STUDIES ON THE NATURE AND EXTENT OF DAMAGE CAUSED BY INSECT PESTS TO STORED TAPIOCA CHIPS

By

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DECLARATION

I hereby declare that this thesis entitled "Studies on the nature and extent of damage caused by insect pests to stored tapioca chips" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

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Vellayani,

29. 3. 1988.

CERTIFICATE

Certified that this thesis, entitled "Studies on the nature and extent of damage caused by insect pests to stored tapioca chips" is a record of research work done independently by Smt. RAMLA BEEVI. S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

INTRODUCTION

Tapioca (Manihot esculenta Crantz.) is the most important tuber crop in India, both in acreage and in total production. Tapioca, considered as the poor man's food has an important role in the economy of Kerala. Kerala occupies a unique position as the main tapioca growing place in India consisting of an area of 2.28 lakh hectares, with an annual production of 38.49 lakh tonnes. Tapioca forms the major source of food for a large section of the middle and lower class people. It also forms the major food for livestock in South India. The textile industry utilises large quantities of tapioca starch for the sizing and finishing operations. Tapioca flour is used for various purposes for which pure starch is required like the manufacture of glucose and biscuits. A considerable quantity of flour is taken up in the veneer wood industry in the manufacture of adhesives and gums. Abraham (1975) recorded that in Java and Malaya, large quantities of tapioca flour are being converted into pearls and flakes for human consumption. Tapioca pearls are now manufactured in Salem in Tamil Nadu; when mixed with benzene hexachloride, it is also used as a poison bait. Tapioca flour is also used to produce high grade alcohol which could be utilised as 20 : 80 mixture (20 alcohol to 80 gasoline) for automobiles (Balagopal et al., 1980).

A considerable quantity of the tuber grown in Kerala is cut into slices or chips, sun dried as such or after par boiling, to

enhance the keeping quality and stored for four months. The sun dried chips are more widely preferred for human consumption. Under storage conditions the chips are subjected to heavy attack by many insect pests, often leading to great economic loss. Joseph and Commen (1963) reported that, stock of tapioca chips kept in several godowns in Trivandrum were reduced into mere powder by depredations by tapioca beetle Araecerus fasciculatus and the material was found unfit even as cattle feed.

As very little work has so far been done on insect pests associated with tapioca chips, and the damage inflicted has been found to be of very severe nature, investigations were undertaken to study in detail the various aspects of the different insect pests associated with stored tapioca chips. The study included:

i. a survey on the insect pests of stored tapioca chips in the godowns of Trivandrum District,

ii. nature and extent of damage caused by A. fasciculatus Sitophilus oryzae and Tribolium castaneum ~~in raw and~~ in raw and parboiled chips,

iii. biology of A. fasciculatus and S. oryzae in chips made from different varieties of tapioca, and

iv. susceptibility of A. fasculatus and S. oryzae to chips made from different varieties of tapioca.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Tapioca chips both raw chips and parboiled chips are subjected to the attack by a number of insects in storage and a great deal of damage is being done.

Ballou (1919) reported severe infestation of the anthribid beetle Araecerus fasciculatus (DeG.) on cassava (Manihot utilisima) loaded in ship in West Indies.

Zacher (1930) recorded seven species of beetles in dried roots of cassava imported into Germany from various countries. They included Sinoxylon sp., Calandra oryzae (L.), Laemophloeus ferrugineus (Steph.), Latheticus oryzae (Waterh.), Necrobia rufipes (DeG.), Araecerus fasciculatus (DeG.) and Rhizopertha dominica (F).

Frappa (1938) noted sixteen species of pests on stored cassava tubers viz. Tenebrioides mauritanicus (L.), Lephocateres pusillus (Klug.), Ahasverus (Cathartus) advena Walkl., Necrobia rufipes (DeG.), Rhizopertha dominica (F.), Dinoderus bifoveolatus Woll., Minthea obsita Woll., M. rugicollis Walk., Sinoxylon conigerum Gerst., Lyctus brunneus Steph., L. africanus Leene., Tribolium castaneum Hbst., T. confusum Dur., Alphitobius laevigatus F. (Piceusol), Calandra oryzae L. and Araecerus fasciculatus (DeG).

Darling (1946) noted that dried cassava roots in Uganda were severely damaged by Calandra oryzae (L.), Xyloperthodes sp.,

and an unidentified Bostrychid and Araecerus sp. and Gnathocerus cornatus F., T. castaneum (Hbst.) and Laemophloeus sp.

During a preliminary survey, Nair and Jones (1948) noticed the occurrence of C. oryzae, A. fasciculatus, R. dominica, Gibbium sp. and Tribolium sp. in stored chips and Rhizopertha sp., Silvanus sp., Calandra sp. and Laemophloeus sp. on tapioca starch in Government godown at Quilon and they worked out the life history of A. fasciculatus on tapioca chips.

Commen and Joseph (1961) recorded two caterpillar pests Setomorpha rutella (Zell.) and Erechthias zebrina (Butler) on stored tapioca in Kerala.

Joseph and Commen (1963) reported the occurrence of 15 species of insects infesting stored tapioca chips. They included coffee-bean weevil, A. fasciculatus; rice weevil, Sitophilus oryzae; drug store beetle, Stegobium paniceum L.; cigarette beetle, Lasioderma serricorne; lesser grain borer, Rhizopertha dominica; rust red flour beetle Tribolium castaneum; flour beetles, Alphitobius piceus, A. laevigatus (F.); saw toothed grain beetle Oryzaephilus surinamensis; flat grain beetle Laemophloeus minutes Oliv.; tapioca moths Pyralis manihotalis Guen., P. pictalis Curt.; fig moth Ephestia cautella Wlk.; tobacco moth, Setomorpha rutella and Erechthias zebrina Butler; A. fasciculatus and P. manihotalis as the most destructive pests in Kerala.

Studies on the host biology relations of A. fasciculatus indicated that the dried tapioca and maize are favourable foods of the pest (Raghunath and Nair, 1970).

Ingram and Humphries (1972) reported that the important pests of tapioca chips are Ahasverus advena (Waltl.), A. fasciculatus DeG., R. dominica (F.), Sitophilus oryzae (L.), T. castaneum (Hbst.) and S. paniceum (L.). Tapioca flour is also infested by T. castaneum.

Pillai (1976) noted that dried cassava chips are subjected to the depredation by a number of storage pests like A. fasciculatus, Pyralis pictus, Dinoderus minutus, Stegobium paniceum, Setomorpha rutella, Lasioderma serricorne, Rhizopertha dominica, Alphitobium piscus, S. oryzae, Oryzaephilus surinamensis, etc., of which A. fasciculatus is the most destructive pest in storage. He (1978) recorded the occurrence of Tribolium castaneum also as a serious pest of tapioca chips in Kerala.

Nwana (1978) reported that processed cassava is damaged by T. castaneum, Tenebroides spp., A. fasciculatus and Stegobium paniceum in Nigeria.

Parker and Booth (1979) stated that the major pests infesting tapioca chips are R. dominica, L. serricorne and A. fasciculatus. Infestation occurs during the sundrying process, and up to 16% reduction in the weight of chips due to insect infestation was recorded after two months of storage.

Thampan (1979) reported that the common pests damaging sundried cassava chips in India are A. fasciculatus (DeG.) and Stegobium paniceum (L.) and these insects are attracted by the fermenting smell of sundried cassava chips.

Parker et al. (1981) recorded Sitophilus zeamais (Motsch.) and Cryptolestes klapperichi (Lefkovitch) as common pests infesting cassava in storage in West Malaysia, but the most abundant species were R. dominica F., Liposalis sp. and T. castaneum (Herbst.).

Major pests

1. Araecerus fasciculatus (DeG.)

Family: Anthribidae, Order: Coleoptera

Nature and extent of damage

A. fasciculatus is a serious pest of a number of storage commodities like tapioca chips, coffee bean, turmeric, arecanut, cocoa leaves and even grossery articles.

Hoyt (1918) reported A. fasciculatus infesting avocado seeds in Mexico and Central America. The adult insect damaged fruits, leaves, stem and seeds even attacking the hard surface of the well dried seeds.

Munro and Thompson (1929) recorded A. fasciculatus as an important pest in a consignment of nutmeg and cocoa beans showed large exit holes and the internal contents converted to yellow powder.

Cotterell (1934) gave a list of host materials of A. fasciculatus including coffee beans, cotton seeds, diseased banana, pods of leguminous plants and stored cereals.

Miwa (1937) reported that the larvae of A. fasciculatus (DeG.) attack the coffee seeds and the adult emerge from July to November in Japan.

Cohic (1950) recorded A. fasciculatus as a pest of Maryland tobacco in New Calidonia in field. Eggs are deposited on the drying leaves, usually near the central vein and the larvae mine the vein and may perforate several leaves in the pile in search of fresh ones, when the first are exhausted. Leaves damaged in this way are unsuitable for cigar wrappings. Attack ceases when the leaves become dry and brittle.

Figueiredojr (1957) reported A. fasciculatus as an important pest of stored coffee in Brazil where the losses amounted to 30% during a storage period of six months.

Joseph and Oommen (1963) recorded A. fasciculatus occurring all over Kerala State as the most destructive pest of tapioca chips. This pest present throughout the year causes severe infestation during June to December; adults causing considerable damage by boring into the chips. The larvae bore into the chips making small tunnels and pupates thereein. Under laboratory conditions cent per cent damage was observed within a period of three months.

Buczek and Malinowska (1964) stated that coffee beans imported into Poland from Columbia was damaged by the coffee bean weevil A. fasciculatus. The pest is susceptible to low temperature but damage occurs in store houses under warm conditions.

Abraham (1975) reported the tobacco beetle Lasioderma sericorne and arecanut beetle A. fasciculatus as the most important pests of stored ginger and turmeric in Kerala and the extent of damage ranged from 30 to 60%. Both adults and grubs of A. fasciculatus are injurious to stored rhizomes.

Lal and Pillai (1977) recorded heavy infestation of A. fasciculatus on stored tubers of Dioscorea alata and Amorphophalus campanulatus. The beetles lay eggs near the cut end of tubers and the grubs soon after hatching bore into the tuber, form zig zag galleries and feed the internal contents reducing it to a black powder. Severely damaged tubers are rendered unsuitable for consumption or for seed purpose. Emergence holes of adults are distinctly visible on the surface and beetles are seen flying on disturbance around the stock.

Thampan (1979) reported that the most common insect pest damaging the cassava chips in India are A. fasciculatus (DeG.). The adult females lay eggs on chips and the entire life cycle of the pest is completed in the chips. Both adults and larvae feed on the chips reducing them to powder in a short period of storage.

Pumbly and Rees (1983) reported the infestation of A. fasciculatus on four species of yam viz. Dioscorea dumetorum, D. rotunda, D. alata and D. cayenensis. The insects attack mainly on cut ends and damaged areas of the stored tubers.

Nwana and Azodeh (1984) assessed the effect of variety and processing method on the susceptibility of A. fasciculatus, by subsequent weight loss and by an index of susceptibility. Both parameters were significantly influenced by variety, but the least susceptible variety did not suffer the lowest weight loss. The method of processing influence the amount of weight loss and the index of susceptibility. Blanching or cooking before drying reduced the intensity of damage.

French (1984) reported that the infestation of A.fasciculatus on grape fruit in Texas and the extent of damage recorded was 0.1 to 0.5%. The larvae feed and caused gumming, premature colouring and abscision of fruits.

Biology and Ecology of A. fasciculatus

Vanhall and Ziekten (1918) reported that coffee berries having a moisture content of 10.5% was infested with A. fasciculatus. Cotterell (1927) stated that stored cacao beans were attacked by the larvae of A. fasciculatus under dark and humid conditions in storage.

Autuori (1931) observed that A. fasciculatus laid eggs on the berries, only one egg being laid on each which hatch in 6 to 9 days.

The larvae feed on the pulp for 10 to 15 days and on the seed for 25 to 30 days, the pupal period lasts for 6 to 9 days.

Cotterell (1934) noted that two days after emergence the females of A. fasciculatus lay 5 to 6 eggs on an average in the cocoa leaves. The larvae hatch in 3.9 days and feed on the cotyledons for 65 days. The pupal period lasts for 6 days. Only one larva bores into each bean, and during its development one-third of the internal content is consumed by each grub. Even-though the primary injury caused to the testa by the feeding and oviposition of the female is negligible, it serves as a pathway for secondary infestation by other pests like Enhestia. Cocoa beans having a moisture content of 10 to 30% is favourable for oviposition and subsequent larval development, below 8% moisture, the larval duration is greatly prolonged.

Sayed (1935) made a detailed study on the biology of A. fasciculatus on maize, nutmeg and cocoa. The sex ratio of A. fasciculatus on maize at high humidities was about 1 : 1; on nutmeg which appeared to be a less suitable food, more female than males were produced. The life cycle could not be completed on maize and nutmeg when the relative humidity was below 60% and in cocoa below 80%. The life cycle varied inversely with the relative humidity for maize and nutmeg, the period always being less in the former. The life cycle on maize at 27°C varied from 57 days at 60% relative humidity to 29 at 100% and the variation occurring only in the larval period. The pupa is the only stage

that could survive relative humidity at less than 60%. Longevity of adults in maize was 27 to 28 days at 50% relative humidity and in cacao only very few adults lived for more than 20 days at relative humidity below 80%.

Yokoo and Taguti (1938) observed that in Korea all stages of A. fasciculatus feed on chinese yeast sometimes causing serious damage. The larval stage lasted about 14 to 28 days and the pupal stage averaged 12.8 days.

Iragory (1940) found that considerable damage was caused to stored coffee beans and maize in Venezuella by A. fasciculatus. The life cycle lasted 56 days in coffee beans and the development was also completed in stored maize. The infestation was more serious on maize than in coffee beans. The larvae also attacked stored mungo beans (Phaseolus mungo) but not the common leguminous seeds.

Sayed (1940) observed that at 90% relative humidity, larvae of A. fasciculatus completed 4 instars each with a duration of 5 to 7 days. Nicol (1941) reported that A. fasciculatus was common and injurious in the Gold Coast but did not seem to survive winter in Britain.

Nair and Jones (1943) recorded A. fasciculatus as a serious pest of stored tapioca chips in Kerala and studied the biology of the pest. Fifty eggs were laid by a female in 3 to 4 weeks.

Cabal Concha (1956) reported that A. fasciculatus caused considerable damage to stored coffee in Columbia. Biology of the

pest on a variety of flour products including ground cocoa and maize flour was studied. On an average 52 eggs were laid by a female; the eggs hatched in 5 to 7 days and the larval stages lasted for 46 to 66 days at 28°C and about 80% relative humidity. The prepupal and pupal stages lasted 1 to 1.5 and 5 to 8 days respectively. Infestation was heaviest on coffee of poor commercial quality in which the beans were softer and more easily bored but it was also heavy on high quality coffee that was stored for more than two years.

Figueiredojr (1957) reported that A. fasciculatus as an important pest of stored coffee in Brazil where the development from egg to adult was completed in 30 to 45 days and 8 to 10 generations were completed in one year.

Cranham (1960) noticed that better drying of cocoa reduced the infestation by A. fasciculatus. Low moisture contents were advantageous in restricting the development of the pest.

Fussid and Pereira (1967) studied the effect of temperature and humidity on the development of A. fasciculatus on coffee beans and the extent of damage. During hottest months the number of adults obtained per 100 gram of infested beans were 72 to 258 at Santos (hot region) and 11 to 27 at Sao Paulo (cold region) and the percentage of bean attacked were 31.5 to 48.4 and 4.7 to 20.5 respectively. The corresponding figures during the cold months were 0 to 3 and 29 to 180 adults and 0 to 2% and 5.7 to 34.5% of the beans attacked at Sao Paulo and Santos respectively. It was

observed that the development was more when the temperature and humidity were higher. Strumpel (1969) reported that A.fasciculatus does not survive on cacao in winter.

Raghunath and Nair (1970) studied the variation in the biological features of A. fasciculatus when reared on different host materials. The results indicated that tapioca and maize were more favourable sources of food than black gram (Phaseolus mungo), ginger (Zingiber officinale) or arecanut (Areca catechu). The developmental period and the adult life of arecanut strains are longer than those of tapioca strain on all the host materials excepting maize. The tapioca strain of A. fasciculatus did not develop on ginger. Abraham (1975) reported that the life cycle of A. fasciculatus on ginger and turmeric lasted 3 to 4 weeks. The grubs on hatching feed on the internal tissues reducing it to powdery material, leaving the outer covering intact. Pupation takes place within the infested rhizomes. Ginger, dried after pealing off the skin shows maximum susceptibility to the pest.

Studies conducted (Pillai, 1976) with dried cassava chips of different hybrids viz. H 226, H 97, H165, H 2304, H 1687, H 38, H 3641, H 312, H 2509 and H 1310 showed that progeny increase of A. fasciculatus was lower in the chips of H 226, H 2364, while in all other varieties, population build up was higher. The quantity of chips damaged was found directly proportional to the progeny increase and among the varieties tried H 2304 and H 226 were found relatively resistant to A. fasciculatus.

Goncalves et al. (1976) reported that under laboratory conditions in A. fasciculatus the preovipoeition period was six days and under condition of high relative humidity the duration of development was negatively correlated with temperature. On an average a female laid 50 eggs and the longevity of the adult female was 85 to 114 days. When the adults were provided with different food materials for egg laying, considerably large numbers of adult beetles emerged from groundnuts than from coffee bean, maize or soya beans. Beetles kept without food died within 15 days.

Lin (1976) studied the biology of A. fasciculatus on stored maize, sweet potato (Ipomoea batatas) and the medical herb chirotta (Ligusticum acutilobum) and reported six overlapping generations a year in all the hosts. On an average 33.4 eggs were laid by a female on maize, sliced sweet potato or chirette. The extent of damage estimated was 22.6, 31.4 and 26.6% on maize, sweet potato and chirette respectively. He studied the biology of the pest on garlic also.

Vitelli et al. (1976) prepared an artificial diet containing chicken eggs, prawn or other dried fruit, noniodised kitchen salt, baker's yeast, lemon juice, honey gelatin, infant feeding formula (SMA + Similac) and whole wheat flour, which were mixed, baked, cut into chunks and coated with thin layer of mixed paraffin wax and bee wax and successfully studied the biology of A.fasciculatus in the medium. Life cycle from egg to adult was completed in 56 days at 72°F and 26 days at 80°F. Pupation was completed within the diet chunks and the adult took 2 to 3 days to come out of the

chunk and 2 days after emergence they mated. Preoviposition period was 6 days and the longevity of adults was 9 weeks.

2. Sitophilus oryzae, Rice weevil

Family: Curculionidae, Order: Coleoptera

Nature and extent of damage

Joseph and Oommen (1963) recorded the incidence of S. oryzae on tapioca chips in Kerala. The larvae bore into the chips making small tunnels and pupate therein. Adults also cause considerable damage by boring into the chips.

Weidner (1967) stated that cassava slices were severely infested by S. oryzae in Hong Kong.

Mookherjee et al. (1968) reported that in severe infestations of S. oryzae, the extent of damage reached to a maximum level of 70, 100, 100, 25, 22.7 and 11% in paddy, wheat, maize, barley, jowar and bajra respectively. Singh et al. (1968) observed that the amount of food consumed by the single weevil during its development varies from 0.11 g to 2.9 g. While assessing the extent of damage Golebiowska et al. (1972) estimated that the adult of S. oryzae consumed an average of 0.4 mg of wheat per day during the course of development.

Gupta and Kadyan (1972) reported that the extent of damage of wheat due to the infestation of S. oryzae was 20.8%. Karan Singh et al. (1974) observed that the loss in weight due to S. oryzae in different varieties of grains varied from 1.3% to 4.5%. Khokhar and Gupta (1974) reported that in wheat high protein content and high grain moisture were linked to susceptibility and

the hardness of grain were positively correlated with resistance.

Macmillian et al. (1981) noted that the loss in weight in grain due to the damage by S. oryzae (L.) during storage varied from 4 to 52% in different sorghum. Banerjee and Nazimuddin (1985) reported that the maximum weight loss to raw rice by the larvae of S. oryzae was 57% whereas by the adult it was only 16.2%.

Biology and Ecology of S. oryzae (L.)

Rice weevil is an important pest of stored grain like rice, wheat, barley, oats, maize, bajra and other stored commodities and of cosmopolitan distribution. Importance of rice weevil as a pest of tapioca chips was reported only from India and Hong Kong. Studies on the biology and bionomics of S. oryzae have been reported by various workers on stored grains in India.

Purthi and Mohan Singh (1950) reported that rice weevil is found throughout India. There are generally 4 to 5 generation a year and on an average life cycle is completed in one month during warm weather and is about 4 to 6 months during autumn and winter.

Reddy and Michelbacher (1953) reported that the life stages of Calandra oryzae were longer in boiled wheat than raw wheat and the adults weighed heavier in parboiled wheat.

Parvett (1960) reported that the peak egg laying of weevil reached during third week of oviposition. De Arora and Enriqueta (1962) studied the ecology of rice weevil and reported that maximum number of rice weevil developed at 90% RH and 30°C and the life history was completed in 35 to 40 days in Argentina.

Khare and Agrawal (1963) observed that the favourable temperature of egg laying for S. oryzae in wheat and maize was 30°C and 75 RH.

Joseph and Oommen (1963) reported the infestation of S. oryzae on tapioca chips in Kerala. Weidner (1967) recorded the occurrence of S. oryzae on cassava in Hong Kong.

Tootia and Singh (1968) noted that the development of the larvae of S. oryzae was better on seeds which are preferred by the weevil for oviposition.

Karan Singh et al. (1973) found that the optimum conditions for multiplication of S. oryzae in wheat was 30°C and 75% RH.

Tyagi and Girish (1975) observed that average number of egg plugs detected on a single kernel was maximum on biggest sized kernels and minimum on smallest sized kernels.

Atwal (1976) reported the occurrence of S. oryzae in paddy field also. A female lays about 400 eggs and the egg hatches in six to seven days.

Sharma and Chahal (1977) observed that the rate of egg laying of rice weevil increased gradually up to 4th week and later

decreased. Singh Karan (1977) stated that the peak breeding period of the weevil was from July to October in Midnapur District in West Bengal. Murthy and Ahamed (1978) reported that the life cycle was completed in 30 days.

Borikar and Tayde (1979) stated that the developmental period of S. oryzae in different varieties of sorghum showed no significant difference between the varieties.

Sharma and Chahal (1980) found that the number of weevils developed at 8.5 and 11.2 per cent initial moisture content was more or less the same, but when the moisture per cent increased from 11.2 to 17, the number of adult emerged were more. There was no egg laying at 8.5 per cent moisture. Maximum egg laying was recorded in the case of 21 day old weevils at 28 ± 1°C and 15 per cent moisture content.

Sudhakar and Pandey (1983) also reported that raw rice grains were preferred to par boiled rice for oviposition and development of S. oryzae and the devolopmental period was longer in par boiled rice.

3. Tribolium castaneum (Hbst.) - Red Flour Beetle

Family: Tenebrionidae, Order: Coleoptera

T. castaneum is a serious pest of flour mills, warehouses and grocery stores and infest a vide varieties of food grains and processed milled products, dried vegetables and fruits. The occurrence of this pest is also reported from copra (Lever, 1934), cotton seed (Bissel, 1935), stored cassava (Frappa, 1938), potato

flour (Kunke, 1938), cacao (Riley, 1957), tapioca flour (Joseph and Oommen, 1963), groundnut (Champ, 1965), oak (Jobert, 1966), Soya beans (Heape, 1966), palm kernels (Riley, 1957), oil cake (Methlan, 1938), yam flour (Courtecy, 1967), cashew nuts (Pinheira, 1968), Gur (Verma and Singhvi, 1973), meat and pepper (Jacob and Mohan, 1973), dried fish (Osuji, 1974), dried capsicum and beans (Teriaki and Yerner, 1975), walnut (Gill et al., 1975), Ginger, turmeric, cardamom (Abraham, 1975) and on dried mushroom (Srinath and Prasad, 1975).

Cotton (1938) reported that T. castaneum does not attack the stored grain unless it is broken or damaged by other insects.

Joseph and Oommen (1963) stated that the rust red flour beetle T. castaneum infests tapioca chips on storage and is occurring all over Kerala as a major pest in Tapioca flour and starch. Both adults and grubs feed on tapioca starch and tapioca flour throughout the year. The incidence of this pest was more in tapioca flour.

Minor Pests

1. Pyralis manihotalis (Guen.)

Family: Pyralidae, Order: Lepidoptera

Pyralis manihotalis is considered as a minor pest of tapioca chips. The occurrence of this as a pest of tapioca chips was reported from Kerala (Joseph and Oommen, 1963).

Beeson (1919) observed P. manihotalis (Guen.) breeding in Opuntia monacantha in Dehra Dun.

Joseph and Oommen (1963) reported the occurrence of tapioca moth E. *menihotalis* as a pest of tapioca chips. The larvae settle down in silken shelves which they rapidly make by webbing together small particles and frass. Damage is severe when they feed on materials already infested with R. *dominica*, A. *fasciculatus*, *Stegobium paniceum*. The pest is occurring throughout the year.

2. *Oryzaephilus surinamensis* (L.)

Family: Cucujidae, Order: Coleoptera

O. *surinamensis* is a serious pest of stored grain and processed cereal products. This was also recorded as pest of tea and desiccated copra (Jepson, 1934), stored flour (Takahashi, 1937), dried dates (Lever, 1943), shelled walnuts (Smith, 1960), oak (Jobert, 1966), raw and yellow crystal sugar (Audroy and Aitken, 1966), processed cereal products (Loschiavo and Smith, 1970), groundnut and sunflower seeds (Verner, 1971), stored turmeric (Srinath and Prasad, 1975), walnuts (Gill *et al*., 1975), noodles and lasagna macaroni (Cline and Highland, 1976), dried fruits (Bucheles, 1982) and soya beans (Horton, 1982).

Joseph and Oommen (1963) reported the occurrence of saw toothed grain beetle, O. *surinamensis* (L.) as a minor pest of stored tapioca chips from Trivandrum, Quilon and Alleppey Districts of Kerala State. Both adults and grubs feed on tapioca chips and occur throughout the year.

3. Rhizopertha dominica (F.)

Family: Bostrychidae, Order: Coleoptera

Potter (1935) reported that R. dominica is an important pest of stored grains particularly in India, Argentina, the United States and New South Wales and has also seen recorded as attacking wood.

This pest was also recorded as a pest of biscuits, stored cassava tubers (Frappa, 1938), coriander seeds and flours (Lever, 1943).

Joseph and Oommen (1963) stated that the lessor grain borer R. dominica occurs all over Kerala as a minor pest of stored tapioca chips. Both adult and larvae cause damage to stored chips reducing them to a tangled mass of flour, web and excreta. The adult can bore directly into the par boiled chips.

4. Stegobium paniceum (L.)

Family: Anobiidae, Order: Coleoptera

Stegobium paniceum is a serious pest of dried roots of medical plants (Porter, 1934 and Srivastava and Saxena, 1975). This was also recorded as a pest of cotton seeds (Bissel, 1935), onion and lettuce seed (Finkenbrink, 1934), flour (Takahashi, 1937), bamboo pieces (Lindley, 1942), stored beans (Olalguiage faure, 1953), cassava chips (Joseph and Oommen, 1963), dried mushroom (Srinath and Saxena, 1975), turmeric, ginger (Abraham, 1975), coriander (Brar and Chahal, 1980) and dried chilli (Rezaur et al., 1982).

5. Laemophloeus minutus (Oliv.)

Family: Cucujidae, Order: Coleoptera

The flat grain beetle L. minutus is a secondary pest of stored grains and other food stuffs. This was recorded as pest of cotton seed (Bissel, 1936), stored grain (Cotton, 1938), rice (Balzer, 1942), wheat (Howe, 1943), dried fruits (Zeck, 1943), maize (Tiensue, 1947) and cacao (Riley, 1957).

Joseph and Oommen (1963) recorded the flat grain beetle L. minutus (Oliv.) as a secondary pest of tapioca chips after infestation by other insects. They feed on tapioca flour damaged by other insects, throughout the year.

6. Lasioderma serricorne (F.)

Family: Anobiidae, Order: Coleoptera

L. serricorne is an important post of great variety of stored products of plant and animal origin. This was recorded as a pest of turmeric (Srivastava and Saxena, 1975; Srinath and Prasad, 1975; Abraham, 1975), tobacco (Reed, 1935), dried ginger, cotton seed meal (Bissel, 1935), stored cumin (Morris, 1938), stored tobacco seed, rice, maize and cacao (Vanderveen, 1940), dried bean pods and dried cabbage leaves (Lever, 1943), dried fruits (Zeck, 1943), cereal grains (Howe, 1957), cassava chips (Joseph and Oommen, 1963), stored cacao (Ghosh and Silva, 1972), teak nurseries (Fernando, 1965), stored castor beans (Hussain and Khan, 1966), dried mushrooms (Srinath and Prasad, 1975), walnuts (Gill et al., 1975), black mushroom (Srinath and

Prasad, 1980), soyabeans (Sirisingh and Kogan, 1981), stored seeds of the drug plant isabgul (Plantago ovata) and dried chilli and coriander (Rezaur, et al., 1982).

Joseph and Commen (1963) reported that the cigarette beetle L. serricorne (F.) occurs all over Kerala as a minor pest of tapioca chips. The grubs and adults bore into the chips and reduce it to mere powder throughout the year. Severe damage was noticed on par boiled tapioca chips collected from Central Travancore.

White (1982) reported that L. serricorne (F.) is an important pest of drugs, tobacco seeds, spices, cereal products, leather and museum specimens. Larvae have the habit of boring into dead hard woods and soft woods.

7. Tenebroides mauritanicus (L.)

Family: Tenebrionidae, Order: Coleoptera

T. mauritanicus was reported to infest a number of stored products like maize and sorghum (Chiaromonte, 1934), rice (Myers, 1934), cotton (Bissel, 1935), tobacco and stored cumin seed (Morris, 1938). Prappa (1938) recorded T. mauritanicus as a pest of stored cassava tubers. Weidner (1967) reported the occurrence of this pest on cassava stock in Hong Kong. This pest was found to occur in shelled groundnuts (Monro et al., 1966), cashewnuts (Pinheira, 1968), starch based stored products (Espanol, 1969), almonds (Moreira and Beiju, 1973), stored ginger and turmeric (Abraham, 1975), stored walnuts (Gill et al., 1975) and dried meat (Rout et al., 1978).

Livingstone and Reed (1936) recorded that T.mauritanicus (L.) is predaceous on all stages of L. serricorne.

8. Ephestia cautella (Wlk.)

Family: Pyralidae, Order: Lepidoptera

Lefroy (1906) reported that E. cautella feed on rice and wheat flour in India. This pest was also recorded as a pest of stored groundnut (Ramakrishna Ayyar, 1919), maize and sorghum (Chiaromonte, 1934), stored coconuts and copra (Bandur, 1940), groundnut, cacao (Riley, 1957), chocolate (Smedley, 1966), almonds (Achillidee, 1967), cashew nuts (Pinheira, 1968), shelled groundnut (Mookherjee et al., 1969), soyabeans (Kapoor et al., 1972), stored cacao (Ghosh and Silva, 1972 and Smith, 1972), walnuts (Gill et al., 1975 and Srinath and Gill, 1976) and chilli powder (Ramzan and Darsan Singh, 1982).

Joseph and Oommen (1963) reported that the fig moth E. cautella Wlk. occurs all over Kerala as a minor pest of tapioca chips. The larvae spin silken threads, webbing and matting the flour particles together and bore into the chips.

Lal and Varma (1974) reported that the larvae of fig moth E. cautella attack dried fruit, chocolate, biscuits, tamarind seed, cacao seeds, lac, malted milk, dried mango juice, anchor, garlic bulbs, appricot seeds, cereals, cereal products, oil seeds, groundnut flour, and stored onion bulbs.

9. Setomorpha rutella (Zell.)

Family: Tineidae, Order: Lepidoptera

Fletcher (1919) reported the distribution of S. rutella in India and Ceylon. Oommen and Joseph (1961) recorded this as a pest of stored rice, sago, coriander, gingelly, tapioca, pulses, pepper, coffee beans and garlic in Kerala and studied the detailed biology of the pest.

Heavy infestation usually occurs and whole grain and grain products are completely reduced to a mass of webbings of frass and excreta.

10. Erechthias zebrina (Butler)

Family: Lyonetiidae, Order: Lepidoptera

Joseph and Oommen (1963) reported E. zebrena occurs as a minor pest of tapioca starch and flour in South Kerala. The caterpillar webs together particles of tapioca flour with a silken thread. Constructs a small tubular gallery and feeds from within.

MATERIALS AND METHODS

MATERIALS AND METHODS

Materials

Tapioca chips

Sun dried raw chips of tapioca varieties viz. Malayan 4, Sree Sahya, Sree Visakham, Neelagiri, Njaruck and Vella were used for the studies. The tubers were procured from the District Agricultural Farm, Peringamala, Trivandrum, and made into chips.

M 4 variety was used for the preparation of par boiled tapioca chips. Chips of tapioca tubers were immersed in boiling water for two minutes and then taken out, sun dried and used.

Glass trough: Circular glass troughs of 20 x 15 cm were used for the bulk rearing of different pests and also for the studies on the nature and extent of damage caused by them.

Specimen tubes: Specimen tubes of size 7 x 2 cm were used to study the biology of different pests.

Glass chimneys: Glass chimneys were used for rearing adult moths.

Petri dishes: Petri dishes of 9 cm dia. were used to study the fecundity and development of different stages of insect pests.

Muslin cloth: Muslin cloth was used to cover the open end of the specimen tubes, chimneys and troughs.

Rubber bands: Rubber bands were used to fix the muslin cloth to the glasswares.

Gunny bags: Gunny bags of size 40 x 20 cm were used to study the varietal susceptibility of pests in storage.

METHODS

A random sample survey on the population of various insect pests and the extent of damage caused by these insects to stored tapioca chips was conducted at monthly intervals. The survey was conducted from 1-8-1984 to 30-11-1984 in ten centres in Trivandrum District viz. Palode, Parassala, Nedumangad, Venjaramoodu, Pothencode, Chirayinkil, Vembayam, Chalai, Sreekariyam and Mangalapuram, where tapioca chips were stored. Random samples of 200 g were drawn from the bulk stock and brought to the laboratory. The samples were transferred in glass troughs and covered with moistened muslin cloth and kept inside wooden box undisturbed for a month. After one month counts of populations of different species of insect pests including their life stages were taken. The extent of damage caused by them was studied by taking weight of infested and non-infested chips and also the weight of powdered materials. The pests collected from the samples were sent for identification.

Nature and extent of damage to tapioca chips caused by different insect pests

Insect pests of tapioca chips were mass cultured in the laboratory. Thirty numbers of each insect species were exposed separately in one kg of tapioca chips, kept in glass trough and covered with muslin cloth and kept undisturbed in insect rearing cages. Observations were taken on the weight of chips damaged by the pests and expressed as percentage of infestation. The weight of powdered material was taken separately and accounted as percentage weight of powdered material. The population count of

different stages of the pest at monthly intervals were also observed. The nature and extent of damage caused by Araecerus fasciculatus, Sitophilus oryzae and Tribolium castaneum were studied on raw and par boiled chips.

Susceptibility of different varieties of tapioca to different pest species

Studies on varietal susceptibility to A. fasciculatus and S. oryzae were undertaken. Two kg of each variety of tapioca chips were taken in gunny bags and stiched with country twine and labelled. Bags containing different varieties were arranged randomly in a circle in insect rearing cage. A trough containing mass cultures of the insect was placed in the middle of the circle for infestation. Observations on the percentage of infestation, percentage weight of powdered material, and the population count of different stages of the pest were taken at monthly intervals for a period of three months.

Influence of different varieties of tapioca on the biology of stored insects

Biology of A. fasciculatus and S. oryzae on tapioca chips of six different varieties were studied. Tapioca chips of different varieties were taken in specimen tubes and ten pairs of adults collected from the bulk rearings of each variety were introduced and closed with muslin cloth. The beetles were separated from the host material after 24 hours. Number of eggs laid were counted under a stereo microscope. Daily observations

were made on the date of emergence of grubs. Tapioca chips were broken gently without killing the grubs to locate the moulted skin and head capsule to study the duration of different instars and fresh chips were introduced as and when necessary. The longevity of the beetles and the sex ratio were recorded. Observations were continued till adult emergence.

In order to study the effect of parboiling the chips on the biology of A. fasciculatus and S. oryzae the insects were confined on the parboiled chips of the popular variety M 4. Observations were made as described earlier.

All the experiments were conducted in completely randomised design with three replications.

Transformations such as $\sqrt{x}$ and $\sqrt{x+1}$ were made for the statistical analysis of the data.

RESULTS

RESULTS

Survey of insect pests of stored tapioca chips

The results of the random survey conducted at different centres in Trivandrum District are presented. The survey was aimed at exploring the extent of damage of tapioca chips stored for different periods due to attack by insect pests.

The major pests observed throughout the survey were, tapioca weevil Araecerus fasciculatus (DeG.), rice weevil Sitophilus oryzae (L.), and rust red flour beetle Tribolium castaneum (Hbst.). The other pests observed were lesser grain borer Rhizopertha dominica (F.), cigarette beetle Lasioderma serricorne (F.), drug store beetle Stegobium paniceum (L.), flat grain beetle Laemophloeus minutus (Oliv.), tapioca moth Pyralis manihotalis (Guen.), tobacco moth Setomorpha rutella (Zell.), flour moth Ephesthia zebrina (Butler), fig moth Ephestia cautella (Wlk.), Tenebroides mauritanicus (L.) and saw toothed grain beetle Oryzaephilus surinamensis (L.), (Plate I, II, III and IV).

Location: Palode

The data relating to population of different insect pests and extent of damage caused by them in samples of tapioca chips stored for different periods collected from Palode are presented in Table 1.

Araecerus fasciculatus

It was observed that the larval population of A. fasciculatus ranged from 8 to 97 under different durations of storage. There

Plate I

Araecerus fasciculatus

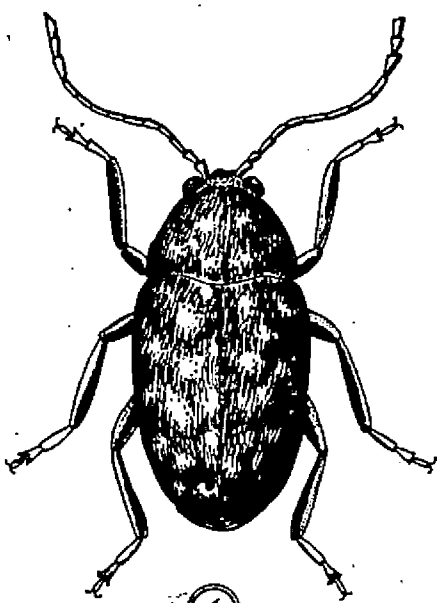
1. Male
2. Female

Plate II

Sitophilus oryzae

1. Male
2. Female

PLATE I



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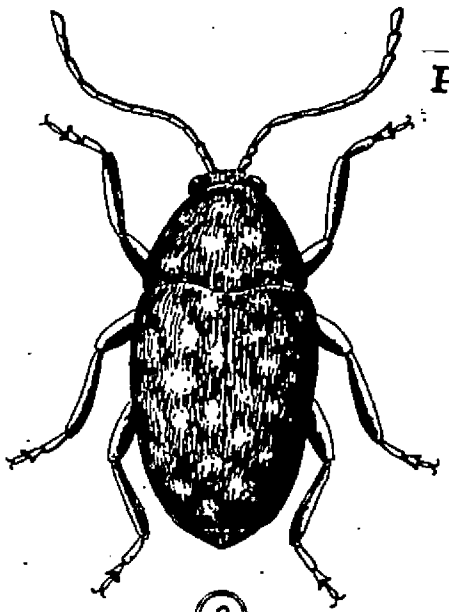

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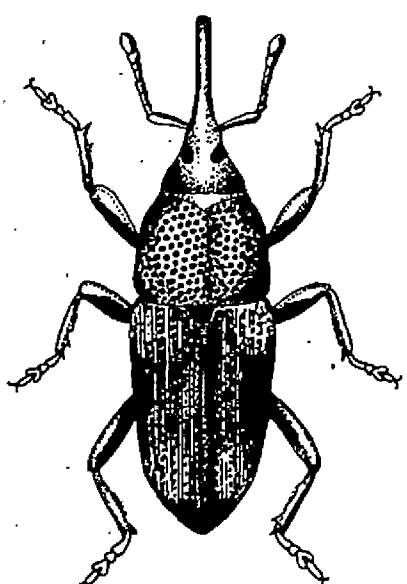

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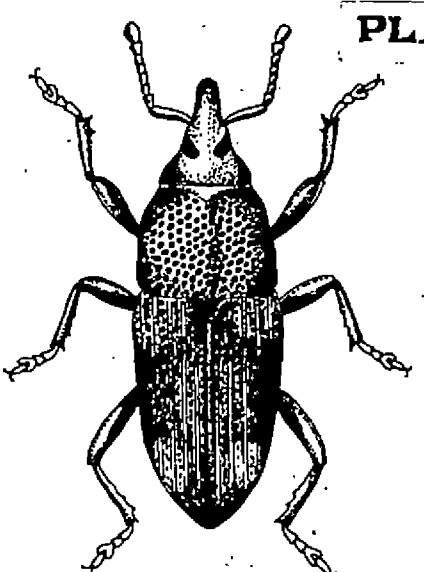

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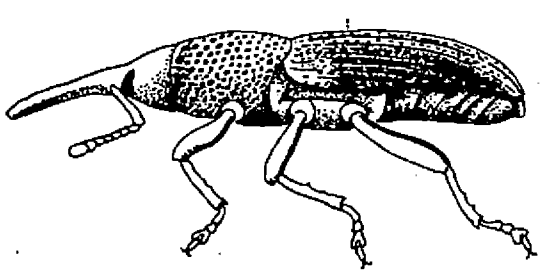

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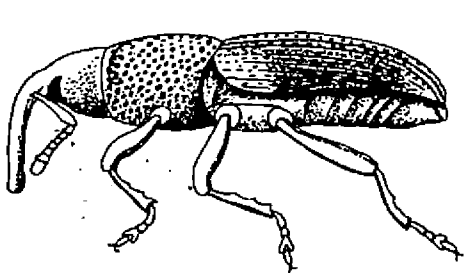

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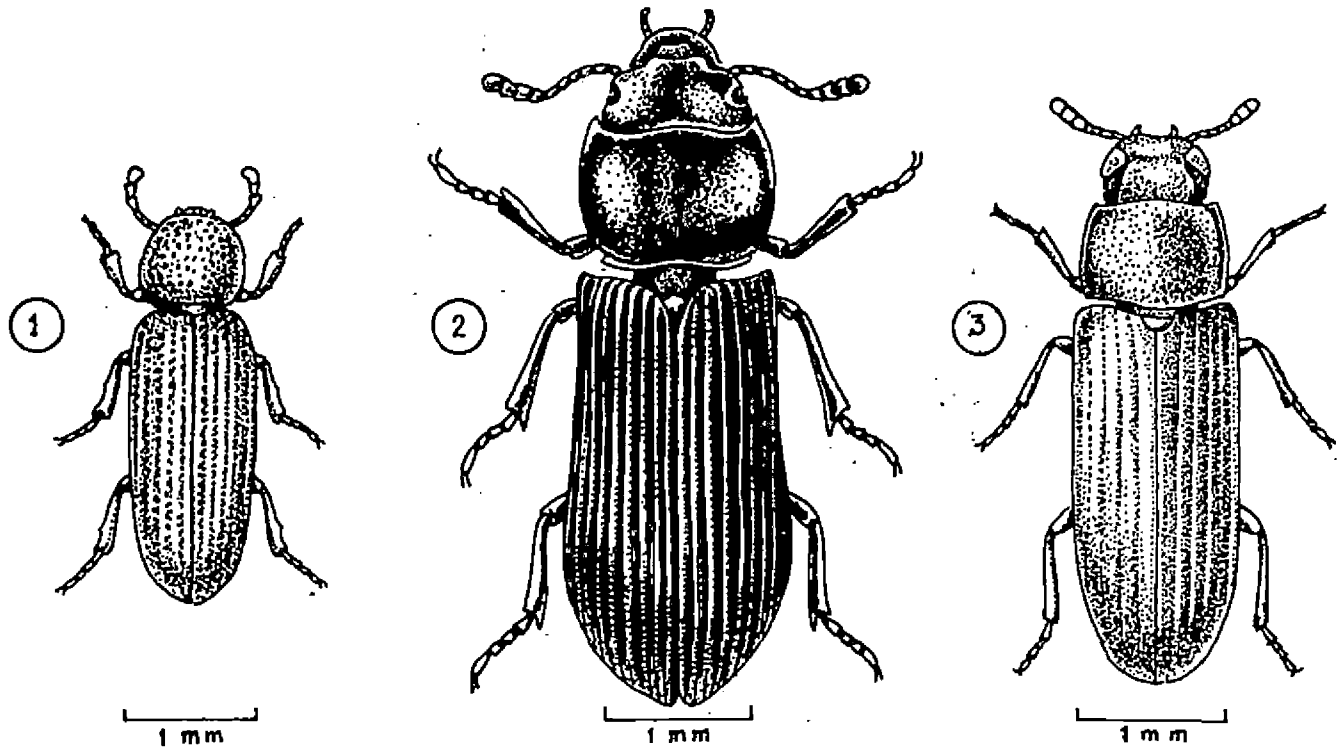
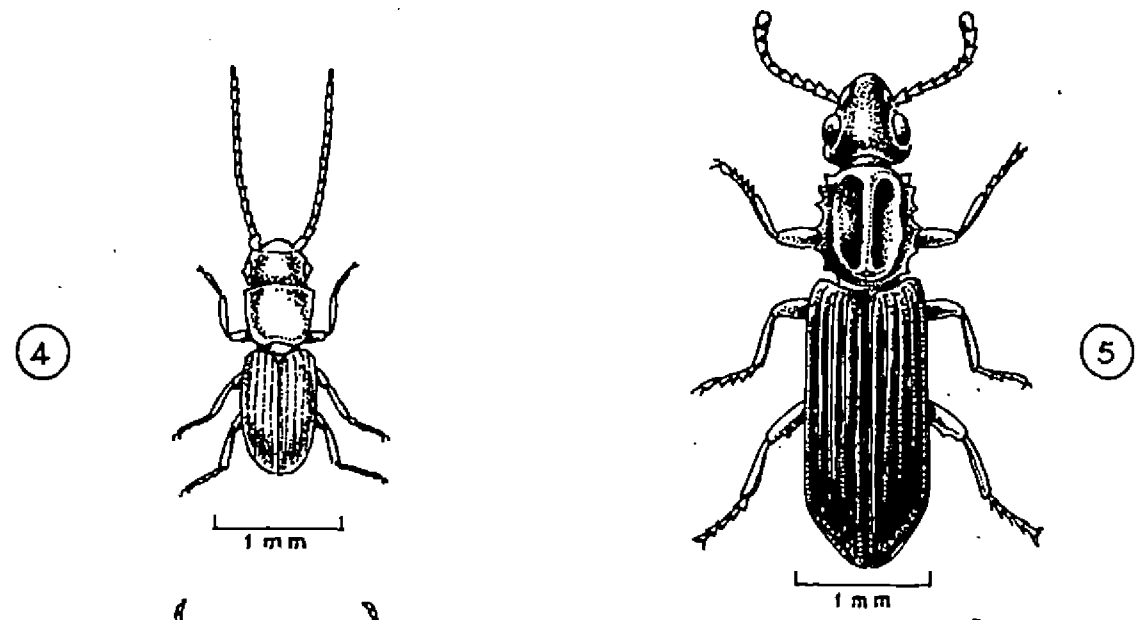
Plate III

1. Lasioderma sericorne
2. Tenebroides mauritanicus
3. Tribolium castaneum
4. Laemophloeus minutus
5. Oryzaephilus surinamensis
6. Lasioderma sericorne
7. Stegobium paniceum

PLATE III





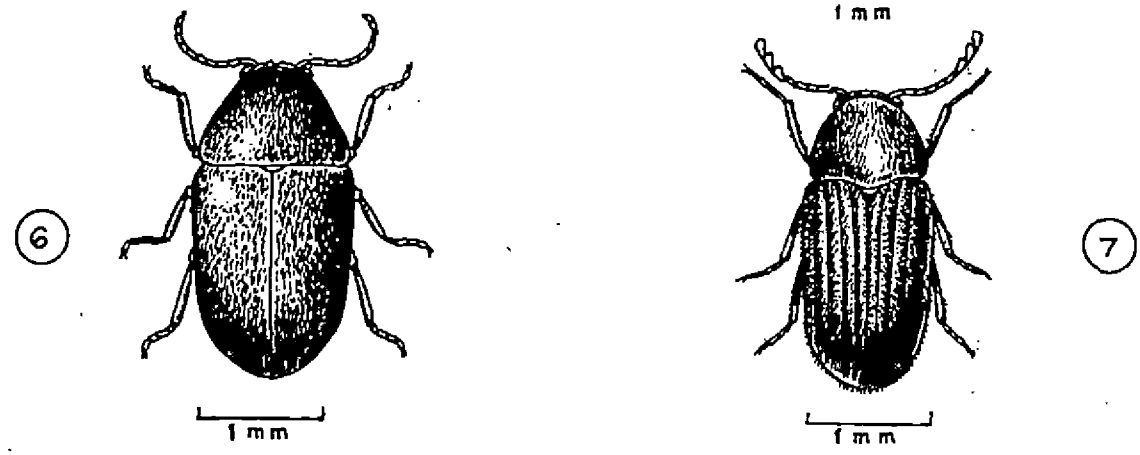


Table 1. Population count and extent of damage caused by different insect species found in the tapioca chips collected from Palode

Insect pests		Duration (in months) after storage			
		1	2	3	4
A. fasciculatus	Larva	8	31	97	27
	Pupa	5	11	16	-
	Adult	40	62	187	12
T. castaneum	Adult	1	3	7	26
S. oryzae	,,	2	4	14	8
R. dominica	,,	1	2	1	-
L. serricorne	,,	1	2	-	1
S. paniceum	,,	-	-	1	-
L. minutus	,,	-	-	2	-
P. manihotalis	,,	-	-	-	1
S. rutella	,,	-	-	1	-
E. zebrena	,,	-	-	1	-
E. cautella	,,	-	-	-	1
O. surinamensis	,,	1	-	2	-
Extent of damage					
Quantity infested (g)		25.4	158.5	200.0	200.0
Quantity powdered (g)		1.2	14.8	186.0	200.0

was gradual increase in the population as the duration of storage increased from two to three months. Four months after storage the population of A. fasciculatus was reduced to 27.

As in the case of larvae, number of pupae also increased gradually up to three months, but pupae were not observed after four months of storage.

With regard to adult population, 40 adults were observed after a month of storage. The population was found to increase to 187 in the samples stored for three months which got drastically reduced to a level of twelve adults in four months.

Tribolium castaneum

There was a gradual increase in adult population of T. castaneum from 1 to 26 as the duration of storage increased from one to four months.

Sitophilus oryzae

The adult population of S. oryzae increased from 2 to 14 as the duration of storage increased from one to three months. But after four months, the adult population count was reduced to eight.

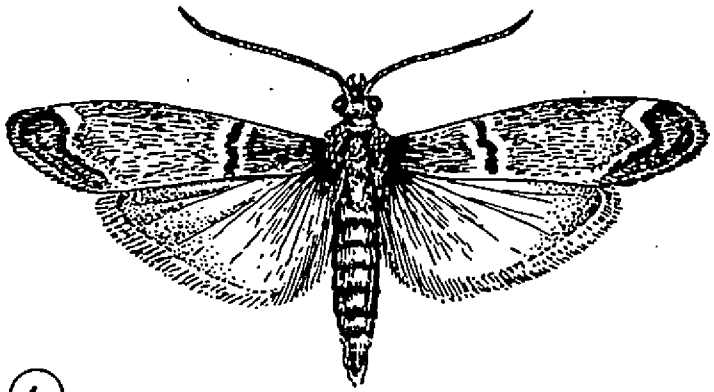
Location: Parassala

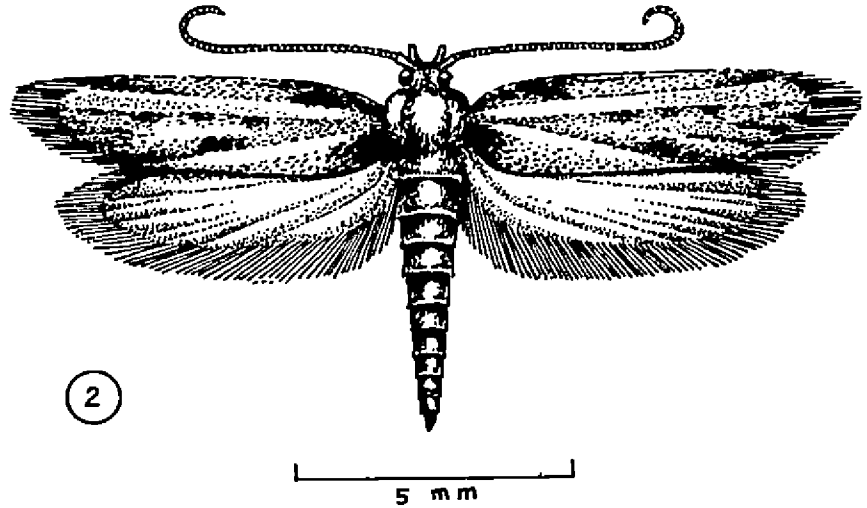
Observations on the population of different insect pests and extent of damage caused in samples of tapioca chips stored for different periods collected from Parassala are presented in Table 2.

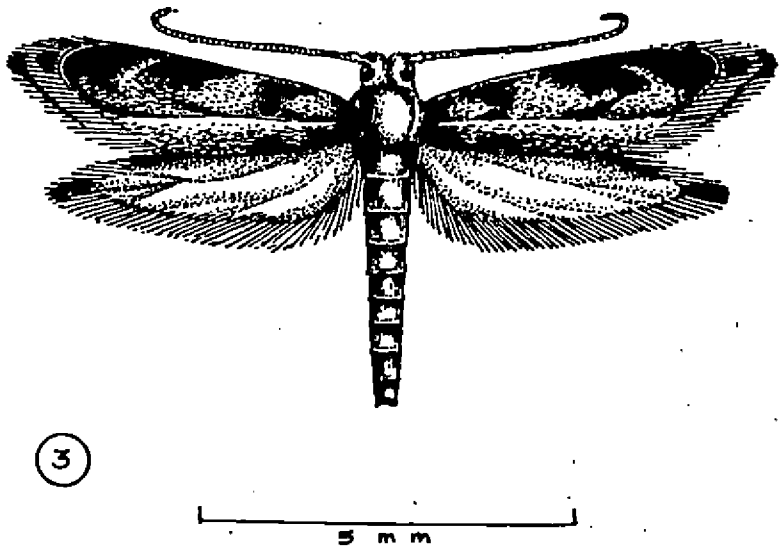
Plate IV

1. Ephestia cautella
2. Setomorpha rutella
3. Brechthiaa zebrina
4. Pyralis manihotalis

PLATE IV







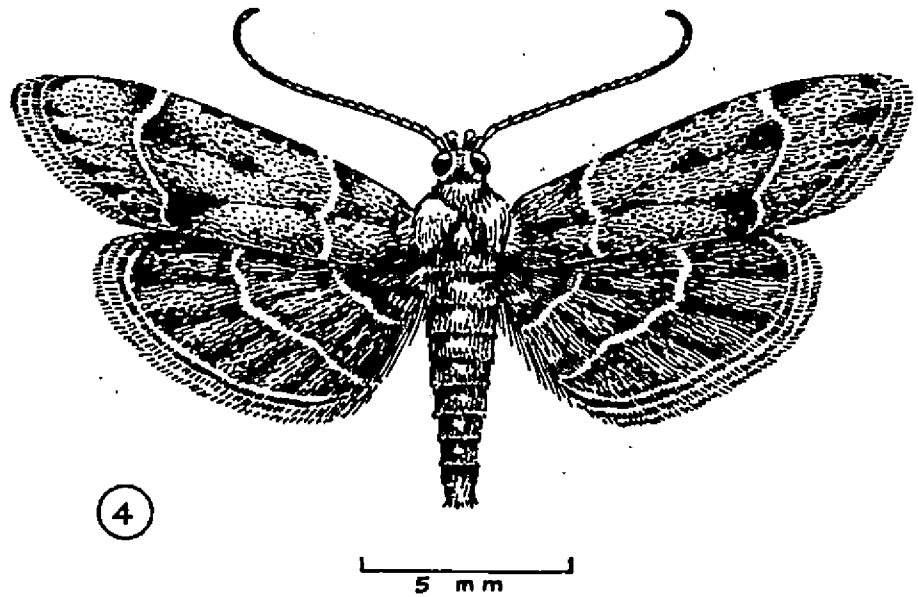


Table 2. Population count and extent of damage caused by different insect species found in the tapioca chips, collected from Parassala

Insect pests		Duration (in months) after storage			
		1	2	3	4
A. fasciculatus	Larva	5	58	141	34
	Pupa	1	7	17	3
	Adult	14	62	201	17
T. castaneum	Adult	1	4	7	12
S. oryzae	,,	2	4	12	4
R. dominica	,,	-	-	2	2
L. serricorne	,,	-	-	-	3
G. paniceum	,,	-	2	-	1
L. minutus	,,	-	-	-	5
P. manihotalis	,,	-	1	-	1
S. rutella	,,	-	-	1	-
E. zebrena	,,	-	-	2	-
E. cautella	,,	-	-	-	1
O. surinamensis	,,	2	1	2	-
Extent of damage					
Quantity infested (g)		45.9	172.2	200.0	200.0
Quantity powdered (g)		1.7	15.1	189.4	200.0

Araecerus fasciculatus

The larval population of A. fasciculatus ranged from 5 to 141 under different durations of storage. There was a gradual increase in the population, as the duration of storage increased from one to three months. Then the larval population drastically reduced to a level of 34 at the end of four months.

Population of pupae was maximum in chips stored for three months (17). There was a gradual increase in pupal population as the duration of storage increased from one to three months. Then the pupal population was reduced to a level of three as the duration of storage increased to four months.

With regard to adult population also, there was a gradual increase in population from 14 to 201, as the duration of storage increased from two to three months. Then there was a drastic reduction in adult population and reaching to a level of 17 at the end of four months.

Tribolium castaneum

As the duration of storage increased from one to four months, there was a gradual increase in adult population of T. castaneum from one to twelve.

Sitophilus oryzae

The adult population of S. oryzae ranged from two to twelve under different periods of storage. There was a gradual increase in adult numbers as the duration of storage increased which

reached to a maximum of twelve in chips stored for three months. Then there was a gradual decrease in adult population to a level of four after four months of storage.

Location: Nedumangad

Table 3 represents the data on the population levels of different posts affecting the stored tapioca chips, collected from Nedumangad. The extent of damage was also assessed.

Araecerus fasciculatus

It was observed that the average larval population of A. fasciculatus ranged from 11 to 197 under different durations of storage. There was a gradual increase in the population as the duration of storage increased from one to three months. Then there was a drastic reduction on larval population to a level of 24 at the end of four months.

As in the case of larvae, population of pupae also increased gradually up to three months and then there was a reduction to a level of two in four months old stock.

The adult population of A. fasciculatus ranged from 56 to 147 under different periods of storage. There was a gradual increase in the population as the duration of storage increased from one to three months. Then the adult population reduced to a level of 56 at the end of four months.

Tribolium castaneum

T. castaneum was not observed in tapioca chip samples up to a storage period of two months. Then there was a gradual increase

Table 3. Population count and extent of damage caused by different insect species found in the tapioca chips, collected from Nedumangad

Insect pests		Duration (in months) after storage			
		1	2	3	4
A. fasciculatus	Larva	11	48	197	24
	Pupa	3	9	16	2
	Adult	56	68	147	56
T. castaneum	Adult	-	-	3	15
S. oryzae	,,	3	11	16	19
R. dominica	,,	-	7	3	4
L. serricorne	,,	1	-	1	2
S. paniceum	,,	-	1	-	-
L. minutus	,,	-	-	2	4
P. manihotalis	,,	-	-	1	2
S. rutella	,,	-	1	-	2
E. zebrena	,,	-	-	-	1
E. cautella	,,	-	-	1	-
O. surinamensis	,,	3	2	-	-
T. mauritanicus	,,	1	-	-	-
Extent of damage					
Quantity infested (g)		28.4	186.2	200.0	200.0
Quantity powdered (g)		1.2	17.1	198.3	200.0

in adult population from three to fifteen as the duration of storage increased from three to four months.

Sitophilus oryzae

The adult population of S. oryzae ranged from three to nineteen under different periods of storage. There was a gradual increase in adult population as the duration of storage increased and reached a maximum of 19 in chips stored for four months.

Location: Venjaramoodu

The data relating to the population of different insect pests and extent of damage caused to samples of tapioca chips stored for different periods collected from Venjaramoodu are presented in Table 4.

Araecerus fasciculatus

It was observed that the average larval population of A. fasciculatus ranged from 9 to 194 under different durations of storage. There was a gradual increase in the population as the duration of storage increased from one to three months and reached to a level of 194, three months after storage. Then the population of larvae got reduced to a level of 68 in four months after storage.

The maximum population of pupae in chips stored for three months was sixteen. Then the pupal population decreased to zero in four months.

With regard to adult population also, there was a gradual increase in population from 24 to 176 as the duration of storage

Table 4. Population count and extent of damage caused by different insect species found in the tapioca chips, collected from Venjaramoodu

Insect pests		Duration (in months) after storage			
		1	2	3	4
A. fasciculatus	Larva	9	86	194	68
	Pupa	5	12	16	-
	Adult	24	107	176	34
T. castaneum	Adult	-	2	6	7
S. oryzae	,,	5	8	13	-
R. dominica	,,	-	1	3	-
L. serricorne	,,	1	-	2	1
S. Paniceum	,,	2	1	1	-
L. minutus	,,	-	-	-	6
P. nanihotalis	,,	-	-	1	1
S. rutella	,,	-	1	-	1
E. zebrena	,,	-	-	-	2
E. cautella	,,	-	-	-	1
O. surinamensis	,,	4	2	-	-
T. mauritanicus	,,	1	-	-	-
Extent of damage					
Quantity infested (g)		50.6	186.4	200.0	200.0
Quantity powdered (g)		1.4	17.9	198.1	200.0

increased from one to three months. Then there was a drastic reduction in adult population and reached to a level of 34 at the end of four months.

Tribolium castaneum

Adult population of T. castaneum was practically nil after one month of storing the chips. There was a gradual increase in adult population as the duration of storage increased from two to four months, the number being two, six and seven respectively.

Sitophilus oryzae

With regard to S. oryzae the adult population under different periods of storage gradually increased and reached to thirteen as the duration of storage increased to three months. Adult insect was not seen in chips stored for four months.

Location: Pothencode

In Table 5 the data relating to the population of different insect pests and the extent of damage assessed in samples of tapioca chips stored for different periods collected from Pothencode are presented.

Araecerus fasciculatus

It was observed that the average larval population of A. fasciculatus ranged from 8 to 161 under different durations of storage. There was a gradual increase in the population as the duration of storage increased from one to three months, and

Table 5. Population count and extent of damage caused by different insect species found in the tapioca chips, collected from Pothencode

Insect pests		Duration (in months) after storage			
		1	2	3	4
A. fasciculatus	Larva	8	57	161	43
	Pupa	-	7	18	14
	Adult	18	46	182	29
T. castaneum	Adult	2	11	19	57
S. oryzae	,,	1	3	7	2
R. dominica	,,	1	2	-	-
L. serricorne	,,	-	1	1	2
S. paniceum	,,	1	-	1	-
L. minutus	,,	-	-	-	6
P. manihotalis	,,	-	-	1	1
S. rutella	,,	-	-	1	2
E. zebrena	,,	-	-	1	2
E. cautella	,,	-	-	-	1
O. surinamensis	,,	3	1	2	-
T. mauritanicus	,,	-	2	-	-
Extent of damage					
Quantity infested (g)		145.0	199.6	200.0	200.0
Quantity powdered (g)		2.2	68.4	198.0	200.0

the population was drastically reduced to a level of 43 in four months old stock.

Population of pupae also increased gradually and reached to a level of 18 in three months under stored conditions and then reduced to a level of 14 in four months old stock.

With regard to the adult population it was found to increase to a level of 182 in the samples of three months after storage and the population was drastically reduced to a level of 29 adults in four months.

Tribolium castaneum

There was a gradual increase in adult population of T. castaneum from 2 to 37 as the duration of storage increased from one to four months.

Sitophilus oryzae

The adult population of S. oryzae also increased gradually up to three months and reached to a level of seven, then reduced to two in four months old stock.

Location: Chirayinkil

The data relating to the population of different insect pests and the extent of damage assessed in samples of tapioca chips stored for different periods collected from Chirayinkil are presented in Table 6.

Table 6. Population count and extent of damage caused by different insect species found in the tapioca chips, collected from Chirayinkil

Insect pests		Duration (in months) after storage			
		1	2	3	4
A. fasciculatus	Larva	6	67	112	37
	Pupa	3	11	23	-
	Adult	14	162	218	27
T. castaneum	Adult	-	5	11	14
S. oryzae	,,	1	4	8	-
R. dominica	,,	5	2	4	1
L. serricorne	,,	-	1	2	1
S. paniceum	,,	-	1	2	-
L. minutus	,,	-	2	4	7
P. manihotalis	,,	-	-	1	1
S. rutella	,,	-	2	-	1
E. zebrena	,,	-	2	1	-
E. cautella	,,	1	-	-	1
O. surinamensis	,,	2	1	1	3
Extent of damage					
Quantity infested (g)		49.1	190.7	200.0	200.0
Quantity powdered (g)		1.9	44.8	200.0	200.0

Araecerus fasciculatus

It was observed that the average larval population of A. fasciculatus ranged from 6 to 112, under different durations of storage. There was a gradual increase in the population, as the duration of storage increased from one to three months and population was drastically lowered to a level of 37 in four months old stock.

As in the case of larvae, population of pupae also increased gradually up to three months; but pupae were not observed in four months old stock.

With regard to adult population, 14 adults were observed one month after storing of the chips. The population increased to a level of 218 in the samples after three months of storage and then reduced to a level of 27 adults in four months.

Tribolium castaneum

The adult population of T. castaneum increased gradually and reached to a maximum of fourteen in four months.

Sitophilus oryzae

There was a gradual increase in the adult population of S. oryzae as the duration of storage increased from one to three months, and reached to a level of eight, but in four months the adult population was zero.

Location: Vembayam

Table 7 represents the data on the population levels of different insect pests and extent of damage caused in samples

Table 7. Population count and extent of damage caused by different insect species found in the tapioca chips, collected from Vembayan

Insect pests		Duration (in months) after storage			
		1	2	3	4
A. fasciculatus	Larva	14	49	165	12
	Pupa	3	11	22	4
	Adult	29	68	187	76
T. castaneum	Adult	1	3	5	7
S. oryzae	,,	3	7	9	2
R. dominica	,,	-	2	2	-
L. serricorne	,,	1	-	2	-
S. paniceum	,,	1	3	1	-
L. minutus	,,	1	3	1	5
P. manihotalis	,,	-	-	-	1
S. rutella	,,	-	-	-	-
E. zebrena	,,	-	-	-	1
E. cautella	,,	-	-	-	1
O. surinamensis	,,	1	2	-	5
Extent of damage					
Quantity infested (g)		56.3	180.7	200.0	200.0
Quantity powdered (g)		2.8	39.0	200.0	200.0

of tapioca chips stored for different periods collected from Vembayam.

Araecerus fasciculatus

The larval population of A. fasciculatus ranged from 12 to 165 under different durations of storage. There was a gradual increase in population as the duration of storage increased from one to three months. Then the larval population decreased to a level of twelve at the end of four months.

Pupal population also increased gradually and reached to a level of 22 in three months, and then the level decreased to four in four months.

The adult population was found to increase gradually up to three months; 187 adults were observed in chips three months after storage but in four months the adult population was reduced to 76.

Tribolium castaneum

There was a gradual increase in adult population of T. castaneum from one to seven as the duration of storage increased from one to four months.

Sitophilus oryzae

The adult population of S. oryzae increased gradually from three to nine as the duration of storage increased from one to three months, but in the fourth month the adult population was reduced to two.

Location: Chalai

The data relating to the population of different insect pests and extent of damage assessed in samples of tapioca chips stored for different periods collected from Chalai, are presented in Table 8.

Araecerus fasciculatus

The larval population of A. fasciculatus ranged from 14 to 108 under different durations of storage. There was a gradual increase in the population as the duration of storage increased from one to three months. But by the fourth month, the larval population was reduced to 33.

As in the case of larvae, the pupal population also increased gradually up to three months from one to seven. But after four months, the population of pupa was reduced to sixteen

Adult population of A. fasciculatus ranged from 5 to 199 under different durations of storage. There was a gradual increase in the population as the duration of storage increased from one to three months. But in four months time the adult population got reduced to 47.

Tribolium castaneum

There was a gradual increase in adult population of T. castaneum from three to eight as the duration of storage increased from one to four months.

Table 8. Population count and extent of damage caused by different insect species found in the tapioca chips, collected from Chalai

Insect pests		Duration (in months) after storage			
		1	2	3	4
A. fasciculatus	Larva	14	40	108	33
	Pupa	1	5	17	6
	Adult	5	48	199	47
T. castaneum	Adult	3	6	7	8
S. oryzae	,,	3	7	13	2
R. dominica	,,	1	-	-	4
L. serricorne	,,	-	-	1	-
S. paniceum	,,	-	1	-	1
L. minutus	,,	-	-	-	2
P. manihotalis	,,	-	-	-	1
S. rutella	,,	-	-	1	1
E. zebrena	,,	-	-	-	1
E. cautella	,,	-	-	-	1
O. surinamensis	,,	3	5	-	4
Extent of damage					
Quantity infested (g)		49.5	119.2	200.0	200.0
Quantity powdered (g)		2.0	29.0	200.0	200.0

Sitophilus oryzae

The adult population of S. oryzae increased gradually from three to thirteen as the duration of storage increased from one to three months, but in fourth month the adult population was reduced to two.

Location: Sreekariyam

In Table 9, the data relating to different insect pests and the extent of damage assessed in samples of tapioca chips stored for different periods collected from Sreekariyam, are presented.

Araecerus fasciculatus

It was observed that the larval population of A. fasciculatus under different durations of storage ranged from 7 to 188. There was a gradual increase in the population as the duration of storage increased from one to three months, but in four month old samples, larval population drastically reduced to 48.

As in the case of larvae, population of pupae also increased gradually and reached to 29 in three months, but pupae were not observed in four months after storage.

With regard to adult population fourteen adults were observed in one month old chips. Then the population was found to increase up to 198 in the samples stored for three months. But after four months the adult population was found to be reduced to 71.

Table 9. Population count and extent of damage caused by different insect species found in the tapioca chips, collected from Sreekariyam

Insect pests		Duration (in months) after storage			
		1	2	3	4
A. fasciculatus	Larva	7	75	188	48
	Pupa	2	14	29	-
	Adult	14	83	198	71
T. castaneum	Adult	12	23	26	37
S. oryzae	,,	4	9	13	4
R. dominica	,,	-	-	4	1
L. serricorne	,,	-	1	-	1
S. paniceum	,,	2	-	1	1
L. minutus	,,	2	-	1	4
P. manihotalis	,,	-	-	-	1
S. rutella	,,	-	-	-	1
E. zebrena	,,	-	-	-	1
E. cautella	,,	-	1	-	-
O. surinamensis	,,	2	3	-	-
Extent of damage					
Quantity infested (g)		54.0	100.7	200.0	200.0
Quantity powdered (g)		1.4	34.0	200.0	200.0

Tribolium castaneum

There was a gradual increase in adult population of T. castaneum from 12 to 37 as the duration of storage increased from one to four months.

Sitophilus oryzae

The adult population of S. oryzae increased gradually from four to thirteen as the duration of storage increased from one to three months. Then the population was reduced to four in four months.

Location: Mangalapuram

Observations on the population of different insect pests and the extent of damage caused in samples of tapioca chips stored for different periods collected from Mangalapuram are presented in Table 10.

Araecerus fasciculatus

The larval population of A. fasciculatus ranged from 4 to 111 under different durations of storage. There was a gradual increase in the population as the duration of storage increased from one to three months. Then the larval population reduced to a level of 39 at the end of four months.

The pupal population also increased gradually up to three months, but pupae were not observed in four months old stock of tapioca chips.

Table 10. Population count and extent of damage caused by different insect species found in the tapioca chips, collected from Mangalapuram

Insect pests		Duration (in months) after storage			
		1	2	3	4
A. fasciculatus	Larva	4	23	111	39
	Pupa	2	17	29	-
	Adult	27	98	182	38
T. castaneum	Adult	1	7	11	36
S. oryzae	,,	4	9	15	2
R. dominica	,,	-	-	4	-
L. serricorne	,,	-	-	1	-
S. paniceum	,,	2	-	1	-
L. minutus	,,	2	2	1	4
P. manihotalis	,,	1	1	-	-
S. rutella	,,	-	-	-	1
E. zebrena	,,	-	-	-	1
E. cautella	,,	-	1	1	-
O. surinamensis	,,	2	3	-	5
Extent of damage					
Quantity infested (g)		80.0	150.0	200.0	200.0
Quantity powdered (g)		2.1	30.0	185.5	200.0

The adult population of A. fasciculatus ranged from 27 to 182 under different durations of storage. There was a gradual increase in the population as the duration of storage increased from one to three months. The population was drastically reduced to a level of 38 adults in four months.

Tribolium castaneum

There was a gradual increase in adult population of T. castaneum from 1 to 36 as the duration of storage increased from one to four months.

Sitophilus oryzae

Adult population of S. oryzae increased gradually from four to fifteen as the duration of storage increased from one to three months. But in four months time the adult population was reduced to a level of two.

Nature and extent of damage caused by *Araecerus fasciculatus* to tapioca chips stored for different periods

Data relating to the nature and extent of damage caused by *A. fasciculatus* to raw tapioca chips of variety M 4 stored for different periods are presented in Table 11 and Plate V.a, b and VI.a to d.

Percentage of chips damaged

The nature and extent of damage of raw tapioca chips at different periods of storage viz., one, two, three and four months showed that the intensity of infestation progressively increased. The percentage of chips infested increased significantly from 50.82 in the 1st month to 99.20 to 100 in the succeeding months. The mean percentage of infestation for 1st, 2nd, 3rd and 4th month were 50.82, 99.20, 100 and 100 per cent respectively. All the chips were damaged after three months.

Percentage of chips powdered

Assessment of damage in terms of the percentage of powdered material at different periods of storage revealed that the percentage of powdered material progressively increased corresponding to the percentage of chips damaged. Percentage of powdered chips after the first month was only 2.45; two months after storage the mean value increased significantly to 7.9. The percentage of powdered material reached to a level of 78.3 after three months and by the end of 4th month the entire quantity of chips was completely reduced to powder. The percentage of powdered chips

Plate V.a

Nature of damage caused by *A. fasciculatus* to raw tapioca chips

Plate V.b

Nature of damage caused by *A. fasciculatus* to par boiled tapioca chips


1
2

Table 11. Extent of damage caused by Araecerus fasciculatus to raw tapioca chips stored for different periods

Period of storage	Percentage of chips infested	Percentage of chips powdered	Mean No.of larvae	Mean No.of pupae	Mean No.of adults
One month after storage	50.82 (45.49)	2.45 (9.03)	88.65 (9.47)	14.06 (3.88)	37.13 (6.18)
Two months after storage	99.20 (84.30)	7.90 (16.31)	162.14 (12.77)	66.71 (8.23)	253.01 (15.94)
Three months after storage	100.00 (90.00)	78.30 (62.22)	261.73 (16.21)	76.17 (8.74)	567.45 (23.84)
Four months after storage	100.00 (90.00)	100.00 (90.00)	21.09 (4.70)	3.28 (2.07)	202.82 (14.28)
Results of statistical analysis					
F 4, 10	235.83**	1135.45**	155.52**	11.84**	29.65**
C.D. at 1% level	8.06	3.63	1.51	2.48	5.03

Figures within parentheses are transformed values

** Significant at 1 Per cent level

Plate VI.a

Extent of damage caused by A. fasciculatus to raw tapioca chips stored for different periods

0 - Control (without insect)

1 - One month after storage

Plate VI.b

Extent of damage caused by A. fasciculatus to raw tapioca chips stored for different periods

0 - Control

2 - Two months after storage


0
1


0
2

formed was found to vary significantly in the different occasions of observations. The percentage of chips damaged by the beetle during the 1st month after storage was found to be significantly different from the other intervals of observations, which were on par among themselves.

Number of larvae

Assessment of damage to tapioca chips on the basis of larval population of A. fasciculatus revealed that one month after storage the mean number of larvae was found to be 88.65. The larval population increased to a level of 162.14 after the second month. The highest mean larval population of 261.73 was recorded after three months of storage. After four months of storage, the larval population dropped drastically to a level of 21.09 when all the chips were reduced to powder. There was significant difference in the larval population at the different durations of storage.

Number of pupae

Mean pupal population after one month of storage was found to be 14.06. It increased significantly to a level of 66.71 after two months and 76.17 after three months storage, but it further got reduced significantly to 3.28 after the fourth month.

Number of adults

One month after storage the mean adult population was found to be 37.13. The population increased to a level of 253.01 after

Plate VI.c

Extent of damage caused by A. fasciculatus to raw tapioca chips stored for different periods

0 - Control

3 - Three months after storage

Plate VI.d

Extent of damage caused by A. fasciculatus to raw tapioca chips stored for different periods

0 - Control

4 - Four months after storage


0
3


0
4

the second month and the highest mean population of 567.43 was recorded after the third month of storage. Four months after storage the adult population declined to 202.82. The adult population was found to vary significantly at the different periods of storage.

The data relating to the nature and extent of damage caused by A. fasciculatus to par boiled tapioca chips stored for different periods are presented in Table 12 and Plate V.b.

Percentage of chips damaged

There was no symptom of damage due to A. fasciculatus one month after storage eventhough adult insects survived in the samples. Mean percentage of infestation after the second month of storage was found to be 11.20. Level of infestation after the third month was 21.8 and by the fourth month it increased to 33.75. The increase in this percentage of chips damaged was found to be significant as the time of storage increased.

Percentage of chips powdered

The chips were not reduced to powder after the first month of storage. There was progressive increase of the powdered material during the successive months. The mean percentage of powder was 1.50 after the second month, which increased to 2.00 after three months. At the end of fourth month the powder produced increased to 4.2 per cent.

Table 12. Extent of damage caused by Araecerus fasciculatus to par boiled tapioca chips

Period of storage	Percentage of chips infested	Percentage of powdered material	Mean number of larvae	Mean number of pupae	Mean number of adults
One month after storage	0.0 (0.0)	0.0 (0.0)	0.0 (1.0)	0.0 (1.0)	14.23 (3.90)
Two months after storage	11.20 (19.55)	1.50 (6.26)	11.84 (3.58)	0.91 (1.38)	33.64 (5.88)
Three months after storage	21.80 (27.82)	2.00 (8.09)	20.97 (4.68)	1.94 (1.72)	74.53 (8.69)
Four months after storage	33.75 (35.53)	4.20 (11.84)	44.49 (6.74)	4.65 (2.38)	85.24 (9.28)
Results of statistical analysis					
F 4, 10	173.67**	68.53**	22.60**	6.67**	69.17**
C.D.	3.86	1.97	1.60	0.68	1.27

Figures within parentheses are transformed values

** Significant at 1 Percent level.

Number of larvae

One month after storage, there were no larvae in the stored material. However, it increased significantly to a level of 11.84 and 20.97 after second and third month respectively. Further increase of larvae (44.49) after the fourth month of storage was also found to be significantly more.

Number of pupae

No pupa was observed one month after storage. The average population of pupae was 0.91 after two months, 1.94 after three months and 4.65 after four months of storage of the chips. The increase in the pupal population from the 1st to 2nd month and from 3rd to 4th month after storage was found to be on par statistically.

Number of adults

The mean adult population also showed an increasing trend corresponding to the increase in the period of storage of the chips. It was 14.23 after one month and 33.64 after two months. The population of 74.53 after three months and 85.24 after four months of storage were found to be on par.

Nature and extent of damage caused by Sitophilus oryzae to tapioca chips stored for different periods

The data relating to the nature and extent of damage caused by S. oryzae to raw tapioca chips (Plate VII.a) stored for different periods are presented in Table 13.

Percentage of chips damaged

The percentage of chips damaged at different periods of storage viz., one, two, three and four months have shown that the intensity of infestation progressively increased which was found to be statistically significant. The mean percentage of infestation at the end of 1st, 2nd, 3rd and 4th month were 6.62, 16.10, 25.10 and 45.20 respectively.

Percentage of chips powdered

Assessment of extent of damage in relation to the percentage of powdered material at different periods of storage revealed that the chips were not reduced to powder after the 1st and 2nd month of storage. There was significant increase in the mean percentage of chips powdered on the 3rd month after storage (0.5%) which was on par with that of the 4th month after storage (1.4%)

Number of larvae

The larval population of S. oryzae one month after storage was 11.61 and 78.25 after the second month. Mean larval population reached 145.41 at the end of 3rd month, which again increased to 316.33 after 4 months of storage. The increase in the larval population at different intervals were found to be significant.

Table 13. Extent of damage caused by *Sitophilus oryzae* to stored raw tapioca chips

Period of storage	Percentage of chips infested	Percentage of chips powdered	Mean number of larvae	Mean number of pupae	Mean number of adults
One month after storage	6.62 (14.91)	0.0 (0.0)	11.61 (3.35)	0.0 (1.0)	19.28 (4.50)
Two months after storage	16.10 (23.67)	0.0 (0.0)	78.25 (8.90)	7.21 (2.86)	39.79 (6.39)
Three months after storage	25.10 (30.06)	0.50 (4.04)	145.41 (12.10)	10.19 (3.35)	167.31 (12.97)
Four months after storage	45.20 (42.24)	1.40 (6.82)	316.33 (17.80)	14.57 (3.95)	283.78 (16.88)
Results of statistical analysis					
F 4, 10	123.35**	329.08**	188.63**	50.51**	496.96**
C.D.	4.51	0.48	1.51	0.59	0.89

Figures within parentheses are transformed values

** Significant at 1 Percent level.

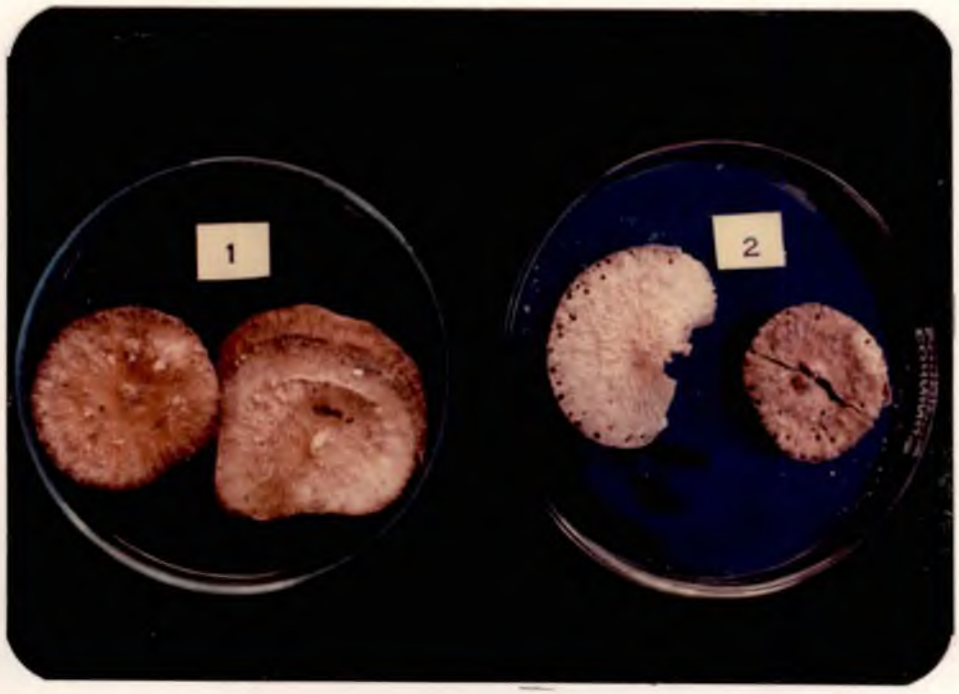
Plate VII.a

Nature of damage caused by *Sitophilus oryzae* to raw tapioca chips

Plate VII.b

Nature of damage caused by *Sitophilus oryzae* to par boiled tapioca chips


1
2


1
2

Number of pupae

The mean pupal population one month after storage was zero. The pupal population showed an increasing trend after the 2nd, 3rd and 4th month of storage, the values being 7.21, 10.19 and 14.57 respectively. However, the population on the 2nd and 3rd month after storage were on par.

Number of adults

The adult population also increased significantly corresponding to the duration of storage, the population count for 1st, 2nd, 3rd and 4th months being 19.28, 39.79, 167.31 and 283.78 respectively.

The data relating to the nature and extent of damage caused by S. oryzae to par boiled tapioca chips stored for different periods are presented in Table 14.

Percentage of chips damaged

There was no symptom of damage due to S. oryzae one month after storage eventhough adult insects were observed in the sample. Mean percentage of infestation after second month of storage was found to be 10.9 and after the third month it was 18.4. By the end of fourth month it increased to 32.65. The percentage of chips damaged increased significantly as the duration of storage increased.

Table 14. Extent of damage caused by Sitophilus oryzae on par boiled tapioca chips

Period of storage	Percentage of chips infested	Percentage of chips powdered	Mean number of larvae	Mean number of pupae	Mean number of adults
One month after storage	0.0 (0.0)	0.0 (0.0)	0.0 (1.0)	0.0 (1.0)	12.59 (3.69)
Two months after storage	10.90 (19.28)	0.0 (0.0)	11.99 (3.60)	0.91 (1.38)	34.10 (5.92)
Three months after storage	18.40 (25.39)	0.48 (3.96)	33.87 (5.91)	2.00 (1.73)	78.50 (8.92)
Four months after storage	32.65 (34.86)	0.60 (4.43)	116.99 (10.86)	4.97 (2.44)	102.19 (10.16)
Results of statistical analysis					
F 4, 10	334.19**	65.33**	348.61**	30.93**	190.22**
C.D.	2.64	0.89	0.68	0.33	0.84

Figures in parentheses are transformed values

** Significant at 1 Percent level.

Percentage of chips powdered

Assessment of the extent of damage in relation to the percentage of powdered material at different durations of storage have shown that the chips were not reduced to powder after the first and second month of storage. The percentage of powder after the third month was 0.48, which increased to 0.60 after four months.

Number of larvae

One month after storage, the population of larvae was zero, but increased to 11.99 after the second month, 33.87 after the third month and 116.99 four months after storage. The increase in the larval population for the different periods was found to be statistically significant.

Number of pupae

One month after storage the mean population was zero, which increased significantly to 0.91, 2.00 and 4.97 after two, three and four months of storage respectively.

Number of adults

The adult population significantly increased with the increase in the duration of storage of chips, the mean population being 12.59, 34.10, 78.50 and 102.19 after 1st, 2nd, 3rd and 4th months of storage respectively.

Nature and extent of damage caused by Tribolium castaneum to tapioca chips stored for different periods

The data relating to the nature and extent of damage caused by T. castaneum to raw tapioca chips stored for different periods are presented in Table 15.

Percentage of chips damaged

The nature and extent of damage of raw tapioca chips stored for different periods viz., one, two, three and four months have shown that the intensity of infestation progressively increased. The percentage of chips infested ranged from 8.30 to 19.60 in different months. The mean percentage of infestation for 1st, 2nd, 3rd and 4th month was 8.30, 9.80, 12.52 and 19.60 respectively. The percentage of chips damaged in the 4th month was found to be significantly more than in the previous occasions.

Percentage of chips powdered

Assessment of extent of damage in relation to the percentage of powdered material at different periods of storage revealed that the quantity of powdered material progressively increased corresponding to the percentage of chips damaged. Percentage of powder after first month was zero. Two months after storage the mean value increased to 0.20 which reached to a level of 0.63 at three months after storage and 0.77 after four months.

Number of larvae

Assessment of damage of tapioca chips on the basis of larval population of T. castaneum revealed that in the first two

Table 15. Extent of damage caused by *Tribolium castaneum* to stored raw tapioca chips

Period of storage	Percentage of chips infested	Percentage of chips powdered	Mean number of larvae	Mean number of pupae	Mean number of adults
One month after storage	8.30 (16.77)	0.0 (0.0)	0.0 (1.0)	0.0 (1.0)	18.28 (4.39)
Two months after storage	9.80 (18.23)	0.20 (2.56)	0.0 (1.0)	0.0 (1.0)	29.34 (5.51)
Three months after storage	12.52 (20.72)	0.63 (4.56)	11.95 (3.60)	0.0 (1.0)	40.65 (6.45)
Four months after storage	19.60 (26.27)	0.77 (5.02)	20.57 (4.64)	3.97 (2.22)	78.63 (8.92)
Results of statistical analysis					
F 4, 10	100.70**	1092.79**	206.35**	89.56**	58.47**
C.D.	3.09	0.23	0.38	0.18	1.17

Figures in parentheses are transformed values

** significant at 1 Percent level.

months after storage the larval population was zero. The population increased significantly by the third month of storage, the count being 11.95, further the population increased to 20.57 after four months of storage.

Number of pupae

The mean pupal population was found to be zero in 1st, 2nd and 3rd month after storage. But after the fourth month the pupal population increased significantly to 3.97.

Number of adults

The adult population recorded one month after storage was 18.28. The population increased to a level of 29.34 after the second month and 40.65 after the third month. In the 4th month after storage the increase was found to be significantly superior over the previous occasions, the value being 78.63.

The data relating to the nature and extent of damage caused by T. castaneum to par boiled tapioca chips stored for different periods are presented in Table 16.

Percentage of chips damaged

There was no symptom of damage of T. castaneum one month after storage eventhough adult insects were collected from the sample. Mean percentage of infestation after the second month of storage was found to be 2.15. Level of infestation increased to 3.30 after three months of storage and 18.30 after four months. But only the increase in the fourth month was found to be statistically significant.

Table 16. Extent of damage caused by Tribolium castaneum to stored par boiled tapioca chips

Period of storage	Percentage of chips infested	Percentage of chips powdered	Mean number of larvae	Mean number of pupae	Mean number of adults
One month after storage	0.0 (0.0)	0.0 (0.0)	0.0 (1.0)	0.0 (1.0)	14.57 (3.95)
Two months after storage	2.15 (8.38)	0.0 (0.0)	0.0 (1.0)	0.0 (1.0)	17.54 (4.31)
Three months after storage	3.30 (10.40)	0.20 (2.56)	4.39 (2.32)	0.0 (1.0)	18.87 (4.46)
Four months after storage	18.80 (25.34)	0.43 (3.77)	5.90 (2.63)	0.91 (1.39)	69.49 (8.40)
Results of statistical analysis					
F 4, 10	59.22**	780.91**	18.00**	3.25**	131.80**
C.D.	4.25	0.20	0.59	-	0.71

Figures in parentheses are transformed values

** Significant at 1 Percent level.

Percentage of powdered material

Assessment of the extent of damage expressed as percentage of powdered material at different durations of storage have shown that the chips were not reduced to powder after the first and second month of storage. There was a progressive increase of the powdered material during successive months. The percentage of chips powdered was 0.20 after the third month, which increased significantly to 0.43 after four months.

Number of larvae

The mean population of larvae was found to be zero up to two months after storage. The larval population increased significantly to 4.39 after the third month which was on par with the population level of 5.90 after the fourth month of storage.

Number of pupae

Mean population of pupae in one, two and three months after storage was zero, but it increased to a level of 0.91 after four months.

Number of adults

With regard to adult population, the mean population of 14.57 adults were observed in one month after storage. Adult population increased to 17.54 after two months and 18.87 after three months of storage. Maximum number of 69.49 was recorded after the fourth month which was found to be significantly more compared to previous months of storage.

Biology of Araecerus fasciculatus on the raw chips of different varieties of tapioca

The results of the experiments on the influence of different varieties of tapioca on the biology of A. fasciculatus are presented in Table 17.

Fecundity

Average number of eggs laid in different varieties of raw tapioca chips is presented in Table 17. Average number of eggs laid in different varieties varied from 37.3 to 46.5 per female. Insects reared on M 4 laid the maximum number of eggs (46.5) followed in the descending order by those reared on Sree Visakham (45.7), Sree Sahya (45.6), Njaruck (43.0), Neelagiri (37.7) and Vella (37.3).

Incubation period

Incubation period of eggs in different varieties of tapioca chips varied from 5.7 to 5.9 days. Egg period was 5.9 days in Vella, Neelagiri and Sree Sahya followed by 5.8 days in Sree Visakham and Njaruck and 5.7 days in M 4.

Larval period

The average larval period was longest in variety Vella (29.1) followed in the descending order by Njaruck (29.0), Neelagiri (28.9). Sree Sahya (28.8), Sree Visakham (28.7) and least in M 4 (28.6).

Table 17. Biology of *Araecerus fasciculatus* on different varieties of raw tapioca chips

Variety	Average No. of eggs laid per female	Average egg period	Average larval period	Average pupal period	Average longevity of adult beetle	Sex ratio Male:Female
Vella	37.3	5.9	29.1	5.4	39.9	3 : 2
Neelagiri	37.7	5.9	28.9	5.3	45.5	3 : 2
M 4	46.5	5.7	28.6	5.1	51.2	2 : 3
Sree Visakham	45.7	5.8	28.7	5.2	50.9	1 : 1
Njaruck	43.0	5.8	29.0	5.2	46.9	3 : 2
Sree Sahya	45.6	5.9	28.8	5.2	42.4	1 : 1
Results of statistical analysis						
F 4, 54	2.39	0.166	0.26	0.47	0.82	

Pupal period

Average duration of pupae in different varieties ranged from 5.1 to 5.4 days. Pupal duration was longest in variety Vella (5.4 days) followed by Neelagiri (5.3 days). For Sree Visakham, Njaruck and Sree Sahya, pupal period was 5.2 days and for M 4 it was 5.1 days.

Sex ratio

The male-female ratio of adult insects reared in different varieties was 3 : 2 in Vella, Neelagiri and Njaruck, 2 : 3 in M 4 and 1 : 1 in Sree Visakham and Sree Sahya.

Longevity of adults

It was found that the longevity of adults reared on different varieties varied from 51.2 days in M 4 to 39.9 days in Vella. It was 50.9 in Sree Visakham, 46.9 in Njaruok, 45.5 in Neelagiri and 42.4 in Sree Sahya.

The biology of A. fasciculatus on par boiled tapioca chips showed that the average number of eggs laid per female was 22.5 and the incubation period was 6 days. The larval and pupal periods were 34.0 and 6.4 days respectively. The adult longevity was only 27.1 days. The sex ratio was found to be 1 : 1.

Biology of Sitophilus oryzae on the chips of different varieties of tapioca

The results of the experiment on the influence of different varieties on the biology of S. oryzae are presented in Table 18.

Table 18. Biology of Sitophilus oryzae on different varieties of raw tapioca chips

Variety	Average No. of eggs laid per female	Average egg period	Average larval period	Average pupal period	Average longevity of adults	Sex ratio Male:Female
Vella	49.8	9.6	30.7	9.6	119.7	3 : 2
Neelagiri	54.9	9.2	30.4	9.0	126.0	1 : 1
H 4	57.8	8.9	29.8	8.5	126.7	2 : 3
Sree Visakham	50.5	9.5	30.3	9.4	122.6	3 : 2
Njaruck	53.7	9.2	30.6	9.4	123.1	1 : 1
Sree Sahya	50.5	9.5	30.4	9.1	122.8	3 : 2
Results of statistical analysis						
F 5, 54	1.35	0.36	0.39	0.66	0.17	

Fecundity

Average number of eggs laid in different varieties varied from 49.8 to 57.8 per female. Number of eggs were maximum in M 4 (57.8) followed by Neelagiri (54.9), Njaruck (53.7), Sree Sahya (50.5), Sree Visakham (50.5) and Vella (49.8).

Incubation period

Incubation period of eggs laid in different varieties varied from 8.9 to 9.6 days. Comparative assessment of the average incubation period of eggs revealed that in M 4, it took only 8.9 days to hatch whereas in Neelagiri and Njaruck the incubation period was 9.2 days and in Sree Visakham and Sree Sahya 9.5 days each and in Vella 9.6 days.

Larval period

Duration of larval period in different varieties varied from 29.8 to 30.7 days; it was comparatively short in M 4 (29.8 days) followed by Sree Visakham (30.3), Neelagiri and Sree Sahya (30.4), Njaruck (30.6) and maximum in Vella (30.7).

Pupal period

Average pupal period in different varieties varied from 8.5 to 9.6 days. Pupal period was short in M 4 (8.5) followed by Neelagiri (9.0), Sree Sahya (9.1), Sree Visakham and Njaruck (9.4) each and Vella (9.6).

Sex ratio

It was also observed that there was variation in the sex ratio of adult beetles reared in different varieties. In

Sree Sahya, Sree Visakham and Vella male / female ratio was 3 : 2 and in Neelagiri and Njaruck it was 1 : 1 but in M 4 the ratio was 2 : 3 with predominance of females.

Longevity

Average longevity of adult of S. oryzae reared in different varieties revealed that the life period was more in M 4 (126.7 days) followed by Neelagiri (126.0 days), Njaruck (123.1 days), Sree Sahya (122.8 days), Sree Visakham (122.6 days) and Vella (119.7 days).

Biological investigations of S. oryzae on par boiled tapioca chips showed that the average number of eggs laid by a female was 29.5 and the incubation period was 9.1 days. The larval and pupal periods were 32.3 and 8.9 days respectively. Longevity of adult beetles recorded in par boiled chips was 117.8 days. The sex ratio was found to be 2 : 3.

Susceptibility of different varieties of tapioca to Araecerus fasciculatus under stored conditions

The extent of damage and the population build up by A. fasciculatus in different varieties of tapioca chips viz., Vella, Neelagiri, M 4, Sree Visakham, Njaruck and Sree Sahya were assessed by storing these different varieties in gunny bags and exposing them to the insect damage by placing them under storage conditions. The results are presented in Table 19.

A. One month after storage

Percentage of chips damaged

The percentage of chips damaged by the pest one month after storage in different varieties ranged from 11.00 to 27.03. The mean percentage of infestation was high in M 4 (27.03) and least in Sree Visakham (11.00). In the other varieties the percentage of infestation recorded was 12.10 in Vella, 26.00 in Neelagiri, 22.85 in Njaruck and 14.20 in Sree Sahya. The percentage of chips damaged in the different varieties did not differ significantly.

Percentage of powdered material

Percentage of chips powdered one month after storage was high in M 4 (0.91) followed by Neelagiri (0.51), Njaruck (0.46), Sree Sahya (0.41), Sree Visakham (0.31) and least in Vella variety (0.27).

Pest population

The larval population was found to be high in M 4 (69.68) followed in the descending order by Njaruck (66.02), Neelagiri (57.58), Sree Visakham (54.36), Vella (42.93) and Sree Sahya (35.51).

With regard to population of pupae, the numbers ranged from 16.85 to 28.05 and it was high in M 4 variety (28.05) and least in Vella (16.85). Pupal populations in other varieties were 23.26 in Neelagiri, 23.93 in Njaruck, 20.35 in Sree Sahya and 18.85 in Sree Visakham.

Table 19. Varietal susceptibility of Araecerus fasciculatus on different varieties of raw tapioca chips stored for different periods

Treatments / varieties	Percentage of chips infested	Percentage of chips powdered	Mean No.of larvae	Mean No.of pupae	Mean No.of adults
A. One month after storage					
Vella	12.10 (20.36)	0.27 (2.95)	42.93 (6.55)	16.85 (4.11)	23.18 (4.81)
Neelagiri	26.00 (30.67)	0.51 (4.09)	57.58 (7.58)	23.26 (4.82)	94.29 (9.71)
M 4	27.03 (31.33)	0.91 (5.49)	69.68 (8.35)	28.05 (5.31)	110.73 (10.52)
Sree Visakham	11.00 (19.35)	0.31 (3.20)	54.36 (7.37)	18.85 (4.34)	61.84 (7.86)
Njaruck	22.85 (28.55)	0.46 (3.88)	66.02 (8.13)	23.93 (4.89)	72.41 (8.51)
Sree Sahya	14.20 (22.15)	0.41 (3.64)	35.51 (5.96)	20.35 (4.51)	26.31 (5.13)
F 5, 12	1.15	0.78	0.31	0.08	4.17**
C.D.	-	-	-	-	3.55
B. Two months after storage					
Vella	55.03 (47.90)	6.10 (14.31)	332.03 (18.22)	77.60 (8.81)	226.50 (15.05)
Neelagiri	95.50 (77.73)	8.60 (17.06)	650.22 (25.50)	176.75 (13.29)	409.09 (20.23)
M 4	98.15 (82.22)	10.85 (19.23)	958.46 (30.96)	287.63 (16.96)	472.54 (21.74)
Sree Visakham	73.03 (58.72)	7.13 (15.47)	580.37 (24.10)	133.85 (11.57)	229.15 (15.14)
Njaruck	95.72 (78.05)	8.10 (16.55)	776.43 (27.86)	181.09 (13.46)	246.97 (15.72)
Sree Sahya	88.80 (70.45)	7.15 (15.52)	712.31 (26.69)	174.05 (13.19)	293.54 (17.13)
F 5, 12	10.48**	5.10**	2.79	3.65**	3.99**
C.D.	12.67	2.24	-	4.30	4.36
C. Three months after storage					
Vella	91.60 (73.14)	40.70 (39.64)	1202.20 (34.67)	87.49 (9.35)	267.48 (16.35)
Neelagiri	97.90 (81.67)	74.65 (59.79)	1494.56 (38.66)	89.61 (9.46)	547.67 (23.40)
M 4	99.75 (87.11)	85.50 (67.61)	1663.43 (40.79)	93.95 (9.69)	671.47 (25.91)
Sree Visakham	94.75 (76.76)	44.15 (41.63)	1319.31 (36.32)	65.32 (8.08)	285.20 (16.89)
Njaruck	96.00 (78.42)	55.05 (47.90)	1362.22 (36.91)	73.69 (8.58)	403.70 (20.09)
Sree Sahya	93.80 (75.59)	43.80 (41.43)	1221.63 (34.95)	54.27 (7.37)	277.44 (16.66)
F 5, 12	0.32	1.76	0.16	0.42	2.13
C.D.	-	-	-	-	-

Figures within parentheses are transformed values

Population of adult insect was high in M 4 (110.73) followed by Neelagiri (94.29), Njaruck (72.41), Sree Visakham (61.84), Sree Sahya (26.31) and Vella (23.18).

In the case of mean number of adults, one month after storage it was found that the population was significantly less in Vella compared to Neelagiri and M 4, but was on par with others.

B. Two months after storage

Percentage of chips damaged

The percentage of chips infested was high in Variety M 4 (98.15) followed in the descending order by Njaruck (95.72), Neelagiri (95.50), Sree Sahya (88.80), Sree Visakham (73.03) and Vella (55.03).

Percentage of powdered material

Percentage of chips powdered two months after storage was high in M 4 (10.85) followed by Neelagiri (8.6), Njaruck (8.1), Sree Sahya (7.15), Sree Visakham (7.13) and Vella (6.1).

Pest population

The larval population was found to be high in M 4 (958.46) followed in the descending order by Njaruck (776.43), Sree Sahya (712.31), Neelagiri (650.22), Sree Visakham (580.37) and Vella (332.03).

With regard to pupal population it varied from 77.60 in Vella, to 287.63 in M 4. The counts in the other varieties were 181.09 in Njaruck, 176. 75 in Neelagiri, 174.05 in Sree Sahya and 133.85 in Sree Visakham.

Population of adult insect was high in M 4 (472.54) followed by Neelagiri (409.09), Sree Sahya (293.54), Njaruck (246.97)

Sree Visakham (229.15) and Vella (226.5). Statistical analysis of the data showed that M 4 was found to be the most susceptible and Vella the least as indicated by the percentage of chips infested, chips powdered and also the mean number of larvae and pupae. Sree Visakham, Njaruck and Sree Sahya were found to be on par with Vella in the case of the mean number of population of adults observed in the different varieties.

C. Three months after storage

Percentage of chips damaged

The percentage of infestation in three months after storage was found to be high in M 4 (99.75) followed by Neelagiri (97.9), Njaruck (96.0), Sree Visakham (94.75), Sree Sahya (93.8) and Vella (91.6).

Percentage of powdered material

Percentage of powdered material was high in M 4 (85.5) followed in the descending order by Neelagiri (74.65), Njaruck (55.05), Sree Visakham (44.15), Sree Sahya (43.8) and Vella (40.70).

Pest population

Larval population was found to be high in M 4 (1663.43) followed in the descending order by Neelagiri (1494.56), Njaruck (1362.22), Sree Visakham (1319.31), Sree Sahya (1221.63) and Vella (1202.20).

Population count of pupa was more in M 4 (95.95) followed by Neelagiri (89.61), Vella (87.49), Njaruck (73.69), Sree Visakham (65.32) and Sree Sahya (54.27).

Adult population ranged from 671.47 to 267.48. Maximum number of adult was observed in M 4 (671.47), followed by

Neelagiri (547.67), Njaruck (403.7), Sree Visakham (285.2), Sree Sahya (277.44) and least in Vella (267.48).

Statistically all the varieties were found to be on par in susceptibility to attack by A. fasciculatus.

Susceptibility of different varieties of tapioca chips to Sitophilus oryzae in storage

The results of the experiment on assessment of extent of damage and consequent population build up of S. oryzae in different varieties (Vella, Neelagiri, M 4, Sree Visakham, Njaruck and Sree Sahya) of tapioca chips at one, two and three months of storage are presented in Table 20.

A. One month after storage

Percentage of chips infested

The percentage of chips infested by the weevil one month after storage ranged from 7.6 to 12.3 in different varieties. Maximum infestation was found in variety M 4 (12.3) followed by Neelagiri (9.2), Sree Visakham (8.8), Njaruck (8.78), Sree Sahya (7.8) and the minimum infestation in variety Vella (7.6).

Percentage of powdered material

Percentage of powdered material was found to be zero in all varieties.

Pest population

Larval population was maximum in M 4 (56.96) followed by Njaruck (47.91), Neelagiri (46-06), Sree Visakham (40.96),

Table 20. Varietal susceptibility of Sitophilus oryzae on different varieties of raw tapioca chips stored for different periods

Treatments / varieties	Percentage of chips infested	Percentage of chips powdered	Mean No.of larvae	Mean No.of pupae	Mean No.of adults
A. One month after storage					
Vella	7.60 (16.00)	0	34.28 (5.86)	0	9.63 (3.10)
Neelagiri	9.20 (17.66)	0	46.06 (6.86)	0	29.32 (5.41)
M 4	12.30 (20.51)	0	56.96 (7.54)	0	36.30 (6.02)
Sree Visakham	8.80 (17.26)	0	40.96 (6.40)	0	18.29 (4.28)
Njaruck	8.78 (17.26)	0	47.91 (6.91)	0	26.24 (5.12)
Sree Sahya	7.80 (16.23)	0	40.37 (6.37)	0	20.31 (4.51)
F 5, 12	2.67	-	5.59**	-	52.53**
C.D.	-	-	0.76	-	0.43
B. Two months after storage					
Vella	17.48 (24.70)	0	74.13 (8.61)	2.94 (1.72)	22.51 (4.74)
Neelagiri	23.75 (29.19)	0	73.80 (8.59)	1.91 (1.38)	49.88 (7.06)
M 4	26.00 (30.63)	0	93.13 (9.65)	5.59 (2.37)	61.55 (7.84)
Sree Visakham	19.82 (26.43)	0	81.63 (9.03)	1.78 (1.33)	36.19 (6.06)
Njaruck	21.43 (27.59)	0	83.88 (9.16)	3.96 (1.99)	48.77 (6.99)
Sree Sahya	19.30 (26.04)	0	78.69 (8.87)	1.30 (1.14)	40.24 (6.34)
F 5, 12	6.24**	-	1.41	4.89**	16.37**
C.D.	2.69	-	-	0.64	0.81
C. Three months after storage					
Vella	66.07 (54.37)	0.65 (4.61)	91.98 (9.59)	3.73 (1.93)	68.83 (8.30)
Neelagiri	96.20 (78.72)	1.48 (6.97)	151.73 (12.32)	1.91 (1.38)	88.84 (9.43)
M 4	100.00 (90.00)	1.98 (8.08)	214.45 (14.64)	9.70 (3.12)	130.12 (11.41)
Sree Visakham	92.80 (74.45)	1.25 (6.40)	120.14 (10.96)	5.03 (2.24)	75.27 (8.68)
Njaruck	95.44 (77.66)	1.48 (6.96)	143.71 (11.99)	4.26 (2.07)	79.79 (8.93)
Sree Sahya	89.30 (70.90)	0.96 (5.60)	134.15 (11.58)	5.39 (2.32)	75.20 (8.68)
F 5, 12	2.76	2.27		1.31	11.84**
C.D.	-	-	-	-	1.009

Figures within parentheses are transformed values

Sree Sahya (40.37) and Vella (34.28), recording the least larval population.

The pupal population was not observed in any of the varieties after first month of storage.

Adult population was high in M 4 (36.3) and least in Vella (9.63). Population recorded in other varieties viz. Neelagiri (29.32), Njaruck (26.24), Sree Sahya (20.31) and Sree Visakham (18.29) were found to be significantly more compared to Vella.

B. Two months after storage

Percentage of chips infested

The variety M 4 recorded a high percentage (26.0) followed by Neelagiri (23.75) and Njaruck (21.43). Percentage of chips infested in Sree Visakham (19.82), Sree Sahya (19.3) and Vella (17.48) were found to be significantly low compared to other varieties.

Percentage of powdered material

There was no powdered material in any of the varieties exposed to S. oryzae.

Pest population

Counts on the population of larvae ranged from 93.13 to 73.8. Maximum population was found in M 4 (93.13) followed by Njaruck (83.88), Sree Visakham (81.63), Sree Sahya (78.69), Neelagiri (73.8) and Vella (74.13).

Population of pupae was found to be significantly high in variety M 4 (5.6) and Njaruck (3.96). In the other varieties, Vella, Neelagiri, Sree Visakham and Sree Sahya, the population was found to be 2.94, 1.91, 1.78 and 1.3 respectively.

Adult population was maximum in M 4 (61.55) followed by Neelagiri (49.88), Njaruck (48.77), Sree Sahya (40.24) and Sree Visakham (36.19); in Vella the population (22.51) was found to be significantly low compared to the other varieties.

C. Three months after storage of chips

Percentage of chips infested

Percentage of chips infested by the pest three months after storage was high in M 4 (100) followed by Neelagiri (96.2), Njaruck (95.44), Sree Visakham (92.8), Sree Sahya (89.3) and Vella (66.07).

Percentage of chips powdered

The percentage of powder obtained after three months of storage was high in the variety M 4 (1.98) followed by Neelagiri (1.48), Njaruck (1.48), Sree Visakham (1.25), Sree Sahya (0.96) and Vella (0.65).

Population of pests

Maximum number of larvae was recorded in M 4 (214.45). In the other varieties Neelagiri, Njaruck, Sree Sahya, Sree Visakham and Vella, the larval populations were 151.73, 143.71, 134.15, 120.14 and 91.98 respectively.

The pupal populations recorded in different varieties were M 4 (9.70), Sree Sahya (5.39), Sree Visakham (5.03), Njaruck (4.26), Vella (3.73) and Neelagiri (1.99).

Population of adult was significantly high in M 4 (130.12) followed by Neelagiri (88.84). In Njaruck (79.79), Sree Visakham (75.27), Sree Sahya (75.2) and Vella (68.83), the population was low.

DISCUSSION

DISCUSSION

In the present investigation, a survey was conducted in ten centres of Trivandrum District to know the important pests associated with tapioca chips under storage. The nature and extent of damage done by the different pest to tapioca chips were studied in detail. Investigations were also undertaken on the varietal susceptibility of tapioca chips to infestation by major insect pests. Biology of Araecerus fasciculatus (DeG.) and Sitophilus oryzae (L.), the two major pests of tapioca chips were also worked out. The results of these studies are discussed below.

The survey of insect pests of stored tapioca chips revealed that among the various insect pests recorded, three species viz. the tapioca weevil, Araecerus fasciculatus (DeG.); the rice weevil Sitophilus oryzae (L.) and the rust red flour beetle Tribolium castaneum (Hbst.) were found to be the major pests. The other pests include the drug store beetle, Stegobium paniceum (L.); the cigarette beetle, Lasioderma serricorne (F.); the lesser grain borer, Rhizopertha dominica (F.); the saw toothed grain beetle, Oryzaephilus surinamensis (L.); the flat grain beetle Laemophloeus minutus (Oliv.); Tenebroides mauritanicus (L.); the tapioca moth, Pyralis manihotalis (Guen.); the fig moth, Ephestia cautella (Wlk.); the tobacco moth Setomorpha rutella (Zell.) and the flour moth Erechthias zebrena (Butler). The populations of the minor pests were found to be very low in all the locations surveyed (Table 1 to 10).

The incidence of these pests on tapioca chips to varying levels was also reported by Ballou (1919), Zacher (1930), Frappa (1938), Darling (1946), Nair and Jones (1948), Commen and Joseph (1963), Ingram and Humphries (1972), Pillai (1976), Nwana (1978), Parker and Booth (1979), Thampan (1979) and Parker *et al.* (1981).

Survey conducted in all the ten locations revealed that the population of larvae, pupae and adults of *A. fasciculatus* steadily increased up to three months, then there was a sudden decline in the population. Similar observations were also seen in the case of *S. oryzae*. The entire quantity of tapioca chips were consumed by the larvae and adults of the pests and converted into powder within a period of three months. This reduction in the population of these pests may be due to the non-availability of fresh chips for oviposition and further development.

In the case of *Tribolium castaneum* the number of adults was found progressively increasing up to the fourth month of storage in all the locations. This being a major pest thriving in broken products and stored flour, there was no shortage of food material for the insects for oviposition and further development.

Observations on the extent of damage of tapioca chips due to insect infestation revealed that in all locations, the entire quantity of chips were converted into powder within a period of three months. When the duration of storage of tapioca chips was increased there was a corresponding increase in the percentage of infestation up to three months; by that time the entire chips

were reduced to powder due to insect infestation. Joseph and Oommen (1963) and Lal and Pillai (1973) reported similar trend in the type of damage to tapioca chips due to the infestation by A. fasciculatus, S. oryzae and T. castaneum.

The nature and extent of damage caused by A. fasciculatus to tapioca chips stored for different periods presented in Table 11 show percentage of chips infested, percentage of chips powdered, mean population of larvae, pupae and adults after the 1st, 2nd, 3rd and 4th month of storage. The intensity of infestation progressively increased up to the third month after storage and by that time the entire chips were damaged. Similarly the percentage of powdered material also increased and all the chips were converted to powder after the fourth month of storage.

The nature and extent of damage caused by A. fasciculatus to par boiled tapioca chips stored for different periods revealed that the damage due to the infestation was significantly less in par boiled chips over a period of four months.

Studies conducted on the nature and extent of damage caused by Sitophilus oryzae to tapioca chips stored for different periods (Table 13) revealed that percentage of chips infested, percentage of chips powdered, mean population of larvae, pupae and adults after 1st, 2nd, 3rd and 4th months of storage increased gradually over the months and reached to a maximum in fourth month after storage.

Studies in general on the nature and extent of damage caused by S. oryzae on par boiled chips have shown that damage due to infestation was significantly less.

Thus the progressive increase of the different stages of the insect A. fasciculatus up to 3rd month after storage as observed by increased larval and adult population and a further reduction in the 4th month after storage of tapioca may be attributed to the non-availability of fresh food material for the development of the larvae and lack of favourable site for egg laying and further development by the insect. In the case of S. oryzae the population of the different developmental stages is found to increase even after four months. This indicates the availability of food material which is remaining undamaged by the insects even after four months could support further development of the different stages of the insect.

The results of studies presented in Table 15, on the nature and extent of damage caused by Tribolium castaneum to tapioca chips stored for different periods revealed the percentage of chips infested and percentage of chips powdered, mean population of larvae, pupae and adults after 1st, 2nd, 3rd and 4th months of storage. The percentage of chips infested and percentage of chips powdered even after the fourth month are comparatively less when compared to that of A. fasciculatus and S. oryzae. Being a major pest thriving more in broken products and stored flour, increased number of the larvae and pupae were seen only from the

third month after storage. Joseph and Oommen (1963) reported that the development of T. castaneum was more in tapioca flour compared to chips.

Assessment of nature and extent of damage caused by T. castaneum on par boiled chips stored for different periods revealed that the damage due to infestation was less in par boiled chips, as in the case of A. fasciculatus and S. oryzae indicating the unsuitability of par boiled chips for the development of the insect. The percentage of chips infested was 19.6 in raw chips after fourth month of storage whereas it was only 18.3 in the par boiled chips. The quantity of powdered material was 0.77% in raw chips and only 0.43% in par boiled chips.

The non-preference of the par boiled chips by these insects may be attributed to the cooking of the chips before drying because that process will result in increasing the hardness of the chips, which will not be favourable for the penetration and feeding of the insects. Nwana and Azodoh (1984) also observed similar findings and reported that cooking before drying reduce the intensity of infestation by A. fasciculatus.

Studies on the biology of A. fasciculatus and S. oryzae on chips of six different varieties of tapioca viz. Vella, Neelagiri, H 4, Sree Visakham, Sree Sahya and Njaruck, have shown that the biological features of the insects vary significantly when reared in different varieties.

Average number of eggs laid by A. fasciculatus was maximum in M 4 (46.5) and least in Vella (37.3) (Table 17). Incubation period, the larval period and pupal duration were also found to be shortest (5.7, 28.6 and 5.1 days respectively) in M 4 and longest in Vella (5.9, 29.1 and 5.4 days respectively). Longevity of adults reared in M 4 was more (51.2 days) whereas those reared in Vella was short (39.9 days). However these differences were statistically non-significant

Same trend in the biological features of S. oryzae was observed when reared in different varieties with high fecundity, shorter developmental periods of egg, larva and pupa and more longevity of insects reared in M 4; in Vella the fecundity and longevity were found to be low, the incubation period and the larval and pupal periods were also found to be extended. The other varieties were responding to the different biological parameters in an intermediary manner in the case of both the insects. According to Raghunath and Nair (1970) also higher fecundity, shorter developmental period of egg, grub, pupa and higher longevity of adults were the criteria of a preferred host of A. fasciculatus when different host materials were exposed to the insect.

The susceptibility of these six varieties of tapioca chips to infestation by A. fasciculatus and S. oryzae was also studied over a period of three months.

Results of these studies on the varietal susceptibility of A. fasciculatus presented in Table 19 indicated that the extent

of damage caused by the pest after three months of storage was least in Vella (91.60) and maximum in M 4 (99.75). The percentage of powdered material (40.70), the number of larvae (1202.20), number of pupae (87.49) and number of adults (267.48) were also least in Vella, but they were highest in M 4, the values being 85.50, 1663.43, 93.95 and 671.47, respectively.

The results presented in Table 20 indicated that the extent of damage due to infestation by S. oryzae as noticed three months after storage was least in Vella (66.07) and maximum in M 4 (100.00). The percentage of powdered material (0.65), the number of larvae (91.98), number of pupae (3.75) and number of adults (68.83) were least in Vella but they were highest in M 4, the values being 1.98, 214.45, 9.70, 150.12, respectively.

It was seen that all the varieties tested were susceptible to attack by A. fasciculatus and S. oryzae. The variety Vella was found to be least susceptible, while M 4 was highly susceptible variety and the other varieties were intermediate in their susceptibility to these pests.

Besides the variety Vella has less cooking quality when compared to M 4, having good cooking quality and softness of chips. These factors also help in host selection for egg laying and easy penetration of the pest and its stages into the chips for feeding and development. Nwana and Asodeh (1984) while studying the effect of variety on the susceptibility of A. fasciculatus also reported that the susceptibility was significantly influenced by the varieties. The differential response of the varieties to

the biological features of these insects may be attributed to the variations in the structural and chemical composition of the local and hybrid varieties of tapioca under study.

Investigations on the susceptibility of chips of different hybrid varieties of tapioca carried out by Pillai (1976) revealed that Sree Sahya is a relatively resistant variety to A. fasciculatus. Contrary to this, under the present investigation Sree Sahya showed a damage to the tune of 93.80 of the chips by the pest over a period of three months, with a population of 179.44 adults in a 2 kg sample of raw tapioca chips.

Great variation in the biological features viz. the average number of eggs laid, incubation period, larval period, pupal period and longevity of adults was observed when the insects were reared in raw and par boiled chips of tapioca variety M 4. Even-though raw chips of M 4 variety is preferred by these insects, par boiled chips of the same variety is not considered as a pre-ferred host. Biological features of both the insects reared in par boiled chips were having low fecundity, longer developmental periods of egg, larvae and pupae and shorter adult life whereas insects reared in raw chips were having high fecundity, short egg, larval and pupal periods and longer adult life. This is in full agreement with the observations made on the nature and extent of damage done by these insects on raw and par boiled chips of M 4 variety in which it was found that par boiled chips were not preferred by A. fasciculatus and S. oryzae.

Future line of work

Detailed investigations on the control aspects of *A. fasciculatus*, the major pest of stored tapioca chips will have to be taken up under storage conditions. The possibility on the usage of natural plant products and insecticides on the control of this pest both under rural storage and godown conditions will have to be explored. Emphasis should be given on the studies on residue problems which may lead to health hazards.

The scientific storing of dried tapioca chips using different storage structures such as polythene bags, polythene lined gunny bags, plastic containers, etc. should also be studied in detail to minimise the attack by this pest.

SUMMARY

SUMMARY

A random sample survey on the incidence of the insect pests of stored tapioca chips in storage houses was conducted in ten centres of Trivandrum District viz. Palode, Parassala, Nedumangad, Venjaramoodu, Pothencode, Chirayinkil, Vembayam, Chalai, Sreekariyam and Mangalapuram. The samples were collected at monthly intervals for a period of four months from August to November 1984. The survey revealed that among the various insect pests, the tapioca weevil Araecerus fasciculatus (DeG.), the rice weevil Sitophilus oryzae (L.) and the rust red flour beetle Tribolium castaneum (Hbst.) were found to be the major pests. The other pests include, drug store beetle, Stegobium paniceum (L.); Cigarette beetle, Lasioderma serricorne(F.); lesser grain borer, Rhizopertha dominica (F.); saw toothed grain beetle, Oryzaephilus surinamensis (L.); flat grain beetle, Laemophloeus minutus (Oliv.); Tenebroides mauritanicus (L.); the tapioca moth, Pyralis manihotalis (Guen); the fig moth, Ephestia cautella (Wlk.); the tobacco moth, Setomorpha rutella (Zell.) and Erechthias zebrena (Butler). The population of larvae, pupae and adult of A. fasciculatus and S. oryzae steadily increased up to three months of storage; thereafter there was sudden decline in the populations, when the entire quantity of tapioca chips was reduced to powder by the larvae and adults of the insect pests.

In the case of the adults of T. castaneum there was a progressive increase in the populations during the period of survey in all the locations.

Observations on nature and extent of damage caused by A. fasciculatus to tapioca chips stored for different periods revealed that the percentage of chips damaged and percentage of chips powdered were 100 and 78.3% respectively at 4th month after storage. The mean number of larvae (261.71), pupae (76.17) and adult insects (567.43) increased gradually as the duration of storage increased and reached the maximum in third month after storage. Thereafter there was a drastic reduction in mean number of larvae (21.09), pupae (3.28) and adult insects (202.82). By that time the entire chips were converted into powder.

In the case of S. oryzae the percentage of chips damaged, percentage of chips powdered and mean number of larvae, pupae and adult insects increased gradually over the months and reached the maximum of 45.2, 1.4, 316.33, 14.57 and 283.78 respectively in four months after storage.

Regarding the nature and extent of damage caused by T. castaneum the percentage of chips damaged, percentage of chips powdered, mean number of larvae, pupae and adult insects, increased gradually over the months and reached the maximum of 19.6, 0.77, 20.57, 3.97, 78.63 respectively in the fourth month after storage.

Assessment on nature and extent of damage caused by A. fasciculatus on par boiled chips for different periods revealed that the damage due to infestation by the pest was less in par boiled chips. Four month after storage the percentage of chips infested was 33.75 and percentage of chips powdered was 4.2. The

mean number of larvae, pupae and adults were less in par boiled chips, the values being 44.49, 4.65 and 85.24 respectively.

In the case of S. oryzae also the damage due to infestation was less in par boiled chips. The percentage of chips infested and percentage of chips powdered were 32.65 and 0.6 respectively. The mean number of larvae (116.99), pupae (4.97) and adult (102.19) were less in par boiled chips.

Regarding the damage caused by T. castaneum on par boiled chips the percentage of chips damaged (18.3), percentage of chips powdered (0.43), mean number of larvae (5.9), pupae (0.91) and adult (69.49) after four month of storage were comparatively less.

Studies on the biology of A. fasciculatus on different varieties of tapioca chips have shown that there was an increased fecundity (46.5 days), short incubation period (5.7 days), short larval (28.6 days) and pupal (5.1 days) periods and more longevity (51.2 days) of insects reared in M 4 variety, whereas in Vella the insect showed low fecundity (37.3 days), longer incubation (5.9 days), larval (29.1 days) and pupal (5.4 days) periods and lower longevity (39.9 days). Other varieties had intermediary effects on the different growth stages of the insects.

The results of the experiment on the biology of S. oryzae on different varieties of tapioca chips also revealed that there was an increased fecundity (57.8), short incubation period (8.9), short larval (29.8) and pupal (8.5) periods and more longevity

(126.7 days) of insects when reared in M 4 variety; the insects showed lower fecundity (49.8), longer incubation period (9.6), larval (30.7) and pupal (9.6) periods and lower longevity (119.7 days) in variety Vella. The other varieties showed intermediary effects on the different growth stages of the insects.

Biology of A.fasciculatus was studied on par boiled chips of the tapioca variety M 4. The results showed that in par boiled chips of the M 4 variety, the species showed low fecundity (22.5), longer egg (6.0 days), larval (34.0 days) and pupal (6.4 days) periods and shorter adult life (27.1).

In the case of S. oryzae also par boiled chips of the same variety showed low fecundity (29.5), longer egg (9.1 days), larval (32.3 days) and pupal (8.9 days) and shorter adult life (117.8 days).

The susceptibility of chips of six different varieties of tapioca namely Vella, Neelagiri, M 4, Sree Sahya, Sree Visakham and Njaruck to A. fasciculatus indicated that the extent of damage caused by the pest was least in Vella (91.6) and maximum in M 4 (99.75). The percentage of chips powdered (40.7), mean number of larvae (1202.2), pupae (87.49) and adult insects (267.48) were least in Vella, but they were highest in M 4. The values were 85.5, 1663.43, 93.95, 671.47 respectively. The other varieties showed intermediary susceptibility. None of the varieties tested was immune to the insect attack.

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In the case of S. oryzae the percentage of chips infested was least in Vella (66.07) and highest in M 4 (100). The percentage of chips powdered (0.67), mean number of larvae (91.98), pupae (3.73) and adult (68.83) were least in Vella. In M 4 percentage of chips powdered (1.98), mean number of larvae (214.45), pupae (9.7) and adult (130.12) were highest. In other varieties extent of damage was found to be intermediary in position. None of the varieties showed resistance to the attack by S. oryzae.

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* Original not seen

STUDIES ON THE NATURE AND EXTENT OF DAMAGE CAUSED BY INSECT PESTS TO STORED TAPIOCA CHIPS

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ABSTRACT OF A THESIS
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ABSTRACT

A survey on the population of different stages of insect pests and the extent of damage caused by these insects to stored tapioca chips were conducted at monthly intervals for a period of four months from August 1984 to November 1984 in ten centres of Trivandrum District viz. Palode, Parassala, Nedumangad, Venjaramood, Pothencode, Chirayinkil, Vembayam, Chalai, Sreekaryam and Mangalapuram, where tapioca chips were stored. Among the various pests recorded three species viz. tapioca weevil (Araecerus fasciculatus DeG.), rice weevil (Sitophilus oryzae (L)), and rust red flour beetle (Tribolium castaneum (Hbst.)) were found to be the major pests. The other species included drug store beetle (Stegobium paniceum (L)), cigarette beetle (Lasioderma serricorne (F)), lesser grain borer (Rhizopertha dominica (F)), saw toothed grain beetle (Oryzaephilus surinamensis (F)), flat grain beetle (Laemophloeus minutus (Oliv.)), Tenebroides mauritanicus (L), tapioca moth (Pyralis manihotalis (Guen)), the fig moth (Ephestia cautella (Wlk)), tobacco moth (Setomorpha rutella (Zell)) and Erechthias zebrina (Butler). It was also observed that the population of larvae, pupae and adult insects of A. fasciculatus and S. oryzae increased up to three months of storage; then there was a sudden decline in the population. The entire quantity of tapioca chips was converted into powder during the period of three months after storage. In the case of T. castaneum the population of adults was seen increasing after four months of storage.

Studies on the biology of A. fasciculatus and S. oryzae on tapioca chips made from different varieties showed that 'Malayan 4' (M 4) was the most susceptible host where the insects showed high fecundity, shorter egg, larval and pupal periods and more longevity of adults. In the case of less susceptible variety 'Vella' there was a corresponding increase in all the different life stages of insects, excepting the longevity of adults which was found to be comparatively less. Other varieties were intermediary in susceptibility to the pests.

Comparative biology of A. fasciculatus and S. oryzae on raw and par boiled chips of variety M 4 showed that raw chips were the most preferred by the insects when compared to the par boiled chips.

Observations on the nature and extent of damage caused by A. fasciculatus and S. oryzae to tapioca chips stored for different periods revealed that percentage of chips damaged, percentage of chips powdered and mean number of larvae, pupae and adult insects increased as the duration of storage increased and reached the maximum in three months after storage; by that time the entire chips were converted into powder. In the case of T. castaneum the percentage of chips damaged was comparatively less and the population of larvae, pupae and adult insects was seen increasing even after four months.

Assessment of the nature and extent of damage caused by A. fasciculatus, S. oryzae and T. castaneum on par boiled chips

stored for different periods revealed that damage due to these pests were less in par boiled chips.

Studies on the susceptibility of dried chips of tapioca prepared from six varieties namely, Vella, Neelagiri, Malayan 4, Sree Sahya, Sree Visakham and Ujaruck to A. fasciculatus and S. oryzae indicated that Vella was the least susceptible, M 4 was the most susceptible and other varieties were intermediary in the susceptibility. None of the varieties tested was immune to insect attack.