STUDIES ON THE EXTENT OF DAMAGE CAUSED BY PESTS OF STORED COPRA AND CONTROL OF THE IMPORTANT PESTS

By

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THESIS

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DECLARATION

I hereby declare that this thesis, entitled 'STUDIES ON THE EXTENT OF DAMAGE CAUSED BY PESTS OF STORED COPRA AND CONTROL OF THE IMPORTANT PESTS', 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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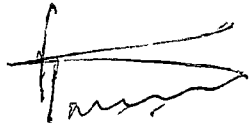

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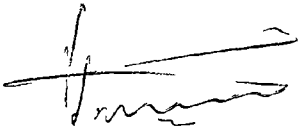
Dr. K.V. MAMMEN 

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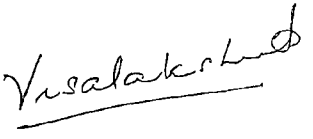
2. Dr.(Mrs.) A. VISALAKSHY 

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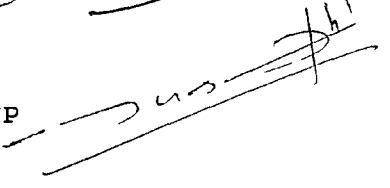
4. Dr.(Mrs.) SUSAMMA PHILIP 

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The coconut (*Cocos nucifera* Linn.) is a crop of great antiquity in Kerala. The nuts from the tree and other products of commercial importance constitute 9.3 per cent of the State's income. The share of the crop to the agricultural income of the State is 34.9 per cent (Aravindakshan, 1988). About 46 per cent of the total produce is converted into copra, out of which 21 per cent is directly used as constituent of consumables and remainder goes to the crushing mills for the production of oil. Out of 3.9 lakh tonnes of copra produced in the country, 3.82 lakh tonnes (98 per cent) is contributed by Kerala (Thampan, 1988). Seven per cent of the 3.3 million tonnes of edible oils produced in India is contributed by Kerala as coconut oil. The production is short of the present need and at the present rate of consumption, India will have to produce more than double the quantity of coconut oil by the turn of the century. Thus copra is a dear commodity for us today and will continue to be so, for many more years to come.

In spite of the dearth of this commodity in the market and the high price it fetches, at various stages of its production, distribution and utilisation, heavy quantitative and qualitative losses occur from insect and

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In spite of the dearth of this commodity in the market and the high price it fetches, at various stages of its production, distribution and utilisation, heavy quantitative and qualitative losses occur from insect and

non insect pests, fungi and other micro organisms. The defects in the processing and storage aggravates such losses (Thampan, 1982).

Many of the insects found attacking copra, are not specific pests of the commodity and the intensity of damage depends on the storage conditions and the nature of other commodities stored in the godowns.

Informations on the magnitude and intensity of the pest problems in stored copra in Kerala and the safe and effective methods for minimising these losses have not been studied in detail so far. The present studies were hence taken up with a view to assessing.

(1) the distribution of insect pests infesting stored copra in the Southern Districts of Kerala

(2) extent of damage caused by the major pests infesting copra and the effect of fungal infection on the damage caused by the insects

(3) susceptibility of copra obtained from different varieties of coconut to insect infestation

(4) influence of moisture content of copra on the development of the insects and the extent of damage caused by them

(5) extent of damage caused by insects to copra kept under different types of storage and

(6) prophylactic and curative methods for controlling insects infesting copra and the residues of insecticides in the commodity after the treatments.

REVIEW OF LITERATURE

1. REVIEW OF LITERATURE

Literature available on various aspects related to the present investigations on pests of copra have been briefly reviewed here.

1.1. Pests reported on copra

The clerid beetle Necrobia rufipes De Geer, the nitidulid beetle Carpophilus sp., the cucujid Laemophloeus sp. and a tineid moth were reported as pests of copra in Sumatra (Rutgers, 1918). DeFremery (1929) recorded Silvanus surinamensis Linn., Tribolium castaneum Hbst. and N. rufipes in Amsterdam, 95 per cent of the insect being S. surinamensis. Mathen (1961) reported the infestation of copra by N. rufipes, the flour beetle T. castaneum, the saw toothed grain beetle Oryzaephilus surinamensis Linn., the khapra beetle Trogoderma granarium Everts, the foreign grain beetle Ahasverus advena Walt., the short winged beetle Carpophilus dimidiatus F., rice moth Corcyra cephalonica Stainton., and the almond moth Ephestia cautella Walk., in Kerala. Peter (1974) collected E. cautella, N. rufipes, T. castaneum and O. surinamensis from copra in Gilbert and Ellice Islands. A survey in Guyana revealed that C. dimidiatus and N. rufipes were serious pests of copra (Rai and Singh, 1977).

Laborius et al. (1980) found that copra was heavily infested by N. rufipes in West Samoa.

1.2. Necrobia rufipes De Geer.

1.2.1. Systematic position

N. rufipes was first described as Dermestes rufipes Fab. in family cleridae under order coleoptera in 1781 (Fletcher, 1914). It was renamed as Necrobia rufipes in 1859 by Leconte (Essig, 1931).

1.2.2. Distribution as a pest of copra

It was reported as a pest of copra from Sumatra (Rutegers, 1918), USA (Simmons and Ellington, 1925), India (Pillai, 1957 and Mathen, 1961), Gilbert and Ellice Islands (Peter, 1974), Guyana (Rai and Singh, 1977) and West Samoa (Laborius et al., 1980).

1.2.3. Alternate food media

N. rufipes was also noted as a destructive pest of dried meat, dried fish, bone meal, cheese, dried egg, hides, fruits and nuts in USA (Simmons and Ellington, 1925), palm kernel in Malaya (Corbett and Dover, 1927), in Sierra Leone (Hargreaves, 1937), dried

banana in Java (Anon, 1928), dried fish and prawns in South India (Pillai, 1957), palm kernels in Port Harcourt (Onyearu, 1967; Riley and Simmons, 1967), benniseed in Nigeria (Heape, 1968), animal feed in Indonesia (Suryoadikusumo, 1983) and cashew kernels in South India (Abraham, 1958; Pillai, 1959; Pillai and Muthu, 1978 and Ommen et al., 1985).

1.2.4. Biology

The biology of N. rufipes was studied by Simmons and Ellington (1925) and Metcalf and Flint (1973). The female were seen laying 400 to 2000 eggs in dry recesses of the food substances. These eggs hatched in 4 to 5 days in warm weather. The purple coloured larvae, one cm long when full grown, migrated from greasy food to dry dark spots for pupation. The life cycle was completed in 36 to 150 days depending on the available food.

Osuji (1975) observed that salt treated fish prolonged larval development, decreased larval and adult body weight, reduced fecundity and egg viability of N. rufipes. Osuji (1977) recorded rapid development of N. rufipes in dried fish, palm kernels, groundnut and copra compared to cacao and maize.

Ommen et al. (1985) observed that the insect laid eggs in batches of five to 35 with an average of 316 and the incubation period varied from four to five days. The larvae had four instars, completed in 23 to 52 days. The full grown larva was 11.5 mm in size. Pre-pupal and pupal periods ranged from four to six days and six to seven days respectively. The males and females lived for six to eight and seven to nine days respectively without food and 28 to 243 days and 10 to 250 days respectively with food.

1.2.5. Nature of damage

N. rufipes was reported as a severe pest of copra, especially when the commodity was processed from immature nuts (Rutgers, 1918). De Fremery (1929) noticed N. rufipes as a serious pest of copra having broken cell structure. Ghani (1939) observed N. rufipes feeding on rotting meat at Lyallpur. The beetles were found damaging woollen cloth causing feeding holes in them (Weidner, 1967). They were found feeding on spongy parts of the bones of whale in Calicut (Adolph and Soans, 1969). Infestation of this pest in dried fish was severe in Nigeria through out the year and was the highest in hot dry months and the least in rainy season (Osuji, 1974a). Mass invasion of the beetle was observed in slaughtering warehouses,

feeding on slaughtering by-products (Martynowiez et al., 1976). The larvae and adults of three species of Necrobia were found feeding on carrion with predation on other saprophagous insects (Gosling, 1980).

1.2.6. Extent of damage

Onyearu (1967) and Riley and Simmons(1967) noticed an average of 80 N. rufipes per bag in palm kernels stored at Port Harcourt. Osuji (1974b) observed that populations of this beetle on stored dried fishes, Citharinus, Clarias, Heterotis and Synodontis were on an average 1.5, 24.5, 19.2 and 9.7 respectively and twenty eight per cent of dried fish sold in Nigeria were found infested by N. rufipes. Guillon (1976) reported 36 per cent loss of dry fish attacked by N. rufipes and Dermestes maculatus De Geer in Mali.

1.2.7. Control

Guillon (1976) reported that immersing dry fish in 1125 ppm tetrachlorvinphos for one hour gave good control of N. rufipes. Rai and Singh (1977) observed that phoxim and pirimiphos methyl emulsions applied on the bagged copra surfaces at 0.4 g a.i./m^2 controlled N. rufipes.

Ommen et al. (1985) found that sumicidin, quinalphos, methyl parathion, endosulfan and fenthion, each as one per cent spray were effective against the adults and larvae of N. rufipes.

1.3. Oryzaephilus surinamensis Linn.

1.3.1. Systematic position

The insect was first described as Dermestes surinamensis Linn. in family silvanidae under order coleoptera in 1758 by Linnaeus and later renamed as Silvanus surinamensis by Lefroy (Fletcher, 1914). The systematic position of the insect was reviewed in detail by Blaschke in 1845 and it was named as Oryzaephilus surinamensis Linn. (Essig, 1931).

1.3.2. Distribution as a pest of copra

S. surinamensis has been reported as a serious pest of copra from Amsterdam (DeFremery, 1929), South India (Mathen, 1961) and Gilbert and Ellice Islands (Peter, 1974).

1.3.3. Alternate hosts

It was recorded as a secondary grain pest from London (Dendy, 1918) and on dates from Baghdad (Winshurst, 1920), in dried banana from Java (Anon, 1928), in dried grapes from London (Mayers, 1928), in ginger and maize from

Sierra Leone (Hargreaves, 1937), in sparrow's nest in Britain (Woodroffe, 1953), in walnuts in Britain (Smith, 1960), in palm kernels from Port Harcourt (Onyearu , 1967), in wheat, barley and rye from Sweden (Mathlein, 1971) and in dum nuts from Sudan (Roonwal, 1971). According to Hughes (1980), among the beetle pests, the most abundant species found infesting stored products in Bermuda was O. surinamensis.

In India, incidence of S. surinamensis was reported from Punjab in dates, apricot, grapes, figs, melon, maize, jowar, rice and wheat (Sohi, 1941); from South India in cashew kernels (Abraham, 1958; Pillai and Muthu, 1978), from Haryana, Punjab, Delhi and Uttar Pradesh on stored walnuts (Gill et al., 1975) and from Orissa in various varieties of rice (Prakash and Rao, 1987).

1.3.4. Biology

The fecundity of the insect has been reported as 45 to 285 (Back and Cotton, 1926), 85 (Sohi, 1941), 79.7 (Joshi, 1975) and 325 to 343.8 (Ali et al., 1980) eggs per female.

The incubation period of the eggs of Oryzaephilus spp., as reported by different authors, showed considerable variations. According to Back and Cotton (1926), the

incubation period ranged from three to 17 days. Sohi (1941) reported that the egg period was seven to nine days and Joshi (1975) observed it as four to five days.

Back and Cotton (1926) observed that the larval duration of O. surinamensis ranged from two to 10 weeks. There were four to five moults and the larvae were full grown in about 36 days as observed by Sohi (1941). Joshi (1975) noted that the larval period of O. mercator extended over 24.5 days with two moults. According to Vijay Singh (1987), the developmental period of O. surinamensis ranged from 25.0 to 25.8 days.

Pupal period of six to 12 days was recorded by Back and Cotton (1926), one week by Sohi (1941), six to seven days by Joshi (1975).

Adult beetles lived for more than three years and the majority of ovipositing females lived for six to eight months (Back and Cotton, 1926; Ommen et al., 1985). According to Sohi (1941) the adult beetles lived for two to five months.

Nigam et al. (1969) observed more rapid development of O. surinamensis from egg to adult, longer female life and oviposition period and greater fecundity at 27°C than at 23.3°C. Dzhamalov (1971) recorded that at 24 to 27°C

O. surinamensis developed all the year round, producing seven to nine generations. The development of this beetle was completed in 105 days at 18°C and in 23.3 days at 32°C and 23.2 days at 36°C (Nawrot, 1974).

Low humidity was found to prolong larval development of O. surinamensis, but varying humidity levels had no effect on the eggs or pupae of the insect (Nigam et al., 1969). At 52 to 65 per cent relative humidity, this beetle developed all the year round producing seven to nine generations a year (Dzhamalov, 1971). But Nawrot (1974) reported that at 75 per cent relative humidity, rapid development of O. surinamensis was noticed and at lower ranges of relative humidity, the development was prolonged considerably.

1.3.5. Nature of damage

De Fremery (1929) observed that the larvae of S. surinamensis, fed freely on copra if it was partly rotten by bacteria. Meawad (1979) reported that stored dates were attacked by this beetle one month after harvest in Saudi Arabia.

1.3.6. Extent of damage

Surup and Srivastava (1971) reported 100 per cent damage of neem kernel by S. surinamensis. Atanasov (1974)

recorded the occurrence of this pest in 62.3 per cent store houses with a maximum density of 16.4 beetles/kg neem seed at 24 to 26°C. Nut infestation of zero to 71 per cent was observed in walnut in Haryana, Punjab, Delhi and Uttar Pradesh (Gill et al., 1975). A general infestation rate of 55 per cent was noticed on walnuts and 70 per cent of the damaged nuts had multiple infestation (Srinath and Gill, 1976). According to Meawad (1979) 100 per cent damage of stored dates occurred in seven months after harvest in Saudi Arabia. Prakash and Rao (1987) recorded 6.0 to 16.6 per cent weight loss of various varieties of rice due to the attack of O. surinamensis.

1.3.7. Control

Lindgren et al. (1958) reported that phosphine used at 4.4 to 9.8 mg/l, with an exposure period of 24 to 96 hours at temperatures of 50 to 70°F, caused 100 per cent mortality of O. surinamensis. Green (1969) observed that spraying malathion @ 80 mg/ft^2 or fenitrothion @ 40 mg/ft^2 on the walls of the godown gave good control of O. surinamensis. Malathion 12 ppm sprayed on stored oats gave complete control of this beetle (Watters, 1974). Rosen (1976) reported that two per cent methoxychlor and one per cent malathion gave 100 per cent and 78 per cent control of O. surinamensis

respectively upto 41 months. Malathion at 4 to 25 ppm protected stored walnuts from damage of this beetle in California (Spitler et al., 1976). Jacobson and Pinniger (1982) observed that the application of one per cent fenitrothion on the exterior and interior walls of farm grain store gave 99.9 per cent control of O. surinamensis.

1.4. Effect of fungal incidence and insect infestation on copra

1.4.1. Fungal deterioration of copra

Fishlock (1929) recorded Aspergillus niger Van Tiegh and Aspergillus flavus Link. as important moulds of insufficiently dried copra. Ward (1937) listed various fungi attacking copra in Malaya and reported that moulds like A. flavus and Aspergillus tamarii Kita. penetrated deep into copra and caused serious damage to the commodity. Subramonian (1956) recorded that Aspergillus spp. caused considerable deterioration of copra and oil in South India while Penicillium sp. had superficial growth. Subramanian (1965) reported that presence of A. flavus, Aspergillus oryzae Ahlburg Cohn. and Rhizopus nigricans Ehrenb. at the early stages of drying and A. tamarii, A. niger, Aspergillus glaucus Link. and Penicillium sp. at later stages of drying coconut kernels. Paul (1969) isolated A. niger, A. flavus, Aspergillus ustus Bain.,

Rhizopus sp., Penicillum sp. and Diplodia sp. from copra collected from the different Districts of Kerala. Nair and Sreemulanathan (1970) observed spoilage of well dried copra with moisture content below four per cent by Penicillium frequentans Westling. Rao et al. (1971) reported that Botryodiplodia theobromae Pat., were responsible for blackening and spoilage of kernels. Sreemulanathan and Nair (1971) isolated species of Aspergillus, Penicillium, Diplodia, Monilia and Rhizopus from dried copra. Among the fungi R. nigricans, A. niger and A. flavus were found to be very destructive.

1.4.2. Effect of fungus on insect growth and development

1.4.2.1. Unfavourable effect on insects

Majumder (1978) reported that stored paddy invaded by storage pests like Sitotroga sp., Plodia sp. and Sitophilus sp. was frequently infected by the storage fungi, Penicillium sp., Embylosporium sp. and Cephalosporium sp. which produced materials, which were toxic to insects. It happened particularly when the grains were not properly dried.

Rodriguez et al. (1980) observed that sterigmatocystin, T_2 toxin and zearolenone at 1, 10 and 100 ppm were lethal to Tyrophagus putrescentiae Schr. reared on an axenic casein

wheat germ diet in the first generation itself and aflotoxin B_1, citrinin, ochrotoxin A and penicillic acid were less toxic and permitted considerable development in the first generation. But in the second generation 100 per cent mortality was observed.

The Penicillium mycotoxins such as ochratoxin and citrinin inhibited larval growth of Attagenus megatoma Fab. at 10 and 1000 ppm respectively. Citrinin and rubratoxin B inhibited larval growth of T. castaneum and Lasioderma serricorne Fab. at 1000 ppm (Wright et al., 1980a). Wright and Burroughs (1983) reported that sorghum grain invaded by Penicillium citrinum Thom. inhibited the growth of T. castaneum and caused 100 per cent mortality in Cryptolestes pusillus Schonh. Gupta and Khare (1985) observed that A. flavus infection at 18 to 20 per cent moisture in wheat caused 60 per cent and 80 per cent mortality of Sitophilus oryzae Linn. and Rhizopertha dominica Fab. respectively.

1.4.2.2. Favourable effect of fungus on insects

Wright et al. (1980a) found that penicillic acid, oxalic acid and rubratoxin B produced by Penicillium were not toxic to Tribolium confusum Duv., L. serricorne and A. megatoma. Wright et al. (1980b) found that T. confusum adults were attracted to fungal isolates with nutritional benefit.

Wright et al. (1980c) reported that Penicillium chrysogenum Thom. and Penicillium viridiculatum Dang. allowed excellent larval growth, minimal developmental time and low mortality of T. confusum. More progeny of T. confusum were produced on P. chrysogenum diets than the control diet, brewer's yeast. Prakash et al. (1982) reported that A. flavus and A. niger infested grains were suitable for the development of Sitotroga cerealella Oliv. than uninfected grain. Adult was more on grain completely covered with fungus than on healthy grain. Wright and Burroughs (1983) recorded that sorghum flour damaged with A. glaucus and Aspergillus candidus Link. was the better media for the growth of T. castaneum, Cynaeus angustus Lec. and C. pusillus than flour which were not derived from mouldy grain. P. citrinum invaded flour supported larval growth of C. angustus.

1.4.2.3. Effect of fungus on biochemical constituents of the produce

Fishlock (1929) observed that Penicillium sp. growing on copra did not cause the production of free fatty acid in oil. Livschitz (1936) found that Penicillium and Aspergillus were capable of splitting fats in oils and the lipolysis induced by the fungal activity was characterised by marked rise in acid value. Unnikrishnan (1968) recorded changes in odour and colour of the oil extracted from copra infected

by fungi. An increase in iodine value and decrease in saponification value were also noticed. Paul (1969) observed a progressive fall in the oil content of copra due to the attack of A. flavus and A. niger. Philip (1978) reported that among the fungi tested A. flavus produced the maximum colour to the oil. Rancid smell was detected seven days after incubation with A. flavus, acid value steadily increased with the period of incubation. No change in saponification value and a gradual increase in iodine value were noted in oil extracted from infected copra.

Lalithakumari et al. (1971) reported that free fatty acid content, saponification number and iodine number of the oil extracted from groundnuts infected by seed borne fungi showed a general increase. Abdel Rahman (1982) found that lipids and free fatty acid content increased in peanuts inoculated with Aspergillus spp. and Rhizopus spp. Slightly lower per cent of palmitic and stearic acids and slightly higher per cent of oleic and linoleic acids were recorded.

1.5. Varietal susceptibility of stored materials to different storage pests

1.5.1. Mechanism of resistance

Rahman (1942) reported that wheat varieties with higher protein, dry glutin and low moisture content were

more susceptible to the attack of stored grain pests. Dang and Pant (1965) revealed that the chemical nature of maize was important for making kernel resistance to T. castaneum. Lacato and Agrobast (1974) found that T. castaneum multiplied in large numbers in maize with high lysine content, whereas it did not have any effect in the multiplication of O. surinamensis and R. dominica.

1.5.2. Incidence of pests on different varieties of stored products

Abraham and Nair (1966) reported that the incidence of S. cerealella varied from 0.02 to 6.83 per cent in 29 rice varieties tested. Nigam et al. (1987) observed varying susceptibility to different varieties of rice to insect pests and they grouped the tested varieties as susceptible, less susceptible and moderately resistant ones.

Pandey et al. (1977) reported that the adult emergence and growth index of Cadra cautella Walk. and the average amount of damage done by the larvae were very high in groundnut variety T-28 and low in the variety M-13.

Patnaik and Samalo (1987) observed that 28.7 per cent seed infestation and 5.3 per cent loss in seed weight in the pigeon pea variety 'ICPL-161' as against seven per cent seed infestation and 2.1 per cent loss in seed weight in the

variety 'ICPL-87'. Singal (1987) reported that chick pea H-83-17 was least susceptible on the basis of percentage adult emergence and growth index of Callosobruchus chinensis Linn. while genotype H-84-43, H-83-152 and H-84-53 were highly susceptible. The adult emergence and loss in weight were found to be positively correlated.

Vijaysingh (1987) recorded that the cashew kernels obtained from some trees in the farm were less susceptible to the attack of O. surinamensis compared to the yield from the other trees as shown by the growth indices of the insect.

1.6. Influence of moisture content of stored products on population build up of storage pests

Many insects preferred low quality copra infected with moulds for egg laying. Bacterial fermentation and growth of moulds were inhibited when moisture content was below 6 per cent (Mathen, 1961). Ramonde (1961) observed that the maximum permissible moisture content for safe oil seed storage was 14 per cent.

Reddy (1950) reported that the activity of S. oryzae in wheat was more in a moisture range of 13.5 to 17.6 per cent and the insect did not lay eggs in wheat having less than 7.4 per cent moisture. Fourie (1967) found that maximum fecundity of S. oryzae occured when the immature stages were

reared in maize at 26°C and 14 per cent moisture. Kosolapova (1970) observed that the larvae and adults on N. rufipes fed on germ of grain, having a moisture content above 12 per cent.

1.7. Prophylactic methods of control

1.7.1. Effect of different types of storage on pest infestation

Marar and Padmanabhan (1960) reported that alkathene lined gunny bags preserved copra in good condition and free from mould and insect attack upto a period of six months. Mathen et al. (1968) found that multiwall paper bags gave good protection against pests of copra upto three months as compared to ordinary gunny bags. Rai and Singh (1977) observed that bags used for storing copra were generally reused and these became the major source of infestation of fresh stock in godowns.

1.7.2. Relative efficacy of insecticide when directly exposed to the toxicant

Malathion at 12 ppm applied on oats controlled the infestation by O. surinamensis (Watters, 1974). On wheat, bioresmethrin plus piperonylbutoxide was found more effective than malathion and less effective than fenitrothion (Carter et al., 1975). Iordanou (1976) found that malathion

and fenitrothion at 12 ppm gave effective protection. Sumicidin, quinalphos, methyl parathion, endosulfan and fenthion each at 0.1 per cent spray applied on glass surfaces was effective against the adults and larvae of N. rufipes (Ommen et al., 1985).

1.7.3. Persistant toxicity of insecticides to storage pests on different substrates

Phoxim at the rate of 3.228 g/m^2 on concrete caused complete mortality of T. castaneum, S. oryzae and R. dominica one hour after application (Girish et al, 1973) and bromophos gave good control of Cryptolestes ferrugineus and T. castaneum (Mensah et al., 1979).

Phoxim applied at the rate of 1.61 g/m^2 on jute bags resulted in complete mortality of T. castaneum, S. oryzae and R. dominica one hour after treatment (Girish et al., 1973).

Malathion one per cent applied on masonite boards gave 100 per cent kill of O. surinamensis upto 41 months after treatment (Rosen, 1976).

Malathion, iodofenphos and bromophos when applied on plywood surfaces, at the rate of 2.5 g/m^2, gave absolute control of O. surinamensis for 52 weeks (Touthong and Watters, 1978). Malathion was more toxic than fenitrothion

at 0.5 g a.i./m^2 and it controlled red flour beetle and rusty grain beetle for 35 weeks (White et al., 1983). Malathion applied on wooden surfaces gave good control of C. ferrugineus and T. castaneum (Mensah et al., 1979).

White et al. (1983) reported that malathion was more toxic than fenitrothion when applied at 0.5 g a.i./m^2 on galvanised steel surfaces for the control of red flour beetle and rusty grain beetle and the effect persisted over 35 weeks.

1.7.4. Effect of insecticidal treatment on gunny bag for the control of different storage pests

Gunny bag impregnation with BHC + DDT and malathion at one per cent concentration gave effective control of red flour beetle and cigarette beetle (Joshi and Kaul, 1965), fenitrothion at the rate of 80 to 160 mg/ft^2 protected bagged grains from O. surinamensis for six months (Kane and Green, 1968). Malathion was the most effective toxicant when the gunny bags used for storing corn were impregnated with insecticides (Morallo-Rejenus, 1975). Impregnation of gunnies with pirimiphos methyl proved effective against the adults of S. oryzae, R. dominica and grubs of T. granarium (Singh and Chahal, 1975). Phoxim applied on the surface of gunny bags at 100 mg a.i./ft^2 gave best control of C. chinensis (Kuppuswamy and Subramonian, 1976). Phoxim and pirimiphos

methyl applied on gunny bags at the rate of 0.4 g a.i./m^2 controlled N. rufipes infesting copra (Rai and Singh, 1977). Phoxim at 400 mg a.i./m^2 gave protection against R. dominica and phoxim 600 mg a.i./m^2 and isofenphos at 800 mg a.i./m^2 were effective against S. cerealella attacking paddy (Devi and Mohandas, 1981).

1.7.5. Effect of treating godowns with different insecticides for the control of storage pests

Spraying of malathion @ 80 mg/ft^2 or fenitrothion @ 40 mg/ft^2 on the walls of the godowns gave good control of O. surinamensis (Green, 1969), grain surface spraying and wall spraying with malathion controlled insect population in stored shell corn (Quinlan, 1977). Application of fenitrothion (one per cent) on the wall of godowns gave 99.9 per cent eradication of O. surinamensis (Jacobson and Pinniger, 1982).

1.8. Curative method

1.8.1. Fumigation of infested produce

Among the fumigants available, phosphine was proved to be the more toxic chemical than other fumigants for the control of storage pests. Cent per cent control of O. surinamensis was obtained by fumigating infested wheat with hydrogen phosphide while only 52.9 per cent control was

obtained with EDCT (Lallan Rai et al., 1964). Phosphine was proved to be more toxic than methyl bromide for the control of Dermestes spp., Necrobia spp. and Piophila spp. (Wainman et al., 1980).

Phosphine came on par with ethylene dibromide and it gave good control of Callosobruchus maculatus F., T. castaneum, O. mercator and Cryptolestes sp. infesting cowpea (Cornes and Adeyemi, 1969). Phosphine preparations (phostoxin and gastoxin) gave 100 per cent mortality of S. oryzae, R. dominica and O. surinamensis and 80 to 100 per cent mortality of Sitophilus granarius Linn. and 46 to 98 per cent kill of T. confusum (Stoyanova and Shikrenov, 1983).

Araecerus fasciculatus De Geer infesting coffee beans was controlled by fumigation with aluminium phosphide using 15, 16 and 30 tablets/ton (Coutinho et al., 1961), one pellet/4 sacs (Puzzi et al., 1968) and 0.5 or 0.4 g ai/m^3 for 48 or 72 h (Bitran, 1974), were reported effective.

Fumigation with 15, 16 and 30 aluminium phosphide tablets/ton of groundnut gave effective control of C. cephalonica (Coutinho et al., 1961). One tablet/ton was recommended for the control of T. castaneum and O. mercator

on groundnut (Halliday and Kazaure, 1969) and 0.6 g pellet for 32 to 82 kg of groundnut gave 100 per cent kill of O. surinamensis (Proctor and Ashman, 1972).

The insects in cacao beans infested by Sitophilus zeamais Mot., T. castaneum and A. fasciculatus were effectively controlled by 0.6 g pellet of aluminium phosphide exposed in 44 gallon steel drum for 24 hours (Qureshi, 1967; Riley, 1969). A. advena, Cryptolestes sp., N. rufipes, L. serricorne, O. mercator, T. castaneum and E. cautella were controlled in infested cacao by using 0.8 g/m^3 of aluminium phosphide (Mejule and Onyuike, 1980).

Fumigation with 8.1 g phostoxin/m^3 for 48 hours resulted in a mortality of 96.8 per cent adults and 99.2 per cent larvae of N. rufipes infesting stored copra (Rai and Singh, 1977).

N. rufipes infesting cashewnut kernels was effectively controlled by using 3 g aluminium phosphide/m^3 (Mohammed, 1982) and 2273 g/1000 m^3 for an exposure period of 72 hours (Ommen et al., 1985).

Phosphine was found as an effective fumigant for the disinfestation of dates from O. surinamensis used at the initial concentration of 649 ppm and 40 hours (Leesch et al., 1982). All stages of this pest could be controlled when a

four day exposure period was adopted at 15° and 25°C and under 60 per cent RH and at a concentration ranging between 0.05 mg/l and 1.6 mg/l (Price and Mills, 1988).

1.8.2. Residues of fumigants in the fumigated commodities

Residues of methyl bromide in garlic bulbs, almonds. hazel nuts, groundnut, copra, royal palm, beans and citrus peel were below tolerence level (Merck-Luengo, 1972).

Residues of phosphine in wheat fumigated with two to ten tablets/ton were below tolerence limit when four to seven days aeration was given and 0.01 ppm to 0.05 ppm residues were found with zero hour aeration (Bruce et al., 1962; Awasthi et al., 1971; Srivasthava, 1980 and Agrawal, 1987).

Groundnut fumigated with 2.08 mg/l and 1.12 mg/l phosphine showed residue below tolerence limit (Proctor and Ashman, 1972 and Leesch et al., 1979). When fumigated with two, four and eight tablets/ton for five days the residue fell below the tolerence limit of 0.01 ppm in 1.9, 2.4 and 2.4 days of aeration (Dhaliwal and Lal, 1974).

Moong, cowpea and pea fumigated with aluminium phosphide @ eight tablets/ton, the residue fell below the tolerence limit in 1.6, 2.2 and 2.5 days (Singh and Srivastava, 1980). When fumigated with 4.5 g/m^3 for five days with 12 hours aeration

no residue could be detected in cowpea (Mohammed, 1982). No residue was present in dhal and gram flour fumigated with 2 to 4 tablets/ton, while in moong flour the residue was 0.01045 ppm (Renusobti, 1985).

A residue of 0.0129 ppm phosphine was present in cashewnut kernel fumigated with 12 g aluminium phosphide/m^3 with an aeration period of 12 hours (Mohammed, 1982).

MATERIALS AND METHODS

2. MATERIALS AND METHODS

2.1. Survey of storage pests associated with copra in the Southern Districts of Kerala

The nature and extent of damage caused by insect pests in stored copra in the godowns of Trivandrum, Quilon and Alleppey Districts of Kerala were studied through a preliminary survey conducted in 1984. Only six godowns could be located where copra was being stored through out the year. The godowns selected were Integrated Coconut Processing Complex, Attingal; Sreekrishna Oil Mill, Sreekaryam; Kannan Oil Mill, Karamana; Vasantha Oil Mill, Nedumangad in Trivandrum District; Nagalingam and Sons, Asramom in Quilon District and a collection centre of Coconut Development Corporation at Shertallai in Alleppey District. In these godowns, the survey was carried out for two years from October 1984 at bimonthly intervals.

Ten samples of copra were collected from each godown during first week of alternate months. The copra bags were taken at random from the bottom, middle and top layers of the stack. These bags were opened and kept undisturbed for two hours. Two hundred gram sample was taken from each bag in a polythene bag. From the stocks

held in heaps, samples were drawn from different depths, mixed and 200 g lots were taken in polythene bags. These samples were brought to the laboratory for further examination.

2.1.1. Observations

The adult insects present in each sample of copra brought to the laboratory were counted. The copra pieces were then split up using a knife and the number of adults and immature stages of all the insects present inside the galleries were counted and recorded. The total number of the immature stages and adults of each insect was treated as its population during the period of observation. The moisture content of each sample was also recorded following the methods of A.O.A.C. (1960).

Data on weather factors viz., maximum and minimum temperature, morning and evening humidity and rainfall prevalent in the locations were also recorded.

The populations of the different species of insects found infesting stored copra at different locations were statistically analysed. The correlation between the weather factors and the population fluctuations were also worked out.

2.2. Assessment of the extent of damage to stored copra by insects and fungus independently and in combination

2.2.1. Preparation of copra

Fresh coconut kernels, sterilised by immersing in 0.1 per cent mercuric chloride solution for five minutes, were washed thrice in sterile water and were kept in hot air oven maintained at 60°C. The moisture content of the sample was ascertained periodically till it was reduced to 8±0.5 per cent as mentioned in para 2.1.1.

2.2.2. Rearing N. rufipes

N. rufipes was collected from the godowns in specimen tubes using a camel hair brush. These insects were brought to the laboratory and were transferred to pieces of copra, having eight per cent moisture, kept in troughs (20 x 15 cm). The troughs were then closed with muslin cloth held in position using a rubber band and were kept undisturbed for 4 months for multiplication of the insects. Insects required for the experiment were obtained by removing all the adults present in the culture and collecting those emerging on the succeeding day, treating them as one day old insects.

2.2.3. Rearing O. surinamensis

O. surinamensis was collected as described in para 2.2.2. These insects were transferred to pieces of copra containing 5 per cent moisture kept in 20 x 15 cm circular troughs and were closed with muslin cloth. The troughs were kept undisturbed for two months. For obtaining insects for the experiments pupae were collected from the mass culture and were kept on tissue paper placed inside petridishes. Just emerged adults were collected from the petridishes and were used for the experiments.

2.2.4. Culturing of the fungus

A. flavus infested copra, cut into small pieces under aseptic conditions, were transferred to 99 ml of sterile distilled water taken in 250 ml conical flask and was shaken in a mechanical shaker for 30 minutes. Serial dilutions were made by transferring one ml aliquot to 99 ml of sterile distilled water. It was shaken for 5 minutes. The process was repeated till the final dilution reached the level of one in million. From this final suspension one ml was pipetted into sterile petridish and 15 ml of melted and cooled peptone dextrose agar with rose bengal was added and it was allowed to

solidify. The petridish was incubated at room temperature. After one week the fungal colonies were transferred to potato dextrose agar plates. These cultures were used for the experiment.

2.2.5. Exposure of copra to fungus, insects and their combinations

The treatments included were the exposure of copra to fungus alone, insect alone, the fungus followed by insect and insect followed by the fungus. There were eight treatments as detailed in Table 3. Each treatment was replicated thrice. Two hundred g of sterilised copra was taken in a screw capped bottle for each replication. The fungal inoculation was done by collecting the spores from the culture maintained in the laboratory using sterilised cotton, under aseptic condition and spreading the same uniformly over pieces of copra. In the case of insects, 100 numbers of each species collected as described in para 2.2.2. and 2.2.3. were released in each replication. Six such lots were set up for each treatment so that each lot could be utilised for observations at monthly intervals from the commencement of the experiment.

2.2.6. Observations

The contents in each bottle was transferred to a piece of paper. Each piece of copra was split open and the powdered portions and faecal matter in the galleries were removed thoroughly using a camel hair brush. The undamaged portions of copra were then weighed and with reference to the weight at the time of storage, the weight of copra damaged by the pest was calculated.

The oil from each replicate was separately extracted, following the soxhlet extraction procedure of A.O.A.C. (1960). The oil was weighed and from the data the percentages of oil in the samples were calculated.

Variations in the intensity of colour of oil due to infection by fungus and infestation by insects were assessed using standard Lovibond tintometer. The samples of oil were taken in the tintometer cell and were matched with various combinations of red and yellow pigments and the intensity of colour was asse,sed in terms of standard units.

The odour of the oil was assessed as normal or rancid by direct smelling.

The fat constants viz., acid value, saponification value and iodine value of oil obtained from each replication were determined following the procedure of A.O.A.C. (1960).

2.3. Assessment of the relative susceptibility of copra obtained from different varieties/cultivars of coconut to *N. rufipes* and *O. surinamensis*

2.3.1. Preparation of copra

The varieties/cultivars of coconut chosen for the experiment were Dwarf x Tall, Laccadive-micro, Gangabondam, Tall x Dwarf, Chavakkad Dwarf Orange, West Coast Tall, Laccadive ordinary, Tall x Green and Chavakkad Dwarf Green. Mature nuts from these varieties were collected and copra was prepared by sun drying the kernel for five days and then keeping in air oven maintained at $60^{\circ}C$ till the moisture content reached the level of 6 ± 0.5 per cent.

2.3.2. Exposure of copra to the insects

Fifty g copra each was taken in a screw capped bottle. Twenty five numbers of one day old insects collected from the mass culture as described in para 2.2.2. and 2.2.3. were released into each bottle. Each variety/cultivar was taken in four replications.

Six such lots were set up so that one lot could be used at the end of each succeeding month for the observations. All the bottles were maintained in the laboratory at room temperature.

2.3.3. Observations

The percentage weight loss of copra and reduction in quality and quantity of oil caused by the insects were assessed at the end of each month as described in para 2.2.6.

2.3.4. Assessment of the effect of copra obtained from different varieties/cultivars of coconut on the biology of *N. rufipes* and *O. surinamensis*

Five g copra from each variety/cultivar was weighed out and it was cut into thin slices and were kept in specimen tubes of 10 x 2.5 cm size.

One first instar larva of the insects was released into each specimen tube. These larvae were obtained from the eggs collected from the mass cultures maintained in the laboratory and kept on a piece of tissue paper placed in a petridish. Emerging larvae were collected carefully from the petridish using camel hair brush within 24 h

after emergence and they were used in the experiments. After the release of the larvae the tubes were kept undisturbed on wooden racks. Ten replications were maintained for each variety.

The data on the incubation period of eggs, larval period, larval mortality, pupal period, pupal mortality, percentage of adult emergence, adult longevity and the fecundity of the beetles were recorded daily. The percentage of adult emergence was calculated with reference to the number of larvae released at the time of setting the experiment. Growth index of the insects in each treatment was calculated by dividing the percentage of adults emerged with the mean number of days for adult formation (larval + pupal periods).

2.4. Assessment of the effect of moisture content of copra on the extent of damage caused by *N. rufipes* and *O. surinamensis* and on the population build up of the pests

Good quality copra was purchased from local market and was kept immersed in four per cent acetic acid for half an hour. The treated copra was oven dried at 60°C for different periods to bring the moisture content to

4±0.5, 6±0.5 and 8±0.5 per cent. From each lot 200 g sample was taken in a bottle and 100 one day old insects were released in each bottle as described in para 2.2.2. and 2.2.3. For each moisture level, three replications were set and six such lots were maintained so that each lot could be used every month for observations during the period of the experiment.

The observations recorded were those described in para 2.2.6. Besides, the number of developmental stages of these insects observed at the end of each month after treatment, were also recorded.

2.5. Control of insect pests of copra

2.5.1. Assessment of the incidence of insect pests on copra kept in godowns in different types of storage

The effect of storing copra in (1) polythene sandwiched gunny bags; (2) alkathene lined gunny bags; (3) gunny bags; (4) netted polythene bags; (5) gunny bag repeatedly used for storing copra and (6) heaps on the floor, on pest incidence was studied in the experiment. Good quality copra locally processed was dried to bring the moisture content to the level of 5±0.5 per cent. Twenty five kg of copra was used for each replication

and three replications were set up for each treatment. Six such lots were maintained for six monthly observations. Copra kept in 50 l polythene buckets closed with tight lids served as control.

The extent of damage caused by the insects was assessed as described in para 2.2.6. The incidence of insect pests in copra was assessed by noting the number of insects observed at different periods after treatment as described in para 2.1.1.

2.5.2. Assessment of relative toxicity of different insecticides to the adults of N. rufipes and O. surinamensis

Technical grades of seven contact insecticides (lindane, carbaryl, fenitrothion, phoxim, malathion, fenvalerate and chlorpyriphos) were used for the experiment.

Stock solution (20 per cent) of each insecticide was prepared by dissolving required quantity of the toxicant in benzene. This was diluted with water containing 0.625 per cent Triton X-100 for obtaining emulsions of required concentrations for the experiments. The concentration of benzene in the final spray fluid was

maintained at five per cent level by adding required additional quantities. Benzene (5 per cent) emulsified in water containing 0.625 per cent Triton X-100 served as control.

Ten numbers of *N. rufipes* collected from stock cultures in specimen tubes (10 x 2.5 cm) and anaesthetised by exposing them to carbondioxide for 3 minutes and ten numbers of *O. surinamensis* collected from the stock culture as described in para 2.2.3. were used for the experiment.

The anaesthetised and non-anaesthetised insects in each tube were released in 9 cm petridishes and were sprayed under Potter's Spraying Tower (2.5 kg/sq.cm pressure) with one ml of the required insecticide emulsion. The dishes were dried under an electric fan and then provided with slices of copra. Each insecticide was applied in different graded doses and each dose was replicated thrice.

The number of insects dead in each replicate at the end of 24 h after treatment was recorded treating the moribund insects also as dead. The percentage mortality was calculated and corrected using Abbott's formula and

the data were subjected to probit analysis (Finney, 1952). The relative toxicity of the insecticides was assessed by computing their LD_{50} values.

2.5.3. Prophylactic treatments of gunny bags for the control of storage pests of copra

In experiment 2.5.2., malathion, fenitrothion and chlorpyriphos were found toxic to the pests. Each insecticide was sprayed at three different doses (Table 32). Three methods of application were also included in the experiment viz., treating the outer surface of gunny bags before filling copra, applying the insecticide on the surface of the bags after filling with copra and spraying the exposed surface of stacks of gunny bags filled with copra.

The gunny bags used for the experiments were of 30 x 20 cm size and one kg copra was used in each replication. In treating the gunny bags before filling the copra and for the treatment after filling the copra, 24 ml of the insecticide emulsion was sprayed on each of the two sides. This ensured a uniform coverage on the surface.

Number of insects present in each replication was recorded monthly for six months by transferring the whole content of the bags over a piece of paper. Simultaneously,

insects present in the control samples were also recorded.

2.5.3.1. Estimation of insecticide residues in treated copra

In the experiment 2.5.3., malathion and fenitrothion were found superior for the control of insect pests. These two insecticides were sprayed on both sides of the bags before and after filling copra as described in para 2.5.3. Samples of copra were drawn at 15, 30 and 60 day intervals for residue analysis.

Twenty five g samples were collected at random from each replication and residues of malathion and fenitrothion were estimated by following the procedure of Getz and Watt's (1964) as modified by Jain et al. (1974).

To assess the reliability of the procedure adopted for the colorimetric estimation, recovery tests were conducted. For this 20 g samples of copra was taken in 250 ml beakers and were fortified with varying quantities of insecticide solutions in acetone. Acetone was added to cover the produce completely. One sample immersed in acetone alone was kept as control. Samples were kept over night, extracted and residues were determined by following the procedure of Getz and Watt's (1964) as modified by Jain et al. (1974).

2.5.4. Evolving curative methods for controlling insects infesting copra

Good quality copra, locally procured, was used for the experiment. Copra filled in gunny bags were kept in the godown for six months for getting the product infested by insects. Three doses of aluminium phosphide and three exposure periods were adopted in the experiment (Table 34). Each treatment was replicated thrice. The infested bags were kept in the fumigatorium and required quantities of aluminium phosphide tablets, wrapped in muslin cloth bag, were introduced into the fumigatorium. The fumigatorium was kept closed for the required periods of exposure. Three lots of the same copra kept closed in glass jars served as control.

Treated bags were taken out of fumigatorium and the contents were aerated for 24 hours. Then they were stored in glass jars, closed with muslin cloth and kept undisturbed in the laboratory for 60 days. During the period, the adults emerging from the surviving immature stages in each treatment, if any, were recorded. From the data, percentage of insects emerging in treatments over control were calculated using the formula,

$P = \frac{MC - MT}{MC} \times 100$, where P was the percentage reduction

of adult emergence, MC was the mean number of insects emerging from the untreated control and MT was the mean number of adults emerging from the treated material.

2.5.4.1. Estimation of residues of phosphine in fumigated copra

The colorimetric method developed by Bruce et al. (1962) and recommended by Joint Committee of FAO and WHO was used for the estimation of phosphine residues in the fumigated copra.

2.5.4.2. Preparation of standard curve and regression equation

A standard solution (100 ppm) of phosphorus was prepared by dissolving potassium dihydrogen phosphate in distilled water. This served as the stock solution which was further diluted to get a 10 ppm solution. From this, aliquots of 0.25, 0.5, 1.0, 2.0 and 4.0 ml were pipetted out into 25 ml volumetric flasks. To each of these solutions, 8 ml of 6 N sulphuric acid was added followed by 2 ml of 5 per cent ammonium molybdate and 0.15 per cent hydrazine sulphate. After the addition of each reagent, the contents of the volumetric flasks were well shaken and the volumes were

made up. A blank was also maintained. These flasks were placed in boiling water bath for 15 minutes. After that they were cooled to room temperature. The colour intensity of the phosphomolybdenum blue complex thus formed was measured by using spectrophotometer at 820 n.m. against the blanks.

A regression equation was worked out with the help of OD values corresponding to each concentration. This equation was used for calculating the amount of phosphorus residues. From this, phosphine equivalent was obtained by multiplying the phosphorus content by the factor 1.097.

2.5.4.3. Recovery test

2.5.4.3.1. Preparation of standard solution of phosphine in carbon disulphide to be mixed with commodities for recovery studies

A standard solution of phosphine in carbon disulphide was prepared. For this, aluminium phosphide pellet was placed in a 100 ml flask with 19/26 outer joint. Twenty five ml of distilled water was added to the flask. Distilling type adapter with 19/26 inner joint containing a gas dispersion tube was quickly inserted into the flask. The other end of the dispersion tube was immersed in 100 ml of reagent grade carbon disulphide in a reagent bottle.

The phosphine gas evolved from aluminium phosphide was allowed to dissolve in carbondisulphide for two hours. The concentration of phosphine in carbondisulphide was determined by oxidising the same with bromine, converting the resulting phosphoric acid to its phosphomolybdenum blue complex and then reading the colour intensity of this complex spectrophotometrically at 820 n.m. The amount of phosphine in carbon disulphide was calculated with reference to the regression equation obtained from potassium dihydrogen phosphate. A series of dilutions were prepared from this concentrated solution of phosphine in carbondisulphide and used for further steps of recovery test.

2.5.4.3.2. Procedure for recovery experiment

Five hundred g of sliced copra was placed in a 5 l round bottomed flask with 24/40 outer joint, kept in water bath, and having an i/c joint with an inlet and delivery tube, the latter being attached to a series of scrubbers. A quantity of 1.5 l of 10 per cent v/v sulphuric acid and 1 ml of carbondisulphide solution containing 1/4 g of phosphine were added. The flask was immediately connected to the scrubbers each containing 7 ml of 0.2 N potassium permanganate and 3 ml of

5 per cent v/v sulphuric acid. Air was bubbled through the flask at the rate of 30 bubbles per minute for 30 minutes. Then the contents of the flasks were heated for two hours with the air flow continuing. The scrubbers were then removed and 7 ml of 0.2 N oxalic acid was added to each scrubber. Then the contents were pooled into a 100 ml volumetric flask and volume was made up by subsequent washing.

An aliquot of 10 ml was transferred to 25 ml volumetric flask, 8 ml of 6 N sulphuric acid was added to this, followed by 2 ml of 5 per cent ammonium molybdate and 2 ml of 0.15 per cent hydrazine sulphate. After the addition of each reagent, the contents of the flask was well shaken and the volume was made up. Control samples were also taken in the same way. Recovery percentage was then calculated referring to the regression equation,

$Y = (0.15674x + 0.02296) \times 1.097$

2.5.4.3.3. Estimation of residues in the fumigated samples

The residues of phosphine in the fumigated copra using doses of 1.5, 3.0 and 4.5 g/m^3 for different exposure periods were estimated 24 h after the period of aeration. Five hundred gram of fumigated copra was placed in

5 l round bottom flask and phosphine content was estimated as done in recovery test.

2.6. Statistical analysis

Data relating to each aspect were analysed statistically. The 'F' test was done by analysis of variance (Panse and Sukhatme, 1978). Significant results were compared on the basis of critical differences.

RESULTS

3. RESULTS

3.1. Important pests of copra

The insects recorded in the survey were Necrobia rufipes De Geer., Oryzaephilus surinamensis Linn., Ephestia cautella Walk., Ahasverus advena Walt., Lasioderma serricorne Fab., Araecerus fasciculatus De Geer. and Tribolium castaneum Hbst. (Plate I).

3.1.1. Ham beetle, N. rufipes (Coleoptera : Cleridae)

The adult was a bluish black beetle having an oval shape. The legs and base of the antennae were reddish brown in colour and it was recorded earlier also as a pest of copra. The damage was seen caused by the extensive feeding of the adults and the grubs. The larvæ made ramifying tunnels inside the copra and fed from within. Pupation also occurred inside the tunnel. The adults did not enter the tunnels. They remained on the surface of the copra pieces and ate inwards from the cut edges. The adults were also observed feeding on their own larvae as well as on the immature stages of other insects present in the godown.

3.1.2. Saw toothed grain beetle, O. surinamensis (Coleoptera : Silvanidae)

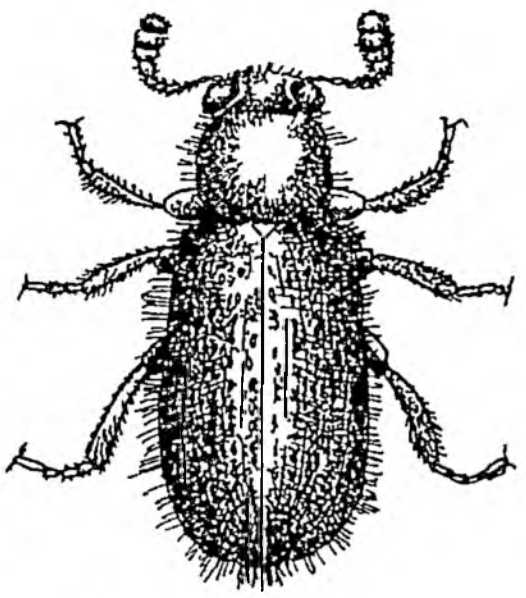
This was a slender dark brown flattened beetle with a row of sharp teeth like projections on either

Plate I

Major insect pests infesting stored copra in the Southern Districts of Kerala

1. N. rufipes
2. O. surinamensis
3. E. cautella
4. A. advena
5. L. serricorne
6. A. fasciculatus

PLATE I

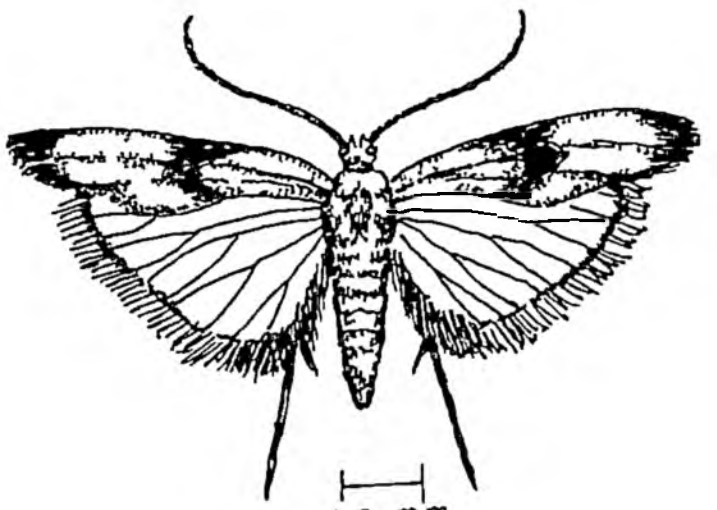


0.8 mm

1

2

0.5 mm



1.6 mm

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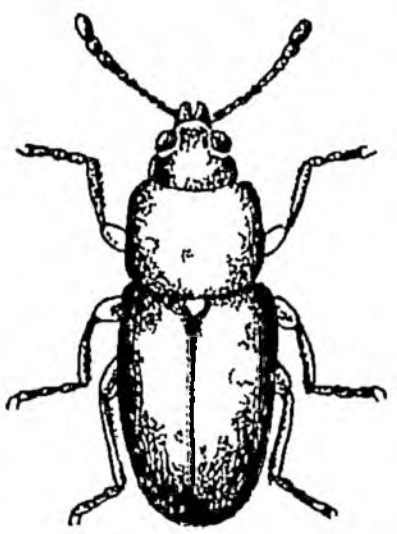
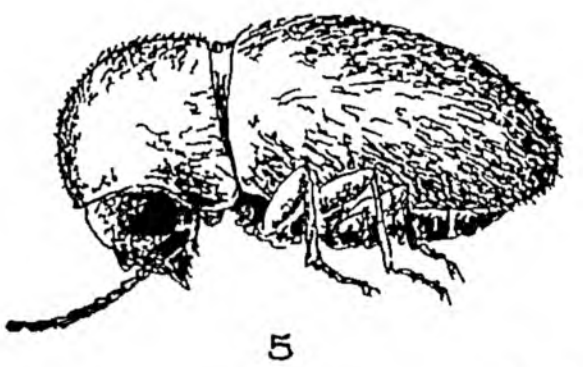


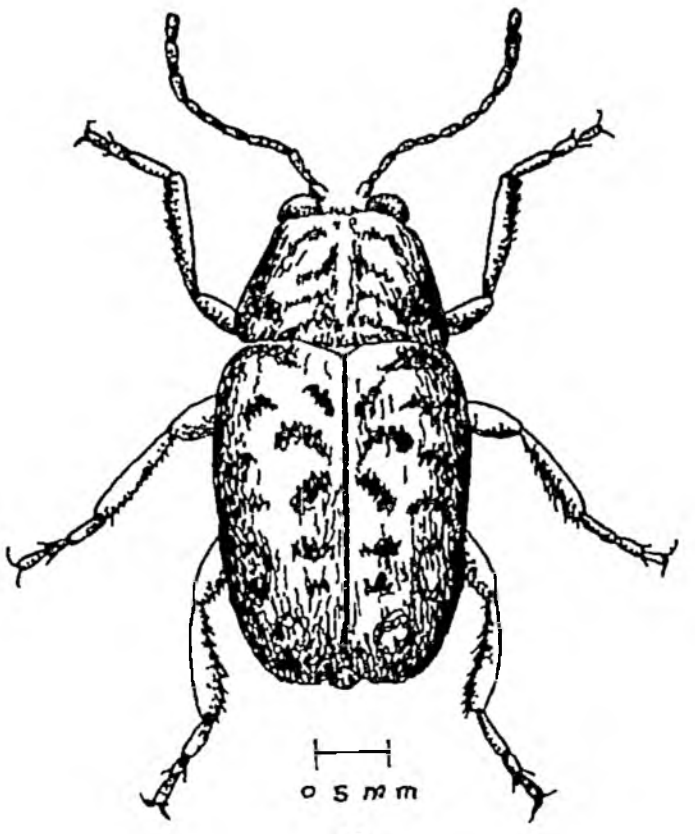
4

0.4 mm



5

0.3 mm



0.5 mm

6

side of the prothorax. The insect was recorded as a secondary pest feeding on powdered or broken grains so rendered by other insects in store. On copra, it was seen as a primary pest and it was the most abundant pest in most of the places covered in the survey. Adults bored in through the cut end of the copra pieces. The adults made extensive galleries between the kernel and testa. The eggs were laid in the galleries. The emerging larvae also fed from within the galleries and made extensive damage. The pupation also occurs inside the galleries. The emerging adults invaded fresh pieces of copra. The existence of the galleries with in the copra was not indicated externally by holes or frass. The very presence of the pest could hence be detected only when the pieces were broken up.

3.1.3. Almond moth, *E. cautella* (Lepidoptera : Phycitidae)

This moth had greyish wings with transverse stripes on the outer region. It laid eggs on the inner surface of copra and the eggs were glued on to it. The emerging larvae made a silk woven mat on the inner surface of the copra and remained within. Remaining inside the silken mat, the larvae fed by scraping the copra from the surface. Thus they caused significant damage to the commodity. The pupation also occurred within the mat and the emerging adults migrated to fresh copra.

3.1.4. Foreign grain beetle, A. advena (Coleoptera : Silvanidae)

This was a small reddish brown oval beetle with smooth elytra and clubbed antennae. The adults bored into the copra in between the dried endosperm and testa and the damage was seen caused by the adults and larvae in the same manner as done by O. surinamensis.

3.1.5. Cigarette beetle, L. serricorne (Coleoptera : Anobiidae)

This was a light brown round beetle with the thorax and head bent downward and this presented a humped appearance to the insect. The elytra was covered with minute hairs. Adults bored into the pieces of copra through the testa and the entry holes could be seen prominently on the surface. The beetles fed by making galleries and laid eggs there. Emerging larvae fed on copra from within the galleries and they completed the life cycle also inside the copra.

3.1.6. Coffee berry borer, A. fasciculatus (Coleoptera : Anthribiidae)

This was a greyish beetle with small dark patches on the elytra and prothorax. The body of the beetle was covered with small hairs. Adults bored into the copra through the inner side and their entry holes could be

prominently seen. The beetles made galleries within the copra and laid eggs there. The life cycle of the insect was seen completed inside the galleries. Larvae also fed on copra from within the galleries and caused severe damage.

3.1.7. Red flour beetle, T. castaneum (Coleoptera : Tenebrionidae)

This was a reddish brown, flat, elongate beetle. Adults of this beetle were found in small numbers in samples collected. They were not found feeding on copra. The immature stages of the pest also were not seen on/in the stored copra. The pest fed and bred on powdered oilcakes which were also available in the godowns covered in the survey.

3.2. Distribution of insect pests of stored copra in the Southern Districts of Kerala

The results of the survey to study the magnitude and extent of damage done by the insect pests of copra are presented in Table 1 and Fig.1.

3.2.1. N. rufipes

The highest mean population of this pest was noticed in Asramom (8.5) and it was followed by the

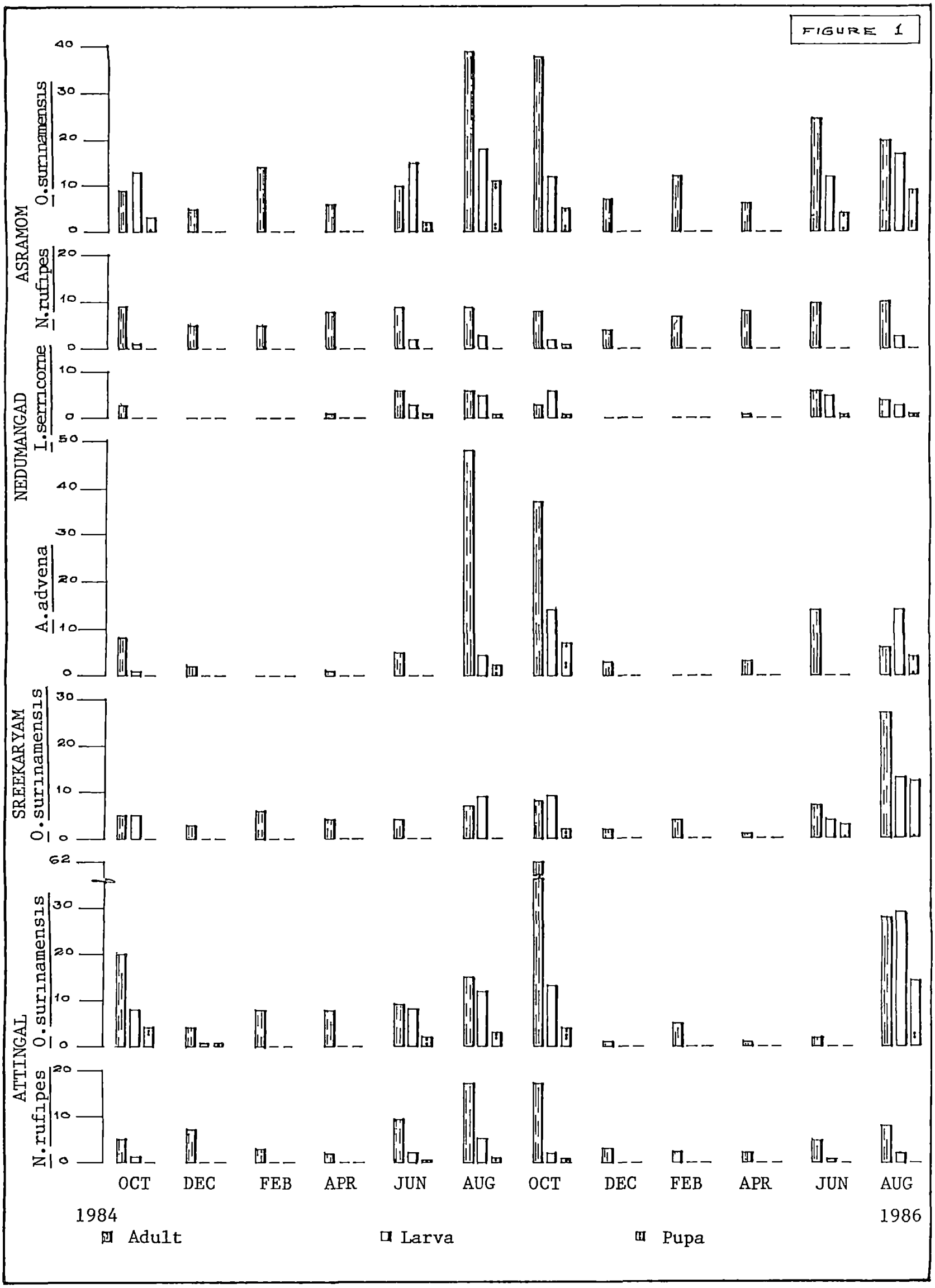
Table 1 Distribution of the insects infesting stored copra in the Southern Districts of Kerala as observed in a survey conducted during 1984 to 1986

Insects	Locations	Mean numbers of insects in 200 g samples collected during												Mean
		Oct. '84	Dec 84	Feb '85	Apr '85	Jun '85	Aug. '85	Oct. 85	Dec. '85	Feb. '86	Apr '86	Jun. '86	Aug 86	
N. rufipes														
	Attingal	5.8	7.2	2.6	2.0	10.2	22.0	19.9	2.8	2.2	1 8	6.1	10.2	7.7
	Sreekaryam	2.1	2.6	1.6	2 6	3.1	6.1	5.2	1.0	2.1	1.4	1.2	7.9	3.1
	Karamana	1.5	1.5	0.9	0.8	1.6	2.6	1.9	0 4	1.1	0.5	1.8	3.1	1.5
	Nedumangad	0.0	0.9	2.2	0.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.34
	Asramom	10.1	4.7	5.2	8.3	10.7	11.9	10.1	3.8	7.1	7.1	9.8	13.6	8.5
	Shertallai	3.0	0.0	0.0	9 8	8.1	7.8	4.6	0.0	0.0	0.0	7.9	8.2	4.1
O. surinamensis														
	Attingal	32.1	9.2	8.3	7.5	18.6	29.3	79.1	0.8	4.5	0.5	2.2	71.1	21.9
	Sreekaryam	10.3	3.4	6.3	4 0	3.9	16.1	18.9	3.1	3.7	0.7	14.2	52.0	11.4
	Karamana	2.3	1.6	2.8	0.5	5.6	10.7	4.7	1.8	0.0	2.5	9.1	6.9	4.0
	Nedumangad	1.4	0.0	0.0	2.0	2.1	3.7	0.6	0.9	1.7	1.9	5.6	3.9	2.0
	Asramom	25.0	5.2	14.4	6.0	27.1	67.3	55.6	6.6	11.6	5.6	36.6	46.9	25.7
E. cautella														
	Attingal	1.8	2.7	4.7	0.0	3.0	2.9	1.2	6.2	12.6	0.0	0.0	4.2	3.3
	Sreekaryam	2.2	1.9	0.7	0.6	2.1	3.3	1.8	3.1	0.5	3.0	0.7	1.6	1.8
	Nedumangad	2.5	0.0	2.1	0.0	1.1	3.1	8.0	0.0	0.0	0.0	0.4	0.2	1.5
A advena														
	Nedumangad	8.9	1.5	0.0	1.0	5.0	53.9	52.4	2.9	0.0	2.8	13.6	23.1	13.8
L serricorne	Nedumangad	2.9	0.0	0 0	0.3	9.0	11.1	8.8	0.0	0.0	0.6	11.0	8.7	4.4

	N. rufipes	O. surinamensis	E. cautella	A. advena	L. serricorne
CD for comparing treatments at 1 per cent level	4.32	18.3	3.86	-	-
CD for comparing periods at 1 per cent level	5.06	21.02	4 59	19.9	7.3

Fig. 1. Distribution of the insect pests observed in copra stored in selected godowns of the Southern Districts of Kerala during October '84 to August '86.

FIGURE 1


NEDUMANGAD
ASRAMOM
A.advena
I.serricorne
N.rufipes
O.surinamensis
SREEKARYAM
O.surinamensis
ATTINGAL
O.surinamensis
N.rufipes
OCT
DEC
FEB
APR
JUN
AUG
OCT
DEC
FEB
APR
JUN
AUG
1984
1986
Adult
Larva
Pupa

population at Attingal (7.7) and they were on par. The pest incidence at Attingal was followed by Shertallai (4.1) and they were on par. The least incidence (0.34) was observed at Nedumangad and it was on par with the incidence at Karamana (1.5) and Sreekaryam (3.1).

The increase in population of the insect observed at Attingal (10.2) in June and the occurrence of immature stages during the period indicated that the pest started breeding. A five fold increase in the population was recorded during June and it doubled in August (22.0) and remained high in October (19.9) also. A sudden decrease in population was noticed from December onwards and immature stages were not observed in the subsequent samples. An increase in population with the occurrence of larval stages was observed during June and August of the succeeding year.

The same trend was noticed at Sreekaryam also. Significantly higher populations of 6.1 and 7.9 were recorded during the month of August in both the years. The population during the remaining period of observations were low and on par (1.0 to 5.2).

At Asramom also the population was high during June to October '85 (10.1 to 11.9) and June to August '86

(9.8 to 13.6). During the remaining period the population ranged from 3.8 to 8.3.

The only insect recorded in stored copra at Shertallai was N. rufipes. No insect infestation was noticed during December '84 to February '85 and December '85 to April '86. The population recorded during April '85 was the highest (9.8) and it was on par with June and August population (8.1 and 7.8 respectively). In October '84 and '85, the population remained low (3.0 and 4.6 respectively)

At Karamana the population ranged from 0.4 to 3.1 only and no conspicuous increase was observed during the month of June to October also. At Nedumangad the pest was seen during December '84 to April '85 and in October '85 only and the population ranged from 0.3 to 2.2.

3.2.2. O. surinamensis

Among the insect pests in stored copra observed in the survey, the most abundant one was O. surinamensis. The mean population of 25.7 was the highest and it was recorded at Asramom, closely followed by the population observed at Attingal (21.9) and followed by that at Sreekaryam (11.4). At Karamana and Nedumangad the populations were very low (4.0 and 2.0 respectively).

At Attingal, an increase in population was noticed during June '85 (18.6) and it reached the peak in

October (79.1). During '86 the rise was noted only in October but it came on par with the population of August '85. From December '85 to June '86, the population was lower and ranged from 0.5 to 4.5 only.

At Sreekaryam, population of O. surinamensis ranged from 0.7 to 52.0. The breeding of the insect was indicated by the higher population (16.1 to 18.9) and immature stages (Fig.1) during August to October '85 and June to August '86 (14.2 to 52.0). Low infestation of stored copra by O. surinamensis was noticed in Karamana and Nedumangad, the populations being in the range of 0 to 10.7 and 0 to 5.6 respectively.

High population of O. surinamensis was observed in Asramom, with a range of 5.2 to 67.3. During the breeding season significantly high population of 25.0, 27.1, 67.3, 55.6, 36.6 and 46.9 insects was recorded during October '84, June '85, August '85, October '85, June '86 and August '86 respectively. Population ranged from 5.2 to 14.4 between December and April during both the years.

3.2.3. E. cautella

Significant differences were lacking in the population of this pest in the three locations covered in the survey and the mean population ranged from 1.5 to 3.3 only. At Attingal the population observed during

different months of 1985 did not show significant variations (1.2 to 6.2) and during 1986, population recorded in February (12.6) was significantly higher than the population observed during the remaining months. Significant variations were not seen in the population recorded at Sreekaryam where it ranged from 0.5 to 3.3 only. A high population of eight insects was recorded during October '85 at Nedumangad. During the remaining period, the population ranged from 0 to 3.1 only.

3.2.4. A. advena

In the godown of Nedumangad alone, high population of A. advena was observed, the population ranging from 0 to 53.9. As in the case of other pests, the higher population in October '84 (8.9), June '85 (5.0), August '85 (53.9), October '85 (52.4), June '86 (13.6) and August '86 (23.1) in comparison with the remaining months (0.2.9), indicated that the breeding season of the insect extended from June to October. But the immature stages of the insect was observed in August to October only (Fig.1), which showed that the breeding of the pest commenced late.

3.2.5. L. serricorne

The mean population of L. serricorne, recorded over a period of two years at Nedumangad was 4.4. and with a range of 0 to 11.1.

Higher population was recorded during June to October '85 (8.8 to 11.1) and June to August '86 (8. to 11). The population during the rest of the months ranged from 0 to 2.9 only.

As shown in Fig.1, high populations of N. rufipes were observed at Asramom and Attingal only while such significantly higher levels of O. surinamensis incidence were observed at Asramom, Sreekaryam and Attingal. None of these pests was recorded from Nedumangad in significant levels. The predominant insects infesting copra in Nedumangad were A. advena and L. serricorne, they were not recorded from other locations. The figure also shows clearly that all the insect pests infesting stored copra breed and build up the population during June to October and the immature stages of the pests were also restricted to the above period.

The correlation between the varying populations of insect pests during the period of observation and the moisture content of copra and different climatic factors were worked out and the results are presented in Table 2. Moisture content of copra had significant positive correlation with mean populations of N. rufipes at Attingal, Sreekaryam, Karamana, Asramom and Shertallai, whereas at Nedumangad, a negative correlation was noticed which was not statistically significant. The moisture

Table 2. Association between the population of different insects infesting stored copra in the Southern Districts of Kerala and the moisture content of the commodity and different climatic factors

Insects	Locations	Correlation coefficients between varying insect populations and					
		Moisture content	Rain fall	Maximum temperature	Minimum temperature	Morning humidity	Evening humidity
N rufipes							
	Attingal	0.757**	0.6584*	-0.5663	0.1281	-0.0607	0.2493
	Sreekaryam	0.834**	0.5671	-0.3704	0.1714	0.1786	0.3940
	Karamana	0.824**	0.5403	-0.5429	-0.1188	0.6449*	0.5925*
	Nedumangad	-0.203	0.2250	-0.0730	-0.3286	-0.0721	-0.3217
	Asramom	0.831**	0.3822	-	-	-	-
	Shertallai	0.945**	0.4038	-0.1385	0.4684	0.4032	0.5175
O surinamensis							
	Attingal	0.661*	0.1702	-0.3525	0.1003	0.3188	0.6502*
	Sreekaryam	0.756**	0.3397	-0.1809	0.1349	0.5374	0.5750
	Karamana	0.801**	0.6964*	-0.3677	0.1739	0.4919	0.5290
	Nedumangad	0.182	0.5731	0.0775	0.4723	-0.0421	0.1859
	Asramom	0.576*	0.6492*	-	-	-	-
E. cautella							
	Attingal	-0.319	-0.1548	-0.1657	-0.6440*	-0.3200	-0.2265
	Sreekaryam	0.271	0.2238	-0.6796*	0.1541	-0.0720	0.1547
	Nedumangad	0.807**	-0.1973	-0.3309	0.2491	0.6868*	0.1963
A. advena							
	Nedumangad	0.929**	0.2373	-0.5520	-0.1802	0.7652**	0.3803
L serricorne							
	Nedumangad	0.747**	0.2466	-0.2799	0.2995	0.5459	0.5671

*Significant at 5% level

**Significant at 1% level

The related data are presented in Appendices I and II

content of copra with the mean population of *O. surinamensis* showed significant correlation at Attingal, Sreekaryam, Karamana and Asramom. At Nedumangad the correlation coefficient was positive but not significant.

In the case of *E. cautella*, significant positive correlation was observed between moisture content of copra and the varying population at Nedumangad whereas at Sreekaryam the association was positive and nonsignificant and at Attingal it was negative and nonsignificant. The populations of *L. serricorne* and *A. advena* observed at Nedumangad also showed significant positive association with the varying moisture content of copra.

Rainfall showed a positive correlation with populations of *N. rufipes*, *O. surinamensis*, *A. advena*, *L. serricorne* at all places and with *E. cautella* at Sreekaryam. The correlation between the rainfall and *E. cautella* population at Attingal and Nedumangad showed a negative correlation. Correlation coefficients relating to *N. rufipes* at Attingal, *O. surinamensis* at Karamana and Asramom alone were statistically significant.

The maximum temperature had a negative correlation with different pests at all locations, but the association was statistically significant in the case of *E. cautella* at Sreekaryam only.

The association between the minimum temperature, morning humidity and evening humidity with mean population of the pests in different locations surveyed showed an erratic trend. The minimum temperature had significant negative correlation in the case of E. cautella observed at Attingal. The morning humidity showed a significant positive correlation with N. rufipes population at Karamana, E. cautella and A. advena at Nedumangad. Positive association of N. rufipes with evening humidity was seen at Karamana and O. surinamensis at Attingal.

3.3. Extent of damage caused by the attack of A. flavus and insects, independently or in combination, to stored copra

3.3.1. Weight of stored copra exposed to insects/fungus

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 3. The mean percentages of reduction in weight of copra infected by the fungus alone (0 to 0.28) did not show statistically significant variations.

When copra was exposed to N. rufipes, a sharp increase in intensity of damage was observed during the first three months (0.86 to 7.22 per cent) and between fourth and fifth month (7.76 to 11.19). The loss between the third and fourth months and between the fifth and sixth months were marginal (7.22 to 7.76 and

Table 3. Extent of loss in stored copra (weight basis) exposed to the attack of a fungus and insects independently or in combination, observed at different intervals after exposure.

Treatments	Mean per cent loss in copra (weight) in treatments over that of control observed at different periods after treatment (months)					
	1	2	3	4	5	6
N. rufipes						
A. flavus alone	0.00 (1.00)	0.02 (1.01)	0.13 (1.06)	0.05 (1.03)	0.23 (1.11)	0.28 (1.13)
N. rufipes alone	0.86 (1.36)	4.02 (2.24)	7.22 (2.87)	7.76 (2.96)	11.19 (3.49)	12.20 (3.63)
A. flavus followed by *N. rufipes*	0.30 (1.14)	0.99 (1.41)	1.40 (1.55)	2.24 (1.80)	3.17 (2.04)	4.75 (2.40)
N. rufipes followed by *A. flavus*	0.97 (1.40)	2.24 (1.80)	3.48 (1.12)	4.49 (2.34)	4.99 (2.45)	6.44 (2.73)
O. surinamensis						
A. flavus alone	0.00 (1.00)	0.02 (1.01)	0.13 (1.06)	0.05 (1.03)	0.23 (1.11)	0.28 (1.13)
O. surinamensis alone	0.12 (1.06)	1.43 (1.56)	1.56 (1.60)	2.17 (1.78)	2.41 (1.85)	2.99 (2.00)
A. flavus followed by *O. surinamensis*	0.50 (1.22)	1.28 (1.51)	1.45 (1.57)	1.62 (1.62)	1.79 (1.67)	2.05 (1.75)
O. surinamensis followed by *A. flavus*	0.38 (1.17)	1.13 (1.46)	1.13 (1.46)	1.58 (1.61)	1.78 (1.66)	2.49 (1.87)

	N. rufipes	*O. surinamensis*
CD at 1 per cent level	0.34	0.28

Figures in parentheses are transformed values, $\sqrt{x+1}$

Number of insects released in each replication of 200 g copra - 100

11.19 to 12.20 per cent respectively). In copra exposed to the fungus followed by the insect, relatively higher increase in damage was observed between fifth and sixth months only (3.17 to 4.75 per cent). The same trend was observed in copra exposed to insect followed by the fungus also.

In the case of O. surinamensis, copra exposed to the insect alone showed a weight loss ranging from 0.12 to 2.99 per cent over a period of six months. When the exposure of the insect was succeeded by the infection of A. flavus, the damages ranged from 0.38 to 2.49 per cent and when preceded by the fungus the damages ranged from 0.50 to 2.05 per cent. Thus the treatments did not show significant differences.

3.3.2. Oil content of stored copra exposed to insect/fungus

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 4.

During first month significantly lower percentage of oil was recorded in copra infected by fungus alone and fungus preceded and succeeded by insects and not in copra infested by N. rufipes alone and in control. This trend

Table 4. Oil content of stored copra exposed to the attac of a fungus and insects, independently or in combination, observed at difrerent intervals after exposure.

Treatments	Mean percentage oil content of copra collected at different periods after treatment (months)					
	1	2	3	4	5	6
• rufipes						
A. flavus alone	61.32	60.68	59.84	59.26	59.40	58.74
N. rufipes alone	61.84	61.60	61.02	60.58	60.26	59.38
A. flavus followed by N. rufipes	60.82	60.66	59.78	59.12	59.16	58.60
. rufipes followed by A. flavus	61.08	60.44	60.10	59.20	58.60	58.44
Control	62.06	62.00	61.54	60.78	60.92	60.80
• surinamensis						
A. flavus alone	61.32	60.68	59.84	59.26	59.40	58.74
O. surinamensis alone	61.70	61.46	60.80	60.50	59.80	58.66
A. flavus followed by O. surinamensis	60.92	60.90	60.84	59.30	58.86	58.78
O. surinamensis followed by A. flavus	61.12	60.94	59.78	59.28	58.70	58.54
Control	62.06	62.00	61.54	60.78	60.92	60.80

	N. rufipes	O. surinamensis
CD at 1 per cent level	0.70	0.69

was followed up to fifth month after treatment. During sixth month all the treatments showed significantly lower percentage of oil content than control. In all the monthly observations, the highest percentage of oil among treatments (excluding control) was observed in copra exposed to insect (59.38 to 61.84), it was followed by fungus (58.74 to 61.32 per cent) and lowest in treatments with two combinations of fungus and insects (58.44 to 61.08 and 58.60 to 60.82).

During first month the copra infested with O. surinamensis alone (61.70) and control (62.06) showed significantly higher percentages of oil than copra infected by fungus (61.32), fungus followed by insect (60.92) and insect followed by fungus (61.12). The same trend in oil content in different treatments was noticed from first to fifth month after treatment. During sixth month, all the treatments came on par and showed significantly lower percentages of oil than control.

3.3.3. Quality of oil obtained from copra exposed to insect/fungus

3.3.3.1. Acid value

Data relating to the acid values of the oil obtained from different treatments and the results of statistical analysis of the data are presented in Table 5.

Table 5. Acid value of oil obtained from stored copra exposed to the attack of a fungus and insects, independently or in combination, observed at different intervals after exposure.

reatments	Mean acid value of oil extracted from copra collected at different periods after treatment (months)					
	1	2	3	4	5	6
. *rufipes*						
A. flavus alone	2.68	3.04	3.80	4.94	5.96	7.50
N. rufipes alone	1.50	2.60	3.06	3.46	4.05	3.94
A. flavus followed by *N. rufipes*	2.70	3.56	4.00	4.59	4.97	7.53
N. rufipes followed by *A. flavus*	3.01	3.21	4.02	4.04	4.63	7.09
Control	1.23	1.50	2.21	2.79	2.82	3.31
. *surinamensis*						
A. flavus alone	2.68	3.04	3.80	4.94	5.96	7.50
O. surinamensis alone	1.52	1.82	2.40	2.68	3.14	5.00
A. flavus followed by *O. surinamensis*	2.58	3.14	4.04	3.92	4.95	6.84
O. surinamensis followed by *A. flavus*	3.03	2.75	3.74	4.22	4.67	6.43
Control	1.23	1.50	2.21	2.79	2.82	3.31

	N. rufipes	*O. surinamensis*
CD at 1 per cent level	1.03	1.02

The acid values of oils obtained from treatments other than N. rufipes infested alone(1.50) were significantly higher than that of the oil obtained from control (1.23) during first month. The same trend was seen in third, fourth and sixth month. During second and fifth month all the treatments showed significantly higher acid values when compared with control.

In the case of O. surinamensis, the acid values of oil, obtained from fungus infected treatments, showed significantly higher levels than oil extracted from copra in control, while the acid value of the oil extracted from copra infested by the insect alone remained on par with that of control. The same comparison of treatments held good from first to fifth month after treatment. During sixth month, the acid values of the oils extracted from copra in all treatments showed significantly higher values than that of control.

3.3.3.2. Saponification value

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 6. In all monthly observations, the lowest saponification values were observed in control (249.74 to 258.26) and it was followed by treatment with N. rufipes alone (253.62 to 265.50). This treatment was on par with

Table 6. Saponification value of oil obtained from stored copra, exposed to the attack of a fungus and insects, independently or in combination, observed at different intervals after exposure.

Treatments	Mean saponification value of oil, extracted from copra collected at different periods after treatment (months)					
	1	2	3	4	5	6
N. rufipes						
A. flavus alone	255.88	258.14	258.54	259.82	263.74	266.90
N. rufipes alone	253.62	255.18	257.12	258.78	262.56	265.50
A. flavus followed by *N. rufipes*	255.10	255.86	262.34	263.92	264.26	266.30
N. rufipes followed by *A. flavus*	256.88	260.00	259.96	261.08	266.82	267.42
Control	249.74	252.30	255.20	255.10	257.30	258.26
O. surinamensis						
A. flavus alone	255.88	258.14	258.54	259.82	263.74	266.90
O. surinamensis alone	253.68	255.96	257.52	258.74	261.84	262.16
A. flavus followed by *O. surinamensis*	255.50	257.88	256.18	263.02	265.58	268.04
O. surinamensis followed by *A. flavus*	257.30	260.68	262.76	262.32	263.70	268.88
Control	249.74	252.30	255.20	255.10	257.30	258.26
			N. rufipes		*O. surinamensis*	
CD at 1 per cent level			4.31		5.19	

control upto the fourth month after treatment. During fifth and sixth month, significantly higher saponification values were recorded from all the treatments compared to control.

The saponification values of oil extracted from copra infected by fungus alone, fungus followed by O. surinamensis and O. surinamensis followed by fungus showed significant increase over that of control. The saponification values of oil extracted from copra infested by insect alone and of control were on par. The same trend was seen from first to sixth month.

3.3.3.3. Iodine value

The data relating to iodine values of oil samples obtained from different treatments and the results of statistical analysis of the same are presented in Table 7. Differences in iodine values were not seen in treatments when compared to control upto third month. During fourth month, the treatments with N. rufipes alone and N. rufipes followed by fungus showed significantly higher iodine value than control. All the treatments showed significant increase over the value in control from fifth month after treatments.

In the case of O. surinamensis, none of the treatments showed differences in iodine values over control

Table 7. Iodine value of oil obtained from stored copra, exposed to the attack of a fungus and insects, independently or in combination, observed at different intervals after exposure.

Treatments	Mean iodine value of oil extracted from copra collected at different periods after treatment (months)					
	1	2	3	4	5	6
N. rufipes						
A. flavus alone	8.43	8.32	9.06	9.12	10.85	12.65
N. rufipes alone	8.12	8.45	9.79	10.26	11.77	12.44
A. flavus followed by N. rufipes	8.87	8.88	9.68	9.92	11.39	12.69
N. rufipes followed by A. flavus	8.48	9.06	9.80	10.50	10.98	13.54
Control	7.87	8.32	8.67	8.87	9.50	9.76
O. surinamensis						
A. flavus alone	8.43	8.32	9.06	9.12	10.85	12.65
O. surinamensis alone	8.32	8.54	10.13	11.03	11.83	12.40
A. flavus followed by O. surinamensis	8.61	8.78	9.27	9.42	10.53	11.27
O. surinamensis followed by A. flavus	8.45	8.69	9.47	10.61	11.02	12.29
Control	7.87	8.32	8.67	8.87	9.50	9.76

	N. rufipes	O. surinamensis
CD at 1 per cent level	1.21	1.25

upto the second month after treatments. During third month, significantly higher values over control (8.67) was noticed in treatment involving insect alone (10.13). Significant variations were observed during the fourth month in treatments with insect alone and insect followed by fungus when compared to control. During fifth month all the treatments except fungus followed by insect were giving significantly higher values over that of control and during the sixth month, all the four treatments showed significant increase in iodine value over that of control.

3.3.3.4. Colour of oil

The data relating to the aspect are presented in Table 8. The oil extracted from uninfested copra stored upto six month did not show red pigments. In fungus infected copra, the red pigments noted after one month of storage was 0.4 units and it rose to 4 units at six months of storage. In copra infested by N. rufipes alone, the red pigments did not develop. When the insect infestation was preceded by the fungus infection, the values ranged from 0.4 to 5 R and when the sequence was reversed the values ranged from 0.2 to 3R. Oil from the samples drawn from control upto three, five and six months after storage showed 0.1, 0.2 and 0.4 units of yellow pigments. Corresponding figures for fungus infection alone were 8, 20 and 20 Y and for insect

Table 8. Colour of oil obtained from stored copra, exposed to the attack of a fungus and insects independently or in combination, observed at different intervals after exposure

Treatments	Colour of oil extracted from copra collected at different periods after treatment (months)					
	1	2	3	4	5	6
N. rufipes						
A. flavus alone	0.4 R + 3.0 Y	0.5 R + 3.0 Y	1.0 R + 8.0 Y	3.0 R + 20 Y	4.0 R + 20 Y	4.0 R + 20 Y
N. rufipes alone	0.0 R + 0.4 Y	0.0 R + 0.4 Y	0.0 R + 0.5 Y	0.0 R + 0.7 Y	0.0 R + 0.9 Y	0.0 R + 1.0 Y
A. flavus followed by *N. rufipes*	0.4 R + 2.0 Y	0.4 R + 3.0 Y	0.8 R + 5.0 Y	1.0 R + 12 Y	4.0 R + 16 Y	5.0 R + 20 Y
N. rufipes followed by *A. flavus*	0.2 R + 2.0 Y	0.4 R + 3.0 Y	0.9 R + 4.0 Y	2.0 R + 8.0 Y	3.0 R + 18 Y	3.0 R + 20 Y
Control	0.0 R + 0.1 Y	0.0 R + 0.1 Y	0.0 R + 0.1 Y	0.0 R + 0.2 Y	0.0 R + 0.2 Y	0.0 R + 0.4 Y
O. surinamensis						
A. flavus alone	0.4 R + 3.0 Y	0 5 R + 3.0 Y	1.0 R + 8.0 Y	3.0 R + 20 Y	4.0 R + 20 Y	4 0 R + 20 Y
O. surinamensis alone	0.0 R + 0.2 Y	0.0 R + 0.3 Y	0.0 R + 0 3 Y	0.0 R + 0.3 Y	0.0 R + 0.5 Y	0.0 R + 0.5 Y
A. flavus followed by *O. surinamensis*	0.1 R + 2.0 Y	0 2 R + 3.0 Y	0.7 R + 4.0 Y	3.0 R + 5.0 Y	3.0 R + 9.0 Y	3.0 R + 12 Y
O. surinamensis followed by *A. flavus*	0.2 R + 3.0 Y	0.3 R + 3 0 Y	0 8 R + 4.0 Y	2.0 R + 5.0 Y	2.0 R + 12 Y	2.0 R + 14 Y
Control	0.0 R + 0.1 Y	0.0 R + 0.1 Y	0.0 R + 0.1 Y	0 0 R + 0.2 Y	0.0 R + 0.2 Y	0 0 R + 0.4 Y

infestation alone, the values were 0.5, 0.9 and 1Y. When fungus infection was followed by insect infestation, the corresponding values rose to 5, 16 and 20 Y and when the reverse sequence was adopted, the pigmentation values were 4, 18 and 20 Y.

The development of red pigments in oil extracted from copra infested by the fungus alone, O. surinamensis alone, fungus followed by insect and insect followed by fungus were in the range of 0.4 to 4, 0 to 0, 0.1 to 3 and 0.2 to 2 R respectively for one to six months after treatment. The corresponding figures for yellow pigment were 3 to 20, 0.2 to 0.5, 2 to 12 and 3 to 14 Y.

3.3.3.5. Odour of oil

The odour of oil extracted from copra in various treatments are given in Table 9. Oil extracted from control had normal pleasant odour upto six months after storage. Copra infested by A. flavus yielded oil with slight rancidity at one month after storage, rancidity at two months after storage and high rancidity from the third month after storage. Oil of copra infested by N. rufipes alone had normal smell when extracted one month after storage, slight rancid smell when extracted two to four months after storage and rancid smell when extracted five and six months after storage. The infestation of copra with N. rufipes followed by the

Table 9. Odour of oil obtained from stored copra, exposed to the attack of a fungus and insects, independently or in combination, observed at different intervals after exposure.

Treatments	Odour of oil extracted from copra collected at different periods after treatment (months).					
	1	2	3	4	5	6
N. rufipes						
A. flavus alone	slightly rancid	rancid	highly rancid	highly rancid	highly rancid	highly rancid
N. rufipes alone	normal	slightly rancid	slightly rancid	slightly rancid	rancid	rancid
A. flavus followed by *N. rufipes*	slightly rancid	rancid	highly rancid	highly rancid	highly rancid	highly rancid
N. rufipes followed by *A. flavus*	slightly rancid	rancid	highly rancid	highly rancid	highly rancid	highly rancid
Control	normal	normal	normal	normal	normal	normal
O. surinamensis						
A. flavus alone	slightly rancid	rancid	highly rancid	highly rancid	highly rancid	highly rancid
O. surinamensis alone	normal	normal	slightly rancid	slightly rancid	slightly rancid	rancid
A. flavus followed by *O. surinamensis*	slightly rancid	rancid	highly rancid	highly rancid	highly rancid	highly rancid
O. surinamensis followed by *A. flavus*	slightly rancid	rancid	highly rancid	highly rancid	highly rancid	highly rancid
Control	normal	normal	normal	normal	normal	normal

infection by fungus did not change the development of rancidity in the oil caused by the fungus. The effect of fungus followed by the infestation by O. surinamensis also showed a pattern similar to that with N. rufipes with regard to the rancidity development in the oil.

3.4. Extent of damage done by insects to stored copra obtained from different varieties/cultivars of coconut

3.4.1. Extent of damage on weight basis

The data on loss caused by insects to copra obtained from different varieties of coconut and results of statistical analysis of the same are presented in Table 10.

The varieties in which highest damage caused by N. rufipes observed after 1, 2, 3, 4, 5 and 6 months of storage were TxD, WCT, DxT, CDG, TxG and LM respectively. The extent of damage did not show any relation with the variety from which the copra was processed. Significant reduction in weight of copra was recorded from third/ fourth month onwards in different varieties. During the sixth month, the minimum weight reduction of 6.73 per cent was recorded in GB and maximum of 8.77 per cent in LM.

Table 10. Extent of damage caused by insects to copra, obtained from different varieties/cultivars kept in storage.

Insects and varieties/cultivars		Mean per cent loss in copra (weight) over that of control observed at different periods after exposure (months).					
		1	2	3	4	5	6
N. rufipes							
Dwarf x Tall	(DxT)	0.86 (1.37)	1.70 (1.64)	4.89 (2.43)	4.85 (2.42)	6.84 (2.80)	8.12 (3.02)
Laccadive micro	(LM)	0.60 (1.26)	1.45 (1.57)	3.78 (2.19)	2.88 (2.21)	6.57 (2.75)	8.77 (3.12)
Gangabondam	(GB)	0.80 (1.34)	2.19 (1.79)	3.79 (2.19)	4.58 (2.36)	4.83 (2.41)	6.73 (2.78)
Tall x Dwarf	(TxD)	1.45 (1.57)	1.19 (1.48)	2.26 (1.81)	5.23 (2.50)	6.39 (2.72)	7.82 (2.97)
Chavakkad Dwarf Orange	(CDO)	1.44 (1.56)	1.97 (1.72)	3.26 (2.06)	4.24 (2.29)	6.62 (2.76)	7.61 (2.94)
West Coast Tall	(WCT)	1.16 (1.47)	2.76 (1.94)	2.57 (1.89)	4.72 (2.39)	5.86 (2.61)	7.25 (2.87)
Laccadive ordinary	(LO)	0.96 (1.40)	2.22 (1.80)	2.57 (1.89)	5.35 (2.52)	5.61 (2.57)	7.86 (2.98)
Tall x Green	(TxG)	0.67 (1.29)	2.35 (1.83)	2.64 (1.91)	4.68 (2.38)	7.08 (2.84)	8.00 (3.00)
Chavakkad Dwarf Green	(CDG)	1.24 (1.50)	2.57 (1.89)	3.06 (2.02)	5.31 (2.51)	6.50 (2.74)	6.77 (2.79)
O. surinamensis							
Dwarf x Tall	(DxT)	0.40 (1.18)	1.50 (1.58)	4.43 (2.33)	6.26 (2.70)	8.65 (3.11)	10.13 (3.34)
Laccadive micro	(LM)	0.99 (1.41)	1.25 (1.50)	4.26 (2.29)	5.00 (2.45)	7.26 (2.87)	8.40 (3.07)
Gangabondam	(GB)	1.24 (1.50)	2.00 (1.73)	2.76 (1.94)	2.75 (1.94)	5.96 (2.64)	8.24 (3.04)
Tall x Dwarf	(TxD)	0.60 (1.26)	3.14 (2.03)	3.13 (2.03)	3.81 (2.19)	7.72 (2.96)	8.56 (3.09)
Chavakkad Dwarf Orange	(CDO)	1.16 (1.47)	2.19 (1.79)	3.72 (2.17)	3.99 (2.23)	6.00 (2.65)	8.39 (3.07)
West Coast Tall	(WCT)	1.73 (1.65)	2.24 (1.82)	3.73 (2.18)	4.80 (2.41)	6.24 (2.69)	7.73 (2.96)
Laccadive ordinary	(LO)	1.46 (1.57)	3.22 (2.05)	3.37 (2.09)	3.85 (2.20)	5.03 (2.46)	6.25 (2.69)
Tall x Green	(TxG)	1.80 (1.67)	2.70 (1.92)	2.90 (1.98)	3.73 (2.18)	5.13 (2.48)	7.66 (2.94)
Chavakkad Dwarf Green	(CDG)	1.93 (1.71)	2.44 (1.85)	3.67 (2.16)	3.80 (2.19)	6.59 (2.76)	7.17 (2.86)

	N. rufipes	*O. surinamensis*
CD at 1 per cent level	(0.38)	(0.37)

Figures in parentheses are transformed values, $\sqrt{x+1}$

Number of insects released in each replication of

The maximum damage caused by O. surinamensis was in DxT at third, fourth, fifth and sixth month after storage while in LM the damage was low during the above periods of observation.

3.4.2. Reduction in oil content

The data relating to the experiment and the statistical analysis of the same are given in Table 11.

The variety in which maximum reduction in oil content of copra was observed in DxT when exposed to N. rufipes (0.40 to 2.36 per cent) and it was followed by WCT (0.38 to 2.18), TxG (0.70 to 2.10), GB (0.66 to 1.96), TxD (0.30 to 1.93), LO (0.91 to 1.79), CDO (0.50 to 1.78), LM (0.68 to 1.69) and the minimum in CDG (0.33 to 1.64). Significant reduction in percentage of oil content was noticed in CDG from third month, in DxT, TxD, CDO and WCT from fourth month, in GB and TxG from fifth month, in LM from the sixth month onwards and there was no significant reduction in oil content in LO upto sixth month after treatment.

The percentage reduction in oil content recorded in TxG by the attack of O. surinamensis ranged from 0.89 to 2.56, and it was followed by WCT (0.87 to 2.42), DxT (0.36 to 2.42), TxD (0.93 to 2.34), CDG (1.30 to 2.25),

Table 11. Oil content of copra extracted from different varieties/cultivars when exposed to the attack of insect pests in store.

Insects and varieties/cultivars		Mean per cent reduction of oil over that of control observed at different intervals after exposure (months)					
		1	2	3	4	5	6
N. rufipes							
Dwarf x Tall	(DxT)	0.40 (1.18)	0.23 (1.11)	0.98 (1.41)	1.70 (1.64)	1.75 (1.66)	2.36 (1.83)
Laccadive micro	(LM)	0.68 (2.30)	0.83 (1.35)	1.18 (1.48)	1.37 (1.54)	1.43 (1.56)	1.69 (1.64)
Gangabondam	(GB)	0.66 (1.29)	0.67 (1.29)	0.87 (1.37)	1.49 (1.58)	1.67 (1.63)	1.96 (1.72)
Tall x Dwarf	(TxD)	0.30 (1.14)	0.59 (1.26)	0.86 (1.36)	1.37 (1.54)	1.58 (1.61)	1.93 (1.71)
Chavakkad Dwarf Orange	(CDO)	0.50 (1.22)	0.82 (1.35)	1.07 (1.44)	1.46 (1.57)	1.81 (1.68)	1.78 (1.67)
West Coast Tall	(WCT)	0.38 (1.17)	0.66 (1.29)	0.82 (1.35)	1.10 (1.45)	1.93 (1.71)	2.18 (1.78)
Laccadive ordinary	(LO)	0.91 (1.38)	0.99 (1.41)	1.45 (1.57)	1.41 (1.55)	1.38 (1.54)	1.79 (1.67)
Tall x Green	(TxG)	0.70 (1.30)	0.98 (1.41)	1.49 (1.57)	1.50 (1.58)	1.76 (1.66)	2.10 (1.76)
Chavakkad Dwarf Green	(CDG)	0.33 (1.15)	0.87 (1.37)	1.21 (1.49)	1.22 (1.49)	1.31 (1.52)	1.64 (1.64)
O. surinamensis							
Dwarf x Tall	(DxT)	0.36 (1.17)	0.59 (1.26)	1.13 (1.46)	1.56 (1.60)	1.41 (1.55)	2.42 (1.85)
Laccadive micro	(LM)	0.62 (1.27)	1.03 (1.42)	0.89 (1.37)	1.08 (1.44)	1.78 (1.67)	2.15 (1.78)
Gangabondam	(GB)	0.77 (1.33)	0.78 (1.34)	1.23 (1.50)	1.49 (1.58)	1.70 (1.64)	2.00 (1.73)
Tall x Dwarf	(TxD)	0.93 (1.39)	1.22 (1.49)	1.52 (1.59)	1.82 (1.68)	2.01 (1.74)	2.34 (1.83)
Chavakkad Dwarf Orange	(CDO)	0.52 (1.23)	0.82 (1.35)	1.08 (1.44)	1.39 (1.55)	1.95 (1.72)	2.20 (1.79)
West Coast Tall	(WCT)	0.87 (1.37)	1.08 (1.44)	1.09 (1.45)	1.48 (1.58)	1.90 (1.70)	2.42 (1.85)
Laccadive ordinary	(LO)	1.15 (1 47)	0.80 (1.34)	1.42 (1.56)	1.51 (1.58)	1.89 (1.70)	2.19 (1.79)
Tall x Green	(TxG)	0.89 (1.37)	0.94 (1.39)	1.14 (1.46)	1.56 (1.60)	2.41 (1.85)	2.56 (1.89)
Chavakkad Dwarf Green	(CDG)	1.30 (1.52)	1.26 (1.50)	1.42 (1.56)	1.59 (1.61)	1.90 (1.70)	2.25 (1.80)

	N. rufipes	*O. surinamensis*
CD at 1 per cent level	(0.33)	(0.28)

Figures in parentheses are transformed values, $\sqrt{x+1}$

CDO (0.52 to 2.20), LO (1.15 to 2.19), LM (0.62 to 2.15) and GB (0.77 to 2.00). When compared with the reduction in oil obtained during the first month, significant reduction was noticed during various periods in different varieties/cultivars. In DxT the oil content got reduced during the third month, in TxD and CDO during the fourth month, in LM, GB, WCT, LO and TxG during the fifth month and in CDG during sixth month after exposure to the insect.

3.4.3. Development of insects exposed to copra obtained from different varieties/cultivars of coconut

The data relating to the experiment and the results of the statistical analysis of the same are shown in Table 12 and Fig.3.

N. rufipes had the longest mean larval duration of 63.98 days in CDO and it was closely followed by the durations in TxD (62.99 days), CDG (62.67 days), TxG and GB (61.33 days), DxT (60.65 days) and WCT (60.64 days). The least larval duration was in LM (52.27 days) and it was closely followed by LO (53.64 days).

The longest mean pupal duration of nine days was observed in CDG in the case of N. rufipes and it was followed by the durations in CDO (8.66 days), GB and TxG (8.33 days). No significant differences were seen

Table 12 Development of the insect pests in stored copra obtained from different varieties/cultivars of coconut

Copra obtained from varieties/cultivars		Larval period	Pupal Period	Total duration	Percentage larval mortality	Percentage pupal mortality	Percentage adult emergence	Growth index	Fecundity	gg period	Adult longevity in copra: without immature stages	Adult longevity in copra: with immature stages
N rufipes												
Dwarf x Tall	(DxT)	60 65 (7 85)	6 33 (2 71)	67 00	20	0	80	1 19	1 59 (1 61)	4 32 (2 31)	19 89 (4 57)	83 67 (9 20)
Laccadive micro	(LM)	52 27 (7 30)	7 33 (2 89)	59 60	10	0	90	1 51	6 48 (2 74)	4 66 (2 38)	33 46 (5 87)	88 64 (9 47)
Gangabondam	(GB)	61 33 (7 90)	8 33 (3 05)	69 66	30	20	50	0 72	3 27 (2 07)	4 32 (2 31)	16 66 (4 20)	75 39 (8 74)
Tall x Dwarf	(TxD)	62 99 (8 00)	7 33 (2 89)	70 32	30	0	70	1 00	1 17 (1 47)	4 33 (2 31)	14 93 (3 99)	92 05 (9 65)
Chavakkad Dwarf Orange	(CDO)	63 98 (8 06)	8 66 (3 11)	72 64	20	10	70	0 96	2 55 (1 88)	4 66 (2 38)	16 33 (4 16)	76 62 (8 81)
West Coast Tall	(WCT)	60 64 (7 85)	7 64 (2 94)	68 29	30	0	70	1 03	5 50 (2 55)	4 32 (2 31)	21 32 (4 72)	69 72 (8 41)
Laccadive ordinary	(LO)	53 64 (7 39)	6 33 (2 71)	60 00	10	0	90	1 50	2 56 (1 89)	5 00 (2 45)	29 97 (5 56)	62 83 (7 99)
Tall x Green	(TxG)	61 33 (7 90)	8 33 (3 05)	69 66	10	20	70	1 00	1 49 (1 58)	4 32 (2 31)	17 08 (4 25)	90 44 (9 56)
Chavakkad Dwarf Green	(CDG)	62 67 (7 98)	9 00 (3 16)	71 67	30	10	60	0 84	1 20 (1 48)	4 00 (2 24)	23 63 (4 97)	76 96 (8 83)
O surinamensis												
Dwarf x Tall	(DxT)	17 33 (4 28)	6 33 (2 71)	23 66	0	10	90	3 81	98 80 (9 99)	3 32 (2 08)	84 15 (9 23)	84 15 (9 22)
Laccadive micro	(LM)	18 33 (4 40)	7 66 (2 94)	26 65	10	40	50	1 88	125 39 (11 24)	3 00 (2 00)	97 87 (9 94)	97 87 (9 94)
Gangabondam	(GB)	18 66 (4 43)	5 33 (2 52)	24 00	20	0	80	3 33	65 76 (8 17)	3 32 (2 08)	78 64 (8 92)	78 64 (8 92)
Tall x Dwarf	(TxD)	17 33 (4 28)	6 00 (2 65)	23 33	10	10	80	3 43	80 93 (9 05)	3 65 (2 16)	81 64 (9 09)	81 63 (9 09)
Chavakkad Dwarf Orange	(CDO)	18 66 (4 43)	6 33 (2 71)	25 00	20	10	70	2 80	65 59 (8 16)	3 00 (2 00)	72 07 (8 55)	72 07 (8 54)
West Coast Tall	(WCT)	17 66 (4 32)	6 98 (2 83)	24 66	30	10	60	2 43	85 47 (9 30)	3 65 (2 16)	74 90 (8 71)	74 89 (8 71)
Laccadive ordinary	(LO)	16 65 (4 20)	7 00 (2 83)	23 65	20	30	50	2 11	108 99 (10 49)	3 32 (2 08)	88 75 (9 47)	88 74 (9 47)
Tall x Green	(TxG)	16.33 (4 16)	6 98 (2 83)	23 33	30	10	60	2 57	52 05 (7 28)	3 00 (2 00)	55 12 (7 49)	55 11 (7 49)
Chavakkad Dwarf Green	(CDG)	17 66 (4 32)	6 33 (2 71)	24 00	30	0	70	2 92	48 59 (7 04)	3 65 (2 16)	63 45 (8 03)	63 45 (8 02)

	Larval period	Pupal period	Fecundity	Egg period	Adult longevity: Without immature stages	Adult longevity: with immature stages
CD at 1 per cent level N rufipes	(0 30)	(0 19)	NS	NS	(0 83)	NS
CD at 5 per cent level O surinamensis	(0 18)	(0 20)	(2 60)	NS	NS	NS

Figures in parentheses are transformed values $\sqrt{x+1}$

among these four varieties/cultivars. In WCT, the pupal period of N. rufipes was 7.64 days and it was followed by those in LM and TxD (7.33 days). The shortest mean pupal period of 6.33 days was observed in DxT and LO and these varieties/cultivars showed significant differences over the others.

Based on the total duration (larval + pupal) the varieties/cultivars could be ranked as follows:

CDO (72.64)$>$CDG (71.67) $>$ TxD (70.32) $>$ GB (69.66) = IxG (69.66)$>$ WCT (68.28) $>$ DxT (67.00) $>$ LO (60.00)$>$ LM (59.60).

In the varieties/cultivars tested, larval and pupal mortality ranged from 10 to 30 and 0 to 20 per cent respectively. Based on the percentage larval and pupal mortality the varieties/cultivars could be ranked as GB = TxD = WCT = CDG (30) $>$ DxT = CDO (20) $>$ LM = LO = TxG (10) and GB = TxG (20) $>$ CDO = CDG (10) $>$ DxT = LM = TxD = WCT = LO (0) respectively.

The percentage of adult emergence ranged from 50 to 90 in various varieties/cultivars tested. On the basis of adult emergence the varieties tested were ranked as LM = LO (90) $>$ DxT (80) $>$ TxD = CDO = WCT = TxG (70) $>$ CDG (60) $>$ GB (50).

The growth indices, based on percentage of adult emergence and total developmental period, varied from 0.72 to 1.51. On the basis of growth indices, the varieties tested could be ranked as follows:

GB (0.72) > CDG (0.84) > CDO (0.96) > TxD (1.00) = TxG (1.00) > WCT (1.03) > DxT (1.19) > LO (1.50) > LM (1.51).

The fecundity of N. rufipes reared in different varieties/cultivars and the incubation periods of the eggs laid by them did not show statistically significant variations. The mean number of eggs laid and the mean incubation periods ranged from 1.17 to 6.48 and from four to five days respectively.

Considering the cannibalistic behaviour of N. rufipes, the longevity of adults was studied by supplying uninfested copra and infested copra containing its own immature stages, which they could feed on. Significant differences in adult longevity was noticed among varieties when uninfested copra was supplied. The longevity ranged from 14.93 to 33.46 days. Significantly lower longevity was recorded in TxD (14.93) and it was on par with CDO (16.33), GB (16.66), TxG (17.08), DxT (19.89) and WCT (21.32). Significantly higher longevity was noted in CDG (23.63) but it was on par with LO (29.97). The highest longevity was in LM (33.46).

The adult longevity of N. rufipes was two to six times higher in different varieties/cultivars when supplied with immature stages also. Though the data showed wide range (62.83 to 92.05 days), statistically significant variations were lacking.

The mean larval period of O. surinamensis showed significant variations in different varieties. The longest larval period of 18.66 days was recorded in GB and CDO which was on par with the larval period obtained in LM (18.33), WCT and CDG (17.66), DxT and TxD (17.33). Significantly shorter larval period was recorded in TxG (16.33) and in LO (16.65).

Pupal period of O. surinamensis also showed significant differences in different varieties. Significantly longest pupal period was observed in LM (7.66) which was on par with LO (7.00), WCT and TxG (6.98). Shortest pupal period of 5.33 days was recorded in GB which was on par with TxD (6.00), DxT, CDO and CDG (6.33).

Based on the total developmental period, the varieties/cultivars could be ranked as follows:

LM (26.65) $>$ CDO (25.00) $>$ WCT (24.66) $>$ GB = CDG (24.00) $>$ DxT (23.66) $>$ LO (23.65) $>$ TxD = TxG (23.33).

The percentage of larval mortality in different varieties/cultivars ranged from 0 to 30, whereas that of

pupae from 0 to 40. Based on larval mortality the varieties/cultivars could be ranked as WCT, TxG, CDG (30 per cent), GB, CDO, LO (20 per cent), LM, TxD (10 per cent) and no larval mortality was recorded in DxT. Considering the pupal mortality, the varieties/cultivars were ranked as follows:

LM (40 per cent) > LO (30 per cent) > DxT = TxD = CDO = WCT = TxG (10 per cent) > GB = CDG (0 per cent).

The percentage of adult emergence ranged from 50 to 90 in different varieties/cultivars. On the basis of percentage adult emergence the varieties/cultivars could be ranked as DxT (90) > GB = TxD (80) > CDO = CDG (70) > WCT = TxG (60) > LM = LO (50).

The growth indices ranged from 1.88 to 3.81. On the basis of growth indices, the varieties/cultivars tested could be ranked as follows:

LM (1.88) > LO (2.11) > WCT (2.43) > TxG (2.57) > CDO (2.80) > CDG (2.92) > GB (3.33) > TxD (3.43) > DxT (3.81).

The fecundity of O. surinamensis reared on different varieties/cultivars showed significant differences. Least number of egg was recorded in CDG (48.59) and it was on par with the eggs in TxG (52.05), CDO (65.59), GB (65.76), TxD (80.93) and WCT (85.47). Highest number

of eggs were observed in LM (125.39), which was on par with LO (108.99) and DxT (98.80).

Significant differences in incubation period of eggs laid by insects reared on various varieties/cultivars (3.0 to 3.65 days) were lacking.

Adult longevity of O. surinamensis reared in different varieties of copra, with and without immature stages, did not show significant variations. The mean adult longevity ranged from 55.12 to 97.87 days.

In overall assessment (Fig.3), DxT, LM and LO may be identified as less desirable for keeping the population build up low while CDG and TxG may be considered better and the remaining varieties/cultivars may be treated as intermediate.

3.5. Extent of damage caused by insects to copra, containing various levels of moisture, stored in godowns

3.5.1. Weight of copra exposed to the insect observed at different intervals

The data relating to the experiment and the results of the statistical analysis are presented in Table 13.

Table 13. Extent of damage caused by insects to copra having varying levels of moisture content.

Moisture content	Mean per cent loss of copra (weight) in treatments over that of control, observed at different intervals after infestations (months).					
	1	2	3	4	5	6
N. rufipes						
4±0.5% moisture	1.07 (1.44)	1.24 (1.50)	1.64 (1.63)	2.97 (1.99)	4.00 (2.24)	4.55 (2.36)
6±0.5% moisture	0.97 (1.41)	1.57 (1.60)	2.63 (1.91)	3.75 (2.18)	5.41 (2.53)	6.94 (2.82)
8±0.5% moisture	1.12 (1.46)	3.73 (2.18)	7.07 (2.84)	8.81 (3.13)	9.98 (3.31)	12.03 (3.61)
O. surinamensis						
4±0.5% moisture	2.27 (1.81)	3.85 (2.20)	5.22 (2.49)	6.70 (2.78)	7.10 (2.85)	7.86 (2.98)
6±0.5% moisture	1.80 (1.67)	4.08 (2.25)	4.23 (2.29)	7.80 (2.97)	9.55 (3.25)	11.69 (3.56)
8±0.5% moisture	0.74 (1.32)	1.81 (1.68)	1.86 (1.69)	1.26 (1.51)	2.63 (1.91)	4.35 (2.31)

	N. rufipes	*O. surinamensis*
CD at 1 per cent level	(0.44)	(0.42)

Figures in parentheses are transformed values, $\sqrt{x+1}$

Number of insects released in each replication of 200g copra - 100

During the first month after treatment, no significant variations in weight of stored copra destroyed by N. rufipes were observed among the different treatments (0.97 to 1.12 per cent). During second month, per cent weight of copra damaged by the pest was significantly higher at 8±0.5 per cent moisture level (3.73) than at 6±0.5 per cent moisture (1.57) or at 4±0.5 per cent moisture level (1.24). The difference between the latter two treatments was not statistically significant. Same trend was observed during the fourth and fifth months after treatment. But during the sixth month, the extent of damage at 6±0.5 per cent moisture (6.94 per cent) also came significantly higher than that observed at 4±0.5 per cent moisture (4.55 per cent) and the maximum damage was at 8±0.5 per cent moisture level (12.03 per cent).

When copra was exposed to the attack of O. surinamensis, higher damage was noted at 4±0.5 per cent moisture than at 8±0.5 per cent moisture level, even at one month after exposure. But the damage at 6±0.5 per cent moisture came on par with the damages at the other two levels of moisture. During the second, third and fourth months, damages at 4±0.5 per cent and 6±0.5 per cent moisture levels remained on par, while at 8±0.5 per cent moisture level, the damage was significantly lower. At fifth month, the damages at the three moisture levels showed statistically significant differences; among themselves the damage being in the

ascending scale at 8±0.5, 4±0.5 and 6±0.5 per cent (2.63, 7.10 and 9.55 per cent) moisture levels. The same trend was observed at six months after exposure, the per cent weight of copra damaged at 8±0.5 per cent, 4±0.5 per cent and 6±0.5 per cent moisture being 4.35, 7.86 and 11.69 per cent respectively.

3.5.2. Oil content of copra exposed to insect attack

The data relating to the experiment and results of statistical analysis are presented in Table 14.

During the first month, the percentage reduction in oil extracted from copra having various levels of moisture content exposed to N. rufipes did not show significant variations. During the second month significantly higher reduction in oil content in copra kept at 6±0.5 per cent moisture (2.19 per cent) than in copra kept at 4±0.5 per cent (0.87 per cent) and at 8±0.5 per cent (1.07 per cent) was observed; the latter two being on par. No significant differences in oil content were observed among the treatments at third, fourth and fifth months after exposure to N. rufipes. During sixth month significantly higher reduction in oil was observed in copra stored at 8±0.5 per cent moisture (3.84 per cent) than in copra kept at 4±0.5 per cent moisture (2.27 per cent), while the reduction at

Table 14. Oil content of copra with varying levels of moisture exposed to the attack of insects in store.

oisture content	Mean per cent reduction in oil content of copra in treatment over that of control observed at different periods after infestation (months).					
	1	2	3	4	5	6
. rufipes						
4±0.5% moisture	0.75 (1.32)	0.87 (1.37)	1.32 (1.52)	1.39 (1.55)	1.95 (1.72)	2.27 (1.81)
6±0.5% moisture	1.13 (1.46)	2.19 (1.79)	2.14 (1.77)	2.34 (1.83)	2.77 (1.94)	3.04 (2.01)
8±0.5% moisture	1.11 (1.46)	1.07 (1.44)	1.50 (1.58)	2.04 (1.74)	2.26 (1.81)	3.84 (2.20)
. surinamensis						
4±0.5% moisture	1.14 (1.46)	1.62 (1.62)	1.75 (1.66)	3.01 (2.00)	3.81 (2.19)	4.65 (2.38)
6±0.5% moisture	1.72 (1.65)	2.45 (1.88)	2.41 (1.85)	2.40 (1.84)	3.59 (2.14)	4.19 (2.28)
8±0.5% moisture	0.80 (1.34)	1.10 (1.45)	1.59 (1.61)	1.57 (1.70)	3.09 (2.02)	4.04 (2.24)

	N. rufipes	O. surinamensis
CD at 1 per cent level	(0.31)	(0.43)

Figures in parentheses are transformed values, $\sqrt{x+1}$

6±0.5 per cent was on par with the above two treatments.

Significant reduction in oil content was noticed by the infestation of N. rufipes from second month onwards in copra kept at 6±0.5 per cent moisture and from fifth month onwards in copra kept at 4±0.5 and 8±0.5 per cent.

The percentage reduction in oil content of copra exposed to O. surinamensis at 4±0.5 per cent moisture was on par with that exposed at 6±0.5 and 8±0.5 per cent. No significant variations among treatments were noticed from first to sixth month.

Significant reduction in oil was recorded in copra kept at 4±0.5 per cent moisture from fourth month onwards and at the higher two moisture levels from fifth month onwards.

3.5.3. Acid values of oils extracted from copra having different levels of moisture exposed to the insects

The data relating to the experiment are given in Table 15.

During the first month, significant differences in acid values were not seen among the treatments. During second and third months, significantly higher acid value was recorded in oil extracted from copra exposed to

Table 15. Acid values of the oil obtained from copra with varying levels of moisture content.

oisture content	Mean increase in acid value of oil extracted from copra in treatments over that of control, observed at different periods after infestation (months).					
	1	2	3	4	5	6
. rufipes						
4±0.5% moisture	0.39 (1.18)	0.45 (1.21)	0.57 (1.25)	0.53 (1.24)	0.76 (1.33)	0.77 (1.33)
6±0.5% moisture	0.25 (1.12)	0.28 (1.13)	0.56 (1.25)	0.81 (1.34)	1.31 (1.52)	1.43 (1.56)
8±0.5% moisture	0.53 (1.24)	0.98 (1.41)	1.28 (1.51)	1.22 (1.49)	1.41 (1.55)	1.87 (1.70)
). surinamensis						
4±0.5% moisture	0.14 (1.07)	0.18 (1.09)	0.60 (1.27)	0.88 (1.37)	1.69 (1.69)	2.01 (1.73)
6±0.5% moisture	0.29 (1.14)	0.30 (1.14)	0.57 (1.25)	0.08 (1.44)	1.51 (1.59)	2.44 (1.86)
8±0.5% moisture	0.24 (1.12)	0.32 (1.15)	0.68 (1.30)	1.11 (1.45)	1.35 (1.35)	1.74 (1.65)

	N. rufipes	O. surinamensis
CD at 1 per cent level	(0.22)	(0.26)

Figures in parentheses are transformed values, $\sqrt{x+1}$

N. rufipes at 8±0.5 per cent moisture content than in oil obtained from copra exposed at 6±0.5 per cent moisture. During fourth and fifth months, significant differences in acid values were noticed in oil extracted from copra treated at moisture level of 8±0.5 per cent when compared with the acid values of oil extracted from copra exposed at 4±0.5 per cent moisture level. At sixth month, there was significant increase in acid value of oil extracted from copra kept at 6±0.5 per cent and 8±0.5 per cent levels than at 4±0.5 per cent level.

When compared with the acid value recorded during first month, no significant difference was noticed upto sixth month in oil extracted from copra kept at 4±0.5 per cent moisture level and significantly higher acid values were recorded from the third month onwards in 8±0.5 per cent and fourth month onwards in 6±0.5 per cent moisture.

The acid values of oils extracted from copra exposed to O. surinamensis at different moisture levels did not show statistically significant variations from first to sixth month after exposure. When compared with the acid values obtained during the first month, significant increase in acid values were recorded from fourth month onwards in all the treatments.

3.5.4. Saponification values of oils extracted from copra in different treatments

The saponification values recorded over six month period in different treatments are shown in Table 16.

In the case of copra infested by N. rufipes, there was no significant difference in saponification values of oils recorded upto the third month after storage. During fourth month, significantly higher values were recorded in oil extracted from copra with 6±0.5 per cent moisture (8.32). During the fifth and sixth month, higher values were recorded in copra with 6±0.5 per cent (8.32 and 8.02) and 8±0.5 per cent moisture (7.28 and 10.45) and the difference between the two levels of moisture did not vary significantly.

There was no significant increase in saponification value of oil extracted from copra kept at 4±0.5 per cent moisture. The oil extracted from copra having higher moisture contents (6±0.5 and 8±0.5 per cent) exhibited significant increase from the third month after storage.

The lowest saponification value was recorded in oil extracted from copra, infested by O. surinamensis kept under 8±0.5 per cent moisture, but it did not show significant differences from the treatments with 6±0.5 and 4±0.5 per cent moisture content upto fourth month after storage. During the fifth month, highest value

Table 16. Saponification values of the oil obtained from copra with varying levels of moisture content.

Moisture content	Mean increase in saponification value of oil extracted from copra in treatments over that of control, observed at different periods after infestation (months).					
	1	2	3	4	5	6
N. rufipes						
4±0.5% moisture	2.20 (1.79)	2.76 (1.94)	3.07 (2.02)	3.00 (2.00)	3.26 (2.06)	3.75 (2.18)
6±0.5% moisture	1.60 (1.61)	3.67 (2.16)	5.99 (2.64)	8.21 (3.04)	8.32 (3.05)	8.02 (3.00)
8±0.5% moisture	1.11 (1.45)	2.61 (1.90)	4.03 (2.24)	4.71 (2.39)	7.28 (2.88)	10.45 (3.88)
O. surinamensis						
4±0.5% moisture	1.63 (1.62)	3.67 (2.16)	4.18 (2.28)	8.14 (3.02)	8.54 (3.09)	12.46 (3.67)
6±0.5% moisture	1.52 (1.59)	4.74 (2.40)	4.89 (2.43)	6.91 (2.81)	10.72 (3.44)	16.46 (4.73)
8±0.5% moisture	1.43 (1.56)	3.01 (2.00)	4.29 (2.30)	4.33 (2.31)	5.59 (2.57)	7.33 (2.89)

	N. rufipes	*O. surinamensis*
CD at 1 per cent level	(0.77)	(0.69)

Figures in parentheses are transformed values, $\sqrt{x+1}$

was noticed in oil obtained from copra with 6±0.5 per cent moisture (10.72) which significantly differed from copra with 8±0.5 per cent moisture (5.59). During sixth month, significantly lower saponification value was recorded in oil extracted from copra having 8±0.5 per cent moisture (7.33) than in oil extracted from copra having 6±0.5 and 4±0.5 per cent moisture content (16.46 and 12.46). Significant difference was noticed between 4±0.5 and 6±0.5 per cent also.

Compared with the saponification value obtained during first month, significant increase was noticed in the samples obtained after four, two and three months of storage under 4±0.5, 6±0.5 and 8±0.5 per cent moisture content respectively.

3.5.5. Iodine value of oils extracted from copra in different treatments

Data relating to this aspect along with the results of statistical analysis are presented in Table 17.

Among the treatments, significant variations in iodine values of oil extracted from copra infested by N. rufipes were not seen upto fourth month after storage. During fifth month, significantly higher iodine value in oil extracted from copra kept at 8±0.5 per cent moisture (1.98) was observed than at 4±0.5 per cent

Table 17. Iodine values of the oil obtained from copra with varying levels of moisture content.

Moisture content	Mean increase in iodine value of oil extracted from copra in treatments over that of control, observed at different periods after infestation (months).					
	1	2	3	4	5	6
N. rufipes						
4±0.5% moisture	0.26 (1.12)	0.58 (1.26)	0.67 (1.29)	0.66 (1.29)	0.68 (1.30)	0.95 (1.40)
6±0.5% moisture	0.45 (1.20)	0.84 (1.36)	0.98 (1.41)	0.90 (1.38)	1.26 (1.50)	2.10 (1.76)
8±0.5% moisture	0.35 (1.16)	0.39 (1.18)	0.89 (1.37)	1.21 (1.49)	1.98 (1.73)	2.23 (1.80)
O. surinamensis						
4±0.5% moisture	0.86 (1.37)	0.77 (1.33)	0.97 (1.40)	1.20 (1.48)	1.25 (1.50)	1.72 (1.65)
6±0.5% moisture	0.17 (1.08)	0.23 (1.11)	0.57 (1.25)	1.11 (1.45)	2.42 (1.85)	2.34 (1.83)
8±0.5% moisture	0.53 (1.24)	0.52 (1.23)	1.34 (1.53)	1.79 (1.67)	2.25 (1.80)	2.65 (1.91)

	N. rufipes	O. surinamensis
CD at 1 per cent level	(0.29)	(0.30)

Figures in parentheses are transformed values, $\sqrt{x+1}$

moisture content. Significant difference in iodine value was not noted for the oil extracted from copra kept at 6±0.5 and 8±0.5 per cent moisture. The same trend was seen in samples obtained after storage for six months.

The iodine value of oil extracted from copra having moisture content 4±0.5 per cent upto sixth month after treatment did not show any significant difference when compared to the iodine value obtained during the first month (0.26 to 0.95). Significant differences in iodine values were noticed during fourth and fifth month after storage at 6±0.5 and 8±0.5 per cent moisture content respectively.

The iodine value of oil extracted from copra infested by O. surinamensis in different treatments were not statistically significant. The iodine value of oil extracted from copra having 4±0.5 per cent moisture did not show significant increase over a period of six months, whereas treatments with 6±0.5 per cent and 8±0.5 per cent moisture recorded significant increase from fourth month onwards when compared to the values at first month after treatment.

3.5.6. Colour of oil extracted from copra in different treatments

The data pertaining to the experiment are presented in Table 18.

When compared to the values in control it was observed that there was no variation in the pigmentation in oil obtained from copra exposed to *N. rufipes* and *O. surinamensis* and collected upto six months after exposure.

3.5.7. Odour of oil obtained from copra exposed to the insects at different moisture levels

The data relating to the change in odour of oil are presented Table 19.

In control, the odour of the oil was normal even when it was extracted from copra after six months of storage. The oil, extracted from copra infested by *N. rufipes* kept at 4±0.5 per cent moisture had normal smell upto two months of storage and in subsequent lots the oil showed slight rancidity. In other two treatments (6±0.5 and 8±0.5 per cent moisture) oil became slightly rancid when the infested copra was stored for two months to five months and when stored for six months, the oil became fully rancid.

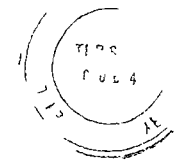
Table 18. Colour of the oil obtained from copra with varying levels of moisture content

Moisture content	Colour of oil extracted from copra collected at different periods after infestation (months)					
	1	2	3	4	5	6
N. rufipes						
4±0.5% moisture	0.0 R + 0.1 Y	0.0 R + 0.2 Y	0.0 R + 0.5 Y	0.0 R + 0.5 Y	0 0 R + 0.7 Y	0.0 R + 0.8 Y
6±0.5% moisture	0.0 R + 0.1 Y	0.0 R + 0.2 Y	0 0 R + 0.5 Y	0.0 R + 0.5 Y	0.0 R + 0.8 Y	0.0 R + 0.9 Y
8±0.5% moisture	0.0 R + 0.5 Y	0 0 R + 0.6 Y	0.0 R + 0.8 Y	0.0 R + 0.9 Y	0 0 R + 1.0 Y	0.3 R + 1.0 Y
O. surinamensis						
4±0.5% moisture	0.0 R + 0 1 Y	0 0 R + 0.2 Y	0.0 R + 0.4 Y	0.0 R + 0.5 Y	0 0 R + 0.8 Y	0 0 R + 0.8 Y
6±0.5% moisture	0.0 R + 0.1 Y	0 0 R + 0 2 Y	0 0 R + 0.3 Y	0.0 R + 0.3 Y	0 1 R + 0.5 Y	0 2 R + 0.6 Y
8±0.5% moisture	0 0 R + 0.2 Y	0.0 R + 0 4 Y	0 0 R + 0.7 Y	0.1 R + 0 8 Y	0 2 R + 1.0 Y	0.4 R + 1 0 Y
Control						
4±0.5% moisture	0 0 R + 0.1 Y	0.0 R + 0.1 Y	0.0 R + 0.3 Y	0.0 R + 0.3 Y	0 0 R + 0.3 Y	0.0 R + 0.5 Y
6±0.5% moisture	0.0 R + 0.1 Y	0 0 R + 0.1 Y	0 0 R + 0.2 Y	0.0 R + 0 4 Y	0 0 R + 0.4 Y	0.0 R + 0.5 Y
8±0 5% moisture	0 0 R + 0.1 Y	0 0 R + 0 1 Y	0 0 R + 0.2 Y	0 0 R + 0.2 Y	0 0 R + 0.4 Y	0.0 R + 0.5 Y

Table 19. Odour of the oil obtained from copra with varying levels of moisture content.

Moisture content	Odour of oil extracted from copra collected at different periods after infestation (months).					
	1	2	3	4	5	6
N. rufipes						
4±0.5% moisture	normal	normal	slightly rancid	slightly rancid	slightly rancid	slightly rancid
6±0.5% moisture	normal	slightly rancid	slightly rancid	slightly rancid	slightly rancid	rancid
8±0.5% moisture	normal	slightly rancid	slightly rancid	slightly rancid	rancid	rancid
O. surinamensis						
4±0.5% moisture	normal	normal	normal	slightly rancid	slightly rancid	slightly rancid
6±0.5% moisture	normal	normal	slightly rancid	slightly rancid	slightly rancid	slightly rancid
8±0.5% moisture	normal	normal	slightly rancid	slightly rancid	slightly rancid	rancid
Control						
4±0.5% moisture	normal	normal	normal	normal	normal	normal
6±0.5% moisture	normal	normal	normal	normal	normal	normal
8±0.5% moisture	normal	normal	normal	normal	normal	normal

In the case of O. surinamensis, the deterioration of oil was slower. Copra with 4+0.5 per cent moisture gave oil with normal smell upto three months after storage and when stored upto six months, this became slightly rancid. But under 6±0.5 per cent and 8±0.5 per cent moisture levels, normal smell was retained only upto two months after exposure and in the former, the oil became fully rancid at the sixth month sample and in the latter at fifth and sixth month samples.



3.5.8. Development of N. rufipes in copra having varying levels of moisture content

The data relating to the experiment and the results of the statistical analysis are presented in Table 20.

The development of N. rufipes on copra having 4±0.5 per cent moisture was not included in the Table, since no immature stages were noticed throughout the period of the experiment.

Significantly lower number of eggs were recorded during fifth month in copra kept at 8±0.5 per cent moisture and sixth month in copra with 6±0.5 per cent moisture. The number of larvae observed during various periods in the two treatments varied from 10.48 to 33.35 (6±0.5 per cent moisture) and 27.03 to 52.10 (8±0.5 per cent moisture). The differences between the two treatments were not statistically significant.

Table 20. Development of N. rufipes on copra having varying levels of moisture

Treatments	Mean number of developmental stages observed at different periods after infestation (months)					
	1	2	3	4	5	6
			egg			
6±0.5% moisture	4.58 (2.36)	3.17 (2.04)	4.78 (2.41)	4.75 (2.40)	2.95 (1.99)	0.44 (1.20)
8±0.5% moisture	7.30 (2.88)	4.69 (2.39)	3.86 (2.20)	5.99 (2.64)	0.00 (1.00)	0.00 (1.00)
			larva			
6±0.5% moisture	19.91 (4.57)	29.02 (5.48)	21.84 (4.78)	33.35 (5.86)	26.64 (5.26)	10.48 (3.39)
8±0.5% moisture	42.72 (6.61)	36.84 (6.15)	41.82 (6.54)	52.10 (7.29)	28.92 (5.47)	27.03 (5.29)
			pupa			
6±0.5% moisture	0.00 (1.00)	0.00 (1.00)	14.79 (3.97)	30.43 (5.61)	20.08 (4.59)	17.71 (4.21)
8±0.5% moisture	0.00 (1.00)	0.00 (1.00)	47.44 (6.96)	19.41 (4.52)	13.60 (3.82)	30.39 (5.60)
			adult			
6±0.5% moisture	35.35 (6.03)	34.06 (5.92)	41.18 (6.50)	92.15 (9.65)	78.62 (8.92)	68.34 (8.33)
8±0.5% moisture	37.10 (6.17)	28.91 (5.47)	65.91 (8.18)	120.70 (11.03)	96.21 (9.86)	56.73 (7.60)

	Egg	Larva	Pupa	Adult
CD at 1 per cent level	(0.85)	NS	(1.48)	(1.30)

Figures in parentheses are transformed values, $\sqrt{x+1}$

The number of pupae recorded in different observations showed significant differences between treatments only during the third month, higher number (47.44) was observed under 8±0.5 per cent moisture.

The number of adults varied significantly in the two treatments in the third and fourth months and higher population of 65.91 and 120.70 being in 8±0.5 per cent moisture compared to 41.18 and 92.15 under 6±0.5 per cent moisture. Populations observed during fifth and sixth months in the two treatments were on par.

3.5.9. Development of O. surinamensis in copra having varying levels of moisture content

The data relating to the experiment and the results of the statistical analysis are presented in Table 21.

The egg laying was high, during the first three months of the experiment. The number of eggs observed at 6±0.5 per cent moisture was significantly higher than those observed at 4±0.5 and 8±0.5 per cent moisture. The numbers observed in these treatments ranged from 98.23 to 154.61, 2.50 to 59.30 and 19.20 to 25.51 respectively. When the egg laying declined, a preference was indicated for the moisture levels of 6±0.5 per cent and 8±0.5 per cent, the difference between these two was statistically insignificant.

Table 21. Development of O. surinamensis on copra having varying levels of moisture.

Treatments	Mean number of developmental stages observed at different periods after infestation (months)					
	1	2	3	4	5	6
			egg			
4±0.5% moisture	59.30 (7.77)	28.33 (5.42)	2.50 (1.87)	2.94 (1.99)	0.00 (1.00)	0.00 (1.00)
6±0.5% moisture	100.54 (10.08)	154.61 (12.47)	98.23 (9.96)	16.53 (4.19)	2.06 (1.75)	1.45 (1.57)
8±0.5% moisture	25.51 (5.15)	23.40 (4.94)	19.20 (4.50)	16.85 (4.23)	7.70 (2.95)	5.73 (2.59)
			larva			
4±0.5% moisture	83.69 (9.20)	57.80 (7.67)	11.03 (3.47)	23.38 (4.94)	0.00 (1.00)	0.00 (1.00)
6±0.5% moisture	327.59 (18.13)	436.67 (20.92)	229.17 (15.17)	110.23 (10.55)	6.16 (2.68)	4.08 (2.25)
8±0.5% moisture	51.51 (7.25)	89.34 (9.51)	49.28 (7.09)	26.28 (5.23)	16.48 (4.18)	14.43 (3.93)
			pupa			
4±0.5% moisture	26.30 (5.23)	54.16 (7.43)	33.58 (5.88)	30.00 (5.57)	4.92 (2.43)	0.00 (1.00)
6±0.5% moisture	258.35 (16.10)	271.86 (16.51)	261.05 (16.19)	57.98 (7.68)	8.05 (3.01)	12.70 (3.62)
8±0.5% moisture	22.21 (4.82)	41.13 (6.49)	44.60 (6.75)	31.98 (5.74)	12.80 (3.71)	14.33 (3.92)
			adult			
4± 0.5% moisture	128.33 (11.37)	201.25 (14.22)	353.44 (18.83)	462.05 (21.52)	350.02 (18.74)	381.64 (19.56)
6±0.5% moisture	177.39 (13.36)	397.56 (19.96)	363.50 (19.09)	449.71 (21.23)	571.08 (23.92)	525.83 (22.95)
8±0.5% moisture	107.51 (10.42)	158.30 (12.62)	232.22 (15.27)	254.22 (15.98)	206.47 (14.40)	214.74 (14.69)

	Egg	Larva	Pupa	Adult
CD at 1 per cent level	(2.01)	(2.99)	(3.11)	(2.45)

Figures in parentheses are transformed values, $\sqrt{x+1}$

Significantly higher number of larvae were recorded upto fourth month in copra kept at 6±0.5 per cent moisture, than in the other two treatments. During fifth and sixth months, the treatments 6±0.5 and 8±0.5 per cent came on par, but the population during the period was very low. Significantly higher number of pupae was recorded upto the third month in copra having 6±0.5 per cent moisture (258.35 to 271.86) and the other two treatments were on par (26.30 to 54.16 and 22.21 to 44.60). From fourth month onwards, a low population was noticed in all treatments and they were on par. The populations in different treatments ranged from 0 to 57.98.

Significantly higher population of adults was observed in copra with 6±0.5 per cent moisture during the first two months (177.39 and 397.56). During third and fourth months, the adult populations under 6±0.5 per cent (363.50 and 449.71) and 4±0.5 per cent moisture (353.44 and 462.05) were on par but the populations at 8±0.5 per cent (232.22 and 254.22) were significantly lower. During fifth and sixth months, significantly higher populations were recorded under moisture of 6±0.5 per cent (571.08 and 525.83) than at moisture levels of 4±0.5 per cent (350.02 and 381.64) and 8±0.5 per cent (206.47 and 214.74).

3.6. Extent of damage caused to copra kept under different types of storage

3.6.1. Incidence of pests in copra kept under different types of storage

3.6.1.1. N. rufipes

The data relating to the experiment and the results of statistical analysis are presented in Table 22.

As there was no pest incidence recorded in different treatments except in heap during the first month after storage, observations during the period were not included in the Table.

Significantly high population of N. rufipes was recorded in heap when compared with other types of storage from second to fourth month. During fifth and sixth months, the population of N. rufipes observed in all the treatments were on par.

The population of N. rufipes observed in polythene sandwiched gunny bag varied from 0 to 3.6 in different periods and did not show any statistical significance. Same trend was seen in other treatments, except in heap where significantly higher population was observed upto fourth month (29.4 to 79.3) and during fifth and sixth month, there was a fall in population (8.1 and 5.1).

Table 22 Incidence of insect pests in copra kept in godown under different types of storage

	Mean number of insects observed at different periods after storage (months)														
	N. rufipes					*O. surinamensis*					Total population of insects				
	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
Polythene sandwiched gunny bag	0 00 (1 00)	1.25 (1 50)	3.60 (2 15)	1.56 (1 60)	2.71 (1 9³)	0 00 (1.00)	5.78 (2.60)	2.60 (1.90)	7.48 (2 91)	12 86 (3.72)	0.00 (1 00)	9 20 (3 17)	7.72 (2 95)	18.82 (4.45)	30.25 (5.59)
Alkathene lined gunny bag	0.00 (1.00)	1.73 (1 65)	2.31 (1.82)	1.55 (1 60)	2.37 (1.84)	0.00 (1.00)	8 22 (3 04)	7 01 (2.83)	6.49 (2.74)	22.36 (4 83)	0.00 (1.00)	17.26 (4.27)	13 16 (3.76)	14 59 (3 95)	35.28 (6 02)
New gunny bag	5 24 (2.50)	3 70 (2.17)	4 23 (2.29)	0 90 (1.38)	5.22 (2.50)	9.04 (3.17)	9.94 (3 31)	46.91 (6.92)	44.19 (6.72)	23.85 (4.98)	15.23 (4.03)	17 49 (4.30)	53.95 (7 41)	52.33 (7.30)	44.78 (6.77)
Netted polythene bag	2 42 (1 85)	1 40 (1 55)	2 70 (1.92)	2.43 (1 85)	2.59 (1.90)	3.67 (2.16)	14.58 (3.95)	13.29 (3.78)	9 89 (3.30)	8 12 (3.02)	9.91 (3 30)	18.61 (4 43)	20.35 (4 62)	19 46 (4.52)	19.21 (4.50)
Reused gunny bag	1.84 (1 68)	1.94 (1.71)	1.78 (1.67)	8.05 (3.01)	7 59 (2 93)	29 41 (5 51)	51.06 (7.22)	105 95 (10 34)	46.30 (6.88)	42.67 (6.08)	37.39 (6.23)	56 30 (7 57)	113.80 (10 72)	96 07 (9.85)	58.57 (7.72)
Heap	29.39 (5 51)	79.33 (8.96)	52 92 (7.34)	8.08 (3.01)	5 13 (2.48)	13 70 (3.83)	3.05 (2.01)	19.20 (4.49)	14 70 (3.96)	25.00 (5.10)	58.82 (7.74)	90 81 (9 58)	95 67 (9.83)	52 02 (7 28)	77 92 (8.88)

	N. rufipes	*O. surinamensis*	Total population
CD at 5 per cent level	(1.57)	(2 46)	(2.45)

Figures in parentheses are transformed values $\sqrt{x+1}$

3.6.1.2. O. surinamensis

The population of O. surinamensis was generally higher than that of N. rufipes in all types of storage except in heap.

During second month, maximum population 29.4 was observed in reused gunny bag, which was significantly higher than numbers in other treatments (0 to 13.7). The same trend was seen upto fourth month. During fifth month, the population of O. surinamensis observed in reused gunny bag and new gunny bag were high and on par (46.3 and 44.2), while in other treatments the populations were low (6.5 to 14.7). In sixth month, higher population was noticed only in reused gunny bag (42.7), the range of population in other treatments was 8.1 to 25 only.

The range in population, during various periods in polythene sandwiched gunny bag, was 0 to 12.9 and alkathene lined gunny bag recorded a population of 0 to 22.4. In both the cases, the highest populations were recorded in fifth and sixth month and were significantly higher than the populations noticed during first month. Population of O. surinamensis recorded in new gunny bag was 9 to 46.9. It was low during second and third month (9 to 9.9) and significantly higher increase was noticed during fourth and fifth month (46.9 and 44.2)

and the population got reduced considerably during the sixth month (23.8). The population of O. surinamensis, recorded in netted polythene bag ranged from 3.7 to 14.6. Variations in populations during different periods were not statistically significant.

When compared with other treatments, higher population of O. surinamensis was recorded in reused gunny bags through out the period and the population ranged from 29.4 to 106. The range in population of O. surinamensis in copra, kept as heap was 3.1 to 25 during the period of six months.

3.6.1.3. Total population of insects

The different insects noticed during the period of experiment were N. rufipes, O. surinamensis, E. cautella, A. advena, L. serricorne, T. castaneum and A. fasciculatus.

During second month after treatment, significantly higher population of insects was recorded in heap (58.8), which was on par with the total population observed in reused gunny bag (37.4). Low populations of insects were noticed in other types of storage, with a range of 0 to 15.2. During third month, significantly higher populations of insects were recorded in heap (90.8), followed by in reused gunny bag (56.3), over other treatments in which the populations were on par and comparatively

low (9.2 to 18.6). During fourth and fifth month, significantly higher population of insects were recorded in reused gunny bag (113.8 and 96.1) which were on par with the populations observed in heap (95.7 and 52) and these were followed by populations recorded from new gunny bags (54 and 52.3). Populations recorded in the other treatments were low with a range of 7.7 to 20.4. During sixth month, significantly low populations were recorded in polythene sandwiched gunny bag, alkathene lined gunny bag and netted polythene bag (19.2 to 35.3) than the populations observed in heap (77.9), which came on par with other treatments.

The total population of insects observed in polythene sandwiched gunny bag varied from 0 to 30.3 in different periods and significantly high population was noticed during fifth and sixth month, when compared to the population in first month. The total population of insects recorded in alkathene lined gunny bag showed significant increase from third to sixth month. Copra stocked in new gunny bag recorded significantly higher population from fourth to sixth month. Significant variations were not seen in copra stored in netted polythene bag from second to sixth months. Higher populations of insects were recorded in reused gunny bags and in heap throughout the period and significantly higher

population were recorded during fourth and fifth months in reused gunny bag.

3.6.2. Extent of damage observed in different types of storage

3.6.2.1. Weight of copra consumed by insects in different treatments

Data relating to the experiment and the results of statistical analysis are presented in Table 23.

During second month, significantly higher damage was noted in copra stocked as heap and in copra stored in reused gunny bag than those in remaining treatments. In the case of copra stocked in polythene sandwiched gunny bag and alkathene lined gunny bag, there was no loss at all. When compared with the above treatments, the weight loss caused to copra stocked in new gunny bag and netted polythene bag was significantly higher and this trend continued upto the third month. However, from the fourth month onwards, all the treatments differed significantly and the treatments came in the following descending order of efficacy, polythene sandwiched gunny bag > alkathene lined gunny bag > netted polythene bag > new gunny bag reused gunny bag > heap.

Table 23. Extent of damage caused to copra kept under different types of storage.

Treatments	Mean per cent loss in copra (weight) in treatments over that of control observed at different intervals after storage (months).				
	2	3	4	5	6
Polythene sandwiched gunny bag	0.00 (1.00)	0.38 (1.18)	1.32 (1.52)	2.50 (1.87)	3.45 (2.11)
Alkathene lined gunny bag	0.00 (1.00)	1.59 (1.61)	2.53 (1.88)	3.33 (2.08)	4.40 (2.32)
New gunny bag	1.05 (1.43)	1.86 (1.67)	3.45 (2.11)	5.46 (2.54)	7.13 (2.85)
Netted polythene bag	0.65 (1.28)	1.15 (1.47)	2.26 (1.81)	3.85 (2.20)	4.79 (2.41)
Reused gunny bag	1.86 (1.69)	3.86 (2.21)	6.00 (2.65)	7.73 (2.96)	9.86 (3.30)
Heap	3.04 (2.01)	4.66 (2.38)	6.93 (2.82)	9.73 (3.28)	12.66 (3.70)

CD at 1 per cent level (0.23)

Figures in parentheses are transformed values, $\sqrt{x+1}$

3.6.2.2. Oil content of copra kept under different types of storage

The results of the experiment to workout the oil content of copra kept under different types of storage are shown in Table 24.

Significantly higher reduction in percentage of oil content was observed in copra stored as heap (1.62) over copra stocked in netted polythene bag, polythene sandwiched gunny bag or alkathene lined gunny bag during the second month.

From third to fifth months, copra stocked in heap and reused gunny bag suffered higher reduction in oil content and was significant (2.77 to 3.45 and 2.23 to 3.20).

During sixth month, the per cent reductions of oil extracted from copra stored in polythene sandwiched gunny bag, alkathene lined gunny bag, new gunny bag and netted polythene bag were significantly lower than that obtained from reused gunny bag which was on par with that obtained from heap.

Highest reduction in oil content in the copra stored for two months was seen in the case of heap storage but it was also on par with reused gunny bag and new gunny bag (0.84 to 1.62). The reduction in sample

Table 24. Oil content of copra kept under different types of storage.

Treatments	Mean per cent reduction in oil content of copra in treatments over that of control observed at different intervals after storage (months).				
	2	3	4	5	6
Polythene sandwiched gunny bag	0.53 (1.24)	1.07 (1.44)	1.97 (1.72)	2.44 (1.86)	3.29 (2.07)
Alkathene lined gunny bag	0.45 (1.20)	1.42 (1.55)	1.78 (1.67)	2.15 (1.77)	3.33 (2.08)
New gunny bag	0.84 (1.36)	1.67 (1.64)	2.30 (1.82)	2.66 (1.91)	3.04 (2.01)
Netted polythene bag	0.83 (1.35)	1.26 (1.51)	1.52 (1.59)	1.75 (1.66)	2.23 (1.80)
Reused gunny bag	1.22 (1.49)	2.23 (1.80)	2.86 (1.96)	3.20 (2.05)	4.91 (2.43)
Heap	1.62 (1.62)	2.77 (1.94)	2.71 (1.93)	3.45 (2.11)	4.18 (2.28)

CD at 1 per cent level (0.30)

Figures in parentheses are transformed values, $\sqrt{x+1}$

collected from polythene sandwiched gunny bag and alkathene lined gunny bag and netted polythene bag were on par. During the fourth month, the least reduction in oil content was observed in the copra stored in netted polythene bag and it came on par with polythene sandwiched gunny bag, alkathene lined gunny bag and new gunny bag, the percentage reduction being in the range of 1.52 to 2.3 only. In reused gunny bag and in heap, there were significantly higher reduction of oil, 2.86 and 2.71 per cent respectively. The same comparison was holding good upto sixth month after treatment.

3.6.2.3. Acid value of oil extracted from copra from different treatments

The results of the experiment are presented in Table 25. The acid values of oil extracted from copra under different types of storage ranged from 0.17 to 1.01 per cent during the second month after storage and the variations among the different treatments were not statistically significant. During the third month, least values were obtained in the oil obtained from copra stored in new gunny bags (0.41) and the alkathene lined gunny bag alone was significantly less effective in protecting the quality of oil (1.77). The remaining treatments came on par with new gunny bag. During

Table 25. Acid values of the oil obtained from copra kept under different types of storage.

Treatments	Mean increase in acid value of oil extracted from copra in treatments over that of control, observed at different periods after treatment (months).				
	2	3	4	5	6
Polythene sandwiched gunny bag	1.01 (1.42)	0.75 (1.32)	0.97 (1.40)	5.52 (2.55)	12.24 (3.64)
Alkathene lined gunny bag	0.81 (1.34)	1.77 (1.66)	1.91 (1.71)	1.98 (1.73)	4.78 (2.41)
New gunny bag	0.17 (1.08)	0.41 (1.19)	0.42 (1.19)	1.01 (1.42)	1.85 (1.69)
Netted polythene bag	0.68 (1.30)	1.29 (1.51)	1.36 (1.54)	1.22 (1.49)	2.35 (1.83)
Reused gunny bag	0.56 (1.25)	0.65 (1.28)	0.72 (1.31)	0.99 (1.41)	2.21 (1.79)
Heap	0.55 (1.24)	0.70 (1.31)	1.04 (1.43)	2.28 (1.81)	3.61 (2.15)

CD at 1 per cent level (0.44)

Figures in parentheses are transformed values, $\sqrt{x+1}$

fifth month, polythene sandwiched gunny bag alone was found less effective (5.52), while the remaining treatments were on par (0.99 to 2.28). During the sixth month, alkathene lined gunny bag (4.78) and polythene sandwiched gunny bag (12.24) were less effective than the other treatments (1.85 to 3.61).

3.6.2.4. Saponification value of oil extracted from copra from different treatments

The data pertaining to this experiment are given in Table 26.

The increase in saponification value ranged from 6.49 to 13.05, 5.47 to 7.38, 6.43 to 14.41, 9.14 to 21.57 and 8.24 to 37.33 in different treatments during the second, third, fourth, fifth and sixth month respectively after treatment. These variations were not found statistically significant.

3.6.2.5. Iodine value of oil extracted from copra from different treatments

The data and the results of statistical analysis of the same are presented in Table 27.

The increase in iodine value varied from 1.02 to 2.47, 1.21 to 2.67, 1.37 to 4.80, 1.39 to 4.99, 1.13 to 4.82 in the different treatments during the second,

Table 26. Saponification values of the oil obtained from copra kept under different types of storage.

Treatments	Mean increase in saponification value of oil extracted from copra in treatments over that of control, observed at different periods after treatment (months).				
	2	3	4	5	6
Polythene sandwiched gunny bag	10.56 (3.40)	5.47 (2.54)	13.98 (3.87)	17.78 (4.33)	37.33 (6.19)
Alkathene lined gunny bag	6.49 (2.74)	5.66 (2.58)	14.41 (3.93)	21.57 (4.75)	23.76 (4.98)
New gunny bag	7.22 (2.87)	7.38 (2.90)	10.56 (3.40)	11.81 (3.58)	8.24 (3.04)
Netted polythene bag	10.40 (3.38)	6.81 (2.79)	8.10 (3.02)	10.24 (3.35)	9.59 (3.25)
Reused gunny bag	13.05 (3.75)	6.59 (2.76)	6.43 (2.73)	12.50 (3.67)	14.27 (3.91)
Heap	9.25 (3.20)	5.52 (2.55)	6.93 (2.82)	9.14 (3.18)	19.39 (4.58)

CD at 5 per cent level NS

Figures in parentheses are transformed values, $\sqrt{x+1}$

Table 27. Iodine values of the oil obtained from copra kept under different types of storage.

Treatments	Mean increase in iodine value of oil extracted from copra in treatments over that of control, observed at different periods after treatments (months).				
	2	3	4	5	6
Polythene sandwiched gunny bag	1.79 (1.67)	2.42 (1.85)	4.80 (2.41)	4.99 (2.45)	4.82 (2.41)
Alkathene lined gunny bag	1.42 (1.56)	1.74 (1.65)	2.71 (1.93)	2.19 (1.79)	3.34 (2.08)
New gunny bag	1.30 (1.52)	2.20 (1.79)	1.86 (1.69)	3.29 (2.07)	3.22 (2.06)
Netted polythene bag	2.25 (1.80)	1.71 (1.65)	1.98 (1.73)	1.39 (1.55)	1.12 (1.46)
Reused gunny bag	1.02 (1.42)	1.21 (1.49)	1.37 (1.54)	2.21 (1.79)	2.10 (1.76)
Heap	2.47 (1.86)	2.67 (1.92)	3.10 (2.02)	3.31 (2.08)	4.26 (2.29)

CD at 5 per cent level NS

Figures in parentheses are transformed values, $\sqrt{x+1}$

third, fourth, fifth and sixth months respectively after treatment. These variations were not found statistically significant.

3.6.2.6. Colour of oil extracted from copra from different treatments

The details of colour of oil recorded from copra kept under different types of storage are presented in Table 28. In control, there was no change in red units and the yellow units increased from 0.1 in the first month to 0.9 during sixth month. Among treatments, maximum colour change was recorded in oil extracted from copra, kept in polythene sandwiched gunny bag (red 1 to 4 units, yellow pigments 4 to 20 units) and it was followed by heaps (red 0.4 to 3, yellow 3 to 11), alkathene lined gunny bag (red 0.6 to 2, yellow 2 to 7), netted polythene bag (red 0.3 to 2, yellow 0.5 to 5), reused gunny bag (red 0 to 0.9, yellow 0.2 to 5) and new gunny bag (red 0 to 0.9, yellow 0.3 to 3).

3.6.2.7. Odour of oil extracted from copra from different treatments

The odour of oil extracted from copra, kept under different types of storage are presented in Table 29. Oil extracted from copra in control, even after storage

Table 28. Colour of the oil obtained from copra kept under different types of storage

›atments	Colour of oil extracted from copra collected at different periods after treatment (months)				
	2	3	4	5	6
lythene sandwiched ıny bag	1.0 R + 4.0 Y	3.0 R + 5.0 Y	3.0 R + 7.0 Y	4.0 R + 14 Y	4.0 R + 20 Y
kathene lined ıny bag	0.6 R + 2.0 Y	0.8 R + 2.0 Y	1.0 R + 3.0 Y	2.0 R + 4.0 Y	2.0 R + 7.0 Y
w gunny g	0.0 R + 0.3 Y	0.0 R + 0.9 Y	0.0 R + 2.0 Y	0.5 R + 3.0 Y	0.9 R + 3.0 Y
tted polythene g	0.3 R + 0.5 Y	0.5 R + 1.0 Y	0.5 R + 2.0 Y	0.8 R + 4.0 Y	2.0 R + 5.0 Y
used gunny g	0.0 R + 0.2 Y	0.0 R + 0.8 Y	0.0 R + 3.0 Y	0.8 R + 4.0 Y	0.9 R + 5.0 Y
ap	0.4 R + 3.0 Y	0.4 R + 4.0 Y	1.0 R + 6.0 Y	1.0 R + 8.0 Y	3.0 R + 11 Y
ntrol	0.0 R + 0.1 Y	0.0 R + 0.1 Y	0.0 R + 0.2 Y	0.0 R + 0.4 Y	0.0 R + 0.9 Y

Table 29. Odour of the oil obtained from copra kept under different types of storage.

Treatments	Odour of oil extracted from copra collected at different periods after treatment (months).				
	2	3	4	5	6
Polythene sandwiched gunny bag	slightly rancid	rancid	rancid	highly rancid	highly rancid
Alkathene lined gunny bag	normal	slightly rancid	slightly rancid	slightly rancid	rancid
New gunny bag	normal	normal	slightly rancid	slightly rancid	slightly rancid
Netted polythene bag	normal	slightly rancid	slightly rancid	slightly rancid	rancid
Reused gunny bag	normal	normal	slightly rancid	slightly rancid	slightly rancid
Heap	slightly rancid	slightly rancid	rancid	rancid	highly rancid
Control	normal	normal	normal	normal	normal

of six months, had normal odour. Oil extracted from copra in polythene lined gunny bag had slight rancidity during the second month and full rancidity during the third and fourth month and high rancidity during fifth month onwards. In alkathene lined gunny bag and netted gunny bag, the oil extracted from copra in third to fifth months showed slight rancidity and at sixth month, the oil became fully rancid in both. In the case of new gunny bag and reused gunny bag , slight rancidity of oil commenced from fourth month onwards.

Oil extracted from copra in heaped up lot had slight rancidity from second to third month after storage, rancidity during fourth and fifth month and high rancidity at sixth month.

3.7.1. Relative toxicity of different insecticides to N. rufipes

Results of the probit analysis of the data obtained from the experiment are presented in Table 30. Among the insecticides, malathion was most toxic to the adults of N. rufipes and it was followed by phoxim, fenitrothion, chlorpyriphos, fenvalerate, carbaryl and lindane in the descending order. The relative toxicities of malathion, phoxim, fenitrothion, chlorpyriphos, fenvalerate and carbaryl at LD_{50} levels, taking lindane as standard (1.00) were 4.87, 4.61, 2.54, 2.07, 1.6 and 1.28 respectively.

Table 30. Relative toxicity of different insecticides to N. rufipes

Insecticides	Heterogenity	Regression equation	LD_{50}	Fiducial limits	Relative toxicity
Lindane	χ^2 = 1.4529	Y = 1.8557x + 2.7586	0.0161	0.0211 0.0115	1.00
Fenitrothion	χ^2 = 3.5078	Y = 2.0609x + 3.3452	0.0063	0.0081 0.0048	2.54
Malathion	χ^2 = 3.1873	Y = 2.0443x + 1.8931	0.0030	0.0042 0.0025	4.87
Fenvalerate	χ^2 = 1.8285	Y = 1.3220x + 3.6805	0.0099	0.0144 0.0062	1.60
Chlorpyriphos	χ^2 = 0.9032	Y = 1.6767x + 3.5073	0.0077	0.0103 0.0056	2.07
Carbaryl	χ^2 = 1.5514	Y = 1.5312x + 3.3174	0.0125	0.0176 0.0091	1.28
Phoxim	χ^2 = 2.5089	Y = 1.8047x + 2.2147	0.0034	0.0045 0.0026	4.61

3.7.2. Relative toxicity of different insecticides to O. surinamensis

The results of the probit analysis of the data relating to the experiment are presented in Table 31. Fenitrothion was most toxic to the adults of O. surinamensis and it was closely followed by malathion, phoxim, chlorpyriphos, fenvalerate, carbaryl and lindane in the descending order. The relative toxicities of fenitrothion, malathion, phoxim, chlorpyriphos, fenvalerate and carbaryl at LD_{50} level, taking lindane as standard (1.00) were 14.16, 13.64, 8.50, 5.11, 4.95 and 2.35 respectively.

3.7.3. Effect of treating gunny bags used for storing copra in godown on the incidence of different insect pests

The data relating to the experiment are presented in Table 32. All the treatments gave absolute protection of copra from the infestation by different insect pests upto third month and hence the data from the fourth month alone had been included in the Table

3.7.3.1. N. rufipes

The mean population of N. rufipes observed in control during the first three months ranged from

Table 31. Relative toxicity of different insecticides to O. surinamensis

Insecticides	Heterogenity	Regression equation	LD_{50}	Fiducial limits	Relative toxicity
Lindane	χ^2 = 0.6247	Y = 1.2989x + 3.0575	0.0312	0.0443 0.0233	1.00
Fenitrothion	χ^2 = 4.1363	Y = 2.0110x + 2.2965	0.0022	0.0027 0.0017	14.16
Malathion	χ^2 = 3.2138	Y = 1.6356x + 2.7749	0.0022	0.0029 0.0017	13.64
Fenvalerate	χ^2 = 3.9481	Y = 2.4166x + 3.0652	0.0063	0.0075 0.0052	4.95
Chlorpyriphos	χ^2 = 3.7526	Y = 1.8648x + 3.5329	0.0061	0.0077 0.0048	5.11
Carbaryl	χ^2 = 0.7442	Y = 1.7559x + 3.0279	0.0132	0.0168 0.0106	2.35
Phoxim	χ^2 = 2.3143	Y = 2.5767x + 0.9456	0.0037	0.0044 0.0031	8.50

Table 32 Effect of treating gunny bags used for storing copra in godown on the incidence of different insect pests

Insecticides		Mean number of insects observed in 1 kg sample																											
		N. rufipes in									*O. surinamensis* in									*A. fasciculatus* in									
		A - at months after treatment			B - at months after treatment			C - at months after treatment			A - at months after treatment			B - at months after treatment			C - at months after treatment			A - at months after treatment			B - at months after treatment			C - at months after treatment		
		4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
Malathion	0.1%	0.0	3.3	5.6	0.0	5.3	9.3	5.0	3.3	18.6	0.0	0.0	17.3	0.0	0.0	9.3	0.0	8.0	15.0	0.0	7.3	9.3	0.0	3.6	12.0	9.0	11.0	13.3
Malathion	0.2%	0.0	0.0	3.6	0.0	0.0	3.6	0.0	5.3	7.3	0.0	0.0	7.0	0.0	0.0	7.0	0.0	0.0	12.3	0.0	0.0	9.6	0.0	0.0	3.6	0.0	11.3	12.3
Malathion	0.4%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.3
Chlorpyriphos	0.25%	1.6	7.6	9.6	4.0	7.3	4.0	4.6	3.0	4.0	3.3	10.0	19.3	8.3	9.3	19.0	10.0	13.3	20.6	6.6	7.6	10.3	6.0	8.3	15.6	3.3	5.0	13.6
Chlorpyriphos	0.5%	0.0	0.0	4.6	0.0	3.6	3.3	0.0	3.3	4.3	0.0	0.0	5.0	0.0	2.6	10.3	0.0	2.3	9.0	0.0	0.0	4.0	0.0	10.3	10.0	0.0	3.3	11.6
Chlorpyriphos	1.0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.6
Fenitrothion	0.2%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	0.0	0.0	0.0	0.0	0.0	0.0	4.0	7.6
Fenitrothion	0.4%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6
Fenitrothion	0.8%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Control		5.6	7.6	8.6	5.6	7.6	8.6	5.6	7.6	8.6	37.3	41.0	68.6	37.3	41.0	68.6	37.3	41.0	68.6	15.0	15.6	12.6	15.0	15.6	12.6	15.0	15.6	12.6

A - Gunny bags sprayed after filling with copra
B - Gunny bags sprayed and dried before filling with copra
C - Spraying exposed surface of stacks of gunny bags filled with copra

Incidence of the pest was noticed in control from first month

3.3 to 8.0. From fourth month onwards infestation of *N. rufipes* was observed in treatments also. Malathion 0.1 per cent applied on gunnies after filling with copra, before filling with copra and in stack gave full protection upto 4, 4 and 3 months respectively and the incidence during the period of infestation ranged from 3.3 to 18.6. At the middle dose, the protection was upto 5, 5 and 4 months while at 0.4 per cent dose, the absolute protection observed were for 6, 6 and 5 months in the three types of treatments. The level of infestation ranged from 3.6 to 7.3 at the middle dose and it was four when treated at 0.4 per cent concentration.

With chlorpyriphos also at the dose of 0.25 per cent pest incidence was observed from fourth to sixth month under all types of treatments and the number ranged from 1.6 to 9.6 per kg sample. At the higher dose of 0.5 per cent, the incidence commenced at sixth month when gunny bags filled with copra were sprayed externally and during fifth and sixth month when copra was stored in pretreated bags and when the stack was treated respectively. At the highest doze of 1.0 per cent, the incidence was noted only when applied on stack and that too at the sixth month after storage only.

The doses of fenitrothion gave complete protection of copra from *N. rufipes* in samples sprayed after filling

and before filling with the produce and at highest dose in copra stacked and sprayed. At the lower two doses mean populations of 4.0 and 7.3 were observed during the sixth month after treatment.

The mean population of N. rufipes observed in control from fourth to sixth month ranged from 5.6 to 8.6.

3.7.3.2. O. surinamensis

In the control, mean populations of 7.0 to 68.6 were recorded from first to sixth month after treatment whereas all the treated samples showed complete protection from O. surinamensis upto third month. Malathion 0.1 per cent, applied on gunny bags after filling copra, before filling copra and in stack gave complete protection upto 5, 5 and 4 months respectively and the incidence of infestation ranged from 8 to 17.3. Malathion at 0.2 per cent gave complete protection upto five months in the three types of storage and the incidence of the pest ranged from 7 to 12.3. At the higher dose, the incidence of 10.3 was noted at sixth month after storage when applied on stack.

Chlorpyriphos at 0.25 per cent and 0.5 per cent, gave the incidence of O. surinamensis as that of N. rufipes in all types of treatments with the population ranging from 3.3 to 20.6 and 2.3 to 10.3 respectively. At the highest

dose of 1.0 per cent, the treatment gave complete protection of copra from O. surinamensis in all types of treatments.

The highest dose of fenitrothion gave complete protection of the produce in the three treatments and at two lower doses complete protection was observed in samples sprayed after filling and before filling the produce. When sprayed on stack the incidences of 9.6 and 10.0 insects were noted during the sixth month after treatment.

3.7.3.3. A. fasciculatus

The mean populations of 3 to 15.6 were recorded in control from first to sixth month after storage. From fourth month onwards, infestation of A. fasciculatus was observed in treatments also. Malathion at 0.1 per cent applied on gunny bags after filling copra, before filling copra and in stack gave complete protection upto 4, 4 and 3 months respectively, and the incidence during the period of infestation ranged from 3.6 to 13.3. Malathion at 0.2 per cent, the protection was upto 5, 5 and 4 months, while at 0.4 per cent dose, the absolute protection observed was for 6, 6 and 5 months under the three types of treatments. The incidence of infestation ranged from 3.6 to 12.3 at the middle dose and it was 9.3 when treated at the higher dose.

With chlorpyriphos at the dose of 0.25 per cent, pest incidence was noticed from fourth to sixth month under all types of treatment and the level of infestation ranged from 3.3 to 15.6. At the higher dose of 0.5 per cent, the incidence commenced at sixth month, when gunny bags filled with copra were sprayed externally and during fifth month, when copra was stored in pretreated bags and when the stack was treated. At the highest dose of 1.0 per cent, the incidence was noted only when applied on stack and that too only at the sixth month after storage.

The different doses of fenitrothion gave complete protection of copra from A. fasciculatus in bags sprayed after filling and before filling the produce and at the highest dose, in copra, stacked and sprayed. At the lower two doses, mean populations of 7.6 and 4.6 were observed during the sixth month after treatment.

3.7.4. Residues of insecticides in copra stored in gunny bags sprayed before filling copra and after filling copra

The data relating to the experiment are presented in Table 33.

The regression equations worked out for the estimation of malathion and fenitrothion were,

Table 33. Residues of insecticides in copra stored in treated gunny bags.

Insecticides	Dose	Residues (ppm) in samples drawn at different intervals (days) from					
		Gunny bags sprayed before filling with copra			Gunny bags sprayed after filling with copra		
		15	30	60	15	30	60
Malathion	0.1%	0.146	BDL	BDL	0.150	0.127	BDL
Malathion	0.2%	0.223	BDL	BDL	0.582	0.204	BDL
Malathion	0.4%	0.344	0.147	BDL	0.867	0.504	BDL
Fenitrothion	0.2%	0.367	0.135	BDL	0.474	0.213	BDL
Fenitrothion	0.4%	0.462	0.177	BDL	0.724	0.377	BDL
Fenitrothion	0.8%	0.795	0.304	BDL	0.867	0.390	0.096

BDL Below detectable level

Y = 0.0188x + 0.0095 and Y = 0.0236x + 0.01 respectively. The residues of malathion detected in copra collected at 15 days after treatment were 0.146, 0.223 and 0.344 ppm for the dosages of 0.1, 0.2 and 0.4 per cent respectively when applied on gunnies before the filling copra and the corresponding values for the treatment after filling with the copra were 0.150, 0.582 and 0.867 respectively. In the case of fenitrothion, the residues ranged from 0.367 to 0.795 in copra when sprayed on gunny bags before filling with copra and slightly higher residues were recorded in gunny bags sprayed after filling with copra (0.474 to 0.867).

Thirty days after application, the residues of malathion dessipated to non detectable levels at two lower doses and at higher dose and a low residue of 0.147 ppm was recorded in copra, when gunny bags were sprayed before filling with the copra. When gunny bags were sprayed after filling with the copra, residues of 0.127, 0.204 and 0.504 ppm were detected for the concentrations of 0.1, 0.2 and 0.4 per cent respectively.

In the case of fenitrothion, the residues ranged from 0.135 to 0.304 and 0.213 to 0.390 for different doses sprayed on gunnies before or after filling with the copra.

Sixty days after application, no residues of malathion or fenitrothion were detected except in the treatment with highest dose of fenitrothion and even the e, the residue was at a low level of 0.096 ppm only, in samples drawn from bags sprayed after filling with copra.

3.7.5. Control of the insect pests infesting copra with phosphine fumigation

The data relating to the experiment are presented in Table 34.

The mean percentage reductions in the emergence of N. rufipes adults from infested copra fumigated with 1.5 g/m^3 of aluminium phosphide were 41.98, 55.24 and 77.48 for exposure periods of 1, 2 and 3 days respectively. For getting 100 per cent suppression of adult emergence of N. rufipes, 3 g/m^3 aluminium phosphide had to be used with an exposure period of 2 days. At the highest dose of 4.5 g/m^3, 100 per cent suppression in adult emergence could be achieved with one day exposure period.

Similar trend was seen in the case of O. surinamensis also but for 100 per cent reduction in adult emergence, aluminium phosphide at 3 g/m^3 with one day exposure period was sufficient and for getting the same effect in A. fasciculatus, aluminium phosphide at 4.5 g/m^3 with one day exposure period was required.

Table 34. Control of the insect pests infesting copra with phosphine fumigations using varying doses of the insecticide and under different exposure periods.

Treatments	Dose (g/m^3)	Exposure period (days)	Mean per cent reduction in the number of adults emerging in treatments over that of control			Residue (ppm)
			N. rufipes	*O. surinamensis*	*A. fasciculatus*	
Aluminium phosphide	1.5	1	41.98	84.04	61.07	BDL
Aluminium phosphide	1.5	2	55.24	89.63	71.18	BDL
Aluminium phosphide	1.5	3	77.48	94.38	78.67	BDL
Aluminium phosphide	3.0	1	87.10	100.00	83.57	BDL
Aluminium phosphide	3.0	2	100.00	100.00	91.43	BDL
Aluminium phosphide	3.0	3	100.00	100.00	97.61	BDL
Aluminium phosphide	4.5	1	100.00	100.00	100.00	0.0003
Aluminium phosphide	4.5	2	100.00	100.00	100.00	0.0024
Aluminium phosphide	4.5	3	100.00	100.00	100.00	0.0038

3.7.6. Residues of aluminium phosphide in treated copra

For estimating the residues of aluminium phosphide in treated copra, the regression equation arrived at was $Y = (0.15674x + 0.02296) \times 1.097$. The residues of phosphine at dosages of 1.5 and 3.0 g/m^3 and for all the three exposure periods were below detectable levels. The residues of phosphine at a dosage of 4.5 g/m^3 were 0.0003, 0.0024 and 0.0038 ppm for the exposure periods of 1, 2 and 3 days. The residues observed were within the tolerance limit of 0.01 ppm.

DISCUSSION

4. DISCUSSION

4.1. Survey on the insect pests of copra in the Southern Districts of Kerala

The detailed survey done, for the first time in the state, revealed that copra is not infested by insects at the processing centres or in small oil mills where the commodity is usually stored for periods not exceeding a month. Around 21 per cent of the copra produced in the State is now being sent to other states in the country for direct consumption and this copra is stocked and transported after fumigation with sulphur dioxide. Such stocks in godowns and in transit were found completely free from insect attack. Copra used for extraction of oil is not treated with sulphur dioxide since this treatment is believed to affect the flavour of the oil. In medium and large oil mills and godowns, where stock is held throughout the year, insects cause significant damage. The extent of damage was observed to be high in copra stored for periods exceeding five months. Insects have not yet been recognised as severe pests of copra in the state, probably because of the restricted prevalence of the menace. The only report available on the pests of stored copra from Kerala was that of Mathen (1961) in which he had listed eight important pests and it was not even

mentioned whether he had recorded these insects from the State. No further attempts were made to study this problem during the past three decades. However, the formation of the National Agricultural Co-operative Marketing Federation and the policy decision of the Government to purchase and stock copra during the peak production period for stabilising the price structure of the commodity will necessitate prolonged storage and obviously the insect menace is bound to assume new proportions in due course. A detailed assessment of the potential of this problem and the evolution of suitable prophylactic and curative methods of control against the pests will be vital in this context and hence these investigations.

The periodic survey done in the Southern Districts of Kerala over a period of two years revealed that the commodity was infested by four major pests, N. rufipes, O. surinamensis, L. serricorne and A. advena. Low populations of E. cautella, A. fasciculatus and T. castaneum were also seen. As observed by earlier workers (Menon and Pandalai, 1958; Mathen, 1961; Child, 1974) none of these insects was specific to copra and the presence of these pests were presumed to be due to the unscientific preparation of copra and the unhygienic conditions of the stores (Child, 1974). But the present studies revealed that even the copra dried to the required levels of

moisture (6 per cent and below) and well preserved (in gunnies or heap) were found infested and the insects had to be considered as the primary pests of the commodity (para 3.1.). The pests were seen more destructive to copra than to other commodities. As described under results, the immature stages of N. rufipes and the larvae and adults of O. surinamensis and A. advena were found tunnelling and feeding the endosperm below the testa, rendering the detection of the infestation difficult in observation. L. serricorne also lived in such tunnels but the entry holes were seen prominently on the surface of copra. The usual process of cleaning done before the crushing of copra did not remove the life stages of the pests and faecal matter within the tunnels, thus affect the quantity and quality of the oil extracted from the infested commodity. In severe infestation, the quality of oil cake obtained from the copra also was seen adversely affected.

The behaviour of the adults of N. rufipes render them a menace in the millsalso. These free living insects rest in large numbers on the gunnies, searching for the immature stages of insects which emerge from eggs laid in the store and on gunnies by them and other insects, and voraciously feed on them. As shown later in this investigation (para 3.4.3), this predation prolongs the life of

the insects remarkably. They also congregate on the oily surface of the containers used for keeping oil and even move into the containers if kept open. Those insects trapped in the oil die and contaminate the product often leading to the rejection of the material at destination. Besides, the beetles which invade every nook and corner of the mills, nearby houses including the kitchen and contaminating all materials, especially the fried food articles become a serious nuisance to the workers and nearby inhabitants. The annoyance caused by N. rufipes has been observed by earlier workers too (Rai and Singh, 1977).

T. castaneum reported as a pest of copra (Menon and Pandalai, 1958; Mathen, 1961; Child, 1974 and Peter, 1974) was found only as a harmless insect on copra. The population of the insect was very low. The immature stages were not observed inside copra. The large population of the predator of this insect (Nalinakumari and Mohandas, 1987) might have contributed significantly in checking the population of T. castaneum in godowns.

The distribution of the above pests in the area covered in the survey (para 3.2.1. to 3.2.5) also showed wide variations. While N. rufipes and O. surinamensis were the serious pests in Asramom and Attingal, N. rufipes alone assumed pest status at Shertallai. Among these pests,

O. surinamensis was more predominent at Asramom and Attingal. At Karamana, Nedumangad and Sreekaryam, the two pests were observed in low population only. This might be due to the shorter duration of continuous stocking of copra in these locations.

A. advena and L. serricorne, the predominent insects observed at Nedumangad, were not seen as pests at other locations. The nature of other commodities stocked in the godowns, climatic factors, and other details observed in the survey could not fully explain the cause of this variation in the occurrence of the different pests. The copra arriving in the godown of Nedumangad contained low grade lots processed from slightly immature nuts and they were occasionally found infected by fungus. A. advena has been reported as a fungus feeder (Onyearu, 1967 and Hill, 1978), probably the above type of copra might be more conducive for the breeding of the pest.

Another interesting observation made in the present investigation was that all the insects were breeding on copra only during June to October (Fig.1). During the remaining period, the immature stages were not seen in copra and the population of adults was also low. While studying the biology of O. surinamensis and N. rufipes in the laboratory also, the pest failed to develop during January to May and November to December.

The correlation studies revealed that the moisture content of the copra held in stock and the variations in the populations of the insects were significantly and positively correlated in most of the locations. The association with different climatic factors observed at different locations showed an erratic trend. Such detailed studies on the distribution and development of insects infesting copra were being done for the first time.

4.2. Extent of damage caused by *N. rufipes* and *O. surinamensis* to copra and the influence of the fungus, *A. flavus* on the incidence of the pests and extent of damage

The extent of damage caused by the predominent pests of copra in Kerala was precisely assessed in the laboratory, since it was not possible to estimate the same directly from the survey. It has been observed by earlier authors that the incidence of the pest was usually on copra processed from immature nuts and containing high moisture content and often infected by the fungus (Thampan, 1982). But in the survey the pest as well as its damage was observed in godowns stocking good quality copra which were dried to the moisture levels ranging from 3.7 to 6.4 (vide appendix I), thus indicating that the commodity is directly susceptible to insect attack and the incidence of mould is not a predisposing factor for insect attack.

In the laboratory study, A. flavus was chosen as the test fungus, since it was reported as the most injurious fungal pathogen occurring in Kerala on stored copra (Subramanian, 1965; Paul, 1969 and Philip, 1978).

The results presented in para 3.3.1. revealed positively that good quality copra containing eight per cent moisture suffered significant damage by the feeding of N. rufipes. The extent of damage caused by a population of 100 insects/200 g weight of copra reached 7.2 per cent by the end of third month after storage and 12.2 per cent by the end of sixth month. Thus the pest was observed as a serious one with high potential for damaging copra. The apparent stagnation observed between the third and fourth and fifth and sixth months might be due to the nonavailability of larval stages synchronising with the biology of the pest. The results also showed that the presence of the fungus was not a pre-requisite for pest attack and the existence of the fungus did not favourably influence the extent of damage caused by the insect. A. flavus had in fact a negative influence on the extent of damage caused by the insect. The extent of damage was reduced to the level by 50 per cent when combined with the fungus. The trend in the increase in damage between months indicated that when combined with the fungus, the breeding of the pest was also negatively affected, since a sharp increase

in the loss of copra between successive months, indicating the emergence of new larvae occurred only once during the period of six months when the observations were made. Thus A. flavus was found to be adversely affecting growth and multiplication of N. rufipes. Similar adverse influence of the fungal pathogens in storage pests, particularly the beetles have been reported earlier also (Wright and Burrough, 1983 and Gupta and Khare, 1985).

The extent of direct damage done to copra by O. surinamensis was observed to be three per cent only, even after a period of six months of storage. The results indicated that the pest to be less destructive. But, subsequent experiments in which the damages caused by the two insects had been compared (para 3.5.1), showed that O. surinamensis was as destructive as N. rufipes. The lesser damage observed with O. surinamensis might have been the result of the unfavourable level of moisture (eight per cent) of the copra used in the experiment. Later studies revealed that the pest was not building up properly under this moisture level. In the experiment (vide para 3.5.9), copra with a high level of moisture had to be chosen since the study of the influence of A. flavus on the extent of damage caused by the pest also was included among the objectives and the fungus was not thriving at moisture levels below eight per cent.

The results of the experiment also revealed that the infection of the fungus, A. flavus adversely affected the oil content of the copra and the incidence of the pests along with the fungus did not alter the effect either favourably or adversely (para 3.5.2.). The insect attack did not reduce the oil content significantly upto the end of fifth month after storage while at sixth month the oil content in the treatment also got significantly reduced over control. The oil extracted from copra infested by insects developed rancidity slightly faster than in the oil obtained from control. However, the adverse effect caused by the fungus was not influenced by the presence of the insects.

As shown in Fig.2 and described in para 3.5.3. to 3.5.6., the quality of oil extracted from copra infested by the insects, N. rufipes and O. surinamensis, was seen adversely affected in terms of the acid value, saponification value and iodine value and pigmentation after a prolonged storage of five to six months only and it was to a slight extent only. The presence of the insects preceding or succeeding the infection of the fungus did not significantly alter the adverse effect on the quality of oil caused by the infection of copra by A. flavus.

The results of the experiments proved conclusively that the common pests of copra, N. rufipes and

Fig. 2. The extent of damage caused by insect pests and A. flavus independently and in combination, to stored copra and the effect of damage on the quantity and quality of oil (observed at sixth month after storage).

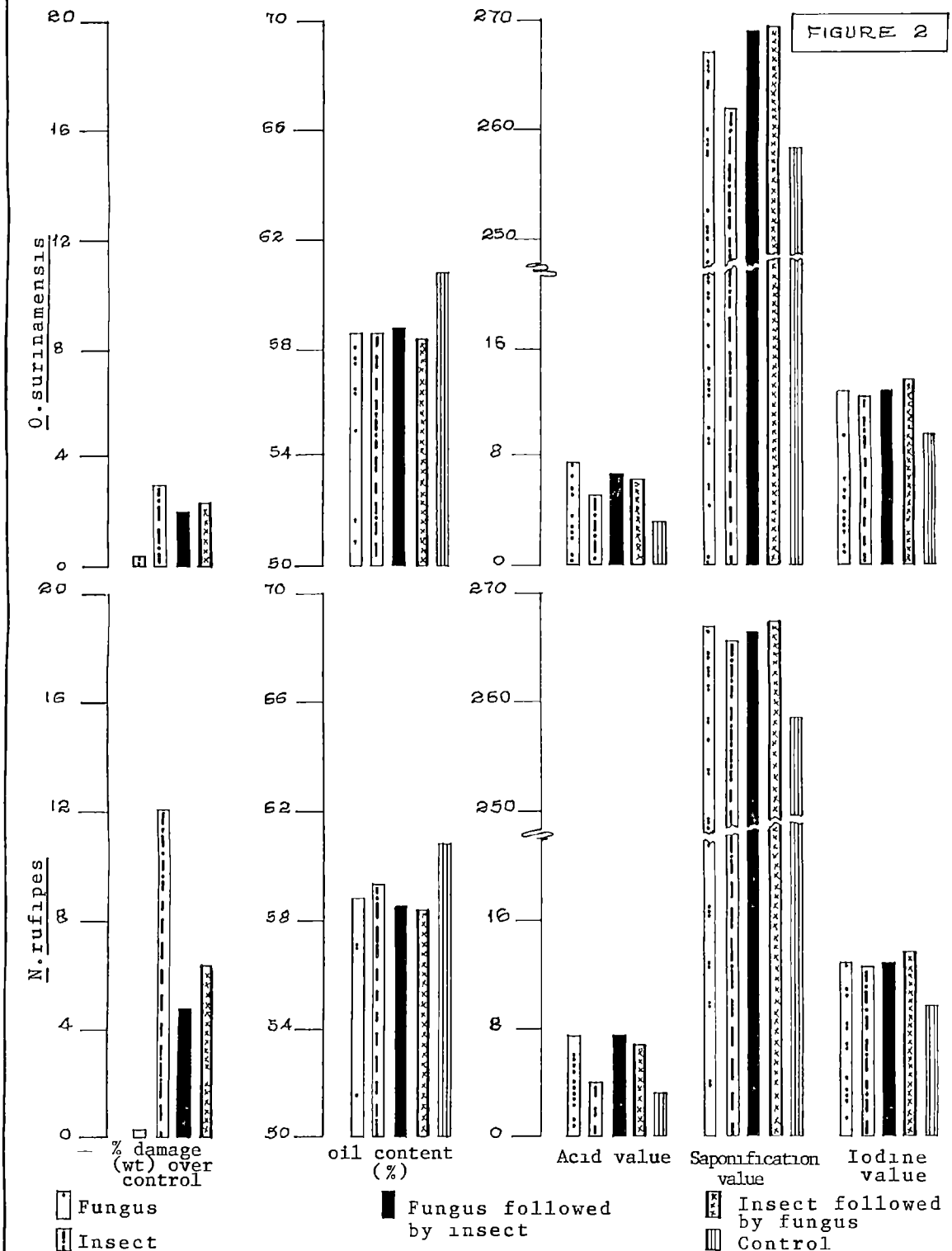


FIGURE 2
O. surinamensis
N. rufipes
% damage (wt) over control
oil content (%)
Acid value
Saponification value
Iodine value
Fungus
Insect
Fungus followed by insect
Insect followed by fungus
Control

O. surinamensis can cause significant loss to copra by direct feeding. The oil content of the copra infested by pest and its quality may be adversely affected, if the incidence persisted for prolonged periods. The adverse effect caused by A. flavus to the quantity and quality of oil was not altered by the presence of insects.

If the results of the study is protracted to the data gathered in the survey, it can be inferred that the commodity is now suffering significant loss in storage due to insect attack, though the malady now goes unnoticed, probably due to the inconspicuous nature of damages caused by the pests. Though the populations of the individual species of insects noted at different locations were lower than those used in the experiment, the collective numbers of different species observed during the peak seasons would be close to those levels and hence the probable loss caused by the insect infestation may be guessed to be in the range of five to seven per cent within three months after storage and 10 to 15 per cent after prolonged storage of five to six months.

4.3. Relative susceptibility of copra obtained from different varieties of coconut to the insect pests

The kernel of different varieties of coconut is known to show wide variations in physical characteristics,

chemical composition and oil content. The copra processed from the kernel is hence bound to show variations in facilitating the entry of the insect pests and in meeting the nutritional requirements of different species of insects. The extent of damage caused by N. rufipes and O. surinamensis on copra obtained from different varieties of coconut and the population build up of the above pests on the same was studied with a view to recommending the avoidance of prolonged storage of susceptible varieties, if any.

It could be concluded from the data presented in para 3.4.1 that the extent of direct loss caused by N. rufipes and O. surinamensis to copra obtained from different varieties of coconut did not show statistically significant variations. Though, the oil content of the copra processed from different varieties when infested by the two insects showed variations, these variations were not statistically significant. The onset of significant loss in stored copra due to the feeding of the two insects also showed variations among the products processed from different varieties of coconut. But the relative suitability of the varieties for prolonged storage with reference to pest infestation was not evident due to the inconsistency in the extent of damage and in the variations in population build observed in different varieties.

The development of the insects in different varieties showed some general trends (Fig.3). The growth indices indicating the suitability of the different varieties for insect multiplication showed that LM and LO were more favourable varieties for the multiplication of N. rufipes. These were followed by the hybrids and WCT. The dwarf varieties, CDO and CDG as well as GB were less favoured. The high growth indices in copra processed from LO and LM was contributed by the short larval and pupal durations and high percentage of adult emergence. The longevity of the adults of N. rufipes emerging from LM and LO and their fecundity were also high. But the varieties which had low growth indices did not show such consistency with reference to their longevity of the adults and their fecundity. Among the varieties chosen LO and LM had the highest oil content (72 to 75 per cent) compared to the remaining varieties (66 to 68 per cent). This factor might have contributed to the higher growth indices of N. rufipes breeding on the varieties. The copra obtained from dwarf varieties of coconut was reported to be softer with a high proportion of wrinkled, distorted and rubbery copra (Thampan, 1982) and this might have rendered the same less suitable for the multiplication of N. rufipes.

The growth indices of O. surinamensis in copra obtained from varieties LO and LM were the least. This was caused by the low percentage of adult emergence and

Fig. 3. The development of *O. surinamensis* and *N. rufipes* in copra obtained from different varieties/cultivars of coconut.

O.surinamensis
N.rufipes
Growth index
Fecundity
Adult longevity
D x T
L M
G B
T x D
C D O
W C T
L O
T x G
C D G

longer larval and pupal duration in LO and in LM, it was largely due to the low percentage of adult emergence. The dwarf varieties and GB which were less favourable to N. rufipes were found more suitable for the multiplication of O. surinamensis. The most favoured varieties were DxT and TxD. Thus, the response of the two insects to the variations in the quality of copra obtained from different varieties of coconut appear to be different. This might be due to the varying nutritional requirements of the two species of insects.

Another interesting observation in the course of the study was the two to six fold increase in the longevity of the adults of N. rufipes when they were provided with their own immature stages for feeding along with copra. The larvae found out of the galleries were immediately seized by the adults remaining in the vicinity and they sucked the predigested body content of the larva and threw away the cuticle. The first instar larvae emerging from the eggs laid on the gunnies and other hidden sites of the godown could be seen running and hiding in debris before gaining access to the copra to escape from predation by the adult beetles. This cannibalistic nature of the beetle had been mentioned by the earlier workers too (Simmons and Ellington, 1925).

4.4. Relative susceptibility of copra containing various levels of moisture to *N. rufipes* and *O. surinamensis*

It is well known that keeping qualities of copra depended on its moisture content. Bacterial action of copra occurs on coconut meat containing 20 per cent or more of moisture. The infection of different species of fungi were reported to be closely related to the moisture regimes (Philip, 1978 and Thampan, 1982). The insects were in general believed to invade the copra of low quality infected by the bacteria and fungi. Further in the survey conducted, as a part of this investigation, revealed that the extent of damage caused by the pests in Kerala was significantly associated with the variations in the moisture content of the samples of copra collected. In this context, the influences of three different levels of moisture, within the range observed in the survey, on the loss caused by the important pests of copra and on the population build up of the pests were studied.

The results presented in para 3.5.1. clearly showed that one month after storage significant variations were not seen in the extent of damage caused by *N. rufipes*. In subsequent observations, damage at eight per cent moisture was significantly higher and those at four and six per cent were on par. This was so upto five months after storage and at sixth month, six per cent moisture level was preferable to the pest over four per cent moisture level.

The damage caused by O. surinamensis was the highest at six per cent moisture level and it was followed by the damages at four and eight per cent moisture levels in succession.

With reference to the oil content of copra infested by N. rufipes upto fifth month after storage, significant variations were not observed. At sixth month, maximum reduction was at eight per cent moisture level, while six and four per cent moisture levels were on par.

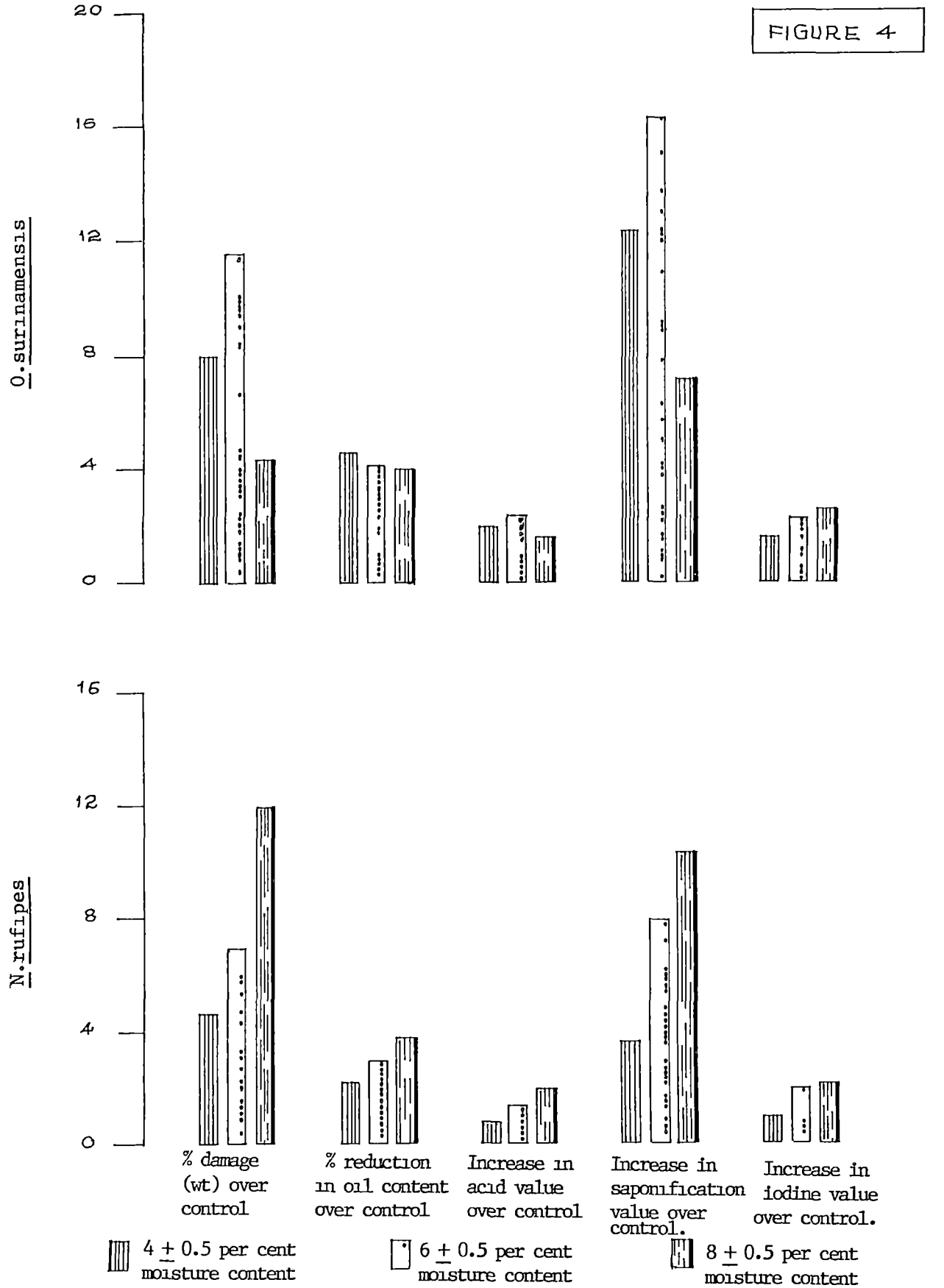
At six per cent moisture level, significant reduction in oil content was noticed from second month, while at four and eight per cent moisture levels such reduction was observed from fifth month onwards. The results thus indicated that the lower moisture content had to be preferred for minimising the loss in oil content.

The effect of the variations in the moisture content of copra was not seen reflected in the loss in oil yield caused by O. surinamensis.

Data presented in para 3.5.3, 3.5.4. and 3.5.5. and the Fig.4 showed that the quality of oil as indicated by acid value, saponification value and iodine value did not show variations in treatments under different levels of moisture upto three months after storage. The oil obtained from copra containing moisture levels favoured by the

Fig. 4. The extent of damage caused by O. surinamensis and N. rufipes to stored copra containing varying levels of moisture and the effect of damage on the quantity and quality of oil (observed at sixth month after storage).

FIGURE 4

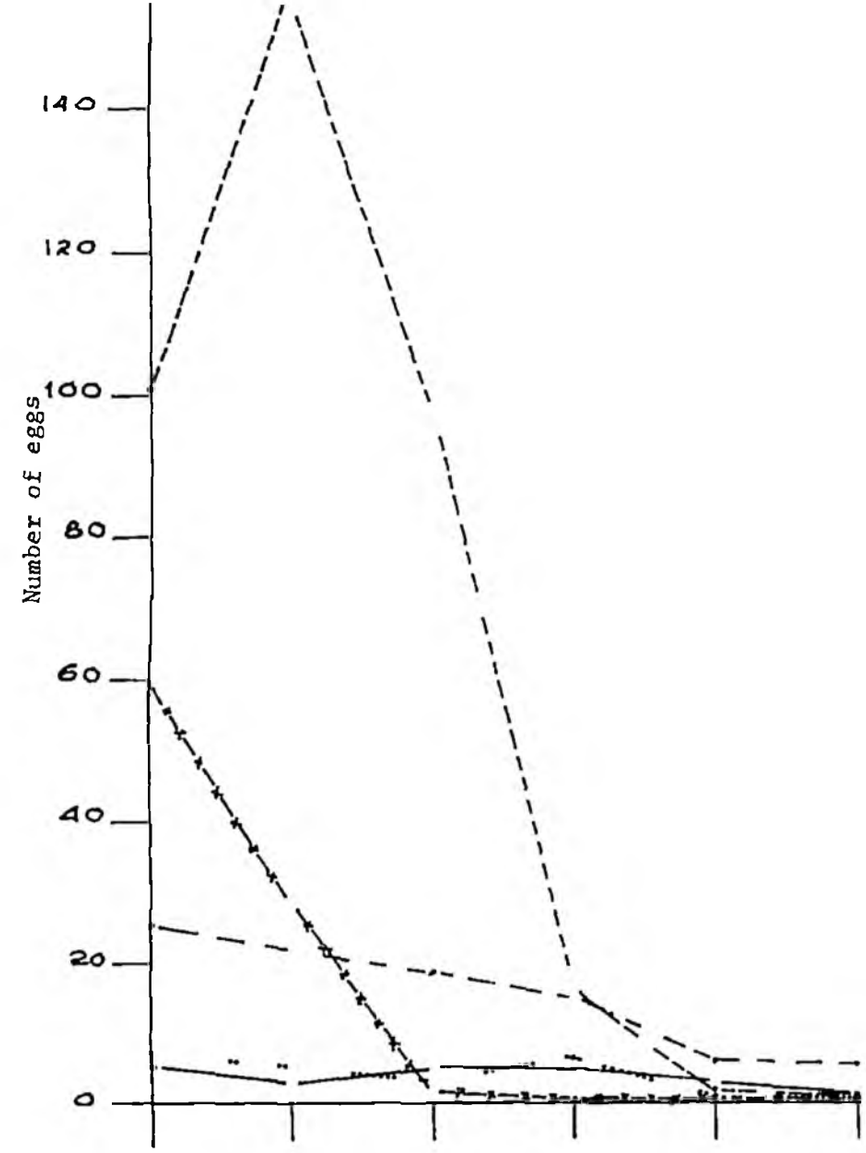

O. surinamensis
20
16
12
8
4
0
N. rufipes
16
12
8
4
0
% damage (wt) over control
% reduction in oil content over control
Increase in acid value over control
Increase in saponification value over control.
Increase in iodine value over control.
4 ± 0.5 per cent moisture content
6 ± 0.5 per cent moisture content
8 ± 0.5 per cent moisture content

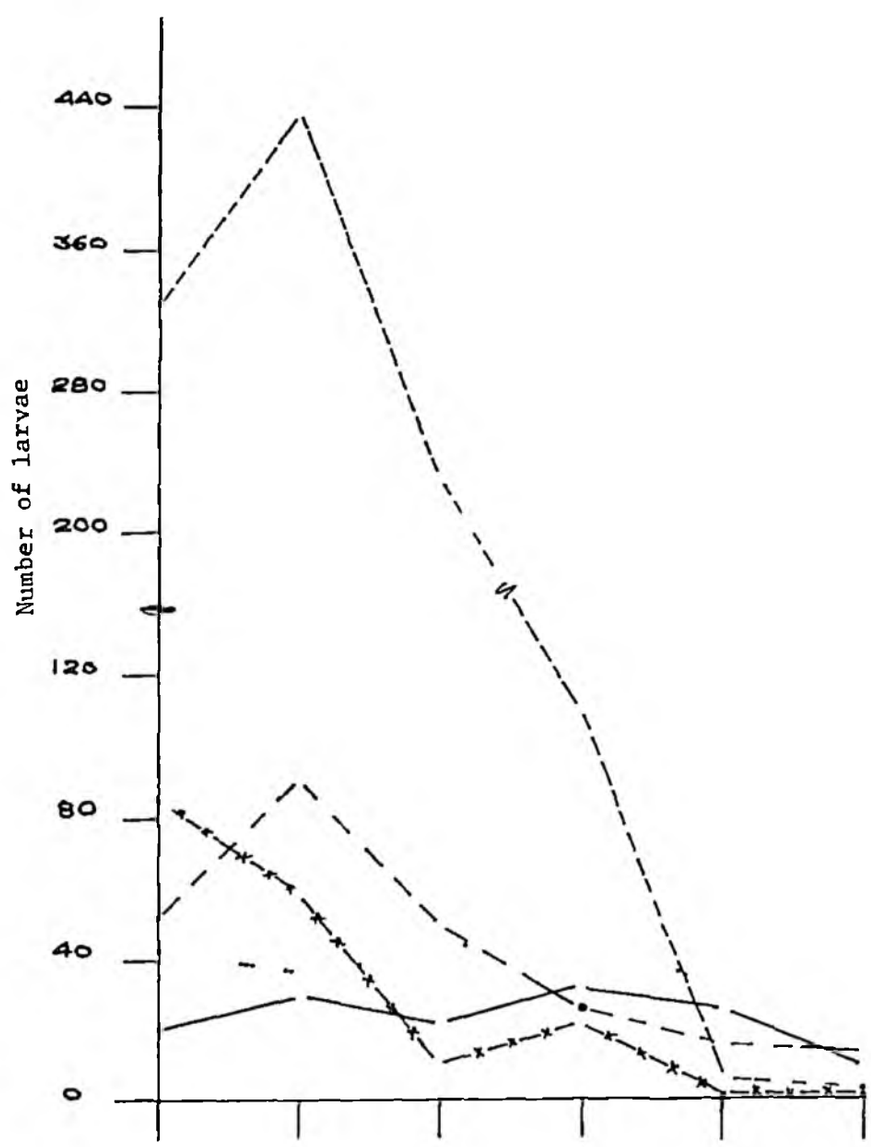
insects, (around eight per cent for N. rufipes and six per cent for O. surinamensis) showed higher acid values and saponification values. In the case of N. rufipes, iodine value also was high at eight per cent moisture, while significant variations were lacking in the case of O. surinamensis. Significant differences were not seen in the pigmentation of oil obtained from different treatments. The oil from copra containing six and eight per cent moisture exposed to N. rufipes became slightly rancid at two months after storage, while in the less favoured moisture level of four per cent, the oil was retaining normal smell. Similar trend was not seen with O. surinamensis. The results indicated an added loss to the commodity when stored at higher moisture level due to the deterioration in quality of oil in the case of N. rufipes. A similar trend was noted at six per cent and four per cent moisture levels in the case of O. surinamensis.

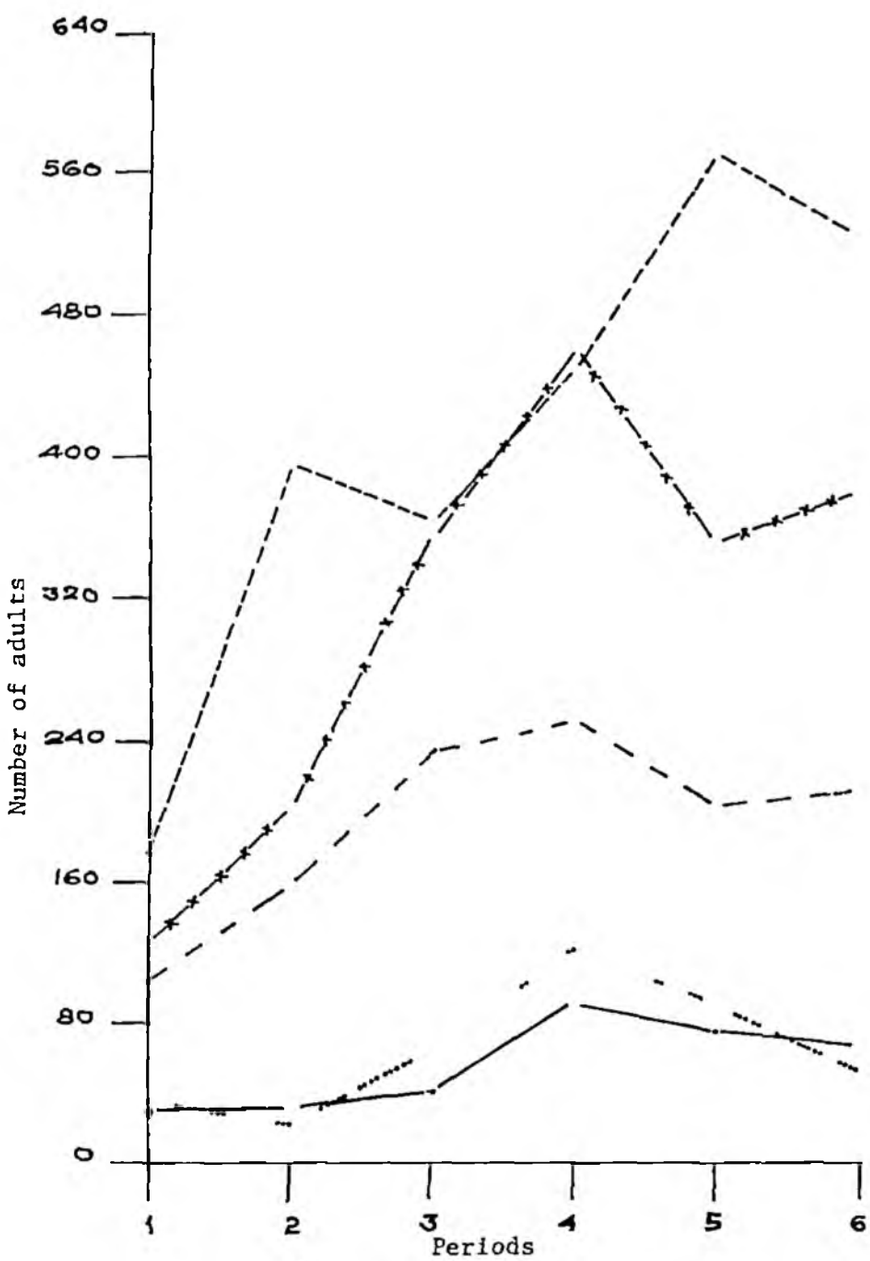
4.4.1. Development of N. rufipes and O. surinamensis in copra having varying levels of moisture content

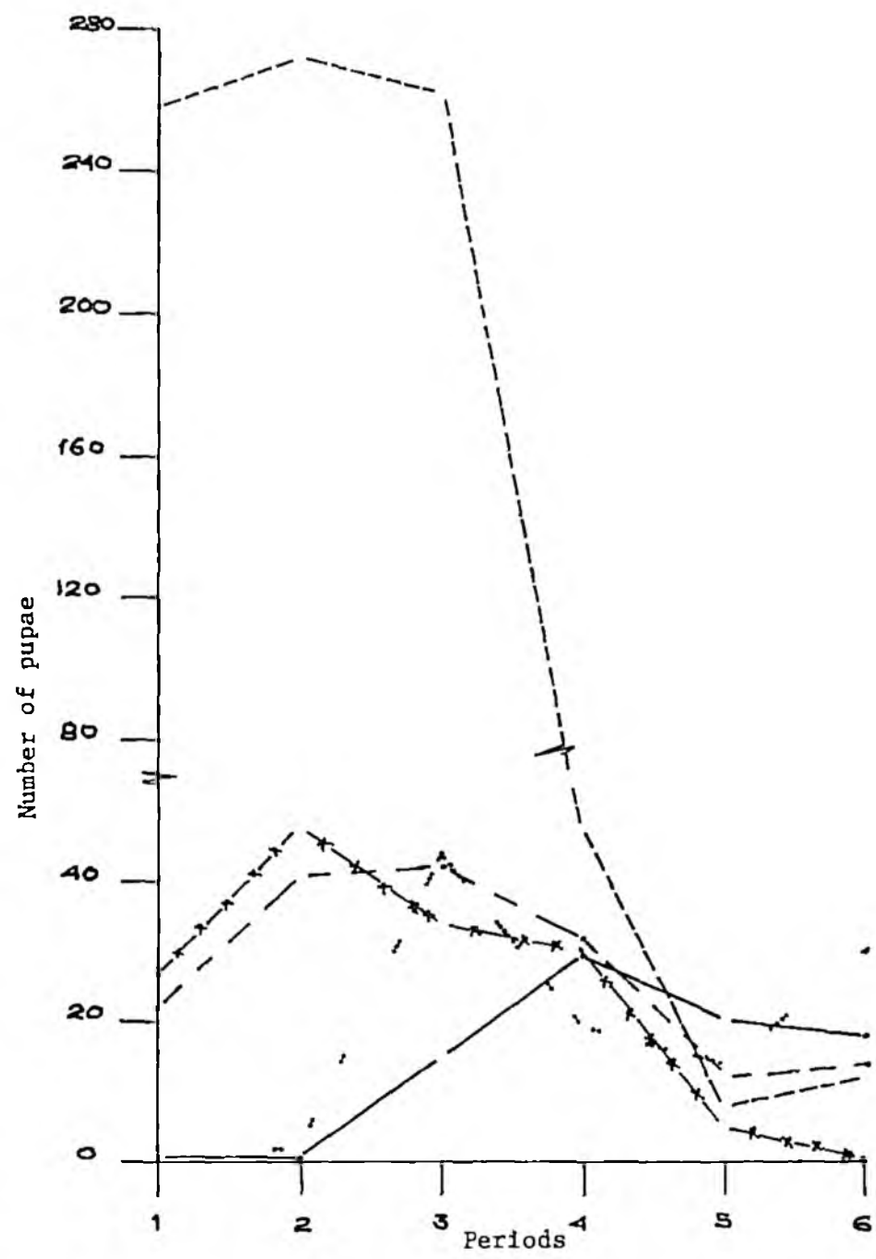
The results presented in para 3.5.8. and 3.5.9. and Fig.5 showed that N. rufipes preferred higher levels of moisture for breeding. The development of immature stages was totally arrested at four per cent moisture level. The number of eggs, larvae and pupae observed

Fig. 5. The development of O. surinamensis and N. rufipes in copra containing different levels of moisture.









N rufipes at 6 ± 0 5% moisture

O surinamensis at 4 ± 0 5% moisture

O surinamensis at 6 ± 0 5% moisture

O surinamensis

over a period of six months showed significant variations. The preferences seen for six or eight per cent moisture levels were not consistent. The number of adults was at the higher level during the third and fourth month after storage and in subsequent months the population showed a general decline. During peak period, the number of life stages observed at eight per cent moisture level was higher than that at six per cent moisture level.

The number of eggs laid by O. surinamensis were significantly higher at a moisture range around six per cent during the peak period of multiplication and the larvae, pupae and adults also showed the same preference and the other two treatments were on par. Response to moisture fluctuations was more conspicuously seen in O. surinamensis than in N. rufipes (Fig.5). The favourable ranges of moisture reported for S. oryzae were 13.5 to 17.6 per cent (Reddy, 1950) and 12 per cent for N. rufipes (Koslapova, 1970). Reddy noted that S. oryzae failed to lay eggs at 7.4 per cent moisture level. The preferred ranges of moisture for the multiplication of N. rufipes and O. surinamensis on copra was studied for the first time. The preferred moisture regime was in general, far below the ranges recorded for pests in other commodities. Usually, copra is stored with moisture levels ranging from four to seven per cent and the suitability

of the low ranges for the multiplication of the two species of insects is perhaps an example of ecological adaptation. The undesirability of eight per cent moisture level for the survival of O. surinamensis was indicated in the experiment set up for assessing the extent of damage caused by the insect also (vide para 3.5.1). The extent of damages caused by O. surinamensis was found to be around half the loss caused by N. rufipes, while in the survey and in the other experiments the damage potential of the two pests were seen on par and O. surinamensis even appeared to be a more serious pest to copra in some situations. Thus the moisture content of the copra appeared to be an important factor in limiting the population build up of the two insects, but the usual ranges of moisture found in the copra stocked in Kerala were not detrimental to either of the two insects. When higher ranges of moisture were preferred by N. rufipes, the lower ranges were more preferred by O. surinamensis and hence by regulating the moisture content of copra stored in godowns, it will not be possible to keep the stock free from insect pests.

4.5. Effect of different types of storage on the incidence of pests in copra and on the extent of damage caused to the commodity

The data presented in para 3.6.1.1. and para 3.6.1.2. showed that the incidence of N. rufipes and O. surinamensis

as well as other pests showed significant variations in different types of storage. The higher incidence of N. rufipes was observed in heap storage and in later periods of storage, in reused gunny bags. With new gunny bags, the highest infestation was found during the sixth month after storage. These observations indicated that the insect have a tendency to avoid boring into the gunnies for getting access to the copra.

In the case of O. surinamensis, population levels were high in the resued gunny bags during the second month after storage and during the third and fourth month also the position remained unchanged. For new gunnies also, the population showed an increase, during the fourth month and by the fifth month, the population came on par with that of reused gunnies. An interesting observation was that the incidence of O. surinamensis was low in heaps of copra during the entire period of observation.

With reference to the other insect pests (E. cautella, A. advena, L. serricorne, T. castaneum and A. fasciculatus) which contributed to the total insect population in different types of storages also, the highest incidence was observed in resued gunny bags and it was followed by the heap storage. In new gunnies, the pest was building up from the fourth month onwards. In polythene and alkathene lined gunnies the stock remained

free of insects for two months, while netted polythene gunnies showed incidence of insects during the second month. In subsequent months, there was an increase in the populations of O. surinamensis and insects other than N. rufipes, thus indicating that the pests could bite through the linings. Further, in these bags condensation of water within the linings and subsequent development of moulds were also observed in the later periods of storage. Hence, the storing of copra in lined gunny bags can be recommended as a sure method for excluding insect pests upto a period of five months.

The results in general revealed that avoidance of keeping copra in heaps will reduce the incidence of N. rufipes and when stored in gunnies, the population of this pest get significantly restricted. The main source of infestation by O. surinamensis and other pests of copra was observed to be through the gunnies which were being regularly reused for storing copra. This fact has been indicated by earlier workers also (Laborius et al., 1980). It can be concluded that the regular cleaning and fumigation of these gunnies or treating the gunnies with suitable pesticides will restrict the incidence of insect pests and consequent damages in copra (Rai and Singh, 1977).

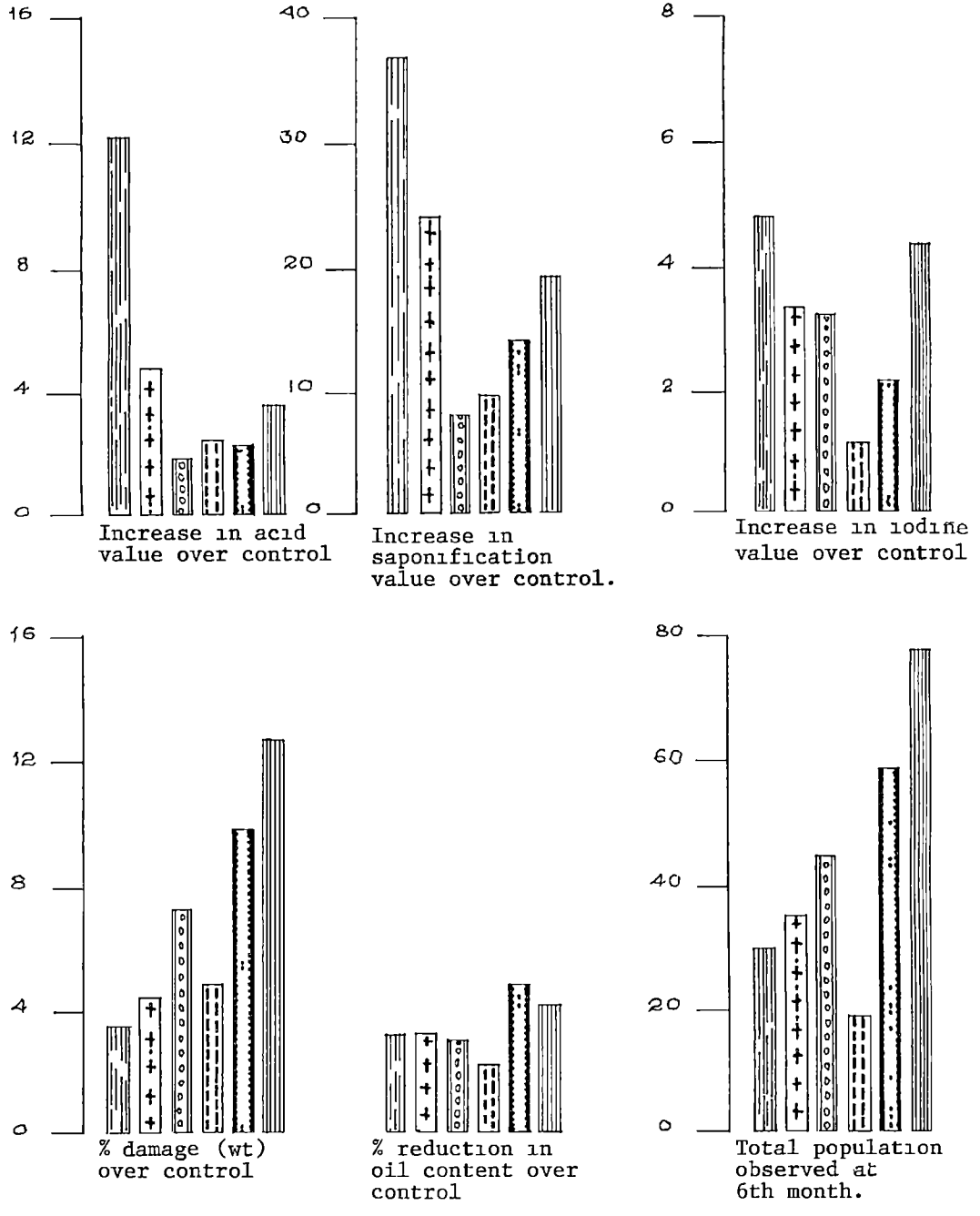
Extent of damage caused to copra exposed to insect infestation in godown was high when kept in heap. The

infestation became high in reused gunnies during third month and in new gunnies from fourth month after storage. As seen from the population build up of pests in stock, the loss can be kept at insignificant levels by using unused gunny bags upto third month and after that by polythene/alkathene lined gunnies or netted polythene bags upto sixth month. The result relating to the percentage reduction in oil content of copra kept in different treatments also agree with the above observations (Fig.6).

Acid values were higher in polythene sandwiched gunnies and in alkathene lined gunnies and that too during fifth and sixth months after storage. The saponification values and iodine values did not show significant variations among the treatments. The colour and smell of oil obtained from copra kept in polythene/alkathene lined bags and netted polythene bag were not significantly different from the samples kept in heap or in bags, though they had deteriorated more than that of control which was kept in sealed buckets. The results thus showed that the quality of the oil obtained from copra stored in polythene/alkathene bags also did not show deterioration even when stored upto six months, though slight development of mould was observed during later periods. So, for reducing the damage of copra caused by insect pests, storage in polythene sandwiched/ alkathene lined bags or in netted gunny bags can be recommended as an adaptable technology.

Fig. 6. The build up of insect pests in copra kept under different types of storage, the extent of damage done by the pests and the effect of damage on the quantity and quality of oil (observed at sixth month after storage).

FIGURE 6


16
12
8
4
0
Increase in acid value over control
40
30
20
10
0
Increase in saponification value over control.
8
6
4
2
0
Increase in iodine value over control
16
12
8
4
0
% damage (wt) over control
% reduction in oil content over control
80
60
40
20
0
Total population observed at 6th month.
Polythene sandwiched gunny bag
Netted polythene bag
Alkathene lined gunny bag
Reused gunny bag
New gunny bag
Heap.

4.6. Control of major insect pests infesting copra under godown conditions

The adults of N. rufipes and O. surinamensis as well as other pests like E. cautella, A. advena, L. serricorne and A. fasciculatus were found in the gunnies, wall and floor of the godowns and N. rufipes even migrate out of the godown during the peak breeding season and cause annoyance. These insects have got to be killed at least when the population goes high and for this, the only feasible method will be the use of insecticides. As a prophylactic method for reducing the possible insect damage in stored copra also, the killing of adults before they reach the commodity and lay eggs, will be essential. With these objectives, the commonly available pesticides which can be used in godown premises were screened against the major pests, N. rufipes and O. surinamensis in the laboratory. The results presented in para 3.7.1. and 3.7.2. clearly showed that malathion and phoxim were much more toxic to N. rufipes than fenitrothion, chlorpyriphos, fenvalerate, carbaryl and lindane. Against O. surinamensis, malathion and fenitrothion were highly toxic, while toxicity of phoxim was only two third of that of the malathion. Rai and Singh (1977) studied the relative residual toxicity of eight contact insecticides and found phoxim and fenitrothion

as more toxic than malathion. They tried these insecticides of gunny and polypropylene sacking, whereas the present experiment was carried out on glass surface (petridishes). This might have caused the deviations in the results. Higher toxicity of phoxim (Girish et al., 1973; Rai and Singh, 1977), malathion (Rosen, 1976; White et al., 1983) and fenitrothion (Jacobson and Pinniger, 1982) to different storage pests were also reported earlier. The efficacy of malathion and fenitrothion on gunny bags for the control of O. surinamensis also have been reported earlier (Kane and Green, 1968; Morallo Rejenus, 1975). The data presented in para 3.7.3. showed that fenitrothion 0.2 per cent (0.4 g ai/m^2) was as effective as malathion 0.4 per cent (0.8 g ai/m^2). These two insecticides sprayed at the above rates on gunny surface protected the copra from insects upto five months and when similarly sprayed with 0.8 per cent (1.6 g ai/m^2) fenitrothion protected copra upto six months after storage. Malathion was not tried at 0.8 per cent level in the experiment based on relative toxicity. Thus, for storage for shorter duration, malathion 0.4 per cent and for prolonged protection, fenitrothion 0.8 per cent may be recommended for adoption. Spraying the gunnies before or after filling the copra was more effective than spraying the stack. Since spraying the stack was effective, in view of the cost and hazards

involved in spraying the gunnies before or after filling copra, the former method can be recommended for adoption.

Rai and Singh (1977) reported the results of spraying phoxim/pirimiphos methyl on stacks of copra and they found that the treatment gave effective kill of the insects coming in contact with the sprayed surface. They did not study the persistent toxicity of the treatments to the different pests infesting copra. Persistent toxicity of fenitrothion for such prolonged periods against the pests of stored commodities have also been reported by Kane and Green (1968).

As described in para 3.7.4., the residues of malathion in copra sprayed at 0.1, 0.2 and 0.4 per cent were well below the tolerance level of three ppm when estimated 15 days after treatment. The residues of fenitrothion at the above recommended dose of 0.2 per cent remained above the tolerance limit of 0.1 ppm even at 30 days after treatment. Thus for storage for shorter duration spraying of malathion will be safe and for prolonged protection fenitrothion may be recommended for adoption.

Results presented in para 3.7.5. showed that for the curative treatment of copra infested by N. rufipes, fumigation with aluminium phosphide at 3 g/m^3 (1.7 g ai/m^3) for 2 days was required. Earlier reports showed that for the control of N. rufipes infesting stored copra,

8.1 g phostoxin/m^3 for 2 days (Rai and Singh, 1977) and for control of the pest on cacao 0.8 g ai/m^3 of aluminium phosphide (Mejule and Onyuike, 1980) had to be used. But at 0.8 g/m^3 dose, emergence of adults was noted in the present studies.

For complete kill of O. surinamensis in infested copra, fumigation with aluminium phosphide @ 3 g/m^3 (1.7 g ai/m^3) for one day was sufficient. Mejule and Onyuike (1980) reported 0.8 g ai/m^3 of aluminium phosphide was effective against O. mercator infesting cacao. In the present investigations 0.8 g ai/m^3 dose was found ineffective against the pest.

For 100 per cent suppression of A. fasciculatus infestation 4.5 g/m^3 (2.5 g ai/m^3) of aluminium phosphide with one day exposure period was found necessary. Bitran (1974) reported 0.4 g ai/m^3 of aluminium phosphide as effective dose for the control of the pest in coffee.

For fumigating a commodity infested by a mixed population of the above insects the dose of 4.5 g/m^3 of aluminium phosphide and an exposure period of one day may be recommended. As described in para 3.7.6. the residue of phosphine in copra fumigated with aluminium phosphide at 4.5 g/m^3 with an exposure period of one day was 0.0003 ppm only. The recovery percentage of phosphine

for the method of estimation adopted in the investigation was 50.7 only. Even after giving allowance for such low recovery, the level of residue in the treated produce will be far below the tolerance limit and hence the methodology is not likely to cause any health hazards.

SUMMARY

5. SUMMARY

5.1. Survey on the incidence of insect pests of copra

A preliminary survey was conducted in six godowns in the Southern Districts of Kerala where copra was being stocked throughout the year. The samples of copra were collected from these godowns at bimonthly intervals for two years and the life stages of different insects present were counted and recorded. The results led to the following conclusions:

(1) stored copra was infested by four major pests *N. rufipes*, *O. surinamensis*, *A. advena* and *L. serricorne*

(2) in medium and large oil mills and godowns, where stock was held for more than five months at a stretch, the insects caused significant damage to the commodity

(3) properly processed copra stored under good conditions also were seen infested by the above pests

(4) the immature stages of *N. rufipes*, the larvae and adults of *O. surinamensis* and *A. advena* were found tunnelling between the endosperm and the testa and the frass or entry holes were not seen. This habit rendered the detection of infested copra by gross examination impossible

(5) the adults of N. rufipes were prevalent all over the godown and even in nereby buildings causing annoyance to man and household animals

(6) T. castaneum was not found damaging copra, though the insect had been recorded as a pest of the commodity earlier

(7) N. rufipes and O. surinamensis had a wide distribution in the godowns of Kerala, while A. advena and L. serricorne were found only at one location (Nedumangad)

(8) the major pests of copra were found breeding between the months of June and October only

(9) the moisture content of the copra stocked in godowns showed a positive correlation with the pest incidence

5.2. The extent of damage caused by N. rufipes and O. surinamensis to stored copra and the influence of A. flavus on the damage.

It was not possible to estimate in the survey the extent of damage caused by different insect pests to stored copra. A separate experiment was hence carried out with four treatments (a) exposing copra (8±0.5 per cent moisture content) to the fungus, A. flavus, (b) exposing to the insects N. rufipes/O. surinamensis, (c) fungus

preceded by insects and (d) fungus succeeded by insects. The quantitative and qualitative losses caused by these organisms were recorded at monthly intervals for six months. The results revealed that:

(1) copra was directly susceptible to insect attack and the incidence of mould was not a predisposing factor for insect attack and the presence of fungus did not favourably influence the incidence of the insect

(2) the extent of damage caused by N. rufipes was reduced by 50 per cent when the incidence was combined with fungus infection and the fungus affected the growth and multiplication of the pests

(3) the extent of damage caused by a population of 100 numbers of N. rufipes in 200 g of copra was 7.2 per cent atthe end of three months and 12.2 per cent at the end of six months

(4) the extent of damage caused by O. surinamensis to copra having 8±0.5 per cent moisture was found to be three per cent only after a period of six months

(5) the infection of the copra by A. flavus adversely affected the oil content and the incidence of the pest along with the fungus did not alter the effect favourably or adversely. Significant reduction in

oil content by insect attack was recorded during six month after storage

(6) the quality of oil extracted from copra infested by insects was seen adversely affected. The presence of the insects preceeding or succeeding the fungal infection did not significantly alter the adverse effect caused by A. flavus.

5.3. Relative susceptibility of copra obtained from different varieties of coconut to the insect pests

As there was wide variations in the physical characteristics, chemical composition and oil content of copra obtained from different varieties of coconut, the extent of damage caused by N. rufipes and O. surinamensis to copra obtained from different varieties of coconut and the population build up of the pests on different varieties were studied by a series of laboratory experiments. The important findings were:

(1) the extent of direct loss caused by these insects to copra and its oil content showed variations, but the data did not exhibit statistical significance

(2) among different varieties tested, LM and LO were the varieties found favourable to N. rufipes and DxT and TxD to O. surinamensis based on the study of growth indices.

(3) two to six fold increase in the longevity of the adults of N. rufipes was observed when they were provided with immature stages of insects along with copra for feeding.

5.4. Relative susceptibility of copra containing various levels of moisture

The survey conducted in the Southern Districts of Kerala revealed that the extent of damage caused by insect pests to stored copra varied with moisture content of the produce. To assess the possible loss caused by major pests to stored copra and to find out the population build up of the pest within a range of four to eight per cent moisture level, a laboratory experiment was carried out. The results showed that:

(1) the extent of damage caused by N. rufipes to stored copra having eight per cent moisture content was significantly higher than those in other treatments. During the sixth month, significant loss was noticed at six per cent moisture content also

(2) highest damage was caused by O. surinamensis in copra containing six per cent moisture

(3) maximum reduction in oil content was observed in N. rufipes infested copra kept at eight per cent moisture level and during sixth month

(4) significant differences were lacking in the oil yield of copra containing various levels of moisture and infested by O. surinamensis

(5) the quality of oil from different treatments did not show significant variations upto three months after storage

(6) the oil from copra containing six to eight per cent moisture when exposed to N. rufipes became slightly rancid at two months after storage. The oil was retaining normal smell when extracted from copra containing four per cent moisture

(7) N. rufipes preferred higher levels of moisture for breeding and the development was totally arrested at four per cent moisture level

(8) significantly higher population of N. rufipes (adults) was recorded at eight per cent moisture than at six per cent moisture level during the peak period of occurrence (third and fourth months after storage)

(9) the larval, pupal and adult populations and the number of eggs laid by O. surinamensis were significantly higher at six per cent moisture during the peak period of occurrence

(10) response of moisture fluctuations was more conspicuously seen in O. surinamensis than in N. rufipes.

5.5. Effect of different types of storage on the incidence of pests of copra

The usual practices of storing copra observed during the preliminary survey, were the different types of bags and as heap. To assess the incidence of different pests and the possible quantitative and qualitative loss caused to copra, an experiment was formulated. The results indicated that:

(1) higher incidence of N. rufipes was observed in heap storage and in later periods in reused gunny bags and new gunny bags

(2) the incidence of O. surinamensis was high in reused gunny bags during second, third and fourth month and in new gunny bags during fourth and fifth month

(3) low populations of O. surinamensis were observed with heap storage of copra during the entire period

(4) the total population of the pests were highest with reused gunny bag, followed by heap storage

(5) the polythene and alkathene lining to gunny bags kept copra free from insects for two months

(6) storing of copra in lined gunny bags can be recommended as a sure method for excluding insect pests upto five months

(7) the quality of oil extracted from copra kept in polythene/alkathene lined gunny bags did not show deterioration even upto six months, though slight development of mould was observed during later periods

5.6. Control of major insect pests infesting copra

5.6.1. Prophylactic methods

As a prophylactic means of reducing the insect damage in stored copra and to kill the adults before they reach the commodity to lay eggs, the commonly available pesticides - phoxim, fenvalerate, chlorpyriphos, malathion, fenitrothion, carbaryl and lindane were tried. The results revealed that:

(1) malathion and phoxim were more toxic to N. rufipes and malathion and fenitrothion were toxic to O. surinamensis

(2) for storage of shorter durations, malathion 0.4 per cent can be recommended and for prolonged protection, 0.8 per cent fenitrothion may be recommended

(3) on gunny bags, malathion 0.4 per cent gave protection upto fifth month against insect pests and fenitrothion, 0.8 per cent for six months

(4) residue of malathion was found to be below tolerance limit at 15 days after treatment and fenitrothion at 30 days after treatment and storage.

5.6.2. Curative methods

Various doses of aluminium phosphide and different exposure periods were tried to standardise the treatment for complete control of the major pests of copra. The results indicated as follows:

(1) for complete control of N. rufipes, aluminium phosphide @ 3 g/m^3 (1.7 g ai/m^3) with an exposure period of two days could be recommended

(2) as a curative treatment for O. surinamensis infestation aluminium phosphide fumigation @ 3 g/m^3 (1.7 g ai/m^3) for one day was found sufficient

(3) for 100 per cent suppression of A. fasciculatus infestation 4.5 g/m^3 (2.5 g ai/m^3) of aluminium phosphide with one day exposure period was found necessary

(4) at the recommended dose and exposure period, the residue of phosphine in the fumigated samples was below the tolerance limit after an aeration for 24 hours.

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APPENDICES

APPENDIX I

Moisture content (%) of copra collected from various godowns from Oct.'84 to Aug. '86

Place	Oct. '84	Dec. '84	Feb. '85	Apr. '85	June '85	Aug. '85	Oct. '85	Dec. '85	Feb. '86	Apr. '86	June '86	Aug. '86
Attingal	5.3	5.1	3.8	4.1	5.4	5.2	5.5	4.0	3.9	3.7	4.8	5.1
Sreekaryam	4.2	4.1	3.8	3.7	3.9	5.1	5.4	4.1	4.0	3.9	4.3	5.2
Karamana	4.2	3.9	4.0	4.0	4.3	4.7	4.3	3.8	3.9	4.0	4.1	4.4
Nedumangad	6.2	4.8	4.9	4.1	6.1	6.2	6.4	4.7	4.4	4.1	4.8	6.4
Asramom	6.3	4.8	5.1	5.3	5.8	5.5	5.7	4.5	4.9	5.0	5.1	6.1
Shertallai	4.2	4.1	3.9	5.7	5.1	5.4	5.2	5.2	4.0	4.1	5.3	5.9

APPENDIX II Weather data during September 1984 to July 1986 at various locations

Attingal					Sreekaryam					Karamana					Nedumangad					Asramom	Shertallai				
Rain fall (mm)	Temp °C Maxi-mum	Mini-mum	RH(%) Morn ing	Even-ing	Rain fall (mm)	Temp °C Maxi-mum	Mini-mum	RH(%) Morn ing	Even-ing	Rain fall (mm)	Temp °C Maxi-mum	Mini-mum	RH( ) Morn ing	Even-ing	Rain fall (mm)	Temp °C Maxi-mum	Mini mum	RH(%) Morn-ing	Even ing	Rain fall (mm)	Rain fall (mm)	Temp °C Maxi-mum	Mini-mum	RH(%) Morn-ing	Even-ing
60 4	30 4	22 9	83 0	77 0	60 4	30 4	22 9	83 0	77 0	40 2	31 0	23.2	83 0	78 0	14 0	31 0	23 2	83 0	78 0	101 0	187 2	30 1	23 6	88 0	85 0
103 7	30 4	21 0	83 9	67 0	103 7	30 4	21 0	83 9	67 0	71 8	30 8	23 3	86 0	78 0	113 0	30 8	23 3	86 0	78 0	50 8	105 0	32 0	24 0	86 0	75 0
27 4	30 8	21.8	77.0	58 0	27.4	30 8	21 8	77 0	58 0	91 7	31 6	22.6	80 0	67 0	6 0	31 6	22 6	80 0	67.0	16 4	69 5	31 6	23 0	79 0	64 0
2.5	33 0	24.0	80 5	70.0	2.5	33 0	24 0	80 5	70 0	13.6	33 4	24 6	77 0	66 0	0.0	33 4	24 9	77 0	66.0	9 0	46 8	33 7	25 4	78 0	71 0
213 9	31 7	25.9	74.5	59 0	231 9	31.7	25.9	74 5	59 0	223 3	32.2	24.9	83 0	79 0	21 0	32 2	24 9	83.0	79.0	291 1	628 8	32 3	25 4	88 0	86 0
80 4	28 9	22 7	75.0	62.0	80.4	28 9	22 7	75 0	62 0	82 5	29 8	22 9	88 0	77.0	96 5	29 8	22 9	88 0	77 0	359 4	334 1	28 9	23 3	93 0	85 0
112 4	30 2	22 6	80 0	77 5	112 4	30.2	21 6	80.0	77 5	96.8	30 9	23 6	84 0	74 0	3 0	30 9	23 6	84 0	74 0	89 6	325 2	30 0	23 7	89 0	83 0
164 7	29 4	21 6	82 0	73 5	164 7	29 4	21 6	82 0	73 5	170.4	30 1	23 7	83 0	75 0	166.0	30.1	23 7	83 0	75 0	298 4	152 8	31 6	23 5	84 0	72 0
5 7	31 9	19 0	74.0	59 0	5 7	31 9	19 0	74 0	59 0	2.2	32 5	22.8	73 0	63 0	2 0	32.5	22 8	73 0	63.0	0 0	3 4	33 3	23 1	76 0	67 0
4 4	32 2	23.3	76 0	57 0	4.4	32 2	23 3	76 0	57 0	2 1	33 3	24 2	76 0	67 0	9 0	33 3	24 2	76 0	67 0	1 4	86 2	33 9	23 4	77 0	68.0
205.5	32 6	22 7	84.0	67.0	205 5	32.6	22 7	84 0	67 0	150 9	32 8	25 3	80 0	74 0	30 3	32 8	25.3	80 0	74 0	16 2	150 1	33 9	25 8	81 0	71.0
122 5	30 9	23 4	87 0	79 0	122 5	30.9	23 4	87 0	79.0	103 0	30 0	23.3	88 0	78 0	153 4	30 0	23 3	88 0	78.0	217 4	37 8	29 9	23 8	91 0	84 0

APPENDIX III. Original data based on which the variations from corresponding control were workedout and presented in various tables.

	Values relating to column					
	1	2	3	4	5	6
Table 11						
	67.1	66.6	67.3	66.9	67.1	66.7
	73.1	72.9	72.3	72.7	71.9	72.0
	66.7	66.4	66.7	66.9	65.9	66.1
	67.2	67.0	66.9	67.1	66.8	66.8
	64.7	65.1	64.9	64.8	64.6	64.1
	67.1	66.8	66.8	66.2	66.0	65.8
	71.8	71.2	71.1	70.2	69.7	70.1
	66.9	66.5	66.8	66.3	66.7	66.1
	64.3	63.8	64.0	63.9	63.8	63.1
Table 14						
	63.2	63.2	63.0	62.5	62.3	62.0
	62.5	62.1	62.0	61.9	61.6	61.8
	62.2	62.2	61.8	61.2	61.7	61.4
Table 15						
	0.77	0.82	1.00	1.07	0.97	1.18
	0.86	1.10	1.43	1.87	2.16	2.96
	0.89	1.12	1.98	2.13	2.78	3.12
Table 16						
	250.9	252.8	251.9	253.7	256.0	256.9
	252.1	253.9	254.1	254.8	254.1	257.8
	250.1	252.7	254.1	255.3	255.0	255.1

APPENDIX III Contd....

Original data based on which the variations from corresponding control were workedout and presented in various tables.

	Values relating to column					
	1	2	3	4	5	6
Table 17						
	7.54	8.10	7.30	8.20	9.10	9.70
	7.73	7.97	8.10	9.17	9.37	9.87
	8.23	8.91	9.12	10.02	10.37	10.45
Table 24						
	67.50	67.04	66.36	64.86	65.16	64.72
Table 25						
	0.64	0.86	1.09	1.45	2.41	2.27
Table 26						
	250.44	250.58	253.92	253.33	252.47	254.33
Table 27						
	7.30	7.40	7.67	7.73	8.33	8.63

APPENDIX IV. SUMMARY OF ANALYSIS OF VARIANCE RELATING TO

Table 1

	N. rufipes		*O. surinamensis*		*E. cautella*		*A. advena*		*L. serricorne*	
	df	MSS	df	MSS	df	MSS	df	MSS	df	MSS
Between treatments	11	335.13**	11	7066.11**	11	48.68	-	-	-	-
Between periods with in treatments	60	192.17**	48	2709.49**	24	74.30**	11	3837.95**	11	234.90**
Error	648	23.30	540	410.61	324	17.40	108	505.04	108	67.94

Table 3

	N. rufipes		*O. surinamensis*	
	df	MSS	df	MSS
Between treatments within each period	20	0.86**	20	0.15**
Error	48	0.04	48	0.03

APPENDIX IV Contd.

SUMMARY OF ANALYSIS OF VARIANCE RELATING TO

Table 4	*N. rufipes*		*O. surinamensis*	
	df	MSS	df	MSS
Between treatments within each period	25	4.04**	25	4.89**
Error	120	0.31	120	0.30
Table 5				
Between treatments within each period	25	9.92**	25	9.68**
Error	120	0.67	120	0.67
Table 6				
Between treatments within each period	25	84.56**	25	79.68**
Error	120	11.87	120	17.18
Table 7				
Between treatments within each period	25	12.06**	25	9.46**
Error	120	0.93	120	0.99
Table 10				
Between treatments within each period	45	1.06**	45	1.05**
Error	108	0.06	108	0.05
Table 11				
Between treatments within each period	45	0.11**	45	0.11**
Error	108	0.04	108	0.03

APPENDIX IV Contd.

SUMMARY OF ANALYSIS OF VARIANCE RELATING TO

	N. rufipes		*O. surinamensis*	
	df	MSS	df	MSS
Table 12				
Larval period				
Treatment	8	0.22**	8	0.03*
Error	18	0.03	18	0.01
Pupal period				
Treatment	8	0.08**	8	0.05*
Error	18	0.01	18	0.01
Fecundity				
Treatment	8	0.63	8	6.18
Error	18	0.81	18	2.29
Egg period				
Treatment	8	0.01	8	0.01
Error	18	0.01	18	0.01
Adult longevity				
Treatment	8	1.29**	8	1.66
Error	18	0.23	18	0.68
Table 13				
Between treatments within each period	15	1.09**	15	0.82**
Error	36	0.07	36	0.06
Table 14				
Between treatments within each period	15	0.25**	15	0.51**
Error	72	0.06	72	0.12

APPENDIX IV Contd.

SUMMARY OF ANALYSIS OF VARIANCE RELATING TO

	N. rufipes		*O. surinamensis*	
	df	MSS	df	MSS
Table 15				
Between treatments within each period	15	0.11**	15	0.34**
Error	72	0.03	72	0.04
Table 16				
Between treatments within each period	15	1.39**	15	2.64**
Error	72	0.37	72	0.30
Table 17				
Between treatments within each period	15	0.19**	15	0.35**
Error	72	0.05	72	0.06
Table 20 and 21				
Egg				
Between treatments within each period	10	2.22**	15	52.27**
Error	48	0.45	72	2.54
Larva				
Between treatments within each period	10	3.31	15	130.40**
Error	48	3.16	72	5.63
Pupa				
Between treatments within each period	10	24.11**	15	82.78**
Error	48	1.35	72	6.10

APPENDIX IV Contd.

SUMMARY OF ANALYSIS OF VARIANCE RELATING TO

	N. rufipes		*O. surinamensis*	
	df	MSS	df	MSS
Adult				
Between treatments within each period	10	17.78**	15	54.41**
Error	48	1.04	72	3.76

Table 22	*N. rufipes*		*O. surinamensis*		Total population	
	df	MSS	df	MSS	df	MSS
Between treatments within each period	24	14.52**	24	18.75**	24	23.14**
Error	270	3.20	270	7.86	270	7.83

Table 23	df	MSS
Between treatments within each period	24	0.95**
Error	60	0.02

Table 24		
Between treatments within each period	24	0.40**
Error	120	0.06

Table 25		
Between treatments within each period	24	0.74**
Error	60	0.07

APPENDIX IV Contd.

SUMMARY OF ANALYSIS OF VARIANCE RELATING TO

Table 26	df	MSS
Between treatments within each period	24	2.09
Error	60	1.48
Table 27		
Between treatments within each period	24	0.16
Error	60	0.14

* at 5 per cent level

** at 1 per cent level

STUDIES ON THE EXTENT OF DAMAGE CAUSED BY PESTS OF STORED COPRA AND CONTROL OF THE IMPORTANT PESTS

By

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ABSTRACT OF A THESIS

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ABSTRACT

The magnitude and intensity of insect pest attack in stored copra, in the Southern Districts of Kerala, were assessed in an elaborate survey, adopting a random sampling technique for two years.

The survey revealed that insects cause significant damage even in well preserved good quality copra stocked for more than five months. *N. rufipes*, *O. surinamensis*, *A. advena* and *L. serricorne* were the major pests recorded. The immature stages of *N. rufipes*, adults and immature stages of the other pests were seen inside the tunnels made between the endosperm and testa. *N. rufipes* and *O. surinamensis* were distributed widely, while the predominent insects observed at Nedumangad were *A. advena* and *L. serricorne*. All the insects were found breeding on copra from June to October. A positive correlation between moisture content of copra and the insect incidence was observed in the studies.

The influence of *A. flavus* on the extent of damage caused by these pests showed that the presence of the mould was not a predisposing factor for insect attack. The extent of damage in copra due to the infestation by *N. rufipes* was 12.2 per cent at the end of sixth month whereas *O. surinamensis* caused only three per cent

damage. When combined with fungus, the damage caused by N. rufipes was reduced by 50 per cent. This effect was not observed on O. surinamensis. The infection by the fungus adversely affected the oil content of copra and this effect was not altered by the preceeding or succeeding infestation of the insect. The insect attack alone caused significant reduction in oil yield of copra during the sixth month after exposure only. The quality of oil was adversely affected when infested by insects and fungus independently. The infestation of insects preceeding or succeeding fungal infection did not alter the adverse effect caused by them independently.

The quantitative loss caused by the attack of N. rufipes and O. surinamensis to copra obtained from different varieties of coconut did not show significant variations. Among the different varieties tested LM and LO were more favourable to N. rufipes and DxT and TxD to O. surinamensis. Two to six fold increase in the longevity of the adults of N. rufipes was observed when they were provided with immature stages in addition to copra for feeding.

N. rufipes and O. surinamensis caused significantly greater damage to copra under eight per cent and six per cent moisture levels respectively. The development

of N. rufipes was totally arrested in copra with four per cent moisture content. The development of immature stages and adult population of N. rufipes were higher in copra containing eight per cent moisture level and those of O. surinamensis in copra containing six per cent moisture. The response to moisture fluctuations was more conspicuously seen in O. surinamensis than in N. rufipes.

Though the population of insects were found to be high in reused gunny bag followed by heap storage, the extent of damage was higher in heap storage than in reused gunny bags. High populations of N. rufipes and O. surinamensis were recorded from heap and reused gunny bagsrespectively. Low populations of insects were recorded in copra stocked in polythene/alkathene lined gunny bags and netted polythene bags. But the oil extracted from copra stored in these types of bags gave significantly higher acid values.

In the trials done to find out a safe prophylactic method of control against pests of copra, malathion and phoxim proved more toxic to N. rufipes and malathion and fenitrothion to O. surinamensis. When these insecticides were evaluated for their persistence on gunny bags, malathion 0.4 per cent gave protection upto five months and fenitrothion 0.8 per cent upto six months. The residues

of malathion and fenitrothion came below tolerance limits, 15 and 60 days after treatment respectively. For complete control of the major pests of copra 4.5 g/m^3 (2.5 g ai/m^3) of aluminium phosphide with one day exposure period was found adequate. The residue of phosphine in the copra fumigated as above was below tolerance limit.