BIONOMICS AND CONTROL OF MUSHROOM MITES

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JULY 1986

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C E R T I F I C A T E

This is to certify that the work recorded in the thesis entitled " BIONOMICS AND CONTROL OF MUSHROOM MITES " submitted by Shri Provat Das for the award of the Degree of Doctor of Philosophy in Agriculture (Agricultural Entomology) of the Bidhan Chandra Krishi Viswavidyalaya, is the faithful and bonafide research work carried out under my personal supervision and guidance. The results of the investigation reported in the thesis have not so far been submitted for any other Degree or Diploma. The assistance and help received during the course of investigation have been duly acknowledged.

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Dated, Kalyani,
The 5th July, 1986.

Provat Das
(PROVAT DAS)

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I N T R O D U C T I O N

INTRODUCTION

It has been predicted by Mr.Thomas W.Merrick (1986), President of the highly respected Population Reference Bureau, a Washington based private, non-profit demographic institute that India's population will reach 1,017 billion in the turn of the century. India, will therefore, have to produce 205 million to 225 million tonnes of foodgrains to feed her projected population. This will naturally call for a production of additional foodgrains of 55 million to 75 million tonnes in just about 15 years. There is no denying fact that the 'green revolution' of which country seems to be so proud, hav not covered much to increase the protein consumption of the masses. Th shortage of protein was around 61.8 tonnes in the year, 1981. India, being a developing country, can not afford to divert its resources from core sectors to increase the protein consumption of its masses. Again, the cost of input/output ratio in the production of protein food is estimated to be very high if otherwise it is not derived from alternate cheap sources. There are many such sources available in Indi with infrastructures of production. Mushrooms can play an important role in this respect because of their nutritive value, palatibility an direct utilisation.

The consumption of mushrooms to supplement protein food is not new in India. The tribal people with their well developed physique and good health derive a major part of their protein nutrition from wild edible mushrooms found in forest areas. Recent studies undertaken on the mushroom nutrition revealed that mushrooms are very rich in protein (26.9%) and contain a good number of amino acids (leucine, isoleucine, valine, tryptophan, lysine, threenine, phenylalanine, tyrosine, cystine, methionine, arginine, histidine) depicting presence of high quality protein (Gray, 1970). Besides these, several minerals like Ca, P, K, Fe, Cd, Zn, Cu, Pb etc. are also found in them (FAO, 1972; Bano *et al.*, 1971; Bano *et al.*, 1981b). Other constituents of mushroom are carbohydrate (2.45%), ash(0.90%), fibre (1.00%) and a negligible percentage of fat (0.4%) (Hayes and Hadded, 1976). Vitamin contents of mushroom are also accountable by virtue of the presence of B_1 (thiamine), B_2(riboflabin), C(ascorbic acid) and niacia (Pantothenin acid) etc. (Anderson *et al.* , 1942).

Keeping in view, the facts maintioned in the foregoing para mushrooms may be popularised among our people to supplement the protei shortage facing due to short supply of mutton, fish, eggs and so on. But there are certain limiting factors to offer mushroom as a viable inexpensive alternative for animal protein among our massess. Firstly, there is a fear regarding their toxic nature which has been removed to a great extent through scientific and extension work. Secondly, pest species take a heavy tool of the crop which is of great concern to commercial grower of mushroom.

The pest complex of mushroom consists of insects, mites, pathogens and so on. Among them, insects are considered as major one while mites are often ignored due to their small size. However, they are of considerable importance at least from the medical view points.

Mite species which are found in association with mushrooms can create severe health problems. Therefore, mites need special attention. There are fiftytwo species of mites reported on mushrooms from various parts of the world and sixteen have been designated as injurious species (Kannaiyan and Ramasamy, 1980).

The recent advancements in mushroom science has brought about a revolution in its cultivation. In particular, the new introductions of high yielding species of mushrooms have added a new dimension from the view point of commercial exploitation of the crop. There are several species of mushrooms now available to grow round the year. Being an indoor crop, it does not require any cultivable land and is not exposed to the mercy of nature. However, indoor conditions provides a typical ecological niche which are highly conductive for optimum growth of acarines. The control measures against acarines on mushrrom are to be taken with great attention and care. The chemical control should be based on pesticides possessing low mammalian toxicity with short residual effect. Alternatively, pesticides of plant origin should be the answer. The total absence of natural enemies of mushroom mites is a distinct disadvantage in framing an integrated control programme for mite pests. However, the inherent resistance in various species of mushrooms to the infestation of mites can be explored to select resistant types to be incorporated in the management programme of mushroom mites.

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The strategy of pest population management offers the most promising solution to many of the present difficulties. Pest management may be defined as management of a negative resource or pest management is part of resource management. Integrated control, the integration and exploitation of all feasible methods which are practical and which will cause the least disruption of ecosystems, is now reasonably well documented (Geier, 1966; Smith and van den Bosch, 1967. The successful pest management of the future will depend on the use of integrated control. With perhaps a few exceptions it is becoming more and more difficult to think of a single effective, continuous control method for pests of a crop, especially if one views the crops as a whole and the complex of pest species that attack the crops. The methodology of pest management is based on six ecological principles, such as determination of status of pest species, evaluation of mortality factors, determination of most important factors in regulating pest density, modelling the pest ecosystem, simulation and field testing, strategy and tactics determination. However, very limited informations are available in this direction. The ecology of most of the mite species found in association with mushrooms has not been worked out. Our country is lagging far behind in this respect. Till-to-date only one published literature is available on mushroom mites (Mukherjee and Somchoudhury, 1972). Considering the vast potentiality and the growing popularity enjoyed by the crop, the present author thought it to be befitting to undertake preliminary investigations on mushroom mites which would be an important limiting factor for mushroom cultivation in a course of time considering their potentiality of multiplication under humid sub-tropical indoor condition. Hence, these studies were undertaken.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The fruit bodies of macrofungi are commonly called mushroom (when edible) or toad stool (when poisonous). They are large fleshy fungus, generally found on decaying organic matters such as old leaves straw, rotten materials, trunks of trees, in the forest floor or in the grass in yards, lawns, fields and pasture, along the road sides, or in damp soil reach in organic substances.

There are nearly 50,000 species of fungi which also cover 2,000 varieties of edible mushrooms. Out of them, 25 have been accepted widely as food. But only three to four have been brought under cultivation (Kannaiyan and Ramasamy, 1980). Normally, a mushroom looks like a round ball or shelve or bracket with a cap supported on slender stems or branched or corel like. A mushroom body consists of ground and aerial portions. The former is seedling part called the spawn or mycelium, consisting of fine white threads running all through the materials upon which the fungus grows. Aerial portion is fruit body consisting of a fleshy cap or pileus supported by a quite solid stalk stipe. The underside of the cap is known as gills or lamellas. There are thin plates standing on edge radiating out from the stalk like the spokes of a wheel. When the fruit bodies are young they are called as button. The gills are protected by a curtain or veil which stretches from the stalk to the edge of the cap. Sometimes a large shargy, bulb or cup like structure is present at the base of the stalk known as volva from which the stipe arises (Pileus).

The systematic study of Indian mushroom was initiated in the year 1901 by Dr. Butler and was subsequently taken up by several workers to make it a new branch of science. A voluminous literatures has been accumulated over the past several years on various aspects of mushroom cultivation. Therefore, the author would elaborate only those references which have direct bearing on the present work.

2.1 Mites found in association with mushroom cultivation

Cultivated mushrooms are generally infested by several groups of mite belonging to the families, Acaridae, Anoetidae, Glycyphagidae, Tarsonemidae, Pyemotidae, Eupodidae, Ascidae, Digamasellidae, Scutacaridae, Tyleidae and Macrocheliadae (Austin, 1937; Hussey, 1963; Bins, 1973; Norton and Ide, 1974; Rota and Grasiella, 1974; Hill and Deahl, 1974). Attempts have been made by the present author to review the entire work undertaken on the past status and distribution of mites found in association with mushroom cultivation throughout the world.

2.1.1 Distribution of mites of the family Acaridae

Tyroglyphid mites are the most predominant group among mushroom mites and they are distributed under eight genera namely, *Tyrophagus*, *Tyroglyphus*, *Caloglyphus*, *Aeroglyphus*, *Blattisocius*, *Oppia* *Rhizoglyphus* and *Eberhardia*. The important species under the genus *Tyrophagus* which are generally found to infest mushroom in U.K. and U.S.A. are *T. fungivorus* Oudemans; *T. longior* Gervies; *T. oudemans* Robertson; and *T. putrescentiae* Schrank (Rivert, 1961; Hussey, 1963;

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Davis, 1968). The last one has been reported by Mukherjee and Somchoudhury (1972) from India to infest mushroom. Under the genus *Tyroglyphus*, four spp. have been described on mushroom in U.K. They are *T.berlesei* Michael; *T.dimidiatus* Herm; *T.lintneri* Osb. and *T.mycophagus* Megnin (Jary, 1938; Hussey, 1963). There are three spp. of mites in the genus *Caloglyphus* namely, *C.berlese* Michael, *C.mycophagus* Megnin, *C.krameri* Berlese to feed on mushroom in U.K.(Hussey, 1963). *C.mycophagus* was reported from Italy by Rota and Graziella (1974) to infest mushroom. The genera *Aeroglyphus* and *Blattisocius* contain only one species each, namely *Aeroglyphus rofustus* Banks (Barker, 1960) and *Blattisocius keegani* Fox (Davis, 1968) and they were reported from U.S.A. The other genus, *Oppia* contains only one species namely, *Oppia nitens* Koch and has been reported to infest mushroom in Austria and U.K. by Masses (1931). The genus *Rhizoglyphus* contains two species viz., *R.echinopus* Fumouze and Robin (Hussey, 1963) and *R.phylloxerae* Riley (Davis, 1938). While there is only one species, *Eberherdia* sp. under the genus *Eberherdia* (Jary, 1937).

2.1.2 Distribution of mites of the family Anoetidae

The anoetid mites which are found on mushrooms as well as in many other habitats have been elaborated by Compton (1933), Jary and Stapley (1936), Jary (1938), Scheucher (1957), Hughes and Jackson (1958) and Hill and Deahl (1978). They are *Glyphanoetus fulmeki* Oudemans, *Histiostoma gracilipes* Banks, *H.feroniarum* Dufour, *H.rostroserratum* Megnin, and *H.heinemanni* Hill and Deahl. They have been reported to infest mushroom in U.K. and U.S.A.

2.1.3 Distribution of mites of the family Glycyphagidae

The Glycyphagid mite is represented by a single species namely, *Glycyphagus phylloxerae* Riley (Davis, 1938) found in mushroom culture in U.S.A.

2.1.4 Distribution of mites of the family Tarsonemaidae

Several species of tarsonemid mites have been reported on mushroom. Since 1956, *Tarsonemus tarsalis* is known as a pest of mushroom in U.S.A. (Moreton, 1956). Subsequently, five *tarsonemus* spp. namely, *T.waitei* Banks, *T.randsi* Ewing, *T.confusus* Ewing, *T.floricolu* Canestrine, *T.myceliophagus* were recorded on mushroom in U.K.(Hussey, 1963). He further reported the infestation of *T.myceliophagus* in U.S.A. The other species namely, *T.mercedesae* Hill and Deahl and *T.lukoschusi* (Hill and Deahl are offten found to infest mushrooms at Pennsylvania (Hill and Deahl, 1978).

2.1.5 Distribution of the mites of the family Pyemotidae

The detailed taxonomic investigations of pyemotid mites (pygmey mite) were undertaken by Wicht (1970) who described ten species under two genera to infest commercial mushroom in U.S.A. They are *Pygmephorus americans* Banks; *P.mesembrinae* Canestrini; *P.quadratus* Ewing; *P.tarsalis* Hirst; *P.allmanni* krezal; *P.lambi* krezal, *P.sellnicki* krazel; *Dolichocybe keiferi* krantz; *Macrodisopodides fungorum* Lambordini; *M.buae* Lambordini. He further described three new spp. of pyemotid mites associated with mushroom cultivation. They are P.flechtmanni from Brazil, P.kneeboni from U.S.A. and P.althiasae from France. The first report of pyemotid mites found in associateion with mushroom cultivation in U.K. comes from Gurney and Hussey (1967). Before that, Krezal (1964) reported the presence of P.lambi and P.allmanni on mushrooms collected in Australia and Newzealand. In 1974, P.mesembrinae was reported from Italy by Rota and Graziella. The other species of pyemotid mite is Pseudopygmeforus smileyi Hill and Deahl found with mushroom cultivation in U.S.A. (Hill and Deahl, 1978).

2.1.6 Distribution of mites of the family Eupodidae

Only one species viz., Linopodes antennaepes Banks (synonym L.motatorius L.) has been reported to infest mushroom from U.S.A. and U.K. (Gahm, 1930; Austin, 1937).

2.1.7. Distribution of mites of the family Ascidae

Binns (1974) reported an ascid mite namely, Arctoseius cetratus Sellnick from mushroom houses in U.K.

2.1.8 Distribution of mites of the family Digamasellidae

Only one sp. of mite is found to infest mushroom in U.K. The species is Digamasellus fallux Leitner (Binns, 1973).

2.1.9 Distribution of mites of the family Scutacaridae

Norton and Ide (1974) described a new sub-species of Scutacarid mite (Scutacarus baculitarsus agaricus N.Sub.sp.) collected from commercial mushroom houses in U.S.A. The mite is said to have phoretic relationship with the phorid fly, Megacilia dacotensis .

2.1.10 Distribution of mites of the family Tyleidae

Only one species of mite is found to infest mushroom. The species is Pronematus bonatii according to Rota and Graziella (1974) and has been reported from Italy.

2.1.11 Distribution of mites of the family Macrochelidae

The Macrochelid mite is represented by a single species namely, Macrocheles merdarius Throm bidiformes found in mushroom culture in Italy (Rota and Graziella, 1974).

2.2 Source of mite infestation in mushroom culture

Attempts are afoot since long to locate the source of infestation of some important species of mites on mushroom. But only a few published literatures are available in this direction. Tyroglyphus dimidiatus, a major pest of mushroom throughout the world is often present in large number in hay, straw, grains and similar materials used for preparing mushroom beds. It was further observed that it feeds on fungi developing on those materials (Eales, 1917; Hussey, 1936; Jary & Stapley, 1937). Similarly, Aleurobius (Tyroglyphus) farinae, a tyroglyphid mite is known to be present in straw and similar materials in large number. The transmission of tarsonemid mite, Tarsonemus tarsalis in the mushroom culture generally occurs through straw (Moreton, 1953). Under certain circumstances, tarsonemid mites survive in cracks and crevices of the mushroom farm building which act as the source of infestation to the newly grown crop (Osborne and Hamilton, 1965). The mode of entry of other important species of mushroom mites may be through different other agents Tyrophagus longior is generally carried in the mushroom bed through old manure used in the compost preparation (Compton, 1935; Jary and Stapley, 1936). Hussey (1964) reported that tyroglyphid mites enter into the mushroom house through manures as well as through dipteran flies. The compost, mainly the spent one acts as the primary source of mite infestation in mushroom firms (Seth, 1982).

It has been reported by several workers that dipteran flies and staphilinid beetles are important carrier of the hypopi of mites belonging to the genera Tyroglyphid , Linopodes and so on (Compton 1935; Hussey, 1964). But Histiostoma gracilipes is occassionally transferred to mushroom bed by flies (Compton, 1935). Gahm (1930) reported that Linopodes antennaepes is also found in straw and may be the main source of infestation. It has also been reported that the presence or absence of a mite species depends largely on the cul tural practices followed in the preparation of mushroom beds.

Pygmephorus mesembrinae is not found in manure heaps and mushroom beds but unsatisfactory compost preparation may lead to the infestation of such mite in mushroom cultivation (Thomas, 1942).

2.3 Damage caused by mushroom mites

The injury caused by various species of mushroom mites varies widely from species to species.

2.3.1 Damage caused by tyroglyphid mites

The damage symptoms of these mites vary from species to species. Austin and Jary (1936) and Jary and Stapley (1936) described the symptoms of damage of one of the most important species, Tyroglyphus dimidiatus. The mite hollows out tiny buttons, bearing only shells. In large mushrooms, cavities of various sizes are found on stalks and caps rendering them unfit for sale.

T.berlesei makes holes on the caps of mushroom which are similar to those of other tyroglyphids (Jary, 1937). T.mycophagus and T.longior are common injurious species on mushroom (Jary and Stapley, 1936; Davis, 1937).

Eberhardia sp. has been reported to damage the caps of mushroom by eating out large cavities (Thomas, 1936; Jary, 1937). It also feeds on mycelial beds of mushroom (Jary, 1937). Massae (1931) reported other two mites namely, Caloglyphus krameri and Oppia nitens as injurious species on mushroom. C.krameri makes deep pits on the stalks and caps of the mushroom. In some cases many buttons are completely hollowed out, tunneling up within the stipe (Austin and Jary, 1934).

Tyrophagus putrescentiae causes similar damage like C.kramer (Davis, 1938; 1944; Thomas, 1942). Mukherjee and Somchoudhury (1972) found this mite feeding on mycelium and sporophores resulting in small, irregular pits on stalks and caps. Under heavy infestation, buttons were found to be completely deraured leaving only a hollow stalk. Occassionally, this condition was accompanied by secondary bacterial decomposition.

Rhizoglyphus echinopus is found on decaying mushroom in Britain and no mycelial damage is recorded. (Hughes, 1961). In U.S.A R.phylloxerae is found to cause severe damage on mycelium (Davis, 1938; Thomus, 1942).

2.3.2 Damage caused by histiostomatid mites

It appears from the available literatures that among the three species of histiostomatid mite namely H.rostroserratum, H.heinemanni and H.gracilipes, only the last named species has been designated as a destructive pest to mushroom. The former two species are not directly harmful since it appears to feed only upon tissues already in a state of decay. (Jary and Stapley, 1936; Hill and Deahl, 1978). On the other hand, H.gracilipes feeds voraciously on spawn as well as on all stages of developing crops (Compton, 1933; 1938).

2.3.3 Damage caused by tarsonemid mites

Six species of tarsonemid mite have been reported to cause considerable damage to mushroom cultivation. According to Davis (1935 and 1941) and Thomas (1942) , *Tarsonemus floreicolus* is a serious pes of mushroom and causes considerable damage on the stem and caps in th form of tiny pits. The lower parts of stipe become reddish brown and the development of many buttons is inhibited. They further reported that *T.myceliophagus*, *T.confusus* and *T.floricolus* are found in thousa on mushroom body in U.S.A. inflicting considerable damage on the myce-lium, stems, caps and sporophores. Affected tissues became reddish and many infested pinheads stopped growing. The bases and stipes of affected mushroom become brown. Beer (1954) reported that *T.waitei* and *T.floricolus* causes similar damage to mushroom. *T.mycophagus* is considered as a major pest of mushroom in U.K. and Japan. The mite is very injurious to mushroom crops. The symptoms of damage along with the loss in yield due to the infestation of this mite has given by Austin and Jary (1934) from U.K.; Smith (1937) from Japan; Hussey and Gurney (1967) from U.S.A. The other important species in U.S.A. is *T.lintneri* which produces similar damage symptoms like *T.mycophagus* found in U.K. On the other hand, *T.tarsalis* though found in large num-ber on mushroom causes no damage. But they have a marked nuisance value.

2.3.4 Damage caused by pygmephorus mites

The damage done by pygmephorus mites is important from the qualitative point of view rather than quantitative. Because, it does not feed on fruit body and restricts its feeding only on mycelium body beneath the casing layer. But their presence in large number on the mushroom caps devaluate the quality of mushroom. The mite has also been reported to cause allergic reaction in U.S.A. (Davis, 1934; Thomas, 1939; 1942; 1955; Wicht, 1970).

2.3.5 Damage caused by linopod mites

The damage caused by Linopodes antelops is said to be primarily on the root system resulting a constriction at the base of stalk and stipe. The lower part of the stipe is often discoloured, the colour being pinkish to brown. In severe cases of damage, the mushroom is held to surface of the bed by only a few withered filaments. The crop loss may be as high as 40 %. They does not feed on mycellium. The damage is more or less identical to Tarsonemus myceliophagus (Gahm, 1930; Austin, 1937; Thomas, 1942; Hussey, 1963).

2.4 Bionomics of mushroom mites

Bionomics of mushroom mites have received little attention till-to-date. As a result, only a few literatures are available in this direction. Tyroglyphid mites have been reported to pass through egg, larva, resting larva, protonymph, resting protonymph, deutonymph and resting deutonymph to become adult. The foremost literature available on the biology of mushroom mite was that of Jary and Stapley (1937). They reported that Tyroglyphus dimidiatus takes 17-24 days to complete its life cycle (egg to adult) at 22°C. A female mite lays 40-60 eggs in her life time. Jary (1937) further investigated the biology of another species of mushroom mite i.e. *Caloglyphus* sp. He reported that the species takes 8-15 days to complete its life cycle at 20-21°C and the maximum number of egg laid by a female mite was as high as 325. He also studied the biology of *Eberhardia* sp. According to him, the mite species takes 11 days to complete its life cycle at 20-21°C and an adult lives around 3 weeks. The Bionomics of *Tarsonemus myceliophagus* was investigated by Hussey and Gurney (1967) and reported that at 24°C the egg to egg developmental period, when mating occurs, was 8 days extending to 12 days at 16°C.

The ecological studies on mushroom mites are rather scanty. The influence of temperature and relative humidity on the biology of *Tyrophagus putrescentiae* was investigated by Rivard (1961). According to him, a definite diminuation in life usually occured with increase in either temperature or humidity and the ovipositional period was most affected. Total egg production and rate of egg laying were highest at 72.5°F and 90 % relative humidity and both generally decreased with an increase in temperature or decrease in humidity from these values. The peak of egg-laying, however, was reached sooner at higher temperature but egg production was maintained at relatively high levels for shorter period. The rate of increase was greatest and approximately the same at 90 % R.H. within the range of 72.5 to 81.5°F. Subsequently, Hilsenhoff and Dicke (1963) undertook detailed observation on the effect of temperature and relative humidity on cheese mites namely, *Acarus siro* L. and *Tyrophagus putrescentiae* which become pest in mushroom houses under certain conditions. It is revealed that no eggs hatched at 32°F regardless of the relative humidity. At 56°F and 100 % R.H., *Acarus siro* required 26 days while it is 38 days for *Tyrophagus putrescentiae*. As the R.H. level at each temperature was decreased, the length of life cycle of the mites was increased. They further reported that a decrease in temperature and relative humidity reduced the viability and delayed the hatching of the eggs of *Acarus siro*. The same was true with *Tyrophagus putrescentiae* except that 84 % R.H. was optimum for this species. Mukherjee and Somchoudhury (1972) reported *Tyrophagus putrescentiae* takes 17 days to complete its life cycle (Egg to adult) at 30 ± 1°C and 80 % relative humidity. The biology of a mushroom infesting mesostigmatid mite, *Arctoseius cetrtus* was studied by Binns (1974) and reported that this mite remained in copula for 4-5 minutes and produced 2.5 eggs/day. The incubation period varied between 5-6 days and the emerging larvae took approximately a week to become adult at 22°C. The life history of histiostomatid mites described by Hill and Deahl (1978)was incomplete in several respects. However, they reported that the incubation period of histiostomatid mite was around 5 days.

2.5 Seasonal incidence of mushroom mites

The seasonal incidence of mushroom mites has not received much attention from scientists. As such very scanty informations are available in this direction till-to-date.

2.6 Incidence of natural enemies of mushroom mites

It appears from the perusal of available literatures that mushrooms mites are devoid of natural enemy complex.

2.7. Control of mushroom mites

2.7.1 Preventive measures

" Prevention is better than control " - this proverb is atleast hold good for mushroom mites as preventive measures has been found to be very satisfactory in most of the situations. Gahm (1930) reported that *Tyroglyphus lintneri* and *Linopodes antennapes* can be controlled by surface steaming of the compost before its utilization in the bed preparation. The treatment of compost at high temp.(130°F) has been recommended as a preventive measure against the mushroom mite infestation. Burning of sulphur in the empty mushroom houses (2-3 lbs/100 cu.ft.) has also been found to be satisfactory against *Histiostoma gracilipes*. The storage of compost manure should at least be kept $\frac{1}{2}$ mile away from the mushroom houses and old compost should be left 1 mile away from the mushroom house to prevent the mite infestation. Use of fumigants like Sodium cyanide at the rate of 5 ounces/1000 cubic feet or cyanogas at the rate of 10 ounces/ 1000 cu.ft. for 24 hrs are highly satisfactory against mushroom mites. The screening of window, doors and ventilation with 20 mesh copper net also helps to prevent infestation of mushroom mites from outside and change of clothing of the worker before entering into mushroom house is also necessary under certain circumstances (Compton, 1935).

Jary and Stapley (1937) advocated removal of debris, the use of an effective disinfectants and fresh manure as preventive measure against Tyroglyphus dimidiatus and T.mycophagus.

Hussey (1963) reported that pasteurisation of compost helps remarkably in the control of tyroglyphid mites. Hussey and Gurney (1967) observed that the exposure of mushroom mite at 39°C for 24 hrs was extreamly lethal and commercial cook out aim to maintain temperature at 67-71°C for several hours was completely reliable against Tyroglyphus mycophagus.

2.7.2 Curative measure

2.7.2.1 Effect of pesticides on mushroom mites

The chemical control of mushroom mites dates back to 1937 when it was found that the application of nicotine could not alter the mite population on infested mushroom. Subsequently, petroleum oil could not be utilized due to the risk of producing distortion as well as its phytotoxic nature of mushrooms (Jary and Stapley, 1937). It was further learnt from the investigation made by Caesar (1937) that tyroglyphid mites could not be controlled by using calcium cyanide, nicotine liquid, nicotine powder, 2 all nicotine, tobacco steams, carbon bisulphide and ammonia. However, paradichlorobengene was highly effective ($1\frac{1}{2}$ lbs to 400 sq.ft.)against them. Morton (1956) observed that TEPP, DDT and gamma-BHC dust ($\frac{1}{2}$ - 1 lbs per 100 sq.ft.) before and after casing and again during cropping are highly effective against tarsonemids, tyroglyphids, linopodes mites. Barker (1969) reported that *Tyrophagus putrescentiae* is susceptible to EDB. The efficacy of malathion was tested against some relatively uncommon mushroom mites like, *Tyrophagus putrescentiae; Aeroglyphus rofustus; Glycyphagus domesticus* and *Blattisocius keegani* and it was found that *T.putresentiae* is highly tolerant to the application of malathion (Barker, 1968). In recent years, it has been reported in several instances that methyl bromide, Silica aerogel insecticides and malathion are no longer effective against *T.putrescentiae* (Barker, 1968; Hussey and Gurney, 1967). Hussey (1963) observed that tarsonemid mites are difficult to control with acaricides and designated them as potential pest of mushroom. However, control of these mites can be achieved to a great success with the application of BHC, dicofol, demeton-methyl and parathion (0.003 % - 0.01 %). Dicofol was most effective against them. But these pesticides could not be recommended for direct application on mushroom due to their fungicidal properties and recommended only to disinfest mushroom houses between crops (Gurney and Hussey, 1967). They also recommended fumigation of mushroom houses with methyl bromide at the rate of 600 mg/hr/1000 cu.ft. The use of methyl bromide at the rate of 120-150 mg/litre/(= 200 mg/hr/2000 cu.ft.) barely affected mycelium but was completely lethal to tyroglyphids under laboratory condition (Osborne and Hamilton, 1966). Efficacy of lindane was tested and it was found that it is lethal to mites although it has some fungicidal properties.Hussey and Gurney (1967) has rightly reported that fungicidal chemicals can not be introduced effectively into cropping beds once an infestation has established in compost. Therefore, efficient control of mushroom mites should be based on prevention rather than control. It is essential to prevent their carry-over from one crop to the other.

2.7.2.2 Effect of natural products on mushroom mites

The uses of natural product as well as their extracts are an age old practice in the control of various pest species. With the advancement of science in modern era, more and more emphasis has been laid down to develop pesticides of plant origin for its low mammalian toxicity. A voluminous literatures have been accumulated over the past two to three decades in this direction. Some of them namely neem mahua, eucalyptus and such other trees hold promose in the control of pests in future. (Mayer, 1952; Oudri, 1973; Skatulla and Meisner, 1975; Pande, Singh and Tiwari, 1977; Sangappa, 1977; Singh *et al.*, 1978). A perusal of available literature reveals that no such work has been undertaken so far on any species of mushroom mites.

MATERIALS AND METHODS

Investigations were undertaken on the bionomics of mites found in association with four species of mushroom cultivated during summer and winter seasons under West Bengal condition. The bio-efficacy of synthetic pesticides as well as various plant products were tested against mite species. Attempts were also made to control the injurious mites through preventive measures. For the purpose of investigations, several materials were used and various methods were employed.

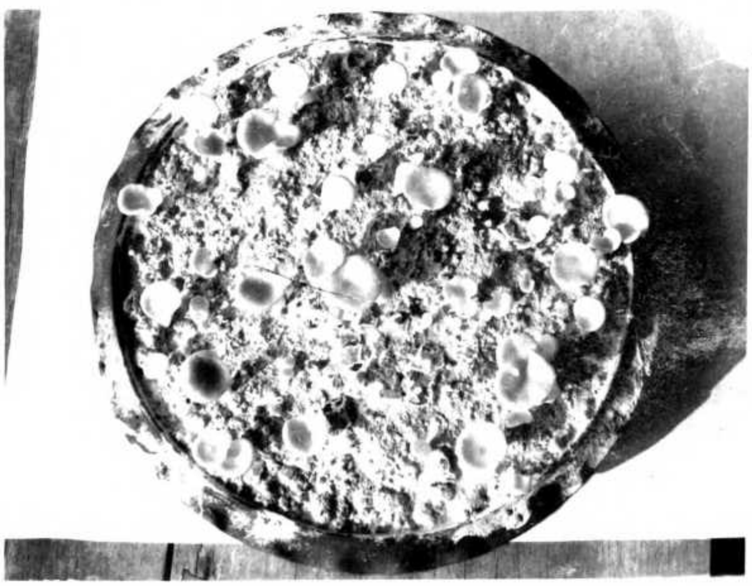
3.1 MATERIALS

3.1.1 Mushroom species : In the present investigation, four species of edible mushroom, namely *Pleurotus sajor-caju* (Fr.) Singer (Plate-3.1), *Pleurotus ostreatus* (Jacquin ex.Fr.) Kummer (Plate-3.2), *Tricholoma lobayense* Hien (Plate-3.3), *Volvariella volvacea* (Bull)(Plate-3.4) were taken into consideration. Of these four species, the former two are cultivated in winter (Winter-type) and the other two species during summer (summer-type). The mushrooms are being cultivated regularly in the Department of Plant Pathology of this Viswavidyalaya under the " All India Co-ordinated mushroom research programme ". The nucleus cultures of these species were obtained from them.

3.1.2 Mite species : The infestation of mites on mushroom are of regular occurrence in the culture room of this Viswavidyalaya. Mites which are found to be present on various types of mushroom round the year were collected. Attempts were made to reveal their identity upto

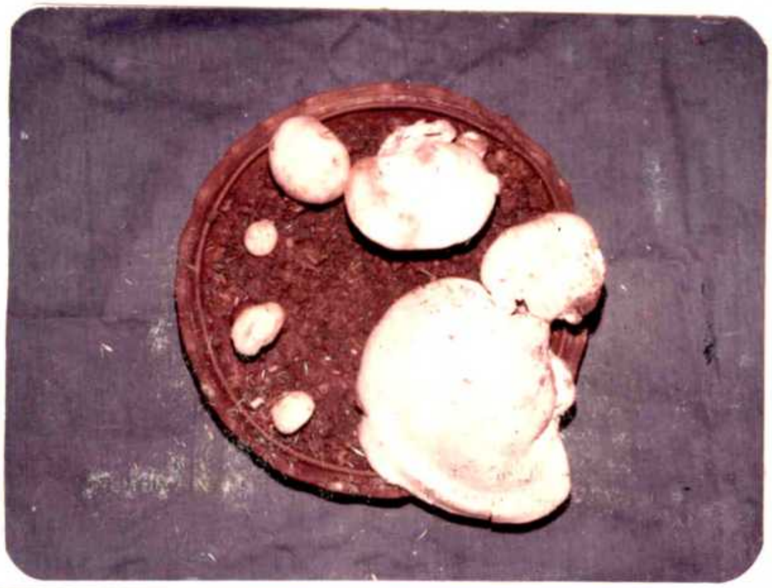
3.1

3.2



<u>Plate</u> 3.1-3.2: 3.1 <u>P.sajor-caju</u> mushroom cultivated in earthen tray; 3.2 <u>P.ostreatus</u> mushroom cultivated in earthen tray.

3.3



3.4

Plate 3.3-3.4: 3.3 T.lobayense mushroom cultivated in earthen tray; 3.4 V.volvacea mushroom cultivated in straw bundle.

the specific level with the help of experts available in India as well as abroad, in the field of Acarology, Dr.E.W.Baker, United States Department of Agriculture, rendered his kind help and identified two species as *Tyroglyphus dimidiatus* Herm (Longior) Gerv. and *Histiostoma heinemanni* Hill & Deahl. Subsequently, Dr.S.K. Gupta, Superintending Zoologist, Zoological Survey of India, Calcutta identified the third and fourth species as *Rhizoglyphus echinopus* Fumouze and Robin and *Hypoaspis miles* Berlese, respectively.

3.1.3 Pesticides : The following synthetic pesticides were tested against the mushroom mites. The details have been given below.

Sl. No.	Trade name	Common name	Concentration (% a.i.)	Source	Chemical name
1	Cythion	Malathion	0.005 0.01 0.02 0.04	M/S.Cyanamid India Ltd., Bombay	0,0-dimethyl phosphorodithioate of diethy mercaptosuccinate
2	Dicofol	Dicofol	0.005 0.01 0.02 0.04	M/S.Khaitan & Company, Calcutta.	4,4-dichloro-(trichloromethyl benzydrol)
3	Mit 505	Ethion	0.005 0.01 0.02 0.04	M/S.Shaw Wallace & Company Ltd., Calcutta.	0,0,0,0-tetraethyl S,S - methylene bis (phosphorodithoate)
4.	Nuvan	Dichlorvos	0.005 0.01 0.02 0.04	M/S.Hindusthan Ciba Giegy Ltd. Bombay	2,2-dichlorovinyl d methyl phosphate

In addition to the above pesticides, several plant products were also tested against them. These are given below.

Sl. No.	English name	Scientific name	Concentrations (% a.i.)	Source
1.	Chaulmoogra	*Chaulmoogra odorata* Roxb.	0.01 0.05 0.25 1.25 6.25	M/S.Central Blue Print, Calcutta.
2.	Java citronella	*Cymbopogon winterianus* Jowitt	0.01 0.05 0.25 1.25 6.25	M/S.Industrial and Chemical Concern, Calcutta.
3.	Clove	*Eugenia caryophylla* Thumb	0.01 0.05 0.25 1.25 6.25	M/S.Central Blue Print, Calcutta.
4.	Karanja	*Sterculia urens* L.	0.01 0.05 0.25 1.25 6.25	M/S.Industrial and Chemical Concern, Calcutta.
5.	Neem	*Melia azadirachta* Linn.	0.01 0.05 0.25 1.25 6.25	M/S.Industrial and Chemical Concern, Calcutta.

6. Wintergreen	Gaultheria procumbens L.	0.01 0.05 0.25 1.25 6.25	M/S.Central Blue Print, Calcutta.

3.2 METHODS

3.2.1 Mushroom cultivation : In case of mushroom, the seed has no sexual origin and is termed as 'spore'. These spores send out exploratory root-like threads in all directions within the growing medium and produce the fruit body (the mushroom itself) without the intermediate stem and leaves stage; and new spores develop inside the cap of the mushroom. The root like threads develop from spores in order to search for food and transmit it to the mushroom. In a multiple of branching and criss-crossing, they frequently fuse together, and are known in the mass as mycelium. The mushroom first appears as a tiny ball and called as bud. As it grows, the stem is discovered, and later the cap (or pileus) begins to open up like an umbrella, fearing away the delicate membrane or veil (or velum by which its outer edge is attached to the stalk (Plate 3.5). For mass cultivation of mushroom the mycelial growth on wheat grains were used as spawn.

3.2.1.1 Spawn Preparation : One kg of healthy wheat grains was first washed in water and then boiled in 1.5 litre water for 30 minutes. The grains were removed before splitting during boiling and placed on wire netting to drain out excess water. Then, 13.33 gm of Calcium carbonate and 3.33 gm of Calcium sulphate were mixed with them. The grains were

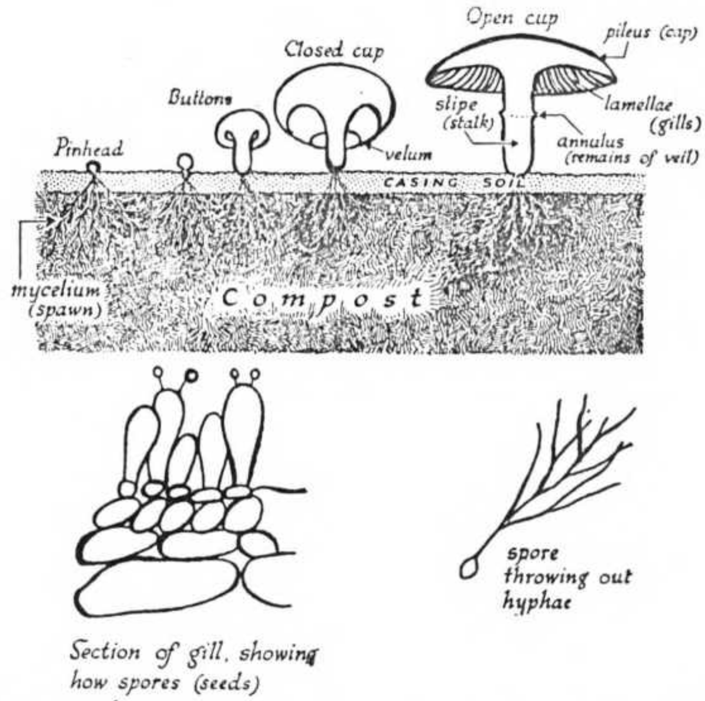
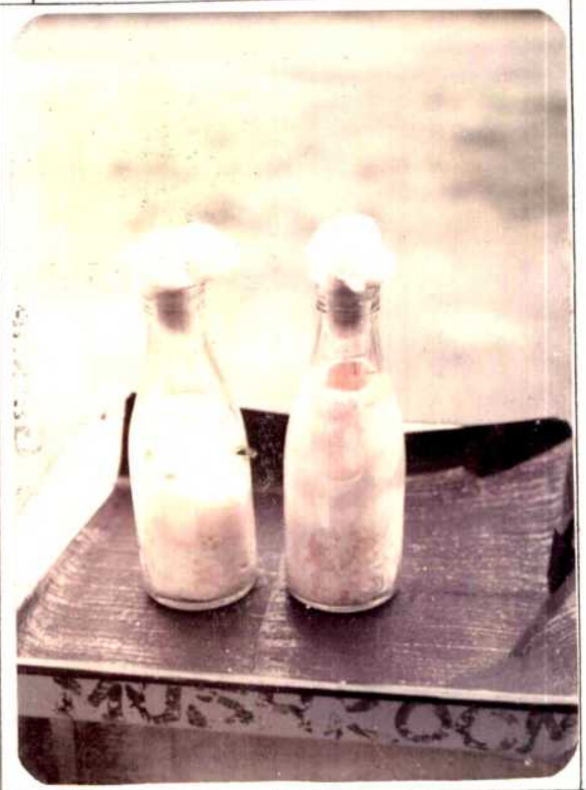


Plate 3.5: Stages in the development of the cultivated mushroom (AFTER AUTKINS,1972)

3.6

3.7



<u>Plate</u> 3.6-3.7: 3.6 Pure mycelial culture of mushroom in test tube; 3.7 Mushroom spawn preparation in bottle.

transferred in 500 ml milk bottles (at the rate of 200 gm/bottle) and plugged with non-adsorbent cotton. The bottles were then sterilized by autoclaving (15 lbs pressure/sq.inch for 30 minutes) for two consequtive days. The bottles were cooled, shaken, and then inoculated under asceptic condition with 1 cm disc. of pure mycelial culture of mushroom fungi (Plate3.6) raised on malt agar medium. The culture bottles inoculated with _Pleurotus sajor-caju_ and _Pleurotus ostreatus_ were kept at 25 ± 1°C and those with _Tricholoma lobayense_ and _Volvariella volvacia_ were incubated at 30 ± 1°C. The contents of the bottles were shaken thrice (on the 6th, 9th and 12th day) during the incubation period for uniform and rapid mycelial growth. After 12-20 days when all the grains were covered up with whitish mycelial growth, the spawn was ready for use (Plate-3.7).

3.2.1.2 Inoculation :

i) Winter type (_Pleurotus sajor-caju_ (Fr.) Singer and _Pleurotus ostreatus_ (Jacquin ex Fr) Kummer)

Well dried paddy straw was chopped into small bits (1 cm length) and soaked in clean cold water for 24 hours. The excess water was drained out. A 2.5 cm thick layer of soaked straw was placed at the bottom of the earthen tray (30 cm diameter x 6.25 cm depth) and 4 gm N,P,K (15:15:15) fertilizer was sprinkled evenly on the straw layer and was again covered with 1 cm thick layer of straw. Wheat grain spawn was sprinkled on this straw layer at the rate of one bottle per 8 trays. Spawn was covered with a 1.5 cm layer of straw. About 500 gm soaked straw was used in a tray. The trays were covered by 0.25 cm thick film of garden soil (collected from 9 cm below and mixed with 15 gm $CaCO_3$ and 5 gm $CaSO_4$/kg of soil) immediately after inoculation. The trays were covered with a black polythene sheet and were placed in shady places.

ii) Summer type

A. *Tricholoma lobayense* Hien : The inoculation technique is same as winter type.

B. *Volvariella volvacea* (Bull) Sacc. : Thirtytwo golden coloured, hand threshed, well dried, paddy straw bundles (weight 1 kg each) were soaked in clean water for 24 hours. Excess water was then drained out and the bundles were bent at the neck portion of ear head and tied with straw to form a bundles of 60 cm length. Then beds (60 cm x 60 cm) were prepared on raised wooden platform by placing the eight bundles side by side with alternate arrangement of upper and lower end of bundles. Now bits of pure paddy straw spawn (two bottles per bed) were inoculated inside each bundle all round the bed, 10-15 cm from the edge. Subsequently, 3 similar layers, each having 8 bundles were made by placing across those of the lower and the entire bed formed a cube. After placing the fourth layer of straw, the bed was pressed down, compacted and covered with black polythene sheet.

3.2.1.3 After Care : Watering was done gently with hose every day in such a way that the straw always remains moist but there was no excess water in the tray/bundle. The black polythene sheet cover was removed when mycelial growth covered the surface of the tray/bundle (Plate-3.8).

3.2.1.4 Harvest : In the case of *Pleurotus sajor-caju* and *Pleurotus ostreatus*, the first flush appears within 3 weeks after sowing and are ready for harvest 4-5 days later. The second flush is found within 9-15 days after 1st flush. In the case of *Tricholoma lobayense* and *Volvariella volvacea* the first flush appears within 21-26 and 18-25 days, respectively. There was an interval of 7-15 days between the first and second flushes.

3.2.2 Collection of mites :

The mites were collected from the infested mushroom with the help of Berlese funnels (Plate-3.9) in 50 % alcohol. Living mites were collected directly from the infested mushroom with the help of a fine brush for mass rearing.

3.2.3 Preservation and permanent slide preparation :

Adult mites collected in the above process were subsequently transferred in A.G.A. solution (eight parts 70 % ethyl alcohol, one part glacial acetic acid and one part glycerine. 300 gm of sorbitol to one gallon of the above) for prolonged preservation.

The permanent slide preparation of the three species of mite namely, *Rhizoglyphus* Fumouze and Robin, *Tyroglyphus dimidiatus* Herm.

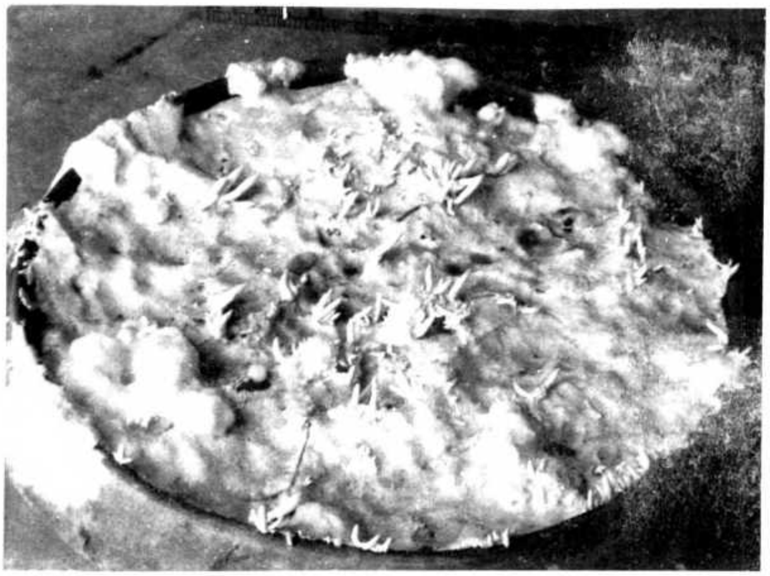
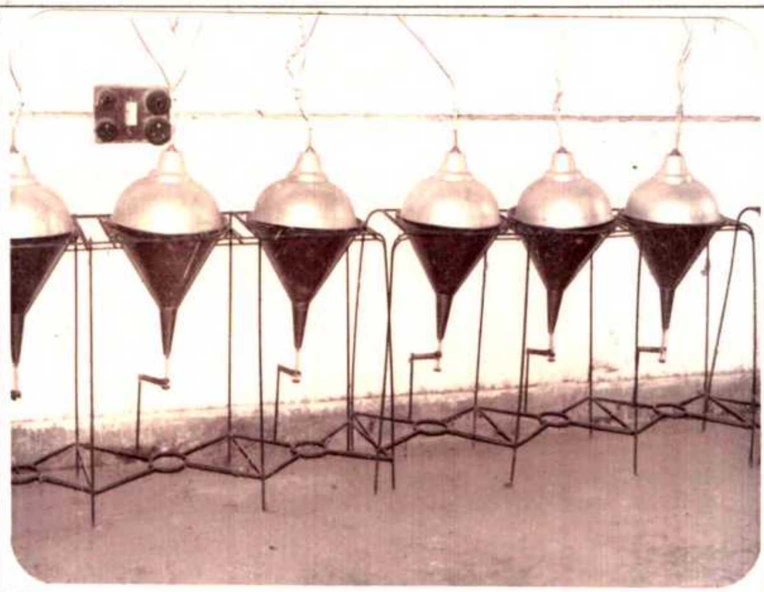


Plate 3.8: Mycelial growth of sajor-caju mushroom in earthen tray.

3.9



3.10

<u>Plate</u> 3.9-3.10: 3.9 Berlese funnel; 3.10 Potter's tower.

(longior) Gerv., Hypoaspis miles Berlese were made in Hoyer's gum chloral medium (dist.Water-15gm, gum arabic - 15 gm, chloral hydrate - 100 gm and glycerol-10 gm). The other species namely, Histiostoma heinemanni needs clearing before mounting. The adult mites were placed in a few drops of 10 % KOH and subsequently warmed to hasten clearing. Finally, they were mounted in Hoyer's medium (Jary and Stapley, 1937).

3.2.4 Identification of mite species :

The permanent slides were sent to Dr.E.W.Baker, United States Department of Agriculture, Agriculture Research Service, North-eastern Region, Beltsville, Maryland, U.S.A. and to Dr.S.K.Gupta, Superintending Zoologist, Zoological Survey of India, Calcutta for identification.

3.2.5 Source of mite infestation in mushroom cultivation :

To study the mode of entry of four species of injurious mites on four cultivated species of mushroom, various components found to be important in this regard were taken into consideration. For this purpose, straw, soil and water were throughly sterilized. Surrounding areas where the rearing jars were placed, were throughly treated with 0.01 % a.i. Kelthane to avoid the infestation of mite by crawling, care was being taken to prevent the dispersal of mite through air/by insects by covering the mouth of the rearing jar (throughly stereilized by washing with 100 % ethyl alcohol) with cotton pad before use in the compost making in the treatment I. Similarly, another compost set (treatment VII) was prepared where all the components were left unsterilized. While in other treatments i.e. from two to six only one component was kept unsterilized. The detailed breakups of the treatments have been given below.

Treatment I - S.straw + S.soil + S.water + S.cotton lid + Surroundings treated with acaricide.

Treatment II - Without cottonlid + S.straw + S.soil + S.water + Surroundings treated with acaricide.

Treatment III - Surrounding without acaricide + S.straw + S.soil + S.water + S.cotton lid.

Treatment IV - Un.S. water + S.straw + S.soil + S.cottonlid + Surroundings treated with acaricide.

Treatment V - Un.S.straw + S.soil + S.water + S.cottonlid + Surroundings treated with acaricide.

Treatment VI - Un.S.Soil + S.straw + S.water + S.cottonlid + Surroundings treated with acaricide.

Treatment VII - All unsterilized.

(S = Sterilized ; Un.S. = Unsterilized).

For the purpose of sterilization, straw and soil were subjected to autoclaving for 1 hr at 15 lbs pressure and continued for two days while water was sterilized under autoclave at 15 lbs pressure for 20 min.

The experiments were conducted on <u>Pleurotus sajor-caju</u> and <u>Pleurotus ostreatus</u> type of mushrooms during winter and <u>Tricholoma lobavense</u> and <u>Volvariella volvacea</u> during summer with 3 replications in each case. The experiment was laid out for each of the 4 species of mite during their time of occurrence. Finally, fruit bodies of mushroom as well as compost from mushroom bed were collected from each treatment and the presence (+) or absence (-) of mite was detected by placing those materials under Berlese funnel.

3.2.6 Nature and symptom of damage:

Two separate sets (3.2.6.1 and 3.2.6.2) of experiments were set up to study the nature as well as symptoms of damage caused by mushroom mites. The details methodology are as follows.

3.2.6.1 Nature of mushroom mites :

The nature of mushroom mites were investigated from three different angles. Therefore, three different experiments were designed.

i) Rate of growth of mushroom mites in compost bed with or without mushroom inoculation :

Each of the thirty six standard mushroom bed as mentioned earlier were prepared with sterilized compost. Females of four different species of mushroom mites namely, *Rhizoglyphus echinopus*, *Tyroglyphus dimidiatus*, *Histiostoma heinemanni* and *Hypoaspis miles* were released separately in the compost bed at the rate of 20/100 gm compost. Out of thirtysix, only twentyfour beds received mushroom inoculation during the compost bed preparation and the rest did not receive any inoculum of mushroom. For *Rhizoglyphus* mite, *Pleurotus* *sajor-caju* and *Pleurotus ostreatus* (winter type) were used while for other three species of mite *Tricholoma lobayense* and *Volvariella volvacia* (summer type) were selected as host. There were three replications in each treatment. For winter type mushrooms, experiment was conducted in winter and for summer type it was conducted in summer.

ii) Rate of Increase of mushroom mites
at different days after spawning :

Similar sets as mentioned in the earlier one were prepared wherein 100 gm compost was removed per tray on the fifteenth day as well as after an interval of ten days till the fourtyfifth day of spawning. The composts thus removed from the mushroom bed were placed in Berlese funnel to collect mite from each sample. The number of mite released initially was 20/100 gm compost. There were three replications for each treatment day and observations were undertaken on four species of mushroom mites on their hosts.viz., *Pleurotus sajor-caju* and *Tricholoma lobayense*.

iii) Rate of distribution of mushroom mites
at different profiles of mushroom bed :

Another set of experiment was conducted in the same way as mentioned earlier wherein composts containing mycelial stage of mushroom were removed from four different profiles based on the depth of the compost layer (up to 1.5 cm, 1.5 - 3 cm, 4.5-6 cm). Composts thus collected from various depths of tray were placed in Berlese funnel (at the rate of 100 gm from each layer) to know the number of mites present per layer. The number of mite released initially per 100 gm compost was 20. There were five replications for each treatment and there were four species of mite grown on two types of mushroom such as, Pleurotus sajor-caju and Tricholoma lobayense.

3.2.6.2. Symptoms of damage caused by mushroom mites :

i) Damage caused during mycelial stage of mushroom :

At the first instance, the damage done on mushrooms during its mycelial stage by four species of mushroom mites was considered. Two sets of experiments, one comprising of Rhizoglyphus echinopus infesting two winter types of mushroom and the other with Tyroglyphus dimidiatus, Histiostoma heinemanni and Hypoaspis miles infesting two summer types of mushroom were laid out. Mycelial mats of four types of mushroom were grown separately providing 20 ml of potato broth in conical flask. Five gm of mycelial mat of each type was placed separately in petridishes, one containing ten (10)mites and the other without any mite (control). There were two such sets for each type of mushroom as well as for each mite species. Each of the four species of mite was inoculated separately and individual set was maintained for each mite species for observation. There were five replications for each treatment. Observations were taken on the weight loss of mycelial mats seven days after mite inoculation as well as in the control experiments kept without mite. Observations had been continued to follow up the course of development of damage symptoms caused by four species of mushroom mites on four different types of mushroom

ii) Damage caused during bud and fruit-body stages of mushroom :

Different types of damage are caused by mites on mushroom. Experiments were set up to follow up the course of damage done by four species of mites on mushroom, based on various parameters such as spawn-run period, number of buds and fruit bodies emerged, circumference, thickness and weight of cap and stalk and damage done during different days of sporophore production. Experiments were conducted in the same way as has been mentioned in the column (3.2.1). Each of the four species of mite was inoculated separately during the time of tray preparation at the rate of 200/100 gm compost and individual set was maintained for each species of mite for observation. For Rhizoglyphus mite, Pleurotus sajor-caju was used while for other three species of mite Tricholoma lobayense was considered as host. The number of replications varied between three to ten according to the need of experimentation.

3.2.7. Damage done on mushroom crop under various level of mite density :

Experiments were designed following the same methodology described in the column (3.2.1). However, the density of mite population was varied between 100 to 300/100 gm compost among different treatments. Observations were then taken on yield of mushroom under various level of mite densities. There were three replications per treatment and a control set was maintained with three replications. Experiments were conducted on two summer and two winter types of mushroom.

3.2.8 Rearing of mushroom mites on artificial diets :

Eight types of artificial diets were prepared and their compositions are given below :

A. 1 gm wheat kernel + 10 cc distilled water-(heated for 10 min at 60 ± 1°C).

B. 0.5 gm agar + 1 gm wheat kernel + 10 cc distilled water- (heated for 10 mins at 60±1°C).

C. 0.5 gm agar + 2 gm dextrose + 10 cc distilled water- (heated for 10 min at 60±1°C).

D. 0.5 gm agar + 0.1 gm yeast extract + 10 cc distilled water- (heated for 10 min at 60±1°C).

E. 0.5 gm agar + 2 gm dextrose + 1 gm wheat kernel + 10 cc water- (heated for 10 min at 60±1°C).

F. 0.5 gm agar + 1 gm wheat kernel + 0.1 gm yeast extract + 10 cc distilled water - (heated for 10 min at 60±1°C).

G. 0.5 gm agar + 2 gm dextrose + 1 gm wheat kernel + 10 cc straw juice (made by heating 5 gm straw + 15 gm distilled water) (heated for 10 min at 60 ± 1°C).

H. 0.5 gm agar + 2 gm dextrose + 1 gm wheat kernel + 2 gm mushroom powder + 10 cc distilled water - (heated for 10 min at 60 ± 1°C)

The suitability of the above mentioned artificial diets was tested against four species of mushroom mites. For the purpose of investigation, fifteen gm of diet was chosen from each category and was placed in a petridish wherein five pairs from each of the four species of mite were released separately to note the population built up of each species of mite after thirty days of inoculation. The experiments were conducted at 20 ± 1°C for Rhizoglyphus echinopus and 30 ± 1°C for other mites being the optimum temperatures for them. The relative humidity level was maintained at 90% R.H. for all the four species. There were three replications for each treatment.

3.2.9 Biology of mushroom mites :

Two types of artificial diets ('F' and 'H') viz., type 'F' for Rhizoglyphus echinopus and type 'H' for Tyroglyphus dimidiatus Histiostoma heinemanni and Hypoaspis miles were chosen based on their suitability to four species of mushroom mites. Thereafter, two gm of each of the two artificial diets were placed separately in cavity slides. Thus, 360 cavity slides were arranged to receive a pair of mite (10 and 19) in each of them. The slides were then covered with glass tops and placed inside desicators wherein three sets of relative humidity viz., 30 ± 5% , 60 ± 5% and 90 ± 5% were being maintained. The desicators were placed in three sets of temperatures viz., 20 ± 1°C, 30 ± 1°C, and 40 ± 1°C to provide various combinations of temperature and relative humidity such as 20 ± 1°C + 30± 5 % R.H., 20 ± 1°C + 60 ± 5 % R.H. and so on. Observations were taken at six hours interval on mating behaviour, pre-ovipositional and ovipositional period, duration of life cycle, mortality at each stage, feeding habit etc.

3.2.10 Seasonal incidence of four species of mites on straw component and on two winter/summer types of mushroom during their mycelial and fruit body stages :

Mushroom beds were prepared in the similar way as mentioned earlier (Column - 3.2.1) except unsterilized straw was utilized in this case. Spawn was inoculated in beds to allow the natural growth of mushroom through mycelial to reach fruit body stage under room temperature. This was done to allow the mushrooms to invite natural infestation of mites. Samples of compost (10 gm) were collected at intervals ranging between fifteen to twenty days when mushroom reached mycelial stage. The samples drawn in the above way during January 1984 to December 1985, were placed in Berlese funnel to collect mites present in the samples during various months of a year. Similarly, samples of fruit body (10 gm) were also taken into account to measure the density of mite population on them. The density of mite population in straw which acts as the sole carrier for mites to mushroom beds was also investigated at an interval of fifteen days. Each treatment was replicated three times. There were two types of winter (*Pleurotus sajor-caju* and *Pleurotus ostreatus*) and summer (*Tricholomo lobayense* and *Volvariella volvacea*)mushrooms on which the four species of mites were recorded and seasonal incidence were studied.

3.2.11 Natural enemies of mushroom mites :

For the purpose of investigations, samples (10 gm) were drawn throughout the year from straw, compost, infested mycelial mats, infested bud and fruit body to note the incidence of natural enemies found in association with mushroom cultivation. The samples collected from the above materials were subjected to critical observation under binocular microscope to locate the presence of natural enemies, if any.

3.2.12 Control of mushroom mites :

3.2.12.1 Prophylactic/preventive method of control :

i) Effect of sterilization of straw used in compost preparation :

Two sets of mushroom bed were prepared for the production of mushroom. One set received sterilized straw while the other was prepared with unsterilized straw. During the course of investigations, compost (50 gm) containing mycelial stage of mushroom as well as 50 gm of fruit body were drawn separately and were placed under Berlese funnel to note the density of mites in each samples. There were three replications for each treatment and the experiment was laid out for each of the four species of mites during their time of occurrence. For *Rhizoglyphus echinopus*, *Pleurotus sajor-caju* was used and for other mites, *Tricholoma lobayense* was used as host.

ii) Effect of heat treatment on mushroom mites :

Four species of mushroom mites (10/jar)were subjected to heat treatment after releasing them in sterilized straw kept in small glass jar. There were ten levels of temperatures varying from 50 to 72.5°C with three levels of exposure period (15,30 and 45 minutes). After the heat treatments, the number of mites survived per treatment were counted. There were four replications per exposure period.

3.2.12.2 Direct method of control :

i) Effect of pesticides :

Four commercial preparations of pesticides viz., ethion, dichlorvos, dicofol and malathion in four concentrations (0.005, 0.01, 0.02, 0.04% a.i.) were tested on each of the four species of mite. Petri dishes containing two grams of artificial diet were sprayed with one ml of pesticidal solution under Potter's tower (Plate 4.10)(Ten pounds pressure). After spraying, petri dishes were allowed to dry over a period of ten minutes to provide a thin film of pesticides. Ten females of each of the four species of mite were released on treated artificial diet kept in petri dishes. Observations were taken on the rate of survival of each mite species after twelve hours and continued till seven days. The experiments were conducted at 30 ± 1°C with 90 % R.H. There were three replications for each concentration of pesticides.

ii) Effect of essential oils :

Experiments were designed in the similar way as mentioned in column 3.2.12.2(i). Before use, oils were emulsified with the help of 5 % emulsifier (hydroxid-X-150). There were altogether six oils viz., chaulmugra, citronella, clove, karanja, neem, wintergreen used in five contentrations such as 0.01, 0.05, 0.25, 1.25 and 6.25 % a.i. The number of replications and the procedure followed in countin dead mites were similar as have been described in the above experiment.

3.2.13 Toxicity of oils on mushroom species :

Six oils namely, chaulmoogra, citronella, clove, karanja, neem, and wintergreen which were found to be effective against mushroom mites were tested for their toxicity on *Tricholoma lobayense* based on three replications. Emulsified oils were sprayed on mushroom beds (10 ml/bed) after inoculation except in one set which served as control. They were allowed to grow until fruit bodies were found. Thereafter, yield data were collected based on the weight of fruit body.

3.2.14 Statistical methods :

To analyse the data obtained during the course of investigations, various statistical methods were used. For finding out the components of variation due to different factors, the data obtained from the experiments conducted on the nature and symptom of damage, and suitability of various artificial diets were subjected to analysis of variance.

Factorial experiment was designed when more than one factor were included such as in the biological study under various levels of temperature and relative humidity. Prior to analysis, all the data on per cent were subjected to inverse sin_e transformation (Fisher and yates, 1938).

Similarly, correlation coefficients were worked out to study the extent of relationship between a climatological factor in one hand and the population density of mite on the other hand.

In the toxicological study, experiments were designed for factorial R.B.D. per cent mortality of the mites obtained due to pesticidal applications was corrected in respect to control mortality by Abbott's formula (1925). $P = \frac{p'-c}{100-c} \times 100$, where p = % correlated mortality; p' = % observed mortality; c = % control mortality.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Experiments were designed to study various aspects of mushroom mites during the present investigation and these were classifie under various broad topics viz., occurrence, damage potential of mushroom mites as well as their biology, seasonal incidence and control. The mushroom culture centre belonging to " All India Coordinated ICAR Research Project on Mushroom" affiliated to the Department of Pathology of this University was chosen as the site for investigations. The Project being a centre of excellence on mushroom research in the eastern part of the country has introduced several species of edible mushrooms and their feasibility from the view point of commercial exploitation are being tested here. The entire sets of experiment were carried out under laboratory condition. The data collected on various aspects of mushroom mites were subject to various statistical analysis. These have been presented below.

4.1 Occurrence of mushroom mites

Among the various species of edible mushroom found to grow under natural condition, only four species, namely *Pleurotus sajorcaju*, *Pleurotus ostreatus*, *Tricholoma lobayense*, and *Volvariella volvacea* have been selected and subsequently introduced by the centre for commercial exploitation considering their adaptibility, nutritional status and amenability to rear under local conditions. Since the year 1978, these four species of mushroom are being cultivated regularly in the centre during different periods of a year.

As a matter of fact a good number of pest species have been found to take a great tool of the crop in recent years of which insects (Sciarid flies etc.) are of considerable importance. Since last four to five years, it has been noticed that mites are becoming more dominant and inflicting severe damage on growing mushrooms. Therefore a detailed investigation pertaining to various aspects of mites was planned with an objective to reveal their identity and to undertake subsequent studies as and when found to be necessary. It may be seen from Fig.4.1 that altogether four species of mite viz., Rhizoglyphus echinopus Fumouze and Robin, Tyroglyphus dimidiatus Herm (Longior) Gerv., Histiostoma heinemanni Hill and Deahl and Hypoaspis miles Berlese are responsible for causing severe damage to mushrooms cultivated in this centre. It is interesting to note that the four species of mite occur in a sequence without overlapping each other. Thus, it forms a mite complex on mushroom. Incidentally, they are hos specific and their occurrences are time-bound as it is revealed from Fig.4.1. The period of occurrence of Rhizoglyphus echinopus ranges from January to March and is found on oyster mushrooms (P.sajor-caju and P.ostreatus) alone. On the other hand, Tyroglyphus dimidiatus, Histiostoma heinemanni and Hypoaspis miles are found only on summer type of mushrooms viz., T.lobayense and V.volvacea.The incidence of T.dimidiatus is found during April to June while those of H.heinemann and H.miles are from June to October and October to November, respectively.

A perusal of available literatures reveals that very scanty informations are available on mites infesting mushrooms in India.

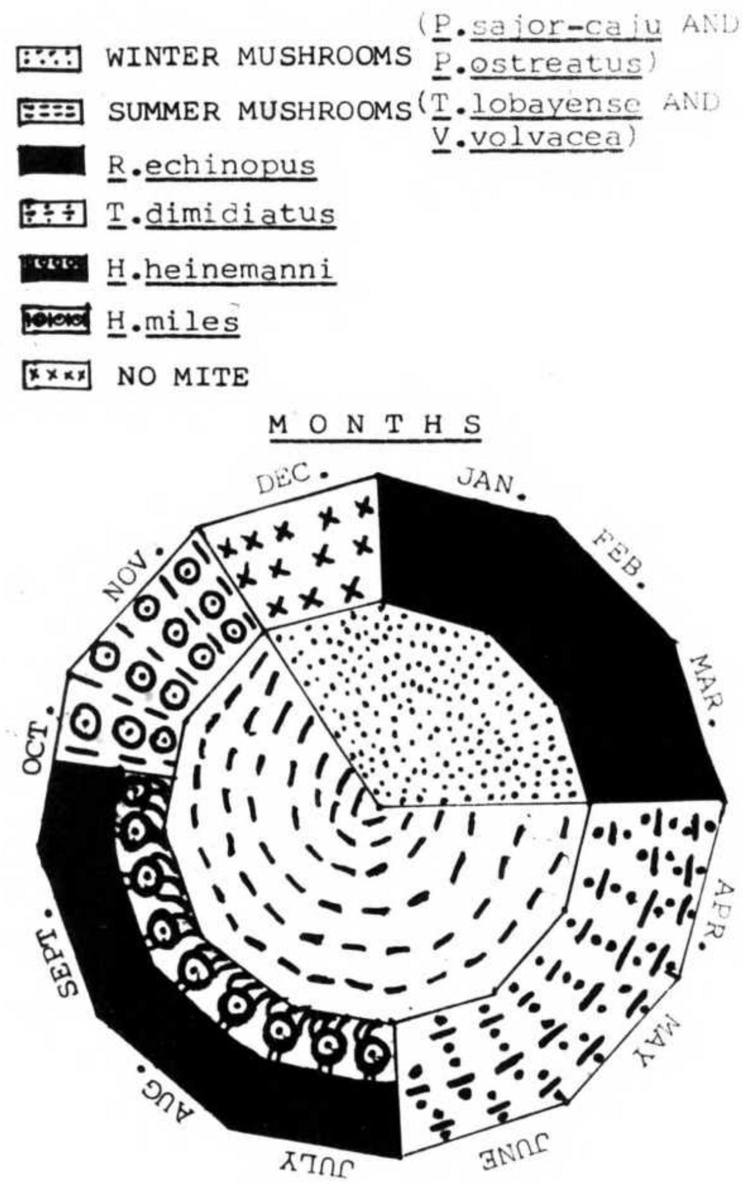


FIG.4.1: SEASONAL DIFFERENCES IN SPECIES COMPOSITION OF THE MUSHROOM MITES.

However, detailed informations in this regard are available in other parts of the World. It has been reported that the majority of mushroom mites belong to eleven families viz., Acaridae, Glycyphagidae, Tarsonemidae, Eupodidae, Anoetidae, Pyemotidae, Ascidae, Digamasellidae, Tyleidae, Scutacaridae and Macrodhelidae. Out of which Acaridae, Tarsonemidae, Eupodidae, Anoetidae are of great importance (Table 4.1). The investigations undertaken by various workers, namely, Jary, Stapley, Hussey, Gahm, Austin, Compton, Hill and Deahl etc.may be mentioned in this context. It is evident from the list presented in Table 4.1 that the problem of mites in mushroom cultivation is of great significance. It is revealed from the reported occurrence of 52 species of mushroom mite throughout the world. The United States of America and Britain are the two countries where most of the mite species are found. Out of 52 species, sixteen are of regular occurrence of mushroom cultivation around the world. In comparison to those two countries, India stands in a comfortable position so far the number of species found in our condition is concerned. It may be mentioned that the commercial cultivation of mushrooms has been undertaken in a limited scale in our country. It may be presumed that with the spread of mushroom cultivation during the course of time there is a possibility that more number of mite species will gradually adapt on our mushroom crop. This is because of the fact that several mite species which have been reported from the U.S.A. and Britain are also found in India. At present they thrive on other hosts. But the pattern of occurrence of mushroom mites found in India <u>vis-a-vis</u> foreign countries is more or less similar. It is apprehended that the problem

Table 4.1 : List of mites found in association with mushroom cultivation and their distribution.

Sl. No.	Species	Family	Reference	Distribution
1.	*Tyroglyphus berlesei* Michael	Acaridae	Jary (1937)	U.K.
2.	*T.dimidiatus* Herm(*longior*) Gerv.	Do	Jary & Stapley (1937),Das(1986).	U.K.,India.
3.	*T.lintneri* Osb.	Do	Gahm(1930),Jary and Stapley(1937).	U.K.,U.S.A.
4.	*T.mycophagus* Megn.	Do	Austin & Jary (1934)	U.K.
5.	*Tyrophagus fungivorus* Oudemans	Do	Hussey(1963)	U.K.
6.	*T.audemansi* Robertson	Do	Hussey(1963)	U.K.
7.	*T.putrescentiae* Schrank	Do	Hussey(1963), Rivert(1961), Mukherjee and Somchoudhury(1972).	U.K.,U.S.A., India.
8.	*T.longior* Gerv.	Do	Hussey(1963), Davis(1968).	U.K.,U.S.A.
9.	*Aeroglyphus rofustus* Banks	Do	Barker(1960).	U.S.A.
10.	*Blattisocius keegani* Tox	Do	Davis(1968).	U.S.A.
11.	*Caloglyphus berlesei* Mihhael	Do	Hussey(1963),Jary (1937).	U.K., France
12.	*C.mycophagus* megnin	Do	Hussey(1963); Rota & Graziella (1974).	U.K., Italy.
13.	*C.krameri* Berlese	Do	Hussey(1963).	U.K.
14.	*Eberhardia* sp.	Do	Jary(1937).	U.K.
15.	*Rhizoglyphus phylloxerae* Riley	Do	Davis(1938).	U.S.A.
16.	*R.echinopus* Fumouze and Robin	Do	Hughes(1961),Das (1986).	U.K., India.
17.	*Oppia nitens* C.L.Koch	Do	Massae (1931).	U.K.

(Contd....)

Table 4.1 (Contd.)

Sl. No.	Species	Family	Reference	Distribution
18.	Glycyphagus domesticus De Geer	Glycophagidae	Davis(1938) Rota & Graziclla (1974)	U.S.A.,Italy
19.	Tarsonemus canestrim	Tarsonemidae	Beer(1954)	U.S.A.
20.	T.confusus Ewing	Do	David &Thomas (1941),Hussey (1963).	U.S.A., U.K.
21.	T.floricolus Canestrini	Do	David & Thomas (1941),Hussey (1963)	U.S.A. ,U.K.,
22.	T.lukoschusi Hill and Deahl	Do	Hill and Deahl (1978)	U.S.A.
23.	T.mercedesae Hill and Deahl	Do	Hill and Deahl (1978)	U.S.A.
24.	T.myceliophagus	Do	Austin and Jary (1934),Hussey (1963)	U.S.A., U.K.
25.	T.randsi Ewing	Do	Hussey (1963)	U.K.
26.	T.tarsalis	Do	Moreton (1956)	U.S.A.
27.	T.waitei Banks	Do	Beer (1954), Hussey (1963).	U.S.A., U.K.
28.	Linopodes antennapes Banks	Eupodidae	Gahm(1930), Austin(1937).	U.S.A., U.K.
29.	Glyphanoetus fulmeki Oudemans	Anoetidae	Compton(1933)	U.S.A.
30.	Histiostoma gracilipes Banks	Do	Compton(1933)	U.S.A.
31.	H.rostroserratum Megn.	Do	Jary and Stapley 1936, Huges and Jackson(1958)	U.K., U.S.A.
32.	H.feroniarum Dufour	Do	Schcucher(1957)	U.S.A.
33.	H.heinemanni Hill and Deahl	Do	Hill and Deahl (1978),Das(1986).	U.S.A., India
34.	Pygmephorus allmanni Krezal	Pyemotidae	Gurney and Hussey (1967),Wicht(1970)	U.K., U.S.A
35.	P.althiasae Wicht	Do	Wicht(1970), Wicht(1970).	U.S.A., France.
36.	P.americans Banks	Do	Davis(1934),	U.S.A.

(Contd...)

Table 4.1(Contd.)

Sl. No.	Species	Family	Reference	Distribution
37.	P.flechtmanni Wicht	Do	Wicht(1970), Wicht(1970).	U.S.A., Brazil.
38.	P.kneeleuni Wicht	Do	Wicht(1970)	U.S.A.
39.	P.lambi Krezal	Do	Gurney and Hussey(1967)	U.K.
40.	P.mesembrinae Canestrini	Do	Moreton (1956) Rota and Graziella (1974).	U.S.A. Italy
41.	P.quadratus Ewing.	Do	Gurney and Hussey(1967).	U.K.
42.	P.sellnicki Krezal	Do	Hussey(1963)	U.K.
43.	P.tarsalis Hirst.	Do	Moreton (1956)	U.S.A.
44.	Pseudopygmephorus smileyi Hill and Deahl	Do	Hill and Deahl (1978)	U.S.A.
45.	Dolichocybe keiferi Krantz	Do	Gurney and Hussey (1967)	U.K.
46.	Macrodispodides buae Lambordini	Do	Gurney and Hussey(1967)	U.K.
47.	M.fungorum lambordini	Do	Gurney and Hussey(1967)	U.K
48.	Arctoseius cetratus Sell nick	Ascidae	Binns (1974)	U.K.
49.	Digmaseellus fallux Leitner	Dignmasellidae	Binns(1973)	U.K.
50.	Hypoaspis miles Berlese	Laelapidae	Das (1986)	India.
51.	Pronematus bonatii Rota and Graziella	Tyleidae	Rota and Graziella (1974).	Italy.
52.	Scutacarus baculitarsus Agaricus	Scutacaridae	Norton and Ide (1974)	U.S.A.
53.	Macrocheles merdarius Throm bidiformes Rota and Graziell	Macrochelidae	Rota and Graziella(1974).	Italy.

of mite on mushroom may be more in India in near future. In recent years, temperate belts of the country have received special attention to grow more mushrooms because of the suitable climatic conditions and this, in turn, would invite more mite problem as these mites fluorish well under temperate condition. This will subsequently help to spread the mites to other parts of India.

Out of four species of mite reported during the present investigations, the three species, namely Rhizoglyphus echinopus Tyroglyphus dimidiatus and Histiostoma heinemanni have also been reported to infest mushroom in temperate countries like the U.S.A. and the U.K. But the fourth species viz., Hypoaspis miles is hitherto unreported to infest mushroom and this may be considered as a new host record of the mite.

In India, the only research article available on mushroom mites is that of Mukherjee and Somchoudhury (1972). They reported Tyrophagus putrescentiae as a pest of Volvaria spp. and Agaricus sp. of mushroom found to grow under natural condition. The observations reported there in are of casual nature. However, T.putrescentiae is widely distributed in nature and is frequently found to infest laboratory cultures of various fungi. It is very surprising to note that this species has not yet adapted on mushrooms grown under our condition. On the other hand R.echinopus which is frequently found on stored potato has adapted on mushroom.

The reported occurrences of T.dimidiatus and H.heinemanni on mushroom by the present author may be considered new so far our country is considered. The new record of H.miles on two species of summer mushrooms is also of great significance. The members of genus Hypoaspi , are frequently found in litters and soil and the mite is probably a new introduction on mushroom.

4.2 Source of mite infestation

During the present investigations, attempts were made to identify the agences repponsible for the carry over of mites to mushroom bed. The results obtained have been presented in Table 4.2. It may be seen that among the various components used in the preparation of mushroom beds, straw alone acts as a carrier/source of mite infestation in mushroom beds. It is revealed from the Set No.V that when unsterilized straw was used in the preparation of compost bed, the incidences of all the four species of mite were noticed on mushrooms. Again, in Set No. VII where each component including straw was used in unsterilized form similar incidences of mite were noticed on growing mushrooms. On the other hand, there were no infestations of mite on mushrooms in spite of using soil, water and cotton lid in unsterilized conditions provided straw alone was sterilized. Similarly, undoing of disinfestation of surroundings had no impact in this regard.

The role of straw component of mushroom bed as the source of infestation of mushroom mites has been emphasised in several instances. Hussey (1936) as well as Jary and Stapley (1937) made similar

Table 4.2 : Source of mite infestation in mushroom cultivation.

Set/treatment No.	Components of mushroom bed sterilized	Set received /not received acaricidaltreatmentfor dis-infesting surroundings.	Set with covered/ uncovered mushroom bed	Present(+) or absent(-) of mites on mushroom			
				R.echinopus	T.dimiatus	H.heinemanni	H.miles
1	All	Received	Covered	-	-	-	-
2	All	Do	Uncovered	-	-	-	-
3	All	Not received	Covered	-	-	-	-
4	All except water	Received	Do	-	-	-	-
5	All except straw	Do	Do	+	+	+	+
6	All except soil	Do	Do	-	-	-	-
7	None	Not received	Uncovered	+	+	+	+

observations. Moreton (1953) reported that *Tarsonemus tarsalis* enters into the mushroom bed through straw. Therefore, the observation made by the present author in the foregoing Para is in full confirmity with those of other workers so far the identification of sources of mite infestation is concerned. However, there are other modes of entry for various species of mushroom mites. For example, *T. dimidiatus* is generally carried in the mushroom bed through old manure (Jary and Stapley, 1936). Hussey (1963) reported that tyroglyphid mites enter into mushroom house through dipteran flies. Similarly, *Histiostoma*, *Linopodes* and so on are transferred to mushroom bed through various beetles and flies (Gham, 1930). The observations recorded during the present investigation have clearly demonstrated that at least insects are not acting as a carrier for mushroom mites under our condition in spite of the fact that dipteran flies are often found to infest mushroom beds. To investigate the role of insects as a carrier of mushroom mites, two sets of experiment were set up (Set No.I and II). In one set, mushroom beds were covered with sterilized cloth (Set No.1) to deny the entry of insects while in other set (No. II) it was kept uncovered. But none of them showed any indication of mite infestation due to the use of sterilized straw which according to my observation is the only source of mite infestation in mushroom beds.

4.3 Habitat, nature and symptoms of damage caused by mushroom mites

Studies were undertaken to observe the habitat and nature of the four species of mushroom mites alongwith the symptoms of damage caused by them on various species of mushrooms. The habitat and nature of mushroom mites were investigated based on their rate of development in spawned and unspawned mushroom beds as well as after different days of spawning. The studies undertaken on the distribution of mushroom mites in different profiles (depth) of a mushroom bed would also indicate some aspects of their nature and habitats. To investigate the symptoms of damage caused by four species of mushroom mites, the course of development of various symptoms was followed up till the end.

4.3.1 Habitat and nature of mushroom mites

The rate of growth of four species of mushroom mites in compost bed with or without mushroom inoculation has been presented in Tables 4.3.1 and 4.3.2. The data indicate that the number of R.echinopus increased from 20.00 to 53.33 after fifteen days of mite inoculation in compost bed which received no inoculum of mushroom. On the other hand, in mushroom inoculated beds, its number increased to 203.33 and 176.62 in sajor-caju and Ostreatus species of mushroom, respectively. The high value of " F " test indicates that a significant increase in mite population has taken place when the compost bed was inoculated with mushroom spawn.

Table 4.3.1 : Rate of increase of *R.echinopus* in unspawned compost bed vis-a-vis spawned with two species of winter mushroom (no. of mite/100 gm compost; mean of three replications)

No.of mite(♀) released /100 gm compost	Density of mite after fifteen days		
	In unspawned bed	In spawned bed of	
		P.sajor-caju	*P.ostreatus*
20	53.33 (166.56)*	203.33 (916.65)	176.62 (783.00)

'F' test - Significant

S.Em(±) - 7.20

C.D.(p=0.05)-43.16

C.D.(p=0.01)-65.38

* Figures in parenthesis indicate percent increase in mite population.

Table 4.3.2.: Rate of increase of three spp. of mushroom mite in unspawned compost bed vis-a-vis spawned with two species of summer mushroom (no.of mite/100 gm compost; mean of three replications).

Mite spp.	No.of mite(♀) released/100 gm compost	Density of mite after fifteen days		
		In Unspawned bed	In spawned bed of	
			T.lobayense	*V.volvacea*
T.dimidiatus	20	33.33 (66.64)*	120.00 (500.00)	103.33 (416.57)
H.heinemanni	20	73.33 (266.65)	306.66 (1433.00)	265.33 (1226.54)
H.miles	20	26.65 (33.25)	123.30 (516.50)	133.33 (566.53)

'F' test - Significant

S.Em (±) - 5.59

C.D.(p=0.05) -49.84
C.D.(p=0.01) -68.27

* Figures in parenthesis indicate percent increase in mite population.

However, no such difference in between mite population was observed when the two species of mushroom were considered.

It may be seen from Table 4.3.2 that similar increase as was observed in the case of R.echinopus has also taken place in the case of other three species of mushroom mites when they were allowed to grow in spawned and unspawned compost beds. For example, the number of mite reached 33.33 from an initial inoculation of 20.00 in the case of T.dimidiatus in the unspawned compost bed. But the same number of mites i.e. 20.00 was found to increase to 120.00 and 103.33 in Tricholoma and Volvariella types of mushroom, respectively under inoculated compost beds. The rate of increase was maximum in the case of H.heinemanni followed by H.miles and T.dimidiatus. The rate of increase of mite population observed between spawned and unspawned mushroom bed was statistically significant in case of all the three species of mite. However, the difference noticed in between the rates of increase of T.dimidiatus and H.miles was non-significant in unspawned as well as spawned mushroom beds.

The course of increase of mite population at different days after spawning was investigated and the data obtained have been presented in Table 4.4. It shows that the population of R.echinopus increased from 20.00 to 490.00 on the twentyfifth day after spawning. But the population level of the mite declined to 100.00 on the fourtyfifth day after spawning. On the other hand, the population of T.dimidiatus gradually increased from the initial day of observation (120.00) to

Table 4.4 : Rate of increase of four mushroom mites at different days of spawing (mean of three replications).

Mite species	No.of mite (♀) released/100 gm compost	No.of mite/100 gm compost after 15 (days)	25 (days)	35 (days)	45 (days)	Regression equation
R.echinopus	20	203.33 (916.65)*	490.00 (2350.00)	313.33 (1466.65)	100.00 (400.00)	$Y=21.228+34.01267x-0.7273x^2$
T.dimidiatus	20	120.00 (500.00)	153.33 (666.65)	200.00 (900.00)	283.33 (1316.66)	$Y=28.1667 + 5.3667\ x$
H.heinamanni	20	306.66 (1433.33)	480.00 (2300.00)	330.00 (1550.00)	96.66 (383.33)	$Y=3.88886 + 34.905226\ x - 0.7259976x^2$
H.miles	20	123.30 (515.00)	143.33 (615.65)	156.66 (683.33)	46.66 (133.33)	$Y=1.06479 + 12.26519x - 0.24443\ x^2$
'F' test	-	Significant	Sig.	Non-significant	Significant	
S.Em(±)	-	9.24	15.85	22.66	6.29	
C.D.(p=0.05)	-	60.28	103.41	-	41.03	
C.D.(p=0.01)	-	87.17	150.45	-	59.70	

* Figures in parenthesis indicate percent increase in mite population.

reach its peak (283.33) on the fourtyfifth day after spawning. The other two species *H.heinemanni* and *H. miles* followed more or less similar pattern in their population growth as has been observed in the case of *R.echinopus*. In the case of *H.heinemanni*, the initial population of 20.00 increased to 480.00 on the twentyfifth day of spawning and then declined to 96.66 within the fourtyfifth day of spawning. The population decline in the case of *H.miles* was to the tune of 46.66 within the fourtyfifth day of spawning after on initial increase in population to 156.66 on thirtyfifth day of spawning.

Statistically, the variations observed among population of four species of mite were significant. In general, no significant differente was observed in between mite population belonging to of *T.dimidiatus* and *H.miles* and between *R.echinopus* and *H.heinemanni*. But these two groups of mite differed significantly between themselves in respect to their mite population. Regression equations calculated for each species of mite in respect of their rate of development at different days after spawning showed that *T.dimidiatus* maintained a positive correlation with the different days of spawning while in cases of other three species the relationship was of higher order which was quadratic in nature.

The rate of distribution of four species of mite at various profiles of spawned mushroom bed has been presented in Table 4.5. It is observed that significant variations were found among the populations of four species of mite recorded at various profiles of

Table 4.5: The rate of distribution of four spp. of mushroom mites at different profiles of spawned mushroom beds after fifteen days of mite inoculation (mean of three teplications).

Mite species	No.of mite (♀) released /100 gm compost	No.of mite/100 gm compost at varying depth(cm) of			
		Upto 1.5	1.5-3	3-4.5	4.5-6
R.echinopus	20	570.00 (55.33)*	240.00 (23.33)	70.00 (6.75)	150.00 (14.85)
T.dimidiatus	20	510.00 (69.64)	180.00 (24.57)	30.00 (4.00)	12.00 (1.66)
H.heinemanni	20	800.00 (64.56)	300.00 (24.22)	90.00 (7.24)	50.00 (4.00)
H.miles	20	320.00 (57.33)	100.00 (17.97)	20.00 (3.58)	118.00 (21.11)

'F' test - Significant
S.Em (±) - 9.81
C.D.(p=0.05) -111.00
C.D.(p=0.01) -147.57

* Figures in parenthesis indicate percent increase in mite population.

mushroom bed. The maximum population of all the four species of mite was observed at the top layer (upto 1.5 cm). However, they differed significantly among themselves in respect to their population densities. The maximum population of mite was observed in the case of H.heinemanni followed by R.echinopus , T.dimidiatus and H.miles. The difference observed between R.echinopus and T.dimidiatus was statistically non-significant. The mite populations were found to decline gradually with the increase in depth. But an insignificant increase in mite population was noticed from the layer (3.0-4.5 cm) and onwards (4.5-6.0 cm) in the cases of R.echinopus and H.miles. However, it appears from the statistical analysis that the population densities of mite observed in two depths i.e. (3.0 - 4.5 cm) and (4.5-6.0 cm) were almost equal.

It is evident from the work undertaken by the present author that all the four species of mushroom mite require mushroom inoculation in compost bed to realise their full biotic potential. However, it is seen from Fig.4.2 that they can multiply to a great extent i.e. to the tune of 166.56 % as has been found in the case of R.echinopus even without mushroom inoculation in compost beds. Similarly, the rate of increase has been found to the tune of 66.55% in T.dimidiatus and 266.65 % and 33.25 % in the cases of H.heinemanni and H.miles respectively under such condition. This clearly indicates that all of them can maintain a thin population in compost bed even without mushroom inoculation. It may be possible that they are deriving nutrition from straw and other materials of compost bed for multiplication. And when compost beds received mushroom inoculation in the presence of mites, an extra-ordinary high rate of multiplication was noticed among mite species being 916.65/783.00 in the case of R.echinopus and 500.00/416.57, 1433.00/1226.54, and 516.50/566.53 in T.dimidiatus, H.heinemanni and H.miles respectively. This is a positive indication that all the four species of mite prefer mushroom as their food. The pattern of increase of four species was more or less similar in spawned as well as unspawned compost beds. The maximum rate of increase was found in H.heinemanni followed by R.echinopus . The rate of increase in T.dimidiatus , H.heinemanni and H.miles varied considerably in the two species of mushroom. The rate of increase of H.heinemanni was much higher in T.lobayense in comparison to that on V.volvacea while it was reverse in case of H.miles . This indicates their preference difference to two types of mushroom species.

It is further evident from Tables 4.3.1 and 4.3.2 that there were little difference in the rate of increase among various mite species though they are found during different seasons of a year. The rate of increase of R.echinopus which is prevalent during cold season on winter mushrooms was around 916.65 % / 783.00 % while the rate of increase of other three species of mite associated with summer mushrooms varied from 416.57 % to 1433.00 % . Therefore, seasonal influence on the rate of growth of mite species was not much pronounced because of the fact that mushrooms are grown under indoor condition without allowing much variation in temperature during different seasons of a year. The mushroom mite found during winter i.e. R.echinopus however, exhibited wide difference in its population growth on two species of mushroom i.e. P.sajor-caju and P.ostreatus. It is probably due to its specific host preference (type of mushroom) for which this variation was noted.

It is revealed from Table 4.4 and Fig. 4.3 that the initial rate of growth of four species of mite was slow. But these acquired a very high momentum with the inoculation of spawn in compost beds. But the rate of increase started declining after twentyfifth day of spawning in the case of three species of mite, namely, R.echinopus , H.heinemanni, and H.miles. The other species, T.dimidiatus maintained a steady rate of increase in itspopulation even upto fourty-fifth day of spawning. This phenomenon of population decline in most of the mites after twentyfive days may be correlated with yield parameter of mushroom which, on the other hand, indicates their rate of feeding on mushroom. It may be mentioned that the first flush/yield of mushroom was obtained around twentyfifth day after spawning. Subsequently, the second flush was obtained after a gap of twenty day. It is interesting to mention that a wide variation in yield exists between first and second flush of the crop. The yield of first flush of mushroom comprised nearly 75 % of the total yield of the crop while the second flush was equivalent to 25 % of the total yield. The decline in mite population after 25th day of spawning was quite logistic as the mite species has consumed a major portion of mushroom crop within that period and thereafter a population decline was noticed due to the lack of food (mushroom). However, in the case of

T.dimidiatus the picture was different. This is probably due to the fact that it has the inherent capacity to multiply even in the absent of prefered food by utilizing alternate food sources found in compost bed. The other explanation would be that the rate of increase in population of *T.dimidiatus* takes place in a arithmetical proportion. In other words, the process of population increase is a gradual one in *T.dimidiatus* while a sudden jump in the rate of increase was observed in other three species between fifteenth to twentyfifth day after spawning with an obvious decline in population.

The habitat of a pest is of great significance from the view point of orienting the control measures to a definite cirection which will, in turn, help to keep a pest population below the economic injury level. Considering this fact in mind, the distributions of four species of mite in mushroom bed were taken into consideration It is revealed from the findings (Table 4.5 and Fig.4.4) that the maximum population of mite was found in the upper surface of mushroom bed i.e. upto 1.5 cm. A good number of mite belonging to all the four species were present beneath the top layer i.e., between 1.5 cm to 3.0 cm depth. However, their number were more or less similar and statistically non significant while their distributions were considered in two other depths i.e., 3.0-4.5 cm and 4.5-6.0 cm. The abundance of mite in the top layer may be correlated with the maximum concentrations of mushroom mycelium and fruit body in the top layer of the mushroom inoculated compost bed. Similar observation was made by Hussey and Gurney (1937) on *Tarsonemus myceliophagus*

According to them, the maximum number of mite was found in the top layer i.e. upto 1.25 cm. In the absence of sufficient published literatures in this direction, an elaborated discussion could not be undertaken by the present author.

4.3.2 Symptoms of damage daused by mushroom mites

All the four species of mite have been recorded to feed on the aerial as well as subterranean partsof mushrooms. The infestation of *R.echinopus* was restricted to winter types of mushroom alone, i.e. *P.sajor-caju* and *P.ostreatus* while the other three species of mites, namely *T.dimidiatus*, *H.heinemanni* and *H.miles* infest summer types of mushroom i.e. *T.lobayense* and *V.volvacea*. The course of development of damage symptoms have been investigated in details and presented below.

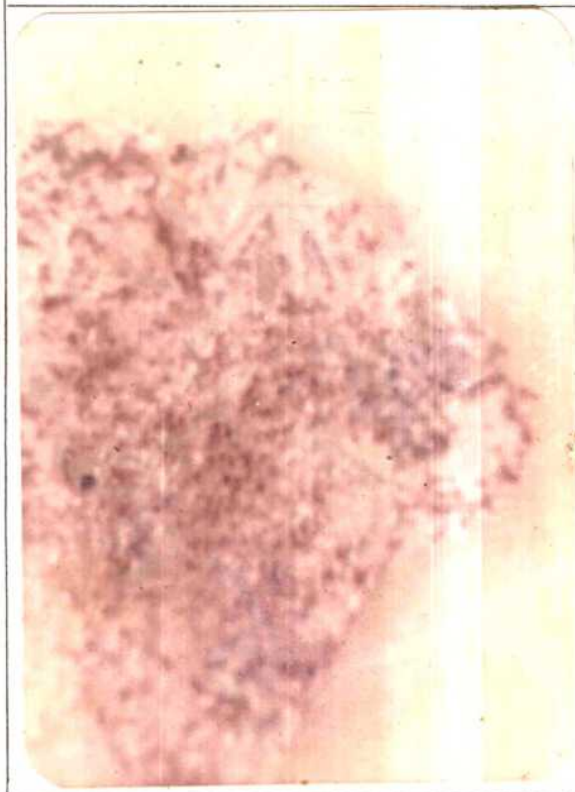
4.3.2.1 Symptoms of damage caused by *Rhizoglyphus echinopus*

The initial infestation of the mite is found on mycelia with small pinhead holes all along the mycelial mat (Plate-4.1 and 4.2). Gradually, the mite attacks the base of the stalk during the budding as well as during the fruit body stage. As a result the basal area becomes pointed instead of bulging out unlike uninfested mushrooms. The lower half of the stipe changes its colour from white to yellow and in some cases brown coloration has also been found to develop. In case of severe infestation, gills are affected and their colour change to yellowish brown. The mite forms a dense cover all over the mushroom bed as well as on affected parts of the mushroom body.

4.1

4.2

4.3



4.4

Plate 4.1-4.4 : 4.1 Mycelial mat of sajor-caju mushroom infested with R.echinopus; 4.2 mycelial mat of ostreatus mushroom infested with R.echinopus; 4.3 mycelial mat of lobayense mushroom infested with T.dimidiatus; 4.4 mycelial mat of volvacea mushroom infested with T.dimidiatus.

4.1

4.2

4.3

4.4

Plate 4.1-4.4 : 4.1 Mycelial mat of *sajor-caju* mushroom infested with *R.echinopus*; 4.2 mycelial mat of *ostreatus* mushroom infested with *R.echinopus*; 4.3 mycelial mat of *lobayense* mushroom infested with *T.dimidiatus*; 4.4 mycelial mat of *volvacea* mushroom infested with *T.dimidiatus*.

Plate 4.9: V.volvacea mushroom infested with T.dimidiatus.

4.3.2.2 Symptoms of damage caused by *Tyroglyphus dimidiatus*

The initiation of infestation of the mite is recorded on mycelia exhibiting similar symptoms (Plate-4.3 and 4.4) as are found in the case of *R.echinopus*. The mite feeds on the inner content of a bud leaving the outer shell of the bud intact. Such infested buds contain all the stages of mite. The damage has been found to be very severe while the mushroom is in fruit body stage (Plate 4.5 - 4.9). The mite hollows out basal portion of the stalk which serves as their entry point to reach up to the cap in course of time. The colour of the infested fruit body changes from white to brown while the stalk colour changes to blackish brown. It also infests lower side of the cap i.e. gills, as a result the shape, size and colour of the infested portions of mushroom exhibit characteristics appearance. In the case of severe infestation, the presence of mite is noticed in the form of dense cover all over mushroom body as well as on mushroom bed.

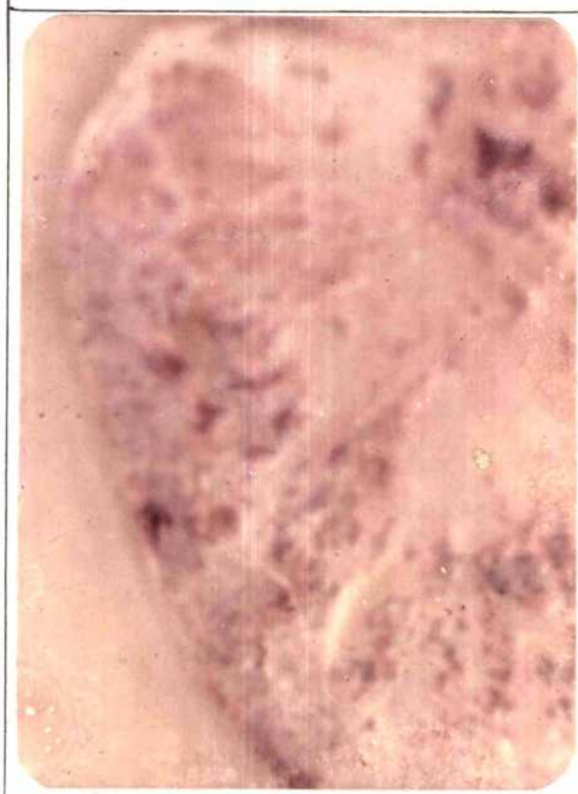
4.3.2.3 Symptoms of damage caused by *Histiostoma heinemanni*

The severe infestation of this mite is recorded in mycelial stage (Plate 4.10 and 4.11) as a result a very few mushrooms attain the fruit body stage. Subsequently, the mite attacks the basal region of the stalk and gradually infests the entire aerial portion of mushroom. The mushroom becomes unable to develop vertically and does not exhibit normal posture like a folded umbrella. However, vertical

4.10

4.11

4.19



4.20

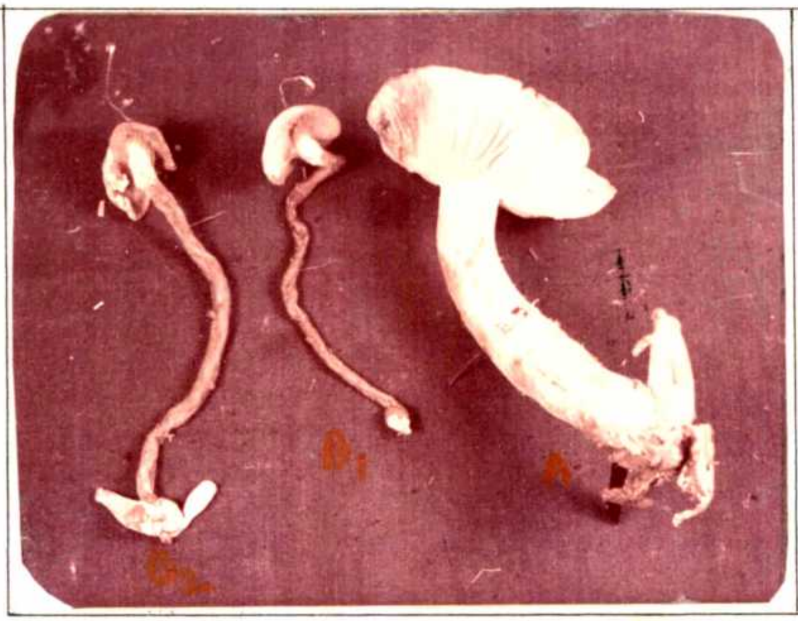
Plate 4.10, 4.11, 4.19, 4.20: 4.10 Mycelial mat of lobayense mushroom infested with H.heinemanni; 4.11 Mycelial mat of volvacea mushroom infested with H.heinemanni; 4.19 mycelial mat of lobayense mushroom infested with H.miles; 4.20. mycelial mat of volvacea mushroom infested with H.miles.

4.12

4.13

Plate 4.12-4.13 : Damage of lobayense mushroom due to H.heinemanni infestation; 4.12 after three days of sporophore production; 4.13 after five days of sporophore production.

4.14



4.15

4.16

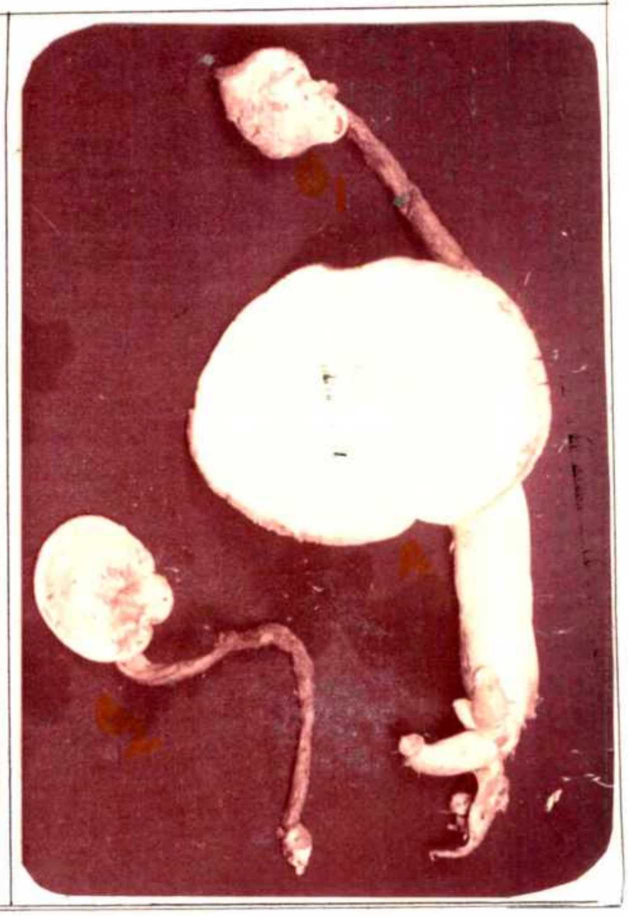
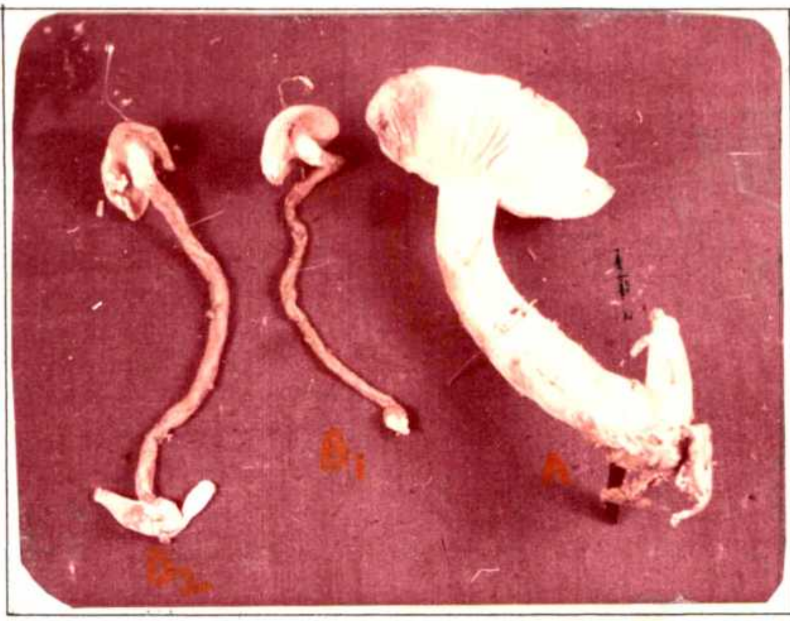


Plate 4.14–4.16: 4.14 T.lobayense mushroom(A)Uninfested;(B_1,B_2) reduction in thickness of cap due to H.heinemanni infestation; 4.15 T.lobayense mushroom (A)uninfested;(B_1,B_2)distortion of cap due to H.heinemanni infestation;4.16 T.lobayense mushroom (A) uninfested; (B_1,B_2)reduction in circumference of cap and stalk due to H.heinemanni infestation.

4.14



4.15

4.16

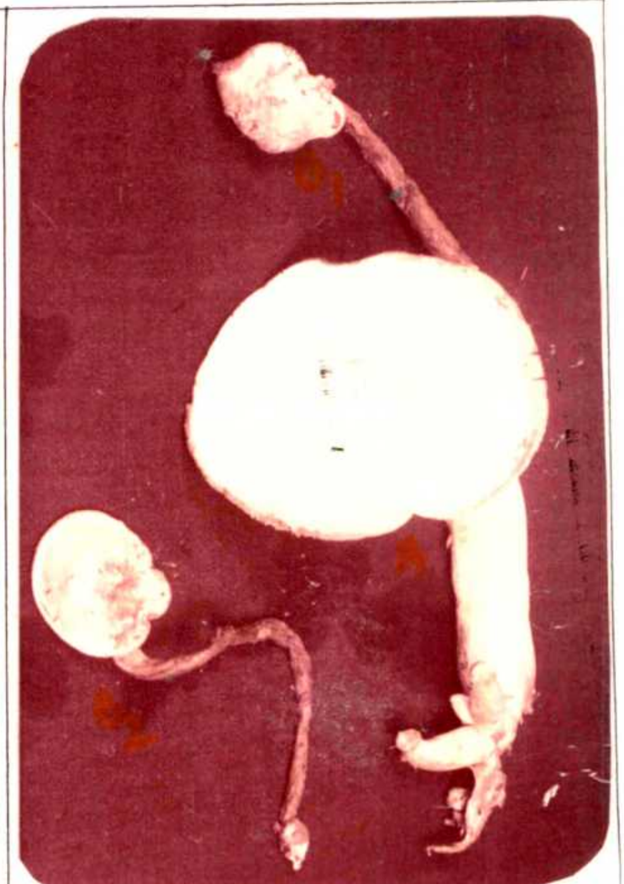


Plate 4.14-4.16: 4.14 T.lobayense mushroom(A)Uninfested;(B_1,B_2) reduction in thickness of cap due to H.heinemanni infestation; 4.15 T.lobayense mushroom (A)uninfested;(B_1,B_2)distortion of cap due to H.heinemanni infestation;4.16 T.lobayense mushroom (A) uninfested; (B_1,B_2)reduction in circumference of cap and stalk due to H.heinemanni infestation.

4.17

4.18

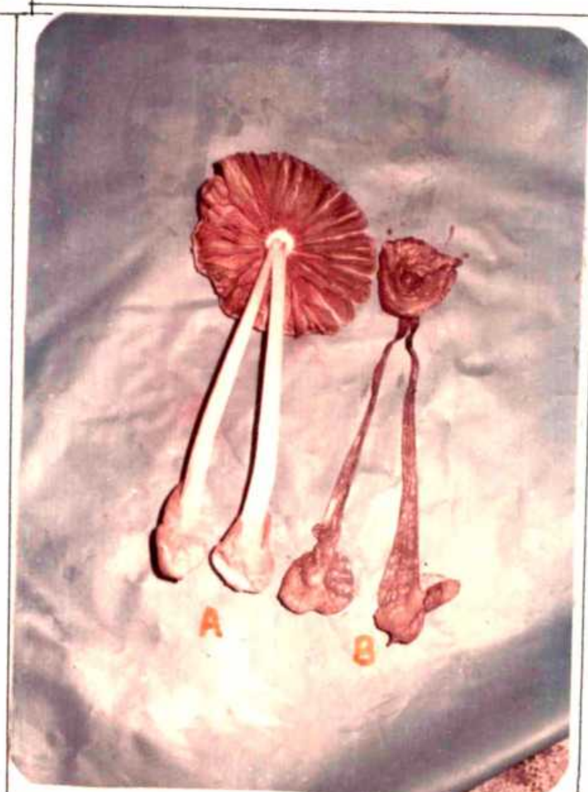


Plate 4.17-4.18: V.volvacea mushroom (A) uninfested; (B) infested with H.heinemanni; 4.18 V.volvacea mushroom(A) uninfested; (B) damage of inner tissues due to H.heinemanni infestation.

Plate 4.21 : Damage caused by H.miles to volvacea mushroom during its bud stage.

4.22

4.23

4.24

<u>Plate</u> 4.22-4.24: 4.22 Volva of <u>volvacea</u> mushroom damaged by <u>H.Miles</u>; 4.23 <u>V.volvacea</u> mushroom (A) uninfested, (B) volva and gills damaged due to infestation of <u>H.miles</u>; 4.24 <u>T.lobayense</u> mushroom infested with <u>H.miles</u>.

development takes place in a crawling manner along the mushroom bed (Plate 4.12 and 4.13). Finally, the entire mushroom body shows the sign of decomposition in the presence of mites both inside and outside of the stalk as well as on cap. The shape of the cap is distorted. Reductions in circumference and thickness of cap are noticed with simultaneous decrease in the circumference and length of stalk (Plate 4.14- 4.18).

4.3.2.4 Symptoms of damage caused by *Hypoaspis miles*

All the stages of mushroom, right from mycelial to fruit body stages are prefered by this mite (Plate 4.19-4.23). The damage is more severe during the bud stage. Due to heavy feeding at the basal region of buds, they are detached from the mushroom bed. In many cases tunnels are found inside buds. When the mushrooms reach fruit body stage, the mites attack the volva and cap of mushrooms. In case of severe infestation, they eat up the entire content of the volva and make several holes in cap portion of mushroom.As a result, the shape of the cap distorted along with a noticeable change in colour to yellow.

4.4 Economic damage caused by mushroom mites

To assess the pest status of the four species of mushroom mite, two sets of experiment were set up one with *R.echinopus* on winter mushrooms while the other with *T.dimidiatus*, *H.heinemanni* and *H.miles* on summer mushrooms. The data obtained on the weight loss during mycelial stage of mushroom due to the infestation of four species of mite have been presented in Tables 4.6.1 and 4.6.2. It

Table 4.6.1 : Damage caused by *R.echinopus* on two species of mushroom in their mycelial stage (mean of five replications).

Treatment	Initial weight of a mycelial mat (gm)	No.of mite (♀) inoculated/mat	Weight loss(gm)/mycelial mat after seven days in	
			P.sajor-caju	*P.ostreatus*
Control	5	0	0.46 (9.20)*	0.58 (11.60)
Mite inoculated	5	10	3.76 (75.20)	3.80 (76.00)

'F' test - Significant.

S.Em(±) - 0.09

C.D.(p=0.05)- 0.37

C.D.(p=0.01)- 0.51

* Figures in parenthesis indicate percent reduction in weight of mycelial mat.

Table 4.6.2 : Damage caused by three spp. of mushroom mite on two spp. of mushroom in their mycelial stage (mean of five replications).

Treatment	Initial weight of a mycelial mat(gm)	No.of mite inoculated /mat	Weight loss(gm)/mycelial mat after seven days in	
			T.lobayense	V.volvacea
Control	5	0	1.26 (25.26)*	1.14 (22.80)
T.dimidiatus inoculated	5	10	3.96 (79.24)	4.02 (80.46)
H.heinemanni inoculated	5	10	4.26 (85.23)	4.32 (86.46)
H.miles inoculated	5	10	3.42 (68.48)	3.70 (74.00)

'F' test - Significant

S.Em (±) - 0.06

C.D.(p=0.05)- 0.36

C.D.(p=0.01)- 0.48

* Figures in parenthesis indicate percent reduction in weight of mycelial mat.

may be seen from the Table 4.6.1 athat the loss in weight were as high as 75.20% and 76.00 % in P.sajor-caju and P.ostreatus, respectively when 5 gms of mycelial mat was inoculated with only ten mites. But under the controled condition, the percent loss in yield were only 9.20 % and 11.60 % in sajor-caju and ostreatus species, respectively. Similar results were also obtained in other three species of mite as is evidenced from Table 4.6.2. The maximum percentage of weight loss in mushroom was inflicted by H.heinemanni followed by T. dimidiatus and H.miles. The results obtained were statistically significant at 5 % as well as 1 % levels. All the observations recorded on T.lobayense were statistically significant among themselves while in the case of V.volvacea no significant difference was observed in between T.dimidiatus and H.miles and between H.heinemanni and T. dimidiatus. But the two species, Histiostoma and Hypoaspis differed significantly between themselves in respect to their capacity in reducing yield of mushroom.

The effect of infestation of R.echinopus on the duration of spawn-run period, number of buds and fruit body emerged/tray as well as on yield has been presented in Table 4.7.1. It appears from Table 4.7.1 that the duration of spawn-run period was significantly delayed by about 5.6 days in the case of first flush of mushroom. The effect of mite incidence on the second flush of crop was total while under normal condition the second flush is observed within 9 to 15 days. Similarly, significant reduction in number of bud as well as fruit body were noticed. This ultimately leads to a

Table 4.7.1 : Damage caused by R.echinopus during spawn run period and on flash emergence, formation of bud and fruit body as well as on yield of P.sajor-caju (mean of three replications).

No.of mite inoculated tray	Spawn run period (days)		No.of bud		No.of fruit body		Yield(gm)	
	1st flash	2nd flash	1st flash	2nd flash	1st flash	2nd flash	1st flash	2nd flash
0	18.00	9.36	36.66	27.60	28.30	15.30	124.00	66.66
1000	23.66 (31.14)*	0.00 (100.00)	13.64 (62.84)	0.00 (100.00)	10.33 (63.60)	0.00 (100.00)	53.33 (57.01)	0.00 (100.00)
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
S.Em(±)	0.52	0.16	1.28	1.17	1.88	0.33	7.31	1.66

Sig. = Significant.

*Figures in parenthesis indicate percent delayed in spawn run period as well as percent reduction in no. of bud, fruit body and yield.

significant reduction in mushroom yield in comparison to that observed in control one.

The effect of infestation of other three species of mushroom mites on duration of spawn-run period, number of bud and fruit body emerged/tray as well as loss in yield has been presented in Table 4.7.2. It is observed from Table 4.7.2 that the duration of spawn-run period is delayed by nearly 7 days due to the infestation of H. heinemanni. The delay in the case of T.dimidiatus and H.miles was nearly 2-5 days and subsequently no second flush was noticed in any of the mite infested mushroom beds. While in mite free compost bed, a second flush was noticed after 13 days. The differences observed in respect to duration of spawn-run period were statistically significant but no significant difference was observed between H.heinemanni and H.miles infested mushroom beds. Similarly, the differences observed among number of bud and fruit body emerged/tray due to the infestation of three species of mite were statistically significant when compared with those of control tray and the minimum number of buds and fruit bodies were recorded in H.heinemanni infested mushroom beds. The difference observed between T.dimidiatus and H.miles infested mushroom beds was not statistically significant. The loss in yield was also maximum in H.heinemanni infested beds followed by H.miles and T.dimidiatus. But the difference observed between the last two species of mite was not statistically significant. However, they differed significantly in respect to control experiment.

Table 4.7.2: Damage caused by three spp. of mushroom mites during spawn run period and on flash emergence, formation of bud and fruit body as well as on yield of *T.lobayense* (mean of three replications).

Treatment	No.of mite inoculted/ tray	Spawn run period		No.of bud		No.of fruit body		Yield(gm.)	
		1st flash	2nd flash	1st flash	2nd flash	1st flash	2nd flash	1st flash	2nd flash
Control	0	27.66	13.00	27.36	9.00	8.00	3.33	91.66	60.00
T.dimidiatus inoculated	1000	29.00 (5.07)*	0.00 (100.00)	16.00 (41.33)	0.00 (100.00)	2.36 (71.25)	0.00 (100.00)	36.00 (60.69)	0.00 (100.00)
H.heinemanni inoculated	1000	34.66 (25.36)	0.00 (100.00)	9.64 (64.83)	0.00 (100.00)	1.36 (83.75)	0.00 (100.00)	7.00 (92.35)	0.00 (100.00)
H.miles inoculated	1000	32.64 (18.11)	0.00 (100.00)	15.00 (45.05)	0.00 (100.00)	2.67 (67.54)	0.00 (100.00)	50.00 (45.41)	0.00 (100.00)
'F' test -		Sig.	Sig.	Sig.	N.Sig.	Sig.	Sig.	Sig.	Sig.
S.Em (±)-		0.39	0.25	0.89	1.38	0.20	0.08	3.76	2.88
C.D.(p=0.05)-		2.54	1.63	5.85	-	1.33	0.54	24.53	18.82
C.D.(p=0.01)-		3.70	2.37	8.51	-	1.93	0.79	35.69	27.39

Sig. - Significant; N.Sig. - Non-significant;

* Figures in parenthesis indicate parcent delayed in spawn run period as well as percent reduction in no. of bud, fruit body and yield.

Table 4.8.1 Damage caused by *R.echinopus* on aerial portion of *P.sajor-caju* (mean of ten replications).

No.of mite inoculated /tray	Circumference of Cap (cm.)	Thickness of Cap(Cm.)	Weight of Cap(gm.)	Length of stalk (cm.)	Weight of stalk(gm.)
0	18.11	1.43	2.24	5.56	1.82
1000	12.15 (32.87)*	1.10 (22.72)	1.46 (36.36)	2.97 (47.27)	1.05 (42.30)
'F' test -	Significant	Significant	Significant	Significant	Significant
S.Em(±) -	0.62	0.06	0.12	0.23	0.06

* Figures in parenthesis indicate percent reduction in different aerial parts.

Table 4.8.2 : Damage caused by three spp. of mushroom mite on aerial parts of *T.lobayense* (mean of ten replications).

Treatment	No.of mite inoculated /tray	Circumference of Cap(Cm.)	Thickness of Cap(Cm.)	Weight of Cap (gm.)	Length of stalk(Cm.)	Weight of stalk(gm.)
Control	0	32.66	2.85	38.26	10.65	24.38
T.dimidiatus inoculated	1000	20.33 (37.73)*	2.10 (26.31)	7.60 (80.10)	6.18 (41.69)	6.30 (74.07)
H.heinemanni inoculated	1000	9.66 (70.55)	0.77 (75.43)	3.37 (91.17)	6.51 (38.58)	3.12 (87.16)
H.miles inoculated	1000	20.30 (37.73)	1.78 (37.54)	11.11 (70.91)	5.43 (48.77)	9.00 (62.90)
'F' test -		Significant	Significant	Significant	Non-significant	Significant
S.Em (±) -		0.54	0.09	0.80	1.05	0.36
C.D.(p=0.05) -		0.25	0.56	4.61	-	2.10
C.D.(p=0.01) -		0.34	0.75	6.18	-	2.81

* Figures in parenthesis indicate percent reduction in different aerial parts.

The effect of infestation of R.echinopus on the aerial portion of P.sajor-caju has been presented in Table 4.8.1. It is revealed from Table that a significant reduction in circumference, thickness and weight of mushroom cap was noticed when compared with those of unin-fested mushrooms. The length as well as weight of stalk showed a significant reduction due to the infestation of the mites.

The effect of infestation of other three species of mite, namely T.dimidiatus, H.heinemanni and H.miles on the aerial parts of T.lobayense has been given in Table 4.8.2. It is revealed from Table that significant reductions in circumference, thickness and weight of mushroom cap were noticed in comparison to those of control experiment. The maximum reduction was noticed with the infestation of H.heinemanni and the differences were statistically significant when compared with those of other two species. The difference observed in respect to reduction of circumference of cap between T.dimidiatus and H.miles was not statistically significant. Similarly, the maximum reduction in thickness of cap was noticed in H.heinemanni which varied significantly from those of other two species. But the differences observed between T.dimidiatus and H.miles in respect to weight and thickness of cap were not statistically significant but they varied significantly from control experiment. The differences observed in respect to reduction in the length of stalk of mushrooms due to the infestation of three species of mites were not statistically significant.

Table 4.9 : Relationship between density of mite population and loss in yield in various species of mushroom.

Density of mite/tray (No.)	Yield of fruit-body(gm)/tray in case of							
	R.echinopus infesting		T.dimidiatus infesting		H.heinemanni infesting		H.miles infesting	
	P.sajor-caju	P.ostreatus	T.lobayense	V.volvacea	T.lobayense	V.volvacea	T.lobayense	V.volvacea
0	192.00	156.60	185.00	120.00	185.00	120.00	185.00	120.00
500	110.60 (42.39)*	96.60 (38.31)	100.00 (45.94)	83.30 (30.58)	56.60 (69.40)	66.60 (44.50)	76.66 (58.50)	51.60 (57.00)
1000	53.30 (72.23)	56.60 (63.85)	37.60 (79.67)	30.00 (75.00)	9.00 (95.13)	15.00 (87.50)	50.00 (72.97)	46.60 (61.16)
1500	45.00 (76.56)	38.30 (75.54)	28.30 (84.70)	24.30 (79.75)	7.00 (96.21)	13.00 (89.16)	43.30 (76.59)	36.60 (69.50)
'F' test -	Significant		Significant		Significant		Significant	
S.Em(±) -	3.08		2.92		2.48		3.88	
For mite population								
C.D.(p=0.05)-	18.48		24.77		21.10		32.90	
C.D.(p=0.01)-	25.47		34.14		29.08		45.34	
For mushroom spp.								
C.D.(p=0.05)-	13.07		24.77		21.10		32.90	
C.D.(p=0.01)-	18.01		34.14		29.08		45.34	

* Figures in parenthesis indicate percent reduction in yield.

The relationship between various densities of mites and loss in yield of mushroom has been presented in Table 4.9. It may be seen that the loss in yield was maximum while the density of mite was increased to 1500/500 gm of compost. This is true for all the four species of mite. However, the differences observed in respect to yield loss in fruit body were not statistically significant when compared with those of 1000 mites/500 gm compost. However, the difference in the yield recorded in between two densities of mite i.e. between 500 and 1000 was statistically significant. But they differed significantly from those of control exp erimment. Again, the differences observed in respect to yield loss in between two different types of mushroom i.e. P.sajor-caju and P.ostreatus due to the infestation of R.echinopus was not statistically significant under three levels of densities i.e. 500, 1000 and 1500 mites per 500 gm compost. But the difference was significant in respect to control experiment. Similar trend was also noticed in other three species of mushroom mites i.e. T.dimidiatus , H.heinemanni and H.miles on their hosts, namely T.lobayense and V.volvacea.

There are seventeen species of tyroglyphid mites reported in association with mushrooms throughout the world. Among them, Tyroglyphus dimidiatus is considered as the most important species. The symptoms of damage appear due to the infestation of this mite have been described by Jary and Stapley (1937). The mite hollows out very tiny buttons leaving only shells to be remain intact and in such buttons, eggs and all immature stages occur. On large mushrooms, cavities of various sizes develop on the stalks and caps due to its feeding rendering them unfit for sale. Similar observations have also been recorded by the present author thus confirming the observations made by Jary and Stapley (1937). However, detailed published records pertaining to damage symptoms of other three species of mite, namely R.echinopus, H.heinemanni and H.miles are lacking. It has been reported that R.echinopus is found on decaying mushrooms in Britain (Hughes, 1961). Similarly, H.heinemanni has also been reported on decaying mushrooms and does not feed on mushroom tissue. It is attracted by the micro-organisms present on decaying mushrooms. Due to its feeding on the micro-organisms, the mite spread certain diseases of mushrooms (Hill and Deahl, 1978). Regarding H.miles no published report is available as it has been reported for the first time by the present author to feed on mushrooms. It is evident from the present investigation that all the four species of mite are very destructive in mycelial stage of mushroom as may be seen from Fig.4.5. The destructive potential of mites are more or less at per with slight higher in H.heinemanni based on the decrement of weight of mycelial mat (85.23 %). The lowest rate of weight decrement was recorded in H.miles which was around 68.48 %. The differences observed in respect to their damage potential on two types of mushroom was very negligible. In other words, it may be said that no varietal preference exists among four species of mushroom mites. The nature of preference for various parts of fruit body was not similar among four species of mite.

It is revealed from the experiments conducted to study the impact of four species of mites on the duration of spawn-run period (Fig.4.6) that the duration was least affected due to the attack of T.dimidiatus followed by H.miles, H.heinemanni and R.echinopus. Durin the spawn-run period, mushroom passes through mycelial stage and therefore, R.echinopus was the most injurious species during this period due to its preference for mycelial stage of mushrooms. The bud stage of mushroom was most prefered by H.heinemanni and R.echinopus as is evidenced from the percent reduction in number of bud which were 64.83 % and 62.84 % in H.heinemanni and R.echinopus, respectively. The percent reduction in number of bud were only 45.05 % and 41.33 % in H.miles and T.dimidiatus, respectively. This again indicates that R.echinopus and H.heinemanni has more capability in causing damage to mushroom in comparison to other two remaining species of mites. The maximum reduction in number of fruit body was noticed due to the infestation of H.heinemanni (83.75 %) followed by T.dimidiatus (71.25 %), H.miles (67.54 %) and R.echinopus (63.60 %) in the descending order. All the four species of mite inflicted severe damag to mushroom crop as a result second crop could not be obtained in the mite infested beds. As such they may be considered as highly injurious to mushroom cultivation.

On the other hand, T.dimidiatus makes a large hole at the basal region of mushroom and gradually hollows up the entire stalk portion. H.heinemanni initiates destruction of mushrooms from the basal region and gradually destroys the entire mushroom. The damage caused by H.miles is undoubtedly peculiar. Initially, it attacks the volva and then it crawls to the cap region. It is revealed from the Fig.4.7 that the reduction of length of mushroom stalk due to the infestation of four species of mite varied between 38.58 % to 48.77%. Therefore, the differences observed among the four species of mite are of little significance. However, the percent reduction in weight of stalk varied enormously among four species of mite. The maximum reduction of weight of stalk was noticed in H.heinemanni (87.16%) while it was as low as 42.30 % in the case of R.echinopus. The reductions noticed in the cases of T.dimidiatus and H.miles were 74.07% and 62.90 % respectively. It is therefore, evident that R.echinopus and H.miles do little damage in the stalk region of mushroom in comparison to those caused by H.heinemanni and T.dimidiatus.

When the effect of infestation of four mites on the cap portion of a mushroom was considered, it was found that H.heinemanni prefers the gill and upper portion of the cap. As a result, a severe reduction in circumference of mushroom cap to the tune of 70.00 % was noticed while in other three species it was around 37.00 %. Similarly, thickness of the cap was also affected adversely due to the infestation of H.heinemanni and the level of reduction was around 75.43 % while in other cases it was below 38.00%, being the lowest in the case of R.echinopus (22.72 %). The percent weight reduction of mushroom cap though highest in the case of H.heinemanni (91.17%) such reductions were also noticed in the case of T.dimidiatus (80.10% and H.miles (70.91 %). However, it was only 36.36 % when the infestation of R.echinopus was taken place. It, therefore, clearly indicates that R.echinopus does not like the cap portion of mushrooms while it is very much liked by H.heinemanni. The other two species of mite, namely, T.dimidiatus and H.miles did not infest the gill portion of the cap but consume the inner tissue of cap portion inflicting severe weight loss of cap region of mushrooms.

Attempts were also made to collect preliminary informations on the economic injury level of four species of mushroom mites. It may be seen in Fig.4.8 that a direct linear relationship in loss of mushroom yield was noticed with the increase in severeness of infestation brought about by simultaneous increase in mite population from 0 to 1500/500 gm of compost. It was observed that the decrement of yield was very fast when the population was increased from 0 to 1000. Thereafter, the rate of yield decrement was slow in between 1000-1500 mites/500 gm of compost. It may be computed arithmatically that a population of 100 mites would bring about nearly 9.0 % loss in yield. Therefore, it may be said that the density of 100-200 mites of R.echinopus would be of great significance and a control measure may be recommended at this stage. The economic injury level would vary among four species of mite as well as between two species of winter/summer mushrooms. The detailed studies on the economic injury level of mites was however beyond the scope of the present investigation and therefore the exact level of economic injury could be mentioned with authenticity. This needs immediate attention. It appears from the published literatures that no attempts have so far been made to study the economy injury level of mushroom mites in any parts of the world.

4.5 Rearing of mushroom mites on artificial diets

The suitability of eight kinds of artificial diet mentioned earlier in column 3.2.8 of Materials and Methods were tested on four species of mushroom mite and the data obtained have been presented in Table 4.10. Significant differences were observed among four species of mushroom mite as well as among eight kinds of artificial diet while the decrease or increase in mite population was considered. It is revealed from Table 4.10 that the type 'F' diet was the most suitable for R.echinopus (Plate 4.25) followed by 'C', 'H' and 'G' types of diet. No significant difference was, however, observed between the last two diets but they differed significantly from the 'F' type of diet while the rate of increase of mite population was considered. The 'D' type of diet was the least suitable while 'A' ,'B and 'E' types were less suitable for rearing R.echinopus. In the case of T.dimidiatus, the 'H' type of diet provided the best result (plate 4.26) followed by 'F', 'C' and 'G' types of diet. No significant difference was observed between 'F' and 'H' types of diet as well as between 'C' and 'G' types of diets. There was no development of mite population on the 'A' type of diet while it was considerably less in the 'B' and 'D' types of diet.

On the other hand, the population of H.heinemanni could not be raised in any of the diet type from 'A' to 'E'. All the inoculated mites (10) died a few days after release. However, the 'H' type of diet was moderately suitable and may be considered as the best type

4.25

4.26

Plate 4.25-4.26: 4.25 Culture of R.echinopus in 'F' type of artificial diet; 4.26 Culture of T.dimidiatus in 'H' type of aritificial diet.

Table 4.10: Suitability of various artificial diets to four spp. of mushroom mites (mean of three replications).

Type of Diet	Numbereof mites re- leased	Increase(+)/Decrease(-) in mite population (No.) after 30 days			
		R.echinopus	*T.dimidiatus*	*H.heinemanni*	*H.miles*
A	10.00	120.00 *(1200.00)	0.00 (0.90)	-10.00 (-100.00)	-10.00 (-100.00)
B	10.00	154.00 (1540.00)	111.00 (1110.00)	-10.00 (-100.00)	0.00 (0.00)
C	10.00	290.00 (2900.00)	277.00 (2770.00)	-10.00 (-100 .00)	0.00 (0.00)
D	10.00	19.00 (190.00)	72.00 (720.00)	-10.00 (-100.00)	0.00 (0.00)
E	10.00	142.00 (1420.00)	151.00 (1510.00)	-10.00 (-100.00)	0.00 (0.00)
F	10.00	416.00 (4160.00)	483.00 (4830.00)	38.00 (380.00)	0.00 (0.00)
G	10.00	211.00 (2110.00)	237.00 (2370.00)	50.00 (500.00)	25.00 (250.00)
H	10.00	230.00 (2300.00)	499.00 (4990.00)	188.00 (1880.00)	95.00 (950.00)

'F' test - significant
S.Em (±)- 4.64

For mite spp.
C.D.(p=0.05) - 74.24
C.D.(p=0.01) - 98.69

For different diets
C.D.(0.05) - 74.24
C.D.(0.01) - 98.69

* Figures in parenthesis indicate percent increase/decrease in mite population.

of diet for the mite species (Plate 4.27). The other two types of diet, namely 'F' and 'G' were less suitable and no significant differences was found between these two diets in respect to population development of mite. They differed significantly in respect to the growth of mite population from the 'H' type of diet. The fourth species of mite, namely, H.miles also reacted in similar fashion like the previous species when the suitability of diet was considered. It appears that the 'A' type of diet was unsuitable for them due to their mortality on such diet. The diets ranging from 'B' to 'F' category were also unsuitable for them as no population growth was recorded on such diets. All the inoculated mites (10) survived till 30 days without any progeny production. The other two diets, namely 'G' and 'H' were suitable to H.miles (Plate 4.28) to certain extent as progeny production was recorded in these two cases. The difference observed in the rate of increase based on these two diets were statistically similar.

The development of a suitable diet of an organism is a prerequisite in the nutritional studies. This, in turn, helps to understand the physiological mechanism of a species which can be utilized in the formulation of the control strategy of a pest. With this objective in mind, eight artificial diets were tested against four species of mushroom mites. It was observed that all the mites differed significantly among themselves in respect to their preference on eight artificial diets signifying their differential nutritional requirements. It is interesting to mention that R.echinopus derived

4.27

4.28

<u>Plate</u> 4.27-4.28: 4.27 Culture of <u>H.heinemanni</u> in 'H' type of artificial diet; 4.28 Culture of <u>H.miles</u> in 'H' type of artificial diet.

their nutrition mostly from wheat kernel as such they may be termed as a germ feeder. The data presented in Table 4.10 and Fig. 4.9 indicate that the maximum rate of population increase was noticed while they were provided with a diet which consists of agar, wheat kernel, yeast and distilled water. But the similar high rate of increase was not maintained when they were provided with a diet consists of agar, wheat kernel, mushroom powder and distilled water. It is confusing to a great extent how the rate of increase of the mite species was so high (2900%) even in the present of a diet consisting of agar, dextrose and distilled water. The data collected for other diets clearly indicates that they can maintain a fairly high level of population growth in the presence of wheat kernel, a major source of nutrition to them.

It may be mentioned in this context that the infestation of R.echinopus is frequently found on various types of vegetables under storage condition. It, therefore, an indication of their non-specific nature of food requirement.And it is not a specific pest of mushroom. The other species, T.dimidiatus can not retain its rate of multiplication only in the presence of wheat kernel. They multiply vigorously (4830 % increase) in the presence of a diet consisting of wheat kernel and yeast extract. It may be seen from Table 4.10 that its rates of multiplications (2770% and 2370 % increase) were considerably high and was possible when it was fed

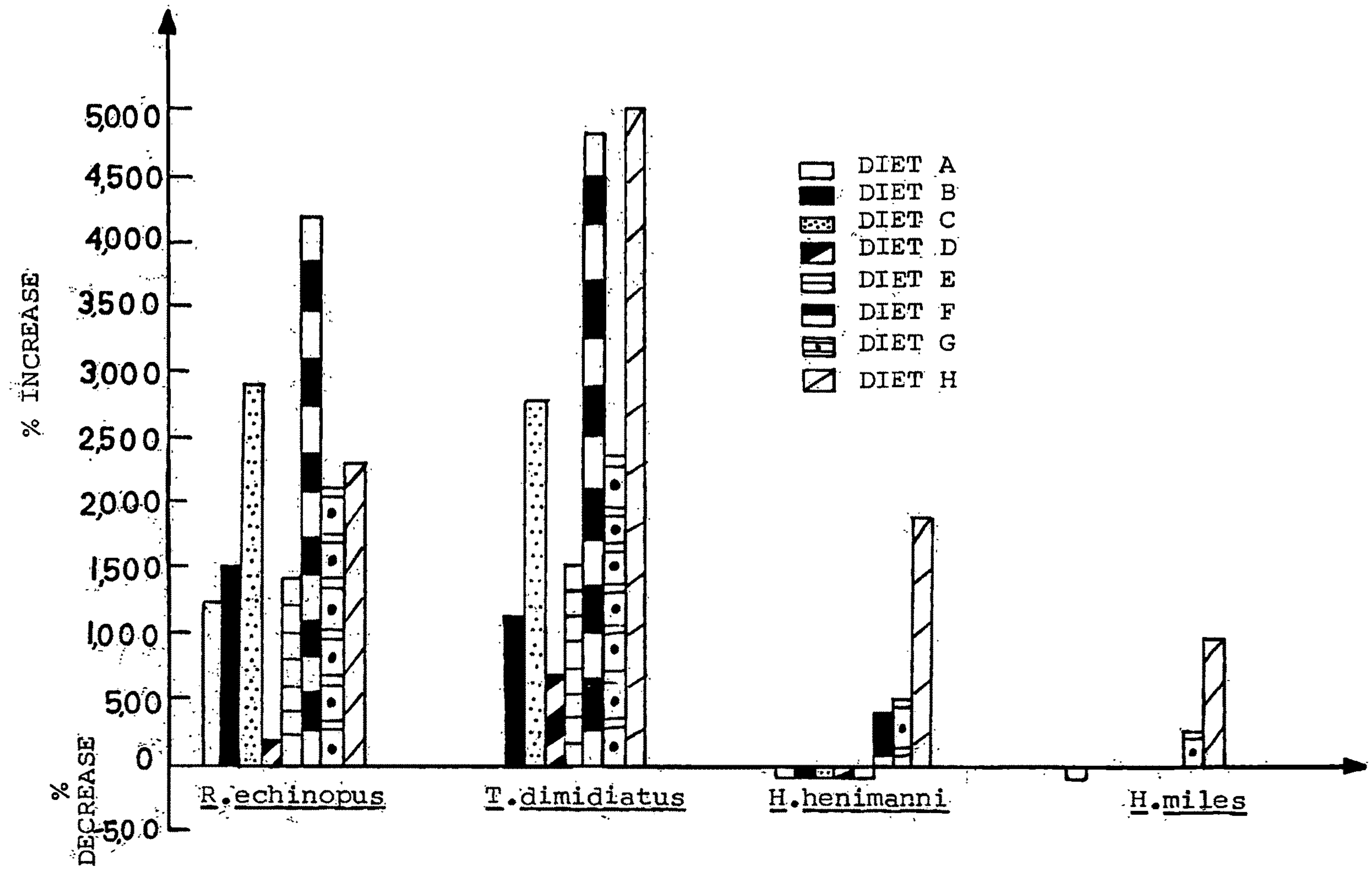


Fig.4.9 RATE OF INCREASE/DECREASE OF FOUR SPECIES OF MUSHROOM MITES ON VARIOUS ARTIFICIAL DIETS.

on diets consisting either of a mixture of dextrose and distilled water or dextrose, wheat kernel and straw juice. Again, the food habit of the species appears to of non-specific in nature though it has a clear preference for mushroom. The other two species, namely H.heinemanni and H.miles showed a clear inclination for mushroom as food. Similarly, their rates of multiplication were high only when they were supplied with mushroom extract as their food. The diet types 'A' to 'E' were unsuitable for H.heinemanni though H.miles was able to derive some amount of nutrition from these diets for their survival but was unable to produce any progeny.

It appears from the available published literatures in this direction that nutritional studies on mushroom mites are lacking. Limited informations are available on storage mites belonging to the Family-Acaridae which forms the major group of mite pest of store grains. Various diets which have been developed by various workers for acarid mites generally consist of yeast extract, dextrose, distilled water, wheat germ etc. A similarity in preference among the mites belong to the Super-Family Tyroglyphoidea is found because of the fact that their ancestors were mostly fungus feeder.

4.6 Developmental pattern of four spp. of mushroom mite in relation to temperature and relative humidity

4.6.1 Effect of three levels of temperature and relative humidity on the duration of mating period

Effect of three levels of temperature and relative humidity on the duration of mating of four species of mushroom mites have been presented in Tables 4.11 and 4.11.1 and Fig.4.10. It may be seen from Table 4.11 that there was significant difference in duration of mating among four species of mushroom mites irrespective of temperature and relative humidity. In other words, the duration of mating was the highest in T.dimidiatus followed by R.echinopus, H.heinemanni and H.miles. The duration of mating of the two species of mite (H. heinemanni and H.miles) could not be recorded at 30 % r.h. as both of them died under such condition.

It may be seen from Table 4.11.1 that the interaction between mite and temperature is significant. This indicates that the duration of mating of the four mite species followed different patterns at three levels of temperature. In general, the duration of mating was the lowest at higher temperature with an exception in the case of H.heinemanni. However, the differences observed in between 20°C and 30°C was not statistically significant in the case of T.dimidiatus and H.miles .

Table 4.11.1 : Effect of interactions of temperature and relative humidity on the duration of mating period (minutes) of four species of mushroom mites.

Mites	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
R.echinopus	15.00	12.76	10.66	1.76	14.86	21.73
T.dimidiatus	22.46	20.93	8.76	9.23	22.23	20.70
H.heinemanni	15.86	10.83	11.03	0.00	16.90	20.83
H.miles	8.03	6.63	4.73	0.00	8.03	11.36
R.H. (%)						
30	3.07	5.17	0.00			
60	20.75	15.45	10.32			
90	22.20	17.75	16.02			

	Mite x Temperature	Mite x Relative Humidity	Temperature x Relative Humidity
'F' Test -	Significant	Significant	Significant
C.D.(p= 0.05)	1.83	1.83	1.59
C.D.(p=0.01)	2.41	2.41	2.09

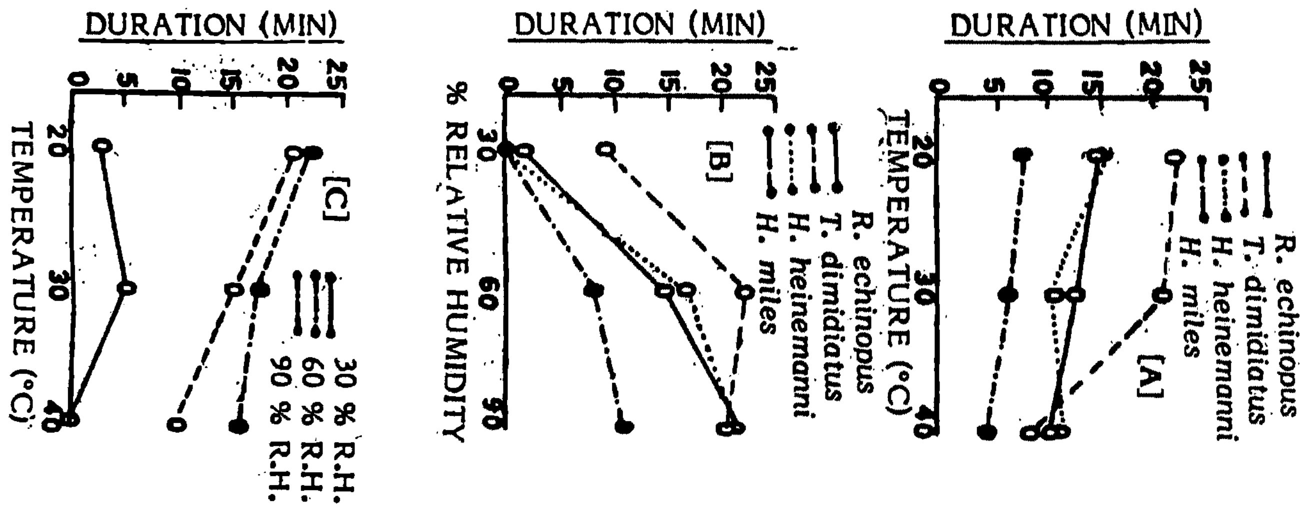


FIG. 4.10 EFFECT OF CONSTANT TEMPERATURES (A), RELATIVE HUMIDITIES (B) AND INTERACTION OF TEMPERATURE AND RELATIVE HUMIDITY (C) ON THE DURATION OF MATING OF FOUR MUSHROOM MITES.

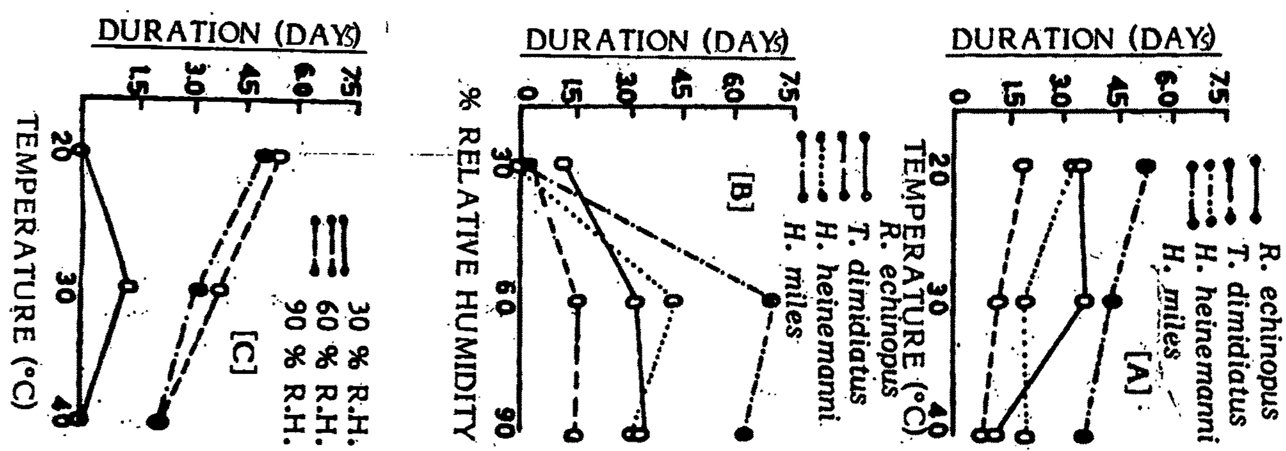


FIG. 4.11 EFFECT OF CONSTANT TEMPERATURES (A), RELATIVE HUMIDITIES (B) AND INTERACTION OF TEMPERATURE AND RELATIVE HUMIDITY (C) ON THE DURATION OF PRE-OVIPOSITIONAL PERIOD OF FOUR MUSHROOM MITES.

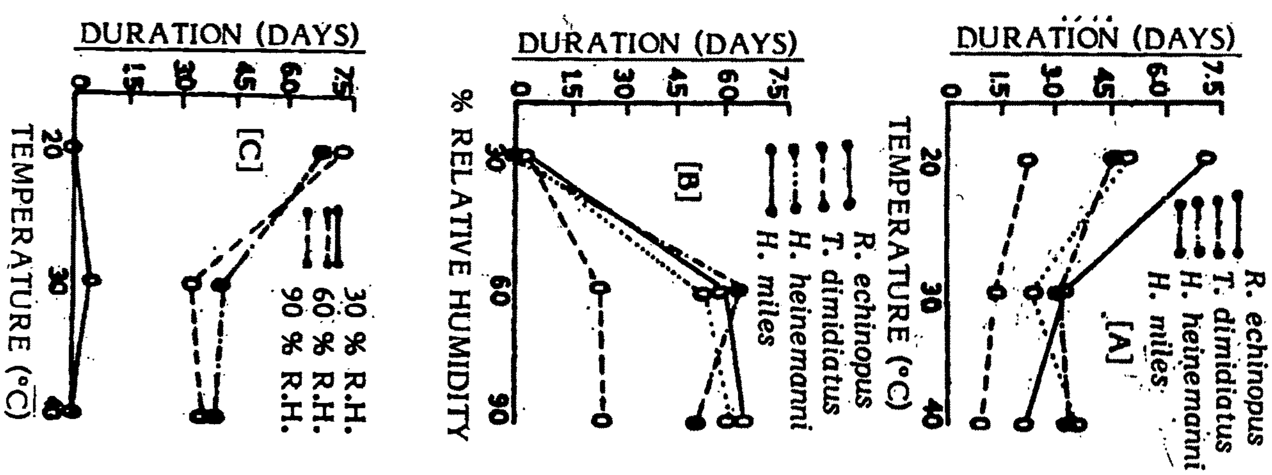


FIG. 4.12 EFFECT OF CONSTANT TEMPERATURES (A), RELATIVE HUMIDITIES (B) AND INTERACTION OF TEMPERATURE AND RELATIVE HUMIDITY (C) ON THE DURATION OF OVIPOSITIONAL PERIOD OF FOUR MUSHROOM MITES.

The significant interaction between mite and relative humidity showed that the pattern followed in respect to duration of mating of four mushroom mites was different in three levels of relative humidity. In general, duration of mating was more at higher ranges of relative humidity but this was not true in the case of T.dimidiatus where the maximum duration of mating (22.23 min) was observed at moderate range of relative humidity i.e. at 60 %.

The effect of interaction between temperature and relative humidity was also significant and it was recorded that the duration of mating was the maximum at 20°C with 90 % R.H.(22.20 min), followed by 20°C x 60 % R.H. (20.75 min.), 30°C x 90 % R.H. (17.75 min), and 40°C x 90 % R.H. (16.02 min.).

4.6.2 Effect of three levels of temperature and relative humidity on the duration of pre-ovipositional period:

Effect of temperature and relative humidity as awell as their interactions on the duration of pre-ovipositional period of four species of mushroom mites have been presented in Tables 4.11 and 4.11.2 and Fig.4.11. Significant variations were observed in respect to duration of pre-ovipositional period among four species of mushroom mites. It was observed that the duration of pre-ovipositional period was the maximum in H.miles followed by R.echinopus, H.heinemanni and T.dimidiatus irrespective of temperature and humidity conditions.

Table 4.11.2: Effect of interaction of temperature and relative humidity on the duration of pre-ovipositional period (days) four species of mushroom mites.

Mites	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
R.echinopus	3.25	3.63	1.10	1.33	3.25	3.40
T.dimidiatus	1.95	1.30	0.83	0.40	1.65	1.50
H.heinemanni	3.46	1.96	2.06	0.00	4.23	3.26
H.miles	5.30	4.36	3.66	0.00	7.06	6.26
R.H.(%)						
30	0.00	1.30	0.00			
60	5.50	3.85	2.25			
90	4.97	3.33	2.25			

	Mite x Temperature	Mite x Relative Humidity	Temperature x Relative Humidity
'F' test -	Significant	Significant	Significant
C.D. (p=0.05)	0.38	0.38	0.33
C.D. (p=0.01)	0.50	0.50	0.43

The significant interaction between mite and temperature on the duration of pre-ovipositional period indicated that the duration of pre-ovipositional period followed different patterns in four species of mushroom mites under three levels of temperature. In general, duration was the lowest at higher temperature and it increased with the decrease in temperature. The only exception was H.heinemanni where the minimum duration of pre ovipositional period (1.96 days) was recorded at 30°C.

The pattern was reverse under humidity condition. The duration was minimum at lower humidity range and the maximum duration was observed under moderate level of humidity (60 %).

The effect of interaction between temperature and relative humidity was also significant. This indicates that the duration of pre-ovipositional period did not follow the same pattern under three levels of temperature and relative humidity combinations. The maximum duration was noticed at 20°C x 60 % R.H. (5.50 days) followed by 20°C x 90 % R.H. (4.97 days) and 30°C x 60 % R.H.(3.85 days).

4.6.3 Effect of three levels of temperature and relative humidity on the duration of ovipositional period

Effect of three levels of temperature and relative humidity on the duration of ovipositional period of four species of mushroom mites as well as their interactions have been presented in Tables 4.11 and 4.11.3 and Fig.4.12. It may be seen from Table that there

Table 4.11.3: Effect of interactions of temperature and relative humidity on the duration of Ovipositional period(days) of four spp. of mushroom mites.

Mites	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
<u>R.echinopus</u>	7.30	3.30	2.20	0.33	5.91	6.55
<u>T.dimidiatus</u>	2.36	1.46	1.03	0.33	2.40	2.46
<u>H.heinemanni</u>	5.00	2.76	0.60	0.00	6.03	6.03
<u>H.miles</u>	4.63	3.13	3.50	0.00	6.26	5.00
<u>R.H.(%)</u>						
30	0.00	0.50	0.00			
60	7.56	3.35	3.77			
90	6.91	4.15	3.97			

	Mite x Temperature	Mite x Relative Humidity	Temperature x Relative Humidity
'F' test	Significant	Significant	Significant
C.D.(p=0.05)	0.50	0.50	0.43
C.D.(p=0.01)	0.65	0.65	0.57

was significant difference in the duration of ovipositional period among four species of mushroom mites irrespective of temperature and relative humidity. The maximum duration of ovipositional period was recorded in R.echinopus followed by H.heinemanni, H.miles and T.dimidiatus.

The effect of interaction between mite and temperature, mite and relative humidity and between humidity and temperature were significant. Therefore, the duration of ovipositional period did not follow the same pattern in all the four species of mite under various levels of temperature and humidity. In general, the duration was higher at lower temperatures and it was reverse at higher temperature (40°C). However, deviations were recorded in the case of H.heinemanni and H.miles where the minimum duration was noticed at 30°C instead of 40°C. In general, the duration of ovipositional period was higher at higher range of relative humidity with an exception in the case of H.miles where the maximum duration (6.26 days) was observed at moderate level of humidity (60 %). The best combination of temperature and relative humidity was observed to be 20°C x 60 % R.H. (7.56 days), followed by 20°C x 90 % R.H.(6.91 days) where the duration of ovipositional period was considerably less.

4.6.4 Effect of three levels of temperature and relative humidity on the duration of egg stage (Plate- 4.29, 4.37, 4.44, 4.52)

Effect of three levels of temperature and relative humidity on the duration of egg stage as well as the effect of interaction of these factors have been presented in Tables 4.12 and 4.12.1. There was significant difference in the duration of egg stage among four species of mushroom mites irrespective of temperature and humidity. The maximum duration of egg stage was recorded in R. echinopus followed by H.miles, T.dimidiatus and H.heinemanni

The interactions between mite x temperature , mite x relative humidity and temperature x relative humidity were also significant. This signified that the duration of egg stage followed different patterns in four species of mite under three levels of temperature and humidity. The duration was the maximum in lower temperature and an inverse relationship was noticed between the temperature and duration of egg stage. But deviations were recorded in case of T.dimidiatus and H.miles where minimum duration was noticed at 30°C. On the other hand, a direct relationship was recorded between relative humidity and the duration of egg stage. The best combinations between temperature and relative humidity were 40°C x 90 % R.H., 30°C x 90 % R.H. and 30°C x 60 % R.H. where the minimum duration of egg stage was noticed.

4.6.5 Effect of three levels of temperature and relative humidity on the duration of larval stage (Plate 4.30, 4.38, 4.45, 4, 53)

Effect of three levels of temperature and relative humidity as well as their interactions on the duration of larval stage have been presented in Tables 4.12 and 4.12.2. It may be seen from Table 4.12 that there was significant difference in duration of

Table 4.12.1: Effect of interactions of temperature and relative humidity on the duration of egg stage (day of four spp. of mushroom mites.

Mites	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
R.echinopus	5.23	2.16	2.26	0.00	5.23	4.43
T.dimidiatus	2.93	1.76	1.33	0.00	3.33	2.70
H.heinemanni	2.20	1.56	1.33	0.00	3.06	2.03
H.miles	4.46	2.10	2.53	0.00	5.00	4.10
R.H.(%)						
30	0.00	0.00	0.00			
60	6.40	3.00	3.07			
90	4.72	2.70	2.52			

	Mite x Temperature	Mite x Relative humidity	Temperature x Relative humidity
'F' test	Significant	Significant	Significant
C.D.(P=0.05)	0.49	0.49	0.43
C.D.(p=0.01)	0.65	0.65	0.56

Table 4.12.2 : Effect of interactions of temperature and relative humidity on the duration of larval stage(days) of four spp. of mushroom mites.

Mite	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
R. echinopus	1.50	1.20	1.21	0.00	1.01	2.90
T. dimidiatus	1.60	0.86	0.33	0.00	1.23	1.56
H. heinemanni	0.66	0.31	0.30	0.00	0.00	1.28
H. miles	2.93	1.73	1.90	0.00	3.56	2.90
R.H. (%)						
30	0.00	0.00	0.00			
60	1.67	1.47	1.21			
90	3.27	1.61	1.60			

	Mite x Temperature	Mite x Relative humidity	Temperature x Relative humidity
'F' test	Significant	Significant	Significant
C.D. (p=0.05) -	0.29	0.29	0.25
C.D. (p=0.01) -	0.38	0.38	0.33

larval period among four species of mushroom mite irrespective of temperature and humidity. In other words, the duration of larval stage was the maximum in H.miles followed by R.echinopus, T.dimidiatus and H.heinemanni. The significant interaction between mite and temperature revealed that the pattern of duration of larval stage of four mushroom mites was not similar under three levels of temperature. In general, the maximum duration was noticed at lower temperature while it was the minimum at highest temperature i.e. at 40°C though in the case of R.echinopus and H.heinemanni, no significant difference was observed in between 30°Cand 40°C.

The effect of interaction between relative humidity and mite indicated that the duration prolonged at higher humidity range while that of between temperature and relative humidity showed 40°C x 60% R.H. as the optimum combination for larval stage (1.21 days).

4.6.6. Effect of three levels of temperature and relative humidity on the duration of quiescent larval stage

Effect of three levels of temperature and relative humidity on the duration of quiescent larval stage of four species of mushroom mite have been presented in tables 4.12 and 4.12.3. It may be seen from Tables that there was significant difference in the duration of quiescent larval stage among four species of mushroom mite irrespective of temperature and relative humidity. The duration was the maximum in H.miles followed by R.echinopus, H.heinemanni and T.dimidiatus.

Table 4.12.3: Effect of interactions of temperature and relative humidity on the duration of quiscent larval stage (days) of four spp. of mushroom mites.

Mites	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
<u>R.echinopus</u>	0.66	0.66	0.43	0.00	0.50	12.6
<u>T.dimidiatus</u>	0.45	0.30	0.00	0.00	0.00	0.80
<u>H.heinemanni</u>	0.36	0.30	0.20	0.00	0.00	0.86
<u>H.miles</u>	0.66	0.63	0.56	0.00	0.92	0.94
<u>R.H. (%)</u>						
30	0.00	0.00	0.00			
60	0.25	0.49	0.33			
90	1.40	0.93	0.57			

4.6.7 Effect of three levels of temperature and relative humidity on the duration of protonymphal stage (Plate 4.31, 4.39, 4.46, 4.54)

Effect of three levels of temperature and relative humidity on the duration of protonymphal stage of four species of mushroom mite have been presented in Tables 4.12 and 4.12.4. It may be seen from Table 4.12 that there was significant difference in the duration of protonymphal stage of four mushroom mites irrespective of temperature and relative humidity. The maximum duration of protonymphal stages was recorded in H.miles followed by R.echinopus H.heinemanni and T.dimidiatus.

The significant interaction between mite and temperature revealed that the four species of mushroom mite did not follow similar pattern in their durations in protonymphal stage under three levels of temperature. An inverse relationship was noticed between the mite and temperature in respect to protonymphal stage. The duration was more under low temperature while it was the minimum under high temperature. However, the differences observed in between H.heinemanni and H.miles in respect to duration were not statistically significant under 30°C and 40°C.

The relationship between the duration of protonymphal stage and relative humidity was direct. The duration increased with the increase in humidity. The interaction between temperature x relative humidity on the duration indicated 30°C x 60 % R.H. as the optimum combination for proper duration(1.07 days) of protonymphal stage.

Table 4.12.4: Effect of interactions of temperature and relative humidity on the duration of Protonymphal period(daeys) of four spp.of mushroom mites.

Mites	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
R.echinopus	1.76	0.83	0.60	0.00	0.60	2.60
T.dimidiatus	0.40	0.26	0.00	0.00	0.00	0.66
H.heinemanni	0.70	0.30	0.26	0.00	0.00	1.26
H.miles	3.33	2.10	2.20	0.00	4.10	3.53
R.H.(%)						
30	0.00	0.00	0.00			
60	1.35	1.07	1.10			
90	3.30	1.55	1.20			

	Mite x Temperature	Mite x Relative Humidity	Temperature x Relative Humidity
'F' test -	Significant	Significant	Significant
C.D.(p=0.05) -	0.27	0.27	0.23
C.D.(p=0.01) -	0.35	0.35	0.30

4.6.8 Effect of three levels of temperature and relative humidity on the duration of quiescent protonymphal stage

Effect of three levels of temperature and relative humidity on the duration of quiescent protonymphal stage of four mushroom mites have been presented in Tables 4.12 and 4.12.5. It may be seen from Tables that there was significant difference in the duration of quiescent protonymphal stage among the four species of mushroom mites irrespective of temperature and relative humidity. The duration was the maximum in R.echinopus followed by H.miles, H.heinemanni and T. dimidiatus

4.6.9 Effect of three levels of temperature and relative humidity on the duration of deutonymphal stage (Plate 4.32, 4.40, 4.47, 4.55)

Effect of three levels of temperature and relative humidity on the duration of deutonymphal stage of four species of mushroom mite have been presented in Tables 4.12 and 4.12.6. Significant difference was recorded in respect to duration of deutonymphal stage among four mushroom mites irrespective of temperature and relative humidity. The maximum duration of deutonymphal stage was recorded in H.miles followed by R.echinopus, T.dimidiatus and H.heinemanni.

The significant interaction between mite and temperature indicated differential pattern in duration of deutonymphal stage under three levels of temperature. An inverse relationship was noticed between temperature and mite species. The highest duration was observed

Table 4.12.5: Effect of interactions of temperature and relative humidity on the duration of quiscent protonymphal stage (days) of four spp. of mushroom mites.

Mites	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
R. echinopus	0.66	0.66	0.60	0.00	0.60	1.33
T. dimidiatus	0.36	0.23	0.00	0.00	0.00	0.60
H. heinemanni	0.40	0.20	0.20	0.00	0.00	0.80
H. miles	0.66	0.62	0.61	0.00	0.96	0.94
R.H. (%)						
30	0.00	0.00	0.00			
60	0.25	0.50	0.42			
90	1.32	0.79	0.64			

Table 4.12.6: Effect of interactions of temperature and relative humidity on the duration of deutonymphal period (days) of four spp. of mushroom mites.

Mites	Temperature (°C)			666 R.H. (%)		
	20	30	40	30	60	90
R. echinopus	2.40	2.26	1.93	0.00	1.76	4.83
T. dimidiatus	0.93	0.40	0.00	0.00	0.00	1.33
H. heinemanni	0.73	0.26	0.30	0.00	0.00	1.30
H. miles	4.20	2.60	3.20	0.00	5.53	4.46
R.H. (%)						
30	0.00	0.00	0.00			
60	1.75	1.80	1.92			
90	4.45	2.35	2.15			

	Mite x Temperature	Mite x Relative humidity	Temperature x Relative humidity
'F' test –	Significant	Significant	Significant
C.D. (p=0.05) –	0.34	0.34	0.30
C.D. (p=0.01) –	0.45	0.45	0.39

at lower temperature. However, in the case of H.heinemanni the differences observed in 30°C and 40°C were statistically non-significant.

The effect of relative humidity on the duration of deutonymph of four mushroom mites was different. The duration was more under higher humidity range. The optimum temperature and humidity condition for deutonymphal stage was 20°C x 60 % R.H.

4.6.10 Effect of three levels of temperature and relative humidity on the duration of quiescent deutonymphal stage

Effect of three levels of temperature and relative humidity on the duration of quiescent deutonymphal stage of four mushroom mite have been presented in Table 4.12 and 4.12.7. It may be seen from Tables that there was significant difference in the duration of quiescent deutonymphal stage among four species of mushroom mites irrespective of temperature and relative humidity. The duration was the maximum in H.miles followed by R.echinopus, H.heinemanni and T.dimidiatus.

4.6.11. Effect of three levels of temperature and relative humidity on the fecundity and rate of survival of different stages of mushroom mite

Effect of three levels of temperature and relative humidity on the rate of egg laying by four mushroom mites have been presented in Table 4.13 and 4.13.1 and Fig. 4.13. It is indicated from Tables that there was significant difference in fecundity among four species

Table 4.12.7 : Effect of interactions of temperature and relative humidity on the duration of quiscent deutonymphal stage(days)of four spp. of mushroom mites.

Mites	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
R.echinopus	0.66	0.66	0.60	0.00	0.60	1.33
T.dimidiatus	0.40	0.26	0.00	0.00	0.00	0.66
H.heinemanni	0.36	0.20	0.16	0.00	0.00	0.73
H.miles	0.70	0.66	0.66	0.00	1.00	1.03
R.H. (%)						
30	0.00	0.00	1.35			
60	0.33	0.50	0.45			
90	1.35	0.85	0.62			

Table 4.13.1: Effect of interactions of temperature and relative humidity on the fecundity of four spp. of mushroom mite.

Mites	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
<u>R.echinopus</u>	65.26	59.23	33.26	4.43	43.93	109.40
<u>T.dimidiatus</u>	22.33	32.96	40.33	0.00	33.26	62.36
<u>H.heinemanni</u>	25.43	50.76	20.30	0.00	18.46	78.03
<u>H.miles</u>	25.46	28.13	14.43	0.00	29.30	38.78
<u>R.H.(%)</u>						
30	0.00	3.32	0.00			
60	33.30	35.70	24.72			
90	70.57	89.30	56.52			

	Mite x Temperature	Mite x Relative humidity	Temperature x Relative humidity
'F' test -	Significant	Significant	Significant
C.D.(p=0.05)-	6.96	6.96	6.03
C.D.(p=0.01)-	9.15	9.15	7.93

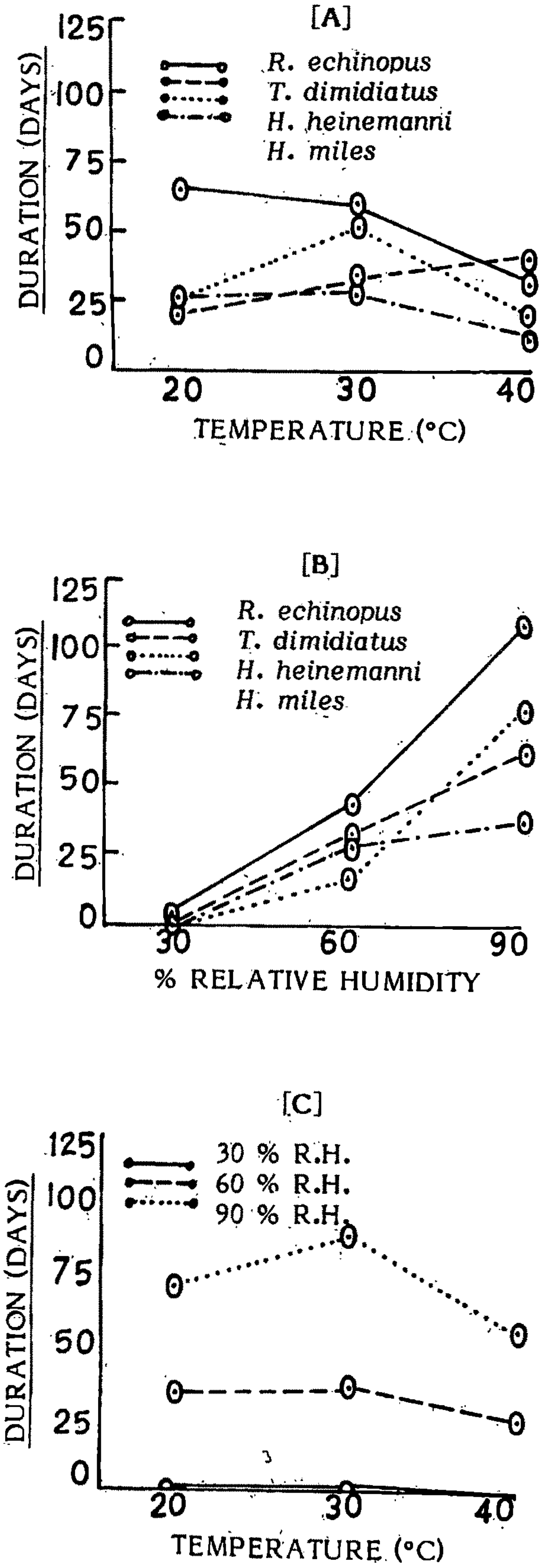


FIG. 4.13 EFFECT OF CONSTANT TEMPERATURES (A), RELATIVE HUMIDITIES (B) AND INTERACTION OF TEMPERATURE AND RELATIVE HUMIDITY (C) ON FECUNDITY OF FOUR MUSHROOM MITES.

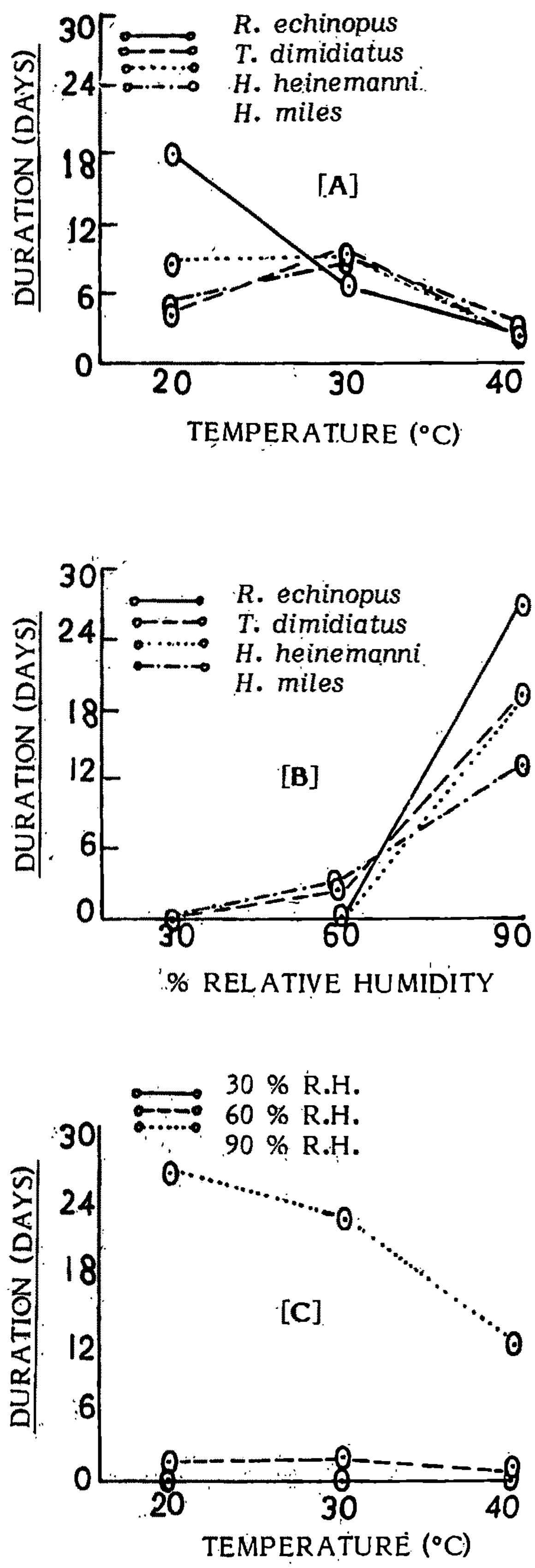


FIG. 4.14 EFFECT OF CONSTANT TEMPERATURES (A), RELATIVE HUMIDITIES (B) AND THEIR INTERACTION (C) ON THE RATE OF ADULT EMERGENCE OF FOUR MUSHROOM MITES.

of mushroom mite irrespective of temperature and relative humidity. The maximum number of eggs was laid by *R.echinopus* followed by *T.dimidiatus*, *H.heinemanni* and *H.miles*. The significant interactions between mite and temperature and between mite and relative humidity revealed that the pattern of egg laying of four mushroom mite was not similar under three levels of temperature and relative humidity. In general, the maximum number of eggs were laid under moderate temperature condition (30°C) with an exception in the case of *R.echinopus* and *T.dimidiatus* . *R.echinopus* laid the maximum number of egg at 20°C (65.26) while *T.dimidiatus* realised it at 40°C (40.33). However, all the mites laid maximum number of eggs at 90 % R.H. The optimum temperature and relative humidity condition was 30°C x 90 % R.H.

Effect of three levels of temperature and relative humidity on the rate of survival of egg stage have been presented in Tables 4,13 and 4.13.2. It appears from Tables that there was significant difference in the rate of survival of egg stage among four mushroom mites irrespective of temperature and relative humidity. The maximum hatching of egg was recorded in *H.miles* followed by *H.heinemanni*, *R.echinopus* and *T.dimidiatus*. The significant interaction between mite and temperature indicated that the rate of survival of four mushroom mites in egg stage did not follow similar pattern under three levels of temperature. Maximum hatching of eggs in *R.echinopus* , *H.heinemanni* and *H.mikes* were recorded at 20°C

Table 4.13.2: Effect of interactions of temperature and relative humidity on the rate of survival in egg stage of four spp.of mushroom mites.

Mites	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
R.echinopus	38.29 (33.36)	27.88 (26.80)	30.64 (28.43)	0.00 (0.00)	38.93 (38.55)	57.88 (50.05)
T.dimidiatus	30.35 (28.19)	35.38 (31.30)	31.30 (28.83)	0.00 (0.00)	31.08 (33.78)	65.96 (54.59)
H.heinemanni	40.20 (34.59)	36.55 (32.21)	28.00 (25.95)	0.00 (0.00)	33.30 (34.13)	71.45 (58.62)
H.miles	41.06 (34.57)	40.61 (34.47)	40.90 (33.03)	0.00 (0.00)	53.28 (45.47)	69.30 (56.59)
R.H.(%)						
30	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)			
60	39.99 (39.13)	35.79 (36.52)	41.66 (38.29)			
90	72.44 (58.91)	69.52 (57.09)	56.47 (48.90)			

	Mite x Temperature	Mite x Relative humidity	Temperature x Relative humidity
'F' test -	Significant	Significant	Significant
C.D.(p=0.05) -	2.78	2.78	2.41
C.D.(p=0.01) -	3.66	3.66	3.17

Figures in parenthesis indicate angular transformed values.

while that of T.dimidiatus was noticed at 30°C. The rate of hatching of egg was always higher at higher humidity range (90 %) and the optimum temperature and relative humidity combination for hatching was 20°C x 90 % R.H.

Effect of three levels of temperature and relative humidity on the rate of survival of larval stage of four species of mushroom mite have been presented in Table 4.13 and 4.13.3. It may be seen from tables that significant difference was noticed in the rate of survival among four mushroom mites irrespective of temperature and relative humidity conditions. The maximum rate of survival in larval stage was noticed in T.dimidiatus followed by H.miles, R.echinopus and H.heinemanni. The significant interaction between mite and temperature revealed that the rate of larval survival among four species of mushroom mite did not follow similar pattern under three levels of temperature. The maximum rate of larval survival was observed at 20°C in the case of R.echinopus and H.heinemanni while in other two species it was observed at 30°C. The maximum rate of larval survival was always noticed at higher relative humidity range (90 %). The optimum temperature and relative humidity combination for maximum rate of larval survival (76.22 %) was noticed at 30°C x 90 % R.H.

Effect of three levels of temperat ure and relative humidity on the rate of survival of protonymph have been presented in table 4.13 and 4.13.4. It may be seen from Tables 4.13 and 4.13.4 that the significant difference existed in the rate of survival

Table 4.13.3: Effect of interaction of temperature and relative humidity on the rate of survival in larval stage of four spp.of mushroom mites.

Mites	Temperature (°C)			R.H.(%)		
	20	30	40	30	60	90
R.echinopus	39.27 (33.66)	23.62 (19.30)	25.84 (20.62)	0.00 (0.00)	14.60 (13.80)	64.07 (59.78)
T.dimidiatus	39.34 (33.59)	48.74 (40.22)	46.59 (39.52)	0.00 (0.00)	56.67 (50.07)	78.01 (63.26)
H.heinemanni	27.26 (21.77)	24.61 (19.80)	22.96 (18.86)	0.00 (0.00)	0.00 (0.00)	74.84 (60.43)
H.miles	42.93 (31.81)	43.32 (36.28)	38.12 (33.56)	0.00 (0.00)	47.55 (43.66)	76.82 (57.99)
R.H.(%)						
30	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)			
60	35.62 (32.68)	29.00 (24.87)	24.49 (23.10)			
90	75.98 (57.94)	76.22 (61.83)	75.65 (61.32)			

	Mite x Temperature	Mite x Relative humidity	Temperature x Relative humidity
'F' test -	Significant	Significant	Significant
C.D.(p=0.05) -	3.48	3.48	3.01
C.D. (p=0.01)-	4.57	4.57	3.96

Figures in parenthesis indicate angular transformed values.

Table 4.13.4: Effect of interactions of temperature and relative humidity on the rate of survival in protomyphal stage of four spp. of mushroom mites.

Mites	Temperature (°C)			R.H. (%)		
	20	30	40	30	60	90
R.echinopus	28.44 (22.69)	23.77 (19.40)	16.01 (14.62)	0.00 (0.00)	0.00 (0.00)	88.23 (56.71)
T.dimidiatus	44.80 (37.59)	57.27 (47.06)	45.25 (37.02)	0.00 (0.00)	67.07 (57.18)	80.26 (64.50)
H.heinemanni	27.08 (21.60)	29.53 (24.01)	21.60 (17.92)	0.00 (0.00)	0.00 (0.00)	78.21 (63.54)
H.miles	48.08 (39.63)	50.85 (41.59)	50.33 (44.10)	0.00 (0.00)	66.84 (58.94)	82.42 (66.38)
R.H.(%)						
30	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)			
60	28.89 (25.14)	40.10 (33.76)	31.43 (28.17)			
90	82.41 (65.99)	80.97 (65.28)	68.46 (57.08)			

	Mite x temperature	Mite x Relative humidity	Temperature x Relative humidity
'F' test -	Significant	Significant	Significant
C.D.(p=0.05) -	3.96	3.96	3.43
C.D.(p=0.01) -	5.21	5.21	4.51

Figures in parenthesis indicate angular transformed values.

of protonymph among four mushroom mites irrespective of temperature and relative humidity. The maximum rate of survival was noticed in H.miles followed by T.dimidiatus, H.heinemanni and R.echinopus. The significant interactions between mite and temperature and between mite and relative humidity indicated that the rate of survival of protonymphal stage in four species of mite was different under three levels of temperature and relative humidity. The maximum survival rate was noticed at 30°C with an exception in the case of R.echinopus where it was observed at 20°C (28.44 %). However, the rate of survival was always higher at higher relative humidity range. The optimum temperature and relative humidity combination for protonymphal survival (82.41 %) was 20°C x 90 % R.H.

Effect of three levels of temperature and relative humidity on the rate of survival of deutonymph have been presented in Tables 4.13 and 4.13.5. There was significant difference in the rate of survival of deutonymph among four species of mushroom mite irrespective of temperature and relative humidity combinations. The maximum rate of survival was noticed in T.dimidiatus followed by H.miles, R.echinopus and H.heinemanni. The significant interactions between mite and temperature and between mite and relative humidity showed that their patterns of survival was different under three levels of temperature and humidity conditions. The maximum survival was noticed at 20°C except in the case of H.miles where it was observed at 40°C (50.56 %). And the rate of survival was always higher at higher

Table 4.13.5: Effect of interactions of temperature and relative humidity on the rate of survival in deutonymphal stage of four spp. of mushroom mites.

Mite	Temperature (°C)			R.H.(%)		
	20	30	40	30	60	90
R.echinopus	27.00 (21.44)	23.39 (20.66)	22.52 (18.51)	0.00 (0.00)	0.00 (0.00)	72.92 (60.62)
T.dimidiatus	52.05 (46.33)	44.85 (37.39)	50.59 (41.77)	0.00 (0.00)	68.22 (59.86)	79.28 (65.63)
H.heinemanni	27.38 (22.06)	26.82 (21.50)	16.14 (14.69)	0.00 (0.00)	0.00 (0.00)	70.35 (58.26)
H.miles	49.31 (39.79)	48.37 (39.71)	50.56 (42.19)	0.00 (0.00)	69.24 (57.95)	79.01 (63.74)
R.H.(%)						
30	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)			
60	40.52 (34.20)	27.33 (23.90)	35.24 (30.26)			
90	76.29 (63.02)	80.25 (65.55)	69.62 (57.61)			

	Mite x Temperature	Mite x Relative humidity	Temperature x Relative humidity
'F' test -	Significant	Significant	Significant
C.D.(p=0.05)	4.19	4.19	3.39
C.D.(p=0.01)	5.51	5.51	4.46

Figures in parenthesis indicate angular transformed values.

humidity range (90%). The best temperature x relative humidity combination for the maximum survival (80.25 %) was 30°C x 90 % R.H.

Effect of three levels of temperature and relative humidity on the rate of adult (Plate 4.33, 4.34, 4.35, 4.41, 4.42, 4.48, 4.49, 4.50, 4.56 and 4.57) emergence in four species of mushroom mite have been presented in Tables 4.13 and 4.13.6 and Fig.4.14. A significant difference was observed among four mushroom mites in respect to adult emergence irrespective of temperature and relative humidity conditions. The maximum number of adult emergence was noticed in R.echinopus followed by T.dimidiatus, H.heinemanni and H.miles. The significant interactions between mite and temperature and between mite and relative humidity revealed that the pattern of adult emergence of four species of mushroom mite was different under three levels of temperature and relative humidity. The maximum number of adult emergence was noticed at 30°C with an exception in the case of R.echinopus where it was occurred at 20°C. The adult emergence was always higher at higher humidity range (90 %). The optimum temperature and humidity combination for maximum number of adult emergence was 20°C x 90 % R.H. followed by 30°C x 90 % R.H.

Various biological parameters, like mating behaviour, pre-ovipositional and ovipositional period, fecundity and duration of life cycle of a species are of great importance in judging its potentiality as pest. The mating behaviour has direct bearing on the sex ratio of a pest. It was observed during the present investigation

Table 4.13.6 : Effect of interactions of temperature and relative humidity on the no.of adult emerged of four spp. of mushroom mites.

Mites	Temperature (°C)			R.H.(%)		
	20	30	40	30	60	90
R.echinopus	18.20	6.86	2.63	0.00	0.00	27.70
T.dimidiatus	4.43	9.96	1.76	0.00	2.40	19.86
H.heinemanni	8.73	9.23	1.66	0.00	0.00	19.63
H.miles	5.46	8.06	3.03	0.00	3.03	13.53
R.H.(%)						
30	0.00	0.00	0.00			
60	1.35	1.57	1.15			
90	26.27	22.52	11.75			

	Mite x Temperature	Mite x Relative Humidity	Temperature x Relative Humidity
'F' test -	Significant	Significant	Significant
C.D.(p=0.05) -	5.17	5.17	4.48
C.D.(p=0.01) -	6.79	6.79	5.58

that the duration of mating was the highest in T.dimidiatus followed by R.echinopus, H.heinemanni and H.miles. It was further observed that the temperature and relative humidity played an important role in the duration of mating. The response of four species of mushroom mite to various levels of temperature and relative humidity was different. Therefore, the duration of mating pattern was different among four mushroom mites under three levels of temperature and relative humidity. It appears that the duration of mating was highest at 20°C x 90 % R.H. followed by 20°C x 60 % R.H., 30°C x 90 % R.H. and 40°C x 90 % R.H. These observations showed that warm temperature along with high relative humidity are preferred for mating.

The duration of pre-ovipositional period is usually determined by complex physiological factors normally associated with the nutritional requirements of the adult females. But the ecologiwal factors like temperature and relative humidity influence the duration of pre-ovipositional period to a considerable extent. The maximum duration of pre-ovipositional period was noticed in H.miles followed by R.echinopus, H.heinemanni and T.dimidiatus. The pre-ovipositional period of four mushroom mites varied greatly under various combinations of temperature and relative humidity. In general, the duration was minimum at higher temperature showing an inverse relationship with temperature while it bears a direct relationship with relative humidity. The shortest duration was recorded under 30°C x 30 % R.H. (1.30 days), followed by 40°C x 60 % R.H. (2.25 days) while it was maximum at 20°C x 60 % R.H. (5.50 days) followed by 20°C x 90 % R.H. (4.97 days).

The duration of ovipositional period is also of great significance to a pest species. It has a direct bearing on the intrinsic rate of increase of a species. The duration of ovipositional period has also indirect influence on the productivity and survival potential of a pest species. It is disatvantagious for a pest to have a too shorte or too long ovipositional period. It was observed that the maximum duration of ovipositional period was recorded in R.echinopus followed by H.heinemanni, H.miles and T.dimidiatus. The duration of ovipositional period was greatly altered under various combinations of temperature and relative humidity. In general, the ovipositional period bears an inverse relationship with temperature while it is reverse in the case of relative humidity. The durations of ovipositional periods were too long under 20°C x 60 % R.H.(7.56 days) and 20°C x 90 % R.H. (6.91 days) while it was shortest (0.50 day) under 30°C x 30 % R.H. The moderate durations were recorded under 30°C x 60 % R.H. (3.35 days), 40°C x 60 % R.H. (3.77 days) and so on.

However, the duration of total life cycle is a better estimate to assess the effect of temperature and relative humidity on development. The developmental time in days from egg to adult may also be expressed in terms of velocity of development. The data presented in Table 4.14, Fig.4.15 and plate 4.29 to 4.57 indicated

Table 4.14 : Duration of life cycle (days) of four spp. of mushroom mites under three levels of temperature and relative humidity (mean of ten replications)

Mites	Temperature(°C)								
	20			30			40		
	R.H. (%)								
	30	60	90	30	60	90	30	60	90
R.echinopus	*N.D.	N.D.	28.70	N.D.	11.00	14.40	N.D.	9.95	13.00
T.dimidiatus	N.D.	N.D.	14.60	N.D.	N.D.	7.80	N.D.	N.D.	N.D.
H.heinemanni	N.D	N.D.	12.90	N.D.	N.D.	6.25	N.D.	N.D.	5.70
H.miles	N.D.	27.50	23.10	N.D.	16.66	14.73	N.D.	19.10	15.94

* N.D. = No development.

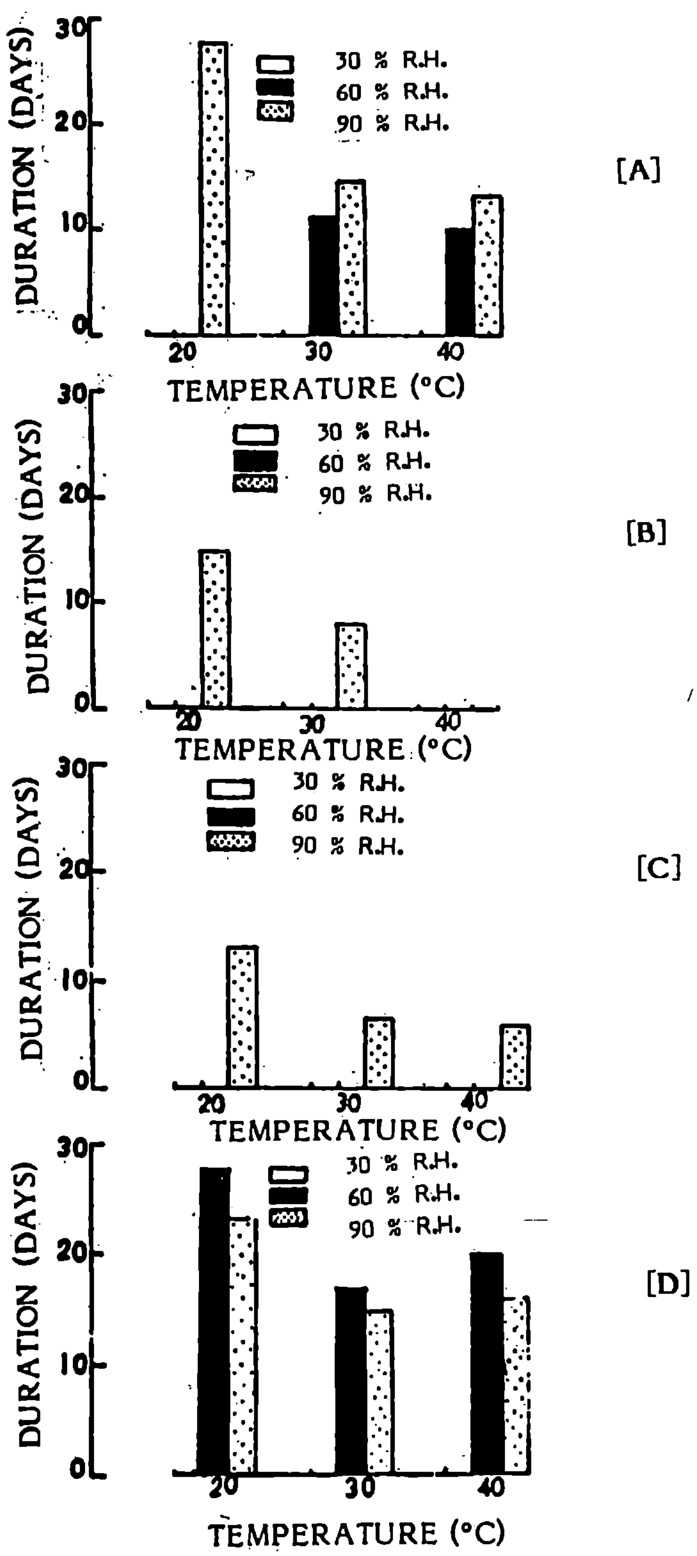
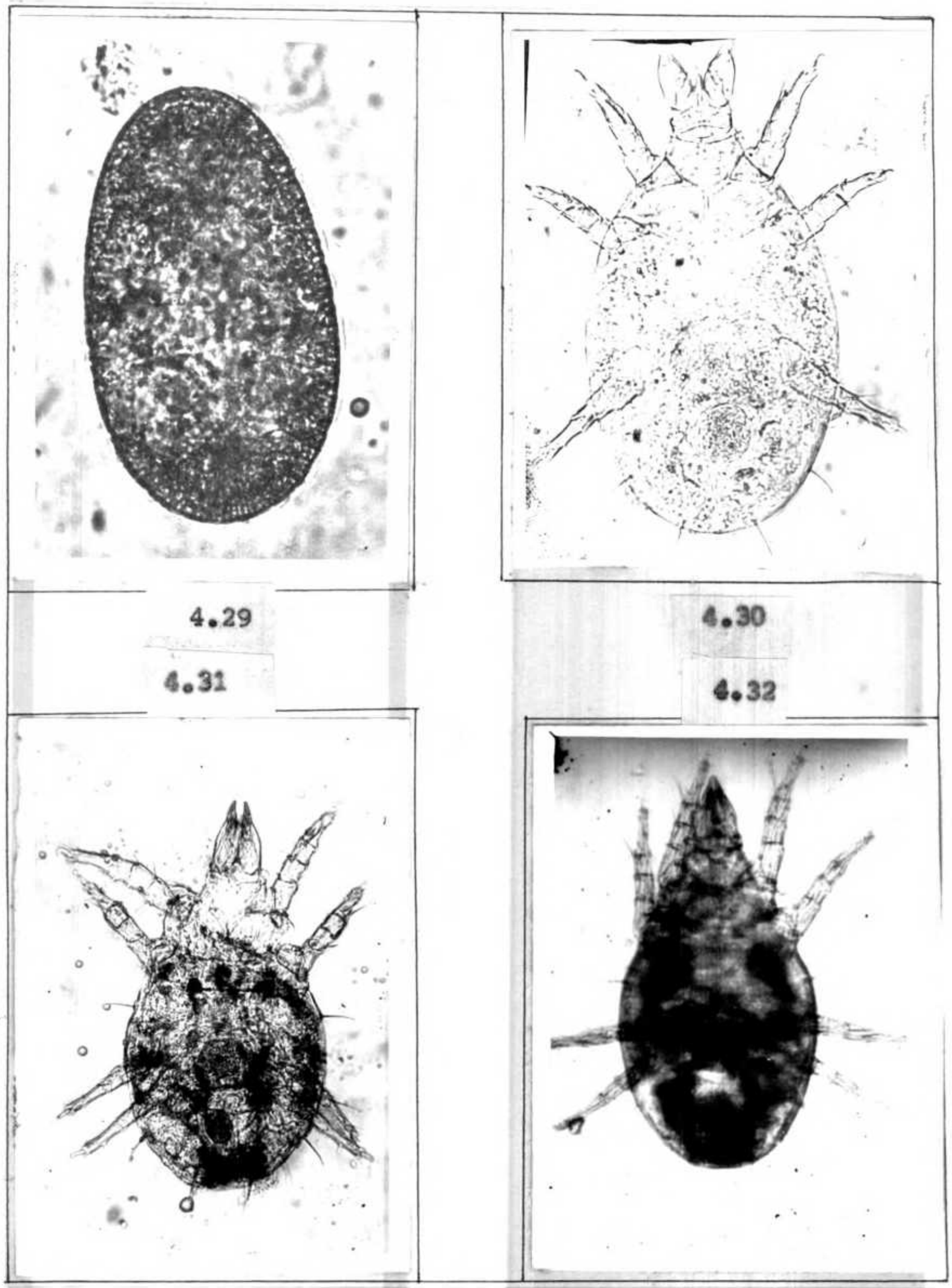
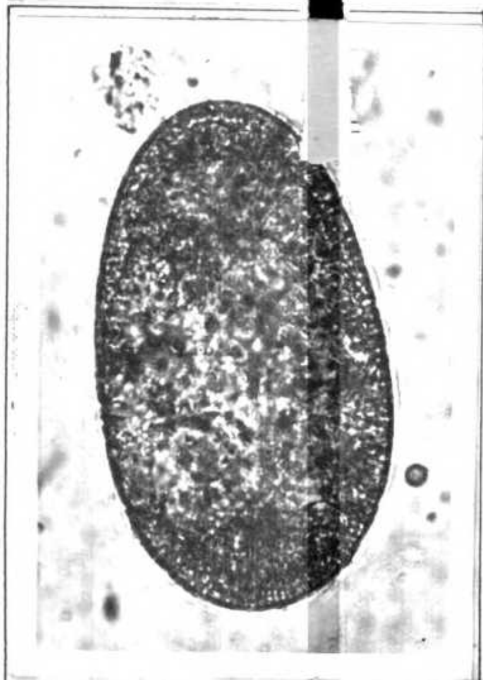


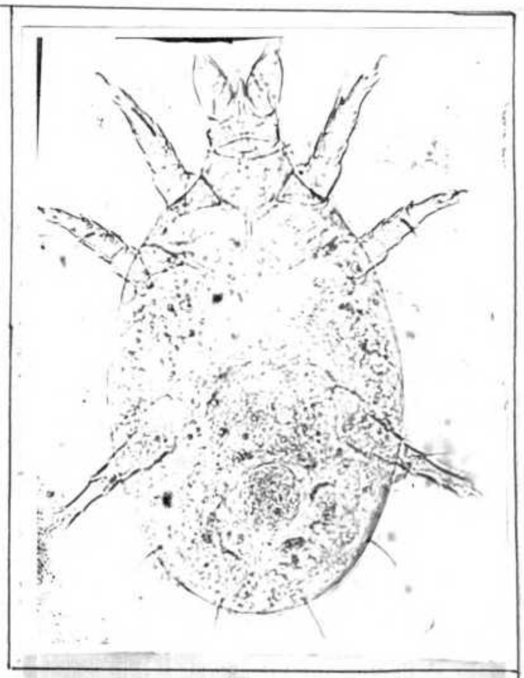
FIG. 4.15 EFFECT OF THREE LEVELS OF TEMPERATURE AND RELATIVE HUMIDITY ON DURATION OF LIFE-CYCLE OF FOUR MUSHROOM MITES (A - R. echinopus, B - T. dimidiatus, C - H. neinemanni AND D - H. mites).



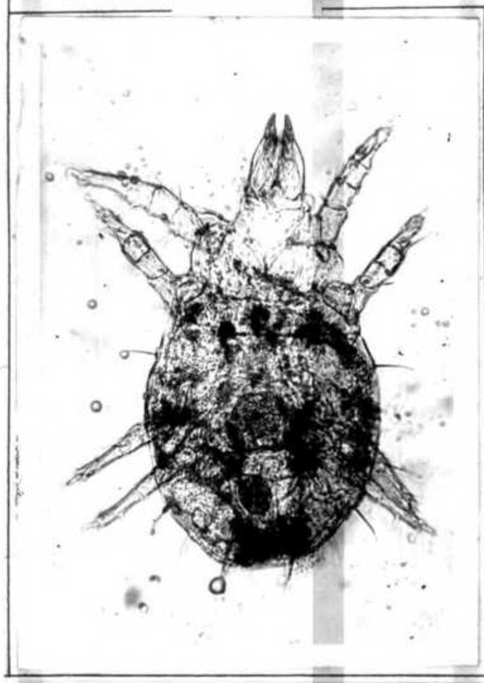
<u>Plate</u> 4.29-4.32: <u>R.echinopus</u> 4.29. Egg; 4.30. larva (ventral aspect); 4.31.protonymph (ventral aspect); 4.32.deutonymph (dorsal aspect).



4.29



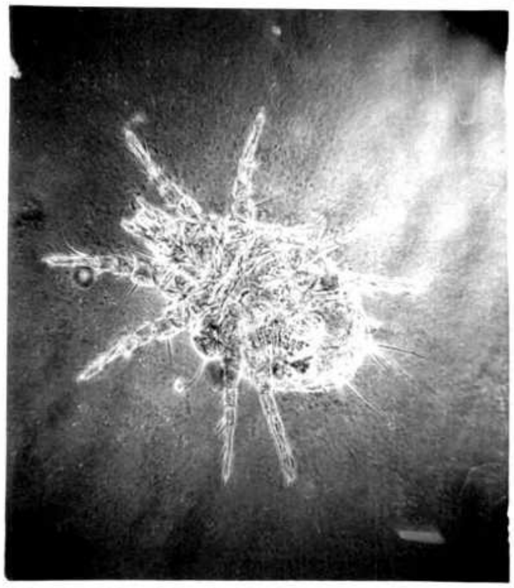
4.30



4.31

4.32

Plate 4.29-4.32: *R. echinopus* 4.29. Egg; 4.30. larva (ventral aspect); 4.31. protonymph (ventral aspect); 4.32. deutonymph (dorsal aspect).



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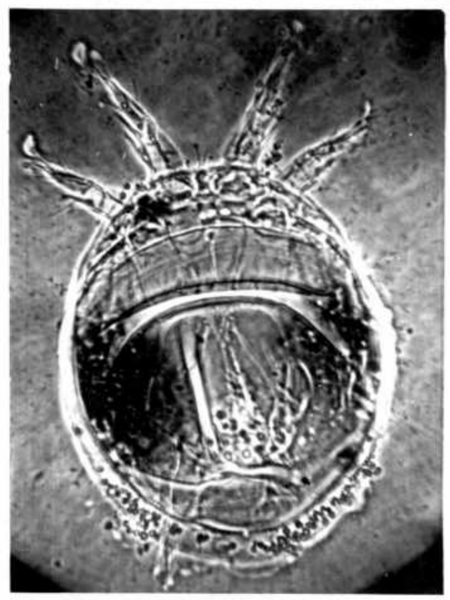
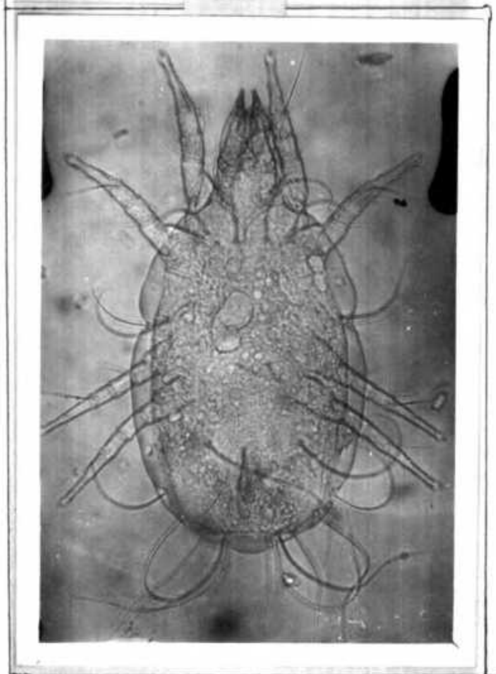


<u>Plate</u> 4.33-4.36: <u>R.echinopus</u> 4.33. homomorphic male(ventral aspect);4.34. heteromorphic male (ventral aspect); 4.35.female (ventral aspect);4.36 hypopus (dorsal aspect)

4.37

4.38

4.39



4.40

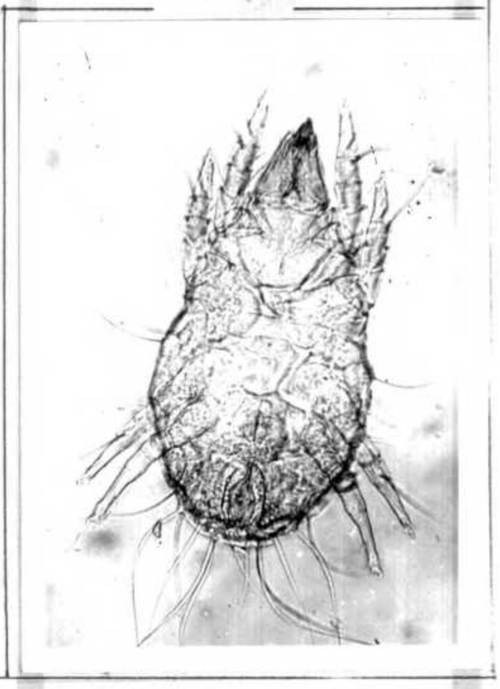
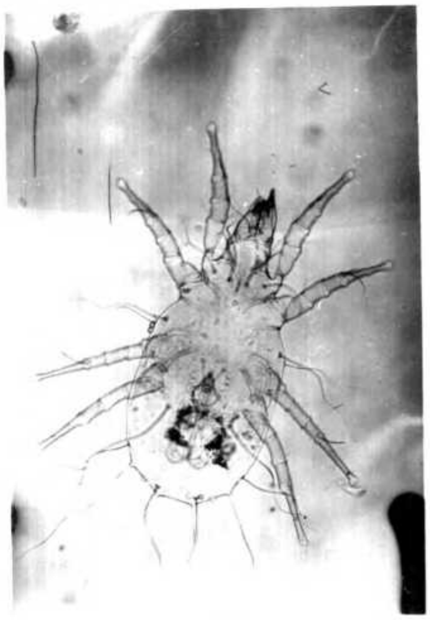


Plate 4.37-4.40: T.dimidiatus. 4.37 egg; 4.38 larva(ventral aspect; 4.39.protonymph (ventral aspect); 4.40 deutonymph (ventral aspect).



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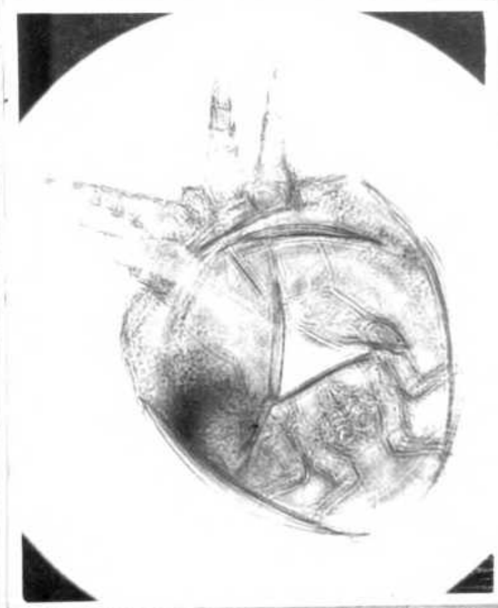
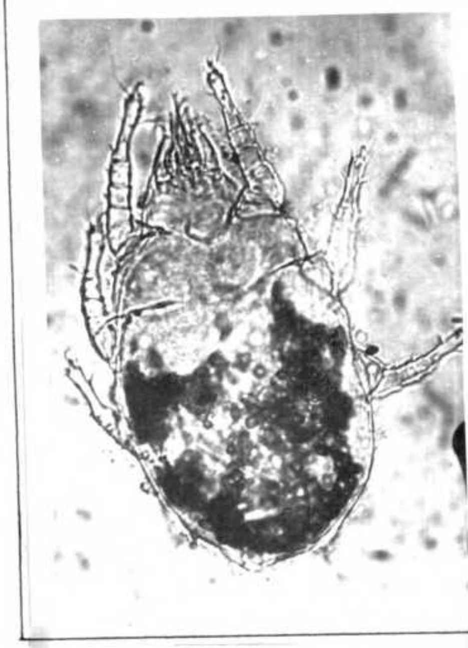


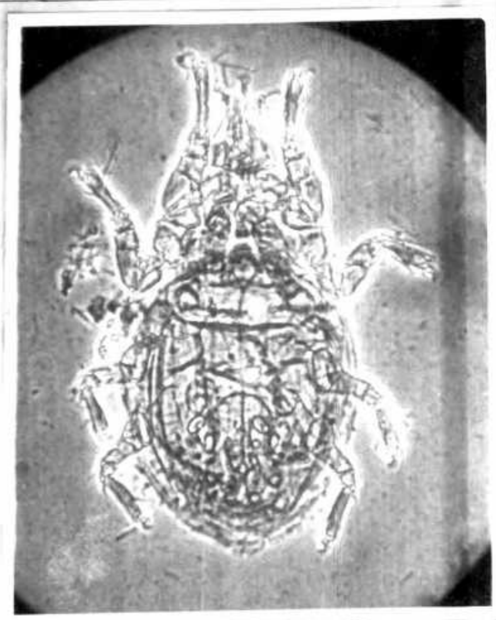
4.43

Plate 4.41-4.43: T.dimidiatus. 4.41 male(Ventral aspect); 4.42 female (ventral aspect); 4.43. hypopus (ventral aspect).

4.44



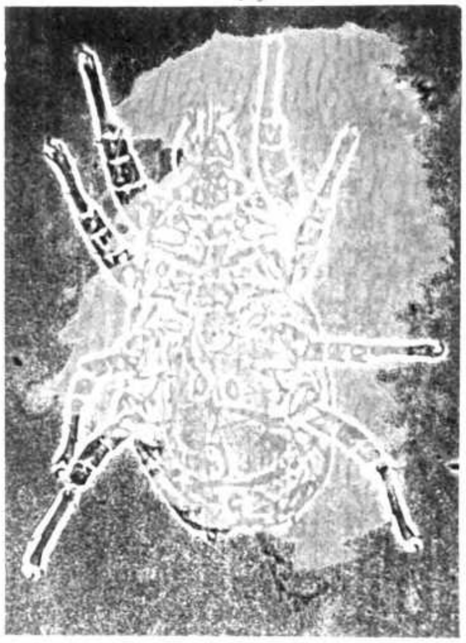
4.45



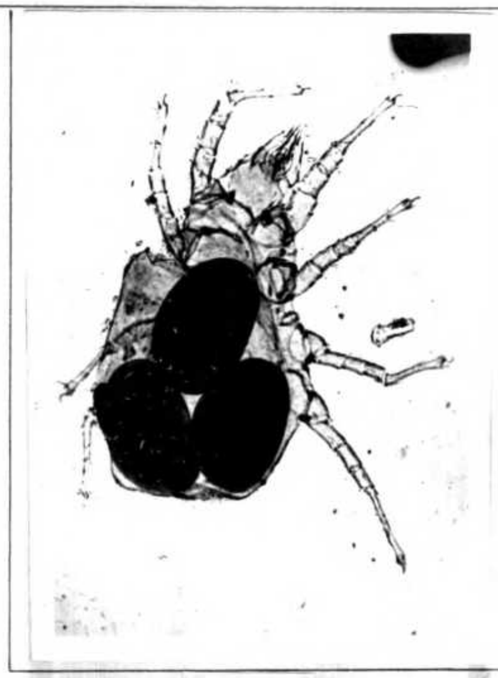
4.46

4.47

<u>Plate</u> 4.44-4.47 : <u>H.heinemanni</u>. 4.44 egg; 4.45.larva(dorsal aspect); 4.46 protonymph (ventral aspect); 4.47 deutonymph(dorsal aspect).



4.48



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4.50

4.51

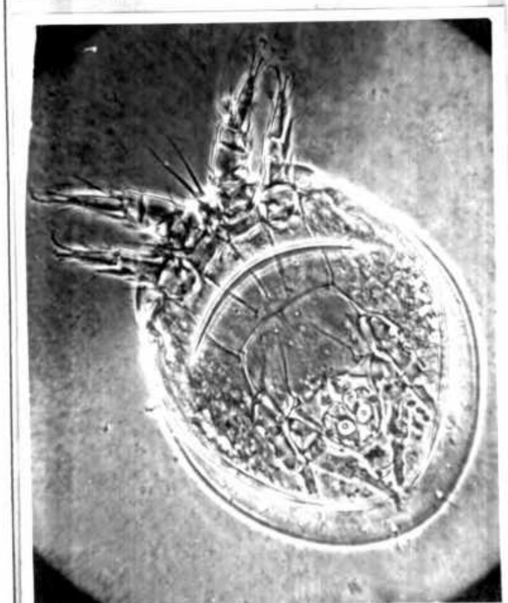
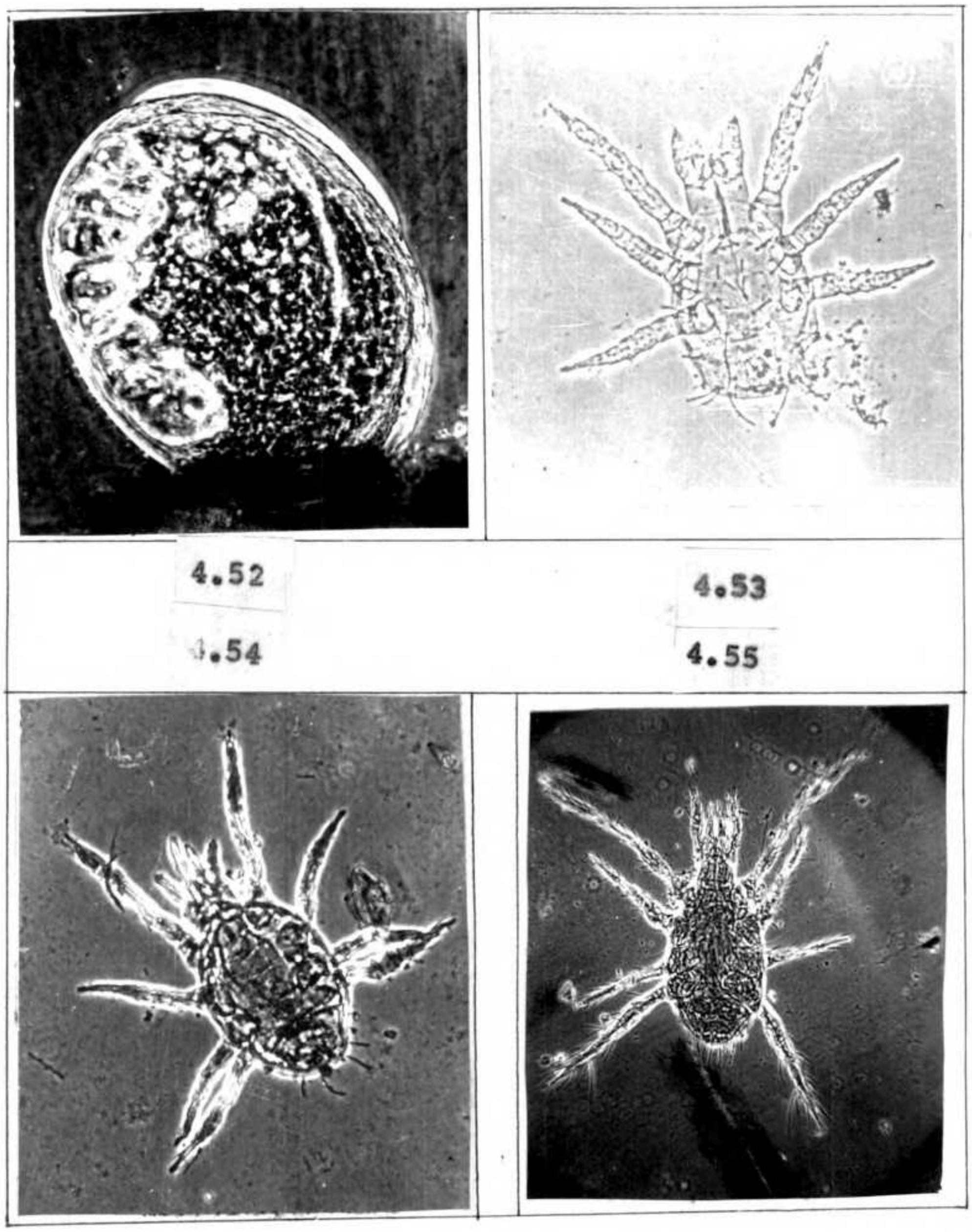
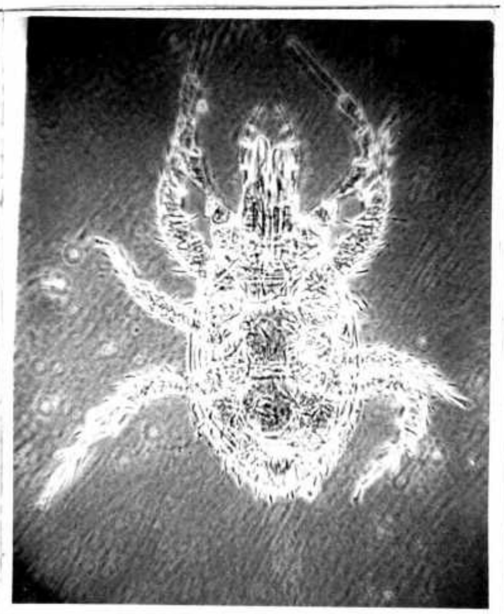


Plate 4.48-4.51: H.heinemanni. 4.48.male (Ventral aspect); 4.49.female(dorsal aspect); 4.50 adult before clearing body covering (dorsal aspect); 4.51.hypopus (ventral aspect).



<u>Plate</u> 4.52-4.55: <u>H.miles.</u> 4.52. egg; 4.53. larva (ventral aspect); 4.54. protonymph (Ventral aspect); 4.55. deutonymph (ventral aspect).

4.56



4.57

Plate 4.56-4.57: H.miles. 4.56.male(ventral aspect); 4.57. female(ventral aspect).

that the speed of development increased progressively with the increase in temperature which was true for all the species of mushroom mites when the temperature was increased from 20°C to 40°C. However, the effect of different levels of relative humidity was less pronounced. In the case of R.echinopus, higher relative humidity (90 %) increased the duration of life cycle while in other three species the duration was increased under lower level of relative humidity. It was observed with surprise that all the four species failed to develop when the level of relative humidity was low (30 %) irrespective of level of temperature. It was further observed that T.dimidiatus and H.heinemanni also failed to develop at 60 % R.H. irrespective of level of temperature. This clearly shows their preferendum for high humidity (90 %). The other two species, R.echinopus and H.miles were able to develop at 60 % R.H. under 30°C and 40°C temperature levels. They had also preference for high relative humidity (90 %). The duration of life cycle was shortest in H.heinemanni followed by T.dimidiatus and the other two species, namely R.echinopus and H.miles did not show much difference in their durations of life cycle. But at 20°C x 90 % R.H. level, the duration of life cycle in H.miles was shorter in comparison to that of R.echinopus. In reverse, the duration of R.echinopus was always shorter in comparison to H.miles at 30°C and 40°C. It is a clear indication that H.miles is better adapted at low temperature condition.

Table 4.13 and 4.13.1 to 4.13.6 and Fig.4.13 and 4.14 summarize the influence of temperature and relative humidity on development of four mushroom mites. The maximum egg laying capacity was observed in R.echinopus followed by T.dimidiatus, H.heinemanni and H.miles. This limitation in H.miles is compensated to a great extent through its relatively higher rate of survival in immature stages during the period of development. The rate of survival of immature stages was also high in T.dimidiatus along with higher capacity for realised fecundity. These attributes have contributed immensely to designate it as the most potential injurious species among mushroom mites. Several authors around the world expressed similar views regarding the pest status of T.dimidiatus (Austin and Jary, 1936; Jary and Stapley, 1936).

It is further evident from the present investigation that all the four species prefer high humidity (90 %) for their optimum developments. This nature is an obvious reflection on their ancestral inheritance being obligatory fungus feeder. In general, fungus (mushroom) grow well under high humid condition and therefore the mites feeding on fungus/mushroom would obviously prefer similar ecological niche. But the temperature preferendum varied widely among four species of mite. R.echinopus being a pest of winter mushroom showed a clear preference for low temperature (20°C) for its optimum development. The remaining three species on the other hand, exhibited a definite inclination for warm temperature (30°C) being summer bound occurrence and at least H.miles showed its ability to multiply even at temperature as high as 40°C.

The informations pertaining to the ecology of mushroom mites are mostly lacking. It has been reported that they prefer warm and high humid conditions for development (Rivert,1970). Similar observation has also been made by the present author. Due to the absence of published literatures on the ecology of four species of mushroom mite, the present author could not undertake elaborated discussion on the subject.

4.7 Seasonal incidence of mushroom mites

It has been discussed in fore-going paragraphs that four species of mite are associated with mushroom cultivation in West-Bengal. They occur in a sequence periodically without overlaping each other (Tables 4.15 to 4.18 and Fig.4.16 to 4.23). *R.echinopus* is prevalent only during January to March when other mite species are absent on mushroom. Attempts were made by the present author to establish relationship between the mite population found during different growth periods of mushroom and major abiotic factors. It is revealed from Table 4.15.1 that a positive correlation exists between temperature and the density of mite population found in straw. Similar relationship was also noticed between temperature and the density of mite population recorded during mycelial stage of mushroom (Table 4.15.2). The non-significant 't' values in respect to relative humidity indicated the non-relationship between the density of mite population and relative humidity. The maximum population of the mite was recorded towards the end of March when maximum

Table 4.15.1 : Influence of major abiotic factors on population fluctuation of R.echinopus in straw component.

Date of observation	No.of mite present / 10 gm straw	Temperature (°C)			Relative Humidity(%)		
		Max.	Min.	Mean	Max.	Min.	Mean
1.1.84	12.66	17.00	15.50	16.25	66.50	62.50	64.50
8.1.84	14.33	22.00	20.00	21.00	70.00	66.00	68.00
15.1.84	18.33	24.00	20.00	22.00	79.00	77.00	78.00
22.1.84	16.66	20.00	17.00	18.50	80.00	76.00	78.00
1.2.84	20.33	21.00	18.50	19.75	75.00	73.00	74.00
8.2.84	20.00	20.00	16.00	18.00	62.00	58.00	60.00
15.2.84	25.33	23.50	18.00	20.75	58.00	54.00	56.00
22.2.84	13.33	25.00	20.00	22.50	43.00	41.00	42.00
1.3.84	20.66	25.00	21.00	23.00	44.00	40.00	42.00
8.3.84	26.66	28.50	26.50	27.50	62.50	58.50	60.50
15.3.84	36.00	33.00	29.50	31.25	63.50	61.50	62.50
1.1.85	25.33	23.00	20.00	21.50	68.00	64.00	66.00
8.1.85	24.66	22.00	19.00	20.50	67.00	65.00	66.00
15.1.85	23.66	23.00	18.00	20.50	56.00	52.00	54.00
22.1.85	24.33	20.00	18.00	19.00	66.00	62.00	64.00
1.2.85	22.66	24.00	20.00	22.00	63.00	61.00	62.00
8.2.85	26.66	24.50	20.50	22.50	68.00	60.00	64.00
15.2.85	23.33	23.00	19.00	21.00	66.00	62.00	64.00
22.2.85	28.33	25.50	22.50	24.00	62.50	60.50	61.50
1.3.85	28.66	26.00	23.00	24.50	62.00	58.00	60.00

Factors	Years observed	Correlation Coefficient	't' test	Remark
1. Mite population and temperature	2	0.70	4.18	Significant
2. Mite population and relative humidity	2	-0.04	-0.16	Not Significant

Table 4.15.2 : Influence of major abiotic factors on population fluctuation of R.echinopus in mycelial stage of mushroom.

Date of observation	No. of mite/10 gm of		Temperature(°C)			Relative Humidity (%)		
	sajar-caju mushroom	Ostreatus mushroom	Max.	Min.	Mean	Max.	Min.	Mean
15.1.84	103.33	93.33	24.00	20.00	22.00	80.00	76.00	78.00
22.1.84	120.00	116.66	25.00	21.00	23.00	80.00	76.00	78.00
1.2.84	133.33	106.66	22.00	17.50	19.75	77.00	71.00	74.00
8.2.84	156.66	136.66	22.00	20.00	21.00	77.00	75.00	76.00
15.2.84	160.00	146.66	21.50	20.00	20.75	59.00	53.00	56.00
22.2.84	153.33	146.66	24.00	20.00	22.00	60.00	56.00	58.00
1.3.84	193.33	140.00	25.00	21.00	23.00	44.00	40.00	42.00
8.3.84	196.66	176.66	32.50	27.50	30.00	66.00	62.00	64.00
15.3.84	236.66	200.00	34.50	28.00	31.25	65.50	59.50	62.50
22.3.84	260.66	256.66	34.00	30.00	32.00	76.00	72.00	74.00
1.4.84	266.66	260.00	35.00	31.00	33.00	76.00	70.00	73.00
15.1.85	96.66	90.00	22.50	18.50	20.50	56.00	52.00	54.00
22.1.85	100.00	93.33	21.00	17.00	19.00	66.00	62.00	64.00
1.2.85	93.33	96.66	24.00	20.00	22.00	64.00	60.00	62.00
8.2.85	120.00	110.00	25.00	20.00	22.50	67.00	61.00	64.00
15.2.85	146.66	123.33	24.00	18.00	21.00	67.00	61.00	64.00
22.2.85	116.66	110.00	26.00	22.00	24.00	62.50	60.50	61.50
1.3.85	130.00	120.00	26.00	23.00	24.50	63.00	57.00	60.00
8.3.85	176.33	164.33	31.00	27.00	29.00	66.00	62.00	64.00
15.3.85	196.66	190.00	32.00	27.00	29.50	64.50	60.00	62.00

Factors	Years observed	Correlation coefficient	't' test	Remark
1. Mite population in sajor-caju mushroom and temperature	2	0.84	6.69	Significant
2. Mite population in Ostreatus mushroom and temperature	2	0.88	8.09	Significant
3. Mite population in sajor-caju mushroom and relative humidity	2	0.313	1.39	Not significant
4. Mite population in Ostreatus mushroom and relative humidity	2	0.03	0.14	Not significant

temperature was recorded. Again, the minimum population was recorded during January when the temperature was the lowest. It may be observed from Table 4.15.3 and Fig.4.16 that a similar positive correlations also exists between temperature and the mite population recorded on fruit body and a non-relationship between relative humidity and mite population. The relationship between mite population and the prevailing atmospheric temperature was of similar nature on two species of mushroom i.e. P.sajor-caju and P.ostreatus. In general, the infestation of R.echinopus started from January and its population gradually increased with the increase in temperature in subsequent months. The mite population reached its peak towards the end of March and disappeared from the month of April.

The influence of two major abiotic factors viz., temperature and relative humidity on T.dimidiatus has been presented in Tables 4.16.1-4.16.3 and Fig.4.17. It is interesting to note that no relationship could be established between the temperature and the mite population found during different growth periods of mushroom. On the other hand, it showed a positive correlation with the atmospheric relative humidity. The infestation of the mite was noticed from the month of April and lasted till June and the degree of infestation vis-a-vis population varied considerably from April to June depending on the increase or decrease in atmospheric relative humidity. It is seen from the Table 4.16.1 that the maximum relative

Table 4.15.3 : Influence of major abiotic factors on the population fluctuation of R.echinopus in fruit body stage of mushroom.

Date of observation	No.of mite/10 gm of		Temperature(°C)			Relative Humidity (%)		
	Sajor-caju mushroom	Ostreatus mushroom	Max.	Min.	Mean	Max.	Min	Mean
19.1.84	16.66	14.66	20.00	16.75	18.37	66.00	62.00	64.00
26.1.84	25.00	28.00	20.00	16.75	18.37	67.00	61.00	64.00
5.2.84	33.00	35.33	25.00	21.50	23.25	67.00	65.00	66.00
12.2.84	38.00	37.33	25.50	22.50	24.00	68.00	64.00	66.00
19.2.84	37.66	38.66	25.50	22.50	24.50	63.00	61.00	62.00
26.2.84	21.33	20.00	24.00	22.00	23.00	58.00	52.00	55.00
5.3.84	23.33	20.33	26.00	23.00	24.50	58.00	52.00	55.00
12.3.84	25.00	26.66	30.00	27.00	28.50	54.00	50.00	52.00
19.3.84	56.66	53.66	33.50	29.00	31.25	57.00	53.00	55.00
26.3.84	28.00	36.00	32.00	28.00	30.00	64.00	60.00	62.00
5.4.84	43.33	46.66	35.00	31.50	33.25	69.00	63.00	66.00
19.1.85	18.66	21.33	23.00	17.00	20.00	64.00	60.00	62.00
26.1.85	26.66	23.33	22.00	16.00	19.00	69.00	63.00	66.00
5.2.85	25.33	28.00	24.00	20.00	22.00	66.00	60.00	63.00
12.2.85	21.66	18.00	23.00	19.00	21.00	62.00	60.00	61.00
19.2.85	34.00	33.00	23.00	15.00	19.00	67.00	63.00	65.00
26.2.85	31.00	30.00	25.00	22.00	23.50	64.00	60.00	62.00
5.3.85	34.66	33.33	26.00	22.00	24.00	67.00	61.00	64.00
12.3.85	42.00	40.00	30.00	26.00	28.00	66.00	62.00	64.00
19.3.85	36.00	38.00	31.00	27.00	29.00	63.00	57.00	60.00

Factors	Years observed	Correlation coefficient	't' test	Remark
1. Mite population in sajor-caju mushroom and temperature	2	0.78	5.40	Significant
2. Mite population in Ostreatus mushroom and temperature	2	0.73	4.57	Significant
3. Mite population in sajor-caju mushroom and relative humidity	2	0.07	0.29	Not Significant
4. Mite population in Ostreatus mushroom and relative humidity	2	0.14	0.62	Not significant

Table 4.15.3 : Influence of major abiotic factors on the population fluctuation of R.echinopus in fruit body stage of mushroom.

Date of observation	No.of mite/10 gm of		Temperature(°C)			Relative Humidity (%)		
	Sajor-caju mushroom	Ostreatus mushroom	Max.	Min.	Mean	Max.	Min	Mean
19.1.84	16.66	14.66	20.00	16.75	18.37	66.00	62.00	64.00
26.1.84	25.00	28.00	20.00	16.75	18.37	67.00	61.00	64.00
5.2.84	33.00	35.33	25.00	21.50	23.25	67.00	65.00	66.00
12.2.84	38.00	37.33	25.50	22.50	24.00	68.00	64.00	66.00
19.2.84	37.66	38.66	25.50	22.50	24.50	63.00	61.00	62.00
26.2.84	21.33	20.00	24.00	22.00	23.00	58.00	52.00	55.00
5.3.84	23.33	20.33	26.00	23.00	24.50	58.00	52.00	55.00
12.3.84	25.00	26.66	30.00	27.00	28.50	54.00	50.00	52.00
19.3.84	56.66	53.66	33.50	29.00	31.25	57.00	53.00	55.00
26.3.84	28.00	36.00	32.00	28.00	30.00	64.00	60.00	62.00
5.4.84	43.33	46.66	35.00	31.50	33.25	69.00	63.00	66.00
19.1.85	18.66	21.33	23.00	17.00	20.00	64.00	60.00	62.00
26.1.85	26.66	23.33	22.00	16.00	19.00	69.00	63.00	66.00
5.2.85	25.33	28.00	24.00	20.00	22.00	66.00	60.00	63.00
12.2.85	21.66	18.00	23.00	19.00	21.00	62.00	60.00	61.00
19.2.85	34.00	33.00	23.00	15.00	19.00	67.00	63.00	65.00
26.2.85	31.00	30.00	25.00	22.00	23.50	64.00	60.00	62.00
5.3.85	34.66	33.33	26.00	22.00	24.00	67.00	61.00	64.00
12.3.85	42.00	40.00	30.00	26.00	28.00	66.00	62.00	64.00
19.3.85	36.00	38.00	31.00	27.00	29.00	63.00	57.00	60.00

Factors	Years observed	Correlation coefficient	't' test	Remark
1. Mite population in sajor-caju mushroom and temperature	2	0.78	5.40	Significant
2. Mite population in Ostreatus mushroom and temperature	2	0.73	4.57	Significant
3. Mite population in sajor-caju mushroom and relative humidity	2	0.07	0.29	Not Significant
4. Mite population in Ostreatus mushroom and relative humidity	2	0.14	0.62	Not significant

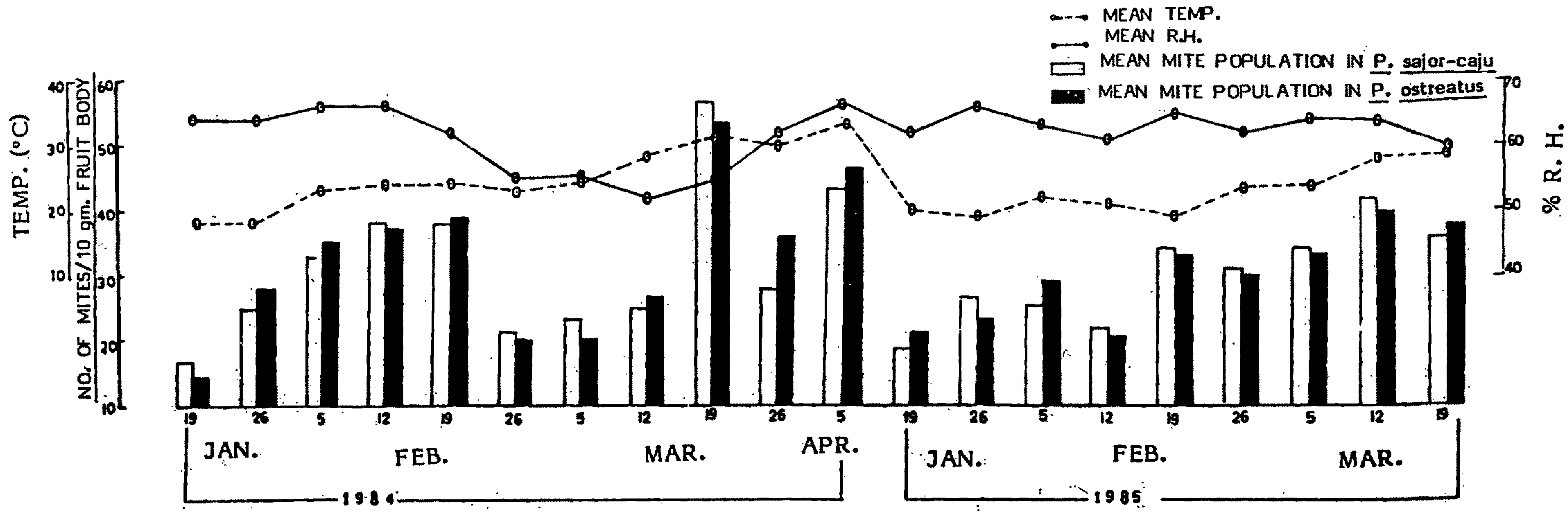


FIG. 4.16 SEASONAL OCCURRENCE OF R. echinopus IN RELATION TO FRUIT BODY STAGE OF MUSHROOM.

Table 4.16.1: Influence of major abiotic factors on the population fluctuation of *T. dimidiatus* in straw component.

Date of observation	No. of mite/ 10 gm straw	Temperature (°C)			Relative humidity (%)		
		Max.	Min.	Mean	Max.	Min.	Mean
1.4.84	36.33	35.00	31.00	33.00	76.00	70.00	73.00
8.4.84	40.66	34.50	29.50	32.00	76.00	72.00	74.00
15.4.84	42.33	34.00	29.00	31.50	77.00	71.00	74.00
22.4.84	41.66	33.00	29.00	31.00	90.00	86.00	88.00
1.5.84	36.33	32.50	29.00	30.75	92.00	86.00	89.00
8.5.84	35.66	37.00	33.00	35.00	88.00	84.00	80.00
15.5.84	36.66	36.50	33.50	35.00	85.00	83.00	84.00
22.5.84	33.33	36.00	32.00	34.00	82.00	78.00	80.00
1.6.84	41.33	36.00	32.00	34.00	80.00	76.00	78.00
15.3.85	18.66	32.00	27.00	29.50	63.00	61.00	62.00
22.3.85	24.66	32.00	27.00	29.50	61.00	55.00	58.00
1.4.85	22.66	31.00	27.00	29.00	58.50	54.50	56.50
8.4.85	23.33	23.00	20.00	21.50	64.00	60.00	62.00
15.4.85	40.00	34.00	31.00	32.50	68.00	62.00	65.00
22.4.85	26.66	34.50	30.50	32.50	66.00	62.00	64.00
1.5.85	21.33	33.00	27.00	30.00	61.00	55.00	58.00
8.5.85	25.66	33.00	29.00	31.00	67.50	63.50	65.50
15.5.85	26.66	33.00	29.00	31.00	70.50	64.50	67.50
22.5.85	23.66	30.00	26.00	28.00	68.50	64.50	66.50
1.6.85	20.33	33.00	32.00	32.00	68.50	62.50	65.50

Factors	Years observed	Correlation coefficient	't' test	Remark
1. Mite population and temperature	2	-0.04	-0.16	Nonsignificant
2. Mite population and relative humidity	2	0.85	7.05	Significant

Table 4.16.2: Influence of major abiotic factors on the population fluctuation of *T. dimidiatus* in mycelial stage of mushroom.

date of observation	No. of mite/10 gm of		Temperature (°C)			Relative Humidity (%)		
	lobayense mushroom	volvacea mushroom	Max.	Min.	Mean	Max.	Min.	Mean
15.4.84	121.00	100.00	33.00	30.00	31.50	76.00	72.00	74.00
22.4.84	150.00	136.66	32.00	30.00	31.00	90.00	84.00	87.00
1.5.84	180.00	153.33	31.50	30.00	30.75	91.50	87.50	89.50
8.5.84	146.66	140.33	35.00	31.00	33.00	89.00	83.00	86.00
15.5.84	136.66	119.33	38.00	33.00	36.50	86.09	82.50	84.50
22.5.84	142.33	140.00	37.00	33.00	35.00	80.00	82.00	84.00
1.6.84	123.33	120.00	36.00	33.00	34.50	80.00	76.00	78.00
8.6.84	184.33	172.66	32.00	28.00	30.00	91.50	87.50	89.50
15.6.84	140.00	128.33	30.50	28.00	27.25	88.50	82.50	85.40
1.4.85	66.66	62.33	30.00	28.00	29.00	58.50	54.50	56.50
8.4.85	108.66	102.33	33.00	30.00	31.50	64.00	60.00	62.00
15.4.85	133.33	116.33	35.00	30.00	32.50	66.00	64.00	65.00
22.4.85	132.33	123.33	35.00	30.00	32.50	66.00	62.00	64.00
1.5.85	71.00	54.00	32.00	28.00	30.00	60.00	56.00	58.00
8.5.85	115.00	118.00	33.00	29.00	31.00	68.50	62.50	65.50
15.5.85	116.66	108.33	33.00	29.00	31.00	69.50	65.50	67.50
22.5.85	112.33	102.00	30.00	26.00	28.00	68.50	64.50	66.50
1.6.85	91.66	83.00	34.00	30.00	32.00	64.50	58.50	61.50
8.6. 85	136.33	120.33	32.00	30.00	31.00	84.50	80.50	82.50
15.6.85	148.33	133.33	31.50	27.00	29.25	88.50	82.50	85.50

Factors	Years observed	Correlation coefficient	't' test	Remark
1. Mite population in *lobayense* mushroom and temperature	2	0.14	0.63	Not significant.
2. Mite population in *volvacea* mushroom and temperature	2	0.17	.74	Not significant.
3. Mite population in *lobayense* mushroom and relative humidity	2	0.86	7.42	Significant
4. Mite population in *volvacea* mushroom and relative humidity	2	0.89	8.50	Significant

Table 4.16.3: Influence of major abiotic factors on the population fluctuation of T.dimidiatus in fruit body stage of mushroom.

Date of observation	No.of mite /10 gm of lobavense mushroom	No.of mite /10 gm of volvacea mushroom	Temperature(°C) Max.	Temperature(°C) Min.	Temperature(°C) Mean	Relative Humidity (%) Max.	Relative Humidity (%) Min.	Relative Humidity (%) Mean
26.4.84	181.33	175.33	34.00	30.00	32.00	88.00	84.00	86.00
5.5.84	250.33	243.33	34.00	30.00	32.00	92.00	86.00	89.00
12.5.84	187.33	193.33	35.00	31.00	33.00	86.00	84.00	86.00
20.5.84	175.00	168.33	34.50	31.50	33.00	88.00	82.00	85.00
26.5.84	188.33	183.66	33.50	30.50	32.00	87.00	85.00	86.00
5.6.84	260.00	246.66	34.00	30.00	32.00	92.00	88.00	90.00
12.6.84	241.33	233.33	32.00	28.00	30.00	89.00	85.00	88.00
20.6.84	210.00	200.00	31.00	27.50	29.00	88.00	86.00	87.00
26.6.84	169.00	154.00	31.00	27.00	29.00	87.00	81.00	84.00
12.4.85	63.00	57.00	33.00	29.00	31.00	68.00	64.00	66.00
20.4.85	37.00	42.66	34.00	30.00	32.00	67.00	61.00	64.00
26.4.85	65.00	62.00	32.50	29.50	31.00	68.00	64.00	66.00
5.5.85	30.33	31.33	31.00	29.00	30.00	63.00	57.00	60.00
12.5.85	54.43	43.33	33.00	29.00	31.00	68.00	64.00	66.00
20.5.85	55.33	60.33	32.00	28.00	30.00	68.00	64.00	66.00
26.5.85	72.33	89.33	32.00	30.00	31.00	73.00	67.00	70.00
5.6.85	103.33	107.33	32.00	28.00	30.00	78.00	74.00	76.00
12.6.85	156.33	152.33	33.00	29.00	31.00	86.00	80.00	83.00
20.6.85	183.33	175.66	32.00	28.50	30.00	88.00	84.00	86.00
26.6.85	178.33	169.66	31.00	27.00	29.00	89.00	83.00	66.00

Factors	Years observed	Correlation coefficient	't' test	Remarks
1. Mite population in lobavense mushroom and temperature	2	-0.01	-0.04	Not significant
2. Mite population in volvacea mushroom and temperature	2	0.01	.04	Not significant
3. Mite population in lobavense mushroom and relative humidity	2	0.97	17.15	Significant
4. Mite population in volvacea mushroom and relative humidity	2	.97	16.85	Significant

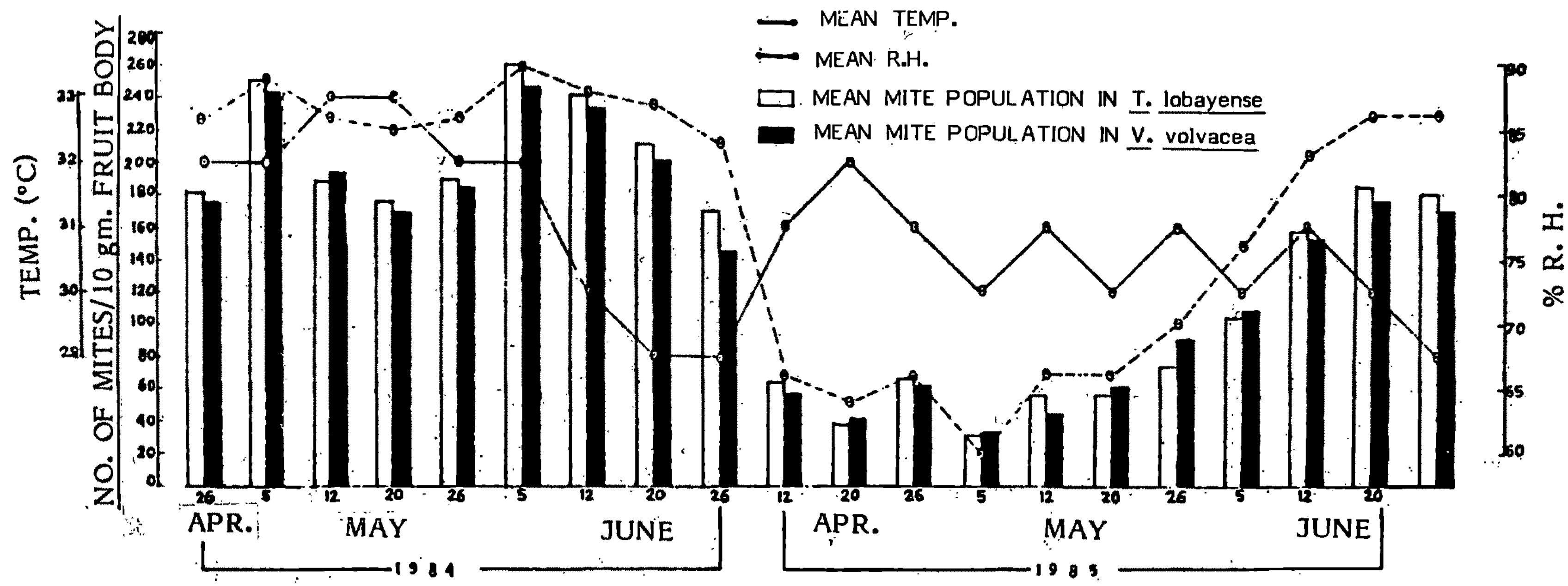


FIG. 4.17 SEASONAL OCCURRENCE OF *T. dimidiatus* IN RELATION TO FRUIT BODY STAGE OF MUSHROOM.

humidity was noticed during the last part of April to the first part of May. The population of the mite was also high during these periods. The minimum population of mite was observed when the atmospheric relative humidity was around 56-60% R.H. Similar observations were also recorded between relative humidity and mite population found in mycelial and fruit body stages. It was observed that the atmospheric relative humidity was around 80 % R.H. during April to June, 1984 favouring the mite species to maintain a high population density level throughout the period. But during the year 1985, the atmospheric relative humidity was at the lower side, i.e. around 65 % except during the month of June and accordingly, the population density of mite was comparatively low during this entire period under observation. The pattern of relationship between relative humidity and mite population was similar on two different types of mushroom i.e. T.lobayense and V.volvacea.

The relationship between two major abiotic factors and the population fluctuation of H.heinemanni has been presented in Tables 4.17.1 - 4.17.3 and Fig.4.18 - 4.20. It appears from Table 4.17.1 and Fig.4.18 that the mite population found in straw showed a positive correlation with both the abiotic factors i.e., temperature and relative humidity. The infestation of H.heinemanni began from the month of June and contibued till October after which it disappeared. The maximum population of the mite was recorded during June-July in the year 1984 and during August in the year 1985 when the temperature

Table 4.17.1: Influence of major abiotic factors on the population fluctuation of *H.heinemanni* in straw component.

Date of observation	No.of mite/ 10 gm straw	Temperature (°C)			Relative humidity(%)		
		Max.	Min.	Mean	Max.	Min.	Mean
15.6.84	29.33	31.50	27.00	29.25	87.50	83.50	85.50
22.6.84	33.33	32.00	28.00	30.00	88.50	82.50	85.50
1.7.84	36.33	31.50	30.00	30.75	85.50	81.50	83.50
8.7.84	36.66	33.00	30.00	31.50	88.50	84.50	86.50
15.7.84	34.66	32.50	30.00	31.25	90.50	84.50	87.50
23.7.84	22.33	30.00	27.00	28.50	90.50	86.50	88.50
1.8.84	26.66	30.00	27.00	28.50	89.00	83.00	86.00
8.8.84	25.33	31.00	28.00	29.50	87.00	83.00	85.00
15.8.84	29.66	32.75	28.00	30.37	78.00	72.00	75.00
22.8.84	24.66	31.00	27.50	29.25	78.00	72.00	75.00
1.9.84	25.33	32.25	28.00	30.12	77.00	73.00	75.00
8.9.84	30.00	33.00	30.00	31.50	71.00	66.00	65.00
15.9.84	28.66	31.00	30.50	30.75	76.00	72.00	74.00
15.6.85	21.66	31.00	27.00	29.00	70.50	66.50	68.50
22.6.85	20.33	30.00	26.00	28.00	70.00	66.00	68.00
1.7.85	26.33	29.50	27.[illegible]0	28.50	70.00	64.00	67.00
8.7.85	26.00	31.00	27.00	29.00	67.50	65.50	66.50
15.7.85	23.33	30.00	27.60	28.50	67.00	65.00	66.00
22.7.85	24.00	30.00	26.00	28.00	69.50	63.5	66.50
1.8.85	23.66	30.00	28.00	29.00	67.00	63.00	65.00
8.8.85	28.33	32.00	28.00	30.00	68.50	66.50	67.50
15.8.85	26.66	31.00	27.00	29.00	71.00	67.00	69.00
22.8.85	28.33	31.00	29.00	30.00	71.00	67.00	69.00
1.9.85	24.33	30.00	26.00	28.00	71.00	68.00	69.50

Factors	Years observed	Correlation coefficient	't'test	Remark
1. Mite population and temperature	2	0.80	6.43	Significant
2. Mite population and relative humidity	2	0.52	2.89	Significant

Table 4.12: Influence of major abiotic factors on the population fluctuation of *H. heinemanni* in mycelial stage of mushroom

Date of observation	No. of mite/10 gm of		Temperature (°C)			Relative Humidity (%)		
	lobayense mushroom	volvacea mushroom	Max.	Min.	Mean	Max.	Min.	Mean
1.7.84	231.33	250.00	32.00	29.50	30.75	85.50	81.50	83.50
8.7.84	260.00	240.00	33.00	30.00	31 50	88.50	84.50	86.50
15.7.84	280.00	250.00	33.50	29.00	31.25	89.50	85.50	87.50
22.7.84	360.00	350.00	30.00	27.00	28.50	90.50	86.50	88.50
1.8.84	310.00	300.00	30.00	27.00	28.50	88.00	84.00	86.00
8.8.84	340.00	320.00	31.00	28.00	29.50	87.00	85.00	86.00
15.8.84	290.00	280.00	32.00	28.75	30.37	77.00	73.00	75.00
22.8.84	281.33	250.00	31.00	27.50	29.25	77.00	73.00	75.00
1.9.84	260.00	270.00	31.25	29.00	30.12	77.00	73.00	75.00
8.9.84	130.00	155.33	33.00	30.00	31.50	71.00	65.00	68.00
15.9.84	210.00	160.00	32.00	29.50	30.75	75.00	73.00	74.00
22.9.84	140.00	155.00	31.00	27.00	29.00	70.50	66.50	68.50
1.10.84	199.99	166.66	31.50	28.50	30.00	74.00	72.00	73.00
1.7.85	100.00	120.00	30.00	27.00	28.50	70.00	64.00	67.00
8.7.85	120.00	90.33	31.00	27.00	29.00	69.50	63.50	66.50
15.7.85	140.00	110.00	29.50	26.50	28.00	68.00	64.00	66.00
22.7.85	123.00	115.00	29.50	26.50	28.00	64.50	63.50	66.50
1.8.85	128.33	125.33	31.00	27.00	29.00	66.00	64.00	65.00
8.8.85	146.66	153.00	31.50	28.50	30.00	70.50	64.50	67.50
15.8.85	163.33	141.00	31.00	27.00	29.00	71.00	67.00	69.00
22.8.85	186.00	161.66	31.50	28.50	30.00	70.00	68.00	69.00
1.9.85	146.66	128.33	29.50	26.50	28.00	72.50	66.50	69.50
8.9.85	90.00	70.00	28.50	25.50	27.00	73.00	63.00	90.00
15.9.85	96.33	82.33	29.50	26.50	28.00	71.50	67.50	69.50

Factors	Years observed	Correlation coefficient	't' test	Remark
1. Mite population in lobayense mushroom and temperature	2	0.38	1.94	Not significant
2. Mite population in volvacea mushroom and temperature	2	0.46	2.47	Not significant
3. Mite population in lobayense mushroom and relative humidity	2	0.87	8.40	Significant
4. Mite population in volvacea mushroom and relative humidity	2	0.99	34.68	Significant

Table 4.17.3: Influence of major abiotic factors on the population fluctuation of H.heinemanni in fruit body stage of mushroom.

Date of observation	No.of mite/10 gm of lobayense mushroom	No.of mite/10 gm of volvacea mushroom	Temperature(°C) Max.	Temperature(°C) Min.	Temperature(°C) Mean	Relative Humidity(%) Max.	Relative Humidity(%) Min.	Relative Humidity(%) Mean
12.7.84	196.33	180.66	32.00	30.00	31.00	88.00	84.00	86.00
20.7.84	230.00	210.00	32.00	28.00	30.00	89.00	87.00	88.00
26.7.84	240.00	200.00	29.00	27.00	28.00	87.50	86.50	87.00
5.8.84	230.00	180.00	31.00	27.00	29.00	88.00	84.00	86.00
12.8.84	100.00	120.00	31.00	29.00	30.00	82.00	78.00	80.00
20.8.84	96.66	87.66	30.00	28.00	29.00	77.00	73.00	75.00
26.8.84	140.00	120.00	32.00	28.00	30.00	78.00	74.00	76.00
5.9.84	128.33	110.00	33.00	29.00	31.00	72.00	68.00	70.00
12.9.84	133.33	121.66	34.00	28.00	31.00	72.00	70.00	71.00
20.9.84	140.00	100.00	32.00	28.00	30.00	74.00	70.00	72.00
26.9.84	100.00	130.00	30.00	26.00	28.00	69.00	67.00	68.00
5.10.84	130.00	121.00	32.00	28.00	30.00	74.00	70.00	72.00
12.10.84	72.66	53.33	31.00	29.00	30.00	73.00	67.00	70.00
12.7.85	170.00	130.00	30.00	28.00	29.00	69.00	65.00	67.00
20.7.85	120.00	130.00	30.00	26.00	28.00	68.00	66.00	67.00
26.7.85	100.00	120.00	30.00	27.00	28.50	68.00	64.00	66.00
5.8.85	120.00	126.66	30.00	27.00	28.50	67.00	63.00	65.00
12.8.85	122.66	143.33	32.00	28.00	30.00	68.00	64.00	66.00
20.8.85	146.00	120.00	31.00	27.00	29.00	72.00	68.00	70.00
26.8.85	170.00	150.00	31.50	28.50	30.00	72.00	70.00	71.00
5.9.85	100.00	112.00	27.00	25.00	26.00	70.00	66.00	68.00
12.9.85	123.33	125.33	29.50	26.50	28.00	70.00	68.00	69.00
20.9.85	136.00	115.00	29.50	26.50	28.00	71.50	67.50	69.50
26.9.85	60.00	34.33	27.50	23.50	27.50	73.00	67.00	70.00

Factors	Years observed	Correlation coefficient	't'test	Remarks
1.Mite population in lobayense mushroom and temperature	2	0.23	1.12	Not significant
2.Mite population in volvacea mushroom and temperature	2	0.16	0.78	Not signficant
3.Mite population in lobayense mushroom and relative humidity	2	0.72	4.93	Significant
4.Mite population in volvacea mushroom and relative humidity	2	0.62	3.77	Significant

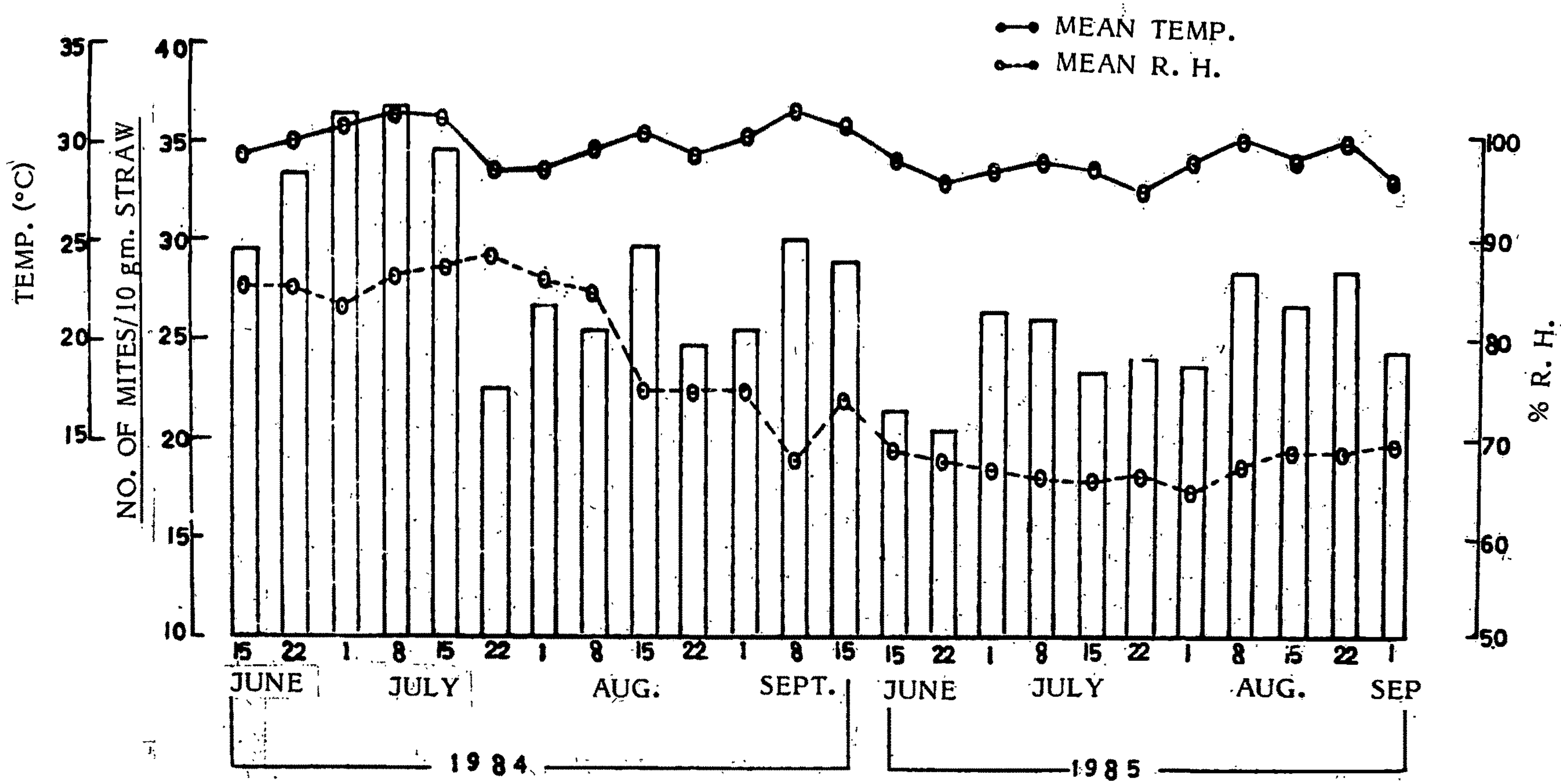


FIG. 4.18 SEASONAL OCCURRENCE OF H. heinemanni IN RELATION TO STRAW.

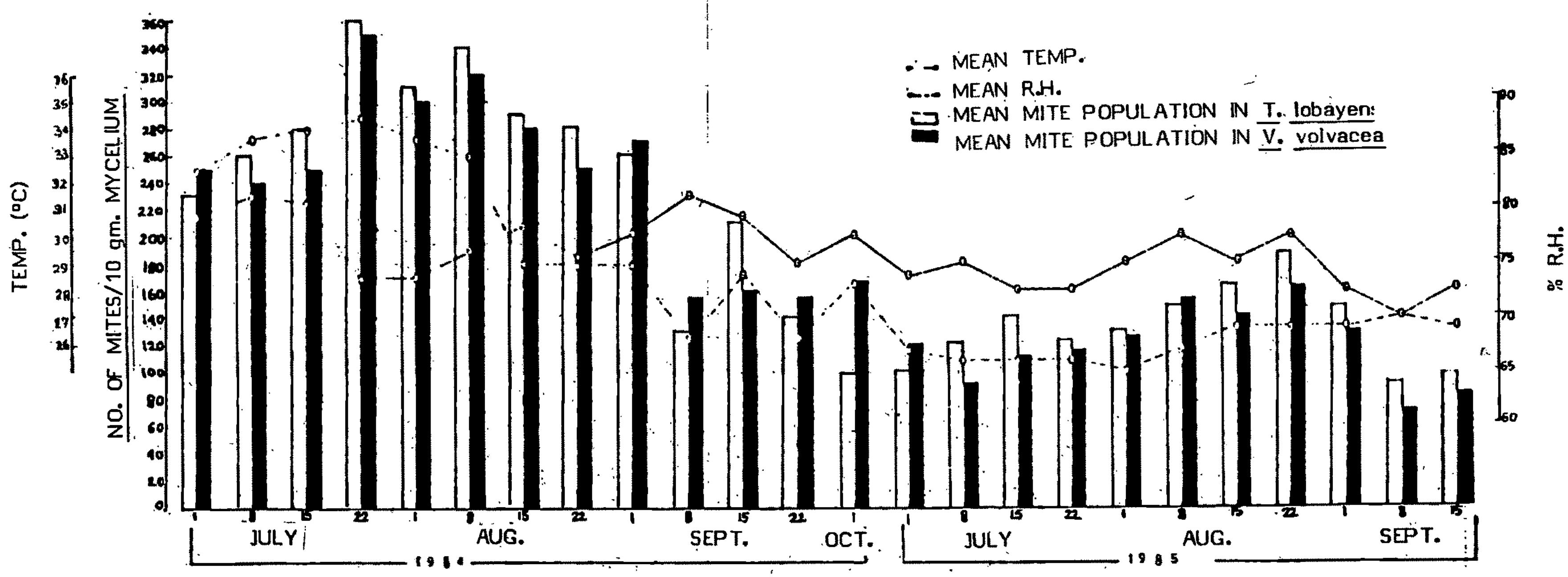


FIG. 4.19 SEASONAL OCCURRENCE OF *H. heinemanni* IN RELATION TO MYCELIAL STAGE OF MUSHROOM.

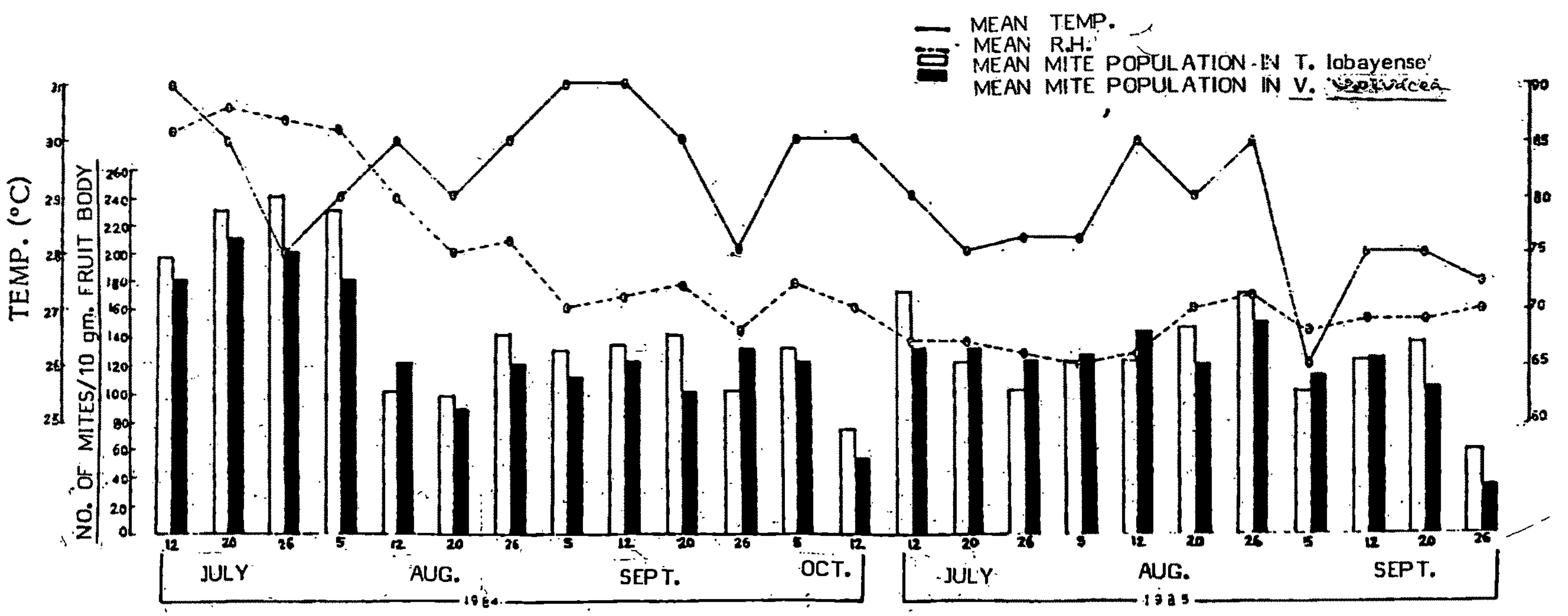


FIG. 4.20 SEASONAL OCCURRENCE OF *H. heinemanni* IN RELATION TO FRUIT BODY STAGE OF MUSHROOM.

was also on the higher side i.e. around 30°C. The minimum population of the mite was recorded during 22.7.84 to 8.8.84 as well as during 15.6.85 to 1.8.85 when the temperature was low. However, it is interesting to note that the population of mite recorded during mycelial stage of mushroom was not influenced by temperature as is evidenced from Table 4.17.2 and Fig.4.19. The maximum population of the mite was recorded during the year 1984 when the atmospheric relative humidity was very high i.e., around 85 %. But in the year 1985, the mite population was low due to the prevailing low relative humidity which was around 65%. The relationship recorded between the relative humidity and mite population on fruit body of mushroom was also of similar nature (Table 4.17.3 and Fig.4.20). The similar type of influence of relative humidity was also noticed on mite population observed during mycelial and fruit bodu stages as well as on two species of mushroom i.e. T.lobayense and V.volvacea.

The incidence of H.miles started from the month of October and ran for a very short period, i.e. till November after which it was no longer found on mushroom. Bot the abiotic factors exerted great influence on the mite population as is evidenced from Tables 4.18.1 - 4.18.3 and Fig.4.21-4.23. It is revealed from Table 4.18.1 and Fig.4.21 that the mite population in straw was greatly influenced by temperature and relative humidity as is evidenced from significant 't' values. In other words, it may be said that with the

Table 4.18.1: Influence of major abiotic factors on population fluctuation of *H.miles* in straw component.

Date of observation	No.of mite/10 gm straw	Temperature(°C)			Relative Humidity (%)		
		Max.	Min.	Mean	Max.	Min.	Mean
1.10.84	21.66	31.00	29.00	30.00	75.00	71.00	73.00
8.10.84	23.33	31.00	29.50	30.25	75.00	71.00	73.00
15.10.84	18.66	30.25	26.50	28.37	73.00	69.00	73.00
22.10.84	17.33	29.50	26.50	28.00	70.00	64.00	67.00
1.11.84	14.33	28.00	25.00	26.50	59.00	55.00	57.00
15.9.85	11.66	28.00	25.00	28.50	68.00	64.00	66.00
22.9.85	16.00	30.00	27.00	28.50	69.00	65.00	67.00
1.10.85	20.33	31.00	28.00	29.50	69.00	65.00	67.00
8.10.85	14.66	30.00	27.00	28.50	69.00	65.00	67.00
15.10.85	18.00	31.00	27.50	29.00	68.50	62.50	65.50
22.10.85	12.33	29.50	26.50	28.00	60.00	56.00	58.00
1.11.85	10.00	28.50	25.50	27.00	58.00	52.00	55.00

Factors	Years observed	Correlation coefficient	't'test	Remark
1. Mite population and temperature	2	0.91	7.11	Significant
2. Mite population and relative humidity	2	0.81	4.47	Significant

Table 4.18.2 : Influence of major abiotic factors on the population fluctuation of H.miles in mycelial stage of mushroom

Date of observation	No.of mite/10 gm of		Temperature(°C)			Relative Humidity(%)		
	lobayense mushroom	volvacea mushroom	Max.	Min.	Mean	Max.	Min.	Mean
15.10.84	138.00	140.00	30.00	26.75	28.37	73.00	69.00	71.00
22.10.84	90.00	100.00	29.50	26.50	28.00	68.00	66.00	67.00
1.11.84	60.00	83.00	28.00	25.00	26.50	59.00	55.00	57.00
8.11.84	91.33	92.00	28.00	25.00	26.50	68.00	64.00	66.00
15.11.84	112.33	103.33	30.00	27.00	28.50	69.00	65.00	67.00
1.10.85	96.00	118.00	31.00	28.00	29.50	68.00	66.00	67.00
8.10.85	110.00	128.33	29.50	26.50	28.00	68.00	66.00	67.00
15.10.85	120.00	110.00	31.00	27.00	29.00	67.50	63.50	65.50
22.10.85	60.00	65.33	29.50	26.50	28.00	60.00	56.00	58.00
1.11.85	53.33	58.33	28.50	25.50	27.00	56.00	54.00	55.00
8.11.85	76.66	71.33	27.50	24.50	26.00	62.00	58.00	60.00
15.11.85	46.66	57.00	27.50	24.50	26.00	56.00	52.00	54.00

Factors	Years observed	Correlation coefficient	't'test	Remarks
1.Mite population in lobayense mushroom and temperature	2	0.67	2.87	Not significant
2.Mite population in volvacea mushroom and temperature	2	0.68	2.93	Not significant
3.Mite population in lobayense mushroom and relative humidity	2	0.94	8.85	Significant
4.Mite population in volvacea mushroom and relative humidity	2	0.93	8.34	Significant

Table 4.18.3: Influence of major abiotic factors on population fluctuation of H.miles in fruit body stage of mushroom

Date of observation	No.of mite/10 gm of		Temperature (°c)			Relative Humidity(%)		
	lobayense mushroom	volvacea mushroom	Max.	Min.	Mean	Max.	Min.	Mean
26.10.84	54.00	50.00	27.00	25.00	26.00	70.00	66.00	68.00
5.11.84	40.00	46.66	28.00	25.00	26.50	62.00	58.00	60.00
12.11.84	52.00	61.00	29.00	26.00	27.50	70.00	64.00	67.00
20.11.84	59.00	66.00	31.00	27.00	29.00	70.00	62.00	66.00
26.11.84	53.33	50.00	28.00	25.00	26.50	70.00	66.00	68.00
12.10.85	40.00	45.00	27.50	24.50	26.00	67.00	63.00	65.00
20.10.85	55.00	64.00	29.50	26.50	28.00	62.00	60.00	61.00
26.10.85	45.00	42.00	29.50	26.50	28.00	60.00	56.00	58.00
5.11.85	16.00	18.00	28.00	25.00	26.50	57.50	53.50	55.50
12.11.85	36.66	39.33	28.50	25.50	27.00	62.00	58.00	60.00
20.11.85	11.33	14.00	27.50	24.50	26.00	57.00	55.00	56.00
26.11.85	18.00	15.00	27.50	24.50	26.00	60.00	56.00	58.00

Factors	Years observed	Correlation coefficient	't'test	Remarks
1.Mite population in lobayense mushroom and temperature	2	0.58	2.26	Nonsignificant
2.Mite population in volvacea mushroom and temperature	2	0.65	2.74	Nonsignificant
3.Mite population in lobayense mushroom and relative humidity	2	0.80	4.28	Significant
4.Mite population in volvacea mushroom and erelative humidity	2	0.74	3.55	Significant

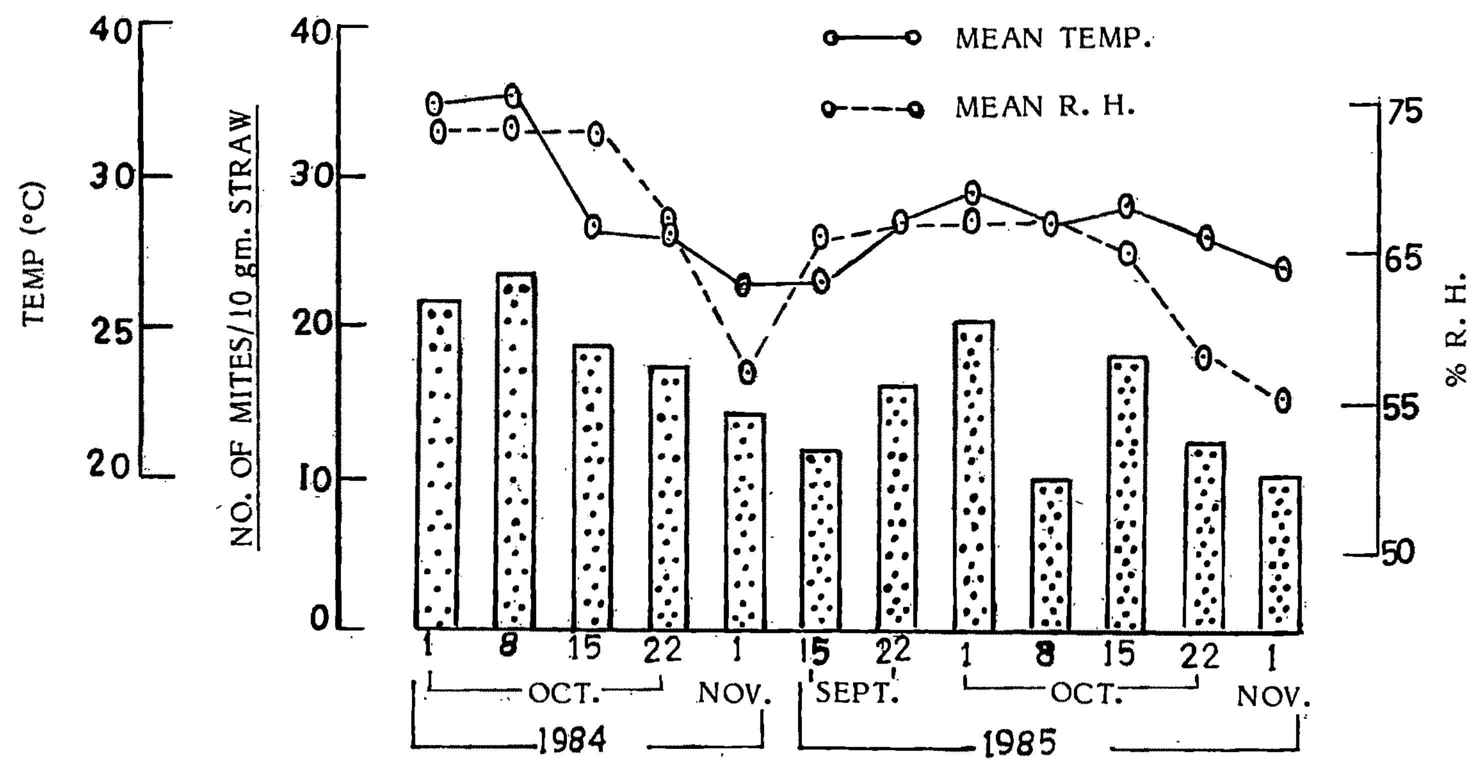


FIG. 4.21 SEASONAL OCCURRENCE OF *H. miles* IN RELATION TO STRAW.

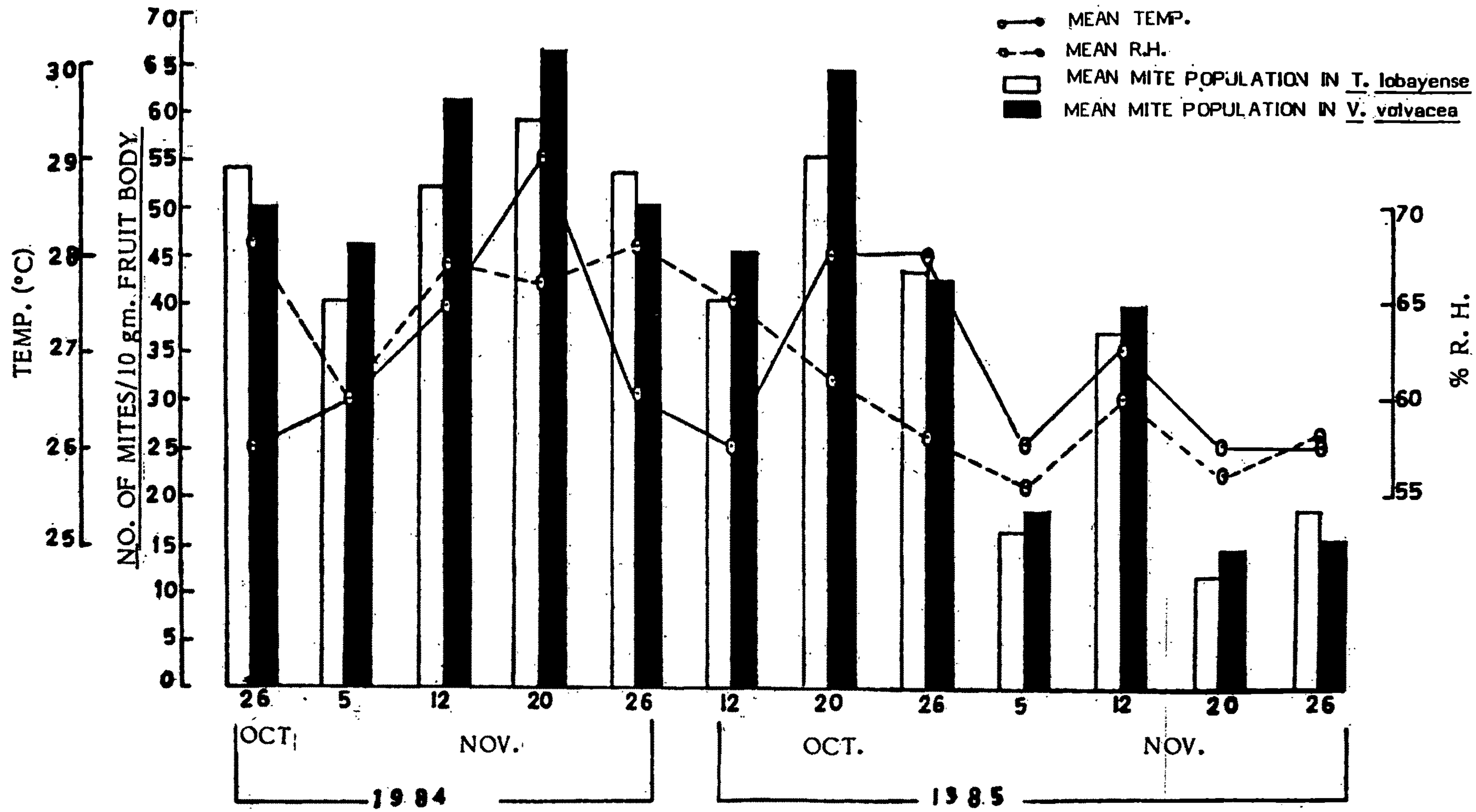


FIG. 4.23 SEASONAL OCCURRENCE OF *H. miles* IN RELATION TO FRUIT BODY STAGE OF MUSHROOM.

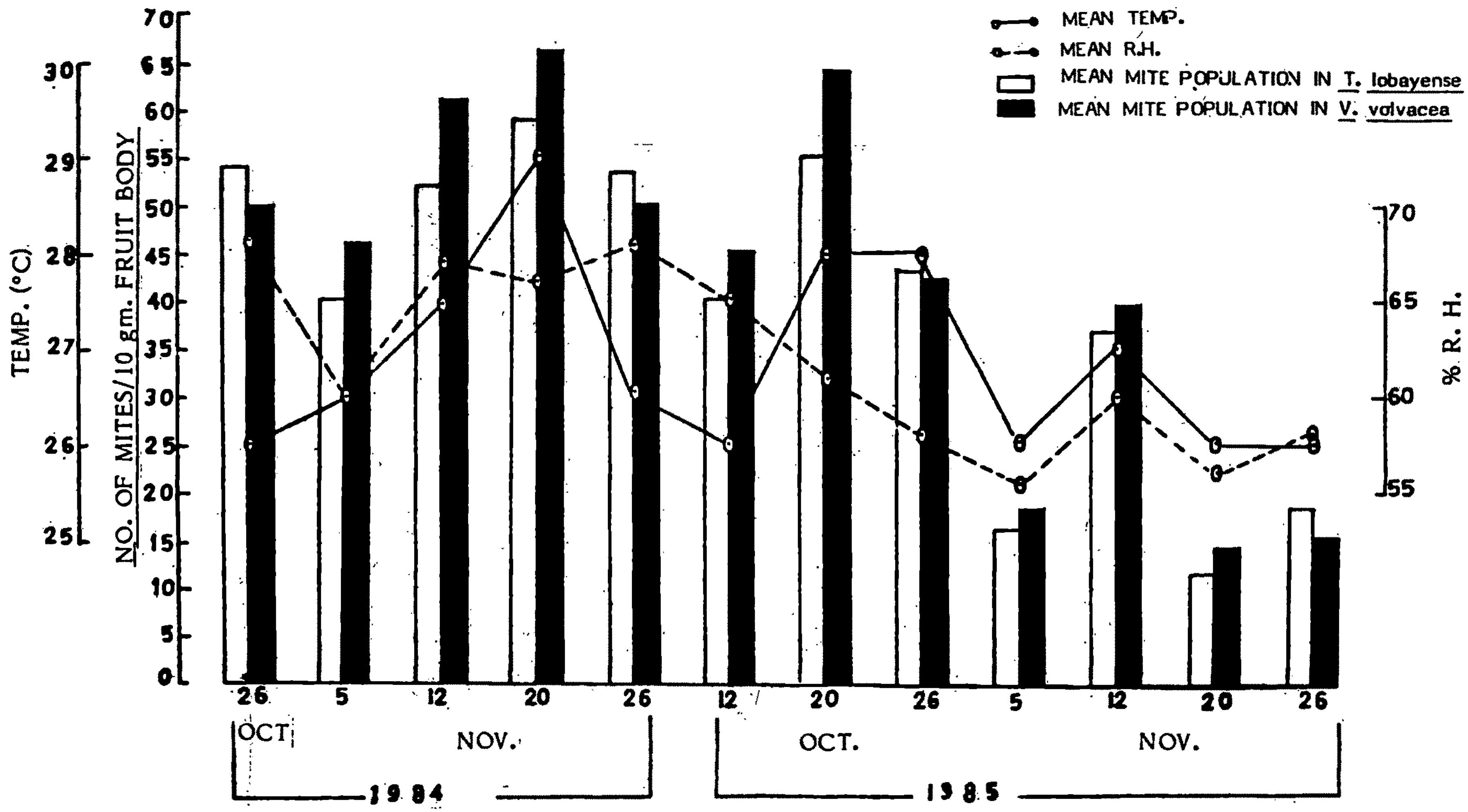


FIG. 4.23 SEASONAL OCCURRENCE OF *H. miles* IN RELATION TO FRUIT BODY STAGE OF MUSHROOM.

increase in temperature and relative humidity the mite population also increased. But it does not hold good when the population of mite found in mycelial stage of mushroom was taken into consideration. Under this situation, only atmospheric relative humidity had a direct influence on mite population (Table 4.18.2 and Fig.4.22). The maximum population of mite was recorded when the atmospheric relative humidity reached around 70 % and it adversely affected the mite population when it went below 60 %. Similar relationship between relative humidity and mite population was recorded on fruit-body stage of mushroom (Table 4.18.3 and Fig.4.23) and the pattern followed in the two species of mushroom i.e. T.lobayense and V.volvacea was also similar.

The seasonal incidence of mushroom mites is the least studied aspect in mushroom science. The investigations undertaken on mushroom mites are mostly restricted to their taxonomic distribution, biology and control. During the present investigation, it was observed with great interest that the four species of mite varied widely in their response to various seasons of a year. The first named species i.e. R.echinopus is prevalent during January to March. It is probably due to its preference for a mild climatic condition prevalent during these months. The species exhibited a definite positive dependence on temperature indicating that the rise in temperature would bring about an increase in mite population. However, it was unable to withstand high temperature beyond 35°C which prevailed during subsequent months. The mite population would not be affected with the increase or decrease in relative humidity as is evidenced from non-significant 'r' and 't' values. With the onset of summer months after March, the disappearance of R.echinopus with subsequent appearance of another species of mushroom mite, T.dimidiatus was noticed. The species was prevalent on mushroom from April to June when high temperature prevailed with a mean value around 33°C. But it is very much surprising to note that the species did not show any relationship with temperature though the variation in temperature was considerable during these three months. It ranged from 29°C - 35°C However, the species showed a positive correlation with atmospheric relative humidity which varied from 56 % to 89 % depending upon the years. The positive nature of correlation between relative humidity and the mite indicated that the mite prefers higher humidity for its multiplication.

After the disappearance of T.dimidiatus from the month of June, H.heinemanni appeared in the scene being the third species in a row. This mite prevailed on mushroom till October after which it was a no longer found till the same season rolls back in next year. The mite species exhibited a definite relation with both the major abiotic factors i.e. relative humidity and temperature when its population fluctuation in straw component of mushroom bed alone was considered. It may be explained in the light that it increased with the increase in temperature and relative humidity upto a certain limit. It may be seen from Fig.4.18 that the mite species prefered a temperature and relative humidity around 30°C and 90 %, respectively. However, the seasonal incidence of mite was more affected due to the variation of relative humidity than temperature (Fig.4.19 and 4.20). The non-significant 'r' and 't' values in the case of temperature vis-a-vis mite population during the mycelial and fruit body stages of mushroom indicate that temperature is not that important as relative humidity. It may be due to the fact that the variations observed in temperature during these months (June-October) was too negligible while relative humidity varied from 66 % to 88 % exhibiting a wide fluctuation. It may be concluded in saying that the species has a definite preference for higher relative humidity and therefore it was found only during rainy season when the atmospheric relative humidity remains always towards higher side.

From the month of October, the incidence of the fourth species of mite, H.miles was observed but its presence was noticed for a very shott period i.e., hardly for one and half month. The mite showed similar relationship with the major abiotic factors as was noticed in the case of H.heinemanni. The population of the mite increased with the increase in temperature and relative humidity while they were found in straw. But it followed different pattern under mycelial and fruit body stages of mushroom. Under these conditions, the population growth of the mite was dependent on the variation of relative humidity alone. No relationship was recorded between the population fluctuation of the mite and the atmospheric temperature. This species was found during post monsoon period when a moderate level of relative humidity (65 %) prevailed under indoor condition along with a more or less constant mean temperature (28°C) which did not vary widely during this period. It may be possible that the species was unable to multiply during rainy season probably due to its non preference towards very high relative humidity and temperature.

4.8 Natural enemy of mushroom mites

Attempts were made during the present investigation to explore the natural enemy complex, if any, of mushroom mites. But the total absence of parasites and predators belonging to any group of animals was noticed. As such the four mushroom mites appears to be devoid of natural enemy complex till to-date. Similarly, no such published literatures is available from any part of the world.

4.9 Control of mushroom mites

4.9.1 Prophylactic control of mushroom mites

Among various preventive measures developed against pests, sterilization/heat treatment is considered as an important tool. Therefore, the following experiment was laid out. The effect of sterilization of straw component of mushroom bed and its subsequent utilization in mushroom cultivation vis-a-vis rate of infestation of mushroom mites during different growth stages of mushroom (mycelial and fruit body) has been presented in Table 4.19. It is seen from Table 4.19 that straw carries all the four species of mushroom mite in it. The mite populations varied between 19.00-38.33/10 gm of straw. But after sterilization not a single mite of any of the four species was survived. As a result, the subsequent utilisation of sterilized straw did not invite any mite infestation on mushroom bed. On the other hand, the utilisation of unsterilized straw in compost bed brought about severe mite infestation.

The effect of heat treatment on the four mushroom mites have been presented in Tables 4.20 and 4.20.1 and Fig.4.24. It is revealed from Table 4.20 that significant variation was recorded in the rate of mortality among four mushroom mites while they were exposed to each of the ten constant temperatures varied between 50.0°-72.5°C under three levels of exposure periods (15, 30, 45 min.). The effect of interaction between temperature and mite indicated that H.miles was the most heat tolerant species followed by H.heinemanni, T.dimidiatus and R.echinopus. The 50 % of the mite population of all the four species died at 62.5° ± 1°C. Therefore, it may be considered as a LD 50 dosage for them. The LD 100 dosage of temperature was located around 67.5°C for R.echinopus and T.dimidiatus while it was 70°C and 72.5°C for H.heinemanni and H.miles respectively. The response of four species of mite to temperature varied

Table 4.19: Effect of sterilization of straw component of mushroom bed on mite population (mean of three replications).

Mushroom mites	No.of mites/10 gm of					
	Straw		Compost		Fruit body	
	Unsterilized	Sterilized	Unsterilized	Sterilized	Unsterilized	Sterilized
R.echinopus	20.33	0.00	160.00	0.00	38.00	0.00
T.dimidiatus	38.33	0.00	175.00	0.00	100.33	0.00
H.heinemanni	33.33	0.00	413.00	0.00	240.00	0.00
H.miles	19.00	0.00	125.00	0.00	49.66	0.00

Table 4.20: Effect of heat treatments on per cent mortality of four spp. of mushrooms mites (mean of three replications)

Temperature (°C)	Period of exposure (min.)	% corrected mortality in			
		R. echinopus	*T. dimidiatus*	*H. heinemanni*	*H. miles*
	15	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
50±1	30	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
	45	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
	15	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
52.5±1	30	76.66 (61.21)	0 (0.00)	0 (0.00)	0 (0.00)
	45	100 (88.19)	100 (88.19)	0 (0.00)	0 (0.00)
	15	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
55±1	30	96.66 (82.65)	0 (0.00)	0 (0.00)	0 (0.00)
	45	100 (88.19)	100 (88.19)	100 (88.19)	0 (0.00)
	15	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
57.5±1	30	100 (88.19)	0 (0.00)	0 (0.00)	0 (0.00)
	45	100 (88.19)	100 (88.19)	100 (88.19)	100 (88.19)
	15	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
60 ± 1	30	100 (88.19)	0 (0.00)	100 (88.19)	60 (51.14)
	45	100 (88.19)	100 (88.19)	100 (88.19)	100 (88.19)

(Contd. ...)

Table 4.20 (Contd.)

Temperature (°C)	Period of exposure (min.)	% correlated mortality in			
		R.echinopus	T.dimidiatus	H.heinemanni	H.miles
62.5 ± 1	15	0.00 (0.00)	36.66 37.14)	0.00 (0.00)	0.00 (0.00)
	30	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	45	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
65 ± 1	15	83.33 (66.14)	73.33 (59.00)	0.00 (0.00)	0.00 (0.00)
	30	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	45	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
67.5 ± 1	15	100.00 (88.19)	100.00 (88.19)	80.00 (63.43)	43.33 (41.15)
	30	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	45	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
70 ± 1	15	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	70.00 (56.99)
	30	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	45	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
72.5 ± 1	15	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	30	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	45	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)

	Mites	Temperatures	Exposure periods
C.D. (p=0.05)	4.17	6.60	3.61
C.D. (p=0.01)	5.49	8.68	4.75

'F' test - Significant.
S.Em (±) - 0.75

Figures in parenthesis indicate angular transformed values.

Table 4.20.1 : Effect of interactions of various treatments(mite, temperature, exposure period) on percent mortality of four species of mushroom mites.

Mites	Temperatures (°C)										Exposure period (min)		
	50+1	52.5+1	55+1	57.5+1	60 +1	62.5+1	65+1	67.5+1	70+1	72.5+1	15	30	45
R.echinopus	0 (0.00)	58.88 *(49.80)	65.55 (56.95)	66.66 (58.79)	66.66 (58.79)	66.66 (58.79)	94.44 (80.84)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	38.33 (33.07)	87.33 (76.11)	90.00 (79.37)
T.dimidiatus	0 (0.00)	33.33 (29.39)	33.33 (29.39)	33.33 (29.39)	33.33 (29.39)	78.88 (71.17)	91.11 (78.46)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	40.99 (36.07)	50.00 (40.09)	90.00 (79.37)
H.heinemanni	0 (0.00)	0 (0.00)	33.33 (29.39)	33.33 (29.39)	66.66 (58.79)	66.66 (58.79)	66.66 (58.79)	93.33 (79.93)	100.00 (88.19)	100.00 (88.19)	28.00 (23.98)	60.00 (52.91)	80.00 (70.55)
H.miles	0 (0.00)	0 (0.00)	0 (0.00)	33.33 (29.39)	53.33 (46.44)	66.66 (58.79)	66.66 (58.79)	81.11 (72.51)	90.00 (77.79)	100.00 (88.19)	21.33 (18.63)	56.00 (49.20)	70.00 (61.73)
Exposure period(min.)													
15	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	9.16 (9.28)	39.16 (31.28)	80.83 (70.24)	92.50 (80.39)	100.00 (88.19)			
30	0 (0.00)	19.16 (15.30)	24.16 (20.66)	25.00 (22.04)	65.00 (56.88)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)			
45	0 (0.00)	50.00 (44.09)	75.00 (66.14)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)			

	Mite x Temperature	Mite x Exposure period	Exposure period x temperature
'F' test -	Significant	Significant	Significant
C.D.(p=0.05) -	13.21	7.23	11.44
C.D.(p=0.01) -	17.36	9.51	15.04

* Figures in parenthesis indicate angular transformed values.

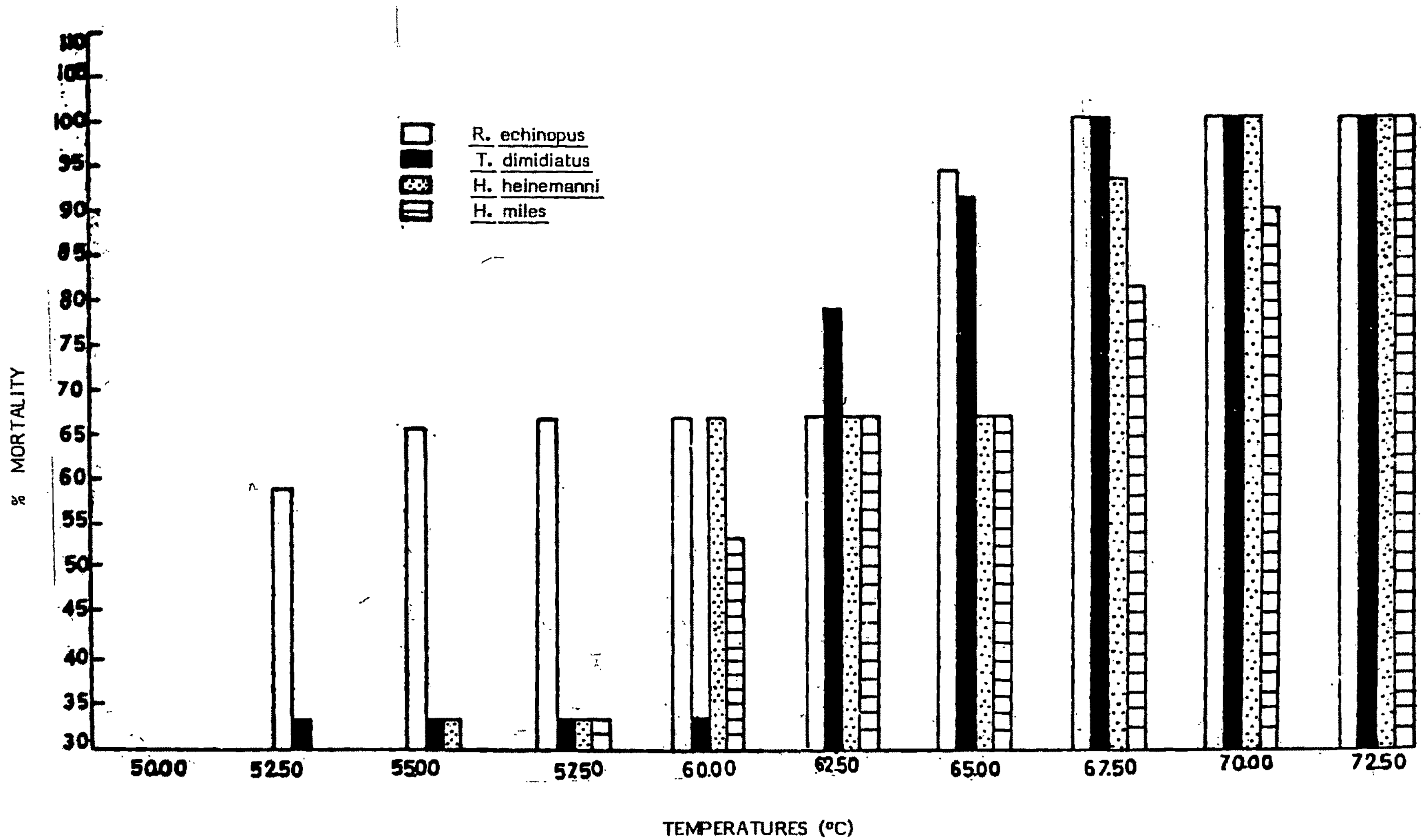


Fig. 4.24 EFFECT OF LETHAL TEMPERATURES ON FOUR MUSHROOM MITES

significantly at lower temperature but these were non-significant at higher temperature ranges.

It is revealed from Table 4.20.1 representing the effect of interaction between exposure time and mite that there was significant variation among four species of mite while their mortality responses were considered under three levels of exposure period. It was observed that H.miles required maximum exposure period for killing followed by H.heinemanni. The responses of the other two species were also same. The effect of interaction between temperature and exposure period on mortality responses of mite have been presented in Table 4.20.1. Significant variation was observed in mortality recorded under various levels of temperature and exposure period combination. In other words, , the pattern of mortality observed under various combinations of temperature and exposure period was different. At an exposure of 15 minutes, no mortality of mites was observed even at a temperature of 60° ± 1°C while under 30 minutes exposure period, nearly 65.00 % mortality was recorded. At the same temperature, the rate of mortality of mites reached as high as 100.00 % under 45 minutes exposure period. It may be mentioned that the difference observed among the rate of mortality under various temperature and exposure period combinations upto 60°C was statistically significant. The differences gradually neutralised at the extreme of temperature.i.e. at 72.5°c. But the differences observed between 15 and 30 minutes exposure period were always statistically significant while those recorded between 30 and 45 minutes exposure periods were mostly non-significant at least above 62.5°C.

This physical method of pest control (heat treatment) may be employed with great success in those situations where the scope for chemical control is restricted. The method appears to be highly promising in the control of mushroom mites. This is because of the fact that mushrooms are grown under indoor condition where decomposition of pesticides would be slow. Moreover, mushroom mites are devoid of natural enemy complex and therefore the scope of natural control is limited to a great extent. The probarb goes in Western countries " Little can be recommended for the control of mushroom mites once they have established in a mushroom house". Therefore, the major thrust in the control of mushroom mites should be based on preventive measures. The control of mites by heat treatment may be of immense help particularly after the discovery of straw as a carrier of mushroom mites. It is revealed from Table 4.19 that when the sterilized straw was utilised no mite infestation was recorded at any stage of mushroom growth. On the contrary, the utilisation of unsterilized straw in mushroom bed brought about severe infestation of all the four mites. Various methods of sterilization are being used since long to control various pest species. But such informations are lacking on mushroom mites. However, Gahm (1930) reported that Tyroglyphus lintneri and Linopodes antenapes can be controlled by surface steaming of compost before its utilization in bed preparation.

Similarly, the treatment of compost at high temperature (130°F) has been advocated as a preventive measure against mushroom mites. During the present investigation, attempts were made to work out the lethal temperatures for four species of mite. It was interesting to note that the response of four mushroom mites was different under various sets of temperature and relative humidity conditions. In general, H.miles was the most tolerant species followed by H.heinemanni, T.dimidiatus and R.echinopus. It further appears from the present investigation that the LD 50 temperature for all the four species was around 60° ± 1°C to 62.5° ± 1°C and a temperature around 70° ± 1°C to 72.5° ± 1°C would provide 100 % mortality (LD 100) of all the four species of mite. Hussey and Gurney (1967) reported that the exposure of mushroom mites at 39°C for 24 hours was extremely lethal. They further said that commercial cooking aimed to maintain temperature 67°-71°C for several hours was completely reliable against Tarsonemus myceliophagus. The objective of the present investigation was to utilise higher temperature range for a shorter period rather than heat treatment of straw at low range temperature for long period as has been done by Hussey and Gurney(1967). High temperatures with short duration (72.5°C for 15 minutes) was highly satisfactory against all the four species of mite. On the other hand, at 30 minutes exposure period total destruction of mite species was obtained at 62.5°C. With the further increase in exposure period to 45 minutes, the intensity of temperature would come down to 57.5°C which would also provide total destruction of mites.

4.9.2 Directed control of mushroom mites

4.9.2.1 Chemical control

The results of bioefficacy of four pesticides on mushroom mites have been presented in Tables 4.21 and 4.21.1 and Fig.4.25. It is seen from Tables that significant difference in mortality was recorded among four species of mite when treated with pesticides in different concentrations. It is revealed from the significant interaction between mite and pesticides that the four mites reacted differently to pesticides. The maximum mortality of R.echinopus was recorded in dichlorvos treated pots (83.85 %) followed by malathion (77.18 %), ethion (72.39 %) and dicofol (66. 66 %) treated pots. The differences observed in between four pesticides in the case of R.echinopus were always statistically significant. In the case of T.dimidiatus the maximum mortality was recorded in dichlorvos (85.31 %) followed by malathion (74.47 %) dicofol (70.52 %) and ethion (67.70 %) treated pots. The difference in mortality recorded in between two pesticides except in between dicofol and ethion treated pots were statistically significant. The maximum mortality of H.heinemanni was also recorded in dichlorvos treated pots (76.45 %) followed by malathion (68.43 %), dicofol(66.66%) and ethion(63.22 %) and the differences observed in between four pesticides were statistically significant except in between malathion and dicofol. Again, the maximum mortality of H.miles was recorded in dichlorvos treated pots (66.35 %) followed by ethion (56.79 %), dicofol(53.22%) and malathion (35.93 %). The differences observed in between four pesticides were statistically significant at all levels.

Table 4.21: Effectiveness of various pesticidal applications on females of four species of mushroom mites (mean of three replications).

Pesticides	Concentration (% a.i.)	Mites	Corrected per cent mortality at different days after application of pesticide							
			0.5	1	2	3	4	5	6	7
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
DICHLORVOS	0.005	*R.echinopus*	13.33 (17.21)	23.33 (28.78)	70.00 (57.28)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	3.33 (6.14)	33.33 (35.01)	66.66 (54.99)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	3.33 (6.14)	56.66 (48.84)	100.00 (88.10)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	16.66 (23.85)	56.66 (48.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	0.01	*R.echinopus*	23.33 (28.28)	30.00 (32.29)	80.00 (63.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	23.33 (28.78)	40.00 (39.06)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	13.33 (21.14)	66.66 (54.99)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	3.33 (6.14)	33.33 (35.21)	76.66 (61.92)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)

(Contd....)

Table 4.21 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
DICHLORVOS	0.02	<u>R.echinopus</u>	40.00 (38.85)	70.00 (56.99)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>T.dimidiatus</u>	40.00 (38.85)	63.33 (53.06)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.heinemanni</u>	13.33 (17.71)	30.00 (33.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.miles</u>	0.00 (0.00)	10.00 (18.43)	53.33 (46.92)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	0.04	<u>R.echinopus</u>	60.00 (50.93)	73.33 (59.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>T.dimidiatus</u>	73.33 (59.00)	86.66 (71.68)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.heinemanni</u>	26.66 (30.29)	36.66 (36.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.miles</u>	0.00 (0.00)	10.00 (18.43)	73.33 (59.21)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
MALATHION	0.005	<u>R.echinopus</u>	0.00 (0.00)	16.66 (23.85)	43.33 (40.78)	73.33 (59.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>T.dimidiatus</u>	0.00 (0.00)	0.00 (0.00)	46.66 (43.07)	90.00 (74.39)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.heinemanni</u>	0.00 (0.00)	0.00 (0.00)	36.66 (37.14)	76.66 (61.21)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.miles</u>	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	10.00 (15.00)	16.66 (23.85)	33.33 (35.01)	66.66 (54.78)	100.00 (88.19)

(Contd....)

Table 4.21 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
MALATHION	0.01	*R.echinopus*	0.00 (0.00)	50.00 (45.00)	86.66 (71.68)	93.33 (77.11)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	36.66 (36.93)	70.00 (56.79)	93.33 (79.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	50.00 (45.08)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	10.00 (15.00)	13.33 (21.14)	23.33 (28.78)	36.66 (37.14)	73.33 (59.00)	100.00 (88.19)
	0.02	*R.echinopus*	0.00 (0.00)	53.33 (46.92)	90.00 (74.39)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	40.00 (39.14)	76.66 (61.92)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	60.00 (50.85)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	20.00 (26.57)	20.00 (26.57)	36.66 (37.22)	40.00 (39.23)	100.00 (88.19)	100.00 (88.19)
	0.04	*R.echinopus*	0.00 (0.00)	70.00 (56.79)	93.33 (77.11)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	46.66 (42.99)	83.33 (66.14)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	66.66 (54.78)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	23.33 (28.78)	23.33 (28.78)	43.33 (41.15)	60.00 (50.93)	100.00 (88.19)	100.00 (88.19)

(Contd...)

Table 4.21 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
ETHION	0.005	R.echinopus	0.00 (0.00)	3.33 (6.14)	40.00 (39.14)	80.00 (67.25)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	23.33 (28.07)	56.66 (48.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	10.00 (15.00)	53.33 (47.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	3.33 (6.14)	36.66 (37.14)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	0.01	R.echinopus	0.00 (0.00)	20.00 (26.07)	70.00 (56.99)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	40.00 (39.14)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	10.00 (15.00)	66.66 (55.07)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	20.00 (26.07)	53.33 (47.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	0.02	R.echinopus	0.00 (0.00)	23.33 (28.78)	73.33 (59.71)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	6.66 (12.28)	50.00 (50.71)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	6.66 (8.85)	33.33 (35.21)	80.00 (63.43)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	26.66 (30.99)	66.66 (55.07)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)

(Contd...)

Table 4.21 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
ETHION	0.04	<u>R.echinopus</u>	0.00 (0.00)	30.00 (33.00)	76.66 (61.71)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>T.dimidiatus</u>	0.00 (0.00)	13.33 (21.14)	66.66 (55.07)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.heinemanni</u>	0.00 (0.00)	6.66 (8.85)	56.66 (48.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.miles</u>	0.00 (0.00)	0.00 (0.00)	30.00 (33.00)	76.66 (61.92)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
DICOFOL	0.005	<u>R.echinopus</u>	0.00 (0.00)	0.00 (0.00)	30.00 (33.00)	66.66 (54.99)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>T.dimidiatus</u>	0.00 (0.00)	0.00 (0.00)	26.66 (30.29)	83.33 (66.64)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.heinemanni</u>	0.00 (0.00)	0.00 (0.00)	23.33 (28.78)	56.66 (48.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.miles</u>	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	13.33 (21.14)	60.00 (50.85)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	0.01	<u>R.echinopus</u>	0.00 (0.00)	0.00 (0.00)	40.00 (39.06)	80.00 (63.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>T.dimidiatus</u>	0.00 (0.00)	0.00 (0.00)	60.00 (50.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.heinemanni</u>	0.00 (0.00)	0.00 (0.00)	46.66 (43.07)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.miles</u>	0.00 (0.00)	0.00 (0.00)	6.66 (12.28)	26.66 (30.99)	83.33 (66.14)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)

(Contd....)

Table 4.21 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
		R.echinopus	0.00 (0.00)	0.00 (0.00)	56.66 (48.93)	90.00 (74.39)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	0.02	*T.dimidiatus*	0.00 (0.00)	3.33 (6.14)	66.66 (54.78)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	46.66 (43.07)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	6.66 (8.85)	33.33 (34.92)	90.00 (74.39)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		R.echinopus	0.00 (0.00)	6.66 (12.28)	63.33 (52.86)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	0.04	*T.dimidiatus*	0.00 (0.00)	16.66 (23.85)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	3.33 (6.14)	56.66 (48.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	23.33 (28.78)	60.00 (51.14)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)

	Mites	Pesticides	Concentrations	Days
C.D.(p=0.05)	1.20	1.20	1.20	1.70
C.D.(p=0.01)	1.58	1.58	1.58	2.23

'F' test - Significant
S.Em (±) - 0.21

Figures in parentheses indicate angular transformed values.

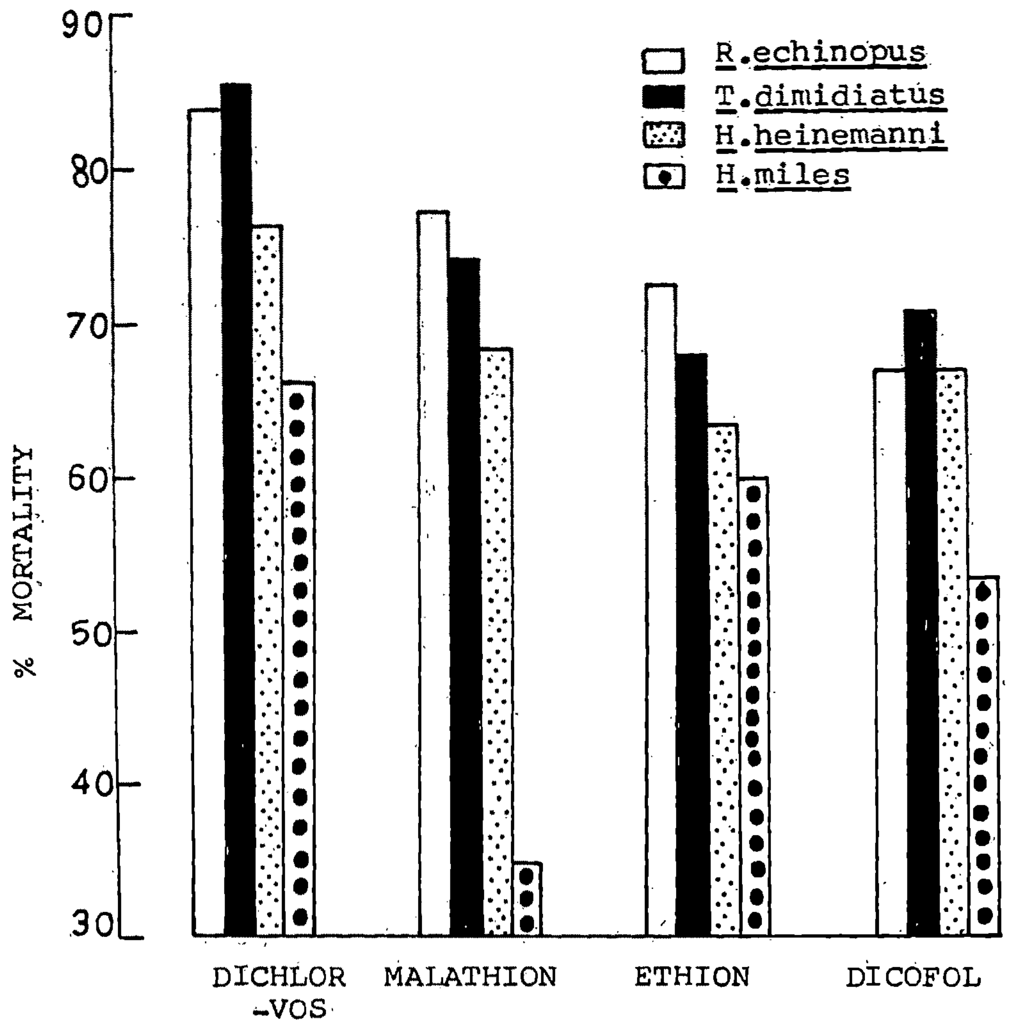


Fig.4.25 RATE OF MORTALITY OF FOUR MUSHROOM MITES AT VARIOUS PESTICIDAL TREATMENTS.

The effect of interaction between concentration and mite was statistically non-significant. It indicates that all the four species of mite responded similarly to four different concentrations of pesticide. The highest concentration i.e. 0.04 % provided the maximum mortality followed by 0.02 and 0.01 % and the minimum mortality was obviously recorded at the lowest concentration i.e. 0.005 %.

The effect of interaction between mite and day was statistically significant. In other wards, the pattern of mortality followed in four species of mite during different days of observation was not similar. While the initial mortality of three mites was recorded just after 12 hours, it was recorded after one day of treatment in the case of H.miles. The corresponding mortality figures for other three species during the same period (one day) were 29.37 24.16 and 6.24 % in R.echinopus, T.dimidiatus and H.heinemanni, respectively. The total mortality of R.echinopus, T.dimidiatus and H.heinemanni were obtained after four days of treatment while it took seven days in H.miles and the differences in mortality recorded in between various days after observation were statistically significant in all the four species of mite.

The effect of interaction between concentration and pesticide on mite mortality was significant. Nearly 85.62 % mortality was recorded in 0.04 % dichlorvos treated pots, while these were 70.51, 69.68, and 69.06 % in ethion, dicofol, and malathion treated pots, respectively. The rate of mortality provided by 0.005 % concentration were 70.10, 56.56 and 59.58 and 58.12 % in dichlorvos, malathion, ethion and dicofol treated pots, respectively. The differences in mortality observed among four pesticides except dichlorvos under various concentrations were statistically non-significant.

The effect of interaction between concentration and day representing rate of mortality of mites have been presented in Table 4.21.1. The significant interaction indicates that the mortality of mite found at different concentrations during different days of observation did not follow the same pattern. It may be seen that total mortality (100 %) was obtained after 7 days at 0.005 % and 0.01 % concentrations while similar mortality rate was recorded after 6 days in other two concentrations, namely, 0.02 % and 0.04 %. The differences in mortality recorded in between 1 to 3 days in different concentrations were mostly significant while the differences in mortality observed in between 4-7 days under different concentrations were mostly non-significant.

Similarly, the effect of interaction between pesticide and day on the mortality of mite was significant. Therefore, different patterns in mortality of mites were recorded during different days of observations in four different pesticide treated pots. Total mortality of mites recorded after four days in dichlorvos and ethion treated pots while it took five days and seven days in the dicofol and malathion treated pots, respectively. An initial mortality to the tune of 19.79 % was recorded after 0.50 hours only in case of dichlorvos treated pots. The differences in mortality recorded in between different days among four pesticide treated pots were mostly significant till it reached 100 % after four days.

The chemical control of mite has thrown a great challenge to applied entomologists because of the fact that response of mite species to various pesticides vary widely. Therefore, selectivity of pesticides is of great importance in the control of acarines. This characteristic feature in acarines is attributed to the physiological ability to react against various acaricides. It has been mentioned in various instances that while one group of pesticides is effective against a group of acarines it is not effective against other group. In general, organophosphorus compounds are not so much effective against tenuipalpid mites while these are highly toxic to tetranychid and eriophyoid mites (Allen, Nakakihara and Schaefers, 1957; Jeppson, Keifer and Baker, 1975). Similarly, endosulfan is highly toxic against tarsonemids but ineffective against tetranychid and tenuipalpid mites. Several other examples may be cited to substantiate this fact. During present investigation, it was observed that highly significant variations existed in the mortality among four species of mite under four pesticidal treatments. This clearly denotes the differential responses of four mites to various pesticidal treatments. However, dichlorvos provided the best control against all the four mites. The second best result was obtained with malathion application against the three species of mite, R.echinopus T.dimidiatus and H.heinemanni but it was the least effective against H.miles providing only 35.93 % control. Ethion occupied the third position but it provided the second best performance i.e. after dichlorvos in the case of H.miles. On the other hand dicofol provided good control of R.echinopus, T.dimidiatus and H.heinemanni but was not much effective against H.miles.

It was further recorded from the present investigation that none of the pesticides provided any knowk down effect on mites as it is revealed from the Interaction Table between pesticide and day. Dichlorvos and ethion showed relatively quicker action providing 100 % mortality after 4 days while it took 5 and 7 days for dicofol and malathion, respectively. It may be seen from the Interaction Table between concentration and mite that even the recommended concentration of a pesticide (0.04 %) did not provide total control of any of the four mite species. It provided only 80 % control in R.echinopus and T.dimidiatus, and it was too low i.e. 60.10 % in the case of H.miles. It is thus evident that H.miles is difficult to control with the pesticides taken into consideration during the present investigation.

The descending orders of efficacy of four pesticides against mushroom mites are as follows :

i) R.echinopus - dichlorvos (83.85 %),malathion (77.18 %), ethion (72.39 %) and dicofol(66.66 %).

ii) T.dimidiatus - dichlorvos (85.31 %), malathion (74.47 %), dicofol (70.52 %) ethion (67.70 %).

iii) H.heinemanni - dichlorvos (76.45 %), malathion (68.43 %), dicofol (66.66 %) and ethion (63.22 %).

iv) H.miles - dichlorvos (66.35 %), ethion (59.79 %), dicofol (53.22 %) and malathion (35.93 %).

The descending orders of efficacy of four concentrations against mushroom mites are as follows :

i) R.echinopus - 0.04 (80.49 %), 0.02 (78.02 %), 0.01 (74.16 %), 0.005 (67.49 %).

ii) T.dimidiatus - 0.04 (80.83 %), 0.02 (76.77 %), 0.01(73.85 %), 0.005 (66.56 %).

iii) H.heinemanni - 0.04 (73.54 %), 0.02 (70.93 %), 0.01 (67.29 %), 0.005 (63.74 %).

iv) H.miles - 0.04 (60.10 %), 0.02 (56.35 %), 0.01 (51.87 %), 0.005 (47.29 %).

A perusal of available literatures showed that the chemical control of mushroom mites has gone long away with the application of nicotine as early as in 1937 through the paradichlorobenzene and of late with malathion dicofol and so on. But the informations pertaining to chemical control of four mites are lacking. The number of trials conducted on chemical control of mushroom mites are relatively less probably due to the fact that the chemical control with recommended dosages of pesticides are not highly effective against them. Further, these applications invite residue problem as well as the fungicidal action on mushroom. Therefore, fumigants like methyl bromide and others used as disinfectant of mushroom house play an important role in the chemical control of mushroom mites. It appears that the best control of mushroom mites lies in preventive measures or utilisation of pesticides of plant origin which has been discussed below.

4.9.2.2 Control of mushroom mites with plant products

The data obtained on the bioefficacy of six oils of plant origin on mushroom mites have been presented in Table 4.22 and 4.22.1 and Fig.4.26. It may be seen from Table that significant difference in mortality was recorded among four species of mite when treated with oils in different concentrations. It is revealed from the significant interaction between mite and oil that the four mites reacted differently to six types of oil. The maximum mortality of *R. echinopus* was recorded in citronella treated pots (70.56 %) followed by clove (56.57 %), wintergreen (45.95 %) Chaulmoogra (45.21 %), Karanja (10.66 %) and neem (7.71 %) treated pots. The differences observed in between two oils in *R.echinopus* were always statistically significant. In the case of *T.dimidiatus*, the maximum mortality was recorded in citronella (67.52 %) followed by clove (51.42% winter green (45.23 %), Chaulmoogra (43.99 %), karanja (7.52) and neem (7.42 %). The difference in mortality recorded in between citronella and clove was statistically significant while those between chaulmoogra and wintergreen and between karanja and neem were statistically non-significant. But all of them were statistically different from citronella and clove.

Table 4.22 : Effectiveness of various plant oil application on females of four species of mushroom mites (mean of three replications).

Plant oils	Concen-trations (% a.i.)	Mites	Corrected percent mortality at different days after application of oils						
			0.25	0.5	1	2	3	5	7
(1)	(2)	(3)	4	5	6	7	8	9	10
CHAULMOOGRA	0.01	R.echinopus	0.00 (0.00)	0.00 (0.00)	6.66 (14.28)	16.66 (23.85)	20.00 (26.57)	40.00 (39.14)	70.00 (56.99)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	23.33 (28.78)	26.66 (30.79)	53.33 (46.92)	73.53 (59.71)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6.66 (12.28)	50.00 (45.00)	50.00 (45.00)	50.00 (45.00)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	10.00 (15.00)	26.66 (30.00)	30.00 (33.21)
	0.05	R.echinopus	0.00 (0.00)	0.00 (0.00)	23.33 (28.78)	36.66 (37.14)	53.33 (47.00)	70.00 (56.79)	90.00 (74.39)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	30.00 (33.00)	43.33 (41.15)	70.00 (56.99)	100.00 (89.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	33.33 (35.21)	73.33 (59.00)	73.33 (59.00)	73.33 (59.00)
		H.Miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	13.33 (21.14)	33.33 (35.21)	33.33 (35.21)	33.33 (35.21)

(Contd...)

Table 4.22 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CHAULMOOGRA	0.25	*R.echinopus*	0.00 (0.00)	0.00 (0.00)	36.66 (37.14)	36.66 (37.14)	50.00 (45.00)	93.33 (79.93)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	6.66 (14.28)	46.66 (43.07)	73.33 (59.00)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	46.66 (43.07)	76.66 (61.21)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	33.33 (35.21)	63.33 (52.86)	63.33 (52.86)	63.33 (52.86)
	1.25	*R.echinopus*	0.00 (0.00)	0.00 (0.00)	30.00 (33.21)	56.66 (48.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	13.33 (21.14)	60.00 (50.77)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	16.66 (23.85)	53.33 (46.92)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	20.00 (26.07)	46.66 (43.07)	76.66 (61.21)	100.00 (88.19)	100.00 (88.19)
	6.25	*R.echinopus*	0.00 (0.00)	20.00 (26.57)	56.66 (48.93)	76.00 (61.21)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	26.66 (30.79)	93.33 (79.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	63.33 (52.86)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	33.33 (35.21)	66.66 (54.78)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)

(Contd...)

Table 4.2* (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CITRONELLA	0.01	<u>R.echinopus</u>	0.00 (0.00)	0.00 (0.00)	33.33 (35.21)	50.00 (56.00)	73.33 (59.21)	86.66 (48.43)	100.00 (88.19)
		<u>T.dimidiatus</u>	0.00 (0.00)	0.00 (0.00)	6.66 (12.28)	20.00 (26.57)	46.66 (43.07)	100.00 (88.19)	100.00 (88.19)
		<u>H.heinemanni</u>	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.00 (26.57)	53.33 (47.00)	100.00 (88.19)	100.00 (88.19)
		<u>H.miles</u>	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	16.66 (23.85)	40.00 (39.14)	100.00 (88.19)	100.00 (88.19)
	0.05	<u>R.echinopus</u>	0.00 (0.00)	3.33 (6.14)	33.33 (34.92)	63.33 (53.14)	76.66 (61.92)	96.66 (82.98)	100.00 (88.19)
		<u>T.dimidiatus</u>	0.00 (0.00)	0.00 (0.00)	26.66 (30.79)	56.66 (48.84)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.heinemanni</u>	0.00 (0.00)	0.00 (0.00)	10.00 (15.00)	40.00 (39.06)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.miles</u>	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	30.00 (33.21)	70.00 (66.99)	100.00 (88.19)	100.00 (88.19)
	0.25	<u>R.echinopus</u>	0.00 (0.00)	36.66 (37.14)	63.33 (53.06)	93.33 (79.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		R. <u>T.dimidiatus</u>	0.00 (0.00)	43.33 (41.15)	73.33 (59.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.heinemanni</u>	0.00 (0.00)	33.33 (34.92)	43.33 (41.07)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		<u>H.miles</u>	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	46.66 (42.99)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)

(Contd..)

Table 4.22 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CITRONELLA	1.25	*R.echinopus*	26.66 (30.73)	83.33 (66.14)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	56.66 (48.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	50.00 (45.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	20.00 (26.57)	50.00 (45.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
	6.25	*R.echinopus*	50.00 (45.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	33.33 (35.21)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	30.00 (33.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	3.33 (6.14)	33.33 (35.21)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
CLOVE	0.01	*R.echinopus*	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6.66 (12.28)	23.33 (27.78)	36.66 (37.22)	63.33 (52.86)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6.66 (8.85)	46.66 (43.07)	50.00 (45.00)	70.00 (56.99)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.00 (26.57)	26.66 (30.99)	26.66 (30.99)	40.00 (39.23)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	13.33 (21.14)	33.33 (35.21)	33.33 (35.21)	33.33 (35.21)

(Contd.

Table 4.22 (contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CLOVE	0.05	*R.echinopus*	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	60.00 (50.85)	93.33 (79.93)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6.66 (8.85)	70.00 (56.99)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.00 (26.57)	56.66 (48.84)	66.66 (54.78)	76.66 (61.21)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	30.00 (33.21)	43.33 (41.15)	46.66 (43.07)	63.33 (52.77)
	0.25	*R.echinopus*	0.00 (0.00)	13.33 (17.71)	33.33 (34.92)	36.66 (37.17)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	30.00 (33.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	30.00 (33.00)	73.33 (59.00)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	43.33 (41.15)	56.66 (48.84)	63.33 (52.77)	80.00 (63.93)
	1.25	*R.echinopus*	0.00 (0.00)	46.66 (43.07)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	10.00 (18.43)	86.66 (68.85)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	6.66 (8.85)	60.00 (50.85)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	20.00 (26.51)	70.00 (56.79)	80.00 (63.93)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)

(Contd..)

Table 4.2 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CLOVE	6.25	R.echinopus	3.33 (6.14)	63.33 (53.06)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	23.33 (28.78)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	53.33 (47.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	46.66 (43.07)	83.33 (66.14)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
KARANJA	0.01	R.echinopus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	0.05	R.echinopus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

(Contd.)

Table 4.22 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
KARANJA	0.25	*R.echinopus*	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	1.25	*R.echinopus*	0.00 (0.00)	0.00 (0.00)	20.00 (26.57)	30.00 (33.00)	33.33 (35.21)	40.00 (39.14)	40.00 (39.14)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	26.66 (30.79)	26.66 (30.79)	30.00 (33.00)	33.33 (35.21)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6.66 (8.85)	23.33 (28.78)	36.66 (37.22)	36.66 (37.22)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	10.00 (18.43)	30.00 (33.00)	30.00 (33.00)	30.00 (33.00)
	6.25	*R.echinopus*	0.00 (0.00)	0.00 (0.00)	36.66 (37.22)	43.33 (41.15)	43.33 (41.15)	43.33 (41.15)	43.33 (41.15)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	36.66 (37.22)	36.66 (37.22)	36.66 (37.22)	36.66 (37.22)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	13.30 (21.14)	36.66 (37.22)	36.66 (37.22)	36.66 (37.22)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	16.66 (23.85)	36.66 (37.22)	36.66 (37.22)	36.66 (37.22)

(Contd..)

Table 4.22 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
NEEM	0.01	*R.echinopus*	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	0.05	*R.echinopus*	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	0.25	*R.echinopus*	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

(Contd.)

Table 4.22 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
NEEM	1.25	R.echinopus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	3.33 (6.14)	23.33 (28.78)	36.66 (37.22)	43.33 (41.15)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	26.66 (30.79)	40.00 (39.23)	46.66 (43.07)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	6.66 (12.28)	23.33 (28.78)	43.33 (41.15)	43.33 (41.15)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	10.33 (17.21)	30.00 (33.21)	36.66 (37.22)	36.66 (37.22)
	6.25	R.echinopus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.00 (26.57)	36.66 (37.14)	53.33 (47.00)	53.33 (47.00)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	36.66 (36.93)	46.66 (43.07)	63.33 (52.77)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	13.33 (21.14)	36.66 (37.22)	36.66 (37.22)	43.33 (41.15)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.00 (26.57)	33.33 (35.21)	36.66 (37.22)	40.00 (39.23)
WINTERGREEN	0.01	R.echinopus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	30.00 (33.00)	30.00 (33.00)	40.00 (39.23)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	33.33 (35.21)	36.66 (37.22)	40.00 (39.23)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	13.33 (21.14)	33.33 (35.21)	33.33 (35.21)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	3.33 (6.14)	16.66 (23.35)	33.33 (35.21)	36.66 (37.22)

(Contd...)

Table 4.22 (Contd..)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
WINTERGREEN	0.5	R.echinopus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	23.33 (28.78)	30.00 (33.00)	30.00 (33.00)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	36.66 (37.22)	36.66 (37.22)	43.33 (41.15)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	13.33 (21.14)	40.00 (39.23)	40.00 (39.23)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	10.00 (15.00)	16.66 (23.85)	40.00 (39.14)	40.00 (39.14)
	0.25	R.echinopus	0.00 (0.00)	0.00 (0.00)	36.66 (36.85)	46.66 (43.07)	53.33 (46.92)	56.66 (48.93)	56.66 (48.93)
		T.dimidiatus	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	40.00 (38.85)	60.00 (50.85)	60.00 (50.85)	60.00 (50.85)
		H.heinemanni	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	36.66 (37.22)	60.00 (50.85)	60.00 (50.85)	60.00 (50.85)
		H.miles	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	20.00 (26.07)	50.00 (45.00)	50.00 (45.00)	50.00 (45.00)
	1.25	R.echinopus	0.00 (0.00)	90.00 (74.39)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	50.00 (45.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	33.33 (35.21)	56.66 (48.84)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	40.00 (39.14)	66.66 (55.07)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)

(Contd..)

Table 4.22 (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
WINTERGREEN	6.25	*R.echinopus*	20.00 (26.07)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		T.dimidiatus	0.00 (0.00)	86.66 (71.68)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.heinemanni	0.00 (0.00)	70.00 (56.79)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)
		H.miles	0.00 (0.00)	53.33 (47.00)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)	100.00 (88.19)

	Mites	Oils	Concentrations	Days
C.D. (p=0.05)	1.38	1.70	1.55	1.83
C.D. (p=0.01)	1.82	2.23	2.04	2.41

'F' test - Significant.
S.Em (±) - 0.25

Figures in parenthesis indicate angular transformed values.

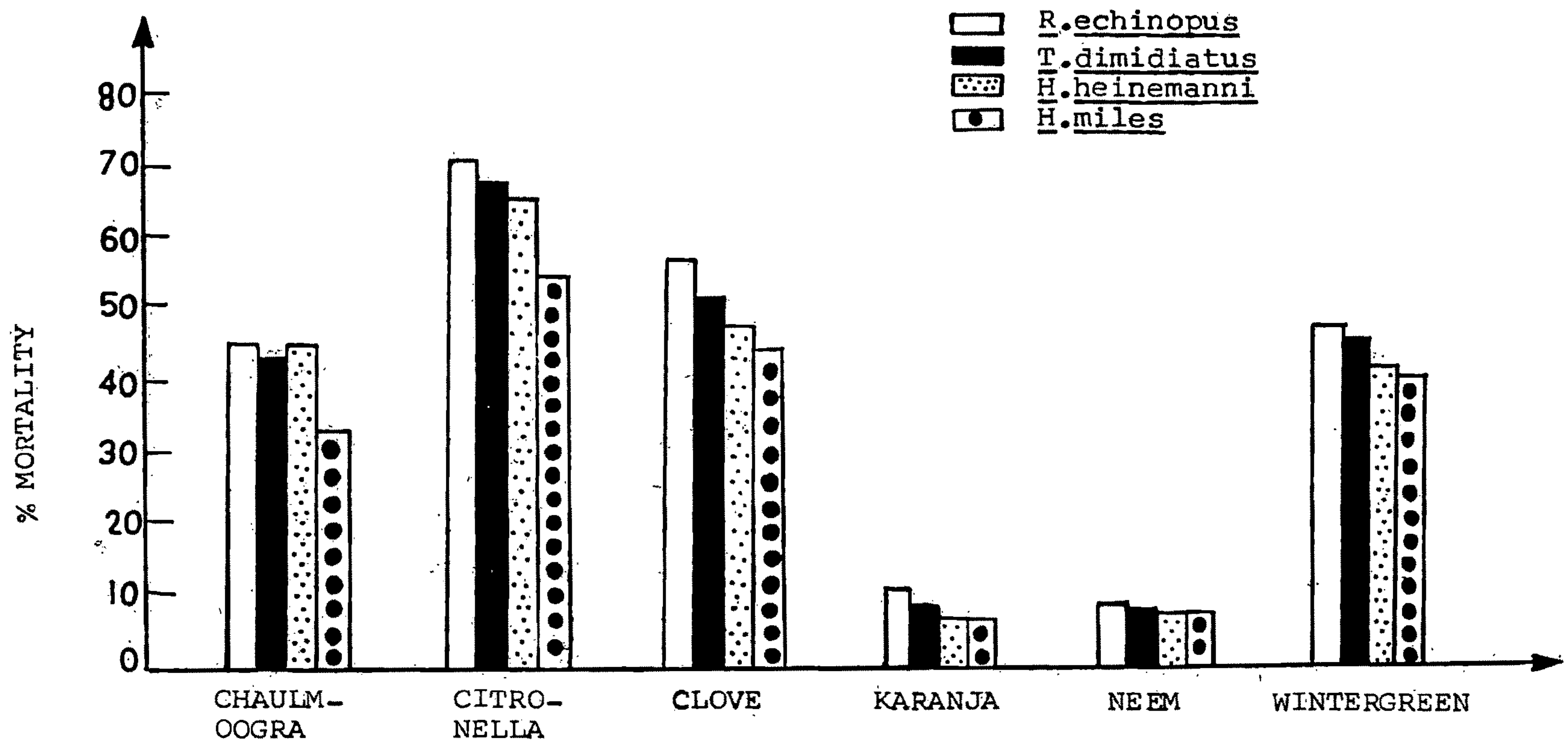


Fig. 4.26 RATE OF MORTALITY OF FOUR MUSHROOM MITES AFTER TREATMENT WITH VARIOUS PLANT OILS.

The maximum mortality of H.heinemanni was also recorded in citronella treated pots (65.14 %) followed by clove (47.33 %), chaulmoogra (44.66 %), wintergreen (41.42 %), neem (7.04 %) and karanja (6.47 %) and the difference observed in between six oils were statistically significant except between chaulmoogra and wintergreen and between karanja and neem. Again, the maximum mortality of H.miles was recorded in citronella (54.57 %) treated pots followed by clove (43.99 %), wintergreen (40.76 %), chaulmoogra (32.76 %), neem(7.04 %) and karanja (6.47 %) treated pots.

The interaction between concentration and mite was statistically non-significant. It therefore indicates that all the four species of mite responded similarly in five different concentrations of oil. The highest concentration i.e. (6.25 % a.i.) always provided the maximum mortality followed by 1.25, 0.25 and 0.05 % a.i. and the minimum mortality was recorded in the lowest concentration i.e. 0.01 %.

The interaction between mite and day was statistically significant. In other words, it indicates that the pattern of mortality followed in four species of mite during different days of observation was not similar. The initial mortality of all the four species of mite was recorded just after 6 hours. The mortality figures of the four mites during 6 hours were 3.33, 1.11, 1.00 and 0.11 % in R.echinopus, T.dimidiatus, H.heinemanni and H.miles respectively. The mortality figures on the seventh day were 64.53, 65.55, 61.11 and 55.77 % in R.echinopus, T.dimidiatus, H.heinemanni and H.miles respectively and the differences in mortality recorded in between various days were mostly significant in all the four species of mite.

The effect of interaction between concentration and oil on mortality of mite was statistically significant. Nearly 87.49 % mortality was recorded in 6.25 % citronella treated pots while these were 83.21, 77.61, 61.99, 21.66 and 20.35 % in wintergreen, clove, chaulmoogra, karanja and neem treated pots, respectively. The rate of mortality provided by 0.01 % concentration were 40.95, 19.76, 18.92 and 13.57 % in citronella, chaulmoogra, clove and wintergreen treated pots, respectively. But the initial mortality in neem and karanja treated pots were recorded only at 1.25 % concentration. The differences in mortality observed in various oils under various concentrations were mostly significant.

The effect of interaction between concentration and day denoting mortality of mites have been presented in Table 4.22.1. The significant interaction indicates that the mortality of mite found in different concentrations during different days of observation did not follow the same pattern. It may be seen that at 6.25 and 1.25 % concentrations, the mortality rates were 81.38 and 79.58 %, respectively after seven days whereas these were 57.08, 49.44 and 40.83 % in cases of 0.25 , 0.05 and 0.01 % a.i., respectively. The differences in mortality recorded in between 0.25-3.00 days under different concentration were mostly significant while those observed in between five to seven days under different concentrations were mostly non-significant.

Similarly, the effect of interaction between oil and day on the rate of mite mortality was significant. Therefore, different patterns in mortality of mites were recorded in various pesticides treated pots during different days under observation. Total mortality of mites were recorded after seven days only in citronella treated pots while it was 86.33, 84.16, 66.49, 18.49 and 14.66 % in clove, chaulmoogra, wintergreen, neem and karanja treated pots, respectively. Initial mortalities i.e. to the tune of 0.16, 7.16 and 1.00 % were recorded after 6 hours in clove, citronella, and wintergreen treated pots. The differences in mortality recorded in between two days in six oil treated pots were mostly significant upto three days.

The response of four species of mushroom mite to the application of various plant oils have been presented in Table 4.22 and Fig.4.26. It is revealed from the present investigation that none of the oils was highly effective in the control of mite species on mushroom. However, the mortality was total in citronella treated pots on the seventh day after application though the initial mortality was very low. Similarly, satisfactory control of mushroom mites was also obtained with the application of clove and chaulmoogra oil. The mortality percentage in these cases were 86.33 and 84.16 % on the seventh day after application inspite of a very low initial mortality and 50%

mortality was recorded only on the second day after oil application. In one hand, wintergreen provided a mortality around 47.83 % while other two oils, namely neem and karanja killed less than 20 % of mite population. The mortality of mite was very low under lower concentrations viz., 0.01, and 0.05% a.i. and with the subsequent increase in concentration to 1.25 % a.i., the mortality percentage increased considerably. Yet a six fold increase in concentration to 6.25 % a.i. did not bring about a significant change in mortality and the mortality percentage remained around 60 % being constant for all the species of mites.

The descending orders of efficacy of six oils against mushroom mites are as follows :

i) R.echinopus - citronella (70.56 %), clove (56.57 %), wintergreen (46.95 %), chaulmoogra (45.21%) karanja (10.66%) and neem (7.71 %).

ii) T.dimidiatus - citronella (67.52 %), clove (51.42 %), wintergreen (45.23 %), chaulmoogra (43.99 %), karanja (7.52 %) and neem (7.42 %).

iii) H.heinemanni - citronella (65.14 %), clove (47.33%), chaulmoogfa (44.66 %), wintergreen (41.42%) neem (7.04%) and karanja (6.47 %).

iv) H.miles - citronella (54.57 %), clove (43.99 %), wintergreen (40.76 %), chaulmoogra(32.76%), neem (7.04 %) and karanja (6.47 %).

The descending orders of efficacy of five concentrations against mushroom mites are as follows :

i) R.echinopus - 6.25 (63.39 %), 1.25 (57.22 %), 0.25 (34.36 %), 0.05(25.79 %) and 0.01(17.30%).

ii) T.dimidiatus - 6.25 (58.49 %), 1.25(52.53%),0.25 (33.17 %), 0.05 (24.28 %) and 0.01(17.45%)

iii) H.heinemanni - 6.25(58.81%),1.25(49.91 %),0.25(31.42%), 0.05(21.82 %) and 0.01(14.84 %).

iv) H.miles - 6.25 (54.20%),1.25 (47.77 %),0.25 (23.41 %), 0.05 (16.74 %) and 0.01 (15.23 %).

A perusal of available literatures reveals that the importance of plant oils in controlling acarines has been overlooked since long. The oils chosen for efficacy trial against mushroom mites during the present investigation are known to possess pesticidal properties.A good number of literatures have been accumulated over the years on the bioefficacy of plant oils against insect pests. Several of them viz., citronella, karanja, neem are known to be highly effective against insect species (Pandey, Singh and Tewari, 1977; Schoonhoven, 1978; Attari, 1980). It is interesting to note that none of the oils performed well on mushroom mites. The most important factor to be considered is their very low initial toxicity on mites. Of course, it was greatly compensated after seven days when nearly total mortality of mushroom mites was observed. Obviously, this limitation can be overcome to a great extent by using very high concentrations of oils.

The differential response of mushroom mites to various plant oils was attributed to their physiological selectivity which was not of great significance under this situation. The overall efficacy of various oils in the descending order was : citronella, clove wintergreen, chaulmoogra, karanja and neem.

4.10 Phytotoxicity of plant oils on mushrooms

During the present investigation, attempts were also made to study the phytotoxic effect of various plant oils, if any, on mushroom. The results have been presented in Table 4.23. The data indicated that the yield of mushroom in the untreated tray was 185.00 gm while these were 146.60, 168.30, 163.30, 193.30, 178.30 and 180.00 gm in the chaulmoogra, citronella, clove, neem, karanja and wintergreen oil treated trays, respectively. There was no significant difference in yield of mushroom between the oil treated and control (untreated) trays. At the same time, none of the oils was found to produce any

Table 4.23 : Effect of various oils of plant origin on mushroom

Treatments (Oils)	Concentrations (% a.i.)	Quantity sprayed/ tray	Yield of fruit body/tray (gm)
Chaulmoogra	6.25	10 c.c.	146.60
Citronella	6.25	"	168.30
Clove	6.25	"	163.30
Neem	6.25	"	193.30
Karanja	6.25	"	178.30
Wintergreen	6.25	"	180.00
Control (Water spray)		"	185.00

'F' test - Not significant.

S.Em. (±) 3.83

visible phytotoxic symptoms on mushrooms. This clearly demonstrates that the application of oils has no adverse effect on growth and yield of mushroom. In the absence of published literatures in this direction, the results obtained during the present investigation could not be elaborated in depth.

S U M M A R Y

S U M M A R Y

i) Studies were undertaken to reveal the identity of mites found in association with each of the two species of summer and winter mushrooms viz., *P.sajor-caju* and *P.ostreatus*, *T.lobayense* and *V.volvacea*, respectively. Subsequently, their damage potentials were assessed. Ecological studies pertaining to seasonal incidence as well as influence of major abiotic factors were carried out on them. Various experiments were designed to work out suitable control measures.

ii) The prevalence of altogether four species of mites belonging to three Families, namely Acaridae, Anoetidae and Laelapidae were noticed. They were *R.echinopus*, *T.dimidiatus*,*H.heinemanni* and *H.miles*. Their occurrence were seasobal and they were host-specific. The foremost species was found only on winter types of mushroom while the remaining three species infested summer types. This is the first report on the mites to infest mushroom under Indian condition and in the case of *H.miles*, it is altogether a new host record.

iii) It is evident from the present investigation that straw a component of mushroom-bed harvours all the four species of mushroom mites and therefore responsible for carry over of mites in mushroom-bed. No other agents like compost or insects were associated in the transportation of mites in mushroom-bed.

iv) It is revealed from a study initiated to confirm the feeding habit of mites on mushroom that the population of four mites varied significantly between unspawned and spawned beds. The rate of increase has been found to be 166.56, 66.55, 266.65 and 33.25 % in <u>R.echinopus</u>, <u>T.dimidiatus</u>, <u>H.heinemanni</u> and <u>H.miles</u> respectively under unspawned condition in contrast to 916.65/783.00, 500.00/416.57, 1433.00/1226.54 and 516.50/566.53 % respectively under spawned condition. It is an obvious indication of their utilisation of mushroom as their preferred food. The rate of increase in <u>T.dimidiatus</u> , <u>H.heinemanni</u> and <u>H.miles</u> varied significantly in between two species of summer mushrooms indicating their preference difference to two types of mushroom. It is further substantiated from their higher rate of increase till the twentyfifth day after spawning with subsequent decline in population resulted from the depletion of food (mushroom) due to their continuous feeding. It was also confirmed from the yield data obtained from infested <u>vis-a-vis</u> control conditions.

v) The distribution of four species of mite in various profiles of spawned mushroom-bed indicated that the variation in population observed among four mites <u>vis-a-vis</u> at various profiles were statistically significant. The maximum population of all the four species was observed in the upper surface of mushroom bed (upto 1.5 cm) probably due to the highest concentration of mushroom mycelium and fruit body in the top layer. The mite population was found to decline gradually with the increase in depth and statistically the densities of mite observed in between 3.0-4.5 cm and 4.5-6.0 cm were equal.

vi) The symptoms of damage produced due to the infestation of each species of mushroom mite are characterised with the change in shape, size and colour. Due to the infestation of R.echinopus, the basal area became pointed and the colour changed from white to yellow or brown. T.dimidiatus, on the other hand, made a large hole at the basal region of mushroom and gradually hollowed it out with a change in colour from white to blackish brown. But the above mentioned species affected the gill portion of cap and formed a dense cover all along the mushroom bed under severe case of infestation.

The infestation of H.heinemanni disrupted vertical growth of mushroom forcing it to develop in a crawling manner and the infested area showed a sign of decomposition. The feeding of H.miles resulted in detachment of buds from the mushroom bed. Several holes developed on cap region and the entire content of the volva was eaten up with a noticeable change in colour to yellow.

vii) All the four species are very destructive in the mycelial as well as fruit body stages of mushroom. The destructive potential of mites were more or less at per with slightly high in H.heinemanni when the decrement of weight of mycelial mat (85.23 %) was considered.

viii) The reduction of stalk length of mushroom due to the infestation of four mites varied between 38.58 to 48.77 % while the stalk weight varied enormously among four species being 87.16,74.07, 62.90 and 42.30 % in H.heinemanni, T.dimidiatus, H.miles and R.echinopus , respectively.

ix) The duration of spawn-run period was significantly delayed by about 5.6 days in R.echinopus while these were 7.0 and 2.0-5.0 days in H.heinemanni, T.dimidiatus and H.miles, respectively. No second flush was noticed in any of the mite infested bed.

x) The bud stage of mushroom was most prefered by H.heinemanni and R.echinopus inflicting 64.83 and 62.84 % damages, respectively. The corresponding values in H.miles and T.dimidiatus were 45.05 and 41.33 %, respectively.

xi) The severe reduction in circumeference of mushroom cap was noticed due to infestation of H.heinemanni (70.00 %) while in other three species, these were around 37.00 % . Similarly, the thickness of cap was reduced to the tune of 75.43 % in H.heinemanni with corresponding figures in other three species around 38.00 % being the lowest in R.echinopus (22.72 %). The percent reduction in weight of cap was around 91.17 % in H.heinemanni while these were 80.10, 70.91 and 36.36 % in T.dimidiatus, H.miles and R.echinopus, respectively. Thus, it indicated that R.echinopus did not like the cap portion of mushroom while it was most preferred by H.heinemanni. The other two species, namely T.dimidiatus and H.miles did not infest gill portion of cap but consumed inner tissue of cap portion inflicting severe damage to this region of mushroom.

xii) Preliminary informations collected on the economic injury level of four mites revealed that a direct linear relationship existed between the loss in mushroom yield and density of mites upto a level of 150 mites/50 gm of compost. The rate of yield decrement was very low in between 50-100 mites/50 gm of compost and a population of 100 mites would bring about nearly 9.0 % loss in yield. Considering the economic significance of 9.0 % loss in yield, control measures may be recommended at this level.

xiii) The four species of mite differed significantly among themselves in respect to their preference on eight artificial diets signifying their differential nutritional requirements. The maximum rate of increase (4160.00 %) was noticed in R.echinopus in the diet consisting of agar, wheat kernel, yeast and distilled water. For T.dimidiatus, it was a mixture of wheat kernel and yeast extract. The other two species, namely H.heinemanni and H.miles showed a clear inclination for mushroom as food. Their rate of multiplication was high only in the presence of mushroom extract and was unable to produce any progeny without it.

xiv) It is revealed from the ecological studies that there was significant difference in duration of mating, pre-ovipositional and ovipositional periods among four species of mushroom mites irrespective of temperature and relative humidity. The effect of interaction between mite and temperature, mite and relative humidity and temperature and relative humidity were also significant showing differential preference of four mite species for various temperatures and relative humidities. The maximum durations of mating, pre-ovipositional and ovipositional periods were recorded at 20°C x 90 % r.h., 20°C x 60 % r.h. and 20° x 60 % r.h., respectively.

xv) The duration of egg, larval, nymphal stages also varied significantly among four species of mushroom mites irrespective of temperature and relative humidity. The effects of interaction between mite x temperature, mitex relative humidity and temperature x relative humidity on the duration of immature stages were also significant indicating that duration did not follow the same pattern in the four mites under various levels of temperature and relative humidity. There were significant difference in fecundity among four mushroom mites irrespective of temperature and relative humidity. The maximum number of eggs were laid by R.echinopus followed by T.dimidiatus, H.heinemanni and H.miles. The pattern of egg laying of four mites was not similar under three levels of temperature and relative humidity. In general, the maximum fecundity was realised under moderate temperature (30°C) with exceptions in R.echinopus and T.dimidiatus where the respective temperatures were 20°C and 40°C, respectively. All the mites laid maximum eggs at 90 % r.h.

xvi) The speed of development increased progressively with the increase in temperature in all the four species of mushroom mites. The duration of life cycle increased at higher relative humidity (90 %) in R.echinopus while in other three mites, it was reverse. However, all of them failed to develop at 30 % r.h. while T.dimidiatus and H.heinemanni also failed to develop at 60 % r.h. irrespective of temperature.

xvii) The rate of survival of various stages of mushroom mites varied significantly among themselves irrespective of temperature and relative humidity. The significant effect of interactions between mite x temperature, mite x relative humidity and temperature x relative humidity on the rate of survival of immature stages denoted that the pattern of survival of four mites was not similar under three levels of temperature and relative humidity. The optimum temperature and humidity combinations for egg, larval, protonymphal, deutonymphal and adult stages were 20°C x 90 % r.h. , 30°C x 90 % r.h., 20°C x 90 % r.h., 30°C x 90 % r.h. and 20°C x 90 % r.h. respectively. The rate of survival was relatively higher in H.miles and T.dimidiatus

xviii) The temperature preferendum varied widely among four mites R.echinopus being a pest of winter mushroom showed a clear preference fo: low temperature (20°C) for its optimum development. The remaining three species, on the other hand, exhibited definite inclination for warm temperature (30°C) being summer bound occurrence and at least H.miles showed its ability to multiply even at high temperature (40°C). All the four mites preferred high humidity (90 %) for their optimum developments

xix) The incidence of four mushroom mites took place in a sequenc with the appearance of R.echinopus during January to March for its preference towards a mild climatic condition. The increase in mite population was dependent on temperature. However, it was unable to withstand high temperature beyond 35°C. The mite population was not affected with the increase or decrease in relative humidity as was evidenced from the non-significant 'r' and 't' values.

T.dimidiatus was found on mushroom from March to May when high temperature prevailed with a mean value around 33°C. The species did not show any relationship with temperature but exhibited a positive correlation with the atmospheric relative humidity which varied between 56 % - to 89 %.

H.heinemanni infested mushroom between June to October.The mite exhibited a definite relationship with both the major abiotic factors and temperature when its population fluctuation in straw component of mushroom bed alone was considered. The non-significant 'r' and 't' values in the case of temperature along vis-a-vis mite population during the mycelial and fruit body stages of mushroom indicated that temperature was not that important as relative humidity.

The fourth species, H.miles was observed on mushroom from October to November. The mite showed similar relationship with the major abiotic factors as was noticed in the case of H.heinemanni. The population of mite increased with the increase in temperature and relative humidity while they were found in straw. But during its presence under mycelial and fruit body stages of mushroom, the population growth was dependent on the variation of relative humidity alone.

xx) Attempts were also made during the present investigation to explore the natural enemy complex, if any, of mushroom mites. But neither any parasites nor any predators were noticed in association with mushroom mites during the course of investigation.

xxi) Sterilisation of straw component of mushroom bed was found to be highly effective in controlling mushroom mites. The mite population varied between 19.0 - 38.3/10 gm of straw. Significant variation was recorded in the rate of mortality among four mushroom mites while they were exposed to each of the ten constant temperatures varied between 50.0°-72.5°C under three levels of exposure periods (15,30 & 45 min). H.miles was the most tolerant species followed by H.heinemanni

T.dimidiatus and *R.echinopus*. The LD_{50} temperature for all the four species was around 60° ± 1°C to 62.5° ± 1°C and a temperature around 70° ± 1°C to 72.5°C ± 1°C provided 100 % mortality (LD_{100}). A constant temperature at 72.5°C for 15 minutes was highly satisfactory for mites. Similarly, the exposure of mites to 62.5°C for 30 minutes and 57.5°C for 45 minutes provided total destruction.

xxii) The contact toxicity of four pesticides in four concentrations (0.04, 0.02, 0.01 and 0.005 %) were tested on adult mites under laboratory condition. Significant difference in mortality was recorded among four species of mite. The significant interaction between mite and pesticide revealed that the mite species reacted differently to pesticides. The relative toxicity of pesticides in the descending order, together with the values (% mortality) were : dichlorvos (77.99 %), ethion (65.77 %), malathion (64.00 %) and dicofol (64.26 %). The maximum concentration (0.04 %) provided only 80 % mortality of *R.echinopus*, *T.dimideiatus* and *H.heinemanni* while it gave 60.10 % mortality against *H.miles*. Dichlorvos and ethion provided total mortality of mite after four days while it took 5 and 7 days for dicofol and malathion, respectively.

xxiii) The contact toxicity of six plant products (oils) were tested on the adult of mushroom mites in five concentrations (6.25, 1.25, 0.25, 0.05 and 0.01 %) under laboratory condition. There was significant difference in mortality among four species of mushroom mite. The significant interaction between mite and oil denoted differential response of four mites to oil treatments. The relative toxicity of plant oils in the descending order, together with the values (% mortality) were:

citronella (64.44 %) clove (49.77 %), wintergreen (43.59 %), chaulmoogra (40.65 %), karanja (7.78 %) and neem (7.30 %). The total mortality of mites were recorded only with the application of citronella oil after seven days while these were 86.33, 84.16, 66.49, 18.49 and 14.66 % in clove, chaulmoogra, wintergreen, neem and karanja, respectively. All of the four mites responded similarly in five different concentrations of oil. The highest concentration (6.25 %) always provided the maximum mortality and the minimum mortality was recorded in the lowest concentration (0.01 %).

It was recorded that none of the oils produced any phytotoxicity on mushrooms. There was no significant difference in yield of mushroom between the oil treated and control trays.

CONCLUSION

C O N C L U S I O N

It is revealed from the present investigation that the mushroom mites are the least studied subject in mushroom science. With the steady progress of mushroom cultivation all over India, it has become imperative to undertake a detailed study on them. It was observed that four species of mites, namely R.echinopus, T.dimidiatus, H.heinemanni and H.miles were found in association with mushroom cultivation. Of course, there are several other species of mites having revealence with mushroom cultivation. But till-to-date they are maintaining a non-pest status. It is predicted that any major change in cultivation technology of mushroom may disturb the natural balance qualifying in their favour. The most important consideration is the total devoidance of natural enemies in the phenology of mushroom mites. Therefore, population dynamics of the mites would be mostly governed by the major abiotic factors like temperature and relative humidity. It is evident from the present investigation that a warm (30°C) and humid conditions (90 % r.h.) are optimum for the rapid development of mites as well as their host (mushroom). Therefore, the mites prefer similar ecological niche to those of their host and are well adopted under such conditions. It is obvious that they have the immense potentiality in inflicting heavy loss in mushroom yield. Furthermore, they attack all the stages of mushroom and occurred in a sequence from the month of January till November avoiding interspecific competition among themselves. All these important traits marked them as the most potential pests of the future. However, they face a great competition from insect group which are the predominent species on mushroom till-to-date.

The most significant contributions made during the present investigation is the development of some artificial diets which would help immensely in understanding the nuttitional status of mites to be utilised in developing newer control measures. The findings on the mode of transportation of mushroom mites has greatly contributed to find out the most effective control measure. Sterilisation of straw at 72.5 °C for 15 minutes and their subsequent utilisation in mushroom bed making would totally eradicate mites from mushroom culture. However, under certain situations where chemical control would be demanding, dichlorvos (0.04 %) may be utilised with great success. However, more rewarding would be the use of plant products like citronella oil at 6.25 % concentration to obtain a total control of mushroom mites without injuring mushrooms.

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