

***Seira* sp.**

The percentage area damaged by the *Seira* sp. in mushroom bed during April 2006 to March 2007 in five locations is depicted in the Table 8.

There was significant variation on the extent of damage caused by *Seira* sp. to the beds of mushroom during different months, the range being 17.9 to 53.70 per cent. The lowest damage was recorded during the month of April 2006 (17.90). A significant increase in the damage was noticed from May 2006 (22.20) reaching the maximum during October 2006 (53.70) which was at par with September 2006 (53.60). There after reduction in the damage was observed, the mean damage being 50.80, 40.30, 30.20, 24.50 and 18.47 respectively for the months of November 2006, December 2006, January 2007, February 2007 and March 2007.

The damage to mushroom bed caused by *Seira* sp. recorded in five different locations indicated that the damage varied significantly among the locations.The damage recorded in location one was significantly higher (37.32) than the other locations, it was significantly lower in the second location (36.30). The damage in third, fourth and fifth locations did not vary significantly the damage being 36.84, 36.77 and 36.64 respectively.

Table 8.Extent of damage (per cent area damaged) caused by *Seira* sp. in five locations in Thiruvananthapuram District

Month	Location 1	Location 2	Location 3	Location 4	Location 5	Mean
April 06'	21.13 (27.35)	17.00 (24.34)	16.92 (24.28)	17.07 (24.39)	17.69 (24.86)	17.90 (25.04)
May 06'	23.94 (29.28)	22.27 (28.15)	22.53 (28.33)	21.31 (37.48)	21.12 (27.35)	22.20 (28.12)
June 06'	29.22 (32.71)	28.28 (32.11)	28.47 (32.23)	27.54 (31.64)	27.27 (31.47)	28.10 (32.03)
July 06'	49.73 (44.83)	46.07 (42.73)	42.98 (40.95)	41.81 (40.27)	40.28 (39.38)	44.10 (41.63)
Aug. 06'	52.16 (46.22)	52.63 (46.48)	51.04 (45.57)	50.68 (45.37)	49.73 (44.83)	51.20 (45.69)
Sept. 06'	53.59 (47.04)	53.96 (47.25)	53.21 (46.82)	53.85 (47.19)	53.86 (47.19)	53.60 (47.10)
Oct. 06'	53.65 (47.07)	53.95 (47.25)	53.51 (46.99)	54.03 (47.29)	53.59 (47.04)	53.70 (47.13)
Nov. 06'	53.63 (47.06)	41.34 (40.00)	53.09 (46.75)	52.92 (46.65)	53.29 (46.87)	50.80 (45.47)
Dec. 06'	41.24 (39.94)	38.75 (38.48)	40.79 (39.67)	40.17 (39.31)	40.76 (39.66)	40.30 (39.41)
Jan. 07'	29.18 (32.68)	30.99 (33.81)	30.13 (33.28)	30.60 (33.57)	30.63 (33.59)	30.20 (33.39)
Feb. 07'	22.45 (28.27)	23.61 (29.06)	25.14 (30.08)	26.55 (31.00)	24.94 (29.94)	24.50 (29.67)
Mar. 07'	17.69 (24.86)	19.15 (25.94)	17.90 (25.04)	18.33 (25.34)	19.31 (26.06)	18.47 (25.44)
Mean	37.32 (36.7)	36.30 (35.0)	36.84 (35.9)	36.77 (35.8)	36.64 (35.6)	

(Figures in parentheses are values after angular transformation)

CD (0.05)

Location : 0.43
Month : 0.64
Location x month : 1.42

The damage by *Seira* sp. during various months at different locations indicated that the extent of damage was the lowest during April 2006 in all the five locations and it ranged from 16.92 to 21.13.

In the first location, the maximum extent of damage was observed from August 2006 (52.16) to November 2006 (53.63) which were at par. The damage was significantly lower during March 2007 (17.69).

In the second location, the maximum damage caused by *Seira* sp.was observed during September, 2006 (53.96) and which was statistically similar to that of August 2006 (52.63) and October 2006 (53.95). There was a significant decline in the damage from November 2006 (41.34) to March 2007 (19.15).

The maximum damage to mushroom beds was observed from August 2006 (51.04) to November 2006 (53.09) which were at par. The damage was significantly lower during April 2006 (16.92) in the third location.

The highest extent of damage was recorded in the fourth location during October 2006 (54.03) and was on par with the damage noted during September 2006 (53.85) and November 2006 (52.92).

In fifth location, the lowest damage caused by *Seira* sp. was during April 2006 (17.69). The maximum damage by the pest was during September 2006 (53.86) and was statistically similar with the extent of damage noted during October 2006 and November 2006 and damage being 53.59 and 53.29 respectively.

***Cyllodes* sp.**

The infestation by *Cyllodes* sp. was recorded throughout the period of observation from all the five locations and the related data is presented in the Table 9.

There was significant variation on the mean damage to the sporocarp by the pest during different months the range being 4.10 to 44.40 per cent. The infestation was lowest during the month of October 2006 (4.10). The maximum damage by *Cyllodes* sp. was during March 2007 (44.40) and which were at par with the damage caused during April 2006 (41.10), May 2006 (40.20) and February 2007 (40.70).

Table 9. Extent of damage (per cent) by *Cyllodes* sp. on sporocarp in five locations in Thiruvananthapuram District

Month	Location 1	Location 2	Location 3	Location 4	Location 5	Mean
April.06'	37.40 (37.68)	44.77 (41.98)	38.18 (38.15)	44.00 (41.54)	41.59 (40.14)	41.10 (39.90)
May 06'	43.08 (41.00)	35.36 (36.47)	44.81 (42.00)	41.33 (39.99)	37.06 (37.48)	40.20 (39.39)
June 06'	43.08 (41.00)	35.36 (36.47)	44.81 (42.00)	41.33 (39.99)	37.06 (37.48)	40.20 (39.39)
July 06'	12.76 (20.92)	3.08 (10.11)	5.06 (13.00)	6.63 (14.92)	7.60 (16.00)	6.60 (14.99)
Aug. 06'	2.79 (9.61)	8.85 (17.30)	3.08 (10.11)	8.18 (16.61)	3.08 (10.11)	4.80 (12.75)
Sept. 06'	9.88 (18.31)	7.71 (16.11)	3.51 (10.80)	3.51 (10.80)	3.08 (10.11)	5.20 (13.23)
Oct. 06'	3.08 (10.11)	3.51 (10.80)	7.71 (16.11)	3.08 (10.11)	3.84 (11.30)	4.10 (11.69)
Nov. 06'	3.84 (11.30)	8.67 (17.12)	7.71 (16.11)	3.08 (10.11)	3.51 (10.80)	5.10 (13.09)
Dec. 06'	9.36 (17.81)	16.50 (23.95)	7.71 (16.11)	3.08 (10.11)	28.35 (32.15)	11.70 (20.03)
Jan. 07'	25.98 (30.63)	28.64 (32.34)	36.48 (37.14)	40.54 (39.53)	40.40 (39.45)	34.20 (35.82)
Feb. 07'	46.01 (42.69)	34.18 (35.76)	44.00 (41.54)	43.61 (41.31)	36.28 (37.02)	40.70 (39.66)
Mar. 07'	38.19 (38.15)	53.25 (46.84)	45.97 (42.67)	44.00 (41.54)	40.78 (39.67)	44.40 (41.78)
Mean	25.60 (18.6)	26.59 (20.0)	26.23 (19.5)	25.63 (18.6)	25.37 (18.3)	

(Figures in parentheses are values after angular transformation)

CD (0.05)

Location : 5.41

Month : 7.13

Location x month : NS

The damage caused by the pest differed significantly in various locations. The damage in the second location (26.59) was higher extent of damage than other locations. The damage in the first location (25.60) had no significant variation with the damage in the second (26.59), third (26.23), fourth (25.63) and fifth (25.37) locations.

No significant difference was observed in the damage caused by the pest when the interaction between the extent of damage observed in different months and locations was considered.

4.3 CORRELATION BETWEEN WEATHER PARAMETERS AND POPULATION OF PESTS AND EXTENT OF DAMAGE

4.3.1 Correlation between Weather Parameters and Population of the Pests *Seira* sp.

Correlation coefficients between the population of *Seira* sp. and weather parameters existed in the previous month and current the month of observations at five different locations are presented in Table10.

Considering the correlation between the population of *Seira* sp. and the weather parameters prevailed in the previous month in all the five locations it could be seen that there existed a significant negative correlation with maximum temperature (r value = -0.6857 to -0.8023). A significant positive correlation with relative humidity, the r values being 0.7813, 0.7450, 0.7548, 0.7588 and 0.8029 for the first, second, third, fourth and fifth locations respectively was observed. Similarly, rainfall and number of rainy days also had a significant positive correlation. However, the minimum temperature did not exert any significant influence the population of *Seira* sp. in all the five locations.

As in the case of the relation between population and maximum temperature of previous month there existed a significant negative correlation between population and maximum temperature prevailed during the current month, the range in the r value being -0.8557 to -0.9557. A significant positive correlation with relative humidity (r-value= 0.9072 to 0.9383), rainfall (r-value= 0.7116 to 0.7623) and number of rainy days (r-value = 0.7918 to 0.8951) was

Table 10. Correlation between the population of *Seira* sp. and weather parameters during the previous and current month in five locations in Thiruvananthapuram District

Parameters	Previous month					Current month				
	Locations					Locations				
	1	2	3	4	5	1	2	3	4	5
Maximum temperature	-0.7011**	-0.7927**	-0.8023**	-0.6857**	-0.7227**	-0.8641**	-0.9557**	-0.9544**	-0.8613**	-0.8557**
Minimum temperature	0.3574	0.2603	0.2692	0.3552	0.3686	0.0848	-0.1215	-0.1175	0.0990	0.1020
Relative humidity	0.7813**	0.7450**	0.7548**	0.7588**	0.8029**	0.9246**	0.9081**	0.9072**	0.9077**	0.9383**
Rainfall	0.7520**	0.6789**	0.7003**	0.7469**	0.7597**	0.7509**	0.7373**	0.7623**	0.7163**	0.7116**
Number of rainy days	0.7969**	0.8146**	0.8257**	0.7822**	0.8090**	0.8235**	0.8809**	0.8951**	0.7918**	0.7968**

** Significant at 0.01
* Significant at 0.05

observed. No significant correlation was noticed between the population and minimum temperature in all the five locations.

Cyllodes sp.

The population of *Cyllodes* sp. and weather parameters was correlated with the previous month and current the month of observation (Table 11).

The population of *Cyllodes* sp. showed significant positive correlation with the maximum temperature prevailed the previous month in first, (0.8822), second (0.9397), third (0.9222), fourth (0.8544) and fifth (0.9101) locations and a significant negative correlation with relative humidity, amount of rainfall and number of rainy days. As in the case of population of *Seira* sp. minimum temperature did not exhibit any significant difference in the population.

Weather parameters prevailed during the current month, it could be seen that the maximum and minimum temperatures had a positive influence, but the minimum temperature did not have a significant influence with the pest population. The population of *Cyllodes* sp. showed significant negative correlation with relative humidity, amount of rainfall and number of rainy days in all the five locations.

***Megaselia* sp.**

Correlation between the incidence of *Megaselia* sp. and weather parameters with the previous month and current month of observation in all the five locations is depicted in the Table 12.

The maximum temperature had significant positive correlation with the population of *Megaselia* sp. (r value = 0.8013 to 0.9143). Where as the relative humidity (-0.5430 to -0.9007) amount of rainfall (-0.5294 to -0.6138) and the number of rainy days (-0.5799 to -0.6759) had significant negative correlation with the population of pest in the previous month in all the five locations. The minimum temperature did not exert any significant correlation with the population.

Examination of the relation between population and a maximum temperature during the current month in all the five locations, it was evident that there existed a significant positive correlation (r-value= 0.7614 to 0.8529). Similarly, minimum temperature also had positively correlated. The population of

Table 11. Correlation between the population of *Cyllodes* sp. and weather parameters during the previous and current month in five locations in Thiruvananthapuram District

Parameters	Previous month					Current month				
	Locations					Locations				
	1	2	3	4	5	1	2	3	4	5
Maximum temperature	0.8822**	0.9397**	0.9222**	0.8544**	0.9101**	0.7954**	0.8805**	0.8367**	0.8244**	0.8575**
Minimum temperature	-0.0612	0.0182	0 .0995	-0.0215	-0.0190	0.1729	0.3748	0.4427	0.2547	0.3363
Relative humidity	-0.8225**	-0.8458**	-0.8014**	-0.8628**	-0.9031**	-0.8027**	-0.7987**	-0.7414**	-0.7725**	-0.7672**
Rainfall	-0.7137**	-0.7133**	-0.6768**	-0.6756**	-0.6787**	-0.5780*	-0.6371**	-0.5512*	-0.5496*	-0.5605*
Number of rainy days	-0.7455**	-0.8448**	-0.8032**	-0.7210**	-0.7271**	-0.6631**	-0.7511**	-0.6681**	-0.6458**	-0.6203**

** Significant at 0.01

* Significant at 0.05

Table 12. Correlation between the population of *Megaselia* sp. and weather parameters during the previous and current month in five locations in Thiruvananthapuram District

Parameters	Previous month					Current month				
	Locations					Locations				
	1	2	3	4	5	1	2	3	4	5
Maximum temperature	0.9072**	0.8013**	0.8296**	0.9143**	0.8533**	0.8197**	0.7614**	0.7969**	0.7677**	0.8529**
Minimum temperature	0.1375	0.3307	0.2413	0.1435	-0.0603	0.5363*	0.7243**	0.6688**	0.5373*	0.3530
Relative humidity	-0.8829**	-0.5430*	-0.6306**	-0.8705**	-0.9007**	-0.6081**	-0.5010*	-0.5164*	-0.5593*	-0.7094**
Rainfall	-0.5930*	-0.5294*	-0.5622*	-0.5680*	-0.6138**	-0.3961	-0.4124	-0.4017	-0.3813	-0.4664
Number of rainy days	-0.6233**	-0.5799*	-0.6759**	-0.5835*	-0.6579**	-0.4456	-0.4514	-0.4795	-0.4062	-0.5220*

** Significant at 0.01
* Significant at 0.05

the pest showed significant negative correlation with relative humidity. No significant correlation was noted between the population and rainfall amount and number of rainy days in all the five locations.

S. nigrofasciatum

The weather parameters during the previous month and current month of observation were correlated with the pest population of *S. nigrofasciatum* and the data are presented in the Table 13.

The population of Staphylinid beetle of the previous month showed significant positive correlation with the maximum temperature in all the five locations, the r values being 0.7240, 0.8922, 0.9457, 0.8090 and 0.8215 for the first, second, third, fourth and fifth locations respectively but significant negative correlation was shown with relative humidity, rainfall and number of rainy days. As in the case of population of *Megaselia* sp. the minimum temperature did not exhibit any significant inference in the population of *S. nigrofasciatum.*

During the current month of observation, the population of *S. nigrofasciatum* had significant positive correlation with maximum temperature (0.7728 to 0.9056) in five different locations and negative correlation with relative humidity (r value = -0.6255 to -0.8810), rainfall (r value = -0.5133 to -0.5407) and number of rainy days (r value = -0.6150 to -0.6569). No significant correlation was observed between the population and minimum temperature in all the five locations.

***Staphylinus* sp.**

The population of *Staphylinus* sp. and weather parameters was correlated with previous and corresponding month of observation in three different locations and the details are depicted in the Table 14.

The population of *Staphylinus* sp. of the previous month of observation had significant positive correlation with maximum temperature in three different locations and the r-values were 0.7893, 0.8584 and 0.8432 respectively. There was significant negative correlation with the relative humidity (-0.7550 to -0.8694) amount of rainfall (-0.7138 to -0.7362) and number of rainy days (-0.8071 to -0.8417) in different locations. The minimum temperature did not correlate significantly with the population of the pest.

Table 13. Correlation between the population of *S. nigrofasiatum* and weather parameters during the previous and current month in five locations in Thiruvananthapuram District.

Parameters	Previous month					Current month				
	Locations					Locations				
	1	2	3	4	5	1	2	3	4	5
Maximum temperature	0.7240**	0.8922**	0.9457**	0.8090**	0.8215**	0.8836**	0.7957**	0.7728**	0.8272**	0.9056**
Minimum temperature	-0.2870	0.0694	0.1584	-0.1416	-0.1201	0.0397	0.4897	0.4840	0.1486	0.2239
Relative humidity	-0.8553**	-0.8510**	-0.8704**	-0.8650**	-0.8806**	-0.8810**	-0.6255**	-0.6675**	-0.8172**	-0.8014**
Rainfall	-0.7083**	-0.7142**	-0.6834**	-0.6237**	-0.6571**	-0.5407*	-0.5133*	-0.5310*	-0.5274*	-0.5086*
Number of rainy days	-0.7775**	-0.8621**	-0.8176**	-0.7100**	-0.7119**	-0.6569**	-0.6150**	-0.6280**	-0.6498**	-0.6224**

** Significant at 0.01

* Significant at 0.05

Table 14. Correlation between the population of *Staphylinus* sp. and weather parameter during the previous and current month in three locations in Thiruvananthapuram District

Parameters	Previous month			Current month		
	Locations			Locations		
	1	2	3	1	2	3
Maximum temperature	0.7893**	0.8584**	0.8432**	0.8601**	0.8770**	0.9030**
Minimum temperature	-0.2967	-0.0154	-0.0869	0.0237	0.4515	0.3976
Relative humidity	-0.8694**	-0.7616**	-0.7550**	-0.9173**	-0.6947**	-0.7360**
Rainfall	-0.7362**	-0.7138**	-0.7297**	-0.7413**	-0.6393**	-0.6102**
Number of rainy days	-0.8071**	-0.8329**	-0.8417**	-0.8045**	-0.7067**	-0.7340**

** Significant at 0.01
* Significant at 0.05

The maximum temperature exerted significant positive correlation with the population of *Staphylinus* sp. during the current month of observation in the first (0.8601), second (0.8770) and third (0.9030) locations, whereas relative humidity, rainfall and number of rainy days had significant negative correlation with the population of pest. No significant correlation was noticed between the population and minimum temperature in all the three locations.

P. necrophori

Correlation between the pest population *P. necrophori* and weather parameters during the month and previous month of observation are presented in Table 15.

The population of mite, *P. necrophori* had significant negative correlation with maximum temperature (r value = -0.5567) during the previous month of observation. No significant correlation was observed between the population and relative humidity, amount of rainfall and number of rainy days. Significant negative correlation with minimum temperature (r value = -0.6330) was observed.

Weather parameters prevailed during the current month, the minimum temperature had significant negative correlation with the population of *P. necrophori* (r value = -0.7342). The maximum temperature had negative correlation while relative humidity, rainfall and number of rainy days had positive correlation with the population of mites, though the relationships were not significant.

Slug

The pest population of slug was correlated with weather parameters previous and current month of observation (Table 15).

During the previous month, the maximum temperature showed significant negative correlation with the population of slug (r value = -0.6467). The relative humidity (0.7197) and number of rainy days (0.6350) indicated significant positive correlation with the pest population. The minimum temperature and rainfall did not exhibit any significant difference in the population.

The maximum and minimum temperature, relative humidity, rainfall amount and number of rainy days did not exert any significant difference in the pest population.

Table 15. Correlation between the population of non- insect pests and weather parameters during the previous and current month in the Instructional Farm, Vellayani.

Parameters	*P. necrophori*		Slug	
	Previous month	Current month	Previous month	Current month
Maximum temperature	-0.5567*	-0.1676	-0.6467**	-0.4220
Minimum temperature	-0.6330**	-0.7342**	-0.2233	-0.4486
Relative humidity	0.4680	0.0995	0.7197**	0.4829
Rainfall	0.3121	0.2807	0.4915	0.4966
Number of rainy days	0.3822	0.2326	0.6350**	0.4909

** Significant at 0.01
* Significant at 0.05

4.3.2 Correlation between Weather Parameters and the Extent of Damage

***Seira* sp.**

The relationship between the extent of damage caused by the sprigtail *Seira* sp. and the weather parameters prevailed in the preceding month and during the month of observations in five different locations are presented in the Table 16.

As observed in the case of population, with respect to the percentage area damaged by *Seira* sp. also significant negative correlation with the maximum temperature prevailed in the previous month in all five different locations (r = -0.8316 to -0.9548) was seen. The infestation had significant positive correlation with the relative humidity, rainfall and number of rainy days of the previous month. The minimum temperature did not exert any significant correlation with extent of damage.

During the current month of observation, the extent of damage caused by *Seira* sp. was observed that there existed a significantly negative correlation with maximum temperature (r-values = -0.7895 to -0.8639). Significant positive correlation with relative humidity, rainfall and number of rainy days and the damage negatively correlated with minimum temperature in all the locations did not exhibited any significant relation.

***Cyllodes* sp.**

The extent of damage caused by *Cyllodes* sp. and weather parameter was correlated with the previous and current month of observation (Table 17).

The damage caused by *Cyllodes* sp. during the previous month had significant positive correlation with maximum temperature (r value = 0.7819 to 0.9281) in five different locations and significant negative correlation with relative humidity, rainfall and number of rainy days. No significant correlation was observed between the population and minimum temperature in all the five locations.

There was significant positive correlation with maximum temperature (r value = 0.7380 to 0.9069) and negative correlation with relative humidity (r value = -0.6733 to -0.8839) and number of rainy days (r value = -0.5521 to -0.7506) in five different locations when the damage by *Cyllodes* sp. during the

Table 16. Correlation between the extent of damage by *Seira* sp. and weather parameters during the previous and current month in five locations in Thiruvananthapuram District.

Parameters	Previous month					Current month				
	Locations					Locations				
	1	2	3	4	5	1	2	3	4	5
Maximum temperature	-0.8316**	-0.9011**	-0.9548**	-0.9025**	-0.9018**	-0.8598**	-0.8639**	-0.8405**	-0.8094**	-0.7895**
Minimum temperature	0.1098	-0.0970	-0.1479	-0.0547	-0.0542	-0.1628	-0.4060	-0.4671	-0.3075	-0.3007
Relative humidity	0.8629**	0.7638**	0.8366**	0.8547**	0.8614**	0.8300**	0.7190**	0.7326**	0.7724**	0.7769**
Rainfall	0.6973**	0.5346*	0.6880**	0.6769**	0.6865**	0.5801*	0.6239**	0.6454**	0.5771*	0.5766*
Number of rainy days	0.7524**	0.7321**	0.8042**	0.7389**	0.7539**	0.6870**	0.6920**	0.6994**	0.6723**	0.6723**

** Significant at 0.01
* Significant at 0.05

Table 17. Correlation between the extent of damage by *Cyllodes* sp. and weather parameters during the previous and current month in five locations in Thiruvananthapuram District.

Parameters	Previous month					Current month				
	Locations					Locations				
	1	2	3	4	5	1	2	3	4	5
Maximum temperature	0.8296**	0.8514**	0.9281**	0.8275**	0.7819**	0.7380**	0.9069**	0.7922**	0.7930**	0.8334**
Minimum temperature	-0.0698	-0.0348	-0.0122	-0.1452	-0.2242	0.1930	0.4171	0.3613	0.1493	0.0080
Relative humidity	-0.8539**	-0.7810**	-0.9041**	-0.9048**	-0.7670**	-0.7788**	-0.7255**	-0.6733**	-0.8272**	-0.8839**
Rainfall	-0.7145**	-0.6569**	-0.6734**	-0.7477**	-0.7290**	-0.4552	-0.6210**	-0.5197*	-0.5269*	-0.6575**
Number of rainy days	-0.7612**	-0.7874**	-0.8852**	-0.8159**	-0.7796**	-0.5521*	-0.7451**	-0.6521**	-0.6055**	-0.7506**

** Significant at 0.01
* Significant at 0.05

current month observation was correlated. The minimum temperature and rainfall did not exhibit any significant difference in the extent of damage.

4.4 FIELD EVALUATION OF BOTANICALS AND INSECTICIDES AGAINST PESTS OF MUSHROOM

4.4.1 Efficacy of Various Insecticidal Treatments on the Incidence of Springtails in Mushroom

Perusal of the data presented in Table 18 indicated significant difference in the population of *Seira* sp. in all the treatments at different time of application. The mean population in the mushroom bed which received chlorpyriphos 0.02 per cent treatment at fifteenth day after bed preparation recorded the lowest mean count of 72.94, which was on par with the population in beds sprayed with dichlorvos 0.02 per cent at fifteenth day after bed preparation and which received floor treatment with lindane 0.05 per cent, the mean count being 78.44 and 113.05 respectively. However, the populations in all the treatments were significantly higher in beds, which received the treatments at the time of bed preparation than which received application at five, ten and fifteen days after bed preparation.

Since the occurrence of the pest was observed on 11 days after bedding, the first day of observation considered with 11 days after spraying in the case of treatment given at the time of bed preparation and 5 days after spraying in the case of treatment given at 5 days after bed preparation and 1 day after spray in the case of treatment given at 10 days after bed preparation.

On the first day of observations there was significant reduction in the population of springtails over control in mushroom beds which received the treatments at the time of bed preparation, 5, 10 and 15 days after bed preparation and also in beds where the floor treatment with lindane was done. The lowest population was recorded in the mushroom beds, which received lindane 0.05 per cent as floor treatment, the mean population was 7.66. This was at par with those recorded in beds which received the Chlorpyriphos 0.02 per cent at fifteenth day after bed preparation (54.66), fifth day (56.33) and 10 day after bed preparation (88.00) and dichlorvos 0.02 per cent at 5 day after bed preparation (82.33) and 15

Table 18.Population of Springtails during different time of insecticides application at different intervals

Treatments	Different intervals after spraying the pesticides					
	10 DAS	13 DAS	15 DAS	17 DAS	20 DAS	25 DAS	Mean
At the time of bed preparation							
Neem Azal 1 %	580.00	592.00	608.00	615.00	633.00	720.00	624.66
Neem oil+ garlic 2 %	520.00	532.00	569.00	590.00	610.00	690.00	585.16
Dichlorvos 0.02 %	504.00	512.00	530.00	562.00	605.00	736.00	574.83
Malathion 0.05 %	485.00	496.00	523.00	549.00	591.00	650.00	549.00
Dimethoate 0.05 %	566.00	580.00	600.00	613.00	638.00	680.00	612.83
Chlorpyriphos 0.02 %	420.00	455.00	486.00	506.00	535.00	602.00	500.66
Fenvalerate 0.03 %	510.00	525.00	540.00	564.00	584.00	600.00	553.83
Lambda cyhalothrin 0.05%	505.00	526.00	578.00	592.00	604.00	656.00	576.83
Control	650.00	690.00	734.00	760.00	810.00	1002.00	774.33
5 Day after bed preparation							
	5 DAS	**8 DAS**	**10 DAS**	**12 DAS**	**15 DAS**	**20 DAS**	**Mean**
Neem Azal 1 %	354.00	245.00	386.00	485.33	607.66	757.66	472.61
Neem oil+ garlic 2 %	125.66	113.66	188.66	312.00	397.66	510.33	274.66
Dichlorvos 0.02 %	82.33	74.00	138.33	206.66	277.66	376.00	192.50
Malathion 0.05 %	215.33	214.66	297.00	373.00	471.00	575.66	357.77
Dimethoate 0.05 %	336.66	227.33	317.33	376.00	439.66	516.00	368.83
Chlorpyriphos 0.02 %	56.33	57.33	130.33	190.00	254.33	326.33	169.11
Fenvalerate 0.03 %	378.33	302.00	471.33	550.66	634.00	724.33	510.11
Lambda cyhalothrin 0.05%	311.66	289.66	376.33	433.00	495.66	544.66	408.50
Control	660.00	726.00	768.00	816.00	924.00	1020.00	819.00

Table18. Continued

Treatments	Different intervals after spraying the pesticides						
	1DAS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS	Mean
10 Day after bed preparation							
Neem Azal 1 %	298.66	249.33	194.00	253.33	319.66	384.66	283.27
Neem oil+ garlic 2 %	134.33	103.66	83.00	148.66	200.66	258.66	154.83
Dichlorvos 0.02 %	99.33	77.00	54.33	126.66	204.00	265.33	137.78
Malathion 0.05 %	212.33	154.66	102.00	183.33	253.00	298.66	200.66
Dimethoate 0.05 %	337.66	211.66	144.00	203.33	264.66	327.33	248.11
Chlorpyriphos 0.02 %	88.00	53.00	17.00	81.33	147.66	196.33	97.22
Fenvalerate 0.03 %	223.66	183.00	144.33	214.00	265.66	320.66	225.22
Lambda cyhalothrin 0.05%	167.00	130.33	98.66	149.00	209.33	275.66	171.66
control	720.00	804.00	840.00	912.00	966.00	1068.00	885.00
15 Day after bed preparation							
Neem Azal 1 %	277.66	217.66	163.66	219.00	280.66	332.66	248.55
Neem oil+ garlic 2 %	104.00	72.33	41.33	105.66	162.66	222.33	118.05
Dichlorvos 0.02 %	71.33	41.66	15.33	63.66	111.00	167.66	78.44
Malathion 0.05 %	156.00	114.33	91.33	154.33	220.00	274.00	168.33
Dimethoate 0.05 %	255.33	214.00	158.66	170.00	228.00	259.00	214.16
Chlorpyriphos 0.02 %	54.66	37.00	11.00	60.66	109.33	165.00	72.94
Fenvalerate 0.03 %	200.33	145.66	102.00	161.66	206.66	264.00	180.05
Lambda cyhalothrin 0.05%	137.33	108.33	73.66	127.33	195.66	237.33	146.61
control	1074.00	1128.00	1200.00	1236.00	1320.00	1410.00	1228.00
Floor treatment							
Lindane 0.05%	7.66	36.33	84.00	94.66	197.66	258.00	113.05
Mean	385.62	382.55	419.01	486.49	560.27	633.20	

CD (0.05)
Treatment (T) : 41.00
Time of pesticide application : 14.66; T X D : 89.20

day after bed preparation (71.33).Though significant reduction over control was observed the population recorded in beds treated with Neem Azal 1 per cent at the time of bed preparation were significantly higher than other treatments.

Data on the third day of observations also indicated that all the treatments significantly decreased the population of springtails. The mean population in the beds which received lindane 0.05 per cent as floor treatment was very low (36.33) compared to others. This was on par with those observed in mushroom beds which received the Neem oil – garlic 2 per cent at the 5, 10 and 15 days after bed preparation, dichlorvos 0.02 per cent at the 5, 10 and 15 days after bed preparation, chlorpyriphos 0.02 percent at the 10 and 15 days after bed preparation and malathion 0.05 per cent at fifteenth day after bed preparation. As observed on one day after spraying though significant reduction over control was recorded in bed treated with Neem Azal 1 per cent at the time of bed preparation, the treatment was significantly inferior.

Fifth day of observations also all the treatments recorded significantly lower population of springtails than control. Among the treatments, chlorpyriphos 0.02 per cent, dichlorvos 0.02 per cent, Neem oil – garlic 2 per cent, lambda cyhalothrin 0.05 per cent at 10 and 15 days after bed preparation, malathion 0.05 per cent at 15 day after bed preparation and floor treatment with lindane 0.05 per cent recorded the low population of springtails compared to others and were at par.

All the treatments recorded significantly lower population of springtail than control on seventh day of observations also. Among the treatments, chlorpyriphos 0.05 per cent treated on tenth and fifteenth day after bed preparation was very low, the mean population being 81.33 and 60.66 respectively which were at par with those recorded in beds which received the Neem oil-garlic 2 per cent, dichlorvos 0.02 per cent, lambda cyhalothrin 0.05 per cent at 10 and 15 days after bed preparation and floor treatment with Lindane 0.05 per cent.

Similar to the previous case, all the treatments significantly reduced the population on tenth day of observation. The lowest mean count of 109.33 and 111.00 was observed in chlorpyriphos 0.02 per cent and dichlorvos 0.02 per cent sprayed at fifteen day after bed preparation and which were on par with chlorpyriphos 0.02 per cent at 10 day after bed preparation, Neem oil- garlic 2 per cent, lambda cyhalothrin 0.05 per cent at fifteenth day after bed preparation and floor treatment with lindane 0.05 per cent. Though the mean population in mushroom beds treated with Neem Azal @ T/S 4 ml/lit and fenvalerate 0.03 per cent at all different time of applications was significantly lower than control and the treatments were significantly inferior to all other treatments.

Significant reduction in springtail population continued on fifteenth day of observation in all the treatments. chlorpyriphos 0.02 per cent (165.00) treated at fifteenth day after bed preparation was significantly lower than other treatments. This was at par with those noticed in beds, which received the Neem – oil garlic 2 per cent, dichlorvos 0.02 per cent, lamda cyhalothrin 0.05 per cent at 15 day after bed preparation and Chlorpyriphos 0.02 per cent at 10 day after bed preparation.

4.4.2 Efficacy of Various Botanicals and Insecticidal Treatments on the Incidence of *Seira* sp. Damage in Mushroom

I. Spawn run period

The data on the extent of damage caused by *Seira* sp. during the spawn run period is presented in Table 19.

There was significant difference in the damage by *Seira* sp. in mushroom beds, which received the treatments at the time of bed preparation, 5, and 10, and 15 days after bed preparation and the floor treatment with lindane, it could be observed that there were significantly lower than untreated control. The damage recorded in beds which received the floor treatment with lindane 0.05 per cent, chlorpyriphos 0.02 per cent was significantly low to other chemicals, the mean damage observed being 1.12 and 2.78 respectively. This was followed by the mushroom beds sprayed with neem oil- garlic 2 per cent (4.60), dichlorvos 0.02 per cent (7.04), malathion 0.05 per cent (8.73), lambda cyhalothrin 0.05 per cent (9.77), dimethoate 0.05 per cent (10.15), Neem Azal T/S 4 ml / lit (10.84) and fenvalerate 0.03 per cent (14.47).

Considering efficacy of pesticide treatments given at different intervals after bed preparation, the treatments at 15 days after bed preparation registered significantly lower damage, the mean percentage damage being 7.46.This was

Table 19. Area of mushroom beds damaged by *Seira* sp. during spawn run period in the different pesticide treatments applied at different intervals

Treatment	Different intervals of bed preparation				
	At the time	5 days	10 days	15 days	Mean
Neem Azal 1%	15.09 (22.85)	10.42 (18.83)	9.97 (18.40)	8.35 (16.78)	10.84 (19.22)
Neem oil+ garlic 2%	6.11 (14.30)	5.37 (13.40)	5.02 (12.94)	2.39 (8.90)	4.60 (12.38)
Dichlorvos 0.02%	9.65 (18.09)	8.33 (16.77)	7.63 (16.03)	3.39 (10.61)	7.04 (15.38)
Malathion 0.05 %	10.53 (18.92)	9.86 (18.29)	9.45 (17.89)	5.54 (13.60)	8.73 (17.18)
Dimethoate 0.05 %	13.02 (21.14)	11.88 (20.16)	11.02 (19.38)	5.55 (13.62)	10.15 (18.57)
Chlorpyriphos 0.02%	3.80 (11.23)	3.51 (10.80)	3.43 (10.66)	0.99 (5.71)	2.78 (9.60)
Fenvalerate 0.03 %	20.28 (26.75)	18.32 (25.33)	14.49 (22.37)	6.64 (14.93)	14.47 (22.35)
Lambda cyhalothrin 0.05 %	11.46 (19.78)	10.72 (19.11)	10.24 (18.65)	6.96 (15.29)	9.77 (18.21)
Control	40.67 (39.60)	42.71 (40.79)	47.37 (43.47)	46.77 (43.13)	44.37 (41.75)
Mean	13.33 (21.41)	12.14 (20.39)	11.68 (19.98)	7.46 (15.84)	
Floor treatment- Lindane (0.05 %)					1.12 (6.09)

CD (0.05) (Figures in parentheses are values after angular transformation)

Treatment mean : 0.65
Period mean : 0.43
T x P : 1.30

followed by 10 days after bed preparation, 5 days after bed preparation and at the time of bed preparation, the mean damage observed being 11.68, 12.14 and 13.33 respectively.

Significant difference in the extent of damage was noted in the interaction between different time of pesticide applications and different treatments. All the treatments significantly reduced the damage caused by springtail over the control. Among the different time of pesticide application, the treatment at fifteenth day after bed preparation was the most effective. chlorpyriphos 0.02 per cent treated mushroom beds showed the lowest damage ranging from 0.99 to 3.80 per cent. The data on the fifteenth day after bed preparation of chlorpyriphos 0.02 per cent indicated the lowest percentage damage of 0.99. This was followed by damage in beds treated after 10 days, 5 days and at the time of bed preparation, the mean percent damage being 3.43, 3.51 and 3.80 respectively.

II. Cropping period

The mean extent of damage by *Seira* sp. during the cropping period is presented in Table 20.

The mean percentage damage by *Seira* sp. revealed that all the treatments significantly reduced the damage over control. The treatments also differed significantly among themselves. The floor treatment with lindane 0.05 per cent (8.97) indicated least damage among the other treatments. This is followed by chlorpyriphos 0.02 per cent, dichlorvos 0.02 per cent and Neem oil – garlic 2 per cent which were at par, the damage being 11.70, 13.32 and 13.29 per cent, respectively.

Considering the different time of pesticide applications on the mushroom beds for the control of springtails, it was seen that treatments given fifteen days after bed preparation (20.03) was the best. The percentage damage observed in beds treated at the time of bed preparation showed highest damage of 30.33 and this was on par with the treatment on the fifth day after bed preparation which resulted in 29.41 per cent damage.

As in spawn run period there was the significant difference in the damage when the interaction between the different time of pesticide applications and

Table 20. Mushroom sporocarps damaged by *Seira* sp. during cropping period in the different pesticide treatments applied at different intervals

Treatment	Different intervals of bed preparation				
	At the time	5 days	10 days	15 days	Mean
Neem Azal 1%	37.22 (37.58)	35.09 (36.31)	31.61 (34.20)	14.62 (22.47)	29.11 (32.64)
Neem oil+ garlic 2%	17.73 (24.89)	16.48 (23.94)	10.58 (18.97)	9.23 (17.67)	13.29 (21.37)
Dichlorvos 0.02%	13.06 (21.18)	15.38 (23.08)	14.90 (22.70)	10.22 (18.63)	13.32 (21.40)
Malathion 0.05 %	29.12 (32.65)	30.21 (33.33)	20.75 (27.09)	16.42 (23.89)	23.88 (29.24)
Dimethoate 0.05 %	39.26 (38.78)	29.16 (32.67)	27.48 (31.60)	19.31 (26.06)	28.54 (32.28)
Chlorpyriphos 0.02%	13.50 (21.55)	13.19 (21.29)	12.97 (21.10)	7.64 (16.04)	11.70 (19.99)
Fenvalerate 0.03 %	41.24 (39.94)	38.49 (38.33)	37.27 (37.61)	25.32 (30.20)	35.44 (36.52)
Lambda cyhalothrin 0.05 %	25.80 (30.51)	26.77 (31.15	19.65 (26.30)	16.89 (24.26)	22.14 (28.06)
Control	64.75 (53.56)	67.74 (55.37	76.52 (60.99	74.99 (59.97)	71.12 (57.47)
Mean	30.33 (33.40)	29.41 (32.83)	26.81 (31.17)	20.03 (26.58)	
Floor treatment- Lindane (0.05%)					8.97 (17.36)

CD (0.05) (Figures in parentheses are values after angular transformation)

Treatments : 1.97
Period mean : 1.31
T X P : 3.93

different treatments were considered. The pesticide application given at all intervals after bed preparation were significantly reduced the damage caused by springtail over control. Among the treatments, chlorpyriphos 0.02 per cent showed the lowest damage, the damage recorded being 7.64 to13.50 per cent. This is followed by dichlorvos 0.02 per cent and Neem oil – garlic 2 per cent which recorded mean percentage damage of 10.22 to 15.38 and 9.23 to17.73 respectively.

4.4.3 Yield

The mean yield per 500 gram of substrates obtained from each treatment is presented in Table 21.

The mean yield in all the treatments, applied at different intervals was significantly higher over control. Among the different treatments the highest yield was recorded in the mushroom beds, which received lindane 0.05 per cent (385.27) and it was followed by dichlorvos 0.02 per cent the mean being 242.26 which were at par with chlorpyriphos 0.02 per cent (239.46). This was followed by malathion 0.05 per cent, Neem oil – garlic 2 per cent and lambda cyhalothrin 0.05 per cent, the mean yield observed being 232.66, 228.00 and 217.94 respectively.

Significantly higher yield was observed in beds treated with pesticides at different time after bed preparation. The highest yield in beds was observed in five days after bed preparation and mean yield was 218.67 which was on par with the yield obtained from beds treated ten days (216.12) and fifteen days (216.82) after bed preparation.

No significant difference in yield was noted when the interaction between treatments and time of application was considered.

4.5 TERMINAL RESIDUES OF INSECTICIDES IN HARVESTED MUSHROOM

The recovery of different insecticides from fortified mushroom samples at 0.05, 0.1 and 1.0 ppm level (Table 22) indicated that percentage recovery of dichlorvos ranged from 74 to 76 per cent, dimethoate (74 to 86 per cent),malathion (76.5 to 84 per cent), chlorpyriphos (80.5 to 90.5 per cent), fenvalerate (80.5 to 86 per cent), lambda cyhalothrin (79.2 to 88 per cent) and lindane (80.4 to 90.2 per cent) was recorded.

Table 21. Yield of mushroom in various insecticides applied at different intervals (g / per 500g of substrate)

Treatment	Different intervals of bed preparation				
	At the time	5 days	10 days	15 days	Mean
Neem Azal 1%	205.89	217.18	214.38	215.13	213.14
Neem oil+ garlic 2%	224.22	231.04	227.74	229.01	228.00
Dichlorvos 0.02%	241.11	242.96	242.23	242.72	242.26
Malathion 0.05 %	224.50	237.30	233.98	234.87	232.66
Dimethoate 0.05 %	197.22	215.24	208.51	210.47	207.86
Chlorpyriphos 0.02%	237.94	240.46	239.73	239.69	239.46
Fenvalerate 0.03 %	193.94	205.86	201.80	202.97	201.14
Lambda cyhalothrin 0.05 %	213.50	220.77	218.42	219.08	217.94
Control	158.94	157.19	158.29	157.42	157.96
Mean	210.81	218.67	216.12	216.82	
Floor treatment- Lindane (0.05 %)					385.27

CD (0.05)

Treatments (T) : 4.61
Period mean : 3.08
T X P : NS

Table 22. Recovery studies of pesticides in mushroom

Insecticides	Fortification level (ppm)		
	0.05	0.10	1.00
	Percentage Recovery		
Dichlorvos	75.00	74.00	76.00
Dimethoate	74.00	81.00	86.00
Malathion	76.50	84.00	82.00
Chlorpyriphos	80.50	88.00	90.50
Fenvalerate	80.50	82.00	86.00
Lambda cyhalothrin	79.20	85.50	88.00
Lindane	80.40	85.60	90.20

Table 23. Terminal residues of pesticides in mushroom following treatments at different days after spawning

Treatments	Mean residues (mg kg $^{-1}$) of pesticides applied at different time of bed preparation			
	At the time	5 days	10 days	15 days
Dichlorvos 0.02%	BDL	BDL	BDL	BDL
Malathion 0.05%	BDL	BDL	BDL	BDL
Dimethoate 0.05%	BDL	BDL	BDL	0.0080
Chlorpyriphos 0.02%	BDL	BDL	BDL	BDL
Fenvalerate 0.03%	BDL	BDL	BDL	BDL
Lambda cyhalothrin 0.05%	BDL	BDL	BDL	0.002
Floor treatment- Lindane 0.05%	BDL			

BDL- Below Detectable Level

The harvest time residues of pesticides in oyster mushroom following insecticides treatment at different days after spawning are presented in Table 23.

The results indicated that the residues were below the detectable level of 0.1, 0.002, 0.001, 0.001, 0.005 and 0.001 mg kg $^{-1}$ for the insecticide treatments *viz.*, Dichlorvos 0.02 per cent, malathion 0.05 per cent, dimethoate 0.05 per cent, chlorpyriphos 0.02 per cent, fenvalerate 0.03 per cent and lambda cyhalothrin 0.05 per cent respectively. However, residues in mushroom treated with dimethoate 0.05 per cent and lambda cyhalothrin 0.05 per cent fifteen days after bed preparation recorded residues to the tune of 0.008 and 0.002 mg kg $^{-1}$ respectively.

DISCUSSION

5. DISCUSSION

Kerala blessed with varied agroclimate, with abundance of agricultural wastes and manpower is most suitable for the cultivation of mushrooms. The technology of mushroom production has advanced dramatically over the past few years. However, majority of the mushroom holdings are either lacking proper environmental control facilities or do not have adequate compost preparation and pasteurization facilities. Under such a situations development of pest problems sufficiently to a level to ruin the mushroom houses cannot be overruled. Further, with the trend towards intensification and continuous cropping, pests can easily establish if attention is not given to hygiene and exact cropping parameters. The mushroom growers must always be aware of these pest problems and it is very important for them to recognize the initial signs with correct identification and to adopt recommended control measures. Considering the importance of the problem, the present investigation was taken up to identify the pests attacking mushroom, to study their nature and extent of damage, relationship with weather parameters, to explore the possibility of managing them with commonly available botanicals and chemical insecticides and also to find out the persistence of pesticide residues if any following application of synthetic pesticides. The results of the study are discussed below.

5.1 SURVEY ON PESTS OF MUSHROOM

The survey conducted in five different commercial mushroom houses for a period of one year from April 2006 to March 2007 in Thiruvananthapuram District revealed that mushroom was infested by insect pests such as springtails, phorid flies, beetles and noctuid moth and non-insect pests *viz.*, mites, slugs and snails (Table-1). Among the various pests recorded the population of springtails was the most predominant (Table 2). The occurrence of springtail as a major pest of oyster mushroom in Kerala was reported earlier by Deepthi et al. (2004) and Balakrishnan (1994). On the other hand, Fletcher et al. (1986) and Sandhu (1990) reported sciarids and phorids as major pests of mushroom from other parts of the country. The predominance of springtails observed in the present study may be explained in terms of the hot and humid condition prevailed in the region, which facilitates the multiplication of springtails. The occurrence of cucujoid beetle *Cyllodes* sp., noctuid moth, the mite *P. necrophori*, slug and snail in oyster mushroom is the first report from Kerala.

Occurrence and Extent of damage by pests of mushroom

Springtails

Among the pests of mushroom, springtails *Seira* sp. was found to be the most serious one in Kerala. Adult springtail had a characteristic jumping movement when disturbed. This unique characteristic of springtails attacking mushroom was reported earlier by Sandhu (1995).

Population of springtails which was low during April 2006 gradually increased reaching the highest during October 2006 to November 2006. There after, a sudden decrease during December 2006 to March 2007.

Considering the population of *Seira* sp. in different locations, it could be observed that the population was significantly higher in the fifth location (Thiruvallam), while no significant variation was observed in the other four locations.

The population observed during various months over a period of one year when correlated with weather parameters revealed high relative humidity, rainfall and number of rainy days favoured springtail population (Fig.1 a, b & c).The population was maximum during the period from May 2006 to November 2006 during which the relative humidity was also higher which ranged from 83.38 to 87.56 per cent. The finding was supported by the highly significant positive correlation with relative humidity, rainfall and number of rainy days (Table-10). However, a significant negative correlation of the population of *Seira* sp. with maximum temperature was observed (Fig.1d). Gill and Sandhu (1995) also reported the maximum activity of this insect under humid condition. They found that the activity of springtails was more when the beds were kept at ground level. In the present study, in order to get high humidity, mushroom beds were kept on

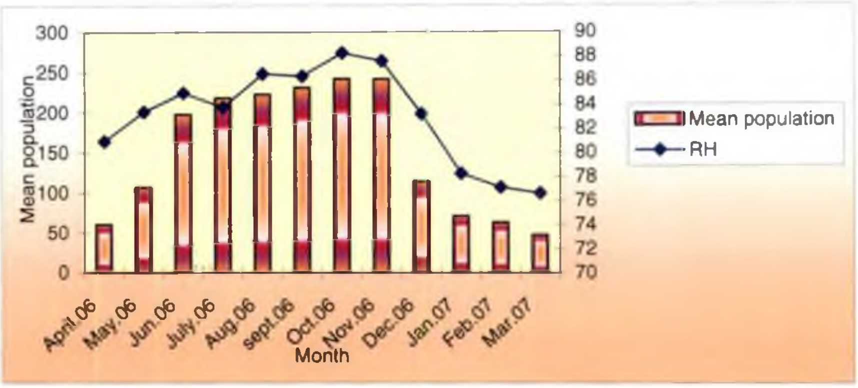


Fig. 1a. Correlation between pest population of *Seira* sp. and Relative humidity

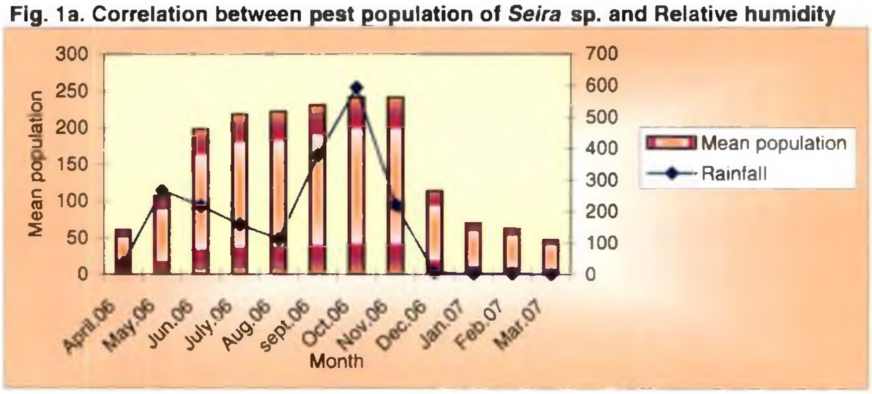


Fig. 1b. Correlation between pest population of *Seira* sp. and Rain fall

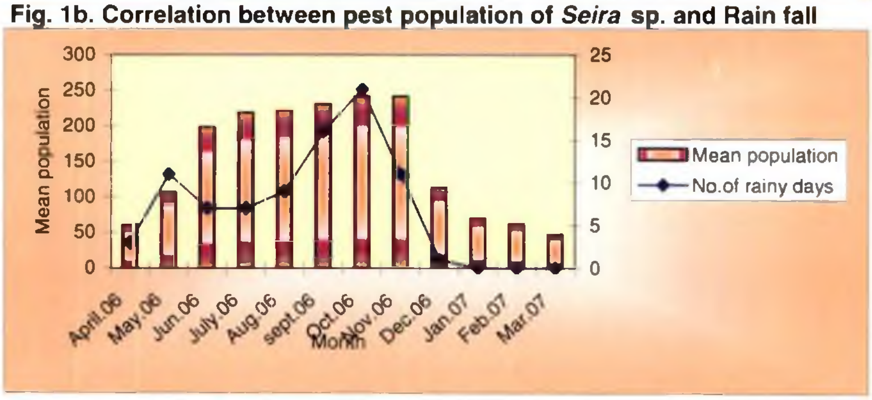


Fig. 1c. Correlation between pest population of *Seira* sp. and Number of Rainy Day

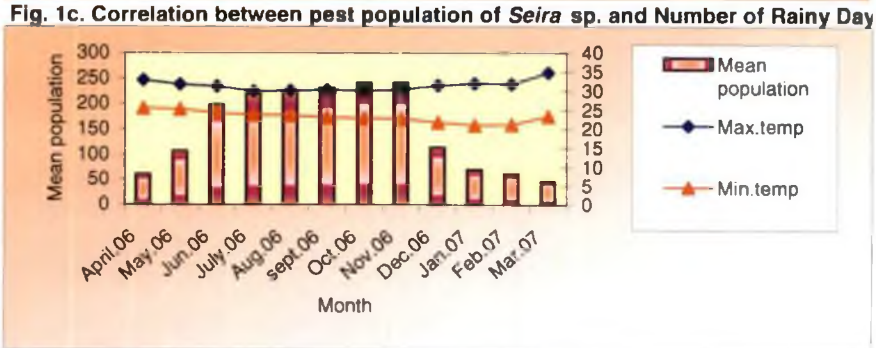


Fig. 1d. Correlation between pest population of *Seira* sp. and Temperature

bricks placed on a layer of moist sand. This further enhanced the population of springtail.

The feeding of springtails resulted in disappearance of mycelium from spawned compost. Sharma and Suman (2006) reported the disappearance of the mycelium from the mushroom beds. They also attack fruit bodies resulting in discoloration and deformation of sporocarps. Similarly, discoloration and deformation of sporocarps were also reporetd by Gill and Sandhu (1994) and Balakrishnan (1994). Significant reduction in yield because the cessation of flush development after the first harvest consequent to crawling of springtails in the beds, crowding of springtails on the lower portion of sporocarp together with their hiding nature between the gills reduce the market value of mushroom (Deepthi et al., 2004).

Perusal of the data on the extent of damage caused by *Seira* sp. indicated a gradual increase from April 2006 reaching the highest during October 2006 and a decline thereafter till March 2007, reaching at par with those recorded in April 2006 (Table 9).

The percentage area damage correlated with weather parameters revealed that as in the case of population, damage was also significantly influenced positively by the relative humidity, rainfall and number of rainy days (Fig.2 a, b& c). On the other hand there existed a negative correlation between the extent of damage and maximum temperature (Fig.2 d).The same trend was observed in the case of population also.

Phorid flies

The phorid fly *Megaselia* sp. was dark brown with hump back, and inconspicuous antennae. Kumar and Sharma (2000), Krishnamoorthy et al. (1991) and Deepthi et al. (2004) reported the occurrence of *Megaselia* sp. in oyster mushroom beds from different parts of the country. Compared to the population of springtails observed in the present study, the population of phorid flies was low in all the five locations during the entire period of study.

Population of *Megaselia* sp. was high during April 2006 and May 2006, and then declined significantly during June 2006 to November 2006. Again the population increased gradually during January 2007 to March 2007. In

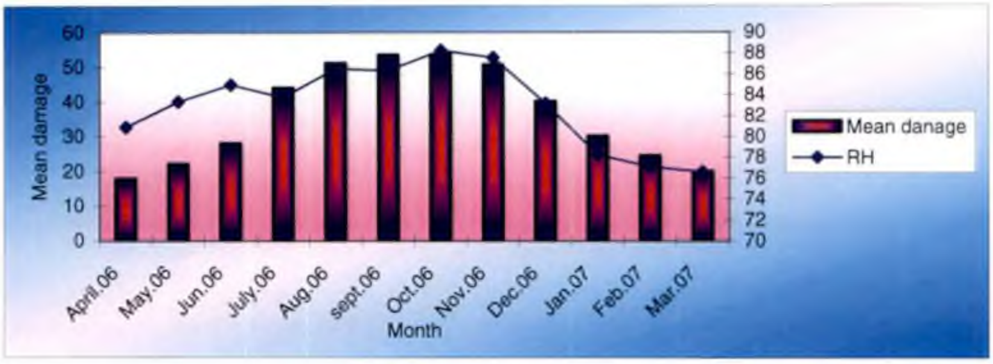


Fig. 2a. Correlation between extent of damage by *Seira* sp. and Relative humidity

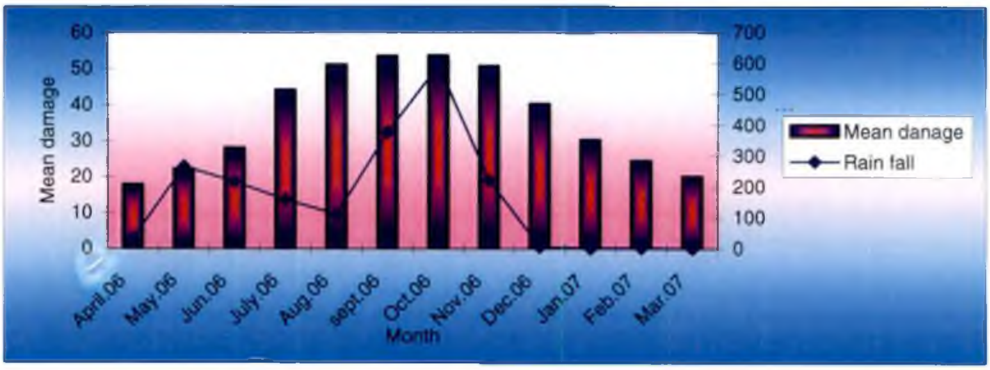


Fig. 2b. Correlation between extent of damage by *Seira* sp. and Rain fall

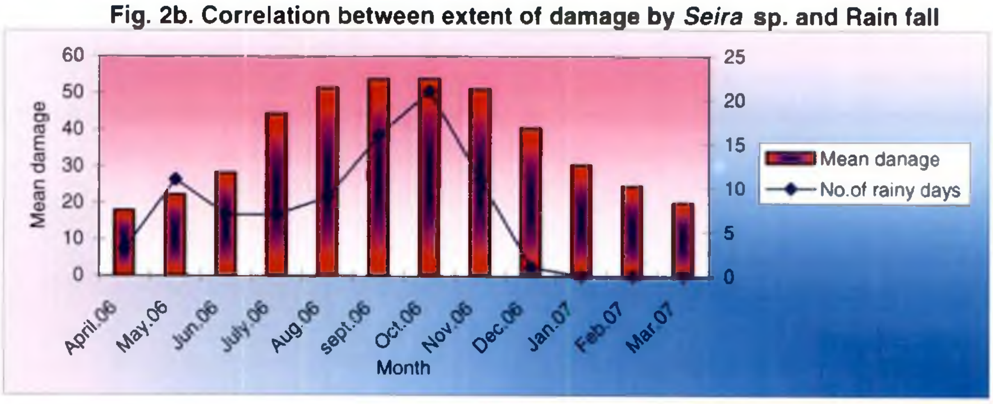


Fig. 2c. Correlation between extent of damage by *Seira* sp. and Number of Rainy days

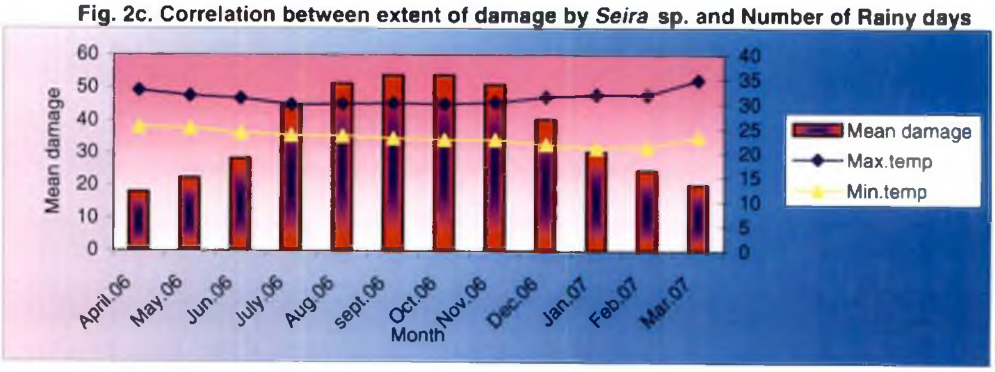


Fig. 2d. Correlation between extent of damage by *Seira* sp. and Temperature

contradictory to the present findings by Kumar and Sharma (2001) from Solan reported that phorids start appearing during the months of May - June and in the following months the populations build up gradually with peak populations during the months of July, August, September, and October. However perusal of the temperature recorded during the period of higher incidence in Solan indicated that temperature was higher during these months compared to other months of the year, substantiating a positive relation of population with maximum temperature.

Krishnamoorthy et al. (1991) reported an unusual occurrence of phorid flies (*Megaselia* sp.) in the months June – September in the spawn running rooms and in the beds of oyster mushrooms in Tamil Nadu. The present finding was in conformity with the observation of Deepthi et al. (2004) in Kerala who reported higher population of phorids during December to May when maximum temperature ranged from 31.5°C to 32.8°C and no population during the months of June to July when temperature was around 30°C. However, in the present study population of phorid flies was present throughout the period of observation from April 2006 to March 2007.

The correlation between the phorid population and weather parameters in the present investigation revealed that a decreasing trend of the population when the relative humidity was high during June 2006 to November 2006.Unlike in the case of springtails having positive correlation with relative humidity, rain fall and number of rainy days and negative correlation with maximum temperature, the population of phorids exhibited a significant negative correlation with relative humidity, rainfall and number of rainy days (Fig. 3 a, b & c).On the other hand, there existed a positive correlation of the population with maximum temperature (Fig.3 d). The phorid population had positive correlation with maximum temperature was earlier reported by various workers (Kumar and Sharma, 2001; Deepthi et al., 2004). Further, Fletcher et al. (1986) also suggested that incidence of phorids was common in summer. Balakrishnan (1994) also reported that the phorid flies prevailed in dry and hot climatic conditions. Negative influence of relative humidity on phorid population build up was also reported by Deepthi et al. (2004).

The maggots and adults were found to feed on mycelium, arresting its

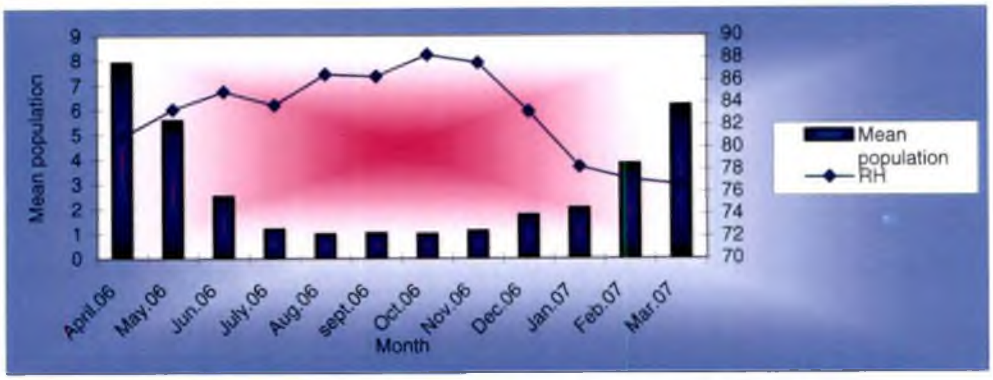


Fig.3a. Correlation between pest population of *Megaselia* sp. and Relative humidity

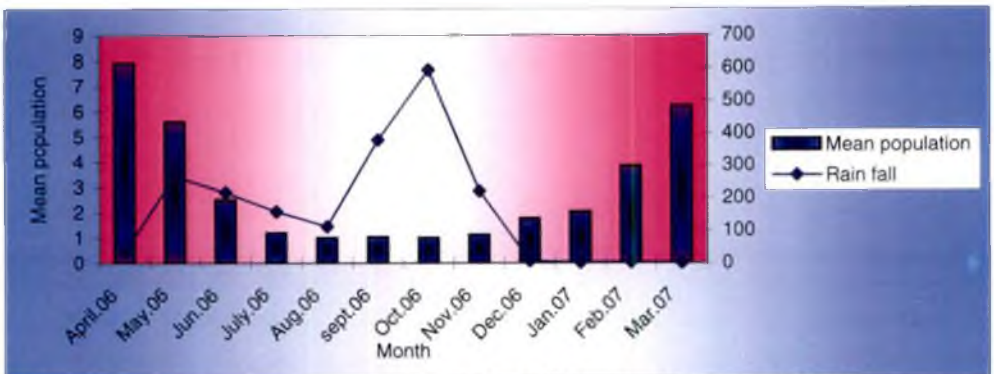


Fig. 3b. Correlation between pest population of *Megaselia* sp. and Rain fall

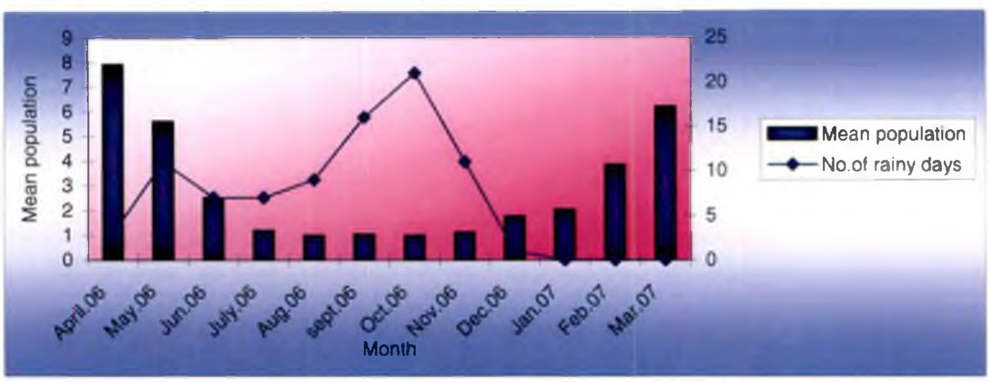


Fig.3c. Correlation between pest population of *Megaselia* sp. and Number of Rainy days

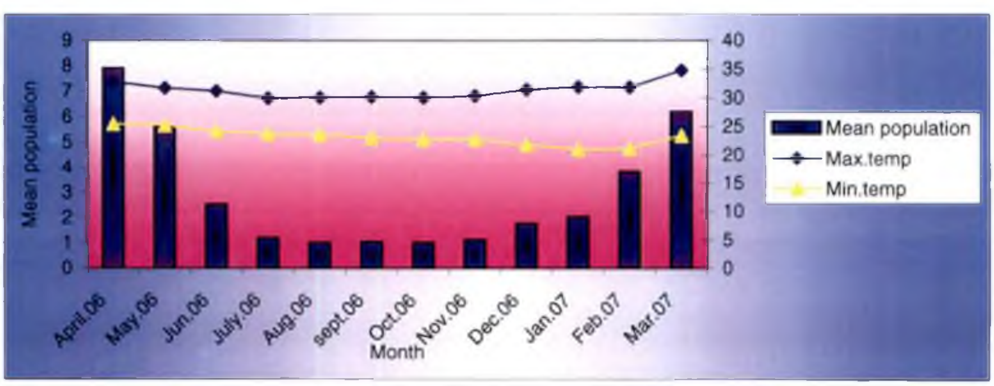


Fig.3d. Correlation between pest population of *Megaselia* sp. and Temperature

growth. This resulted in decaying of the substrate and emission of foul smell. They also made tunnels in the stipe resulting in discolouration and its decay. Atkins (1972) and Balakrishnan (1994) reported similar damage caused by the phorid flies. Krishnamoorthy et al. (1991) also reported that phorid larvae feed on mycelium forming wet rot zone around the holes.

Cucujoid beetle

The adult is reddish in colour and slightly broadened in the middle. The population of *Cyllodes* sp., which was the highest during April 2006 gradually decreased till August 2006. From October 2006 onwards increase in the build up of the population was observed till March 2007.

Correlation study between the weather parameters and the population indicated that as in the case of phorid fly, cucujoid beetle population showed a significant negative correlation with relative humidity, rainfall and number of rainy days (Fig.4 a, b & c) and significant positive correlation with maximum temperature (Fig. 4 d). High relative humidity adversely affected the population build up of the beetle.

The grubs and adults of cucujoid beetle crawled on the surface of fruiting bodies, fed voraciously and made tunnels on the sporocarps, resulting in the rotting of sporocarps. The same type of damage reported by Johal et al. (1992) from Punjab.

The extent of damage caused by *Cyllodes* sp. on the fruit bodies of mushroom indicated that the infestation was the lowest during October 2006 whereas it was the highest during March 2007.

The percentage sporocarp damage was correlated with weather parameters and showed that the damage was significantly accelerated by maximum temperature. There existed a highly significant positive correlation of the damage with maximum temperature (Fig.5 d) and significant negative correlation with relative humidity, rainfall and number of rainy days (Fig.5 a, b & c).

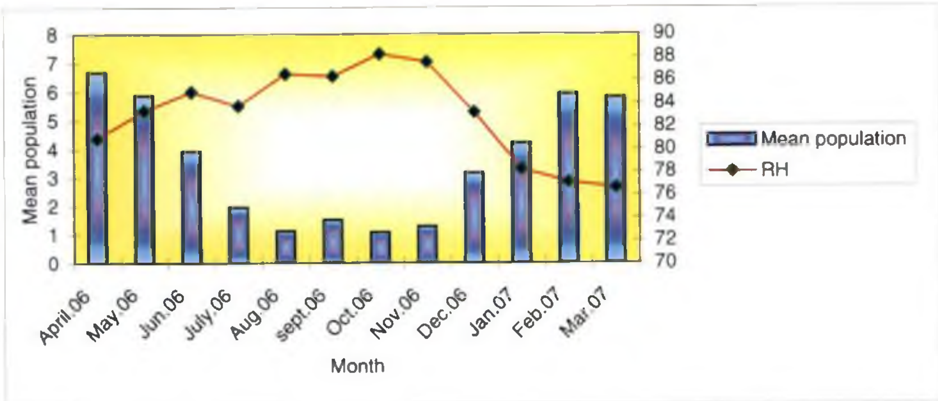


Fig.4a. Correlation between pest population of *Cyllodes* sp. and Relative humidity

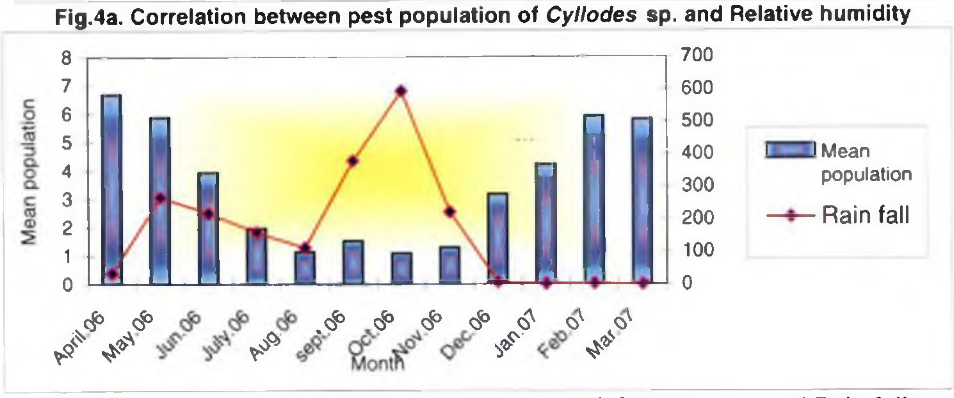


Fig. 4b. Correlation between pest population of *Cyllodes* sp. and Rain fall

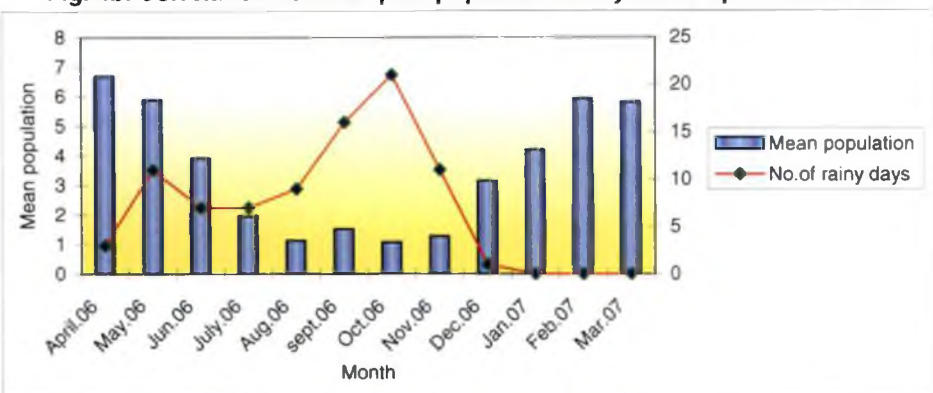


Fig.4c. Correlation between pest population of *Cyllodes* sp. and Number of Rainy days

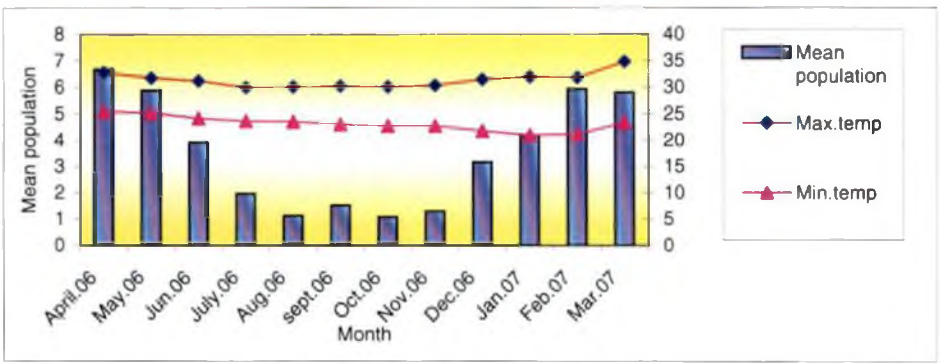
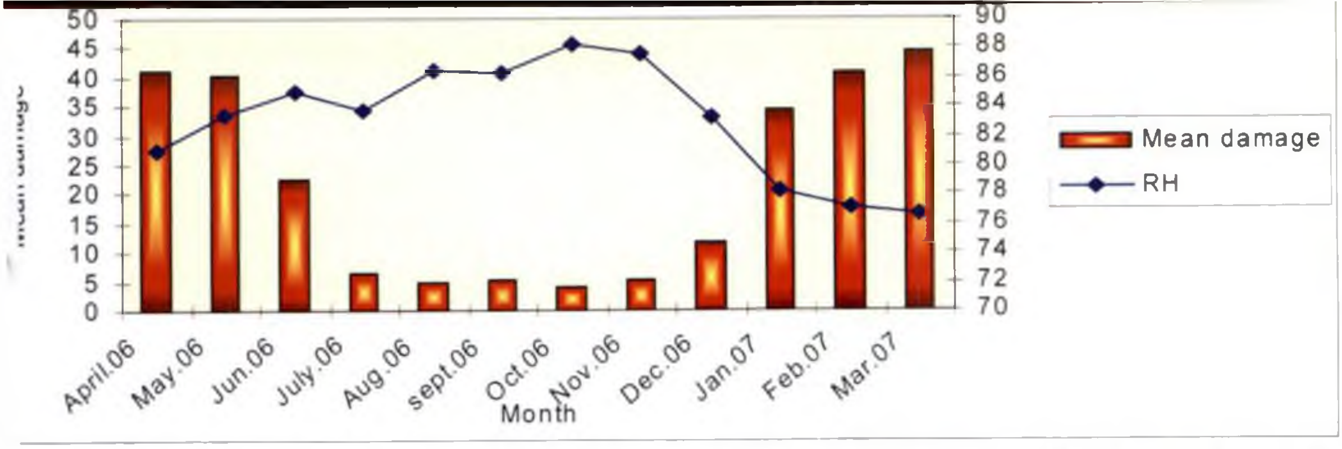


Fig.4d. Correlation between pest population of *Cyllodes* sp. and Temperature



g. 5a. Correlation between extent of damage by Cyllodes sp. and Relative humidity

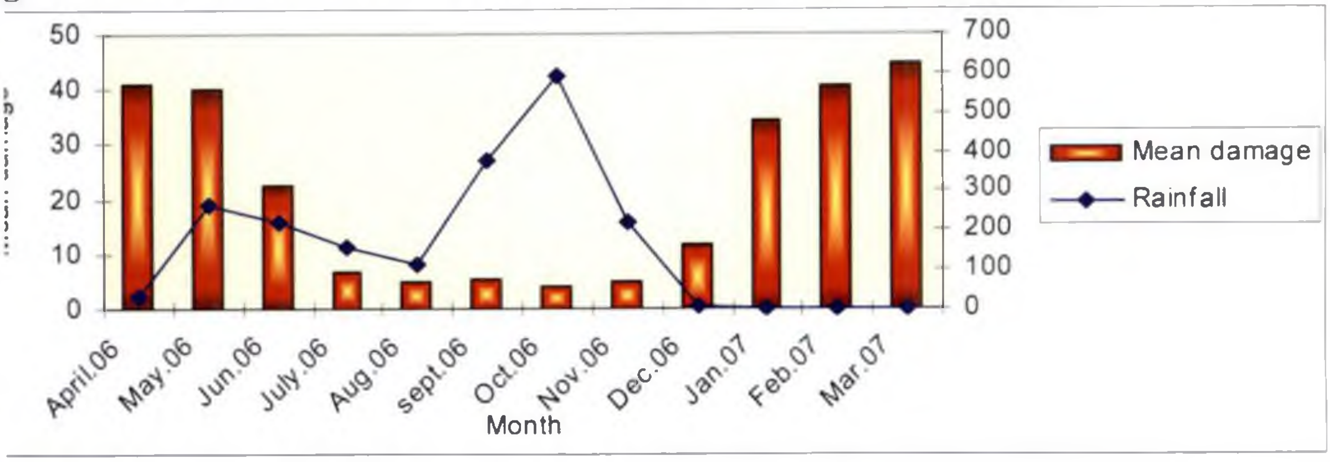
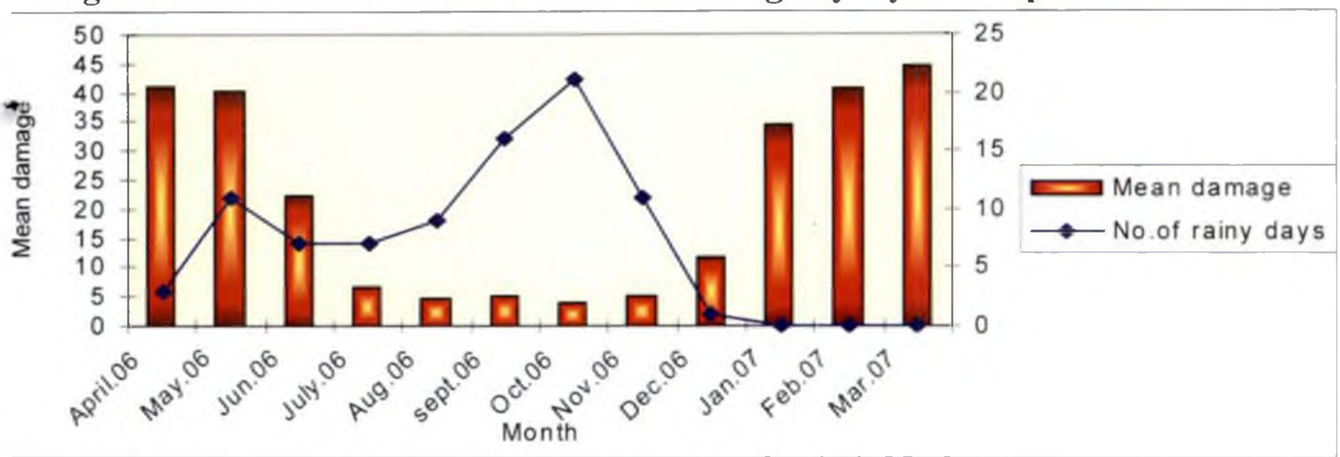


Fig. 5b. Correlation between extent of damage by Cyllodes sp. and Rain fall



g. 5c. Correlation between extent of damage by Cyllodes sp. and Number of Rainy days

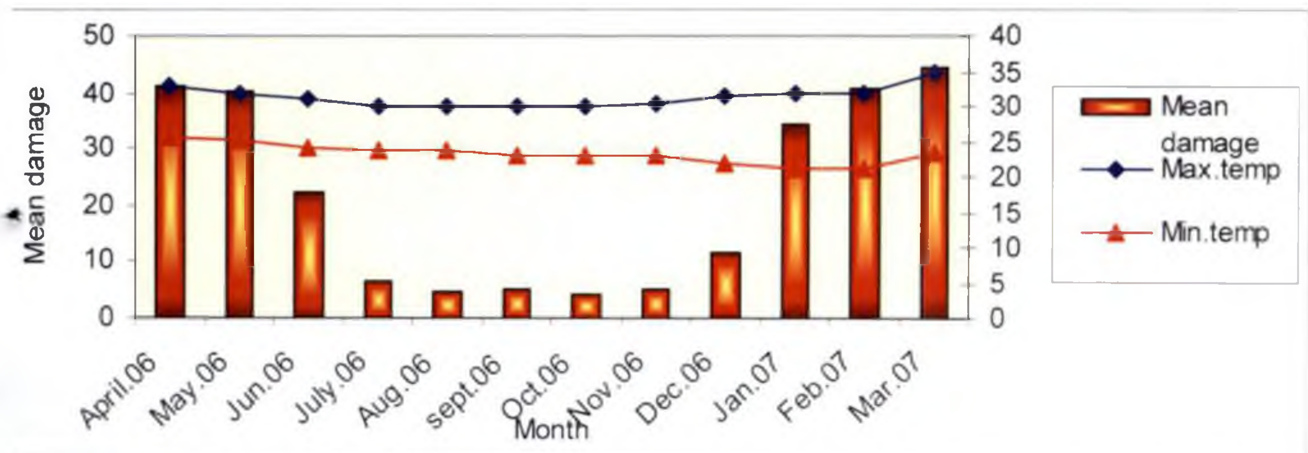


Fig. 5d. Correlation between extent of damage by Cyllodes sp. and Temperature

Staphylinid beetles

***Staphylinus* sp.**

The adults of *Staphylinus* sp. was brown in colour with short elytra, large membranous hind wing and posterior end of the abdomen curled dorsal wards. The same beetle pest was reported in mushroom beds by Asari et al. (1991) and Balakrishnan (1994) and later Deepthi et al. (2004) identified the same as *Staphylinus* sp. Among the five locations under study, the population of *Staphylinius* sp. was observed only in three locations. Even though the beetle was reported from 1991 onwards, it was not a common pest in all mushroom areas.

The population of staphylind beetle observed for a period from April 2006 to March 2007 revealed that the highest population observed during April 2006 started declining gradually till November 2006 and thereafter gradual build up to March 2007 reaching at par with those obtained in the month of April 2006. The population build up of *Staphylinius* sp. observed in the present study was in agreement with the report by Deepthi et al. (2004) where the highest population of *Staphylinus* sp. per sporocarp was observed during April when the maximum temperature was 32.8°C.

The correlation co-efficient between the weather parameters and the population of *Staphylinius* sp. showed that there existed a significant positive correlation with maximum temperature, whereas a significant negative correlation between the relative humidity, rainfall and number of rainy days with the pest population (Fig. 6 a, b & c). The maximum temperature greatly influenced the population build up (Fig.6 d). The result was in harmony with the report of Deepthi et al. (2004).

S. nigrofasciatum

Adults are deep brown with hypognathus head, short elytra and long and light brown leg. As in the case of *Staphylinus* sp. the higher population of *S. nigrofasciatum* was observed during April 2006 and May 2006 which were at par and then started declining gradually till November 2006 and thereafter gradual build up to March 2007 with maximum population.

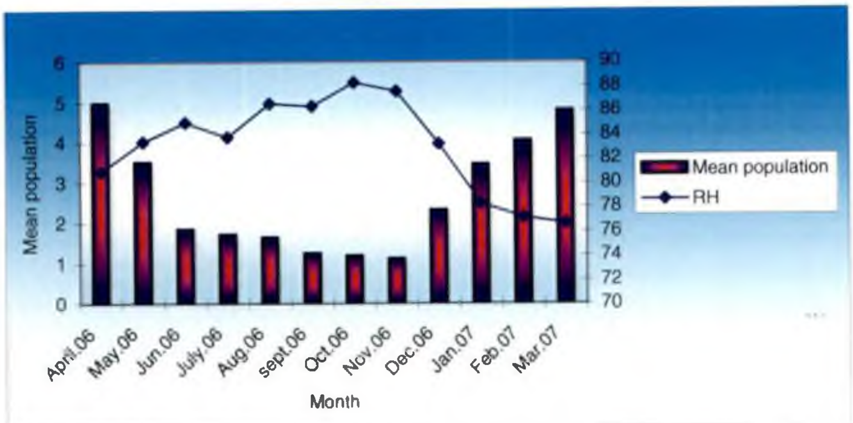


Fig.6a. Correlation between pest population of *Staphylinus* sp. and Relative humidity

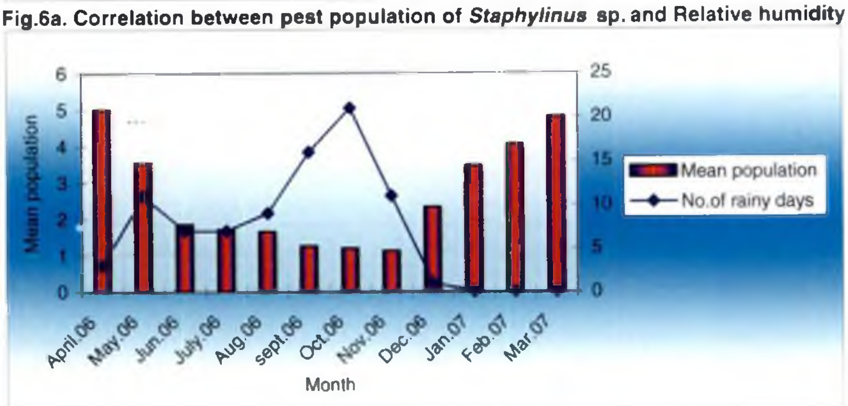


Fig. 6b. Correlation between pest population of *Staphylinus* sp.and Rain fall

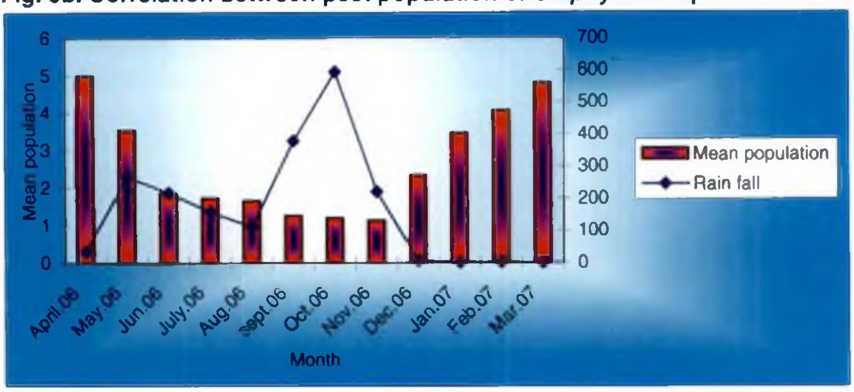


Fig.6c. Correlation between pest population of *Staphylinus* sp. and Number of Rainy days

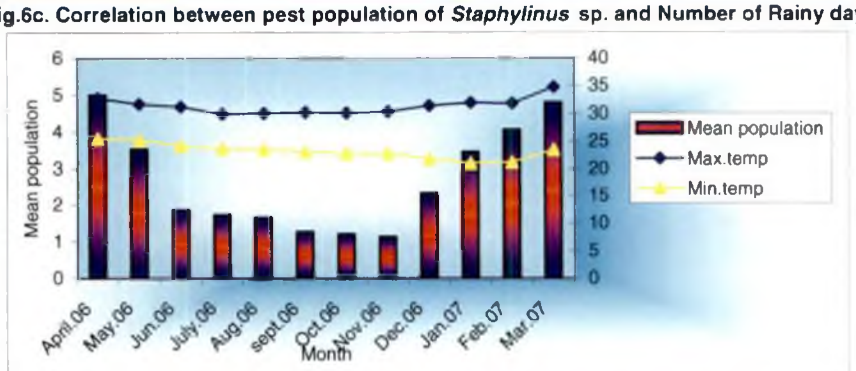


Fig.6d. Correlation between pest population of *Staphylinus* sp. and Temperature

Correlation between weather parameters and pest population revealed the existence of a significant positive correlation with maximum temperature (Fig.7 d) and a significant negative correlation with relative humidity, amount of rainfall and number of rainy days (Fig.7 a, b & c). As in the case of phorid flies, cucujoid beetle and *Staphylinius* sp., the *S. nigrofasciatum* also showed same trend with climatic factors.

Feeding of the grubs and adults of the beetles on the fruit bodies resulted in formation of irregular holes and rotting. The heavily infested fruit bodies were totally deformed. Similar symptoms of infestation were reported earlier by Asari et al. (1991), Balakrishnan (1994) and Deepthi et al. (2004).

Mite

P. necrophori are light brown in colour, body oval with slightly narrow anteriorly and all the four pairs of legs long with simple setae. Pre tarsi of all legs ending with a pair of claws and an empodium distally. The same genera was already reported infesting mushroom by Ramaraju and Madanlar (1998).

Among the five locations under study, the population of *P. necrophori* was observed only in one location. No mite infestation was recorded for the period from April 2006 to August 2006. A sudden occurrence was noticed from September 2006 to March 2007.

As in the case of springtails, the *P. necrophori* population correlated with weather parameters revealed significant positive correlation with relative humidity amount of rainfall and number of rainy days (Fig.8 a, b & c). On the other hand, there existed a negative correlation between the population and maximum temperature (Fig.8 d).

The mites were found feeding on mycelium arresting its growth. This resulted in the decaying of the substrate and the beds were also found contaminated with weed moulds. Decaying of the substrate and occurrence of weed moulds were reported by Ramaraju and Madanlar (1998).

Slug

Among the different locations surveyed, infestation of slug was observed in only one location. The slug observed was green in colour and body asymmetrical

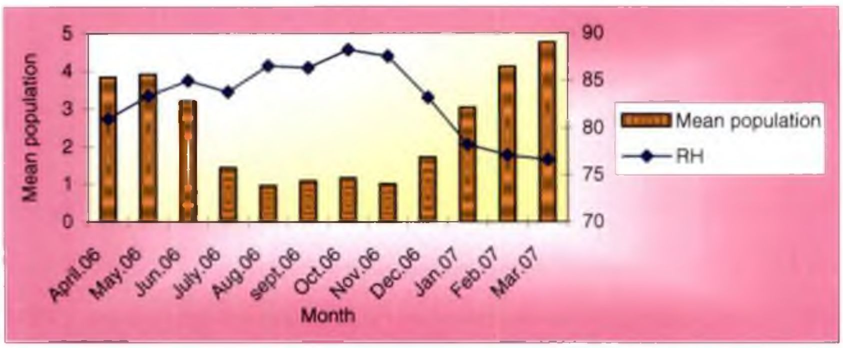


Fig. 7a. Correlation between pest population of *S. nigrofasciatum* and Relative humidity

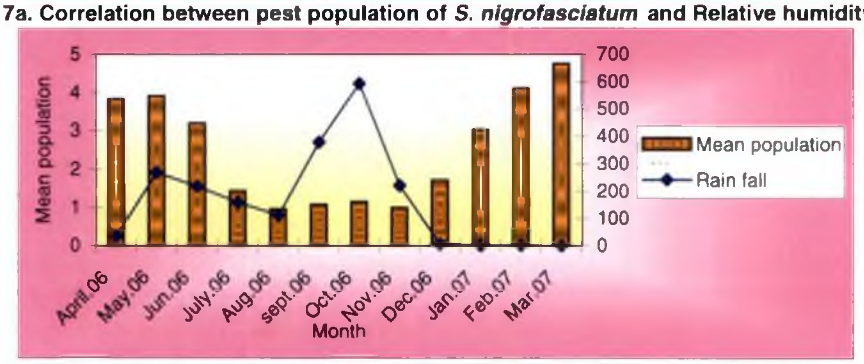


Fig. 7b. Correlation between pest population of *S. nigrofasciatum* and Rain fall

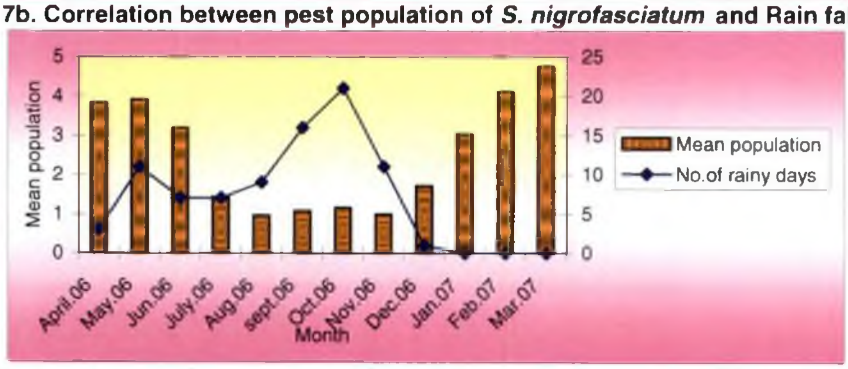


Fig. 7c. Correlation between pest population of *S. nigrofasciatum* and Number of Rainy days

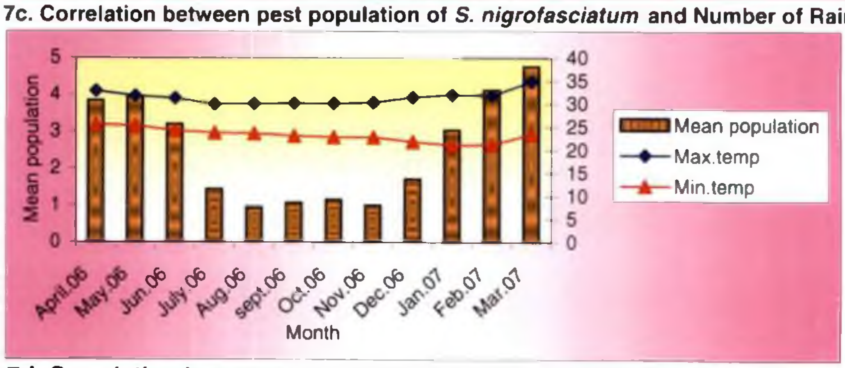


Fig. 7d. Correlation between pest population of *S. nigrofasciatum* and Temperature

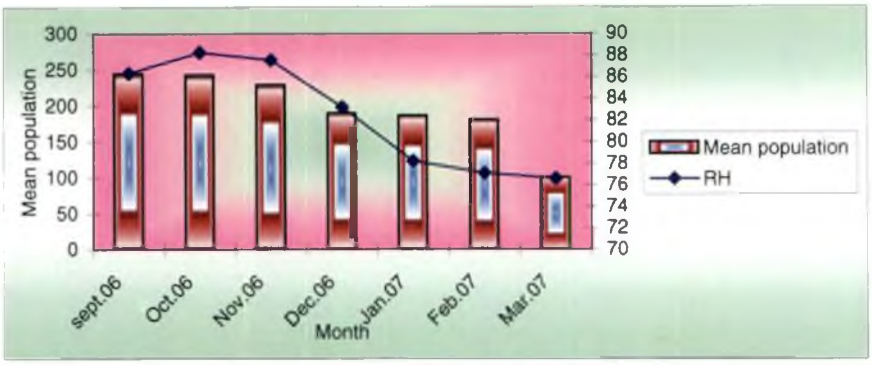


Fig.8a. Correlation between pest population of *P.necrophori* and Relative humidity

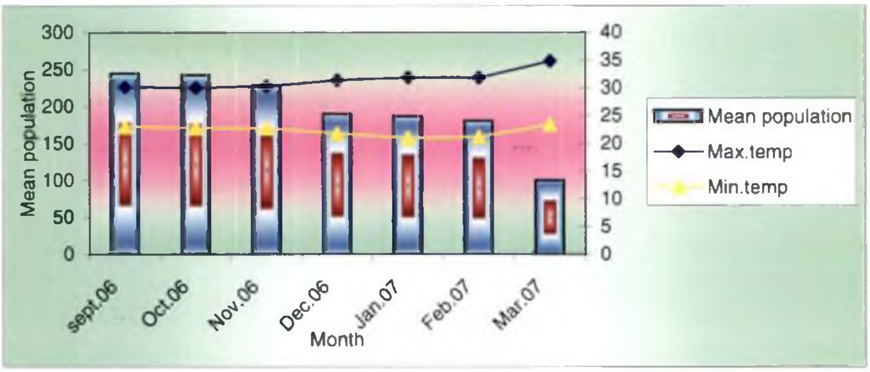


Fig. 8b. Correlation between pest population of *P.necrophori* and Rain fall

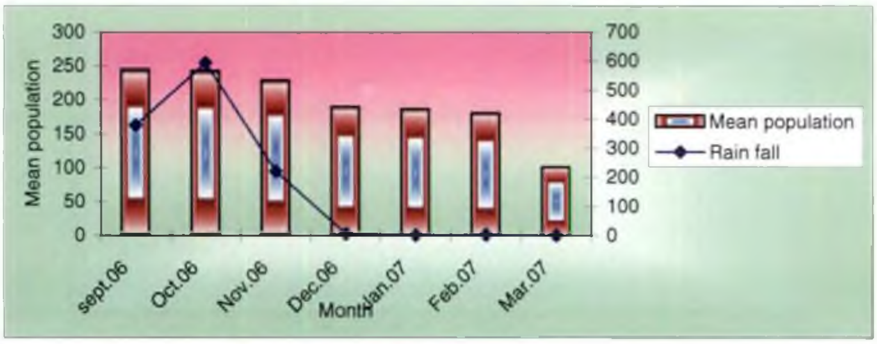


Fig.8c. Correlation between pest population of *P.necrophori* and Number of Rainy days

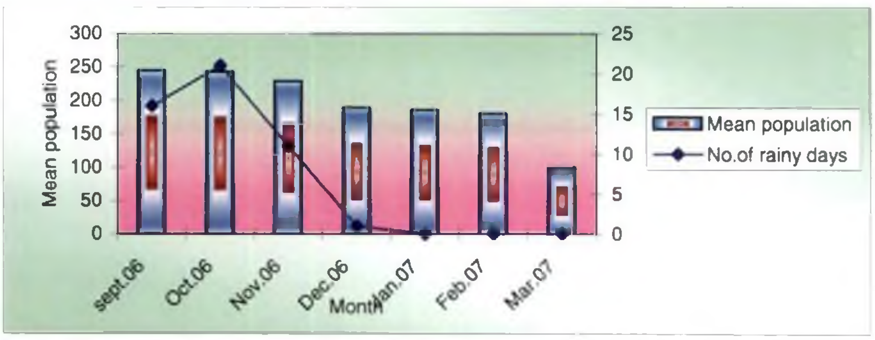


Fig.8d. Correlation between pest population of *P.necrophori* and Temperature

and spirally coiled when disturbed. Kumar and Sharma (2006) reported occurrence of slug in shiitake mushroom from Solan.

As in the case of mite, no slug infestation was recorded for the period from April 2006 to August 2006. A sudden occurrence was noticed from September 2006 to March 2007.

The correlation between the pest population and weather parameters showed significant positive correlation with the relative humidity, amount of rainfall and number of rainy days (Fig.9 a, b & c) and negative correlation with maximum temperature (Fig.9 d).In contradictory to the present study Kumar and Sharma (2006) from Solan, reported that the slugs were found feeding on Shiitake in the cropping rooms during the month of April and May of the year is highly favourable for the perpetuation of slugs. However, perusal of the relative humidity recorded during the period of higher incidence in Solan, indicated that relative humidity was higher during these months compared to other months of the year, substantiating a positive relation of population with relative humidity.

Slugs were found to feed voraciously and made tunnels on stipe, pileus and gills. Kumar and Sharma (2006) reported the same type of damage caused by slugs.

5.2 MANAGEMENT OF THE MUSHROOM PESTS

The commonly used botanicals and synthetic insecticides applied at different intervals after bedding were evaluated for their efficacy in controlling the major pests of mushroom. The occurrence of pests in the mushroom bed was observed only when the mycelial growth appeared on the bed surface and hence the efficacy of different treatments for their management becomes evident only after mycelial appearance in the bed. Thus it could be seen that floor treatment with lindane 0.05 per cent before bed preparation was as effective as application of chlorpyriphos 0.02 per cent or dichlorvos 0.05 per cent at fifteenth day after bed preparation in reducing the population of springtails. This was followed by application of neem oil- garlic 2 per cent and lambda cyhalothrin 0.05 per cent at fifteenth day after bed preparation. In the present study the superiority of floor treatment with lindane 0.05 per cent before bedding over other treatments given at the time of bedding, 5 or 10 days after bedding with all the pesticide clearly depict

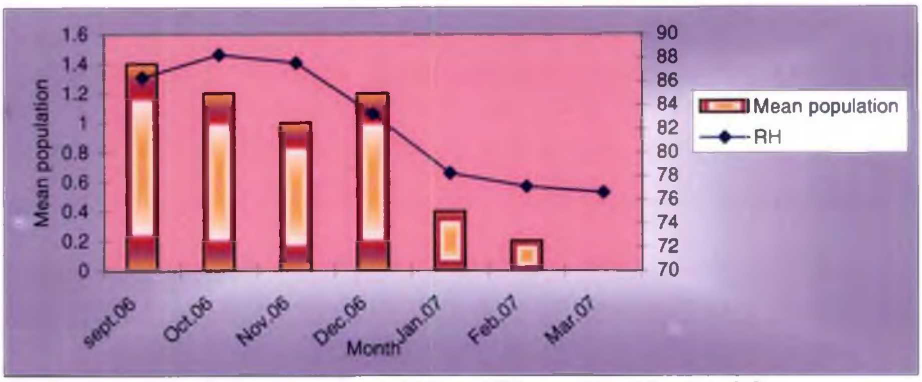


Fig. 9a. Correlation between pest population of Slug and Relative humidity

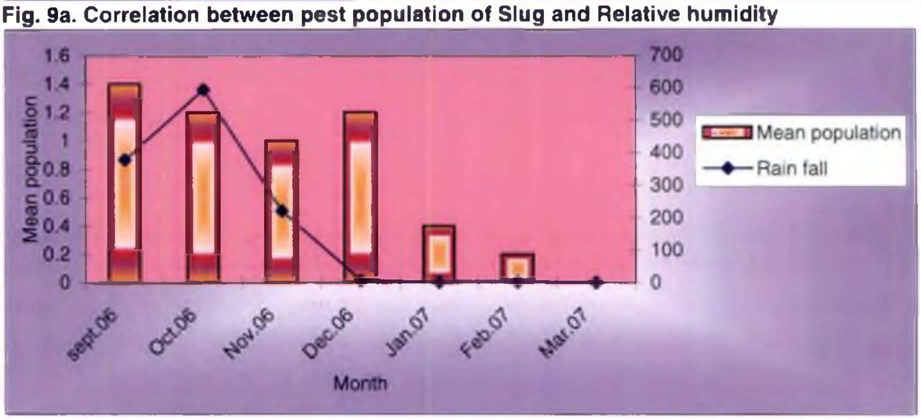


Fig. 9b. Correlation between pest population of Slug and Rain fall

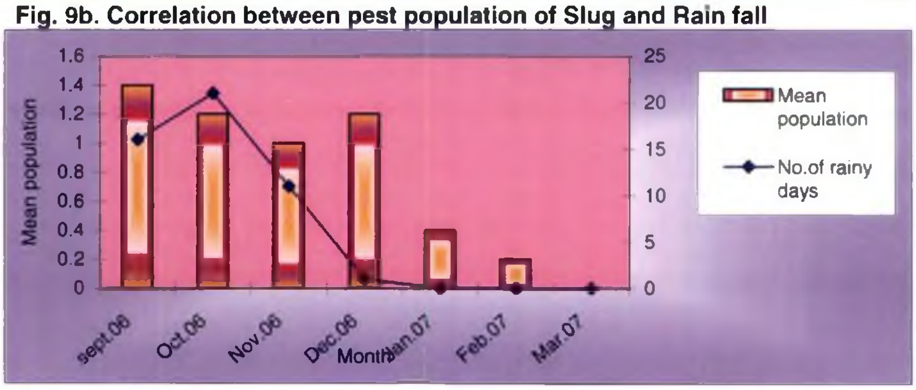


Fig. 9c. Correlation between pest population of Slug and Number of Rainy days

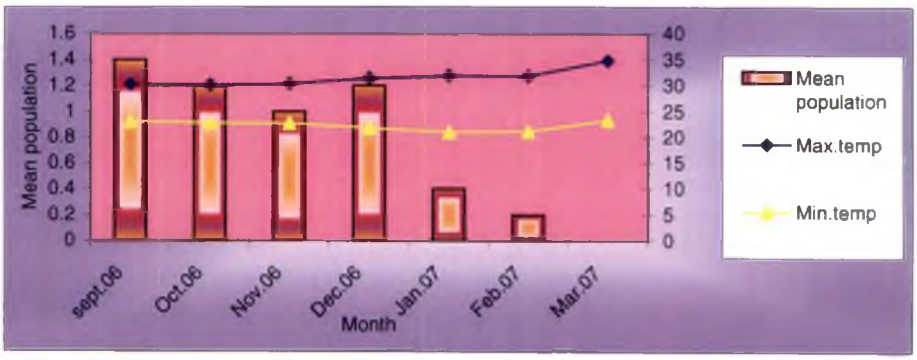


Fig. 9d. Correlation between pest population of Slug and Temperature

the scope of lindane as floor treatment rather than treating the bed at different intervals after bedding there by reducing the chances of contamination of both the sporocarps and spent compost. The effectiveness of dichlorvos for the management of springtails obtained in the present study was supported by the findings of Deepthi (2003). Sandhu (1995) also recommended use of dichlorvas 76EC 30 ml/100m^2 in mushroom house and ceiling but pointed out that direct spraying on bed should be avoided as a precautions to avoid chances of residues in mushroom sporocarp. However, the result obtained in the study is safer than the finding of Sharma and Suman (2006) who reported that chlorpyriphos applied at 50 ppm in compost and 25 ppm in casing soil had potential control for mushroom flies. Lindane 20 EC @ 200 ml / 1000 kg of straw after dilution in water at final stage of compost preparation was used for the control of mushroom flies (Sandhu and Arora, 1990).

Considering the extent of damage during spawn run period caused by springtails it could be seen that beds which received the floor treatment with lindane 0.05 per cent, chlorpyriphos 0.02 per cent and neem oil- garlic 2 per cent were the most effective treatment in reducing the extent of damage. Management of springtails with garlic extract 2 per cent was reported by Deepthi (2003).

During the cropping period, the data generated in the present study revealed that beds, which received the floor treatment with lindane 0.05 per cent, chlorpyriphos 0.02 per cent, dichlorvos 0.02 per cent and Neem oil – garlic 2 per cent, were the most effective insecticides in reducing the damage.

5.3 YIELD

The yield of mushroom in beds, which received insecticide application, was significantly higher than control. The highest mean yield was recorded from the mushroom beds which received lindane as floor treatment and recorded 143.90 per cent increase over control (Fig.10).This was followed by mushroom beds treated with dichlorvos 0.02 per cent and chlorpyriphos 0.02 per cent applied at fifth day after bed preparation. The number, size and weight of sporocarp from the bed which received synthetic insecticides application were higher compared to control. (Plate 8). The enhanced production of sporocarps in insecticide treated beds could

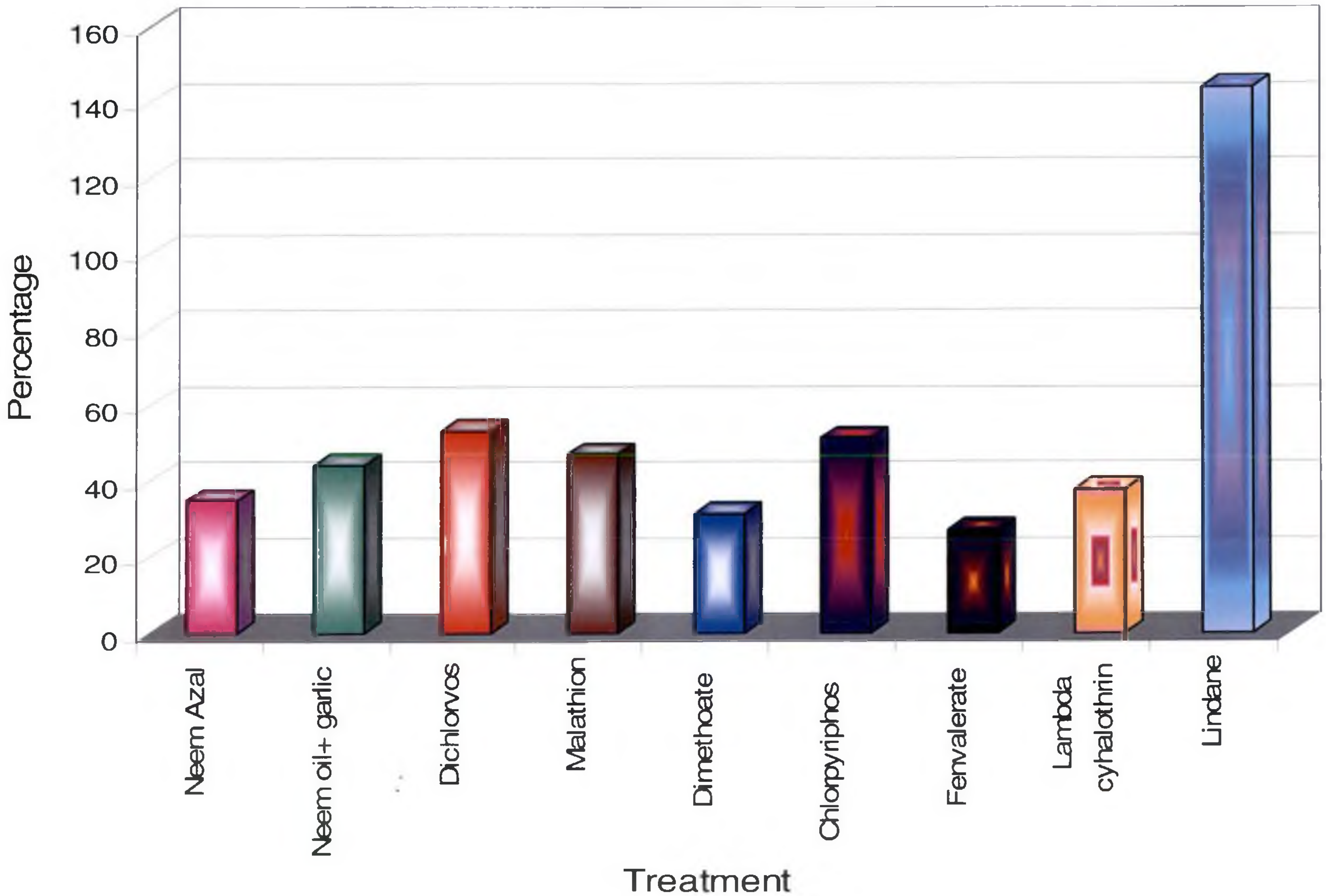


Fig.10 Percentage yield increase over control

control

Number of Sporocarp increased

control

Size of sporocarp increased

control

Bunch weight of sporocarp increased

be presumed to be due to reduction in the pests affecting the crop in the bed and during sporophore production. Another possibility is the potential break down of the insecticides by the basidiomycetes fungus into simpler less toxic bio molecules with the help of the extra cellular enzymes. The cleavage of large bio polymers result in utilization, evolution of CO_2 and releases of energy. The degraded organic products could be utilized by the fungus for enhancement of biomass that could be reflected also in increasing sporophore production. The oyster mushroom, *Pleurotus florida* had the ability of accelerating the degradation of pesticides like imidacloprid and metalaxyl (Mohapatra et al., 2005). Rodriguez et al. (2006) reported that enhanced decomposition and resultant the removal or elimination of endosulfan from the substrate matrix by *Pleurotus pulmonarius*.

5.4 PERSISTENCE OF RESIDUES IN SPOROCARP

Terminal residues persisting in the sporocarp from mushroom beds received pesticide application at the time of bed preparation, five, ten and fifteen days after bed preparation and floor treatment with lindane 0.05 per cent showed that no residues were seen except beds sprayed with lamda cyhalothrin 0.05 per cent and dimethoate 0.05 per cent at fifteenth day after bed preparation. The mean residues present in the sporocarp following lambda cyhalothrin 0.05 per cent at fifteenth day after bedding was 0.002 mg kg^{-1}, while that of dimethoate 0.05 per cent at fifteenth day after bedding was 0.0080 mg kg^{-1}. The maximum residue limits for lambda cyhalothrin and dimethoate had not been fixed on mushrooms. However, taking into consideration the maximum residue limits fixed on vegetables for lambda cyhalothrin (0.2 mg kg^{-1}) and dimethoate (2.0 mg kg^{-1}), the level of these insecticides residues in mushroom harvested at first flush were much below the maximum residue limit rendering them safe for consumption. Therefore present observation showed that the synthetic pesticides lamda cyhalothrin 0.05 per cent or dimethoate 0.05 per cent can be safely recommended to control the pests in case of severe infestation provided a safe interval of 10 days is given between the application and harvest of mushroom. The non detectable level of dichlorvos obtained in the study conformed the finding by Nath et al. (1996) who found that residues of dichlorvos were below detectable level in white button mushroom, *A.bisporus* after 42 hours following application at 0.05 per cent and 0.1 per cent at primordial stage. A safe waiting period of one day was recommended for dichlorvos in white button mushroom based on the dissipation studies. Further Sharma et al. (1997) and Arora et al. (1989) observed more or less similar dissipation pattern of dichlorvos in *A.bisporus*. The property of highest vapour pressure, fast dissipation and low persistence of dichlorvos paved the way for its use in mushroom houses for controlling flies and springtails all over the world without posing any residue problem. The non detectable level of lindane obtained in the study conformed the finding by Sandhu (1995) who found that residues of lindane in the first flush mushrooms, when incorporated at 25, 50 and 100 ppm dosage in compost, casing soil and compost + casing were below the maximum residue limit of 10 ppm as prescribed by FAD (USA). The present management strategy recommended for pests of mushroom include soaking the substrate 0.2 per cent lime water, covering the holes in the mushroom beds with cotton, spraying botanicals, garlic 2 per cent extract and synthetic insecticides, 0.01 per cent dichlorvos around the vicinity of mushroom beds and increases the pH of straw soaking water from 6-8 (Suharban,2005).

The present study thus revealed that the dominant pest of mushroom in Kerala is the springtail *Seira* sp. Mushroom being an indoor crop, provide a very suitable habitat for the springtails due to which pests remain protected from the vagaries of the weather. Moreover, maintenance of optimum temperature and humidity in the cropping rooms provide an ideal condition for the maximum activity and population build up of springtails. Though the different control methods *viz.,* cultural, physical, biological, use of botanicals were effective to some extent in tackling the pests, the present investigation showed the effectiveness of synthetic insecticides over botanicals. Lindane 0.05 per cent applied as floor treatment before bedding was proved to be the most potential management strategy for the pest with substantial increase in yield. Based on the present study, lindane 0.05 per cent given as floor treatment could be recommended for the control of pests without any residues in the harvested sporocarps.

SUMMARY

6. SUMMARY

The agroclimatic conditions of Kerala are suitable for cultivation of mushroom almost round the year. Due to continuous cultivation insect pests get easy source of food which often results in their tremendous build up. The present investigation was carried out to document the pests of mushroom, their nature and extent of damage, their relationships with weather parameters and to evaluate the efficacy of some botanicals and synthetic insecticides for the management of the pests. The major findings are summarized below.

The pests of mushroom encountered in the five locations at monthly intervals for a period of one year from April 2006 to March 2007 are springtails, mushroom flies, beetles, noctuid moth and non- insect pests *viz.*, mites, slugs and snails. Of these, incidence of cucujoid beetle *Cyllodes* sp., noctuid moth, parasitc mite *P.necrophori*, slugs and snails are observed for the first time in Kerala as pests of oyster mushroom.

The springtail *Seira* sp. was the most dangerous pest of mushroom and was present throughout the year in all the five locations. However, the population varied among different locations and months. The springtails caused damage at both the spawn run period and cropping period. Infestation at spawn run period resulted in disappearance of mycelium, while at cropping period, browning, discolouration and deformation of sporocarps were observed. The population and damage were higher during humid conditions. Positive correlation with relative humidity, rainfall and number of rainy days and negative correlation with maximum temperature existed with population and damage.

The springtail population was effectively suppressed by treatments such as floor treatment with lindane 0.05 per cent before bedding, sprays of chlorpyriphos 0.02 per cent and dichlorvos 0.02 per cent at fifteen day after bed preparation.

Spray application of lindane 0.05 per cent, chlorpyriphos 0.02 per cent at fifteenth day after bed preparation gave maximum suppression of damage by springtails during spawn running and cropping period.

The grubs and adults of cucujoid beetle *Cyllodes* sp. were found to feed voraciously, making holes all over the fruit bodies and resulting in the rotting of sporocarps. They were present throughout the year in all the locations. The population and damage had positive correlation with maximum temperature and negative correlation with relative humidity, rainfall and number of rainy days.

As in the case of springtail, the larvae and adults of phorid fly *Megaselia* sp. caused damage both during the spawn run and cropping period. During the spawn run stage, they were found feeding on mycelium, arresting its growth and resulting in the decay of the substrate and during cropping stage, they made tunnels in the stipe resulting in the discolouration and decay of the sporocarp. *Megaselia* sp. was present throughout the year in all the five locations. The population had positive correlation with maximum temperature and negative correlation with relative humidity, rainfall and number of rainy days.

The staphylinid beetle *viz., S. nigrofasciatum* and *Staphylinus* sp. were found to feed voraciously, making tunnels on the sporocarps. The adults made holes all over the fruit bodies, resulting in rotting and deformation of sporocarps. The infestation of beetles was prominent only during cropping stage. The maximum temperature had significant positive correlation. Relative humidity, rain fall had significant negative correlation with the pest population.

The incidence of non-insect pests *viz., P. necrophori* and slug was observed only in one location during September 2006 to March 2007. The feeding by *P. necrophori* resulted in disappearance of mycelium from spawned compost and rotting of mushroom beds was observed. Slugs were found to feed voraciously and made tunnels on the sporocarps. The population of *P. necrophori* and slug had positive correlation with relative humidity, rainfall and number of rainy days and negative correlation with maximum temperature.

The yield of the mushroom in beds, which received insecticides application, was higher than untreated control. The highest mean yield was recorded from the mushroom beds, which received lindane 0.05 per cent as floor treatment. This was followed by dichlorvos 0.02 per cent and chlorpyriphos 0.02 percent applied at fifteenth day after bed preparation.

Mushroom harvested from beds receiving pesticide application at different intervals *viz.*, floor treatment with lindane, bed treatment with pesticides at the time of bed preparation, 5 and 10 days after bed preparation did not content any pesticide residues. There was also no residues in the different treatments except lambda cyhalothrin 0.05 per cent and dimethoate 0.05 per cent to the tune of 0.008 and 0.002 mg kg^{-1} respectively in the mushroom beds treated on fifteenth day after bed preparation.

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* Original not seen.

APPENDICES

APPENDIX I

Weather parameters recorded during April 2006 to March 2007 from Department of Agricultural Meteorology, College of Agriculture, Vellayani.

Month	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	Relative humidity (%)	Amount of rain fall (mm)	Number of rainy days
April 06	32.78	25.46	80.92	34.3	3
May 06	31.7	25.21	83.38	267.5	11
June 06	31.19	24.21	84.983	217.8	7
July 06	29.91	23.73	83.774	158.6	7
Aug. 06	30.05	23.58	86.532	111.7	9
Sept. 06	30.18	23.07	86.33	379	16
Oct. 06	30.06	22.8	88.25	594	21
Nov .06	30.31	22.78	87.56	221.2	11
Dec. 06	31.4	21.8	83.2	6	1
Jan.07	31.9	21	78.24	0.6	0
Feb. 07	31.8	21.2	77.1	2.2	0
Mar 07	34.8	23.42	76.6	0	0

APPENDIX II

Weather parameters recorded during April 2006 to March 2007 from India Metrological Department, Trivandrum.

Month	Maximum temperature (^{0}C)	Minimum temperature (^{0}C)	Relative humidity (%)	Amount of rain fall (mm)	Number of rainy days
April 06	33.9	25.5	79	70.8	4
May 06	32.7	25	81	216.4	10
June 06	31.9	24.2	83	191.1	8
July 06	30.7	23.3	88	161.1	12
Aug. 06	31.1	23.4	86	101.7	10
Sept. 06	31.1	23.5	86	416.4	13
Oct. 06	30.8	23.1	89	569.3	15
Nov .06	31.3	22.5	88	318.2	13
Dec. 06	33.3	21.7	76	4.1	1
Jan.07	33	21.8	77	1.5	0
Feb. 07	33.1	22.4	77	2.3	0
Mar 07	34.1	24.1	80	1.6	0

APPENDIX III

POPULATION OF SPRINGTAILS BEFORE APPLICATION OF TREATMENTS

Treatments	Precount	
	Time of pesticide application	
	10 day after bed preparation	15 day after bed preparation
Neem Azal	715.00	1052.00
Neem oil+ garlic	750.00	1036.00
Dichlorvos	734.00	1044.00
Malathion	698.00	1000.00
Dimethoate	802.00	1063.00
Chlorpyriphos	755.00	1110.00
Fenvalerate	784.00	1121.00
Lambda cyhalothrin	795.00	1118.00
control	766.00	1058.00

PESTS OF TROPICAL MUSHROOM AND THEIR MANAGEMENT

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Abstract of the
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ABSTRACT

The occurrence of mushroom pests and their extent of damage in five different locations in Thiruvananthapuram district were studied in a survey conducted at monthly intervals for a period of one year from April 2006 to March 2007. An experiment was conducted to evaluate the efficacy of various botanicals and synthetic insecticides for the management of major pests of mushroom in the Mushroom house, Instructional Farm, College of Agriculture, Vellayani.

The study revealed that the common pests of mushroom were springtails *Seira* sp., phorid flies *Megaselia* sp., sciarid flies, cucujoid beetle *Cyllodes* sp., staphylinid beetles viz., *Staphylinus* sp. and *Scaphisoma nigrofasciatum* Champ, noctuid moth, parasitic mite *Poecilochirus necrophori* Vitzthum, slugs and snails. Of these, the occurrence of *Cyllodes* sp., *P. necrophori*, noctuid moth, slugs and snails in oyster mushroom were reported for the fist time from Kerala.

The common pests of mushroom namely *Seira* sp., *Megaselia* sp., *S. nigrofasciatum, Cyllodes* sp. were observed throughout the year in all the five locations. *Staphylinus* sp. was observed in three locations for a period of one year. *P. necrophori* and slug population were recorded only in one location from September 2006 to March 2007.

Correlation studies between the population and extent of damage with weather parameters revealed that *Seira* sp., *P. necrophori* and slugs had positive correlation with relative humidity and rainfall, while it showed negative correlation with maximum temperature. Population of *Megaselia* sp., *S. nigrofasciatum*, *Cyllodes* sp., *Staphylinus* sp. were positively correlated with maximum temperature and negatively correlated with relative humidity and rainfall

Efficacy of various botanicals and synthetic insecticides applied at different intervals after bed preparation on the incidence and extent of damage caused by mushroom pests in mushroom beds showed that lindane 0.05 per cent applied as floor treatment before bedding was the most effective. This was followed by dichlorvos 0.02 per cent and chlorpyriphos 0.02 percent applied at fifteenth day after bed preparation, which were at par. Among the various treatments adapted for the control of pests in mushroom, floor treatment with lindane before bedding has been found superior compared to other treatments. Considering a better control of pests and absence of residues, the floor treatment with lindane can be suggested for getting an effective control of pest, which presumed to result in a consequent higher yield.