

**INSECTICIDAL, ANTIFEEDANT, AND REPELLENT
PROPERTIES OF PLANT EXTRACTS AGAINST
THE RICE MOTH, *Corcyra cephalonica* STANTON
(LEPIDOPTERA : PYRALIDAE)**

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**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE**

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(LEPIDOPTERA : PYRALIDAE)**

G. M. SRILATHA

Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements
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IN

AGRICULTURAL ENTOMOLOGY

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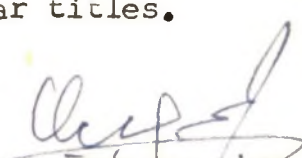
*To My Parents
and
Brothers*

Department of Agricultural Entomology
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BANGALORE

CERTIFICATE

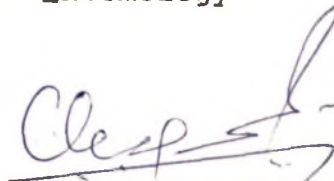
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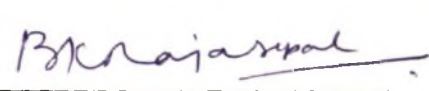
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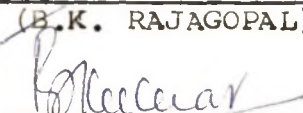

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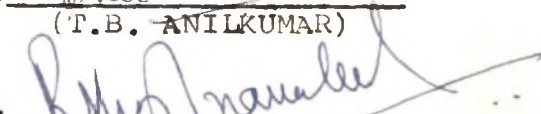
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INTRODUCTION

I. INTRODUCTION

In India, most of the food grains produced are being stored at farmers level under the most primitive conditions of storage and hence are easily accessible to the attack of a variety of insect-pests and other agents in storage. Our country is therefore is loosing on an average 9.33 per cent of the stored grains. This reflects on the magnitude of the pest problem in storage.

Under South Indian conditions, rice is used as major food grain. Rice in storage is damaged by a number of agents like insects, rodents, fungi, mites, moisture and birds. Among all these, storage insects are the notorious pests causing considerable loss to stored grains and their products every year. Nearly a dozen storage insects are recorded on rice, among which rice moth, Corcyra cephalonica (Stnt) is considered to be one of the major polyphagous pest, which attacks not only rice but also many other cereals and oil seeds under storage conditions. The larvae of this species feed by boring into grain and cause different types of losses viz., quantitative or weight losses by direct feeding on grain kernals, and qualitative losses like feeding on grain kernals, chemical changes in grain contents, contamination of grains with their body parts, and also loss of seed viability.

Rice moth is recorded not only in India but throughout the world. The cosmopolitan distribution of C. cephalonica was reported 50 years ago by Ayyar (1934) and Freeman (1976), has listed its occurrence on various food stuffs imported into the United Kingdom. Rao (1954) explained the wide distribution of C. cephalonica by its ability to infest almost all kinds of stored food products, whether cereal grains, oil seeds or legumes. Some workers observed that C. cephalonica is a secondary pest, which needs damaged grain for successful establishment (Kamel and Hassanein, 1967).

To save stored grains and their products from insect menace, pesticides are indispensable. The most common and toxic chemicals used to control the stored insect pests are, malathion (as spray), ethelene bromide, ED/CT or other volatile substances as fumigants. Of course these chemicals offer efficient protection against pests, but unfortunately, they also cause certain undesirable side effects like residual toxicity, contamination of ecosystem, application hazards, etc. Seed dressing compounds, which include residual chlorinated hydrocarbons and organomercurials, that are highly toxic to human beings and higher animals are incorporated in grains meant for seed purposes during processing and storage. Though they are not actually meant for human or animal consumption, the surplus quantity of treated seeds inadvertently find entry

into trade channels and pose the problem of environmental pollution and also migration of pesticides through food chain to human and animal tissues. The fumigants which are employed in food grain storage, though volatile, are sorbed by the tissues of the grains during their exposure period, thus causing the problems of residues. To overcome these complex problems, scientists are in search of other methods of insect control, which are effective but non-hazardous to man and domestic animals. It is in this context that the scientists all over the world are screening different plant materials which could be employed in crop and grain protection. Using plant products in storages is an age old practice in India. The usefulness of nicotine and pyrethrum as insecticide was realised as early as 1828. Similarly rotenone, neem, ryania etc., are known to possess insecticidal properties.

Plant products are considered to be a novel approach. It has been demonstrated by many workers that numerous plant species showed insecticidal, antifeedant, repellent, antigrowth and oviposition inhibiting properties. In general the plant products do not possess quick knock down effect (except natural pyrethrins and nicotins) unlike synthetic contact insecticides and fumigants, which are currently being recommended for the control of stored grain insect pests. However, plant products have many advantages over the

synthetic chemicals. They possess the least or no mammalian toxicity and thus constitute no health hazards, surface persistence lasts for long time with no adverse effects on seed germinability, cooking quality and milling, less expensive and are easily available. In Pakistan some indigenous plants have been used for keeping insects away from human beings, food materials and woolens (Golob and Webley, 1980). The use of insect repellents antifeedants offers a scope for protection of stored grain from insect attack.

Insecticides obtained from plant sources are safer, devoid of residue problems and application risks are almost negligible as compared to synthetic chemical pesticides. Although some of these plant products have been used as crop protectants, their utility in food grain storage has not been fully exploited. Therefore the present studies were undertaken with the following objectives to determine ;

1. Insecticidal properties
2. Feeding behaviour
3. Repellent activity
4. Feeding deterrent effects (antifeedants), of the test plant extracts on the test insect.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Literature reviewed on different aspects of pest of field crops and stored grains viz., chemical pesticides and natural plant products are presented under the following headings.

2.1 Control of insect pests using plant products as

- Toxicants
- Antifeedants
- Repellents

2.2 Test insect, Ricemoth (Corcyra cephalonica Stainton)

- Damage caused
- Biology

2.3 Control of ricemoth by using

- Plant products
- Chemical pesticides.

2.1 Control of insect pests using plant products as

2.1.1 Toxicants

Neem

Goyal et al. (1971) tried 19 extracts and isolates of cake made from the seeds of neem in the lab for their toxicity to adults of, Rhopalosiphum nymphaeae (Linn). They found that out of 19, 11 of the substances caused mortality in R. nymphaeae

after 24 hours, the most effective being the alcoholic extract of the cake. They also observed the antifeedant activity of eight substances (all containing sulphur) against the adults of Schistocerca gregaria (Forsk) and of them one substance (the water soluble fraction from the alcohol extract) was found to be effective. In 24 hours the starved locusts consumed 78.7 per cent of untreated strips of cabbage leaf as compared with 19.4, 8.4, 5.9 and 0.6 per cent of strips that had been sprayed with the substance at concentrations of 1, 2, 3 and 4, respectively.

Quadri et al. (1977) tested the insecticidal action of custard apple, (Annona squamosa) in combination with neem against Callosobruchus chinensis (L), Rhizopertha dominica(F), Musca domestica nebulosa F. Individuals of each species were exposed for 24 hours to the extracts of seeds of neem and custard apple and to DDT as a standard of comparison in the form of dry deposits on glass. The statistical analysis of the results showed that neem extract alone was less toxic than either custard apple extract or DDT, but that it had synergistic action when combined with custard apple extract. The combined seed extract of 4 to 5 parts of neem to one part of A. squamosa was as toxic as DDT to Musca domestica nebulosa F., half as toxic as DDT to C. chinensis and about 1/5th as toxic as DDT to R. dominica.

Abraham and Ambika (1979) observed that the topical application of leaves and seed kernels of neem on 3rd, 4th and 5th instar nymphs of Dysdercus cingulatus caused 55 per cent and 80 per cent mortality, respectively. But both the extracts caused similar degeneration of the ovarioles of the sixth instar with no vitellogenesis and they also showed similar effects on molting.

According to Kubo and Klocke (1982) azadirachtin isolated from neem when tried against some lepidopterous pests, some disruptions in behaviour and development were exhibited and also exhibited strong antifeedant activity in Heliothis zea and Spodoptera frugiperda. They also found that azadirachtin inhibited the larval ecdysis in H. zea (EI₉₅₋₂), S. frugiperda (EI₉₅₋₁) and also in Pectinophora gossypiella (EI₉₅₋₁), Heliothis virescens (EI₉₅₋₂). Concentration of azadirachtin lower than that inhibiting ecdysis (3 ppm) inhibited the growth rate of feeding larvae by more than 50 per cent.

Sayed (1983) studied the effects of various concentrations of suspensions of ground seeds of neem on eggs and larvae of the cotton pest Spodoptera littoralis in the laboratory. The results showed that the larval weight gain was greatly reduced when the second and third instar larvae were

fed for three days on leaves that had been treated with the suspensions of 0.5 per cent concentration. Untreated second instar larvae were about 13 times as large as those fed on treated leaves. The average weight of treated larvae was inversely proportional to the concentration of the suspension. He also reported that the treatment of first to fifth instar larvae at 0.2 to 0.5 per cent caused 100 per cent mortality by the end of the larval stage, larval treatment also caused pupal mortality and adult deformity; when the eggs were dipped in a 2 per cent suspension 90 per cent of them failed to hatch.

According to Ivbija Rao (1983) maize grains when mixed with dry ground seeds of neem at 0.5, 1.0 and 2.5 g/20 g were protected for six months from damage caused by Sitophilus oryzae (L) in storage. He also reported that at the highest rate neem seed prevented oviposition, at the lowest rate, it markedly reduced oviposition and at all the concentrations the post embryonic development of egg was normal. Mortality among the parent weevils reached 100 per cent within five days. Adult weevils placed on maize that had been treated 4 months previously with 2.5 g neem per 20 g of maize failed to oviposit and 76 per cent of them died within ten days. Neem seed had no adverse effect on the viability of grains and no fungus or shrinkage were observed.

Ho and Kibuka (1983) reported the insecticidal properties of neem oil, neem seed cake and urea-neem cake, by spraying neem oil on rice plants and incorporating urea-neem cake in 4:1 ratio at 1, 30 and 55 days after transplantation, the results showed that neem oil, at higher concentrations gave better protection at the stages of early vegetative growth than neem cake or urea-neem cake against the main pests (Maliarpha separtella Rag., Sesamia calamistis Hamps, Diopsis macrophthalama Dalm. and D. apicalis Dalm). Plots treated with urea-neem cake had more dead hearts than those treated with neem cake. At harvest the per cent of stems infested by Maliarpha separtella was significantly lower in plots treated with neem cake and urea-neem cake than in untreated plots and those treated with neem oil, there was no significant difference in the number of white heads. The highest grain and straw yields were obtained from plots treated with neem cake and urea-neem cake. At harvest many of the infested stems contained dead larvae or larvae whose development was arrested possibly through the systemic effect of neem.

Adhikary (1984) carried out some field trials to determine the effectiveness of crude methanol extracts of leaves and seed kernels of neem against Podagrica sp. and

Sylepta derogata on okra. The extract was sprayed six times at weekly intervals at 1, 2 or 4 per cent concentration and it was observed that the number of feeding holes in the leaves of okra by S. derogata was reduced when compared with the untreated plants. The yield estimation of undamaged okra pods was 4 to 5 tonnes per hectare in the treated plots as compared with 1.5 to 2.5 tonnes per hectare in the untreated ones.

Fagoone and Toory (1984) studied the control aspects of the leaf miner (Liriomyza trifolii) by neem. They reported that the steam distillates of neem leaves seriously affected the larvae and pupae upon treatment by contact, to as low a dose as 0.3 per cent of the extract. Field trials showed that the treatment with aqueous neem extracts (0.5%) gave good protection to the onion crop.

Koul (1984) studied the interaction of azadirachtin (prepared from the methanol extract of neem seed kernels), with reproductive behaviour of Dysdercus koenigii (F). Various concentrations of azadirachtin were applied to adults topically or by abdominal injection. Fifty per cent mortality was observed after seven days of application of the extract at 1 μ g per insect, and also the fertility of the surviving insects was reduced considerably especially in females. It was also observed that embryogenesis was severely impaired

by topical application and preliminary histochemical studies indicated the damage to trophocytes.

Kumar and Sangappa (1984) reported the effectiveness of neem seed kernel extract, neem oil and honge oil when applied to bengal gram (Cicer arietinum) against Heliothis armigera at 3 and 5 per cent concentrations, the mean per cent of the damaged pods was reported to be 1.05 to 3.10 per cent (as compared with 7.45 per cent for no treatment), but there was no significant effect on yields.

According to Sujatha and Punnaiah (1985) seeds of green-gram (Vigna radiatus) treated with different oils viz., sesame, cotton seed, oil of palm and neem at concentrations of 0.25 per cent or those of groundnut and coconut at 0.5 per cent were protected from the bruchid (Callosobruchus chinensis) attack. They also reported that treatment with the oils at 0.125 per cent resulted in lower infestations than the control.

Prabhaker et al. (1986) studied the effect of neem seed extract by incorporating the extract in the artificial diets (at 0.02, 0.20 and 2.00 per cent w/v concentrations) of Spodoptera exigua and Trichoplusia sp. and they found that the extracts prolonged the developmental period and also induced mortality in all the larval instars of both the insect species. Only one non-reproductive adult female of Trichoplusia sp was

produced when fifty, fifth instar larvae were exposed to the diet containing the lowest concentration of the extract, the pupae were not formed from the larvae of S. exigua treated at any stage of their development, with any concentration of the extract tested. They also reported that the mortality of both the noctuids was the most pronounced during ecdysis indicating activity similar to that of insect growth regulators.

Mustard

Sangappa (1977) tested the effectiveness of oils of mustard, sunflower, safflower, castor, cotton, neem (Melia azadirachta L.) , honge and hippe (Bassia latifolia) against Callosobruchus sp by treating the redgram seeds. Based on the results he concluded that these oils acted as surface protectants by checking the infestation of bruchids. There was no insect emergence from redgram seeds treated with honge oil applied at 1.0 per cent up to period of 319 days and emergence was very low compared with that of control even after 375 days. Mustard oil was found to be effective at one per cent concentration by reducing the number of eggs laid on the treated grains and 84 per cent of adult mortality was observed.

According to Varma and Pandey (1978) the fecundity of Callosobruchus maculatus(F) was inhibited when stored seeds

of green gram (Vigna radiatus) were treated with coconut, mustard, groundnut, sesame or sunflower oil at 0.3 parts of oil per 100 parts of grain by weight. Oviposition was completely inhibited when coconut or mustard oils were used. Very few eggs were found in the seeds treated with the other oils, the development of the beetle was also prevented for atleast 5 months, but the viability of the seed was not adversely affected.

Verma et al. (1983) conducted some experiments to find out the efficacy of oils (at 1 ml/kg of grain) and cakes (50g/kg grain) of neem, castor, linseed and mustard along with malathion 5 per cent dust and chalk against Sitotroga cerealella oliv. The cakes, oils and chalk (5g/kg grain) as well as 5 per cent malathion dusts were mixed in the grain. The results showed that less number of eggs were laid on grains treated with neem oil and malathion (33.33 eggs) in comparison to other treatments. The maximum being 126.66 eggs in control. Minimum incubation period was observed in the grains treated with castor cake (6.74 days), while the maximum in mustard cake (8.08 days). Hatching of the eggs obtained from malathion and neem oil treated grains was less being 16.60 and 20.00 per cent, respectively as against 86.60 and 83.30 in control, respectively, which was much higher in control (78.33%). All the protectants retarded the developmental period ranging from 27.97 to 31.22 days in comparison to control (36.06 days).

Less damage to grain was observed in malathion and neem oil treated grains (2.62 and 3.09%) thus providing minimum loss in weight also (1.07 and 1.22%) as against 21.56 and 14.35 per cent damaged grains and loss in weight, respectively. No adverse effect of any of the protectants on germination was observed.

Daharey et al. (1986) reported that some edible oils viz., coconut, groundnut, mustard, sesame and taramira oils at 1.0 per cent concentration was effective against Callasobruchus chinensis (L) by reducing the seed damage. Whereas, oils of coconut, groundnut and mustard oils at 1.0 per cent were found to be more effective against Callasobruchus maculatus (F) even upto six months after treatment. Sunflower oil at all the concentrations tried against C. chinensis and safflower oil against C. maculatus were found to be ineffective as the percentage of seed damage was recorded higher, than other oils, but both the oils significantly reduced the seed damage than malathion six months after treatment. Thus all the oils were found to be superior to malathion.

Eucalyptus

According to Jacobson et al. (1975) ethereal extracts prepared from the eggs, larvae and pupae of 10 species of insects and from various parts of 343 species of higher plants

showed juvenile hormone activity at 500 μ g concentration in Tenebrio molitor L., and Oncopeltus fasciatus (Dall). Results showed that the extract of the larvae of the Stomoxys calcitrans (L.) exhibited activity in both the species, whereas an extract of the pupae was active only on O. fasciatus. Judging on JH ratings they have concluded that extracts of the roots of Echinacea angustifolia and the seeds of Chamaecyperis lawsoniana showed high activity in Tenebrio molitor (4 and 2.2 respectively). Extracts of the stems, leaves and fruits of Clethra nifolia, roots and bark of Sassafras albidum, stem and bark of Eucalyptus camaldulensis, twigs and leaves of Pinus rigida and the roots, stems and fruits of Iris douglasiana were found to be highly active in O. fasciatus (3.0, 3.0, 2.0, 1.6 and 2.0, respectively). An extract of the leaves of Tsuga canadensis showed lower activity in the bug. Extracts of 16 other species of plants were also tested for their toxicities against O. fasciatus and they all were found to be highly effective on the test insect but lacked juvenile hormone activity in either species.

Saxena and Basit (1982) reported oviposition inhibition of Amarasca devastans when the host plants were sprayed with some essential oils. The effectiveness of the volatiles of the plants in inhibiting oviposition decreased in the order, Eucalyptus (E. citriodora) > Coriander = castor = tomato > lime

(Citrus limetiodies) > basil being without effect. Among the volatile plant chemicals tested, the inhibitory effects decreased in the order : citrol=carvacrol > citronellol = farnesol = geraniol = Eucalyptus oil > neem oil = cymbopogan oil. These chemicals served as volatile anti-ovipositants and did not reduce the arrival or stay of the insects on cotton. Carvacrol had a slight toxic effect on the nymphs, but none of the volatiles was toxic to the adults.

Lemongrass

Kayumov (1937) tried some essential oils against the pests of cotton. When emulsions of the oils of Dracocephalum moldavica, Pelargonium roseum, Salvia sclarea, Coriandrum sativum, Cymbopogan citratus, Lippia citriodora and Lavandula-officinalis were sprayed on Tetranychus telarius L., on potted cotton plants and Aphis gossypii Glov., on cut leaves of pumpkin, all the above mentioned oils showed scorching symptoms at 2 per cent concentration. When applied at 2 per cent emulsion the oils of D. moldavica, C. citratus and Lippia killed over 90 per cent of the mites in 24 hours and other oils killed 50 to 80 per cent, whereas, all the oils killed over 90 per cent of the aphids. Oils of Cymbopogan and Pelargonium at 3 per cent emulsions caused scorching of the foliage over 93 per cent and it lead to the death of

the plant. So he suggested that these oils can be applied only to the weeds. Even at a concentration of one per cent, oils of Lippia and Lavandula killed over 67 per cent of mites and oil of Lippia killed 92.7 per cent of aphids. He has also conducted some experiments to see the feeding behaviour of test insects on test plant. He concluded that when T. telarius were artificially infested to plants like P. roseum., L. officinalis, Satureia hortensis, D. moldavica, S. sclarea, four species of Occimum and Trachyspermum copticum, they were survived and developed normally only on P. roseum and P. gossypii, fed readily only on S. sclarea.

Asari and Thomas (1974) examined the effects of aqueous extracts of five locally available plant materials against brinjal pests; these extracts were applied in spray form for five times at intervals of 15 days and the mortality counts of aphids (Aphis gossypii Glov.), shoot and fruit borer (Leucinodes orbonalis) and leaf rollers (Autoba olivacea (wlk)) at intervals of ten days were recorded. They found that none of the extracts was effective against fruit borer and leaf roller, but an extract of Lemongrass (Cymbopogon sp.) prepared by grinding 10 g of green leaf in one litre water caused a statistically significant reduction in aphid population (0.30) at five per cent concentration, when compared to control(1.37).

Singh et al. (1976) reported that the fractions of 23 species of plants acted as synergists for pyrethrins against the adults of Tribolium castaneum (Hbst). Extracts of Anethum sowa, Commiphora mukul, Cymbopogon martini var. motia, Quisqualis indica and Thevetia neriifolia were found as synergists.

Datura

Rajendran and Gopalan (1979) reported the insecticidal activity of acetone extracts of Acorus calamus, garlic, Datura stramonium and Ocimum sanctum by topical (or) oral application to 5th instar nymphs of Dysdercus cingulatus (F)., 3rd instar larvae of Spodoptera litura and Pericallia ricini (F). In case of extracts of rhizomes of Acorus calamus they have recorded 100 per cent mortality of D. cingulatus nymphs at dosage of 7 μ l per nymph and at 4 μ l per dose, 15 per cent of nymphal mortality and 82.5 per cent mortality recorded during the nymph adult moult. Extracts of all the four plants caused significant mortality in S. litura. Garlic was found to be the most effective by giving 90.05 per cent mortality at 5 μ l per larva. The garlic extract also killed P. ricini fed on castor leaves treated at 0.7 μ l per leaf which resulted in 100 per cent mortality. D. stramonium at 50 μ g per nymph caused 15 per cent mortality and at higher concentration i.e., 250 μ g per nymph caused 75 per cent mortality of Spodoptera litura.

2.1.2 Antifeedants

The use of insect antifeedants offers a hope for protection of field crops and stored grains from insect attack, because they are quite specific and have low mammalian toxicity. To aid in the protection of stored products from insect attack, there is a continuing need for repellents and antifeedants that are more effective, more persistent and economical than the existing synthetics available.

Neem

Mane (1968) studied the efficacy of aqueous suspensions of neem seed kernels as an antifeedant against the larvae of Euproctis lanata Wlk., Spodoptera litura F., Utethesia pulchella L., and the adults of Acrida exultata Wlk, and Aulachophora foveicollis, which are leaf feeding pests. In tests with neem seed suspension spray against E. lanata, it was found that absolute protection to castor leaves could be offered at the concentration of 0.5 per cent, with regard to the caterpillars of S. litura, it was found that 2.5 per cent neem kernel suspension was effective against third instar larvae by reducing the feeding to the extent of 79.2 per cent. Repellent action of neem seed suspension was also observed to be fairly effective against the caterpillars of U. pulchella, it was found that 3.0 per cent concentration protected the foliage to an extent of 70.9 per cent.

Sarup and Srivastava (1971) observed that, the stored neem seed kernels were damaged by some of the stored grain pests, like Oryzaephilus surinamensis, which caused 100 per cent damage, Rhizopertha dominica which could cause only nine per cent damage, but they were unable to complete their development, whereas in case of Corcyra cephalonica the larvae just nibbled a few kernels. They conducted an experiment with damaged neem kernels (by O. surinamensis) to compare the antifeedant activity of damaged neem kernels and fresh neem kernels at concentrations of 0.1, 0.5 and 1.0 per cent against Schistocerca gregaria by spraying on potted cabbage plants. Based on the results they concluded that there was practically no difference in the amount of feeding in plants treated with the suspension prepared from either healthy or damaged neem seed kernels. They also reported that the active antifeeding principles such as meliantol and azadirachtin are probably not affected in the neem seed kernel as a result of damage caused by O. surinamensis.

Attri (1975) conducted an experiment to compare the antifeedant properties of neem oil extractive - a byproduct of the refinement of neem oil for soap or pharmaceutical purposes and water extract of neem seed kernel. He found that the water extract inhibited the feeding of Schistocerca gregaria when sprayed on their host plants. Based on the results he concluded

that the reason for this is active substance present in neem seed was hydrophilic in nature rather than lipophilic. So absolute deterency was achieved at as high as 2 per cent oil extractive whereas, it was as low as 0.05 per cent with water extract of the kernel.

Attri and Singh (1977) carried out some experiments to see the loss of antifeedant activity with time and temperature under storage conditions. The minimum concentrations tested for absolute feeding deterency to adult of Schistocerca gregaria, of water suspensions of kernels for 2, 12, 24, 36 and 84 months old were 0.04, 0.06, 0.20, 0.60 and 1.2 per cent respectively and that of suspensions of cakes 2, 12, 24 months old respectively, were 0.03, 0.05, 0.1 per cent. They concluded, **heat** treatment does not affect the antifeedant property of neem seed kernels.

Rembold et al. (1980) observed the antifeedant and growth disruption activities of partially purified fractions of neem seed viz., N N 18-704 and NN-18-701C against Epilachna varivestis Muls; Ephestia kuehniella Zell and Apis mellifera. Results showed that both fractions caused **severe** growth disruptions without acute toxicity, but only NN-18-704 exhibited a slight antifeedant activity. The 2 fractions interfered with larval and pupal development, induced pupal and adult malformations and resulted in a high rate of mortality. In the

larvae of Apis mellifera, one-tenth of the dose was effective, ~~and~~ for the other two species., caused disruption of larval development and a reduction in the rates of caste determination with insects and survival.

Chari and Muralidharan (1985) showed that neem kernel suspension at 2,3, and 5 per cent concentrations and neem leaf suspension at concentrations of 5 and 10 per cent had anti-feedant activity, on 4th instar larvae of the noctuid Achoea janata, a pest of castor. It was found that the larvae did not touch the treated food till 24 hours and larvae moved to treated food after 48 and 72 hours when the food in the untreated control was exhausted. Excreta was produced only at the lowest concentration of the neem leaf extract. In the untreated control, the leaves were completely devoured. They suggested that neem seed suspension at 2 per cent or neem leaf extract at 10 per cent would be an effective and economical treatment for the control of the pest.

Dhandapani et al. (1985) reported the antifeedant properties of some plants from India against different insects. It was found that the neem seed kernel extract at 3 per cent concentration reduced feeding activity of chewing insects such as the pyralid Cnaphalocrosis medinalis, the lymantriid Psalis pennatula, the satyrid Melanitis ledaismene, the

hesperiid, Pelopidas mathias and the arctiid, Pericallia ricini. However, neem products were ineffective against sucking insects such as Aphis sp., the cicadellid Amrasca biguttula biguttula and the Noctuid Erias sp. In studies on the emulsion concentrates of 5 different plant extracts, neem oil and leaf extracts of neem, Parthenium, Vinca rosea and Solanum xanthocarpum on the Coccinellid Henosepilachna vigintiocto punctata, neem oil resulted in a 63 per cent reduction in the population. Leaf extracts of Cyperus rotendus and Cynodon doctylon showed anti-feedant activity against larvae of the arctiid Amsoceta albistriga.

Lidert et al. (1985) reported that Azadirachtin from Azadirachta indica and Praeuriarinin (and its artificially produced acetate) from the bark and stem wood of Nymania capensis exhibited strong antifeedant activity (90-100%) at the highest concentrations of 19.8 $\mu\text{g per cm}^2$, till two days. Even at the lowest concentrations viz., 6 $\mu\text{g per cm}^2$ and 1.5 $\mu\text{g per cm}^2$ it showed antifeedant activity against the tobacco bud worm (Heliothis virescens), the southern army worm (Spodoptera eridania) and the mexican bean beetle (Epipoly stachya).

Tewari and Moorthy (1985) stated that the petroleum ether extracts of the drupes of Melia azadirachta or the rhizomes of Acorus calamus or the seed oil at the concentrations ranging from 0.05 to 0.50 per cent showed varying degrees of antifeedant activity against both the larvae and adults of Henosepilachna

vigintioctopunctata which are the important pests of solanaceous and cucurbitaceous crops both the extracts and the oil at 0.1 and 0.3 per cent gave 100 per cent protection to leaves.

According to Verma and Singh (1985) 0.1 per cent aqueous extract of the leaves of sacred basil (Ocimum sanctum) or 0.1 per cent water emulsion of the seed oil of neem, pongamia, (Pongamia pinnata) or bold seeded mustard (Brassica juncea) showed antifeedant activity against the 4th instar larvae of Amsacta moorei an important pest of rainy season crop in arid and semi-arid regions. Based on results they have concluded that the 0.1 per cent neem seed oil was the most effective antifeedant followed by 0.1 per cent pongamia oil.

Eucalyptus

Abivardi and Benz (1984) screened the extracts of 21 common medicinal plants to find out the antifeedant activity against the larvae of Pieris brassicae by binary choice and non-choice studies. The studies revealed that some extracts showed significant antifeedant activity, those extracts being Mentha piperita, Angelica archangelica, Eucalyptus sp., Artemisia absinthium and Melissa officinalis.

Datura

Nadasy and Sringer (1985) reported the inhibitory effects of Saps of various plants on feeding by the curculionid, Sitona humeralis. The sap was pressed from different parts of plants and smeared on lucerne leaves. Sap from roots, stalks, flowers and fruits of various Papilionaceous plants inhibited feeding on the lucerne leaves, the strongest effect being shown by the sap from the flowers. According to them, of the saps pressed from plants other than Papilionaceae those obtained from Petunia sp. (Solanaceae) had the strongest inhibitory effect on adult feeding. Lucerne leaves smeared with sap from the leaves of non-food plants such as Avena fatua (Graminae) and Datura stramonium (solanaceae) were consumed by the pest to some extent.

2.1.3 Repellents

Neem

Mansour and Ascher (1983) proved the repellent activity of neem seed kernel extracts, extracted with different solvents and aqueous extracts in carmine spider mite.

Tetranychus cinnabarinus by treating the bean (Phaseolus vulgaris) leaves with different concentrations of neem extract. Based on the results they have concluded that these extracts made females to get repelled from treated surface and also oviposition was reduced. On the basis of the EC_{50} for both parameters the order of decreasing effectiveness of the solvents was pentane (0.04 and 0.05%) chloroform (0.05, 0.08%) N-butanol (0.14, 0.11%) and methanol (0.37 and 1%), respectively. The aqueous extracts were found to be ineffective. They also said that the activity of the extracts decreased with increasing dielectric constant of the solvent. The chloroform and butanol extracts were found to be phytotoxic. Pentane and acetone extracts caused mortality and reduced the fecundity of the females even after seven days of spraying, but did not repel them when sprayed directly on to the females on bean leaf discs. These solvents acted as repellents, toxicants and reduced the fecundity of mites.

Eucalyptus

Ahmed and Eapen (1986) studied the 2 aspects i.e., vapour toxicity and repellency of some essential oils to insect, pests. Of the essential oils screened, those from Gaultheria, dill (Anethum graveolens), Japanese mint (Mentha sp.)

Eucalyptus and Cinelone, Harpentines were found to be promising against Musca domestica, Callosobruchus chinensis by showing 100, 98 per cent mortality in case of Gaultheri, 82, 100 per cent mortality incase of Eucalyptus, Cinelone showed 100, 100 per cent mortality against the above mentioned insects, respectively. In case of Eucalyptus the per cent repellency recorded was 80 per cent after 10 minutes 50 per cent after 30 minutes and after 60 minutes it decreased to 20 per cent, these essential oils were also found to be effective against Sitophilus oryzae and Stegobium paniceum.

Lal (1987) reported the repellent properties of the leaves of Ambrosia artemisiifolia, Anemone elongata, Eupatorium odoratum, Eucalyptus globulus and Lantana aculeata against the gelechiid Phthorimaea operculella Zell. infesting stored potatoes. They compared the effects of essential oils with a microbial insecticide (0.2% suspension of Bacillus thuringiensis) and a chemical insecticide (0.1% carbaryl) the tubers were covered in a 2.5 cm layer of dried and crushed leaves of the plant species. After six months of storage the results indicated that the leaves of Lantana camara provided good protection, by reducing tuber damage to below five per cent and sprout damage to below three per cent compared with 70 per cent and 45 per cent, respectively. In the untreated control. The most effective treatment was

Eucalyptus globulus followed by B. thuringiensis. They have also reported that none of the treatments had any adverse effect on germination or yield of the subsequent crop.

Mustard

Metzger and Trier (1973) have given details of the tests in which the degree to which various compounds attracted or repelled the adults of Pegomyia betae Curtis. Results showed that none of the plant amino acids and other compounds tested attracted the flies in sufficient measure to be of practical use; with most of them an increase in concentration was accompanied by an increase in repellent effect. Butylacetate and mustard oil were found to be repellents at low concentrations.

Pandey and Chatteraj (1976) examined insecticidal anti-feedant and repellent properties of some plant origin insecticides against the larvae of Utethesia pulchella which feeds on Heliotropium indicum (though up to 65% of the larvae are unable to complete their development on this plant), Melilotus indica, Crotolaria mysorensis and C. juncea. Based on the results they reported that the water extracts of Heliotropium indicum killed 56 per cent of the young larvae, but did not affect 5th and 6th instar larvae; fifth instar larvae were repelled when the water extracts of tobacco leaves were smeared on the leaves of C. juncea they were also repelled by the leaves of C. juncea that had been smeared with mustard oil.

2.2 Test insect rice moth (Corcyra cephalonica (Stnt))

2.2.1 Damage done by rice moth and its biology

This pest has a very wide range of distribution in all the rice growing areas of the world including India, Pakistan, Burma and Ceylon (Sri Lanka). It is a serious pest of stored rice and jowar and thrives well in humid climate. Now it has been recorded as a pest of considerable importance on other stored food stuffs like cereals and pulses, oil seeds and oil cakes, dried fruits, cocoa, chocolate and biscuits, suji, wheat flour etc. Besides polluting food grains with copious quantities of frass and silken tubes webbing together the food grains into large lumps, The presence of the fleshy larvae leads to serious public discrimination. Rao (1957) reported that in case of infestation of groundnut kernels by Corcyra cephalonica, the changes effected are, decrease in thiamine content , reduction in the viability of seeds; reduction in the yield of oil and increase of fat percentage. It is further reported (pest inf . Res. Report 1954) that the damage caused by Corcyra cephalonica to decorticated nuts is responsible for mouldiness and caking of nuts.

Avilespacheco and Acevedo (1983) reported the nature and extent of damage caused by the larvae of Corcyra cephalonica (Stnt.) to polished rice of different industrial qualities.

They reported that feeding by the larvae on surface of the grains caused these to stick together in clumps, which contained intact and broken grains, exuviae, silken threads, dust and detritus. They have calculated that each larvae gave rise to some 4 to 6 clumps and a single larvae completes it's development (in 250 g rice) by contaminating 7'g of grain by forming clumps. When more than 16 larvae were developing in 250 g, a change in the colour of rice was noticed, together with an unpleasant odour.

2.2.2 Biology

General behaviour

Observations made by Seshagiri Rao (1956) indicated that the larval development is more rapid, but the mortality is higher during the periods of high temperature and low relative humidity and the development is slower but the rate of emergence is higher when the temperature is low and humidity high as in the monsoon and winter months.

Fecundity

Thomas (1961) said that the adults copulate within a day or two of emergence and start laying eggs. The author further reported that the egg laying is stimulated if the adult females have an access to water. Pruthi and Mohan Singh (1950) stated

that eggs are laid indiscriminately and a single female may lay about 90 to 200 eggs. While Seshagiri Rao (1956) reported that the bigger moths laid more eggs than the smaller ones, the average numbers being 139 and 93 per female, respectively and in both the cases, eggs were laid till the death of the moth and the presence of food for the moths was not essential for oviposition.

Incubation period

The incubation period varies from 3 to 5 days according to Pruthi (1950) and Thomas (1961).

Larval period

It is completed in about 23 to 35 days sometimes extending up to 50 days as observed by Pruthi (1950) and from 48 to 60 days as observed by Seshagiri Rao (1956).

Pupal period

It occupies 10 days as an average as recorded by Pruthi (1950) and Thomas (1961).

Adult longevity

The moth is short lived with a life span of 7 to 15 days. Seshagiri Rao (1956) reported that males and females lived on an average 4.8 to 7.2 days, respectively.

2.3 Control of rice moth *Corcyra cephalonica* (Stnt) by using

2.3.1 Plant products

The loss of food grains during storage due to this pest is a serious problem. Control of insects by insecticides has serious drawbacks, such as the development of resistant strains, toxic residues, workers safety and increasing costs. In ancient times, some plant origin insecticides like seed oils, leaf powders etc. were used to protect stored grains from insect attack. In recent years, attention has been given to the control of stored grain pests with plant origin insecticides to overcome the problems with synthetic insecticides.

Trematerra et al. (1983) examined the activity of four plant ecdysones (α -ecdysone, β -ecdysone, macisterone and muristerone-A) against the stored product moths *Ephestia cautella* (Wlk), *E. kuehniella* Zell and *Corcyra cephalonica* (Stnt) which were reared on a diet containing maize flour, wheat flour, wheat bran, brewer's yeast, wheat germ, a vit mixture, Wessen's salts, glycerine, and honey treated with the test ecdysones. According to them all the four had similar effects differing mainly in degree and timing. Eggs in contact with the treated diet failed to hatch, the larvae and pupae died or showed malformations after having fed on it and the adults were malformed or showed total or partial sterility with no egg hatch.

Pandey et al. (1985) observed the effect of neem (Azadirachta indica A. Juss) oil, powdered kernels, cake, leaves, flowers and Babulgum (Acacia arabica) when mixed with wheat (Triticum vulgare Host) seed at the rate of 0.1, 1.0, 5.0, 1.0, 0.5 and 1.0 parst (w/w or w/v) respectively, per 100 parts of seed. Treated seeds proved to be protectants against Corcyra cephalonica by causing adverse effects on the developmental period, high mortality, less per cent of adult emergence with less number of females. Some of the adults emerged from the seeds treated with kernel powder and oil had crumpled (or) undeveloped wings. In the treated seeds the developmental periods of larvae, pupae and complete development were considerably increased viz., 35.00 to 53.33, 10.83 to 13.33 and 46.00 to 65.08 days, respectively. When compared to control i.e., 34 to 37, 10.33 to 11.66 and 45.33 to 48.3 days respectively. The per cent adult emergence (16.66 to 31.66%) heavily decreased in treated seeds while it was 61.66 to 70.00 per cent in the untreated seed and 53.23 to 50.00 per cent in the seeds treated with babulgum.

The damage done by 20 larvae during their development was found to be 37.00 to 40.00 g in untreated seed, which was protected from 67.30 to 87.42 when seeds were treated with various products of neem with neem kernels proved to be most effective while the leaves, the least. The germination

of the treated seeds was not impaired in any case during the exposure period of about four months.

Pandey et al. (1985) conducted an experiment to see the behaviour of Corcyra cephalonica adults. Wheat seeds mixed with different neem products viz., oil, powder of kernels, cake, leaves and flowers and also babulgum (Acacia arabica Wild) at the rate of 0.1, 1.0, 5.0, 1.0, 0.5 and 1.0 parts (w/w or w/v) per 100 parts of wheat seed. The results showed that the treated seeds acted as ovipositional deterrents and less fecundity was recorded. The eggs laid by moths were minimum (73.66) in case of neem kernel powder which was followed by neem oil, flower powder, cake powder, leaf powder being 75.66, 84.33, 10.33 and 113.66 eggs, respectively. Babulgum was also found to be effective in reducing the oviposition by giving less number of eggs (187.66) in comparison to control (240 eggs). Other than ovipositional deterrence and fecundity it also showed some other effects like survival period, and fertility of the adults, which on treated seed, were reduced in comparison to the adults developed on untreated seed, they have also observed that the germination power of seed was not impaired in any treatment.

Chander and Ahmed (1987) evaluated the effectiveness of natural embelin isolated from berries of Embelia ribes as grain protectant of wheat in storage. More than 50.0 per cent

of mortality of Sitophilus oryzae adults was observed in wheat grains when treated with embelin at 0.025 per cent. The F_1 progeny was reduced in treatments. However, productivity (progeny/21 adult days) in treatment was not significantly different from the controls. In case of Rhizopertha dominica they have recorded 50 per cent adult mortality at 0.025 per cent concentration after 1 day and three months of storage and both progeny and productivity were reduced significantly at all the concentrations. After 8 months of storage, only highest concentrations of 0.1 per cent exhibited appreciable adult mortality. F_1 progeny and productivity were significantly low with all concentrations of embelin against larvae of Corcyra cephalonica and Ephestia cautella. A 0.0125 per cent concentration retained its effectiveness even after 8 months, while concentrations of 0.05 and 0.1 per cent offered good protection against Trogoderma granarium.

2.3.2 Chemical pesticides

According to Dale and Saradamma (1974) fentin acetate had insecticidal and chemosterilant action against the first instar larvae of Corcyra cephalonica. They released the first instar larvae into treated wheat flour with fentin acetate at 0.0025 to 0.04 per cent concentration at 0.02 to 0.04 per cent, mortality per cent recorded was 100 and at 0.01 and

(in brackets) 0.0025 per cent, it averaged to 80.0 per cent (20%). The duration of development was 44.2 (39.7) days, the ratio of adult males to females being 1:0.50(1:1.40) and the fecundity 63 (311) eggs laid per female as compared with 6.6 per cent, 37.8 days. 1:1.63 and 386 eggs per female, for no treatment. Practically all the eggs laid by treated and untreated females hatched.

Srivastava et al. (1975) reported that 45 days old larvae of Corcyra cephalonica (Stnt) when immersed for 15 minutes in 0.5 per cent aqueous solution of chemosterilants viz., hempa, tepa, thiotepa and metepa, it was found that hempa was the most effective chemosterilant (resulting in 98.74% sterility of subsequent adults) followed by thiotepa (92.92%) and tepa (88.36%), as metepa cause high larval and pupal mortality, its effectiveness as chemosterilant could not be evaluated.

Bitranand Campos (1975) conducted a fumigation test of methyl bromide and phosphine gas. They found that these chemicals gave good control of all states of Corcyra cephalonica at 25 ml per m³ concentration (with an exposure time of 24 hours) phosphine gas was found to be less effective when compared to methyl bromide.

Bitran and Oliveira (1977) reported the effect of high humidity on malathion. Malathion at the rate of 8 ppm was mixed to coffee beans infested with Corcyra cephalonica (Stnt) and Araecerus fasciculatus (Deg). The treated grains were stored for 6 months in small jute sacks and were kept in screen cages in ware house where the relative humidity was maintained throughout at about 90 per cent. At the end of the test, they observed that when the humidity was raised to more than 15 per cent, malathion had not remained stable and the development of the pest had been in no way inhibited, as compared with the development in untreated beans stored under same conditions. A highly significant correlation was found between the per cent weight loss of the samples and the per cent of the damaged beans.

Yadav (1980) reported the toxicities of P, P-DDT, lindane and malathion to 13 species of stored product pests. Based on the calculated LC_{50} values DDT was the most toxic to Cryptolestes minutus (12.5) followed by Callosobruchus chinensis (L.) (25.60) Stegobium paniceum (L) (26.33), Rhizopartha dominica (F). (39.86), Corcyra cephalonica (Stnt). (64.03), etc. DDT was found to be less toxic to Trogoderma granarium Everts (29270.00). Lindane was most toxic to C. minutus (11.55) followed by S. paniceum (22.29), T. granarium (28.02) and C. cephalonica (35.40) etc. and

it was least toxic to Tribolium castaneum (3000.00). In case of melathion the mortality was more in C. minutus only (0.581) and it was less toxic to T. castaneum (17.30).

Pawar and Yadav (1982) carried out some experiments to determine the toxicity of 6 organophosphorus insecticides with low mammalian toxicity [Phoxim (Baythion)], Bromophos fenitrothion, iodo fenphos, malathion and pirimiphosmethyl to 1 day old, 10 day old and 20 day old larvae and also adults of the stored product pests, Ephestia cautella (Wlk) and Corcyra cephalonica. On the basis of calculated LC_{50} values Phoxim was the most toxic to E. cautella while fenitrothion was the most toxic to C. cephalonica (0.468 33.03, 269.10 being the LC_{50} 's 1, 10, 20 days old larvae). Phoxim was found to be ineffective against 30-day old larvae of C. cephalonica. Melathion was also toxic to the larvae of C. cephalonica (0.839, 75.88, 356.30 to 1,10,20 day old larvae), but it was found to be ineffective against E. cautella.

MATERIAL AND METHODS

III. MATERIALS AND METHODS

3.1 Maintenance of test insect culture (*Corcyra cephalonica*)

The test insect used was the rice moth, [*C. cephalonica* (Stainton)]. The nucleus culture was collected from the Central Biological Control Station (CBCS) (of the Directorate of Plant Protection and Quarantine, Government of India), Ganganagara, Bangalore. According to recommendations 0.5 cc of eggs were used to infest 1 kg of broken jowar grain. The culture was maintained in *Corcyra* rearing boxes (Plate 1). In each box three kg of grain was put and the grains were infested with one-and-half cc of eggs of rice moth, (Plate 2). Adults that emerged out were collected in glass specimen tubes (3 cm x 1 cm) and transferred to egg laying cages. The eggs laid were collected in petri dish. Eggs were cleaned with a camel hair brush and healthy eggs were use to infest the fresh jowar grain to build up the culture. Fresh broken jowar grain was infested with freshly laid eggs at different dates to get different instars of larvae at a time for experimental purposes (Plate 3).

3.2 Plant products/extracts

The following five species of plants were used to evaluate the insecticidal, antifeedant and repellent properties against the test insect, *C. cephalonica* (Stnt) (Table 1).

Plate 1: Corcyra rearing boxes: Maintenance of culture.

Plate 2: Differences between healthy and infested grain of jowar by Corcyra cephalonica (Stnt) I



Plate 3: Life cycle of rice moth [Corcyra cephalonica (Stnt)]

- 1) Eggs
- 2) Five different larval instars
- 3) Pupa
- 4) Adults (Male and Female)



Table 1. List of plant extracts used for the study

Botanical name	Common name	Family	Plant part
<u>Azadirachta indica</u>	Neem	Meliaceae	Seed
<u>Brassica juncea</u>	Mustard	Brassicaceae	Seed
<u>Cymbopogon citratus</u>	Lemongrass	Poaceae	Leaf
<u>Datura Stramonium</u>	Datura	Solanaceae	Seed
<u>Eucalyptus citriodora</u>	Eucalyptus	Myrtaceae	Leaf

Of the above plant products, mustard oil was extracted at the local oil mills. The essential oils of lemongrass and eucalyptus were procured from the CIMPO, NAL Campus, Indiranagar, Bangalore.

3.2.1 Extraction procedure for datura seed and neem seed cake
Apparatus and materials required for extraction of plant products

1. Datura seeds
2. Neem seed cake
3. Oven
4. Waring blender, Sieve
5. Soxhlet apparatus
6. Cloth bags
7. Petroleum ether BP 40° - 60°C
8. Glass beakers (250 ml) Funnel
9. Filter paper (Whatman No.1)
10. Steam distillation apparatus
11. Thermometer

Collection and Drying

Datura seeds were collected around paddy fields M.R.S., Hebbal, Bangalore. Whereas neem seed cake was obtained from Mr. Ketkar, Pune, India. The collected datura seeds were dried in oven at 60°C temperature.

Grinding - the dried seeds were ground in a waring blender into fine powder.

Extraction: Weighed amount of the seed powder was filled in cloth bags and was kept in soxhlet apparatus jar (Plate 4) and then the jar was filled with petroleum ether which was used as the solvent. This was run for 48 hours and the extracted product was collected into other beaker, and filtered to remove foreign matter. The filtered extract was then subjected to steam distillation (Plate 5) to remove the solvent (Petroleum ether). This was run for 5 - 7 hours at temperature 40° - 50°C, and the extract was used for experimental purposes.

In addition to these five plant products, malathion (cythion 50 EC) was used as a standard insecticide for comparison of the efficacies of the candidate plant products.

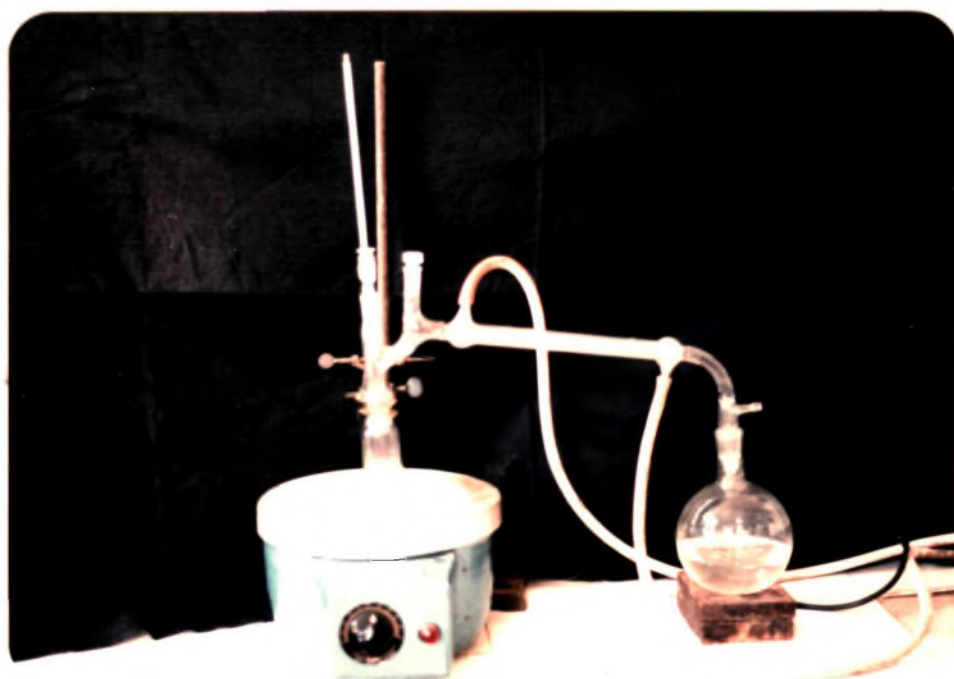
3.2.2 Details of the treatments

The plant extracts viz., mustard seed oil, datura seed oil, neem seed cake extract, eucalyptus and lemongrass essential oils were tested, each at four concentrations for their different properties viz., insecticidal, antifeedant, repellent, the feeding behaviour of the larvae of the test insect C. cephalonica (Stnt), was also studied.

To prepare different concentrations of these extracts, emulsified water (0.1 per cent labolene and 5 per cent benzene (as solvent)) was used as diluent to prepare different concentrations of plant extracts along with treatments, two controls (control I, distilled water and control II, emulsified water) were kept to observe the effect of emulsified water and natural mortality of test insect.

Plate 4: Soxhlet apparatus - For extraction of plant extracts.

Plate 5: Steam distillation apparatus: To recover petroleum ether from plant extract.



Concentrations tried

<u>Plant extracts</u>	<u>Per cent</u>
Mustard seed oil	1.5, 2.5, 3.5, 4.5
Neem seed cake extract	1.5, 2.5, 3.5, 4.5
Datura seed oil	2.0, 4.0, 6.0, 8.0
Lemongrass essential oil	1.5, 2.5, 3.5, 4.5
Eucalyptus essential oil	0.5, 1.0, 1.5, 2.0
Melathion Cythion 50 EC	0.5

3.2.3 Insecticidal properties of plant products against rice moth

The toxicity of different extracts was determined by the topical application of the respective concentrations of each extract at 2 ml solution on different larval instars of rice moth (second, third, fourth and fifth instars) by using potters tower (Plate 6). Ten larvae were used per replicate and the number of replicates was four. The untreated check received water and emulsified water spray. The mortality counts were taken after 24, 48, 72 hours interval. The data was analysed by factorial experiment with interaction. Comparisons were made between different concentration of plant extracts and among different plant extracts were made by student - Newman - Keuls test (Zar, 1959). The comparisons between different larval instars were made by using latin square design method.

Plate 6: Potters tower : For spraying different concentrations of plant extracts on egg and larvae of test insect.



Lethal concentrations and regression equation were calculated from the mortality data by using probit analysis method described by Finney (1964).

Concentrations tried

<u>Plant extracts</u>	<u>Per cent</u>
Neem	1.5, 2.5, 3.5, 4.5
Mustard	1.5, 2.5, 3.5, 4.5
Datura	2.0, 4.0, 6.0, 8.0
Lemongrass	1.5, 2.5, 3.5, 4.5
Eucalyptus	0.5, 1.0, 1.5, 2.5
Malathion	0.5
Control-I (Distilled water)	-
Control-II (Benzene + Lobolene)	5.0 + 0.1 per cent

3.2.4 Determination of feeding behaviour of test insect on treated foods of different plant extracts

The experiment was conducted in two ways;

- i) Choice chamber test (Plate 7)
- ii) No choice chamber test (Plate 8)

Feeding behaviour experiment

Plate 7: Choice chamber test

Plate 8: No choice chamber test



3.2.4 a) Choice chamber test

Plastic tub of diameter 10 cm and height $4\frac{1}{2}$ cm was taken and the base was demarkated into six equal sized sections by cardboard pieces of height 1 cm. To each section 5 g of treated broken rice grains were provided, the following were the treatments (Table 2).

The experiment was replicated 4 times. As mentioned before 5 g of broken rice grains were taken and mixed with the respective concentrations of the candidate plant products. The grains thus treated were dried under an electric fan at room temperature.

In each replication, the treated grains were provided randomly to the 6 respective sections. Thirty six healthy, same sized 3rd instar larvae were released at the centre of the tub and were allowed to move freely. Then following observations were taken.

- i) The number of larvae that preferred to enter the food
- ii) The number of larvae that consumed the food this test was ensured by the formation of webs by the larvae.

Table 2. Concentrations (%) allotted to different sections of tub

Products	Concentrations (%)					
	Section					
	1	2	3	4	5	6
1. Mustard	1.5	2.5	3.5	4.5	Control (H ₂ O)	Control Benzene Lobolene
2. Datura	2.0	4.0	6.0	8.0	-do-	-do-
3. Neem	1.5	2.5	3.5	4.5	-do-	-do-
4. Lemongrass	1.5	2.5	3.5	4.5	-do-	-do-
5. Eucalyptus	0.5	1.0	1.5	2.0	-do-	-do-

3.2.4 b) No choice chamber test

The experimental procedure was similar to that of choice chamber test, but here the two controls viz., only water and water + benzene + laeolene - (treated food) were eliminated the number of larvae present in the empty sections was also recorded. The observed results were analysed by one-way analysis of variance method. Comparisions between concentrations of plant extracts and among different plant extracts were made by using student - Knewman - Keuls test (Zar, 1959).

3.2.5 Determination of feeding deterrent properties of selected plant products against the rice moth larvae

The antifeedant activity of the extract was investigated by the Highland's standard Insect Penetration Test (Highland et al., 1970) with slight modifications. Blotting paper was cut into discs of 4 cm diameter. The discs were sprayed with 1 ml of different concentrations of the plant products and were dried under electric fan at laboratory temperature. The tests were made on third instar larvae of Corcyra cephalonica (Stnt) with 4 replicates. Each penetration test unit consisted of 4 parts i.e., the base ring, the centre ring, a wire mesh disc and an upper ring (identical with the base ring). The treated blotting paper was inserted into the base ring and the center ring was placed on the blotting paper. The outer surface of

the centre ring fitted into the flange of the base ring and upper ring. Five larvae were introduced and then the wire mesh disc was placed on the centre ring to confine the insects, and was held in place by the upper ring. The number of holes punctured in the blotting paper discs were counted from the underside of the unit without opening it after 24, 48, 72 and 96 hours after the release of insects. Antifeedant activity was taken as being inversely proportional to the number of holes made by the larvae. Untreated paper discs were used as control. The data here also analysed by the same method that is mentioned earlier (Feeding behaviour experiment).

3.2.6 Repellent properties of different plant products against *C. cephalonica* (Stnt).

The repellency of different extracts was tested against the third instar larvae of *C. cephalonica* (Stnt) using the method discribed by McDonald et al. (1970). Filter paper strips (Whatman No.1, 4 cm x 8 cm) were treated with 1 ml of different concentrations of extracts in emulsified water and dried under electric fan at laboratory temperatures. The treated paper strips were joined length wise to untreated paper strips (4 cm x 8 cm) with cellotape on the reverse side, glass rings were placed on filter paper in such a way to cover half area of each treated and untreated paper to provide test arenas with equal areas of treated and untreated paper. Ten larvae of test insect were released in each test arena and the number of insects on treated and untreated papers was recorded after 10 minutes, 2 hours, 4 hours,

8 hours, 16 hours, 24 hours and 48 hours. Each treatment was replicated four times. The average per cent repellency was calculated by doubling the difference between the per cent of insects on the treated half and the 50 per cent distribution expected if only untreated papers were used (Gillenwater and McDonald, 1975). The repellency category was classified as Category I - 0.1 to 20.00, Category II - 20.1 to 40.0 Category III - 40.10 to 60.00 Category IV - 60.1 to 80.0 and Category V - 80.1 to 100.0 per cent repellance (McGovern et al., 1977).

Details of treatment for antifeedant activity and repellent activity

<u>Plant extract</u>		<u>Concentration (%)</u>
Mustard		1.5, 2.5, 3.5, 4.5
Datura		2.0, 4.0, 6.0, 8.0
Neem		1.5, 2.5, 3.5, 4.5
Lemongrass		1.5, 2.5, 3.5, 4.5
Eucalyptus		0.5, 1.0, 1.5, 2.0
Control -I	Distilled water	-
Control -II	Benzene	5 per cent

RESULTS

IV. RESULTS

4.1 Toxicological studies of plant products against eggs and different larval instars of the rice moth *Corcyra cephalonica* (Stnt).

The detailed experimental findings on the hatchability of eggs and mortality of the larvae of *C. cephalonica*, subjected to different plant products viz., neem, mustard, datura, eucalyptus, lemongrass, and malathion 50 E.C. (Cythion) being used as the standard insecticide for comparison are presented in Table 3-6.

4.1.1 Toxic effect of plant products on the hatchability of rice moth, *C. cephalonica*

The effect caused by different plant products viz., neem, mustard, datura, eucalyptus, lemongrass and malathion (as standard insecticide for comparison) on the hatchability of eggs of the test insect are presented in Table 3.

The analysed data showed that all the plant products tested were on par with one another, irrespective of their concentrations. Taking concentrations in to consideration, eucalyptus registered as the first plant extract in the order of toxicity followed by neem, lemongrass, mustard and datura.

Table 3. Effect of plant products on per cent hatchability of the eggs of rice moth [*Corcyra cephalonica* (Stnt)]

Plant extract	Conc. (%)	% Hatchability of eggs		
		No. of eggs treated	Average	Percent
Mustard	1.5	10	9.25(3.123) a	92.5
	2.5	10	9.00(3.080) a	90.0
	3.5	10	5.50(2.443) be	55.0
	4.5	10	*2.25(1.627) be	22.5
Datura	2.0	10	3.75(2.059) ae	37.5
	4.0	10	2.75(1.772) ae	27.5
	6.0	10	*1.50(1.403) abe	15.0
	8.0	10	0.25(0.837) b	2.5
Neem	1.5	10	4.25(2.177) ae	42.5
	2.5	10	*1.25(1.274) be	12.5
	3.5	10	0.25(0.837) b	2.5
	4.5	10	0.00(0.707) b	0.0
Lemongrass	1.5	10	*2.25(1.610) ae	22.5
	2.5	10	1.00(1.274) ae	10.0
	3.5	10	0.75(1.095) ae	7.5
	4.5	10	0.75(1.095) ae	7.5
Eucalyptus	0.5	10	3.50(1.914) ae	35.0
	1.0	10	*1.25(1.274) be	12.5
	1.5	10	0.50(0.966) b	5.5
	2.0	10	0.00(0.707) b	0.0
Malathion	0.5	10	2.75(1.762) e	27.5

Values in parenthesis are transformed values ($Y = \sqrt{x+0.5}$)

*: Best concentrations

Comparisions among best concentrations of plant extracts

• Eucalyptus	(1.0)	1.25 a
Datura	(6.0)	1.50 a
Mustard	(4.5)	2.25 a
Neem	(2.5)	1.25 a
Lemongrass	(1.5)	2.25 a
Malathion	(0.5)	2.75 a

a, b, c, d and e figures followed by the same letter are not significantly different

Eucalyptus caused a low percentage of hatchability of eggs. At 0.5 per cent, the hatchability was 35.00 per cent. By increasing the concentrations, per cent hatchability decreased significantly. At 2.0 per cent no eggs hatched. The per cent hatchability recorded at 1.0 per cent was 12.5, which was found to be on par with that caused at 2.0 per cent.

A 100 per cent mortality of eggs was observed, when neem was used at 4.5 per cent. This was found to be on par with 2.5 per cent which caused 12.5 per cent of the eggs to hatch.

As far as lemongrass was concerned all the concentrations tried were found to be statistically on par. However a maximum hatchability of 22.5 per cent (at 1.5%) and the minimum of 7.5 per cent hatchability (at 4.5%) were observed.

Mustard, when tried at 1.5 per cent, the per cent hatchability recorded was high (92.5%). The per cent hatchability observed at 4.5 per cent was not statically different from 1.5 per cent. A concentration of 3.5 per cent of mustard was found to be the best with the corresponding hatchability of 55.0 per cent, which is found to be on par with hatchability per cent at 4.5 per cent.

Datura was the least effective among all the plant extracts. The per cent hatchability at 2.0, 4.0 and 6.0 per cent were on par with one another. But at 8.0 per cent the hatchability per cent was on par with that of 6 per cent. So 6 per cent was considered as best concentration at which the hatchability recorded was 15.0 per cent.

Comparisons of the plant products with malathion revealed that the standard chemical was not significantly different from the plant products (irrespective of their concentrations) with respect to per cent egg hatch.

4.1.2 Toxic effects of plant extracts against different larval instars of *C. cephalonica* (Stnt) at 24, 48, 72 hours interval

The data on the mortality percentages of different instars of larvae was analysed by Factorial experiment with interaction. Pair wise comparisons were made between plant products and different larval instars with mean mortality of all instars and mean mortality of all plant products respectively by using student - Newman - Kuels test method (Zar, 1959).

a) Mortality observations of larvae 24 hours after the treatment

The results regarding mortality percentages of all larval instars that are affected by plant products were showed in Table 4.

Table 4. Toxic effects of plant products against different instars of the larvae of *C. cephalonica* (Stnt) after 24 hour of treatment.

Plant extract	Conc.(%)	Mortality								Mean mortality of larvae	% mean mortality of larvae
		2nd instar		3rd instar		4th instar		5th instar			
		Mean	%	Mean	%	Mean	%	Mean	%		
Mustard	1.5	1.00	10.00	1.25	12.50	2.25	22.50	0.25	2.50	1.19 a	11.88
	2.5	3.50	35.00	2.25	22.50	4.00	40.00	1.25	12.50	2.75 ab	27.50
	*3.5	5.75	57.50	4.25	44.50	4.75	47.50	2.00	20.00	4.19 bc	41.88
	4.5	8.75	87.50	6.50	65.00	6.50	65.00	6.25	62.50	7.00 ce	70.00
Datura	2.0	0.75	7.50	1.25	12.50	0.25	2.50	0.00	0.00	0.56 a	5.63
	4.0	1.50	15.00	3.00	30.00	1.00	10.00	3.75	37.50	2.31 ab	23.13
	*6.0	4.75	47.50	5.75	57.50	4.25	42.50	4.25	42.50	4.75 bce	47.50
	8.0	6.25	62.50	7.25	72.50	6.75	67.50	6.25	62.50	6.63 ce	66.25
Neem	1.5	1.00	10.00	1.25	12.50	1.25	12.50	1.00	10.00	1.13 a	11.25
	*2.5	3.75	37.50	1.75	17.50	3.25	32.50	1.75	17.50	2.63 ab	26.25
	3.5	5.75	57.50	4.75	47.50	3.75	37.50	2.25	22.50	4.13 be	41.25
	4.5	8.00	80.00	5.25	52.50	4.25	42.50	4.25	42.50	5.44 be	54.38
Lemongrass	1.5	2.00	20.00	1.25	12.50	1.25	12.50	0.00	0.00	1.13 a	11.25
	2.5	3.75	37.50	2.25	22.50	1.75	17.50	2.00	20.00	2.44 ab	24.38
	*3.5	5.75	57.50	5.75	57.50	4.50	45.00	4.50	45.00	5.13 bce	51.25
	4.5	6.25	62.50	7.00	70.00	5.50	55.00	4.75	47.50	5.88 ce	58.75
Eucalyptus	0.5	0.50	5.00	0.50	5.00	0.00	0.00	0.00	0.00	0.25 a	2.50
	1.0	2.25	22.50	2.00	20.00	0.25	2.50	0.00	0.00	1.13 a	11.25
	*1.5	5.50	55.00	4.25	42.50	1.00	10.00	1.25	12.50	3.00 b	30.00
	2.0	7.55	75.50	7.25	72.50	2.25	22.50	2.25	22.50	4.81 be	48.13
Malathion	0.5	8.25	82.50	8.25	82.50	9.00	90.00	8.00	80.00	8.38 e	83.75
Mean	-	2.11	21.10	2.01	20.10	1.79	17.90	1.62	16.20	-	-

*: Best concentration

Comparisons among best concentrations of plant extracts

Plant extract	% mean mortality
Neem (2.5%)	26.25 a
Eucalyptus(1.5%)	30.00 a
Mustard (3.5%)	41.88 a
Datura (6.0%)	47.50 abe
Lemongrass(3.5%)	51.25 ae
Malathion (0.5%)	83.75 e

Comparison between instars

Instar	% mean mortality
Second	21.10 a
Third	20.10 b
Fourth	17.90 c
Fifth	16.29 d

a, b, c, d and e, figures followed by the same letter are not significantly different.

Based on per cent mortality eucalyptus was found to be the most effective among all aplant extracts tried. The mean mortality percentage of larvae at 0.5 per cent was 2.50. At 1.0 per cent the mean mortality percentage was on par with that at 0.5 per cent. The concentrations at 1.5 per cent and 2.0 per cent were found to be on par, with respect to mean mortality percentage of larvae. Thus among all the concentrations tested 1.5 per cent was found to be the best at which the recorded mean per cent mortality of larvae was 30.00.

Lemongrass at 1.5 per cent gave the mean mortality per cent value of 11.25, while the 3.5 per cent and 4.5 per cent were found to be on par with each other. So the concentration of 3.5 per cent could be selected as the most preferable one wherein mean mortality percentage recorded was 51.25. With respect to the extent of mortality caused, neem seed cake extract ranked third. At 1.5 per cent the mean mortality percentage was found to be 11.25. When the concentration was increased to 2.5 per cent there was no significant differences in percentage mean mortality. At 3.5 and 4.5 per cent the percentage mortality was on par with each other. So the best concentration is 2.5 per cent at which 26.25 was the per cent mortality of larvae.

In case of mustard, 3.5 per cent was found to be the best concentration where in mean larval mortality percentage of 41.88 was recorded. This mortality percentages found to be on par with that caused by 4.5 per cent extract.

The least effective was datura. At 2.0 per cent the mean larval mortality percentage was 5.63. Among all the concentrations tested the concentration of 3.5 per cent was found to be the best in which case the percentage of mean mortality value was 47.5.

Comparisons among the best concentrations of plant products with malathion showed that the mortality percentages caused by the standard chemical was on par with those caused by eucalyptus (at 2.0%) datura (at 6%), lemongrass (at 3.5%), mustard (at 4.5%) and neem (at 2.5%).

b) Mortality of larvae with the treatment of plant products after 48 hours

Results obtained on the comparative efficacy of the different plant extracts in the mortality of the different instars of rice moth larvae after 48 hours of treatment are presented in Table 5.

It was evident from the data that eucalyptus was the most effective product. At 0.5 per cent the mean larval mortality percentage observed was 4.38 which was on par with mean larval

Table 5. Toxic effects of plant extracts against different instar larvae of *C. cephalonica* (Stnt) after 48 hours of treatment.

Plant extract	Conc.(%)	Mortality								Mean mortality of larvae	% mean mortality of larvae
		2nd instar		3rd instar		4th instar		5th instar			
		Mean	%	Mean	%	Mean	%	Mean	%		
Mustard	1.5	1.25	12.50	2.25	22.50	1.25	12.50	1.25	12.50	1.50 a	15.00
	2.5	4.75	47.50	2.75	27.50	4.25	42.50	2.75	27.50	4.00 ab	40.00
	*3.5	6.25	62.50	4.50	45.00	5.25	52.50	3.25	32.50	4.81 bc	48.10
	4.5	9.25	92.50	7.00	70.00	7.25	72.50	6.25	62.50	7.44 c	74.40
Datura	2.0	0.75	7.50	1.25	12.50	0.25	2.50	0.00	0.00	0.56 a	5.60
	4.0	2.00	20.00	3.75	37.50	1.50	15.00	3.75	37.50	2.75 b	27.50
	*6.0	4.75	47.50	6.25	62.50	5.75	57.50	5.75	57.50	5.63 c	56.30
	8.0	6.75	67.50	7.25	72.50	7.00	70.00	6.25	62.50	6.81 c	68.10
Neem	1.5	3.00	30.00	1.75	17.50	1.25	12.50	1.25	12.50	1.81 a	18.10
	2.5	5.50	55.00	3.25	32.50	3.25	32.50	1.75	17.50	3.44 a	34.40
	*3.5	6.00	60.00	5.00	50.00	4.25	42.50	3.75	37.50	4.75 ab	47.50
	4.5	8.25	82.50	6.00	60.00	5.00	50.00	5.75	57.50	6.25 b	62.50
Lemongrass	1.5	2.75	27.50	1.25	12.50	1.25	12.50	1.00	10.00	1.56 a	15.60
	2.5	5.00	50.00	2.75	27.50	2.00	20.00	2.25	22.50	3.00 b	30.00
	*3.5	6.25	62.50	6.25	62.50	5.00	50.00	5.25	52.50	5.69 bc	56.90
	4.5	7.25	72.50	7.50	75.00	6.50	65.00	6.00	60.00	6.81 c	68.10
Eucalyptus	0.5	1.25	12.50	0.50	5.00	0.00	0.00	0.00	0.00	0.44 a	4.40
	1.0	4.00	40.00	2.75	27.50	0.25	2.50	0.00	0.00	1.75 ab	17.50
	*1.5	6.00	60.00	4.75	47.50	1.00	10.00	1.25	12.50	3.25 bc	32.50
	2.0	8.25	82.50	7.50	75.00	3.00	30.00	2.25	22.50	5.25 c	52.50
Malathion	0.5	10.00	100.00	10.00	100.00	10.00	100.00	10.00	100.00	10.00 e	100.00
Mean	-	2.30	23.00	2.14	21.40	1.87	18.70	1.80	18.00	-	-

* : Best concentration

Comparisons among best concentrations of plant extracts

Plant extract	% mean mortality
Eucalyptus (1.5%)	32.50 a
Neem (3.5%)	47.50 ab
Mustard (3.5%)	48.10 ab
Datura (6.0%)	56.30 b
Lemongrass (3.5%)	56.90 b
Malathion (0.5%)	100.00 e

Comparisons between larval instars

Instar	% mean mortality
Second	23.00 a
Third	21.40 b
Fourth	18.70 c
Fifth	18.00 c

a, b, c, d and e, figures followed by the same letter are not significantly different.

mortality percentage at 1.0 per cent. But at 1.5 per cent the mortality percentage increased significantly. At 2.0 per cent the mean larval mortality percentage was 55.25 which was found to be on par with 1.5 per cent mean larval mortality percentage..

In case of lemongrass at 1.5 per cent the mean larval mortality percentage was 15.63. The per cent mortality at 2.5 per cent was on par with that of 1.5 per cent. By increasing the concentration to 3.5 per cent the per cent mortality also increased considerably, which was significantly different from the lowest concentration (1.5%), where as at highest concentration (4.5%) the mean larval mortality percentage was 68.13 which is on par with 56.88 per cent mean mortality at 3.5 per cent.

A 3.5 per cent concentration of mustard was found to be the best which caused a mean larval mortality of 48.13 per cent. The mean mortality percentage of larvae at 4.5 per cent was found to be on par with mortality percentage at 3.5 per cent. Neem was the next best plant product. The comparisons between different concentrations of extract showed that at 3.5 per cent concentration the mean larval mortality percentage found was 47.5, which was found to be on par with 62.5 per cent mortality at 4.5 per cent of extract. So 3.5 per cent could be selected as best concentration of neem.

In order of effectiveness datura was found to be the least effective one. When this extract was tested at lower concentrations (2%) the mean mortality percentage recorded was 5.625,

when this was compared with mortality percentages at 4 per cent, they were found to be significantly different from each other, and at 6 per cent also the mortality percentage was significantly different from the mortality percentage corresponding at 4 per cent. At the concentrations of 6 and 8 per cent the mortality percentages were on par with each other. The concentration of 6 per cent could be selected as best one.

c) Mortality of larvae with the treatment of plant products after 72 hours

The mortality percentages recorded after 72 hours indicates that eucalyptus, mustard, neem and lemongrass were on par with one another, whereas datura was found to be on par with mustard, neem and lemongrass irrespective of their concentrations used (Table 6).

In case of eucalyptus among the different concentrations tried, at 0.5 per cent and 1.0 per cent, the mean mortality percentages were found to be on par with each other. When concentration increased from 1.0 to 1.5 per cent also there was no significant increase in per cent larval mortality when compared with mortality per cent at 1.0 per cent. The mortality percentages at 1.5 and 2.0 per cent were also found to be on par with each other. The best concentration could be selected as 1.5 per cent at which 48.75 was the observed mean larval mortality percentage.

Table 6. Toxic effects of plant extracts against different instars of larvae of *C. cephalonica* (Stnt) after 72 hours of treatment.

Plant extract	Conc.(%)	Mortality								Mean mortality of larvae	% mean mortality of larvae
		2nd instar		3rd instar		4th instar		5th instar			
		Mean	%	Mean	%	Mean	%	Mean	%		
Mustard	1.5	3.50	35.00	3.00	30.00	2.50	25.00	1.75	17.50	2.69 a	26.90
	2.5	6.00	60.00	4.25	42.50	4.50	45.00	3.50	35.00	4.56 ab	45.60
	*3.5	7.25	72.50	5.50	55.00	6.25	62.50	4.50	45.00	5.88 bc	58.80
	4.5	9.75	97.50	8.50	85.00	7.75	77.50	7.00	70.00	8.25 ce	82.50
Datura	2.0	3.00	30.00	3.00	30.00	1.00	10.00	0.75	7.50	1.94 a	19.40
	4.0	5.75	57.50	5.25	52.50	3.75	37.50	4.75	47.50	4.80 b	48.80
	*6.0	8.75	87.50	8.25	82.50	7.50	75.00	6.25	62.50	7.69 bce	76.90
	8.0	10.00	100.00	10.00	100.00	8.75	87.50	8.00	80.00	9.19 ce	91.90
Neem	1.5	3.75	37.50	2.50	25.00	2.25	22.50	2.00	20.00	2.63 a	26.30
	2.5	6.00	60.00	4.75	47.50	4.50	45.00	4.00	40.00	4.81 ab	48.10
	*3.5	7.25	72.50	7.00	70.00	5.25	52.50	5.25	52.50	6.19 bc	61.90
	4.5	9.50	95.00	8.75	87.50	7.00	70.00	6.75	67.50	8.00 ce	80.00
Lemongrass	1.5	3.50	35.00	2.50	25.00	2.50	25.00	2.00	20.00	2.63 a	26.30
	2.5	6.25	62.50	4.75	47.50	4.50	45.00	3.75	37.50	4.81 ab	48.10
	*3.5	7.00	70.00	6.25	62.50	7.00	70.00	5.75	57.50	6.50 bc	65.00
	4.5	8.75	87.50	8.25	82.50	8.25	82.50	7.75	77.50	8.25 ce	82.50
Eucalyptus	0.5	3.25	32.50	2.25	22.50	0.50	5.00	0.75	7.50	1.69 a	16.90
	1.0	5.00	50.00	4.25	42.50	1.75	17.50	1.25	12.50	3.06 ab	30.60
	*1.5	7.50	75.00	6.75	67.50	2.50	25.00	2.75	27.50	4.88 bc	48.80
	2.0	8.75	87.50	8.50	85.00	3.25	32.50	3.25	32.50	5.94 c	59.40
Malathion	0.5	10.00	100.00	10.00	100.00	10.00	100.00	10.00	100.00	10.00 e	100.00
Mean	-	2.64	26.40	2.48	24.80	2.27	22.70	2.11	21.10	-	-

* : Best concentration

Comparison among best concentrations of plant extracts

Plant extract	% mean mortality
Eucalyptus (1.5%)	48.80 a
Mustard (3.5%)	58.80 ab
Neem (3.5%)	61.90 ab
Lemongrass (3.5%)	65.00 ab
Datura (6.0%)	76.90 bc
Malathion (0.5%)	100.00 e

Comparisons between larval instars

Instar	% mean mortality
Second	26.40 a
Third	24.80 b
Fourth	22.70 c
Fifth	21.10 d

a, b, c, d and e, figures followed by the same letter are not significantly different.

Lemongrass was the next best among all plant products. In this case, the comparisons made between mean mortality percentages for each concentration revealed that the concentration of 1.5 per cent and 2.5 per cent; 2.5 per cent and 3.5 per cent ; 3.5 per cent and 4.5 per cent, were on par with each other. The best concentration to get good kill of larvae was 3.5 per cent at which the recorded mean mortality percentage was 65.0.

Neem seed cake extract was found to be third in order of effectiveness. Even here, the mortality percentages at different concentrations were on par with one another as mentioned in the above case. The concentration of 3.5 per cent was found to be the best where the mortality percentage recorded was 61.88.

In case of mustard also, the mortality percentages at different concentrations were the same as already explained in the above cases. The mean mortality percentage at 3.5 per cent was 58.75.

Datura was least effective, when mortality per cent values were compared, the mean mortality percentages at 2 per cent and 4 per cent, were significantly different from each other and at 6 per cent and 8 per cent the mortality percentages were on par with each other. From the results it is clear that

6 per cent is the best concentration which gave 76.88 per cent mean larval mortality.

From the above data it can be inferred that eucalyptus was the most effective, the least being datura. The order of effectiveness of the five plant products is : Eucalyptus > Lemongrass > Neem > Mustard > Datura.

Comparisons among plant products with malathion(0.5%) showed that the mortality percentages caused by the standard chemical was on par with those caused by lemongrass (at 4.5%), neem (at 4.5%), mustard (at 4.5%) and datura (at 8.0%). When comparisons made between different larval instars irrespective of plant products tried, it was noted that the mortality percentages of each and every instar were significantly different from one another. That indicates all instars are not equally susceptible to these plant products.

4.2.1 Determination of LC_{50} values of ovicidal effect of plant products in the eggs of rice moth (*C. cephalonica*)

The experimental results of ovicidal effects are presented in table 7 and Fig.1.

The procedure followed to analyse the data was same as given in materials and methods. The order of effectiveness of plant products were as follows. The LC_{50} values were 0.41599,

Table 7. Toxic effect of plant products on the eggs of Corcyra cephalonica (Stnt).

Plant extract	Conc. (%)	No. of eggs used	Total No. unhatched	LC ₅₀	Regression equation (Y = a + bx)
Eucalyptus	0.5	40	26	0.62135	Y = 6.1699 + 2.6311X
	1.0	40	35		
	1.5	40	38		
	2.0	40	40		
Neem	1.5	40	23	0.82850	Y = 4.5711 + 3.1776X
	2.5	50	35		
	3.5	40	39		
	4.5	40	40		
Lemongrass	1.5	40	31	0.41599	Y = 5.5712 + 1.4860X
	2.5	40	36		
	3.5	40	37		
	4.5	40	37		
Mustard	1.5	40	3	3.62279	Y = 2.4382 + 4.6041X
	2.5	40	4		
	3.5	40	18		
	4.5	40	31		
Datura	2.0	40	25	1.82360	Y = 4.0502 + 3.6576X
	4.0	40	29		
	6.0	40	34		
	8.0	40	39		

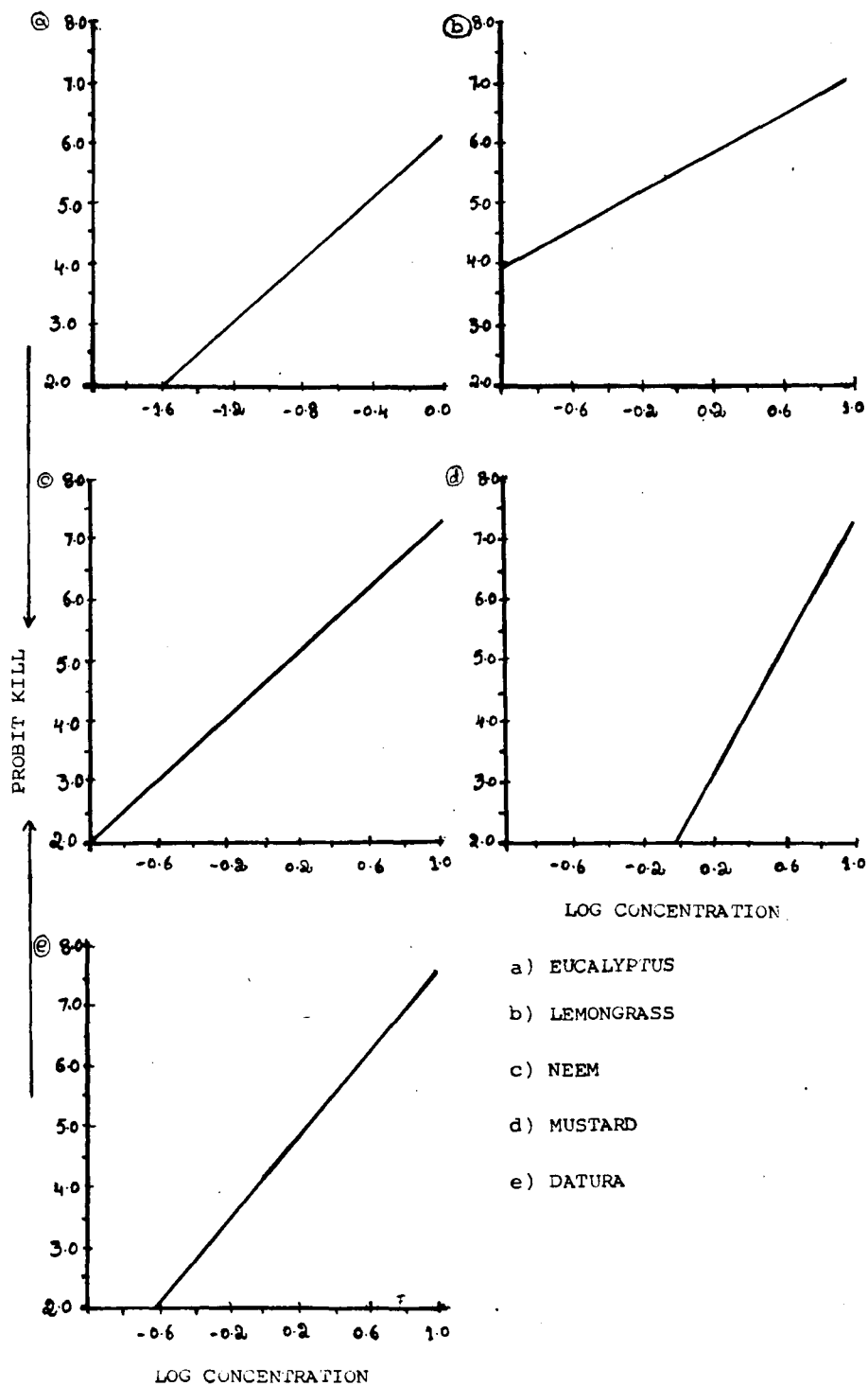


Fig.1: CONCENTRATION - MORTALITY OF EGGS OF RICE MOTH, *C. cephalonica* (Stnt) TO DIFFERENT CONCENTRATIONS OF PLANT EXTRACTS.

0.62135, 0.8285, 1.8236 and 3.62279 for lemongrass, eucalyptus, neem, datura and mustard respectively.

4.2.2 Calculated LC_{50} values for different larval instars of rice moth (*C. cephalonica*)

a) Determination of LC_{50} values after 24 hours exposure

The calculated LC_{50} values, their regression equations ($Y = a+bx$) given by Finney (1964) are presented in table 8 and 9 (Fig.2).

Eucalyptus oil with LC_{50} values of 1.41553, 1.56422, 3.10837 and 3.46502 per cent were found to be the most effective against the second, third, fourth and fifth instar larvae respectively. Datura was found to be the least effective whose, LC_{50} values recorded were 6.7653, 5.305, 6.78398 and 6.2121 per cent for second, third, fourth and fifth instar larvae, respectively. The other plant products that were found to fall in between the above two were, mustard (with LC_{50} values of 2.93113, 3.80716, 3.310161, 4.4896), neem (with LC_{50} values of 3.00117, 4.24643, 5.0599, 6.58612) and lemongrass (with LC_{50} values of 3.41086, 3.351, 4.21939, 4.54091) for the second, third, fourth and fifth instar larvae respectively.

Table 8. Toxic effects of plant products against the 2nd and 3rd instar larvae of rice moth C. cephalonica after 24 hours exposure.

Plant extract	Conc. %	2nd instar larvae				3rd instar larvae			
		No. of larval used	Total No. killed	LC ₅₀	Regression equation	No. of larvae used	Total No. killed	LC ₅₀	Regression equation
Eucalyptus	0.5	40	2	1.41553	Y=4.4295+3.8673X	40	2	1.56422	Y=4.3226+3.5864X
	1.0	40	9			40	8		
	1.5	40	22			40	17		
	2.0	40	30			40	29		
Mustard	1.5	40	4	2.93113	Y=2.7664+4.8590X	40	5	3.80716	Y=3.176+3.1539X
	2.5	40	14			40	9		
	3.5	40	23			40	17		
	4.5	40	35			40	26		
Lemongrass	1.5	40	8	3.21086	Y=3.7102+2.5442X	40	5	3.35100	Y=3.071+3.6826X
	2.5	40	15			40	9		
	3.5	40	23			40	23		
	4.5	40	25			40	28		
Neem	1.5	40	4	3.00117	Y=2.9417+4.3264X	40	5	4.24643	Y=3.2451+2.7858X
	2.5	40	15			40	7		
	3.5	40	23			40	19		
	4.5	40	32			40	21		
Datura	2.0	40	3	6.76530	Y=2.4986+3.0124X	40	5	5.30500	Y=2.8864+2.9271X
	4.0	40	6			40	12		
	6.0	40	19			40	23		
	8.0	40	25			40	29		

Table 9. Toxic effects of plant products against the 4th and 5th instar larvae of rice moth C. cephalonica after 24 hours exposure.

Plant extract	Conc. %	4th instar larvae				5th instar larvae			
		No. of larval No. used	Total No. killed	LC ₅₀	Regression equation	No. of larvae used	Total No. killed	LC ₅₀	Regression equation
Eucalyptus	0.5	40	0	3.10837	Y=3.0322+3.9941X	40	0	3.46502	Y=3.2923+3.1638X
	1.0	40	1			40	0		
	1.5	40	4			40	5		
	2.0	40	9			40	9		
Mustard	1.5	40	9	3.310161	Y=3.8315+2.2515X	40	1	4.48960	Y=2.1617+4.3576X
	2.5	40	16			40	5		
	3.5	40	19			40	8		
	4.5	40	26			40	25		
Lemongrass	1.5	40	5	4.21939	Y=3.2213+2.8395X	40	0	4.54091	Y=2.9802+3.1530X
	2.5	40	7			40	8		
	3.5	40	18			40	18		
	4.5	40	22			40	19		
Neem	1.5	40	5	5.0599	Y=3.5867+1.9996X	40	4	6.58612	Y=3.2814+2.0966X
	2.5	40	13			40	7		
	3.5	40	15			40	9		
	4.5	40	17			40	17		
Datura	2.0	40	1	6.78398	Y=1.6505+4.032X	40	0	6.21210	Y=3.3965+2.0240X
	4.0	40	4			40	15		
	6.0	40	17			40	17		
	8.0	40	27			40	25		

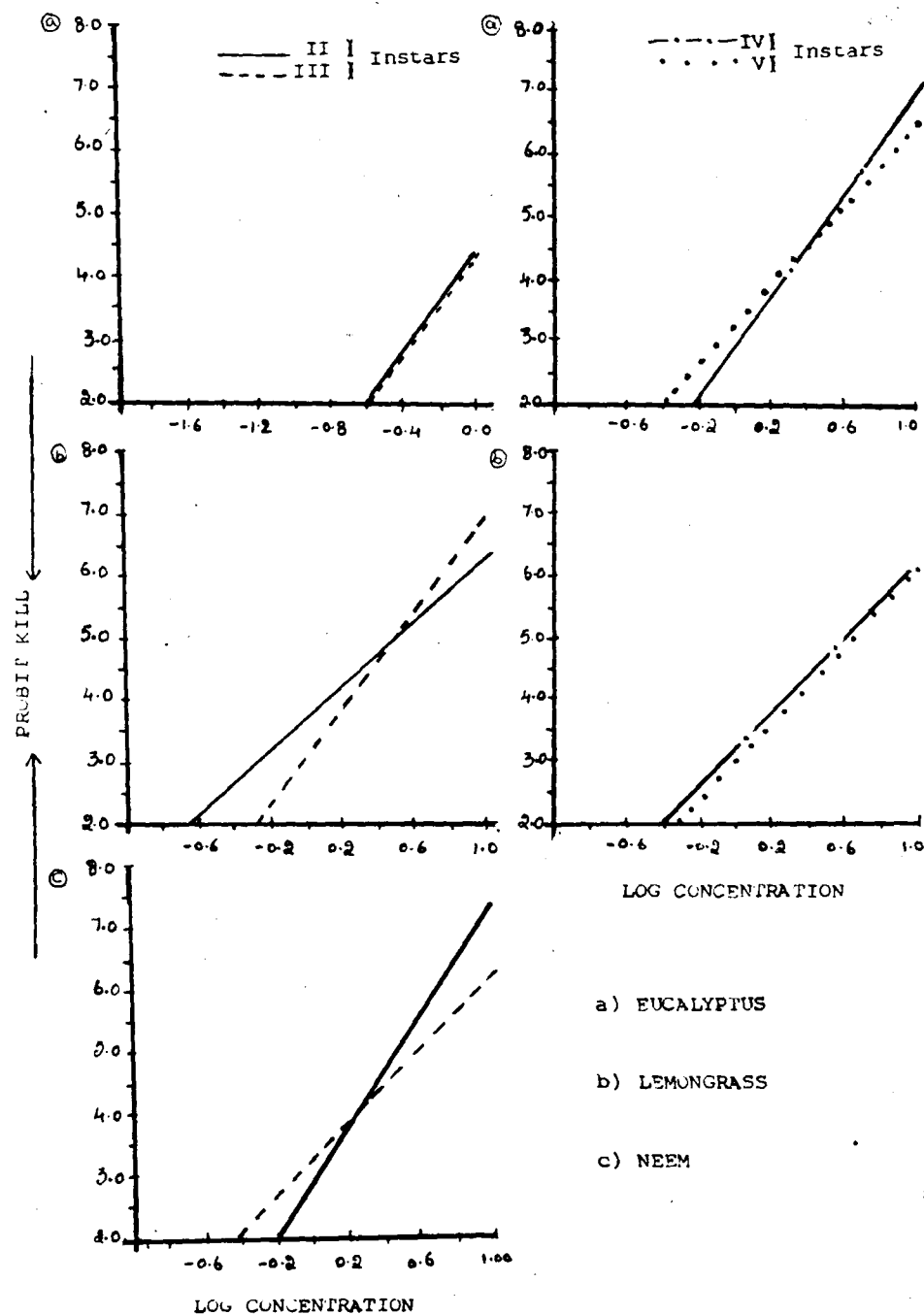


Fig.2: CONCENTRATION - MORTALITY RESPONSE OF DIFFERENT LARVAL INSTARS OF *C. cephalonica* (Stant) TO DIFFERENT CONCENTRATIONS OF PLANT EXTRACTS (After 24 hours).

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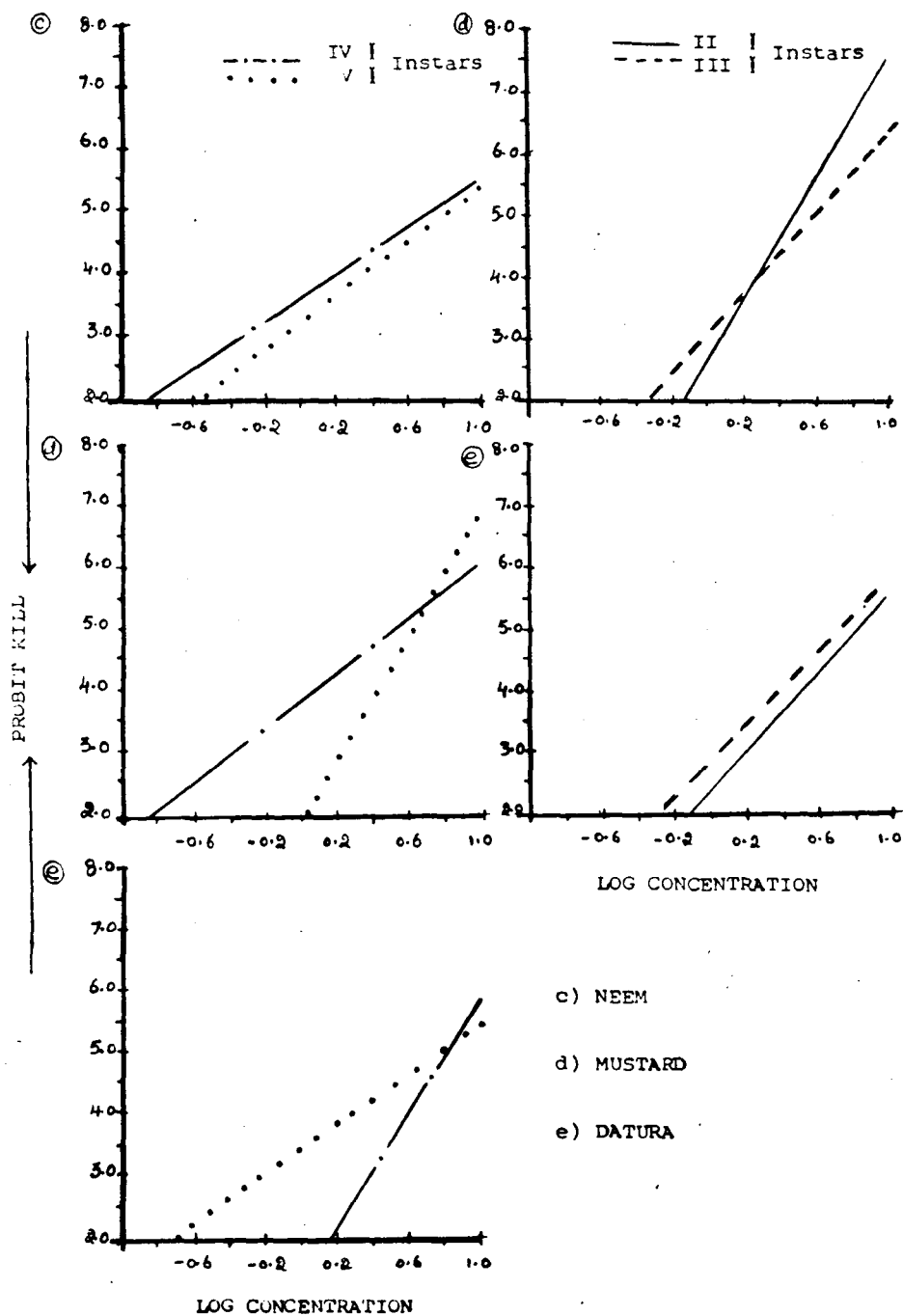


Fig.2: CONCENTRATION - MORTALITY RESPONSE OF DIFFERENT LARVAL INSTARS OF *C. cephalonica* (Stnt) TO DIFFERENT CONCENTRATIONS OF PLANT EXTRACTS (After 24 hours).

b) Determination of LC_{50} values after 48 hours exposure

The same procedure as described earlier was followed for determining the LC_{50} values and the regression equations and the same are presented in Table 10 and 11(Fig.3).

The order of effectiveness of plant products tried were same as mentioned above, but the LC_{50} values were further less, because of increased mortality. The LC_{50} values in case of most effective plant product i.e., eucalyptus were 1.16084, 1.51224, 2.6592 and 3.46503 per cent for second, third, fourth and fifth instar larvae.

Next effective one found was mustard, the calculated LC_{50} values for second, third, fourth and fifth instar larvae were 2.65478, 3.46235, 3.09251, 4.1111 per cents respectively.

In case of neem the LC_{50} values were, 2.3729, 3.5925, 4.2365 and 4.3795 per cents for second, third, fourth and fifth instar larvae respectively.

Lemongrass was the fourth effective one. The LC_{50} values for second, third, fourth and fifth instar were 3.6651, 3.7056, 2.5729, 3.101638 per cents respectively. For the least effective plant product, i.e., datura, the LC_{50} values were 6.30124, 4.9294, 6.0045 and 5.3903 for second, third, fourth and fifth instar larvae respectively.

Table 10. Toxic effects of plant products against the 2nd and 3rd instar larvae of rice moth C. cephalonica after 48 hours exposure.

Plant extract	Conc. %	2nd instar larvae				3rd instar larvae			
		No. of larvae used	Total No. killed	LC ₅₀	Regression equation	No. of larvae used	Total No. killed	LC ₅₀	Regression equation
Eucalyptus	0.5	40	5	1.16084	$Y=4.7992+3.3338X$	40	2	1.51224	$Y=4.3413+3.7845X$
	1.0	40	16			40	7		
	1.5	40	24			40	19		
	2.0	40	33			40	30		
Mustard	1.5	40	5	2.65478	$Y=2.8996+5.0508X$	40	9	3.46235	$Y=3.6313+2.5521X$
	2.5	40	19			40	11		
	3.5	40	25			40	18		
	4.5	40	37			40	28		
Lemongrass	1.5	40	11	2.57290	$Y=3.979+2.4852X$	40	5	3.10638	$Y=3.0499+3.9772X$
	2.5	40	20			40	11		
	3.5	40	25			40	25		
	4.5	40	29			40	30		
Neem	1.5	40	12	2.37290	$Y=3.9611+2.7915X$	40	7	3.5925	$Y=3.5964+2.5288X$
	2.5	40	22			40	13		
	3.5	40	24			40	20		
	4.5	40	33			40	24		
Datura	2.0	40	3	6.30124	$Y=2.4985+3.1402X$	40	5	4.92940	$Y=2.9452+2.9664X$
	4.0	40	8			40	15		
	6.0	40	19			40	25		
	8.0	40	27			40	29		

Table 11. Toxic effects of plant products against the 4th and 5th instar larvae of rice moth, C. cephalonica after 48 hours exposure.

Plant extract	Conc. %	4th instar larvae				5th instar larvae			
		No. of larvae used	Total No. killed	LC ₅₀	Regression equation	No. of larvae used	Total No. killed	LC ₅₀	Regression equation
Eucalyptus	0.5	40	0	2.6592	$Y=2.9952+4.7117X$	40	0	3.46503	$Y=3.2923+3.1638X$
	1.0	40	1			40	0		
	1.5	40	4			40	5		
	2.0	40	12			40	9		
Mustard	1.5	40	5	3.09251	$Y=3.2784+3.5043X$	40	5	4.1111	$Y=3.2987+2.7787X$
	2.5	40	17			40	11		
	3.5	40	21			40	13		
	4.5	40	29			40	25		
Lemongrass	1.5	40	5	3.6651	$Y=3.1219+3.3339X$	40	4	3.7056	$Y=3.0595+3.4101X$
	2.5	40	8			40	9		
	3.5	40	20			40	21		
	4.5	40	26			40	24		
Neem	1.5	40	5	4.2365	$Y=3.4831+2.4133X$	40	5	4.3795	$Y=3.2104+2.7911X$
	2.5	40	13			40	7		
	3.5	40	17			40	15		
	4.5	40	20			40	23		
Datura	2.0	40	1	6.0045	$Y=1.6431+4.3119X$	40	0	5.3903	$Y=3.4154+2.1647X$
	4.0	40	6			40	15		
	6.0	40	23			40	23		
	8.0	40	28			40	25		

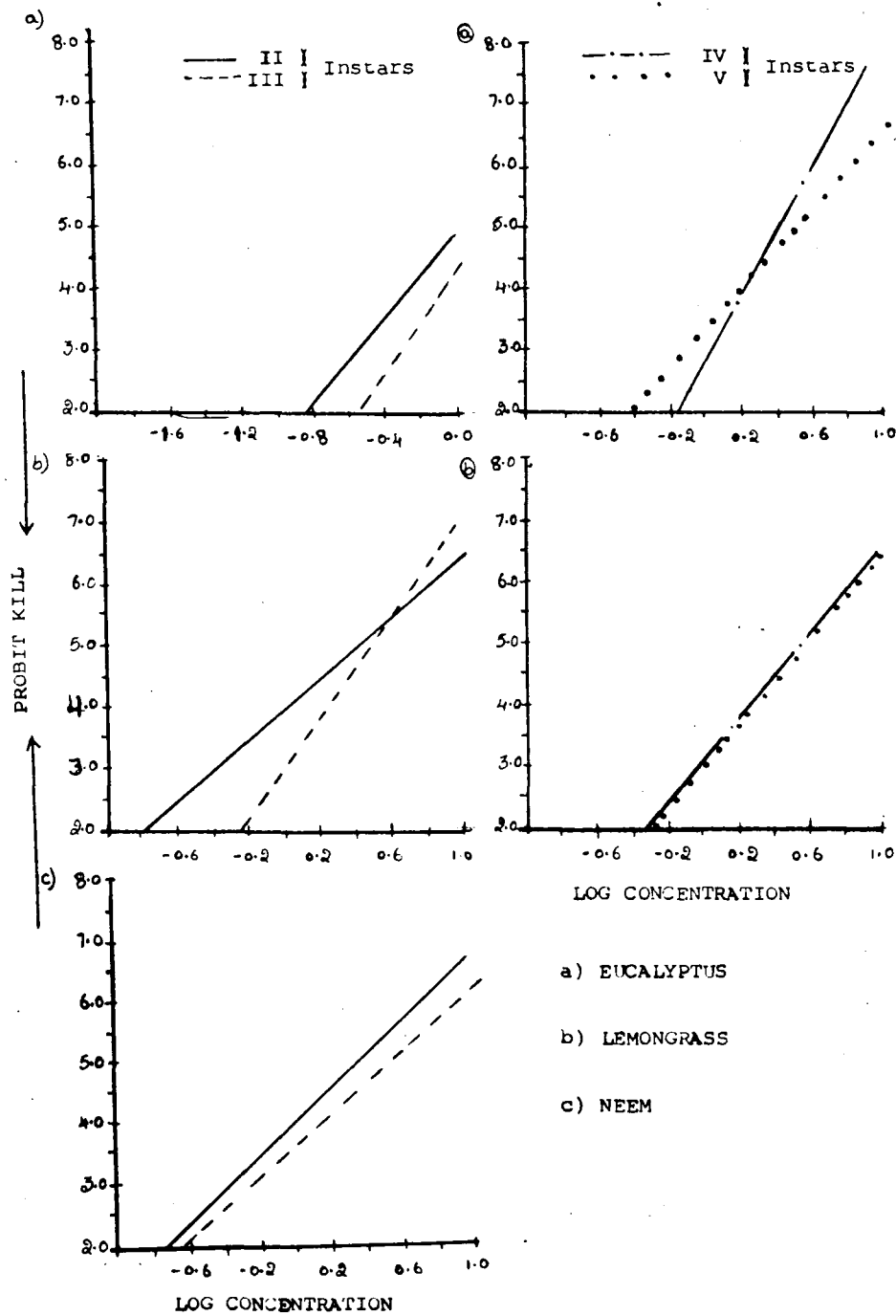


Fig.3: CONCENTRATION - MORTALITY RESPONSE OF DIFFERENT LARVAL INSTARS OF *C. cephalonica* (Stnt) TO DIFFERENT CONCENTRATIONS OF PLANT EXTRACTS (After 48 hours)

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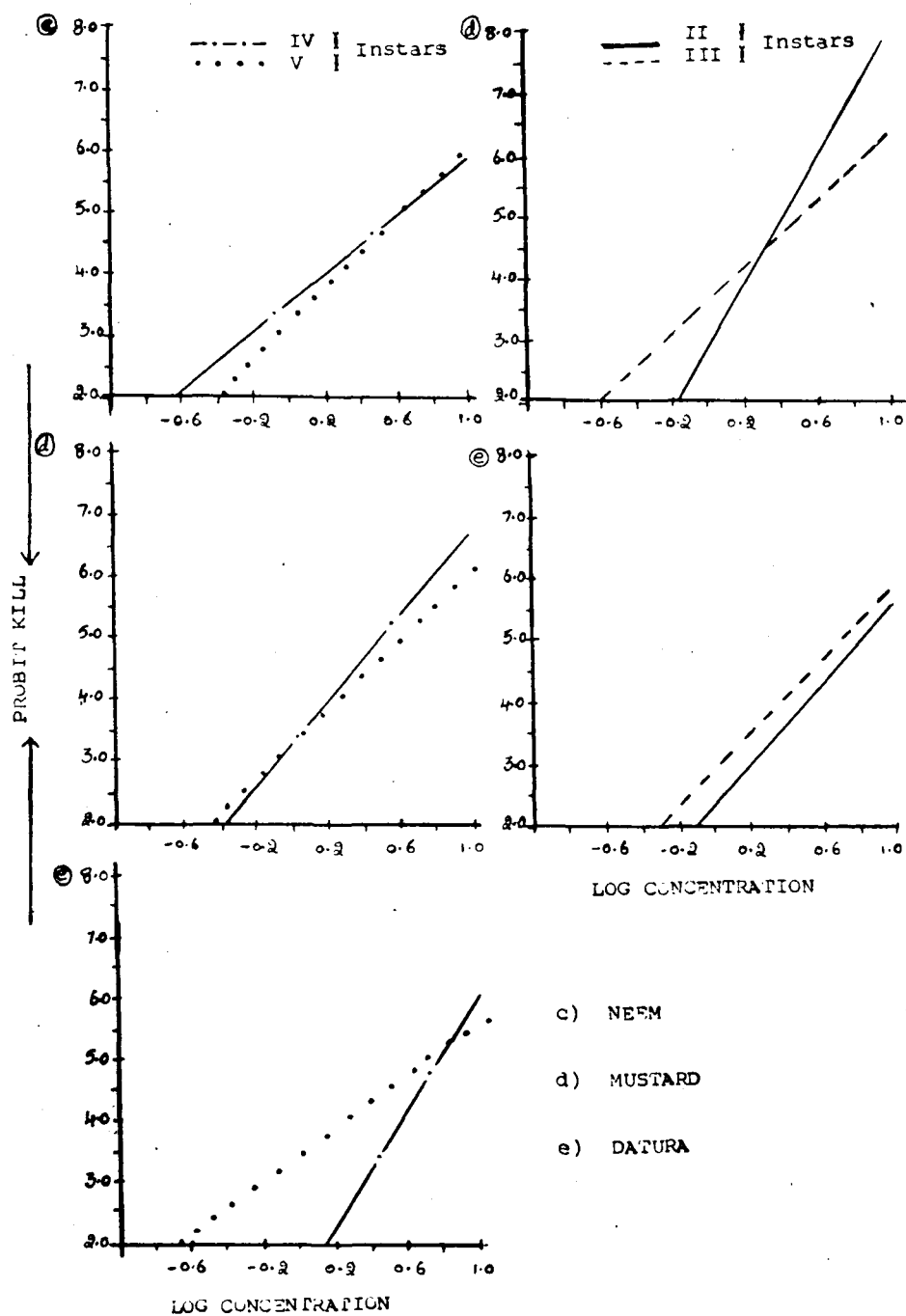


Fig.3: CONCENTRATION - MORTALITY RESPONSE OF DIFFERENT LARVAL INSTARS OF *C. cephalonia* (Stnt) TO DIFFERENT CONCENTRATIONS OF PLANT EXTRACTS (After 48 hours).

c) LC₅₀ values for different instars after 72 hours

The calculated LC₅₀ values were very low in this case as compared to the LC₅₀ values for 24 and 48 hour exposure period. The LC₅₀ and regression equation are presented in Table 12 and 13 (Fig.4).

The calculated LC₅₀ values were very low in case of eucalyptus followed by mustard, neem, lemongrass and datura respectively.

LC₅₀ values in case of eucalyptus were found to be as follows : 0.8327, 1.00801, 3.2596, 3.721 for second, third, fourth and fifth instar larvae respectively. Datura was found to be the least effective by giving 50 per cent mortality at very high concentrations; LC₅₀ values are as follows: 3.06681, 3.25196, 4.33805, 4.62422 for second, third, fourth and fifth instar larvae respectively. The places between these two plant products were occupied by mustard, neem, lemongrass in order of toxicity.

4.3 Effect of plant products on the feeding behaviour of larvae of *C. cephalonica* (Stnt.)

4.3.1 Choice chamber test

The data on the percentage of larvae entered in to treated and control foods (broken rice grain) as well as the percentage of larvae consumed the food are presented in Table 14.

Table 12. Toxic effects of plant products against the 2nd and 3rd instar larvae of rice moth C. cephalonica after 72 hours exposure.

Plant extract	Conc. %	2nd instar larvae				3rd instar larvae			
		No. of larvae used	Total No. killed	LC ₅₀	Regression equation	No. of larvae used	Total No. killed	LC ₅₀	Regression equation
Eucalyptus	0.5	40	13	0.8327	$Y=5.2263+2.6465X$	40	9	1.00801	$Y=5.0083+2.9106X$
	1.0	40	20			40	17		
	1.5	40	30			40	27		
	2.0	40	35			40	34		
Mustard	1.5	40	14	2.0637	$Y=4.1539+2.6866X$	40	12	2.5934	$Y=3.7976+2.9688X$
	2.5	40	24			40	17		
	3.5	40	29			40	22		
	4.5	40	39			40	34		
Lemongrass	1.5	40	14	2.0482	$Y=4.0718+3.0038X$	40	10	2.5463	$Y=3.7017+3.2231X$
	2.5	40	25			40	19		
	3.5	40	28			40	25		
	4.5	40	35			40	33		
Neem	1.5	40	15	2.0383	$Y=3.8789+3.761X$	40	10	2.4231	$Y=3.5773+3.7422X$
	2.5	40	24			40	19		
	3.5	40	29			40	28		
	4.5	40	38			40	35		
Datura	2.0	40	12	3.06681	$Y=3.3737+3.3869X$	40	12	3.25197	$Y=3.5113+2.9379X$
	4.0	40	23			40	21		
	6.0	40	35			40	33		
	8.0	40	40			40	40		

Table 13. Toxic effects of plant products against the 4th and 5th instar larvae of rice moth
C. cephalonica after 72 hours exposure.

Plant extract	Conc. %	4th instar larvae				5th instar larvae			
		No. of larvae used	Total No. killed	LC ₅₀	Regression equation	No. of larvae used	Total No. killed	LC ₅₀	Regression equation
Eucalyptus	0.5	40	2	3.2596	$Y=3.9863+1.9722X$	40	3	3.7210	$Y=4.0139+1.7216X$
	1.0	40	7			40	5		
	1.5	40	10			40	11		
	2.0	40	13			40	13		
Mustard	1.5	40	10	2.6372	$Y=3.7622+2.9497X$	40	7	3.3587	$Y=3.5068+2.852X$
	2.5	40	18			40	14		
	3.5	40	25			40	18		
	4.5	40	31			40	28		
Lemongrass	1.5	40	10	2.49314	$Y=3.6554+3.4084X$	40	8	2.90091	$Y=3.5005+3.2643X$
	2.5	40	18			40	15		
	3.5	40	28			40	23		
	4.5	40	33			40	31		
Neem	1.5	40	9	2.9671	$Y=3.8038+2.5352X$	40	8	3.14814	$Y=3.6846+2.6439X$
	2.5	40	18			40	16		
	3.5	40	21			40	21		
	4.5	40	28			40	27		
Datura	2.0	40	4	4.3365	$Y=2.3989+4.1129X$	40	3	4.62422	$Y=2.5197+3.7063X$
	4.0	40	15			40	19		
	6.0	40	30			40	25		
	8.0	40	35			40	32		

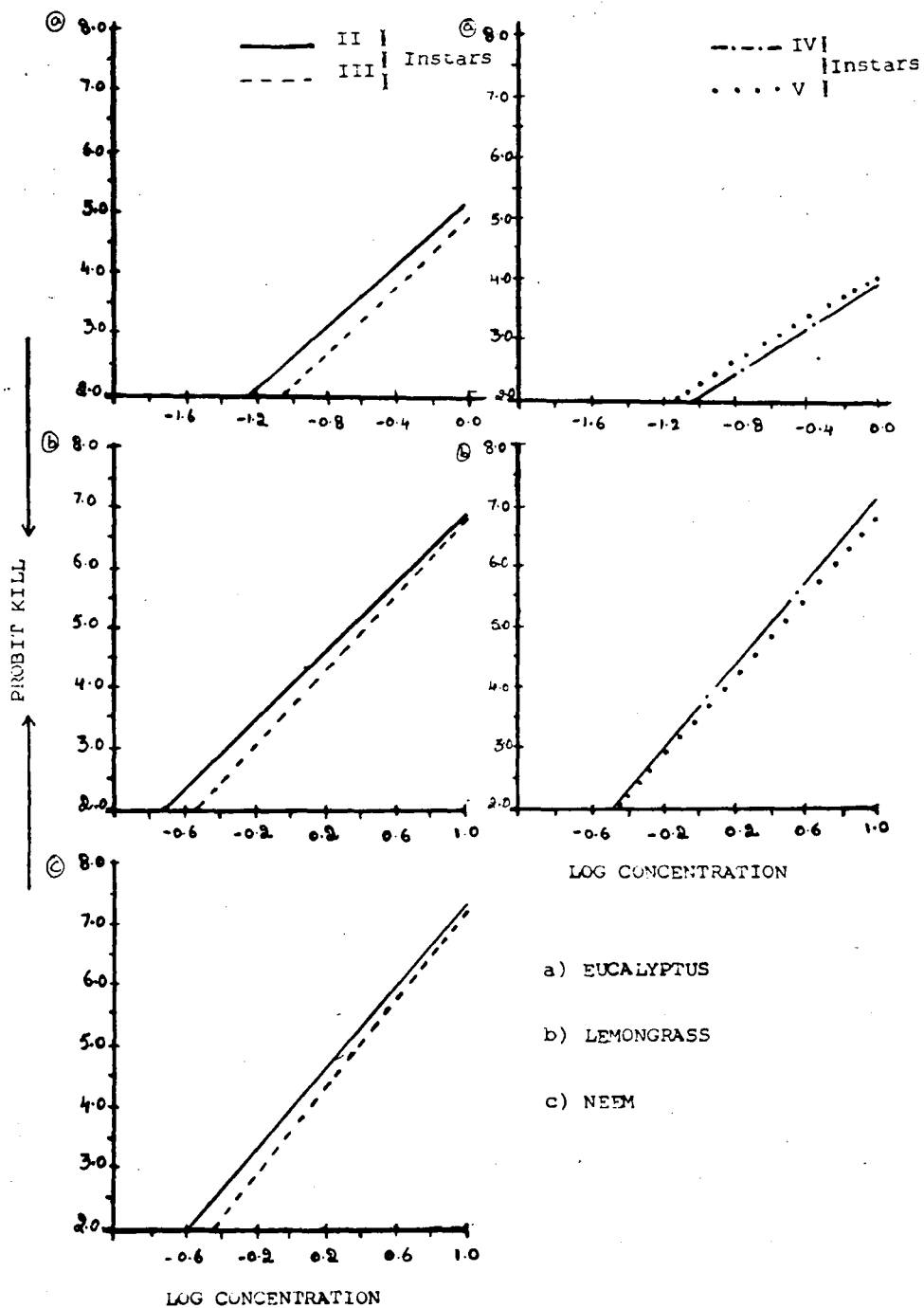


Fig.4: CONCENTRATION - MORTALITY RESPONSE OF DIFFERENT LARVAL INSTARS OF *C. cephalonica* (Stnt) TO DIFFERENT CONCENTRATIONS OF PLANT EXTRACTS (After 72 hours)

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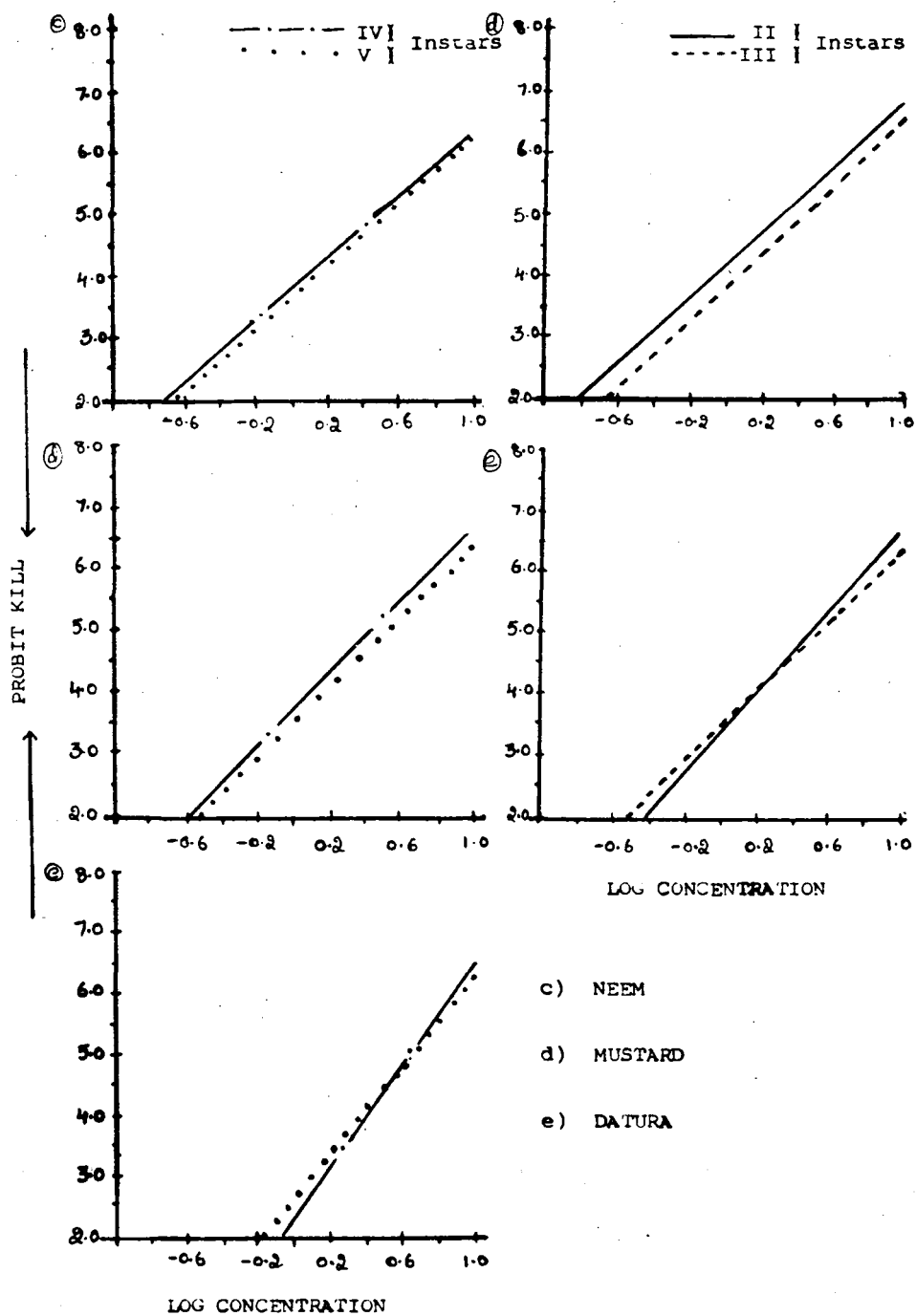


Fig.4: CONCENTRATION - MORTALITY RESPONSE OF DIFFERENT LARVAL INSTARS OF *C. cephalonica* (Stnt) TO DIFFERENT CONCENTRATIONS OF PLANT EXTRACTS (After 72 hours).

Table 14. Studies on the feeding behaviour of the larvae of rice moth
C. cephalonica

a) Choice chamber test

Plant extract	Conc. (%)	No. of larvae preferred to enter into the food		No. of larvae consumed the food	
		Total	Average	Total	Average
Mustard	1.5	25	6.25 a	25	6.25 a
	2.5	16	*4.00 ab	9	*2.25 ab
	3.5	8	2.00 b	5	1.25 b
	4.5	4	1.00 b	4	1.00 b
Control-I	-	40	10.00 ec	43	10.75 c
Control-II	-	51	12.75 d	58	14.50 d
Datura	2.0	30	*7.50 ac	37	9.25 ad
	4.0	25	6.25 ac	20	*5.00 bd
	6.0	25	6.25 ac	16	4.00 bd
	8.0	18	4.50 ac	13	3.25 bd
Control-I	-	19	4.75 c	20	5.00 c
Control-II	-	28	7.00 c	38	9.50 d
Neem	1.5	22	5.50 ac	24	6.00 ac
	2.5	21	5.25 ac	10	*2.50 ab
	3.5	9	*2.25 ab	4	1.00 b
	4.5	5	1.25 b	1	0.25 b
Control-I	-	32	8.00 c	34	8.50 c
Control-II	-	55	13.75 d	70	17.50 d
Lemongrass	1.5	24	6.00 ac	22	5.50 ac
	2.5	18	*4.50 abc	14	*3.50 ab
	3.5	11	2.75 ab	9	2.25 ab
	4.5	4	1.00 b	3	0.75 b
Control-I	-	31	7.75 c	35	8.75 c
Control-II	-	56	14.00 d	61	15.25 d
Eucalyptus	0.5	17	4.25 a	20	5.00 a
	1.0	9	*2.25 ab	10	*2.50 ab
	1.5	3	0.75 ab	5	1.25 b
	2.0	1	0.25 b	3	0.75 b
Control-I	-	38	9.50 c	46	11.50 c
Control-II	-	76	19.00 d	60	15.00 d

Control-I = Distilled water ;
Control-II = 0.1% labolene + 5.0% benzene

*: Best concentration

Comparisons among best concentrations of plant products

	No. of larvae preferred to enter	No. of larvae consumed the food
Eucalyptus	(1.0) 0.75 a	(1.0) 2.5 a
Neem	(3.5) 2.25 a	(2.5) 2.5 a
Mustard	(2.5) 4.00 a	(2.5) 2.2 a
Lemongrass	(2.5) 4.50 a	(2.5) 3.5 a
Datura	(2.0) 7.50 b	(6.0) 5.0 a

a, b, c and d, figures followed by the same letter are not significantly different.

Eucalyptus was followed by lemongrass, mustard, neem and datura in terms of number of larvae preferred to enter into treated food.

Analysis of results (one-way analysis of variance) showed that the mean numbers of larvae that entered into food treated with different concentrations of plant products was on par with one other, irrespective of their concentrations. On the basis of concentrations, the average number of larvae that preferred to enter in to food treated with eucalyptus (0.5, 1.0, 1.5 and 2.0 per cent) was lower than the larvae entered into the control foods. The results are follows; 4.25, 2.25, 0.79, 0.25, 9.5 and 19.0 at 0.5, 1.0, 1.5, 2.0 and control-I and control-II respectively. The comparisions showed that 1.0, 1.5, 2.0 were on par with each other. The best concentration of eucalyptus selected was 1.0 per cent.

In case of lemongrass the mean number of larvae that preferred to enter into treated food were 6.25, 4.5, 2.75, 1.00, 7.75, 14.0 at 1.5, 2.5, 3.5, 4.5, control-I and II, respectively. From comparisions made (student Newman - Keuls) the mean number of larvae preferred to enter at the first three concentrations (1.5, 2.5, and 3.5%) were on par with one other and at second, third, fourth concentrations (2.5, 3.5, and 4.5%) also were on par with one another and at the first concentration (1.5%) was on par with control-I.

Taking neem and mustard into consideration the number of larvae that preferred to enter into the treated food were 6.25, 4.00, 2.00, 1.0, 10.0, 12.75; 5.5, 5.25, 2.25, 1.25, 8, 13.75 at 1.5, 2.5, 3.5 and 4.5 per cent of mustard and neem, respectively. From comparisons it could be concluded that in case of neem at the first three concentrations and last two concentrations the mean number of larvae that preferred to enter were on par with one another. In case of mustard, the mean number of larvae that preferred to enter into first two concentrations and the last three concentrations were found to be on par with one other.

The number of larvae that preferred to enter into food treated with different concentrations of datura were found to be the same at all concentrations (2, 4, 6, and 8%) and control-I and control-II. The results were as follows: 7.5, 6.25, 6.25, 4.5, 4.75, 7 at 2.0, 4.0, 6.0, 8.0 per cent concentrations and control-I and II, respectively.

The number of larvae that entered into two different control foods were significantly different from one another in all cases viz., 10.0, 12.75, 8.0, 13.75, 4.75, 7.0, 9.5, 19.0, 7.75, 14.0 at control-I and control-II for mustard, neem, datura, eucalyptus and lemongrass, respectively.

The comparative studies made in the case of mean number of larvae that consumed the treated foods with different candidate plant products indicated that, neem, eucalyptus, mustard and lemongrass were on par one another, whereas, in case of datura, the number of larvae, that consumed the food were significantly more than the other plant products.

The mean number of larvae consumed the food in case of neem were; 6.0, 2.5, 1.0, 0.25, 8.5, 17.5 at 1.5, 2.5, 3.5, 4.5 per cent and control-I and II, respectively. The observations at 2.5, 3.5, 4.5 per cent were found to be on par with one other and at 1.5 and 2.5 per cent also were on par with one another.

In case of eucalyptus, the mean number of larvae that consumed the food were, 4.25, 2.25, 0.75, 0.25, 9.5, 19.00 at 0.5, 1.0, 1.5, 2.0 per cent control-I and II, respectively. The observations at 0.5, 1.0, 1.5 and 2.0 per cent were on par with one another.

Lemongrass was found to be the next in other, where, less number of larvae consumed food next eucalyptus (5.5, 3.5, 2.25, 0.75, 8.75 and 15.25 at 1.5, 2.5, 3.5 and 4.5 per cent control-I and II, respectively). The comparisons between treatments showed that the first two concentrations and the last three concentrations were on par with one another.

In case of mustard, the mean number of larvae that consumed the food were 6.25, 2.25, 1.25, 1.0, 10.75, 14.5 at 1.5, 2.5, 3.5, 4.5 and control-I and II, respectively. Observations at 1.5 and 2.5; and 2.5, 3.5 and 4.5 were found to be on par with one another.

More number of larvae consumed the food in case of datura even at high concentrations, when compared to other plant products (9.0, 5.0, 4.0, 3.25, 5.0 and 9.5 at 2, 4, 6, 8 per cent and control-I and II, respectively).

The values of two controls were found to be significantly different from each other.

4.3.2 No choice chamber test

This experiment was conducted with a view to observe the feeding behaviour of larvae on food treated with different concentrations of plant products in the absence of control food. The results are presented in Table 15.

Studies on number of larvae preferred to enter into treated food

The results revealed that the mean number of larvae that entered in to food (broken rice) treated with all plant products were found to be on par with one another, irrespective

Table 15. Studies on the feeding behaviour of the larvae of rice moth *C. cephalonica*

b) No choice chamber test

Plant extract	Conc.(%)	No. of larvae preferred to enter into food		No. of larvae consumed the food	
		Total	Average	Total	Average
Mustard	1.5	58	14.50 a	70	17.50 a
	2.5	24	* 6.00 b	27	6.75 a
	3.5	17	4.25 b	13	*3.25 b
	4.5	10	2.50 b	6	1.50 b
Empty space	-	35		28	7.00
Datura	2.0	57	14.25 a	69	17.25 a
	4.0	30	7.50 b	29	7.25 b
	6.0	28	*7.00 bc	25	*6.25 b
	8.0	21	5.25 c	18	4.50 b
Empty space	-	4.0	2.00	3.0	0.75
Neem	1.5	64	16.00 a	73	18.25 a
	2.5	30	7.50 b	31	7.75 b
	3.5	22	*5.50 bc	12	*3.00 c
	4.5	10	2.50 c	5	1.25 c
Empty space	-	18	4.50	23	5.75
Lemongrass	1.5	33	8.25 a	41	10.25 a
	2.5	22	*5.50 ab	16	* 4.00 ab
	3.5	7	1.75 b	13	3.25 b
	4.5	6	1.50 b	7	1.75 b
Empty space	-	76	19.00	67	16.75
Eucalyptus	0.5	33	8.25 a	41	10.25 a
	1.0	18	*4.50 b	34	8.50 ab
	1.5	10	2.50 b	22	*5.50 bc
	2.0	6	1.50 b	9	2.25 c
Empty space	-	77	19.25	38	9.50

* : Best concentration

Comparisons among best concentrations of plant extracts

	No. of larvae preferred to enter	No. of larvae consumed the food
Eucalyptus	(1.0%) 4.50 a	(1.5%) 5.50 a
Lemongrass	(2.5%) 5.50 a	(2.5%) 4.00 a
Neem	(3.5%) 5.50 a	(3.5%) 3.00 a
Mustard	(2.5%) 6.00 a	(3.5%) 3.25 a
Datura	(6.0%) 7.00 a	(6.0%) 6.25 a

a, b, and c, figures followed by the same letter are not significantly different.

of their concentrations. Concentration wise, at very low concentration of eucalyptus (0.5 per cent) the number of larvae entered in to treated food were less, as compared to the other products. Considering the mean number of larvae that entered into treated food the order of effectiveness was; eucalyptus followed by lemongrass, neem, mustard and datura.

In case of eucalyptus, the number of larvae that entered into treated food were, 8.25, 4.5, 2.5, 1.5 at 0.5, 1.0, 1.5, 2.0 per cent concentration, respectively. From comparisons, it is evident that at 0.5 and 1.0 per cent the mean number of larvae that entered were on par with each other, whereas second concentration (1.0%) was found to be on par with the other two higher concentrations (viz., 1.5 and 2.0%).

The mean number of larvae that entered into foods treated with different concentrations of lemongrass were more as compared to eucalyptus, at concentrations 1.5, 2.5, 3.5 and 4.5, The larvae entered were, 8.25, 5.5, 1.75, 1.5, respectively.

In treated foods with neem the mean number of larvae entered were 16, 7.5, 5.5 and 2.5 at 1.5, 2.5, 3.5, 4.5 per cent concentrations, respectively. The results at the first (1.5%) concentration was not on par with other concentrations (2.5, 3.5, 4.5%).

In case of mustard, datura, the results were 14.5, 6.0, 4.25 and 2.5 at 1.5, 2.5, 3.5 and 4.5 per cent concentrations and 14.25, 7.5, 7.0, 5.25 at 2, 4, 6, 8 per cent of mustard and datura, respectively. The results of second, third, and fourth concentrations were found to be on par with one another in case of mustard, but at the first concentration (1.5%) the results were significantly different from the others.

In case of datura, the results of the second concentration (4.0%) were on par with the third concentration (6.0%) and fourth concentration (8.0%). But at first concentration results were significantly different from others. The number of larvae recorded in empty space were 19.25, 19.0, 8.75, 4.5, 2.0 for eucalyptus, lemongrass, mustard, neem and datura respectively.

Effect of plant products on the number of larvae that preferred to consume the food

When comparisons were made with respect to the mean number of larvae that consumed the treated food, significant differences were found among the concentrations of each plant product.

When the best concentrations of five plant products were compared in terms of the mean number of larvae that consumed the treated food, no significant differences were observed. All were

found to be on par with one another. However, the mean number of larvae that consumed to food was the least in case of neem, followed by eucalyptus, lemongrass, mustard and datura.

The mean number of larvae preferred to consume treated food with neem were, 18.25, 7.75, 3.00, 1.25 at 1.5, 2.5, 3.5, 4.5 per cent concentration respectively. The mean larvae consumed food at first two concentrations (1.5 and 2.5%) are significantly more than second concentration, and at second and third concentrations also, but the mean number of larvae that consumed food at third and fourth concentrations (3.5 and 4.5 per cent) were on par with each other.

In case of eucalyptus, the mean number of larvae that consumed food treated with the third and fourth concentrations (1.5 and 2.0) were on par with each other. The behaviour observed in case of food treated with lemongrass showed that the mean number of larvae that consumed food at the first and second concentrations (1.5 and 2.5% respectively) were on par with each other and at second, third and fourth concentrations (1.0, 1.5 and 2.0 per cent respectively) were also on par with one another.

In case of datura the differences between second, third (4 and 6%) and fourth concentrations (8 per cent) were not significant, whereas, at the first concentration (2 per cent) the results were significantly higher than other three higher concentrations (4, 6, 8%).

The number of larvae present in the empty space were also recorded to see the effect of treated foods. The results were 5.75, 9.5, 16.75, 7.0, 0.75 for neem, eucalyptus, lemongrass, mustard and datura respectively.

Plant products as antifeedants against *Corcyra cephalonica* (Stnt)
mean performance based on number of holes made by larvae on
created paper

Experiment was conducted to assess the antifeedant properties of the candidate plant products of neem, datura, mustard, eucalyptus and lemongrass. From this data, multiple comparisons were made between the treatment means by using 'Student - Newman-Kuels test'. Results obtained on the feeding deterrence against test insect are presented in Table 16.

The results revealed that, of the different plant products treated neem gave the best results followed by eucalyptus lemongrass, mustard and datura. At 1.5 per cent of neem the number of holes made by larvae were 7.5, 13.5, 19.25 and 26.0 at intervals of 24, 48, 72 and 96 hours respectively. When the concentration was increased to 2.5 per cent there were no significant differences in the performance. However at 3.5 per cent there was a significant increase in feeding deterrence. The next level i.e., 4.5 per cent did not show critical differences in results when compared at 3.5 per cent. Therefore, 3.5 per cent was determined to be the best concentration at which the

Table 16. Antifeedant activity of candidate plant extracts after 24, 48, 72, 96 and 120 hours after treatment against third instar larvae of *C. cephalonica* (Stnt).

Plant extract	Conc. (%)	Number of holes made by larvae on treated paper, after							
		24 hours		48 hours		72 hours		96 hours	
		Total	Mean	Total	Mean	Total	Mean	Total	Mean
Mustard	1.5	52	(3.66)13.00 ae	66	(4.11)16.50 ae	72	(4.28)18.00 ae	109	(5.24)27.25 ae
	2.5	36	(3.07) 9.00 ab	45	*(3.40)11.25 ab	52	*(3.66)13.00 ab	90	(4.79)22.50 ab
	3.5	33	*(2.95) 8.25 bc	40	(3.24)10.00 bc	50	(3.60)12.50 b	79	(4.49)19.75 b
	4.5	21	(2.37) 5.25 c	30	(2.82) 7.50 c	40	(3.24)10.00 b	54	*(3.73)13.50 c
Datura	2.0	52	(3.66)13.00 ae	74	(4.35)18.50 ae	103	(5.11)25.75 ae	122	(5.57)30.50 ae
	4.0	37	*(3.10) 9.25 abc	50	(3.58)12.50 ab	70	(4.23)17.50 b	80	(4.51)20.00 b
	6.0	24	(2.54) 6.00 b	40	*(3.23)10.00 bc	47	*(3.49)11.75 c	78	(4.46)19.50 b
	8.0	21	(2.38) 5.25 b	26	(2.63) 6.50 c	34	(2.98) 8.50 c	50	*(3.59)12.50 c
Neem	1.5	30	(2.80) 7.50 a	54	(3.74)13.50 a	77	(4.44)19.25 ae	104	(5.14)26.00 ae
	2.5	21	(2.39) 5.25 a	28	(2.73) 7.00 b	31	(2.87) 7.75 b	37	(3.12) 9.25 b
	3.5	5	*(1.22) 1.25 b	14	(1.98) 3.50 c	22	(2.44) 5.50 b	27	(2.68) 6.75 c
	4.5	0	(0.71) 0.00 b	3	*(1.06) 0.75 d	8	*(1.51) 2.00 c	10	*(1.73) 2.50 c
Lemongrass	1.5	38	(3.14) 9.50 ae	62	(3.98)15.50 ae	104	(5.14)26.00 ae	116	(5.43)29.00 ae
	2.5	24	(2.51) 6.00 ab	54	(3.73)13.50 a	83	(4.61)20.75 ab	93	(4.87)23.25 b
	3.5	18	(2.23) 4.50 b	42	(3.29)10.50 a	73	(4.33)18.25 b	84	(4.63)21.00 b
	4.5	8	*(1.54) 2.00 c	11	*(1.76) 2.75 b	23	*(2.43) 5.75 c	29	*(2.69) 7.25 c
Eucalyptus	0.5	37	(3.12) 9.25 ae	60	(3.90)15.00 ae	92	(4.54)23.00 ae	110	(5.28)27.50 ae
	1.0	26	(2.63) 6.50 ab	42	(3.29)10.50 ab	80	(4.52)20.00 a	90	(4.79)22.50 ab
	1.5	16	(2.11) 4.00 b	26	(2.64) 6.50 b	68	(4.18)17.00 a	84	(4.63)21.00 b
	2.0	6	*(1.39) 1.50 c	10	*(1.73) 2.50 c	25	*(2.59) 6.25 b	41	*(3.28)10.25 c
Control-I (Dis. water)		57	(3.83)14.25 e	81	(4.54)20.25 e	103	(5.120)25.75 e	128	(5.68)32.00 e
Control-II(water + 5% benzene)		56	(3.79)14.00 e	81	(4.55)20.25 e	104	(5.144)26.00 e	128	(5.68)32.00 e
S.E.m.			0.183		0.188		0.169		0.129

* : Best concentrations ; Values in parenthesis are transformed values ($Y = \sqrt{x + 0.5}$)

S.E.m. = Standard error of the means.

	Comparisons among best concentrations of plant extracts			
	24 hours	48 hours	72 hours	96 hours
Neem	(3.5) 1.25 a	(4.5) 0.75 a	(4.5) 2.00 a	(4.5) 2.50 a
Eucalyptus	(2.0) 1.50 a	(2.0) 2.50 b	(2.0) 6.25 b	(2.0)10.25 c
Lemongrass	(4.5) 2.00 a	(4.5) 2.75 b	(4.5) 5.75 b	(4.5) 7.25 b
Mustard	(3.5) 8.25 b	(2.5)11.25 c	(4.5)13.00 c	(4.5)13.50 c
Datura	(4.0) 9.25 b	(6.0)10.00 c	(8.0)11.75 c	(8.0)12.50 c

a, b, c, d and e, figures followed by the same letters are not significantly different.

mean number of holes made by the larvae were : 1.25, 3.50, 5.5, 6.75 at intervals of 24, 48, 72 and 96 hours, respectively.

In case of eucalyptus, when tested at 0.5 per cent 9.25, 15.00, 23.00, 27.50, were the number of holes made by the larvae at the end of 24, 48, 72 and 96 hours, respectively. But the performance at this concentration was found to be same as in control. No critical difference was observed in subsequent concentrations viz., 1.0 and 1.5 per cent, respectively. But at 1.5 per cent the holes made by the larvae were significantly different from that at 0.5 per cent. The highest concentration 2.0 per cent was found to be the best concentration, To prevent larvae from feeding the treated food. At this level, the mean number of holes made were 1.50, 2.50, 6.25, 10.25 at 24, 48, 72 and 96 hours intervals, respectively.

Lemongrass was the third best in performance, at 1.5 per cent the mean number of holes made by larvae was more. By increasing the concentration to 2.5 per cent the mean number of holes made by larvae decreased significantly. But at 2.5 and 3.5 per cent differences were found to be insignificant. But at the highest concentration (4.5%) the number of holes made by larvae was significantly less than at other concentrations (1.5, 2.5 and 3.5%), the results recorded were 2.0, 2.75, 5.75, 7.25, at 24, 48, 72 and 96 hours, respectively.

Mustard came next in the order of effectiveness. Wherein at 1.5 and 2.5 per cent the number of holes made were comparable to control, which indicates these two concentrations were not effective but at 3.5 per cent, the holes made were less and it was on with the second concentration (2.5%). The deterrence was found to be best at 3.5 per cent, because at the highest concentration (4.5%) the mean number of holes recorded was on par with holes made in the case of the third concentration (3.5%). The results observed were 8.25, 10.0, 12.5, 19.75 at 24, 48, 72 and 96 hours of treatment.

Datura was found to be less effective than other plant products at the lowest concentrations (2 and 4%). At the higher concentrations (6 and 8%) the number of holes made were noted to be on par with results recorded at 4 per cent. Hence 4 per cent could be selected as the best concentration wherein the mean number of holes made were 9.25, 12.5, 17.5, 20.0 at 24, 48, 72 and 96 hour intervals, respectively.

Two different controls were kept for comparison. In one, the blotting paper was treated with distilled water and in case of the other, the paper was treated with a mixture of water and 5 per cent benzene solution as mentioned already in materials and methods. There were no significant differences between these two controls, in terms of mean number of holes made by larvae. The comparisons were made between controls

and different concentrations of different plant extracts. The results show that in case of neem, the number of holes made by larvae at all concentrations were significantly different from the controls. Whereas, in case of eucalyptus and lemongrass at the lowest concentrations viz., 0.5 and 1.5 per cent respectively, the holes made were the same as in case of controls. But at higher concentrations the mean number of holes made were significantly different from controls. Other two products viz., mustard and datura at concentrations of 1.5, 2.5 and 2, 4 per cent respectively the number of holes made were equal to the controls, at higher concentrations, the feeding deterrence was significantly more than in the controls.

Malathion was also tested in the same manner, but because of its contact toxicity, the larvae became inactive after some time and died eventually.

4.5 Studies on repellent properties of candidate plant products against larvae of rice moth

Plant species were tested for their repellent activity, against the most active instar i.e., third instar larvae of rice moth and results are presented in Table 17.

From the comparisons, it is evident that the eucalyptus and lemongrass oils were the most effective ones by showing the

Table 17. Repellency of plant products against larvae of Corcyra cephalonica (Stnt)

Percent repellency after

Plant extract	Conc- %	10 min- utes	C	1 hr.	C	2 hr.	C	4 hr.	C	8 hr.	C	16 hr.	C	24 hr.	C	48 hrs.
Eucalyptus	0.5	10	I	0	-	-5	-	0	-	0	-	-10	-	0	-	0
	1.0	45	III	30	II	15	I	0	-	-10	-	0	-	-5	-	0
	1.5	75	IV	55	III	50	III	5	-	0	-	0	-	0	-	0
	2.0	95	V	85	V	65	IV	50	-	15	-	0	-	0	-	0
Lemon-grass	1.5	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	2.5	25	II	10	I	5	I	-5	-	0	-	0	-	0	-	0
	3.5	50	III	35	II	35	II	25	-	10	-	0	-	0	-	0
	4.5	85	V	85	V	70	IV	35	-	10	-	5	-	-5	-	0
Mustard	1.5	0	-	0	-	0	-	0	-	0	-	-5	-	0	-	0
	2.5	15	I	15	I	20	I	15	-	15	-	5	-	0	-	0
	3.5	20	II	25	II	20	I	20	-	20	-	5	-	0	-	0
	4.5	45	III	50	III	45	III	45	-	45	-	30	-	10	-	0
Neem	1.5	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
	2.5	-5	-	0	-	0	-	0	-	-5	-	0	-	0	-	0
	3.5	0	-	0	-	5	I	10	-	10	-	10	-	15	-	5
	4.5	15	I	20	I	15	I	15	-	20	-	25	-	30	-	20
Datura	2.0	0	-	0	-	0	-	0	-	0	-	0	-	-5	-	0
	4.0	0	-	-5	-	0	-	0	-	0	-	-5	-	0	-	0
	6.0	0	-	0	-	0	-	-5	-	-5	-	0	-	0	-	0
	8.0	-5	-	0	-	0	-	-5	-	-5	-	0	-	0	-	0
Untreated paper	-	0	-	0	-	0	-	0	-	0	-	0	-	-10	-	-5
Standard error of the mean	-	0.121	0.132	0.121	0.114	0.096	0.089	0.088	0.078							

C = Category

maximum per cent repellency from the treated surface, followed by mustard, neem and datura; irrespective of their concentrations. The observations were recorded for different periods to see the decline in the repellent activity of plant products. Two following controls were kept for comparisons are filter paper treated with (a) distilled water (b) mixture of water and benzene as already mentioned.

It was observed that after 10 minutes eucalyptus showed repellent activity from category-I to category-V at different concentrations, vi.z, 0.5, 1.0, 1.5, 2.0 per cent, respectively. The per cent repellency was found to be very high at 2.0 per cent (95.0%).

The trend of results after 1 hour period was different from that of 10 minutes period by exhibiting different classes of repellency per cent from 0, II, III and V at 0.5, 1.0, 1.5 and 2.0 per cent, respectively.

The observed per cent repellency after 2 hours followed the category as follows 0, I, III, IV for 0.5, 1.0, 1.5 and 2.0 per cent, respectively.

After 4 hours of treatment the third and fourth concentrations occupied I, and III categories of per cent repellency, respectively. Whereas at the other concentrations,

(0.5 and 1.0%) the per cent repellency was nil. After 8 hours at the highest concentration, the per cent repellency recorded was 15 per cent i.e. it falls in to category I. At other concentration the per cent repellency was found to be zero. When observations recorded after 8, 16, 24, 48 hours periods the per cent repellency was found to be zero at all concentrations.

Lemongrass was the next best among all plant products tested. The results after 10 minutes show repellency per cent of 0, 25.0, 50.0, 85.0 per cent for 1.5, 2.5, 3.5, and 4.5 per cent concentration, respectively which occupied 0, II, III and V categories of repellency per cent.

The observations recorded after 1 hour period were less, indicating that the per cent repellency was reduced to 0.0, 10.0, 35.0, 85.0 per cent at 1.5, 2.5, 3.5, and 4.5 per cent, follows an order of category 0, I, II and V, respectively. The per cent repellency trend after 2 hour period was as follows: 0.0, 5.0, 35.0, 70.0 per cent repellency at 1.5, 2.5, 3.5 and 4.5 per cent and these comes under categories 0, I, II and IV, respectively. At 4 and 8 hours period also the trend was category 0, 0, II, II and 0, 0, I, I at 4 and 8 hours periods for 1.5, 2.5, 3.5 and 4.5 per cent, respectively. Whereas, after 16 hours period, the categories of repellent per cent were changed as follows: 0, 0, 0, I at 1.5, 2.5, 3.5 and 4.5 per cent respectively. The results noted after 24 hour and 48 hour period were the same showing zero per cent repellency.

Mustard was found to be the next best by showing the next maximum per cent repellency. The categories of per cent repellency given after 10 minutes and 1 hour at different concentrations were the same at all periods; 0, I, II, III at 1.5, 2.5, 3.5 and 4.5 per cent respectively.

The order of categories was changed slightly after 2 hour, 4 hour and 8 hour periods from 1 hour period. The order given was 0, I, I, III at 1.5, 2.5, 3.5 and 4.5 per cent.

At 16 hour period, the per cent repellencies recorded by category wise were 0, I, I, II for 1.5, 2.5, 3.5 and 4.5 per cent concentrations, respectively. At 24 hours the order of categories were 0, 0, I, II and at 48 hour period 0, 0, 0, II for 1.5, 2.5, 3.5 and 4.5 concentrations, respectively.

Next best one was found to be neem in terms of giving higher per cent repellency against rice moth larvae. The categories determined based on per cent repellency at 10 minutes, 1, 2, 4, 8 hours were as follows; 0, 0, 0, I; 0, 0, 0, I; 0, 0, I, I; 0, 0, I, I; 0, 0, I, I for 1.5, 2.5, 3.5 and 4.5 per cent respectively.

The repellency per cent after 16, 24, 48 hour was the same viz., 0, 0, I, II at 1.5, 2.5, 3.5, 4.5 per cent respectively.

Datura was found to show zero per cent repellency at all concentrations, at all intervals of time period as shown in the case of control.

DISCUSSION

V. DISCUSSION

Results obtained on the studies of different properties of plant products viz., neem, mustard, datura, eucalyptus and lemongrass as toxicants, feeding deterrents and repellents against the egg and larvae of Corcyra cephalonica (Stnt) revealed that, some of these materials are effective in protecting the stored grains from insect infestations. Relative merits and demerits of these plant products in comparison with malathion 0.5 per cent are being discussed.

Studies on the effect of plant extracts on per cent hatchability of eggs of rice moth (Corcyra cephalonica)

In causing less per cent hatchability of eggs eucalyptus occupies first place. Among different concentrations tried the second concentration (1.0 per cent) was found to be the best concentration by giving 12.5 per cent of egg hatchability. When concentrations were increased from 1.0 to 1.5 and 2.5 per cent, the per cent hatchability was not significantly increased.

When compared to the per cent hatchability of eggs in case of eucalyptus with malathion, both were found to be on par with each other. Thus indicating that eucalyptus essential oil as a safer ovicide may be used to spray on stored grains to kill the eggs of rice moth. Whereas because malathion, a very toxic chemical we cannot spray this on grains used for consumption.

Neem was also found to have ovicidal activity by occupying a place next to eucalyptus. When tried at different concentrations the maximum hatchability of eggs was found at 2.5 per cent (12.50 per cent). Here also increased concentrations (3.5 and 4.5 per cent) did not show any critical differences from per cent hatchability of eggs at 2.5 per cent

In case of lemongrass the per cent hatchability at best concentration (1.5 per cent) was found to be 22.5 per cent. When concentrations increased to 2.5, 3.5 and 4.5 per cent there was no significant decrease in hatchability of eggs of rice moth. When mustard was tried at 1.5, 2.5, 3.5 and 4.5 per cent maximum hatchability per cent of eggs was found at 4.5 per cent by giving 22.5 per cent of egg hatch. At low concentrations of 1.5, 2.5 and 3.5 per cent the per cent egg hatchability recorded was 92.50, 90.00 and 55.00 respectively. The results at first two (1.5 and 2.5 per cent) were found to be on par with each other. But at the third and fourth concentrations (3.5 and 4.5 per cent) the per cent egg hatchability was not on par with any other concentrations. Ali et al. (1983) reported the ovicidal activity of mustard and neem against eggs of Callosobruchus chinensis(L), at 1.0 ml/100 g of seed. It was found that neem caused 100 per cent of mortality when mixed with seed at 1.0 ml per 100 g of seed, and mustard was found to be less effective in terms of egg mortality than neem.

Datura the least effective one gave better egg hatch (15.0%) at 6 per cent. The per cent egg hatch at 2.0 and 4.0 per cent were not significantly different from each other. But the per cent egg hatchability at 8.0 per cent concentration was on par with 6.0 per cent concentration.

When the per cent egg hatch at best concentrations of plant products viz., neem, lemongrass, mustard and datura was compared with per cent egg hatch at 0.5 per cent malathion, there were no significant differences irrespective of their concentration. Malathion can be replaced with 2.5, 1.5, 4.5, 6.0 per cent concentrations of neem, lemongrass, mustard and datura, respectively, to control infestation of rice moth. These plant products which are less toxic to human being can also be used to treat the stored grains meant for consumption.

One control was kept to see the effect of benzene and labolene on mortality of eggs. Hundred per cent of the eggs were found to hatch and that indicates benzene and labolene did not effect the eggs of rice moth.

Studies on insecticidal properties of plant products on the larvae of *C. cephalonica*

Eucalyptus was found to be the most effective toxicant against the rice moth larvae. It gave 48.75 per cent mean

larval mortality percentage at 1.5 per cent after 72 hours of treatment. These results shows that the early instars are very susceptible to this plant product as compared to the later instars (third and fourth). At lower concentrations of 0.5 and 1.0 per cent the mortality recorded was significantly less than that at the third concentration (1.5%). Increasing the concentration from 1.5 per cent to 2.0 per cent did not improve the performance. These findings indicate that eucalyptus at 1.5 per cent can be used as a toxicant to control infestation of rice moth under storage conditions. Raymudo and Alcazar (1983) reported that dusting the plants of potato six times with the ashes of Eucalyptus sp., reduced the tuber infestation of Liriomyza huidobrensis to a considerable extent. Similar results were also obtained by Raman et al. (1987) who stated the control of potato tuber moth under storage conditions by covering stored potatoes with the dried foliage of Eucalyptus globulus.

During experiments the treated larvae mostly third, fourth and fifth instar larvae showed some symptoms like the colour of treated larvae was changed from cream to dark brown by next day and the microscopic observations on day third showed that the third and fourth instar larvae could not moult their old skin and head capsules. Whereas in the case of 5th instar larvae which was about to go for pupation also could

not moult its head capsule and skin, because it could not enter into pupation, and by five days after treatment the larvae were found dead. From these observations it may be concluded that the Eucalyptus extract is also acting as moulting inhibitor. So we can exploit this extract to control other insect pest species also. Jaipal (1983) observed the juvenile hormone like activity of crude extracts of wood and bark of Eucalyptus naundina against the 5th instar larvae of Dysdercus koenigii (the cotton stainer).

The toxic effect of eucalyptus against second and third instar larvae were on par with that of malathion 0.5 per cent E.C. Hence, eucalyptus can replace malathion as a toxicant against early stages of rice moth infestation in stores. In addition to toxic effects it also exhibits molting inhibitor activity by causing deformations in all larval stages of rice moth.

Lemongross tested on different instar larvae caused less mortality at lower concentrations (1.5 and 2.5%) but when the larvae were treated with 3.5 per cent concentration it gave maximum mean per cent of larval mortality i.e., 65.0 per cent by the end of the experiment.

After 24 hours of treatment the larvae showed symptoms like the change of larval colour from cream to light brown and also the effected larvae could not move and did not feed indicating the inactivity of larvae and finally found dead. The other observational symptoms were that the effected larvae contracted and first few abdominal segments were swollen with the ruptured skin over there. This symptom may be due to some unknown changes in some biochemical reactions with digestive juices of insect. The larvae that showed such type of symptoms were found dead after some time. Kayumov (1937) showed the toxic effects of Cymbopogan citratus (lemongrass) when sprayed at 2.0 per cent of Tetranychus telarius L. and Aphis gossipii Glov., it gave 90 per cent mortality after 24 hours of treatment. Zhang and Zhao (1983) tried the volatile essences of Cymbopogan caesius at 0.5 ml per petri dish against adult weevils of Sitophilus oryzae they recorded 100 per cent mortality of adult weevils with in three days.

On comparison with malathion 0.5 per cent (EC), lemon-grass was found to on par with mortality per cent of malathion at 4.5 per cent concentration-mean per cent mortality of . . 82.5 per cent.

The mortality per cent recorded in mustard and neem were nearly equal to each other. Here also with increasing concentrations the mortality per cent was also increased. The

best concentration selected was 3.5 per cent for both of the plant extracts. At this concentration the recorded mean per cent mortality was 58.80 per cent and 61.90 per cent of mustard and neem, respectively. Ali et al. (1983) showed toxic effects of seed oils of neem and mustard against eggs, larvae and adults of Callosobruchus chinensis by mixing the oils with food. When these tried at 0.05 ml per 100 g of seed the effect was found to be very less, but at 1.0 ml per 100 g of seed of neem found to cause 100 per cent of larval mortality and 100 per cent adult mortality after three days of treatment. But mustard was found to be less effective than neem against all stages of C. chinensis. Similar results were obtained by Das (1986) who stated that neem and mustard gave maximum per cent of mortality of adults of Callosobruchus chinensis, when chickpea was treated with these oils.

In addition to toxic properties these two products i.e., neem and mustard also exhibited juvenile hormone activity showing symptoms like improper moulting of old skin and old head capsule. Gujar and Mehrotra (1983) showed the same results when the final instar larvae of Spodoptera litura fed on treated castor leaf with various doses (1.0, 5.0, 10.0, 25.0 and 50.0 μ g/insect) of azadirachtin (isolated from neem) showed some disruptions like larval pupal inter-mediate and improper molting of old skin. Many other workers have reported

the juvenile hormone activity of neem on different insects. The studies on improper moulting of larvae (mustard), found for the first time in the present studies. From the studies it could be concluded that the 3.5 per cent concentration of neem and mustard could be used to control the infestation of rice moth.

Malathion was superior both to mustard and neem in terms of per cent mortality recorded at 3.5 per cent. But the per cent larval mortality at higher concentration (4.5%) was on par with mortality per cent of malathion.

Datura did not give encouraging results, when tried at low concentrations viz., 1, 2, 3, and 4 per cent, so concentrations were increased to 2, 4, 6 and 8 per cent to see at what concentration it will give maximum mortality per cent. The mean mortality per cent recorded at the best concentration (6.0 per cent) was 76.88 per cent. Rajendran and Gopalan (1979) reported the insecticidal properties Datura stramonium against Spodoptera litura when tried at 50 μ g per larva the per cent mortality recorded was 15.0 per cent and when tried at higher concentration i.e., 250 μ g per larva it gave 75.0 per cent mortality of larvae.

Datura did not show any symptoms like other plant products, that indicates it does not have any moulting inhibitor activity against the test insect. Datura was found to be on

par with malathion at 8.0 per cent concentration in terms of per cent mean mortality.

Malathion at 0.5 per cent concentration gave 100 per cent mortality of all instars after 48 hours only. But in case of plant products the maximum mortality per cent (less than 100) was recorded after 72 hours of treatment. This indicates that plant products are slow in their action when compared to malathion and also the effect caused on different instars were significantly different from one another irrespective of plant extracts.

To make different concentrations of plant products Benzene 5 per cent was used as solvent and labolene 0.1 per cent was used as emulsifier. To see the effect of these chemicals on mortality of the larvae, one control was run by spraying these on different instars of larvae. The results showing that Benzene has a very quick knock down effect by showed inactiveness of treated larvae, but after 10 minutes all larvae recovered and became normal and there was no record of mortality after 24, 48 and 76 hours as shown in case of larvae treated with plant extracts. That indicates it does not have any toxic properties.

Ovicidal properties of plant products

Based on the calculated LC_{50} values the increasing order of ovicidal activity was lemongrass, eucalyptus, neem, datura and mustard.

From the results it is clear that lemongrass essential oil caused maximum per cent of egg mortality with low LC_{50} values and mustard was found to be the least effective in causing egg mortality.

From the results the following conclusions can be drawn;

The above plant products lemongrass (LC_{50} value of 0.41599%) less than eucalyptus (LC_{50} value of 0.62135%) less than neem (LC_{50} value of 0.82285%), > datura (LC_{50} values of 1.8236%) less than mustard (LC_{50} values of 3.62279%) which acted as ovicides by causing maximum egg mortality at low concentration could be exploited in pest control programmes.

Studies on determination of LC_{50} values against mortality of larvae

The LC_{50} values were calculated for mortality per cent caused after 24, 48, 72 hours intervals to see the rate of action of plant products in causing mortality of larvae. The calculated LC_{50} values for all instars indicate that the LC_{50} values were less in case of the earlier instars as compared

to the later instars. This shows early instars are more sensitive of less resistant than later instars when treated topically at different concentrations of plant products.

Based on calculated LC_{50} values eucalyptus was found to be the most effective by showing 50 per cent mortality at very low concentrations. Datura was the least effective which caused 50 per cent mortality of larvae at higher concentrations.

Feeding behaviour of the test insect on food treated with different plant products

The behaviour of the test insect with different plant products in presence and absence of control foods (choice and no choice chamber test) was observed.

In case of choice chamber test when comparisons made between plant products in terms of the mean number of larvae that preferred to enter into treated food, eucalyptus was found to be the best by preventing the entering of the larvae in to the treated food. The mean number of larvae that entered into food at the best concentration (1.0%) was 2.25 per cent. This indicates, because of repellent property of eucalyptus the larvae did not prefer to enter into this food. The same results were reported by Lal (1987) when potato tubers were covered with powdered leaves of Eucalyptus

globulus (in a 2.5 cm layer). The results showed that the per cent infestation of tuber was very less. Because of repellant properties of eucalyptus insects could not enter into treated potatoes under storage conditions. Therefore eucalyptus essential oil can be used by mixing with grain to prevent the entrance of larvae under storage conditions.

Eucalyptus was found to be very effective when compared to control I and II. The number of larvae that entered into control were significantly more than those that entered into the best concentration of eucalyptus (1.0%).

In case of lemongrass also the number of larvae that preferred to enter was very less as in eucalyptus. The mean larvae entered at best concentration (2.5%) were 4.5. On comparing to control I and II the mean number of larvae that entered into the controls were significantly more than those that entered into lemongrass treated food. This implies lemongrass essential oil also exhibited repellent properties by preventing the larval entrance. Thus lemongrass may be used as a repellent to prevent insect infestation under storage conditions.

When the food was treated with mustard at best concentration (2.5%) the mean number of larvae that entered were 4.00. When this number was compared with control I and II the

differences were significant. The next effective one i.e., neem, the mean number of larvae that entered into treated food at the first concentration (1.5%) was found to be 5.5 and at 2.5 per cent concentration also the number entered was nearly the same (5.25). But only 2.5 mean number of larvae entered into food treated with 3.5 per cent of the product, When comparisons made between 3.5 per cent and 4.5 per cent the mean number of larvae that entered was not significantly different from each other. So 3.5 per cent could be selected as best concentration. The mean number of larvae that entered into food treated with 3.5 per cent compared with control I and II was significantly different-one another. So these can be used to protect grains, protectants, which are cheap and less toxic to human beings.

The number of larvae that entered into food treated with different concentration of datura and controls, on par with each other. That indicates the insects randomly selected their places to avoid competition between them for food. From these results we can say that datura has only toxic properties as mentioned earlier but not repellent properties as observed in case of other products. So we cannot use this as insect repellent to prevent infestation by driving off the insects from the treated foods.

Second aspect observed was the number of larvae that consumed the food. These observations were recorded based on web formation by larvae after entering into the treated food. By nature this insect webs the grains by forming clumps of grain, then feeds on this grain. From the results it is evident that the number of larvae that consumed food in case of neem was found to be less followed by eucalyptus, mustard, lemongrass and datura.

In case of neem at lower concentration (1.5%) the mean number of larvae that consumed the food was 6, which was found to be on par with the second concentration (2.5%) when concentrations were increased to 3.5 and 4.5 per cent the mean number of larvae that consumed the food was significantly different from 2.5 per cent. The best concentration selected from the above results was 2.5 per cent, wherein the mean number of larvae that consumed food was 2.5. On comparing the results at 2.5 per cent with both the controls the values at 2.5 per cent concentration are significantly different from control values. This shows that neem exhibited feeding deterrent property against rice moth larvae. Different reports from literature show that neem as very effective antifeedant. Attri (1975) showed the antifeedant activity of neem oil extractive and water extract of neem seed kernel against

Schistocerca gregaria when sprayed on their host plants. The same results are reported by several research workers. Neem seed cake extract can be used as an antifeedant by mixing with grain under storage conditions.

Eucalyptus also exhibited same property by preventing the maximum number of larvae (2.5) from feeding at 1.0 per cent. The comparisons between the different concentrations were as follows : The mean number of larvae consumed food at 0.5, 1.0 per cent and 1.0, 1.5 and 2.0 per cent concentrations are on par with each other. In case of mustard the mean number of larvae consumed food at 1.5 per cent were 6.25 at the next concentration (2.5%) the values are on par with the first concentration (1.5%). Whereas at concentrations of 2.5, 3.5 and 4.5 per cent the mean number of larvae that consumed food was on par with one another. The best concentration based on the above comparisons was 2.5 per cent at which mean number of 2.25 larvae consumed the food.

The least effective one i.e., datura also exhibited antifeedant activity against rice moth larvae. When tried at 2.0 per cent, 9.25 per cent of larvae consumed the food. When the concentration was increased to four per cent number of larvae that consumed food was significantly decreased from 2 per cent concentration results. But at further

increased concentrations of 6 and 8 per cent no significant differences from the results at 4 per cent were observed.

When the results of mustard, neem and datura (best concentrations) compared with control I and II, all were found to be significantly different from controls. So we can exploit this property of plant products to control insect pest infestation under storage conditions.

The comparisons between both controls viz., control I (Distilled water) control II (Benzene 5% + labolene 0.1% + water) were found be significantly different. In case of both aspects i.e., mean number of larvae preferred to enter into food and mean number of larvae consumed the food. The mean number of larvae were more in case of control II. Which indicates that the mixture of this exhibiting some attractant property. Because of this property more number of insects entered into control II. To see which chemical is acting as attractant .separate experiment was conducted and lobolene was found to show some atractant properties. For later experiments this was not used to avoid influence of this on different properties of plant products.

No choice chamber

This experiment was conducted to see the behaviour of test insect with treated food of plant products in the absence

of control foods. The order of plant products in performance was the same as in choice chamber test. In almost of all cases more number of larvae entered into food treated with low concentrations because, in choice chamber test there were two controls, which did not show any repellent property, most of the larvae entered into control food, but in no choice chamber test wherein only food treated with different concentrations were kept, most of the larvae preferred to enter into low concentrations levels which are less effective than higher concentrations.

In case of eucalyptus and lemongrass the number of larvae recorded in empty space was more, because of their high repellent activity. More number of larvae recorded next to eucalyptus and lemongrass was in mustard followed by neem and datura. The second aspect i.e., mean number of larvae that consumed the food, the trend was found to be the same as explained in the earlier case. In exhibiting antifeedant activity neem was the first one but the number of insects present in empty space was more in case of lemongrass and eucalyptus essential oil. This must be due to their high repellent property that the larvae could not enter into treated food.

From the above discussion it may be concluded that almost all candidate plant products were very effective by exhibiting antifeedant activity and repellent activities against the test insect. Therefore it is suggested that synthetic

chemicals may be replaced with these plant products to control infestation of pests.

Antifeedant properties of plant products

Antifeedant activity was taken as inversely proportional to number of holes made by the larvae as mentioned in materials and methods.

Among the plant product used, neem was found to be the best antifeedant against test insect larvae as indicated by less number of holes on the treated paper. When neem was tried at 1.5 per cent level 7.5, 13.5, 19.25 and 26.0 were the mean number of holes made by larvae at intervals of 24, 48, 72 and 96 hours, respectively. The number of holes made at 2.5 per cent were found to be on par with 1.5 per cent. When the concentration increased to 3.5 per cent there was significant decrease in number of wholes made by larvae, but by increasing the concentration further (4.5%) it did not show any increase in antifeedant activity indicated by number of holes on par with 3.5 per cent. So 3.5 per cent was selected as best concentration wherein, the mean number of holes made by larvae was 1.25, 3.50, 5.50, 6.75 at intervals of 24, 48, 72 and 96 hours, respectively. From the results it is evident that the number of holes increased progressively from 24 to 96 hours period indicating the decrease in the antifeedant activity. Many workers have proved the antifeedant activity of neem against

wide range of insect pests. Malik and Naqvi (1984) proved antifeedant activity of azadirachtin (isolated from neem) against Rhizopertha dominica adults by showing less mean number of holes made on treated paper (0.92). Joshi et al. (1984) tested neem seed kernel suspension against the tobacco pest Spodoptera litura by spraying on its host plant, the results showed that neem protected tobacco plants from S. litura for seven days by exhibiting antifeedant activity.

Datura was the least among all the plant products tested. The number of holes made at ~~six~~ per cent were as follows, 9.25, 12.5, 17.5 and 20.0 at 24, 48, 72 and 96 hours intervals respectively. Nadasy and Safringer (1985) showed less antifeedant activity of datura when tried against Sitona humaralis.

In between these two products eucalyptus, lemongrass and mustard were found to be best in exhibiting antifeedant activity.

Two controls were run, control I (distilled water) and control II (Benzene 5% and Distilled water). There was no significant difference between these two controls. This indicates that benzene did not influence the antifeedant activities of plant products, when comparison were made between controls and plant products it was found that in case of neem

the results at all concentrations (1.5, 2.5, 3.5 and 4.5 per cent) were significantly different from controls exhibiting thereby maximum antifeedant activity up to 48 hours. At 72 and 96 hours the mean number of holes made at 1.5 per cent was found to be on par with control. This indicates the concentration 1.5 per cent, the least effective as compared to the other concentrations. Whereas in case of other plant products from the beginning the number of holes made at the lower concentrations of eucalyptus, lemongrass, mustard and datura (0.5, 1.5, 1.5 and 2.0% respectively) were found be on par with one another.

The results recorded (feeding behaviour experiment) for mean number of larvae consumed food at different concentration of different plant products showed the same results as in the above experiment.

From this discussion it may be concluded that neem seed cake extract at 3.5 per cent can be used as effective antifeedant to control insect pests. Eucalyptus at 2.0 per cent and lemongrass, mustard and datura at 4.5, 3.5 and 4.0 respectively can also be used as effective antifeedants.

Repellent properties of plant products

Repellent property is different from the antifeedant property. Repellent activity means insects get repelled from the treated surface or the insects cannot go and touch the food, whereas in antifeedant activity the insects can go or

enter into the food and stay there but cannot feed on the food because of disagreeable taste of food (non preference).

From the results it is evident that eucalyptus was the most effective one, by giving nearly 100 per cent of repellency against the test insect, after 10 minutes of treatment at the highest concentrations. At lower concentrations 0.5, 1.0 and 1.5 per cent, the per cent repellency recorded falls into the categories of I, III and IV. The observations after 1 hour showed decreased per cent of repellency at different concentrations 0, 30, 55 and 85 per cent at 0.5, 1.0, 1.5 and 2.0 per cent respectively. The per cent repellency decreased after each and every interval of time period. The reason for this may be because, as this is an essential oil, loses its activity very fast, by the end of 16 hours the per cent repellency recorded was zero at all concentrations. The same trend of results were reported by Ahmed and Eapen (1986) when essential oil of eucalyptus tried against Sitophyllus oryzae and it showed 80 per cent repellency after 10 minutes, 50 per cent after 30 minutes and after 60 minutes it decreased to 20 per cent.

The loss of activity of eucalyptus at consequent interval periods may be due to the volatile nature of the essential oil.

In case of lemongrass oil also, the loss of activity was found to be similar to eucalyptus. Initially (after 10 minutes) it showed 85 per cent of repellency but the persistency effect was more when compared to eucalyptus oil. This indicates the rate of volatility of this essential oil less than the eucalyptus essential oil. Here also after a period of 16 hours the repellency per cent became zero.

Datura was found to show zero per cent repellency at all concentrations which indicates its non-repellent properties

When mustard and neem extract were compared in terms of per cent repellency, mustard was found to be superior showing 35 per cent of repellency on an average. Panday and Chatteraj (1976) reported the repellent properties of mustard when smeared on Crotalaria juncea, host plant of Utethesia pulchella got repelled from the treated surface.

Neem was found to be the next effective with repellency percentage of 20 (on an average) against the test insect. Pierce (1981) proved the repellent activity of neem extract against striped cucumber beetle, (Acalymma vittatum) when pieces of Cantaloupe leaves dipped in the extract solution kept in a dish along with untreated leaf pieces. The results showed that the beetles were repelled and the treated leaves were protected for 22 hours.

When the per cent repellency caused by plant products were compared with per cent insects present on or got repelled from control I and control II papers, it was found to be significantly different from per cent repellency caused by plant products. The per cent repellency in both cases of controls was not significantly different. This indicates there was no influence of benzene (5%) which was used as solvent to prepare different concentration of plant products on repellent properties of candidate plant products.

These plant products viz., eucalyptus 2 per cent lemongrass 4.5 per cent mustard 3.5 and neem 4.5 per cent can be used as repellents, in pest control programmes. The results recorded here were comparable with feeding behaviour with feeding by recording mean numbers of larvae entered into treated food.

The use of these indigenous products of plant origin for the protection of human foods has considerable advantages over those of conventional toxic chemicals as they do not pose residue problems, application risks, contamination and health hazards. Further these plant products besides being effective are safer in handling. Application of these plant products not only in the field of storage entomology but also in field crops in a systematic manner based on the findings, will help in the exploitation of plant resources for agricultural use thereby improving the overall economy of rural communities.

SUMMARY

VI. SUMMARY

Extracts of different plant products of neem, mustard, datura, eucalyptus and lemongrass were studied for their insecticidal, repellent and antifeedant properties against the rice moth, Corcyra cephalonica (Stnt). These products were tested at 1.5, 2.5, 3.5, 4.5; 1.5, 2.5, 3.5, 4.5; 2.0, 4.0, 6.0, 8.0; 0.5, 1.0, 1.5, 2.0 and 1.5, 2.5, 3.5, 4.5 per cent concentration\$ levels respectively to asses their relative performance.

To evaluate insecticidal properties of above mentioned plant products results were recorded, at 24 hours intervals and determined the percentage mortality and LC_{50} values of the egg and larvae of test insect. Of the different plant products tested, essential oil of eucalyptus gave maximum per cent mortality of both egg and different instars of larvae at low concentrations when compared to other plant products. Its performance was on par with malathion 50 E.C. at 0.5 per cent.

Other plant products viz., lemongrass, neem, mustard and datura gave mortality percentages on par with eucalyptus oil irrespective of their concentrations used. All these products were found to be on par with malathion at 0.5 per cent in terms of mortality percentage. So all candidate plant

products were found to be effective in same manner against the test insect irrespective of their concentrations used.

Feeding behaviour tests showed the preference and non-preference of treated foods with candidate plant products by recording mean number larvae entered and mean number of larvae consumed, the treated food. The experimental results in case of antifeedant activity proved the neem as the best antifeedant by indicating less number of holes on treated paper at best concentration. (3.5%).

Eucalyptus and lemongrass were found to be the best antifeedants next to neem. When paper treated with these products less number of holes (1.5 and 2.0) were made at best concentrations of 2.0 and 4.5, respectively.

Datura was found to be the least effective one indicated by more number of holes on treated paper. But when compared with controls the differences were significant.

Determination of repellent properties of plant products indicated that eucalyptus was the best one among all by showing nearly 100 per cent of repellency of test insect from treated surface at 2.0 per cent, but because of volatile nature of oil the per cent repellence recorded was low at different intervals of treatment.

Lemongrass was also found to show maximum per cent repellency at 4.5 per cent. In case of other products mustard and neem the per cent repellency was significantly less than eucalyptus and lemongrass essential oils. But in case of datura it was found to be devoid of repellent activity. Thus it was found that all the plant products tested do possess toxic, antifeedant and repellent properties against rice moth [Corcyra cephalonica (Stnt)]. There is a good scope in exploiting the protectant and toxic properties of neem, eucalyptus, lemongrass against the rice moth in the large scale storage of human food as they do away with the disadvantages posed by the use of toxic chemicals.

With the background of literature reviewed on various aspects of the subject and from the results of the present investigations it is evident that these plant products are very useful and non-toxic to non-target organisms, easily biodegradable in nature and very cheaper than synthetic chemicals. Our country is very rich in plant flora, among which some of them have already exhibit plant and grain protectant properties, in pest control programme. Considering the present status of our knowledge especially on the continuous indiscriminate use of pesticides and their undesirable side - effects in pest control programmes, including environmental pollution, plant products could become an alternate

source in place of synthetic and hazardous pesticides. Therefore, there is ample scope for increased research in the development of more effective and environmentally safer, chemicals from plant species in the near future.

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*Original not seen.

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