STUDIES ON THE CHEMICAL CONTROL AND INSECT-PLANT RELATIONSHIPS OF THE RICE LEAFROLLER, *CNAPHALOCROCIS MEDINALIS* GUENEE (PYRAUSTIDAE: LEPIDOPTERA)

By

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THESIS

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CERTIFICATE

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Shri. N. Mohandas under my supervision. No part of the work embodied in this thesis has been submitted earlier.

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INTRODUCTION

INTRODUCTION

The rice leaf roller Cnaphalocrocis medinalis Guenee is known and recorded as a pest of paddy from 19th century onwards. But till recently it was considered only as a minor pest in India. With the introduction of high yielding strains of rice and consequent changes in the pattern of rice cultivation, the relative importance of various pests on this crop has undergone drastic changes. The continuous and often overlapping cropping pattern of paddy has provided an unlimited and perennial food supply for insects. This, combined with the equable and subtropical weather conditions, prevailing in the west coast regions of India, led to the rapid multiplication of many of the pests. The high yielding strains of rice need high doses of fertilizers and the application of these, especially the nitrogenous ones, makes the crops more susceptible to pest attack. Protection of the high yielding strains thus necessitated extensive and intensive use of pesticides which inter alia caused the eradication of the natural enemy complex. As a result of all these, many innocuous pests built up their population to unbelievable heights and became major pests causing regular and extensive damage to rice. The rice leaf-roller is one among these pests.

During the last one or two decades, reports of very severe damages caused to paddy crop by leaf-roller have appeared from different parts of India (Usman and Patturudriah, 1955; Abraham, 1958; Rajamma and Das, 1969; Dorge et al., 1971; Anon., 1971, 1972; Patel, 1972). The information avaliable on the control of this pest is restricted to the field evaluation of some pesticides (Abraham, 1958; Cendana and Calora, 1964; Rajamma and Das, 1969; Chaudhary and Bindra, 1970; Anon., 1971 and 1972; Balasubramoniam et al., 1973; Venkataraman et al., 1973). These reports show that many of the newer insecticides are not fully effective against leaf-roller of paddy. Similarly, insecticides reported effective at one place, have proved ineffective at other places. Objective studies were hence taken up with a view to evolving more effective control measures against C.medinalis. These studies covered the assessment of relative toxicity of insecticides to the different stages of the pest, relative efficacy of various insecticides to the larvae in their natural habitats within leaf folds, the performance of various insecticides (when applied at biweekly intervals) in preventing leaf injury under field conditions and the persistent toxicity of different pesticides applied under field conditions to the first instar larvae.

The insect-plant relationships between *C.medinalis* and different rice varieties also were studied in detail. The aspects covered in these studies were the effect of infestation on the yield of rice when infested at different stages of the crop, the effect of infestation on different rice varieties at boot leaf stage, oviposition preference of the moths of *C.medinalis* to different rice varieties, and the effect of varieties on the extent of leaf consumed by the larvae and on the biology of the past. The extent of damage caused to different rice strains when grown in the field was also studied.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Cnaphalocrocis medinalis Guenee (Subfamily-Pyraustinae; Family-Pyraustidae; Order-Lepidoptera) was first described by Guenee (1854) under the name *Salbia medinalis*. Walker (1859) changed the name to *Botys rutelalis*. In 1863 Lederer described it under the name *Cnaphalocrocis iolinalis* and later in the same year Guenee made detailed studies on the insect and named it as *Cnaphalocrocis medinalis*. This name remains unchanged.

Distribution

It has been recorded as a minor pest from different parts of the world. As early as 1896 Hampson reported it from the Oriental and Australian regions. Other places from where this pest was recorded are Hanoi and Thaiwan in Indochina (Duport, 1913 and 1919; Ou, 1957), Ceylon (Huston, 1920; Jardine *et al.*, 1924), China (Hsu, 1932), Philippines (Canus, 1921; Goco, 1921; Sylayan, 1938; Oatanes and Sison, 1941; Anon., 1965), Labian and adjacent islands of Malaya and in Malaya (Gater, 1924 1925; Wyatt, 1957; Ahmed Yunus, 1964), Dutch East India (Goot, 1927), Hokaido & Japan (Kuwayamma, 1928; Higuchi *et al.*, 1968), Madagascar (Frappa, 1929), Cochin China (Commun, 1930), Siam (Ladell, 1933), Japanese mandated

South Sea Islands (Esaki, 1940) and Pakistan (Alam and Alam, 1964).

The first record of this pest in India was that of Lefroy (1909). Fletcher (1914) observed it as a minor pest of paddy, occasionally causing considerable damage in Northern Circars. Ayyar (1917) recorded it from Godavari and Visagapatnam areas. It was also recorded as a sporadic pest in Calcutta (Misra, 1920), Malabar (Bellard, 1921) and Ganjam (Ayyar, 1932). Usman and Putturudriah (1955) reported the occurrence of this pest in Mysore causing upto 25 per cent damage. A very severe damage of the thaladi crop in Madras was reported by Abraham (1958). Bap Reddy (1968) recorded leaf-roller of paddy as a minor pest in Andhra Pradesh, Bihar, Kerala, Maharashtra, Mysore, Orissa, West Bengal and Tamil Nadu. Vevai (1968) observed it as a minor pest in Assam, Maharashtra and Uttar Pradesh. Severe incidence of this pest has been reported from Kerala (Rajamma and Das 1969) Madras (Anon., 1971), Konkan, Thana and Kolaba Districts of Maharashtra (Dorge et al., 1971), Punjab (Chaudary and Bindra, 1970; Anon., 1972) and Titaban region of Assam (Anon., 1972). Light to heavy incidence of C.medinalis was reported from several centres in India where All India Co-ordinated Rice Improvement Project trials are in progress (Anon., 1971 and 1972).

<u>Biology and seasonal incidence</u>

A brief description of the biology of the pest was given by Fletcher (1914). He observed that the pupa was brownish and the larvae pupated in leaf folds and pupal period lasted for six days. The nature of eggs and egg laying and the duration of larval and pupal periods were first described by Otanes and Sison (1952, unpublished) as seen quoted by Cendana and Calora (1964). Abraham (1958) studied the duration of different life stages of the pest in Madras. Biology was studied briefly by Alam and Alam (1964) in Pakistan and Cendana and Calora (1964) in Philippines. The biology and bionomics of the pest were studied by Rajamma and Das (1969) in Kerala.

The pest was reported to be prevalent during August-September in Madagascar (Frappa, 1929), during April in Indonesia (Commun, 1930), throughout the year in Taiwan (Ou, 1957), during October-January in Thanjavur District of Madras (Abraham, 1958), in August-September in Philippines (Cendana and Calora, 1964) and during October, November and April at Coimbatore in Madras (Veluswamy <u>et</u> <u>al</u>., 1973).

Nature of damage

Duport (1913) reported C.medinalis as a minor pest of paddy, the larvae of which bore into the stems of the plants. Lefroy (1914) observed that the caterpillars of this pest lived on the leaves of rice plants and some varieties of grass, folding over the edges of the leaves and fastening it with a few silken threads. The nature of larval feeding and the damage caused were described by Rajamma and Das (1969).

Alternate hosts

Box (1953) and Kalra (1964) recorded C.medinalis as a pest of sugarcane. Cendana and Calora (1964) reported that the insect feeds on rice, corn, sugarcane, millets, sorghum and grass species in Philippines. The grasses Pennisetum pedicellatum, Dichanthium annulatum and Panicum sp. were recorded as alternate hosts of leaf-roller (Gargav and Katiyar, 1971). This pest has also been reported from ragi in Mysore (Vishakantaiah and Jayaramaiah, 1972). The wild species of rice Oryza perennis, O. echingeri, O. subulata, O. latifolia, O. malampuzhensis, O. alta and a cross between O. perrenis and O. echinger were also found harbouring the larvae of C.medinalis (Veluswamy et al., 1973).

Natural enemies

A number of parasites have been reported from different life stages of the pest. Apanteles angustibasis and Brachymeria excarinata (Gohan 1925), A.ruficeps and Melcha maciliceps (Alam and Alam, 1964), Elasmus sp., Rhysipolis sp., Macrocentrus sp., Spathius sp., Goniosus sp., Apanteles sp., G. triangularis, Diatora lissonata, Chatomyobia fuvana (Narayanan et al., 1964), Sympiesis sp., Eurytoma sp., Eupteromalus sp., Goniozus sp. nr. depressus, Apanteles sp. nr. opacus, Bracon sp., Bracon gelechiae, B. ricinicola, Cardiochiles sp., Cedria anomala, Hormius sp., Meteorus bacoorensis, Micropletis sp., Labrorynchus apicalis, Leptobatopsis annulipes, Pristomerus sp., Syzeuctus sp., Temelucha sp. nr. basimacula (Rao et al., 1969), Apanteles syleptae, Coelenius sp. (Abraham et al., 1972) were the larval parasites recorded. Trichospilus pupivora could be reared on the pupae of C.medinalis. (Ananthanarayan, 1934). Xanthopimpla sp., X. immaculata, Tetrastichus sp. (Narayanan et al., 1964), Brachymeria sp., B. excarinata, Pectrobius sp., T. ayyari, Eupteromalus sp., Trichomalopsis apanteloctenus (Rao et al., 1969) and Tetrastichus israeli (Abraham et al., 1972) were the pupal parasites known. Alam and Alam (1964) noted 2 species of spiders and a carabid larva prédacious on leaf-roller caterpillars. They also found that *Tetragnatha* sp and *Oxyopes javanus* (spiders) were predatory on moths. Minah feeding on the moths in field and the lizards eating up the moths in laboratory were also recorded as natural enemies by them. A granulosis virus has been reported on *C.medinalis* from Fiji (Steinhaus and Marsh, 1962) and from Kerala (Jacob *et al.*, 1971).

Control measures

Duport (1925) and Frappa (1929) suggested destruction of the stubbles after harvest to check the pest population. Application of 0.08 per cent parathion (Israel *et al.*, 1955) TEPP, parathion and toxaphane (Calora, 1956; Rivera, 1956), BHC after destruction of leaf-rolls (Ou, 1957), 0.025 per cent parathion, 0.02 per cent endrin and 0.03 per cent BHC (Abraham, 1958), soap solution and DDT sprays (Cendana and Calora, 1964), sevin, parathion and DDT at 0.2, 0.04 and 0.2 per cent respectively (Rajamma and Das, 1969), endrin, dimetheoate, phosphamidon, BHC, DDT and carbaryl (Chaudhary and Bindra, 1970), endrin 0.05 per cent, carbaryl 0.24 per cent (Dorge *et al.*, 1971) were reported effective against *C.medinalis*. In the insecticidal trials conducted under the All India Co-ordinated Rice Improvement Project during 1970, monocrotophos granule (G) and emulsion (E), SD 6626 G, diazinon G, cytrolane G, dichrotophos G and E., phosphamidon E, fenitrothion E and phosvel E at1.5 and 0.71 kg per hectare gave some control of leaf-roller caterpillars though the results were not conclusive (Anon., 1970a). During 1971 in similar trials, cytrolane G and carbofuran G at 0.5 and 1.0 kg. ai/ha were evaluated at 15 centres in India along with local practice of insecticidal schedule. Pest incidence was severe at 5 centres viz. Aduthurai, Cuttack, Mandya, Marutheru, Pattambi and Tenali. At Aduthurai and Pattambi the local practice of applying 0.05 per cent parathion gave the best control. Carbofuran was found better than cytrolane at Aduthurai and Cuttack and reverse was the result at other centres. In a second trial dursban and quinalphos granules at 0.75 and 1.25 kg ai/ha were evaluated at 12 centres. Dursban at the higher dose and quinalphos at either dose, applied 3 or 4 times, proved effective. But local practice of spraying with parathion 0.05 per cent and carbaryl 0.2 per cent alternately at 15 days intervals was the most effective treatment. In a third experiment, phosvel, chlorofevinphos, dicrotophos, phosloneat 0.5 kg ai/ha, dursban at 0.25 kg ai/ha, methomyl, carbaryl, BHC and diazinon at 1.5 kg. ai/ha were evaluated at 12 centres. The leaf-roller incidence was high at Tenali only. There spraying with leptophos, chlorofevinphos, methomyl and dursban were found effective and comparable with parathion weekly sprayings. Dicrotophos, phosalone, quinalphos, ambithion and fenthion also were indicated effective. In another experiment conducted at seven selected centres (based on previous incidence of leaf-roller attack) lindane, malathion, fenitrothion and diazinon at 0.75 kg. ai/ha, ethyl parathion, dicrotophos, phosphamidon, quinalphos, formothion and endrin at 0.40 kg. ai/ha, cytrolane, furadan and dursban at 1.5 kg. ai/ha were evaluated. The centres chosen were Aduthurai, Coimbatore, Ludhiana, Mandya, Pattambi, Rajendra Nagar and Tenali. Weekly application of parathion was effective at Aduthurai. When judged on the basis of larval counts none of the other treatments were effective. But all treatments except dicrotophos, formothion and endrin were found effective at Coimbatore. At Rajendra Nagar also all treatments were equally effective; fenitrothion and phosphamidon were slightly better than others. At Ludhiana the incidence was too low for an evaluation. Lindane, phosphamidon and dicrotophos were most effective and comparable with parathion at Mandya. These were followed by fenitrothion, diazinon and quinalphos during thaladi crop (Anon., 1971). At Pttambi, parathion was found to be the best; fenitrothion and dicrotophos in Kuruvai season and quinalphos and dicrotophos during the thaladi season also gave good control (Anon., 1971). Dimecron, dursban, folidol and ekalux were reported effective at Aduthurai, Faizabad and Ludhiana and galecron, tameron, furadan (G), birlane, fundal, carbofuran and phosvel were moderately effective at Maruteru (Anon., 1972). Balasubramoniam et al., (1973) reported that parathion, toxaphane and DDT were most effective against the pest followed by methyl parathion + DDT, phosphamidon and carbaryl. Raj and Morachen (1973) observed in an experiment using complex, mixed and straight types of fertilisers that the last treatment recorded the maximum infestation by leaf-roller while the others were on par.

Varietal resistance

Veluswamy et al. (1973) screened 100 varieties of rice in a field experiment and found some varieties resistant to leaf-roller infestation but it did not include any of the common varieties grown in Kerala. Haneefa et al. (1973) found that plant height, second internode distance and length of second leaf were negatively correlated and width of second leaf positively correlated with leaf-roller infestation.

MATERIALS AND METHODS

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Materials

Moth collection cage (Figs. 1 A and B)

This cage is rectangular measuring 2 m long, 1 m broad and 1.5 m high. The frame is made of 22 x 2 mm angle iron. The sides, except the bottom are covered with mosquito net clothing.

Oviposition cage (Fig.2 A)

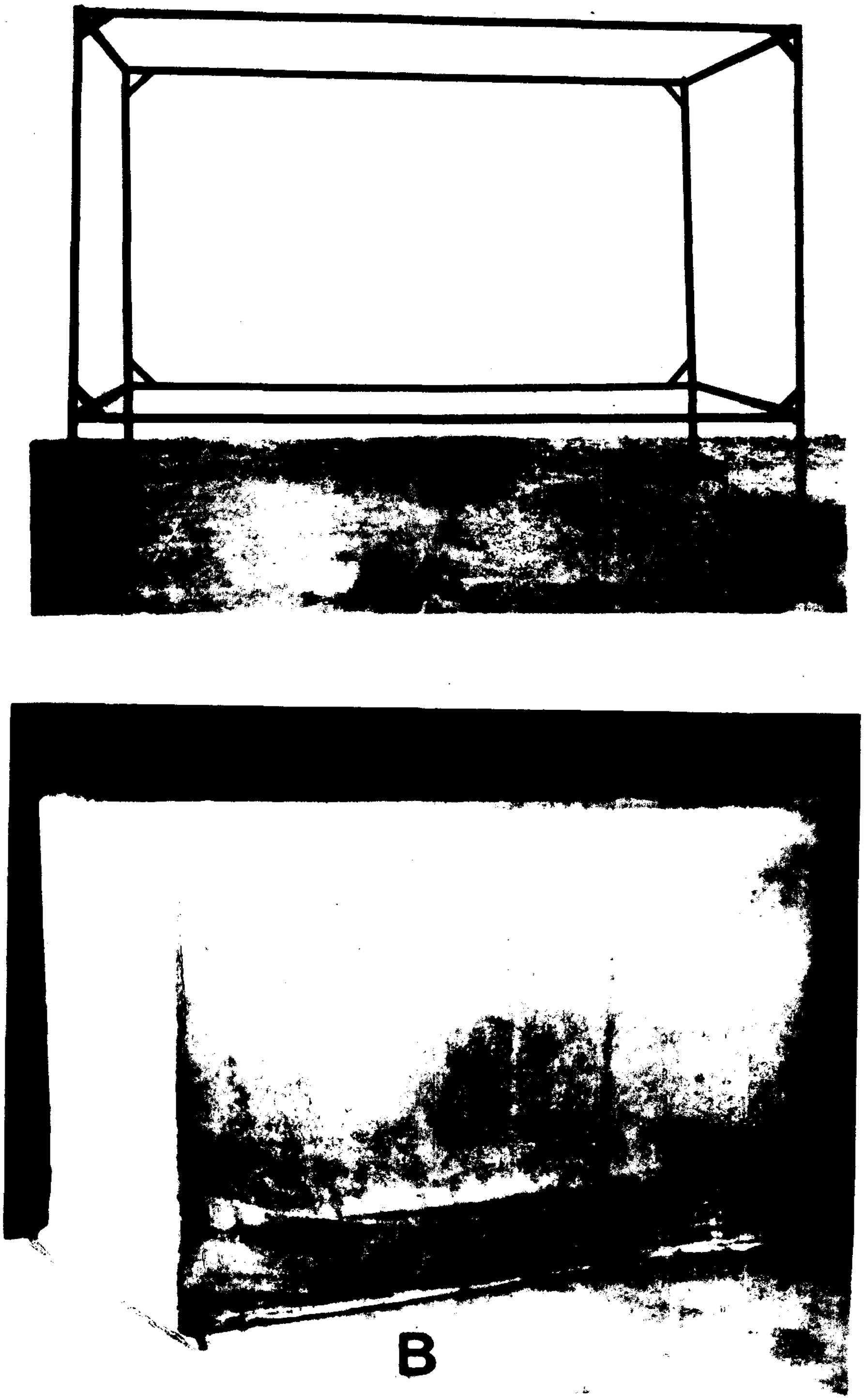
This has an iron frame consisting of three rings held one above the other with iron bars. The uppermost ring measures 35 cm, the middle one 14 cm and the lowest 15.5 cm in diameter. The uppermost and middle rings are at a distance of 35 cm while the middle and lower rings are 12 cm apart. The space enclosed between the middle and upper rings is approximately an inverted cone. A cloth bag (in mosquito net clothing), open at both ends and stitched to occupy the above space, is fixed to the frame as seen in the figure. The upper end is closed with a piece of mosquito net clothing held in position with a thread tied round the top ring.

Fig. 1. Moth collection cage

A. Angle iron frame of the cage

B. Cage complete with mosquito net clothing

FIG 1



B

Fig. 2 A. Oviposition cage, complete with moths of C.*medinalis* set for oviposition.

2 B. Paddy tillers ready for exposure to moths for oviposition.

2 C. Paddy plants with eggs tied up and kept for hatching of eggs.

Fig. 3. Insect proof cage

3 A. Potted plants with the frame work of the cage alone.

3 B. The complete cage over potted plants.

Insect proof cage (Figs. 3 A and B)

The plants raised for the assessment of quantitative reduction in yield due to leaf-roller attack were protected from pests using an insect proof cage. This cage has an inner frame made of cane ring (35 cm diameter) fitted to 4 numbers of 120 cm long bamboo splinters. The lower ends of the splinters are connected with pieces of iron wire which prevented the sliding down of the cage over the pot and the thread tied round the free ends of the splinters prevented the topling of the cage. The frame is covered with a cylindrical cage stitched to size with mosquito net clothing. The upper end also is closed. The lower end of the cage is tied round the pot.

Insecticides used

Details of the insecticides used are given in Table 1.

Sprayers used

A Potter's spraying tower, working at a pressure of 24 cm mercury was used for laboratory sprayings and a 6 litre pneumatic sprayer (knapsack) was used for field sprayings.

Paddy strains used

IR 8 alone was used for rearing the insects required for insecticidal experiments and also for the different laboratory

FIG 2

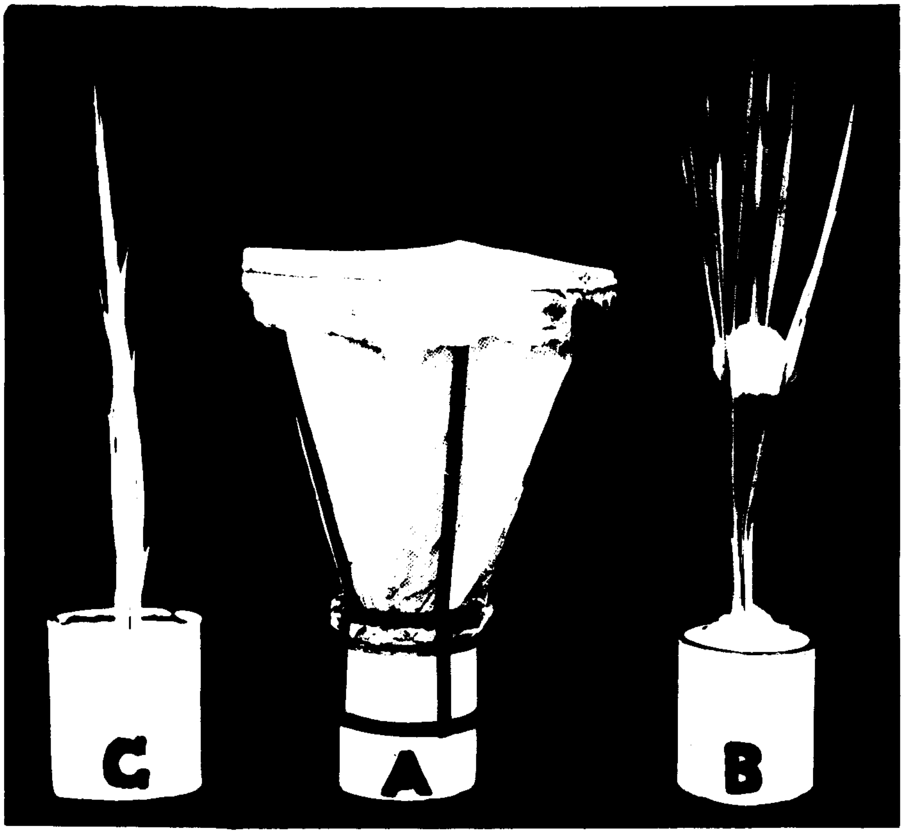


FIG 3

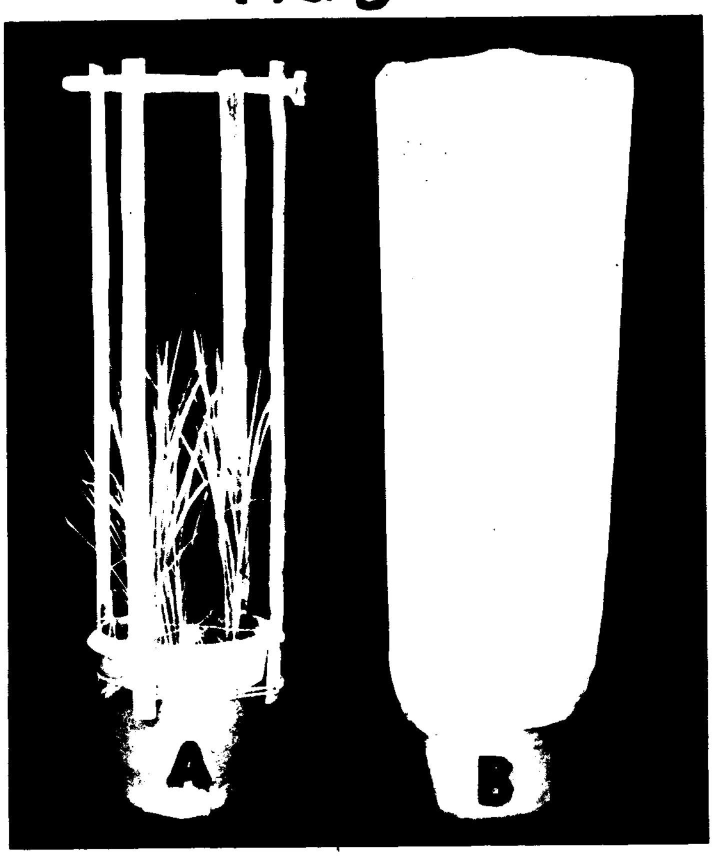


Table 1 Details of the insecticides used in the studies on the control of C.medinalis

Common name	Commercial name	Chemical name	Source (Name of Distributors)
Benzene hexa-chloride	Gammaxane	1,2,3,4,5,6-hexachloro-cyclohexane	Tata Fison, Bombay.
Endrin	Endrin	1,2,3,4,10,10-hexa-chloro-6,7,epoxy 1,4,4a, 5,6,7,8,8a octa hydro 1-4,5,8 dimethanonaph-thalnene	Tata Fison, Bombay.
Endosulfan	Thiodan	6,7,8,9,10,10-hexachloro-1,5,5a,b,9,9a-hexahydro 6,9-methano 2,4,3-benzo dioxa thiepin-3-oxide	Hoescht Pharmaceuticals, Bombay.
Ethyl parathion	Folidol	0,0-diethyl-0-4-nitro phenyl phosphorothioate	Bayer India Ltd., Bombay.
Methyl parathion	Metacid	0-0-dimethyl-0-p-nitro-phenyl phosphoro thioate	Bayer India Ltd., Bombay.
Dichlorvos	Nuvan	2-2-dichlorovinyl dimethylphosphate	CIBA of India Ltd., Bombay.
Carbophenothion	Trithion	0-0-diethyl-S-(p-chloro-phenyl thiomethyl) phos-phorodithioate	Mysore Insecticides, Madras.
Diazinon	Basudin	0,0-diethyl-0-(2-iso-propyl-6-methyl-4-piri-midinyl phosphorothio-ate	Tata Fison, Bombay.
Elsan	Elsan	0,0-dimethyl s-(phenyl acetic acid ethyl ester) dithio phosphate	Bharat Pulverising Mills Ltd., Madras.
Fenthion	Lebaycid	0-0-dimethyl-0-(4,methyl -mercapto 3-methyl phenyl) thiophosphate	Bayer India Ltd., Bombay.
Malathion	Malathion	0-0,dimethyl-s-(1,2, dicardethoxy ethyl) phosphorodithioate	Cynamid India Ltd., Bombay.
Leptophos	Phosvel	0-(2,5-dichloro-4-bromo phenyl) 0-methyl phenyl thiophosphonate	Mysore Insecticides, Madras.

Common name	Commercial name	Chemical name	Source (Name of Distributors)
Acephate	Orthene	O,s-dimethyl N-acetyl phosphoramidothioate	Tata Fison, Bombay.
Quinalphos	Ekalux	O,O-diethyl-O-(quino-xaly-2 thionophosphate)	Sandoz India Ltd., Bombay.
Carbaryl	Sevin	1-naphthyl N-methyl carbamate	Union Carbide India Ltd., Bombay
Fenitrothion	Sumithion	O,O-dimethyl O-(3-methyl 4-nitrophenyl) phophoro-thioate	Tata Fison, Bombay.
Trichlorfon	Dipterex	Dimethyltrichloro-hydroxyethyl phosphonate	Bayer India Ltd., Bombay.
Thiometon	Ekatin	O,O-dimethyl-s-ethyl-mercaptoethyl dithio-phosphate	Sandoz India Ltd., Bombay.
Phosphamidon	Dimecron	2-chloro-2-diethyl carbamoyl-1-methyl-venyl-dimethyl phosphate	CIBA of India Ltd., Bombay.
Dimethoate	Rogor	O,O-dimethyl-s-(N methyl carbamoyl methyl) phos-phorodithioate	Tata Fison Ltd., Bombay.
Monocrotophos	Nuvacron	Cis-(2-ethyl carbamoyl-1-methyl vinyl)-dimethyl phosphate	CIBA of India Ltd., Bombay.
Formothion	Anthio	O,O-dimethyl-S-(N-formyl -N-methyl-carbomyl-methyl) phosphorodithio-ate	Sandoz India Ltd., Bombay
Phorate	Thimet	O,O-diethyl-S-(ethylthio)-methyl-4-phosphorodithio-ate	Cynamid India Ltd., Bombay.
Methyl demeton	Metasystox	O,O-dimethyl-S-2(ethyl-thio) ethylphosphoro-thioate	Bayer India Ltd., Bombay

and field experiments. In the experiments for studying the insect-plant relationships 18 rice varieties viz. IR8 (Peta x Dee Geo Woo Gen), Karuna (IR8 x Adt27), IR20 (IR262 x TKM6), Pankaj (Peta x Tankai Rottan), H4 (Muringakayan x Mass), Rohini (Ptb10 x IR8), Aswathi (Ptb10 x Dee Geo Woo Gen), Triveni (Ptb15 x Annapoorna), Jaya (TN1 x T141), Annapoorna (TN1 x Ptb10), Cavery (TN1 x TKM6), Mashoori (Mayang Ebos 80/2 x Thaichung 65), Adt 27 (GEB 24 x Noorin 8), TKM6 (CO 18 x GEB 24), Jagannath (a mutant from T141), Ptb9 (a pure line selection), TKM1 (a pure line selection) and Kochuvithu (a local variety) were used.

Methods

Collection of moths of *Cnaphalocrocis medinalis* from field

Moths required for the studies were collected from field using the moth collection cage. The cage was put in rice fields where the moths occurred in large numbers. The plants enclosed in the cage were disturbed from below with a stick. This caused the moths to leave the plants and settle inside the cloth cage. When sufficient number of moths had thus settled, the cage was taken out and placed on the field bunds and the moths collected in specimen tubes from inside the cage. This method enabled the collection of the moths without any injury.

<u>Rearing of *C.medinalis* in the laboratory</u>

Moths were also reared out in the laboratory, using the larvae collected from infested fields and reared on potted plants. When the larvae pupated in leaf folds, the pots were put under the moth collection cage. On emergence the moths settled within the cage and they were collected as described earlier.

<u>Collection of the eggs of *C.medinalis*</u>

Eggs were collected with the help of the oviposition cages. A few tillers of paddy were planted in a tin can (16x14 cm) filled to 3 quarters with mud. The tillers were made to pass through a circular opening at the centre of the lid closing the tin. The opening of the tin was closed with cotton wool wound round the tillers. A small cotton swab dipped in honey diluted with water (1:1), was provided as feeding material for the moths as shown in Fig.2B. The oviposition cage was then placed over the tin in such a way that the second ring of the cage tightly fitted around the upper rim of the tin. About fifty moths were introduced in each cage. They laid eggs entirely on the plants avoiding the mosquito netting of the cage. The cage along with the moths was transferred over fresh plants daily so that each day's eggs could be collected separately.

Collection of first instar larvae of *C.medinalis*

The leaves of the tillers on which eggs were laid were held together by tying a thread around (Fig.2 C). This helped in retaining the first instar caterpillars in groups (when they emerged) on the leaves, which otherwise tended to run about on emergence and fall to the ground. When the tied-up leaves were released on the third or fourth day of egg laying, the first instar larvae could be seen moving actively and some hanging down on silken threads from the margins and tips of leaves. These could be collected easily with a camel hair brush. A table lamp focused on the leaves could hasten the activity of the larvae and this arrangement was found necessary for the collection of first instar larvae when the population was low.

Rearing of caterpillars of *C.medinalis*

The caterpillars were reared on potted paddy plants in the laboratory. First instar larvae were put on potted plants.

When the leaves of the plants in one pot were eaten up the larvae were transferred to fresh potted plants. The larvae in the different stagés, required for various experiments, could be drawn from the cultures thus maintained in the laboratory.

Assessment of contact toxicity of various insecticides to moths of *C.medinalis*

Moths used in this experiment were reared out of grown up caterpillars collected from field and maintained on potted plants in the laboratory. The moths were collected with the moth collection cage and were transferred to the oviposition cages and fed with honey. No paddy tillers were provided in these cages. These moths were collected back at the end of 48 hours, put in petridishes (9 cm diameter) 10 moths in each dish and closed with wire gauze covers and sprayed under Potters' tower, using 1 ml of the spray fluid for each dish. The sprayed dishes were dried under an electric fan for five minutes and the moths transferred to 500 ml glass beakers and closed with muslin cloth. Honey on cotton swabs was provided as food for the moths in each beaker. Mortality counts were taken at the end of 24 hours, counting moribund ones also as dead. LC 50 values were calculated from the data obtained, by probit analysis (Finney, 1952).

Assessment of relative toxicity of insecticides to the fourth instar caterpillars of *C.medinalis*

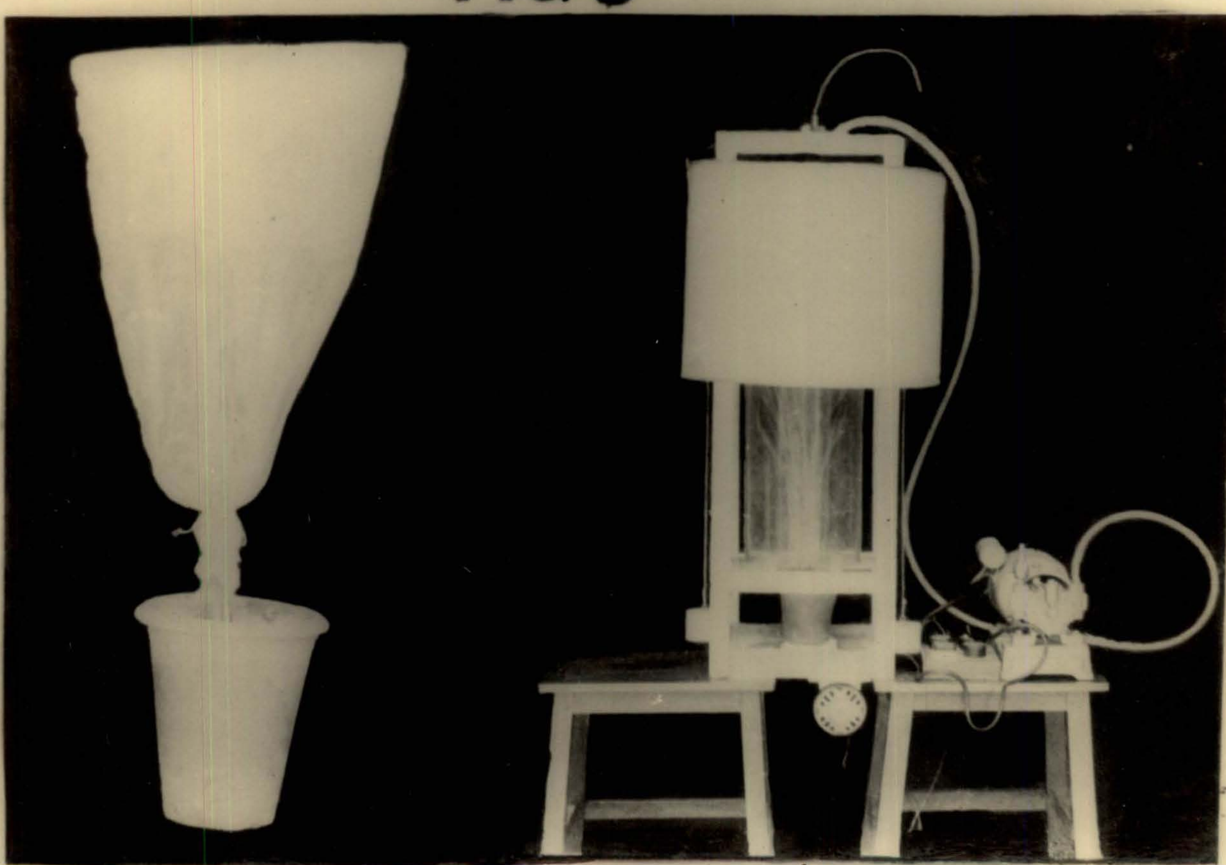
The caterpillars for this experiment were collected from infested rice fields. They were removed from the leaf folds and liberated in a large trough which ensured a proper mixing up of the test insects. From these, actively moving fourth instar caterpillars measuring about 8 mm long were used for the experiment. The caterpillars were sprayed under the Potters' tower in petri dishes. The larvae in each dish were sprayed with 1 ml of the insecticide emulsion. The sprayed dishes were covered and kept under an electric fan for 10 to 15 minutes with the lids slightly open. When the spray fluid had dried up the treated caterpillars were transferred to untreated paddy tillers planted in pots and enclosed in cages (40 x 3.5 cm) made of perforated polythene sheets (Fig.4). The lower end of the cage was tied to the base of the tillers with a bit of cotton wool in between. The upper end of the cage was sealed with a flame after introducing the treated larvae. A piece of galvanised iron wire bent in a circle at the top and placed inside served to keep the polythene cage extended. The mortality of treated caterpillars was recorded at the end of 48 hours, counting

Fig. 4. Insecticide treated caterpillars of C.medinalis set on untreated paddy tillers planted in flower pots and enclosed in polythene bags, for mortality observations.

Fig. 5. The modified Potters Spraying tower used for spraying C.medinalis caterpillars in leaf folds.

FIG 4

FIG 5



B A

the moribund ones also as dead. The per cent mortality was corrected with Abbott's formula. The data were subjected to probit analysis (Finney, 1952) and LC 50 values calculated.

Assessment of the relative toxicity of insecticide sprays to caterpillars of *C.medinalis* in rice leaf folds

Culms of paddy of uniform size were planted in 23 cm flower pots. The tillers were then thinned so that 30numbers of more or less similar leaves were retained in each pot. Fourth instar larvae were made to establish on these leaves by putting the larvae on them and giving 24 hours for their establishment. The plants were then sprayed under a Potters' tower (modified) with insecticides. For this the lower platform of the spraying tower was removed and the pot was placed under the tower on a revolving platform operated by 0.5 H.P. motor (Fig.5 A). The sprayed plants were allowed to dry in the room. Each plant was then enclosed in a cage made of perforated polythene sheet, 45 cm long, 15 cm diameter at the upper and and 7.5 cm at the lower end (Fig.5 B). The mortalities caused by the insecticides were noted at the end of 48 hours after spraying. The data were statistically analysed.

Assessment of the effect of insecticide sprays on the population of caterpillars of *C.medinalis* in field

Seventy five plots, each 2x2 m were demarcated in a highly infested field, with 1 m border around each plot, ensuring as far as possible, similarity in the intensity of attack based on visual observation. A pre application count of the larvae in each plot was made in terms of the number of live caterpillars present in 200 leaf folds collected at random. The caterpillars were liberated back, in the respective plots, after counting. The insecticides were then applied on the plants using a knapsack sprayer, taking adequate precautions, with the aid of screens, to prevent contamination by drift. Fortyeight hours after spraying the population in each plot was reassessed as done earlier. From the pre-and-post-treatment counts the per cent reduction in population was estimated and the data were statistically analysed.

Assessment of the extent of leaf damage caused by caterpillars of *C.medinalis* in fields treated with insecticides at biweekly intervals

Paddy was transplanted in the field at a spacing of 15x15 cm, adopting standard agronomic practices. Two weeks after planting, three blocks of 25 plots, each plot measuring 3m long and 3m wide, were marked out in the field with 1m border around each plot. Insecticides were applied as was done in preceding experiment. The spraying was repeated at intervals of 14 days till the boot leaf stage. At late boot leaf stage, when the incidence usually reached the peak, the plants in each plot were cut out and brought to the laboratory. The leaves were counted and rated under 5 categories based on the extent of damage noted.

A	no attack
B	less than 25 per cent leaf area eaten
C	between 25 and 50 per cent leaf area eaten
D	between 50 and 75 per cent leaf area eaten
E	more than 75 per cent of the leaf area eaten

An index was worked out for each plot using the following formula:

$$I = \frac{A \times 0 + B \times 1 + C \times 2 + D \times 3 + E \times 4}{A + B + C + D + E}$$

These indices were statistically analysed for determining the effect of the treatments on the extent of leaf damage. The experiment was repeated in three seasons.

Assessment of persistent toxicity of insecticides on paddy plants to the first instar caterpillars of *C.medinalis* under field conditions.

Paddy seedlings were transplanted in field with 15x15 cm spacing. Two hundred and nineteen plots, each of 2x2 m size, were marked out in the field with 1 m border around each plot. The insecticides were applied with a knapsack sprayer. A randomised block design was adopted for the experiment. Gunny screens were kept all around the plots, while spraying, to avoid side effects due to drift of insecticides. To assess the persistent toxicity, 4 tillers were uprooted at random from each plot, at different intervals after spraying and were immediately transferred to specimen tubes along with some mud and water. They were then brought to the laboratory and caged. The tube with the tillers was passed through a 40x3.5 cm polythene bag, open at both ends, in such a way that the leaf portion of the tillers got enclosed in the cage. The lower end of the cage was tied round the base of the tillers with some cotton wool in between. The tube was then removed and the tillers planted in flower pots. This method minimised the loss of residues from the leaf surface by handling during caging. First instar larvae were exposed to the plants in the cages for 48 hours. Then the tillers were cut out and placed on white paper. The dead and living caterpillars on the tillers and in the cage were counted. Per cent mortality thus obtained was corrected with Abbott's formula. The residual toxicity was calculated in terms of PT index following the method of Pradhan (1967) where P is the period for which toxicity persisted and T the sum of corrected mortalities divided by the number of observations.

Assessment of the effect of infestation by caterpillars of *C.medinalis* on three varieties of rice in relation to the stage of the crop

Flower pots, 30 cm diameter, were filled with soil collected from rice fields. Manures and fertilisers were applied at standard doses and nine paddy seeds were sown in each pot. Ten days after the sowing, all except 3 seedlings were removed from each pot. These plants were protected from natural pest infestation with insect proof cages. At different stages of growth caterpillars were allowed to feed on the plants in sufficient numbers so as to ensure thorough feeding of the leaves in 2 days time (Fig. 6). At the end of 2 days the larvae were collected back, the insect proof cages

Fig. 6. Paddy plants showing the maximum damage due to leaf-roller infestation (left 3 pots) as against uninfested plants (right 3 pots).

Fig. 7. Measurement of paddy leaf area eaten by leaf-roller caterpillars. A. Paddy leaf damaged by the larva. B. Graph paper. C. Glass plate. The leaf is kept spread fully on the graph paper with the glass slide put over it. The lighter areas on the leaf are those eaten by the caterpillars.

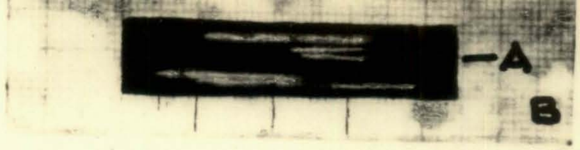
removed, the pots transferred to field cages (6x2x2 m) and maintained till harvest. Potted plants of corresponding stages unexposed to caterpillars and transferred to field cages served as control. Subsequent pest incidence was prevented by the application of carbofuran granules at 1.5 kg ai/ha and by spraying parathion 0.05 per cent as and when required. The yield in infested plants and the corresponding control plants was recorded separately. The effect of infestation at different stages of the crop was assessed in terms of the per cent reduction in yield (compared to corresponding controls). The data were statistically analysed.

Assessment of the effect of infestation by the larvae of *C.medinalis*, at different levels of population, on the yield of different varieties of rice

This was done at the pre booting stage of the crop. First instar caterpillars were introduced at different levels. The establishment of the larvae on the host plants was facilitated by bringing and tying together the leaves of the plants and the leaves were released 2 days later. The insect proof cages were removed at the end of 3 weeks and the pots were transferred to field cages along with corresponding controls.

FIG 6

FIG.7



Subsequent pest incidence was prevented by spraying 0.05 per cent parathion. The yield data were collected and analysed as done in the preceding experiment.

Assessment of oviposition response of moths of *C.medinalis* in relation to different varieties of rice

One month old rice plants of each variety were planted in mud taken in 90 x 60 mm specimen tubes. Twelve leaves were retained in each lot. The tubes with the tillers were arranged at random in a moth collection cage and 50 moths were introduced into the cage. Cotton swabs soaked in diluted honey were provided in the cage for feeding the moths. At the end of 48 hours the tillers were removed from the cage and the number of eggs present on each variety were counted and recorded. A similar experiment using the different varieties of rice at bootleaf stage also was carried out.

Assessment of the effect of varieties on the extent of leaf consumed by caterpillars of *C.medinalis*

Fourth instar caterpillars were individually confined to the boot leaves of potted plants of different rice varieties using long polythene cages. At the end of 48 hours the larvae were removed. Each damaged leaf was placed between a glass slide (75 x 25 mm) and a piece of transparent graph paper (Fig. 7). This was held against light and the area eaten by the caterpillar (transparent portions) was read from the graph paper in sq. mm.

Assessment of the effect of rice varieties on the duration of larval and pupal development of *C. medinalis* and the per cent mortality during the period

Newly hatched caterpillars were confined on tillers of different rice varieties grown in pots using elongated polythene cages. When the leaves in the cages were eaten up the larvae were transferred to fresh tillers which were caged in the same manner. The larvae were allowed to pupate inside the cages. The emergence of moths in each cage was recorded daily. From the data obtained the duration of larval and pupal development and the percentage of mortality during the immature stages were calculated.

Assessment of the effect of rice varieties on the size and sex ratio of the moths of *C. medinalis*

First instar caterpillars were put on potted plants of different rice varieties at the rate of 50 larvae per pot.

Moths emerging from each variety were collected separately and preserved in 70% alcohol. The size and sex ratio of 60 moths, collected at random from each lot, were determined. The size was determined in terms of the length of the body and the width across wings. These were measured by placing the moths on a glass slide kept over a graph paper. Then the abdomen of each moth was cut out separately and treated with KOH, glacial acetic acid and carbol xylol (phenol and xylol 1:1) for dehydration and clearing. Then the sex was determined by examinining the external genitalia of the severed abdomen. The length and width of the male and female moths could thus be obtained separately. The ratio of the males to females in the whole lot of 60 moths was calculated.

Assessment of the effect of rice varieties on the longevity and fecundity of moths of *C.medinalis* and the hatching percentage of the eggs laid

Moths obtained from different rice varieties were taken in oviposition cages provided with few tillers of the corresponding varieties. The tillers thus exposed were changed on alternate days till all the moths in the cages died. The mortality of the moths was recorded daily and the dead moths were collected and preserved in 70 per cent alcohol. Sex of these moths was determined as described earlier. The fecundity was calculated by dividing the total number of eggs observed on each variety by the total number of females present. The eggs laid were maintained for 5 days after counting and the number of eggs hatched was recorded.

<u>Assessment of the damage caused by *C.medinalis* to different rice varieties grown in field</u>

The different varieties of rice were grown in field in 3 x 3 m plots. A Randomised Block Design was adopted for this experiment. The time of planting in different plots was adjusted so that all the varieties came to bootleaf stage simultaneously. At late bootleaf stage the plants were cut and brought to the laboratory. The leaves were counted and rated on the basis of leaf roller damage as described earlier.

DETAILS OF EXPERIMENTS AND RESULTS

DETAILS OF EXPERIMENTS AND RESULTS

A series of experiments were undertaken to study

1) Control of *C.medinalis* using insecticides and
2) Insect-plant relationships between *C.medinalis* and rice varieties

STUDIES ON THE CONTROL OF *C.MEDINALIS* USING INSECTICIDES

Experiment 1

Dosage-mortality relation between various insecticides and moths of *C.medinalis*

Experimental details

Insects used	: One day old moths reared out in the laboratory
No. of moths in each replication	: 10
No. of replications for each treatment	: 3
Treatments	: 24 insecticides at doses shown in Appendix I were used
Control	: This consisted of treatments

with water+solvent+emulsifier (maintaining the concentration of solvent and emulsifier at 5 and 0.625 per cent respectively)

Preparation of insecticides : All the insecticides except diazinon and elsan were prepared from pure or technical grades. These were fomulated as emulsions using benzene (Chloroform in the case of carbaryl) as solvent and Triton x 100 as emulsifier. Stock solutions of toxicants at 20 times higher strength than the required concentrations were prepared by dissolving adequate quantities of the materials in the respective solvents. One mlof the stock solution when diluted 20 times with water containing 0.658 per cent emulsifier gave an emulsion maintaining the solvent and emulsifier at 5 and 0.625 per cent levels respectively. In the case of low dilutions the quantity of toxicants required for such stock solutions were too small to be weighed out and hence the same was prepared by diluting stock solutions of higher strengths with respective solvents. While formulating each insecticide allowance was made for the active ingredient present in the technical grade. In the case of diazinon and elsan commercial emulsifiable concentrates (basudin 20E and Elsan containing 20 and 30 per cent active ingredients respectively) were diluted with water to prepare the concentrations required in this experiment.

Period of the experiment	:	1-12-1971 to 30-1-1972
Temperature under which the experiment was conducted	:	29 ± 2°C.

Relative humidity under which the experiment was carried out : 78 ± 4 per cent

Procedure : As described under methods (Page 20)

Results:

Appendix I gives the per cent mortality of the moths when sprayed with different dilutions of insecticides as observed at the end of 48 hours of spraying. Fig. 8 gives the ld-p lines and Table 2 gives the summary of the results of probit analysis of the data. A biotogramic representation of the LC_{50} values is given in Fig. 10. Comparing the toxicity of insecticides, taking BHC as a unit, it is seen that all insecticides other than trichlorfon and endrin were more toxic than BHC. Ethyl parathion was very highly toxic to the moths, being 1296.8 times as toxic as BHC. Methyl parathion and diazinon also showed high toxicity being 369.8 and 311.9 times as toxic as BHC respectively. Elsan (197.34 times toxic), fenitrothion (167.38), carbaryl (75.32), and acephate (39.89) were also remarkably toxic to leaf roller moths. The relative toxicity of other insecticides were in the following descending order: fenthion, quinalphos, carbophenothion, methyl demeton, malathion, thiometon, phorate, phosphamidon,

Fig. 8. ld-p lines for C.*medinalis* moths and different insecticides

1.	BHC	13.	Acephate
2.	Endrin	14.	Quinalphos
3.	Endosulfan	15.	Carbaryl
4.	E.parathion	16.	Fenitrothion
5.	M.parathion	17.	Trichlorfon
6.	Dichlorvos	18.	Thiometon
7.	Carbophenethion	19.	Phosphamidon
8.	Diazinon	20.	Dimethoate
9.	Elsan	21.	Monocrotophos
10.	Fenthion	22.	Formothion
11.	Malathion	23.	Phorate
12.	Leptophos	24.	Methyl demeton

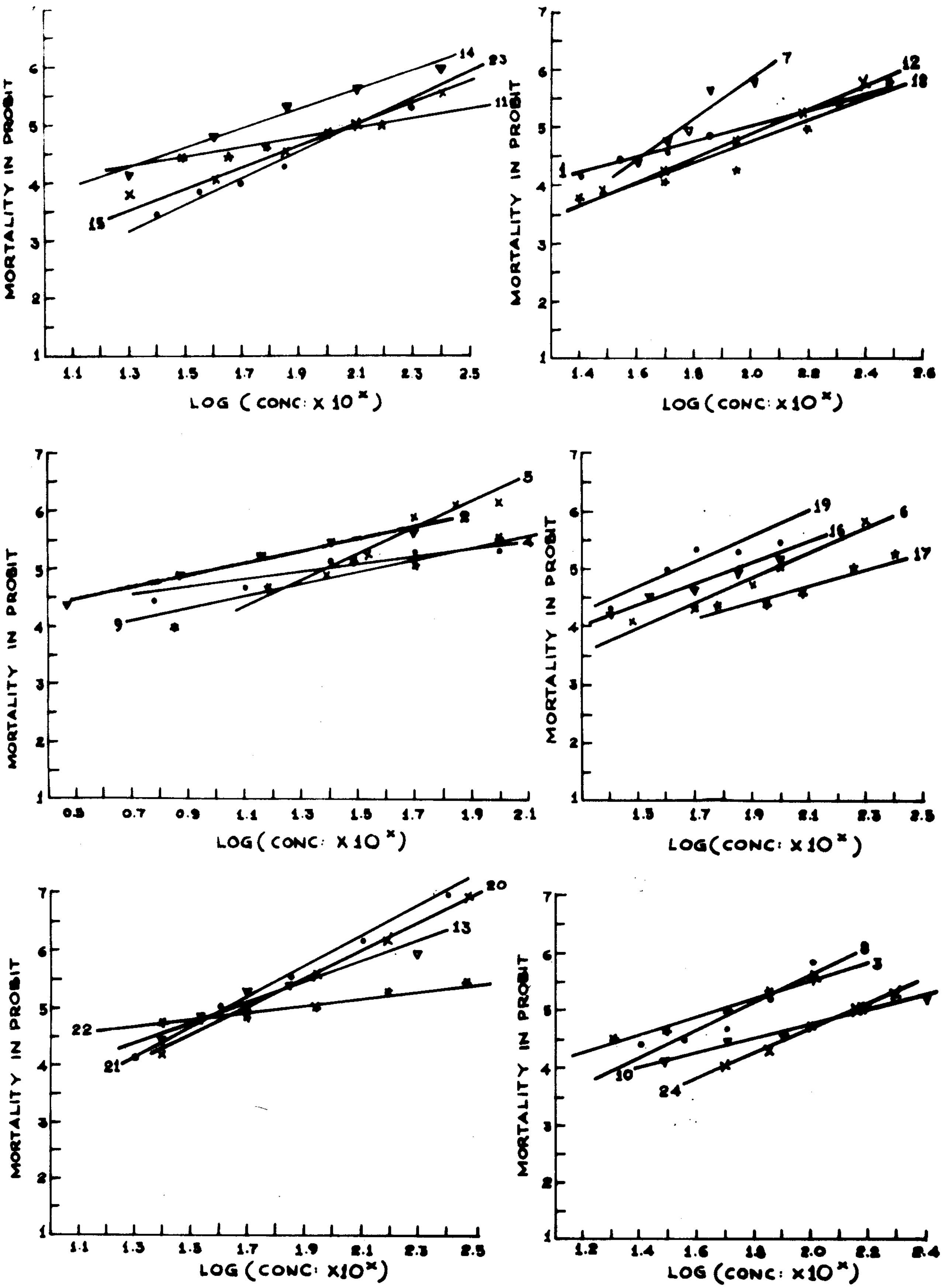

MORTALITY IN PROBIT
LOG (CONC: X 10^x)
14
23
11
15
7
12
18
1
5
2
4
9
19
16
6
17
20
13
22
21
8
3
10
24

Fig: 8

Fig. 10. LC_{50} values of various insecticides of the moths of C.medinalis.

Fig. 11. LC_{50} values of various insecticides to 4th instar caterpillars of C.medinalis.

Fig. 12 A to D.

Per cent mortality of caterpillars of C.medinalis in leaf fold when sprayed with different insecticides at 3 graded concentrations and their means.

12 A. Lowest doses
12 B. Medium doses
12 C. Highest doses
12 D. Mean

1. BHC
2. Endrin
3. Endosulfan
4. E.parathion
5. M.parathion
6. Dichlorvos
7. Carbophenothion
8. Diazinon
9. Elsan
10. Fenthion
11. Malathion
12. Leptophos
13. Acephate
14. Quinalphos
15. Carbaryl
16. Fenitrothion
17. Trichlorfon
18. Thiometon
19. Phosphamidon
20. Dimethoate
21. Monocrotophos
22. Formothion
23. Phorate
24. Methyl demeton

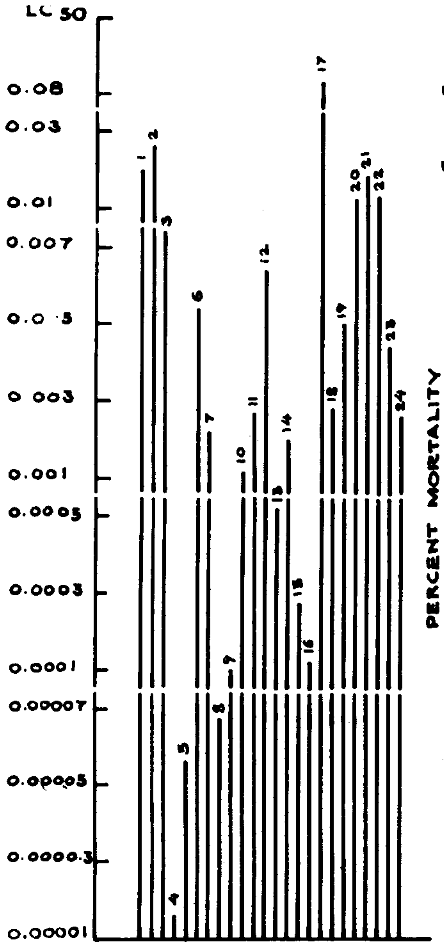


FIG: 10.

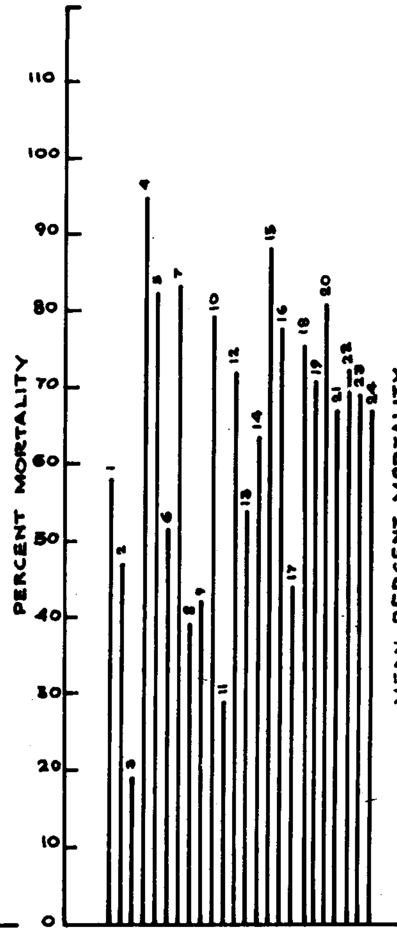


FIG: 12.C.

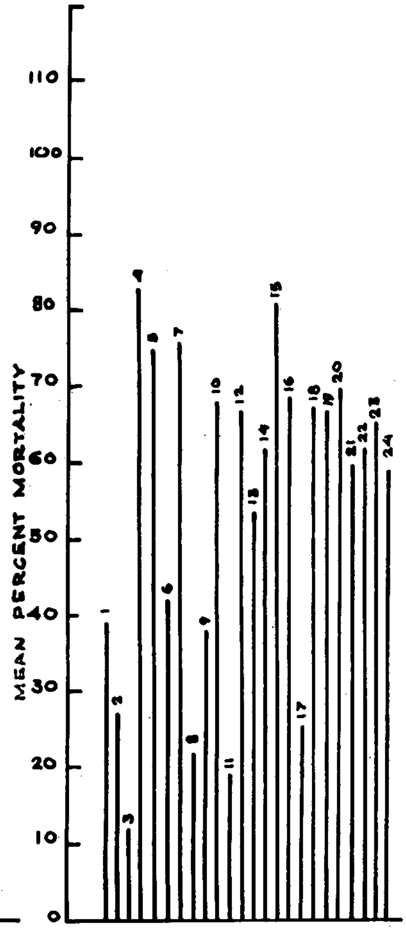


FIG: 12.D.

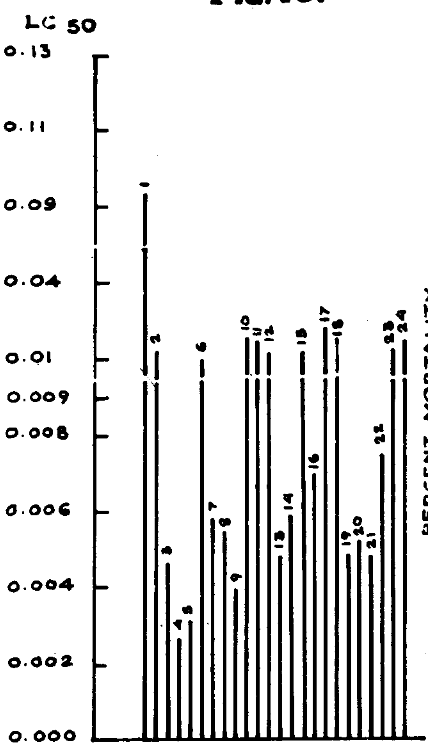


FIG: 11.

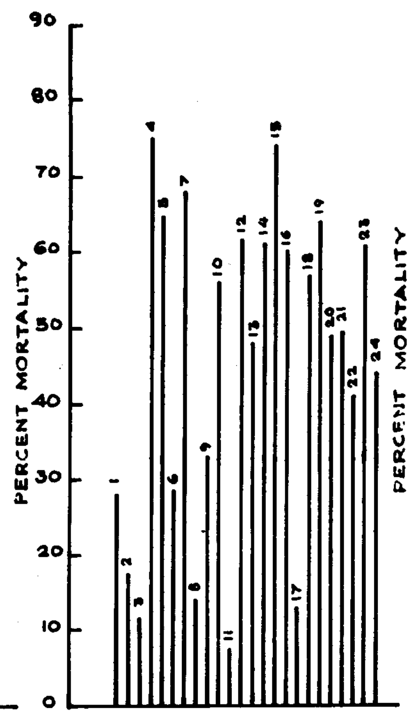


FIG: 12.A.

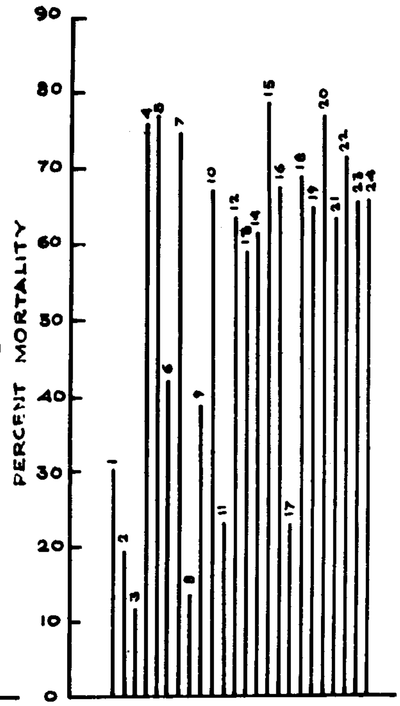


FIG: 12.B.

Table 2 Contact toxicity of various insecticides to the moths of *C.medinalis*

Insecticides	Heterogenity* $x^2_{(3)}$	Regression Equation	LC_{50}	Fiducial limits	Relative toxicity	Remarks
BHC	3.010	Y = 1.343x + 3.229	0.02084000	0.03019000 0.01439000	1.000	x=log(conc.x10^3)
Endrin	0.850	Y = 2.384x + 1.605	0.02655000	0.03494000 0.02017000	0.785	x=log(conc.x10^3)
Endosulfan	0.820	Y = 4.314x - 3.645	0.00741300	0.00910700 0.00616100	2.811	x=log(conc.x10^4)
E.parathion	1.010	Y = 1.223x + 3.691	0.00001600	0.00001135 0.00002275	1296.800	x=log(conc.x10^6)
M.parathion	1.010	Y = 2.362x + 0.861	0.00005636	0.00006042 0.00005255	369.765	x=log(conc.x10^6)
Dichlorvos	1.309	Y = 2.425x + 0.804	0.00537000	0.00722200 0.00399900	3.880	x=log(conc.x10^4)
Carbophenothion	4.392	Y = 2.454x + 1.716	0.00217800	0.00267100 0.00177500	9.568	x=log(conc.x10^4)
Diazinon	0.214	Y = 3.723x - 1.798	0.00006697	0.00007447 0.00005872	311.180	x=log(conc.x10^6)
Elsan	0.980	Y = 1.380x + 2.204	0.00010570	0.00141900 0.00074490	197.140	x=log(conc.x10^5)
Fenthion	0.105	Y = 2.297x + 0.576	0.00116900	0.00112100 0.00093240	17.827	x=log(conc.x10^5)
Malathion	0.827	Y = 1.058x + 3.497	0.00266700	0.00312200 0.00228000	7.814	x=log(conc.x10^4)
Leptophos	4.122	Y = 1.516x + 3.777	0.00640766	0.00876000 0.00468700	3.252	x=log(conc.x10^3)

Acephate	1.404	Y = 1.127x + 4.191	0.00052740	0.00062690 0.00043530	39.892	$x=\log(\text{conc.}\times 10^4)$
Quinalphos	9.870	Y = 2.630x + 1.544	0.00206100	0.00258200 0.00164400	10.112	$x=\log(\text{conc.}\times 10^4)$
Carbaryl	1.920	Y = 2.703x + 1.062	0.00027670	0.00330400 0.00023170	75.316	$x=\log(\text{conc.}\times 10^5)$
Fenitrothion	0.573	Y = 1.619x + 1.607	0.00012450	0.00016830 0.00008204	167.381	$x=\log(\text{conc.}\times 10^4)$
Trichlorfon	1.592	Y = 1.037x + 4.072	0.08337000	0.10770000 0.06451000	0.250	$x=\log(\text{conc.}\times 10^2)$
Thiometon	5.586	Y = 1.940x + 2.185	0.00282500	0.00363400 0.00219600	7.376	$x=\log(\text{conc.}\times 10^4)$
Phosphamidon	0.495	Y = 1.368x + 2.670	0.00501400	0.00751900 0.00334400	4.156	$x=\log(\text{conc.}\times 10^4)$
Dimethoate	0.210	Y = 0.529x + 4.404	0.01279000	0.03206000 0.00509300	1.629	$x=\log(\text{conc.}\times 10^3)$
Monocrotophos	0.808	Y = 2.268x - 0.160	0.01884000	0.02375000 0.01494000	1.106	$x=\log(\text{conc.}\times 10^4)$
Formothion	0.554	Y = 1.109x + 2.638	0.01355000	0.01717000 0.01070000	1.538	$x=\log(\text{conc.}\times 10^4)$
Phorate	0.397	Y = 0.852x + 3.620	0.00444000	0.00867800 0.00197500	5.034	$x=\log(\text{conc.}\times 10^3)$
Methyl demeton	1.336	Y = 1.310x + 3.130	0.00263000	0.00450400 0.00153900	7.915	$x=\log(\text{conc.}\times 10^3)$

*Data were not heterogenous in these cases; LC_{50} = Concentration calculated to give 50 per cent mortality; Y = Probit kill.

dichlorvos, leptophos, endosulfan, dimethoate, formothion, monocrotophos.

Experiment 2

Dosage-mortality relation between different insecticides and caterpillars of *C.medinalis*

Experimental details

Stage of caterpillars used	:	Fourth instar, measuring about 8 mm in length
No. of caterpillars in each replication	:	15
No. of replications	:	3
Treatments	:	Twenty four insecticides at doses shown in Appendix II were used
Control	:	As in Experiment 1
Preparation of insecticide dilutions	:	As in Experiment 1
Period of the experiment	:	4-2-1972 to 3-4-1972
Temperature under which the experiment was conducted	:	29 ± 1°C

The relative humidity under which the experiment was conducted : 78 ± 4 per cent

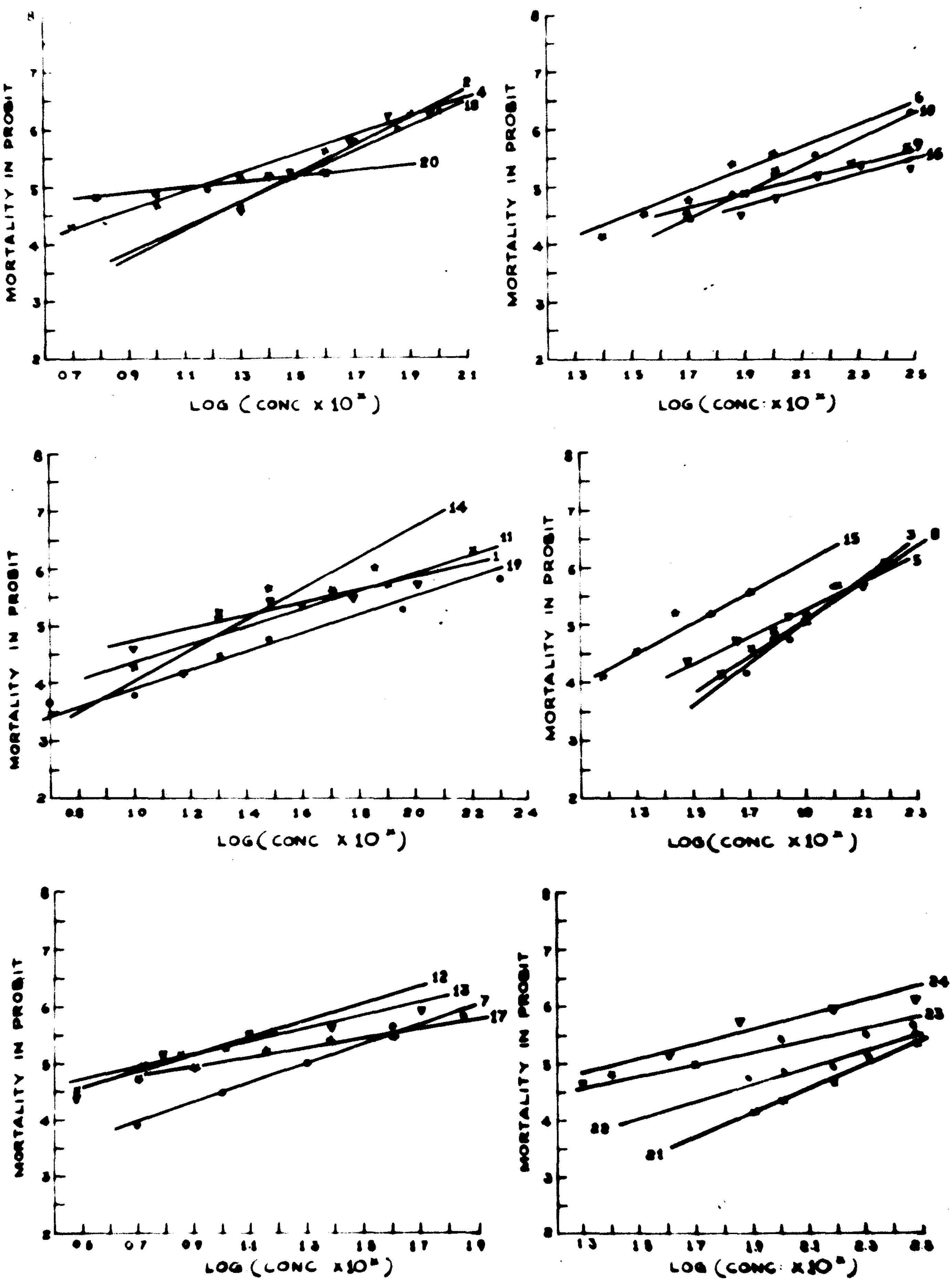
Procedure : As described under methods (Page 21)

Results:

Appendix II gives the per cent mortality of the larvae observed at the end of 48 hours after treatment with various insecticides. The results of probit analysis of the data and the relative toxicity of various insecticides taking BHC as standard are presented in Table 3. Fig. 9 gives the ld-p lines for the various insecticides. A biotogramic representation of the LC_{50} values of the insecticides is given in Fig. 11. The result showed that ethyl parathion was the most toxic chemical being 35.19 times as toxic as BHC. It was followed by methyl parathion, elsan and endosulfan which were 29.10, 23.93 and 20.47 times as toxic as BHC respectively. Phosphamidon, acephate, monocrotophos, dimethoate, diazinon, carbophenothion, quinalphos, fenitrothion and formothion which were more than 10 times as toxic as BHC may also be considered effective against the pest. The relative toxicity of other insecticides were in the following

Fig. 9. ld-p lines for *C. medinalis* caterpillars and various insecticides

1.	BHC	13.	Acephate
2.	Endrin	14.	Quinalphos
3.	Endosulfan	15.	Carbaryl
4.	E.parathion	16.	Fenitrothion
5.	M.parathion	17.	Trichlorfon
6.	Dichlorvos	18.	Thiometon
7.	Carbophenothion	19.	Phosphamidon
8.	Diazinon	20.	Dimethoate
9.	Elsan	21.	Monocrotophos
10.	Fenthion	22.	Formothion
11.	Malathion	23.	Phorate
12.	Leptophos	24.	Methyl demeton


MORTALITY IN PROBIT
LOG (CONC x 10^n)
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24
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22
21

Fig. 9

Table 3 Contact toxicity of various insecticides to the 4th instar caterpillars of <u>C.medinalis</u>

Insecticides	Heterogenity* $x^2_{(3)}$	Regression equation	LC_{50}	Fiducial limits	Relative toxicity	Remarks
BHC	0.037	Y = 1.413x + 2.183	0.092900	0.129300 0.066830	1.000	x = log (conc. x 10^3)
Endrin	1.882	Y = 0.869x + 4.052	0.012300	0.0192800 0.007852	7.552	x = log (conc. x 10^3)
Endosulfan	0.384	Y = 1.541x + 2.447	0.004539	0.005856 0.003519	20.467	x = log (conc. x 10^4)
E.parathion	1.721	Y = 0.712x + 3.989	0.002640	0.004493 0.001532	35.189	x = log (conc. x 10^4)
M.parathion	5.593	Y = 2.825x + 0.752	0.003102	0.003835 0.002656	29.104	x = log (conc. x 10^4)
Dichlorvos	1.597	Y = 2.127x + 0.743	0.010020	0.012300 0.008166	9.271	x = log (conc. x 10^4)
Carbophenothion	3.078	Y = 3.791x + 1.670	0.005834	0.006577 0.005250	15.923	x = log (conc. x 10^4)
Diazinon	4.631	Y = 2.708x + 0.386	0.005346	0.006194 0.004613	17.377	x = log (conc. x 10^4)
Elsan	1.757	Y = 1.197x + 3.097	0.003882	0.005483 0.002748	23.930	x = log (conc. x 10^4)
Fenthion	0.459	Y = 1.198x + 2.374	0.015560	0.023360 0.010380	5.970	x = log (conc. x 10^4)
Malathion	0.612	Y = 0.896x + 3.054	0.014880	0.030010 0.007379	6.243	x = log (conc. x 10^4)
Leptophos	0.273	Y = 2.046x + 0.785	0.011480	0.015110 0.008730	8.092	x = log (conc. x 10^4)

Acephate	0.729	Y = 1.652x + 2.230	0.004753	0.006102 0.003788	19.550	X = log (conc. x 10^4)
Quinalphos	3.307	Y = 1.584x + 2.198	0.005875	0.007650 0.004511	15.812	x = log (conc. x 10^4)
Carbaryl	1.234	Y = 1.709x + 1.469	0.011640	0.015470 0.008937	7.981	x = log (conc. x 10^4)
Fenitrothion	1.500	Y = 1.860x + 1.572	0.006966	0.009099 0.005434	13.336	x = log (conc. x 10^4)
Trichlorfon	0.965	Y = 1.398x + 1.840	0.018200	0.025590 0.012940	5.104	x = log (conc. x 10^4)
Thiemeton	4.662	Y = 1.906x + 0.084	0.015210	0.019400 0.011910	6.110	x = log (conc. x 10^4)
Phosphamidon	5.193	Y = 1.727x + 2.110	0.004710	0.005932 0.003774	19.723	x = log (conc. x 10^4)
Dimethoate	0.515	Y = 2.600x + 0.530	0.005234	0.006873 0.003895	17.749	x = log (conc. x 10^4)
Monocrotophos	0.178	Y = 2.471x + 0.905	0.004764	0.006292 0.003939	19.500	x = log (conc. x 10^4)
Formothion	o.272	Y = 0.673x + 3.743	0.007523	0.016600 0.003422	12.349	x = log (conc. x 10^4)
Phorate	0.394	Y = 2.129x + 0.531	0.012590	0.022580 0.006889	7.380	x = log (conc. x 10^4)
Methyl demeton	0.118	Y = 2.082x + 0.474	0.014900	0.018780 0.011820	6.230	x = log (conc. x 10^4)

*Data were not heterogenous in these cases; LC_{50} = Concentration calculated to give 50 per cent mortality; Y = Probit kill.

descending order: dichlorvos, leptaphos, carbaryl, endrin, phorate, malathion, methyl demeton, thiometon, fenthion, trichlorfon, BHC.

Experiment 3

The relative toxicity of insecticide sprays to the fourth instar caterpillars of *C.medinalis* in rice leaf folds

Experimental details

Treatments	:	Insecticides used were the same as in Experiment1
Preparation of insecticide dilutions	:	Each insecticide was applied at three levels (vide Table 4). The different concentrations of insecticides were prepared by diluting commercial formulations with water. BHC and carbaryl were used as suspensions prepared from wettable powders, acephate and trichlorfon as solutions prepared from soluble powders and the other insecticides

as emulsions prepared from emulsion concentrates. While formulating the various concentrations of insecticides the active ingredient in the commercial preparation alone was taken into consideration.

Insects used	:	Fourth instar larvae of _C.medinalis_
No. of larvae in each replication	:	30
No. of replications	:	3
Control	:	Larvae in leaf folds sprayed with water alone.
Period of the experiment	:	1-4-1971 to 22-4-1971
Temperature under which the experiment was carried out	:	29 ± 2°C
Relative humidity under which the experiment was carried out	:	78 ± 4 per cent
Procedure	:	As described under methods (Page 22)

Results:

The data are presented in Table 4. A biotogramic representation of the corrected per cent mortality is given in Figs. 12A, B, C and D. Ethyl parathion which gave 75 per cent kill was the most toxic at the lowest doses of the different insecticides. At this level the comparative efficacy of the insecticides which gave more than 50 per cent kill were in the following descending order: ethyl parathion, carbaryl, carbophenothion, methyl parathion, phosphamidon, leptophos, phorate, quinalphos, fenitrothion, thiometon, fenthion. At the middle level carbaryl was found to be the best, the efficacy of other insecticides being in thefollowing descending order: carbaryl, dimethoate, methyl parathion, ethyl parathion, carbophenothion, formothion, thiometon, fenitrothion, fenthion, m. demeton, phorate, phosphamidon, leptophos, monocrotophos, quinalphos, acephate. The relative toxicity of various insecticides which caused more than 50 per cent mortality, in the highest doses, were in the following descending order: Ethyl parathion, carbaryl, carbophenothion, methyl parathion, dimethoate, fenthion, fenitrothion, thiometon, formothion, leptophos, phosphamidon, phorate, monocrotophos, methyl demeton, quinalphos, BHC, acephate, dichlorvos. Based on the means of the per cent mortalities at three

Table 4 **Relative toxicity of insecticides**

Insecticides	Concentrations			Mean
	L_1	L_2	L_3	L_1
BHC	0.10	0.20	0.30	28.01 (31.96)
Endrin	0.02	0.04	0.06	17.42 (24.67)
Endosulfan	0.02	0.04	0.06	11.07 (19.43)
E.parathion	0.02	0.04	0.06	75.00 (60.00)
M.parathion	0.02	0.04	0.06	64.57 (53.47)
Dichlorvos	0.04	0.08	0.10	27.59 (31.69)
Carbophenothion	0.02	0.04	0.06	68.03 (55.57)
Diazinon	0.02	0.04	0.06	13.86 (21.85)
Elsan	0.02	0.04	0.02	33.07 (35.10)
Fenthion	0.05	0.075	0.10	56.29 (48.62)
Malathion	0.03	0.06	0.10	7.43 (15.68)
Leptophos	0.05	0.075	0.10	61.67 (51.75)
Acephate	0.05	0.075	0.10	47.59 (43.62)
Quinalphos	0.03	0.06	0.10	60.55 (51.09)
Carbaryl	0.10	0.20	0.30	74.21 (59.48)
Fenitrothion	0.02	0.04	0.06	60.20 (50.84)
Trichlorfon	0.05	0.10	0.20	12.71 (20.76)
Thiometon	0.03	0.05	0.10	56.74 (48.87)
Phosphamidon	0.02	0.04	0.06	63.81 (53.07)
Dimethoate	0.03	0.05	0.10	49.24 (44.57)
Monocrotophos	0.02	0.04	0.06	49.28 (44.59)
Formothion	0.03	0.06	0.10	41.04 (39.83)
Phorate	0.02	0.04	0.06	60.68 (51.17)
Methyl demeton	0.03	0.05	0.10	44.26 (41.70)

Figures in parentheses are angular transformations of percentage sprayed on caterpillars of *C.medinalis* in rice leaf folds

per cent mortality in L2	L3	Mean
30.24 (33.36)	58.03 (49.62)	38.42 (38.31)
19.42 (26.16)	47.09 (43.33)	27.09 (31.38)
11.64 (19.95)	18.86 (25.74)	13.68 (21.70)
75.77 (60.52)	94.92 (76.78)	83.14 (75.76)
76.69 (61.13)	82.37 (65.08)	74.88 (59.92)
42.34 (40.60)	51.34 (45.77)	40.20 (39.55)
74.77 (59.85)	83.39 (65.95)	75.67 (60.45)
13.48 (21.53)	38.78 (38.52)	22.04 (28.25)
39.10 (38.72)	42.29 (40.57)	38.10 (38.13)
66.92 (54.89)	79.34 (62.97)	67.87 (55.47)
22.84 (28.55)	29.38 (32.82)	18.78 (25.68)
63.56 (52.87)	72.21 (58.19)	65.90 (54.27)
59.19 (50.29)	53.84 (47.27)	53.56 (47.03)
61.36 (51.55)	63.57 (52.88)	61.83 (51.84)
78.76 (62.56)	88.42 (70.11)	80.85 (64.05)
67.26 (55.10)	77.59 (61.75)	68.54 (55.89)
22.77 (28.50)	44.07 (41.59)	25.32 (30.21)
69.02 (56.18)	75.43 (60.29)	67.27 (55.11)
64.75 (53.58)	70.98 (57.41)	66.57 (54.68)
76.86 (61.25)	81.10 (64.24)	69.82 (66.68)
63.36 (52.75)	67.00 (54.94)	59.98 (50.76)
71.23 (57.58)	72.41 (58.31)	61.93 (51.90)
65.55 (54.06)	69.32 (56.38)	65.23 (53.87)
65.80 (54.21)	66.97 (64.92)	59.16 (50.27)

Analysis of Variance Table

Source	SS	DF	MS	F
Total	40843.10	215.00	560.70	
Treatment	39809.60	71.00		78.09**
Error	1033.50	144.00	7.18	

**Significant at 1 per cent level

C.D. for comparison among insecticides (mean) at 5 per cent level (2.48)

C.D. for comparing insecticides at each level (4.30) levels of the insecticides tried, the relative efficacy of those insecticides which caused more than 50 per cent mortality were in the following descending order: Ethyl parathion, carbaryl, carbophenothion, methyl parathion, dimethoate, fenitrothion, fenthion, thiometon, phosphamidon, leptophos, phorate, formothion, quinalphos, monocrotophos, methyl demeton, acephate. BHC, endrin, endosulfan, dichlorvos, diazinon, elsan, malathion and trichlorfon were ineffective at all levels of treatments. In general ethyl parathion, carbaryl, carbophenothion and methyl parathion appeared to be most effective against *C.medinalis* larvae when sprayed in their leaf folds.

Experiment 4

Effect of insecticide sprays on the population of the larvae of *C.medinalis* in an infested field

Experimental details

Treatments	:	24 insecticides at doses shown in Table 5 were sprayed
Preparation of dilusions of insecticides	:	The insecticides were prepared from commercial formulations as in Experiment 3
Control	:	Plots sprayed with water alone served as control

No. of replications	:	3
Design of experiment	:	Randomised Block Design
Plot size	:	2 x 2 m
Period of experiment	:	29-1-1972 to 7-2-1972
Temperature during the period	:	maximum 30.4 to 30.7°C Av.30.6°C minimum 21.4 to 21.7°C Av.21.6°C
Relative humidity during the period	:	maximum 91.6 to 93.6 per cent Av.92.6 per cent minimum 56.1 to 62.9 per cent Av.59.5 per cent
Procedure	:	As described under methods (Page 23)

<u>Results</u>:

Results are given in Appendix III, Table 5 and Fig. 13. The insecticides which gave more than 50 per cent reduction in pest population can be ranked in the following descending order: Ethyl parathion (72.53 per cent), carbaryl (69.03), Carbophenothion (67.64), methyl parathion (66.79), dimethoate (64.25), fenthion (64.20), fenitrothion (62.23), leptophos (61.07), phosphamidon (59.04), phorate (57.18), formothion (52.44), methyl demeton (52.18),

Fig. 13. Mean per cent reduction of the larval population of *C.medinalis* caused by spraying of various insecticides in an infested field.

Fig. 14 A to C.

Mean indices of leaf damage caused by caterpillars of *C.medinalis* in plots treated with different insecticides at biweekly intervals.

14 A. First season 14 B. Second season
14 C. Third season

Figs. 15 A to C.

Persistent toxicity of various insecticides on paddy to the first instar caterpillars of *C.medinalis* when applied at three graded concentrations.

15 A. Lowest doses 15 B. Middle doses
15 C. Highest doses

1. BHC
2. Endrin
3. Endosulfan
4. E.parathion
5. M.parathion
6. Dichlorvos
7. Carbophenothion
8. Diazinon
9. Elsan
10. Fenthion
11. Malathion
12. Leptophos
13. Acephate
14. Quinalphos
15. Carbaryl
16. Fenitrothion
17. Trichlorfon
18. Thiometon
19. Phosphamidon
20. Dimethoate
21. Monocrotophos
22. Formothion
23. Phorate
24. Methyl demeton
25. Control

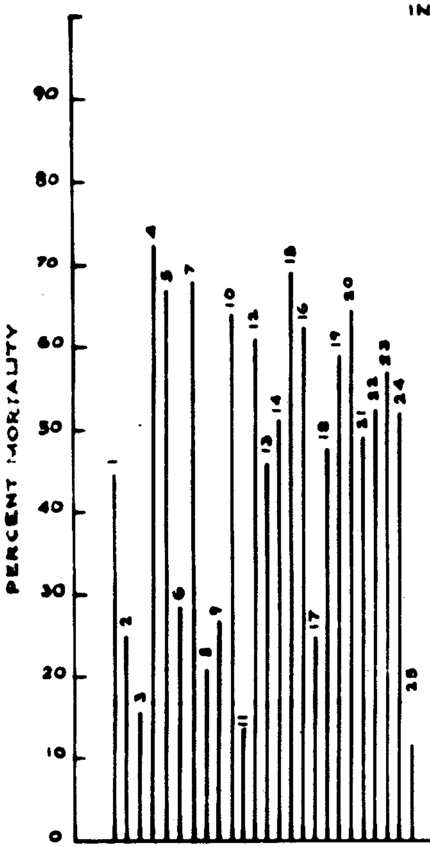


FIG: 13.

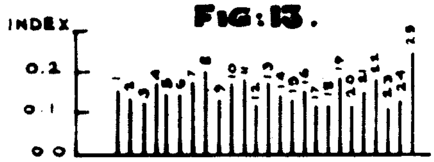


FIG: 14. A

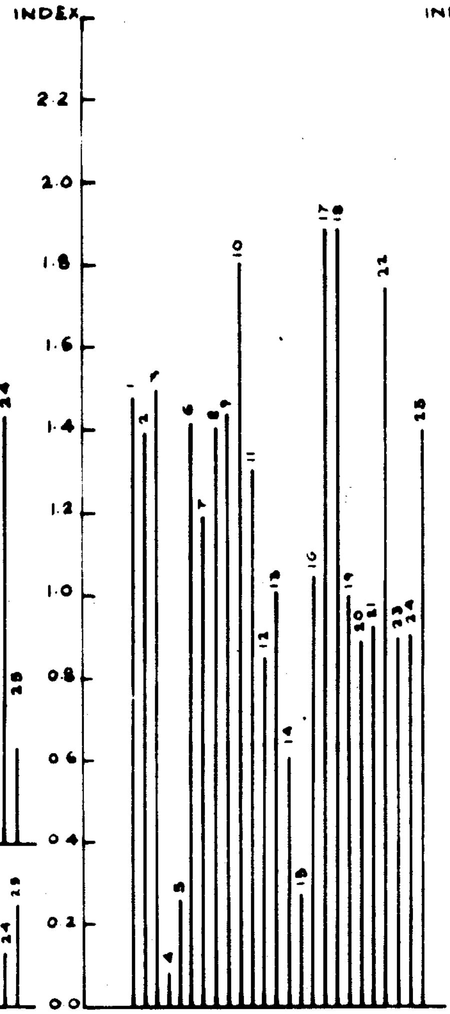


FIG: 14. B.

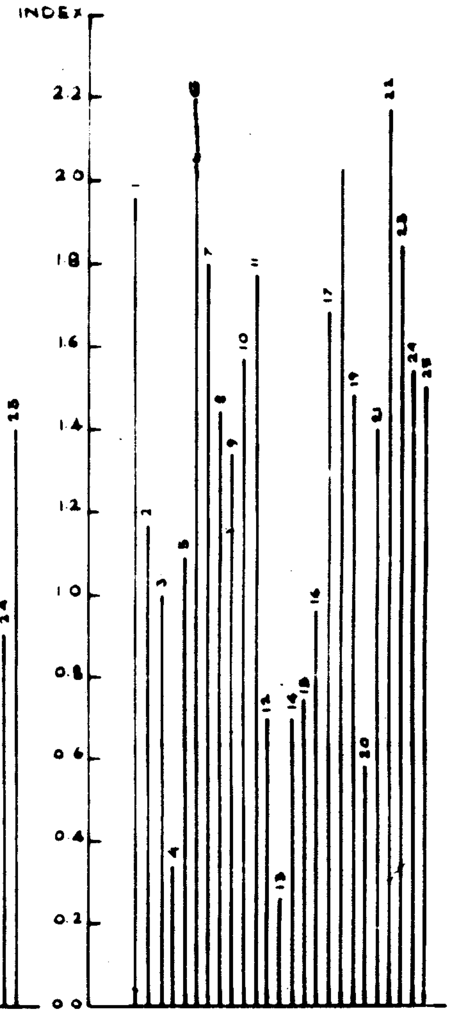


FIG: 14. C.

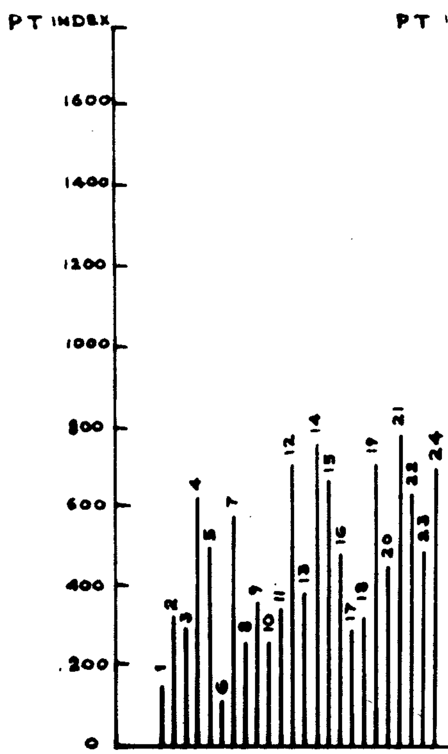


FIG: 15. A

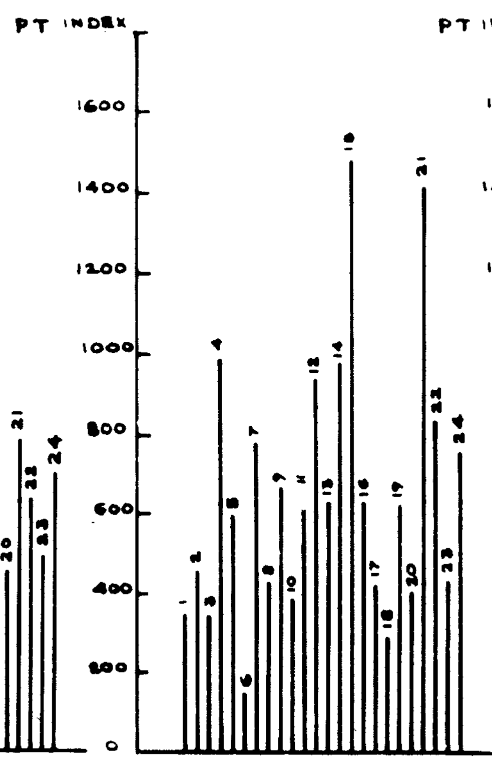


FIG: 15. B.

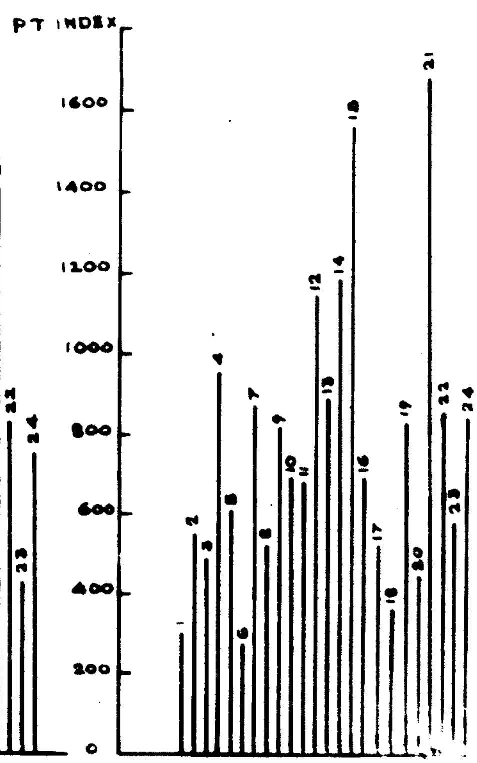


FIG: 15. C

Table 5 Reduction of the larval population of *C.medinalis*, caused by spraying various insecticides, in an infested field

Insecticides	Concentration (Per cent)	Mean percentage reduction in population
BHC	0.20	44.67 (41.93)
Endrin	0.04	24.84 (29.89)
Endosulfan	0.04	15.81 (23.33)
E.parathion	0.04	72.53 (58.36)
M.parathion	0.04	66.79 (54.81)
Dichlorvos	0.08	27.54 (31.65)
Carbophenothion	0.04	67.64 (55.33)
Diazinon	0.04	20.67 (27.04)
Elsan	0.04	27.11 (31.87)
Fenthion	0.075	64.20 (53.25)
Malathion	0.06	15.30 (23.03)
Leptophos	0.075	61.07 (51.39)
Acephate	0.075	45.97 (42.69)
Quinalphos	0.06	51.26 (45.73)
Carbaryl	0.20	69.03 (56.19)
Fenitrothion	0.04	62.23 (52.08)
Trichlorfon	0.10	24.69 (29.79)
Thiometon	0.05	46.78 (43.18)
Phosphamidon	0.04	59.04 (50.21)
Dimethoate	0.05	64.25 (53.28)
Monocrotophos	0.04	49.17 (44.53)
Formothion	0.06	52.44 (46.40)
Phorate	0.04	57.18 (49.18)
Methyl demeton	0.05	52.18 (46.25)
Control		10.94 (19.31)

Figures in parenthesis are angular transformations of percentages.

Analysis of Variance Table

Source	SS	DF	MS	F
Total	12076.49	74		
Treatment	10966.89	24	456.95	20.59**
Error	1106.81	50	22.19	

**Significant at 1 per cent level. C.D. at 5 per cent level = (7.69) quinalphos (51.26). The chlorinated hydrocarbons and cyclodienes were ineffective in controlling the pest in field. Carbaryl was highly effective. Among organophosphates both contact and systemic insecticides reduced the population significantly. Monocrotophos (49.17), thiometon (46.78), acephate (45.97) and BHC (44.67) also may be considered moderately effective. Dichlorvos, elsan, endrin, trichlorfon, diazinon, endosulfan and malathion were ineffective.

Experiment 5

The extent of damage caused by *C.medinalis* in fields treated with different insecticides at biweekly intervals

Experimental details

Treatments	:	The insecticides used and their doses were the same as in Experiment 4
Preparation of dilutions of insecticides	:	As in Experiment 4
Design of experiment	:	Randomised Block Design
Plot size	:	3 x 3 m
No. of replications	:	3
Control	:	Treatment with water alone

Period of experiment	:	
First season	:	4-6-1971 to 20-8-1971
Temperature during the period	:	maximum from 27.9 to 29.09°C
		Av.29.18°C
		minimum from 21.6 to 23.9°C
		Av.22.74°C
Relative humidity	:	maximum from 87.3 to 96.0 per cent
		Av.90.74 per cent
		minimum from 69.7 to 81.62 per cent
		Av.74.73 per cent
Total rainfall	:	770.0 mm
Second season	:	12-12-1971 to 20-2-1972
Temperature during the period	:	maximum from 22.9°C to 34.7
		Av.30.93°C
		minimum from 19.6°C to23.4°C
Relative humidity	:	maximum from 80.9 to 94.1 per cent
		Av.90.10 per cent
		minimum from 54.7 to 76.7 per cent

		Av.62.84 per cent
Rainfall	:	Nil
Third season	:	19-2-1972 to 29-4-1972
Temperature during the period	:	maximum from 32.0 to 32.3°C
		Av.31.91°C
		minimum from 20.8 to 25.5°C
		Av.23.01°C
Relative humidity	:	maximum from 85.1 to 91.3 per cent
		Av.87.61 per cent
		minimum from 55.3 to 63.9 per cent
		Av.61.37 per cent
Total rainfall	:	38.4 mm
Procedure	:	As given under methods (Page 24)

Results:

The results of the experiments conducted in three seasons are presented in Tables 6 and Appendices IV, V and VI. A biotogramic representation of the same is given in Figs. 14A, B and C. In the first season the damage in treatments did not differ from control significantly. In the second season leaf damage was significantly lower in plots treated with ethyl parathion, methyl parathion and carbaryl when compared with

Table 6 Mean indices of leaf damage caused by C.medinalis in plots treated with insecticides at biweekly intervals

Insecticides	Conc.%	First season	Second season	Third season
BHC	0.20	0.153	1.482	1.960
Endrin	0.04	0.132	1.384	1.165
Endosulfan	0.04	0.120	1.515	1.070
E.parathion	0.04	0.175	0.081	0.336
M.parathion	0.04	0.146	0.263	1.089
Dichlorvos	0.08	0.142	1.423	2.231
Carbophenothion	0.04	0.172	1.193	1.797
Diazinon	0.04	0.199	1.409	1.440
Elsan	0.04	0.125	1.438	1.338
Fenthion	0.075	0.167	1.806	1.564
Malathion	0.06	0.172	1.335	1.768
Leptophos	0.075	0.116	0.849	0.713
Acephate	0.075	0.171	1.021	0.255
Quinalphos	0.06	0.140	0.619	0.700
Carbaryl	0.20	0.131	0.273	0.743
Fenitrothion	0.04	0.151	1.047	0.962
Trichlorfon	0.10	0.113	1.875	1.681
Thiometon	0.05	0.118	1.887	1.985
Phosphamidon	0.04	0.182	1.022	1.482
Dimethoate	0.05	0.115	0.885	0.577
Monocrotophos	0.04	0.146	0.925	1.396
Formothion	0.06	0.178	1.749	2.177
Phorate	0.04	0.105	0.896	1.836
Methyl demeton	0.05	0.125	0.903	1.534
Control		0.245	1.400	1.502
C.D.		Not significant	0.959	0.736

Analysis of Variance Table

	Source	SS	DF	MS	F
Second season	Total	35.26	74.00		
	Treatment	17.43	24.00	0.73	2.14**
	Block	1.53	2.00	0.77	2.26
	Error	16.30	38.00	0.34	
Third season	Total	66.91	74.00		
	Treatment	53.41	24.00	2.23	19.91**
	Block	8.09	2.00	4.05	36.16
	Error	5.41	48.00	0.11	

**Significant at 5 per cent level

control. The indices of damage in these treatments were 0.081, 0.263 and 0.273 respectively. The comparative efficacy of other treatments (which were more effective than control) was in the following descending order: quinalphos (0.619 damage index), leptophos (0.849), dimethoate (0.885), phorate (0.896), methyl demeton (0.903), monocrotophos (0.925), acephate (1.021), phosphamidon (1.022), fenitrothion (1.047), carbophenothion (1.193), malathion (1.335). During the third season the damage in plots treated with acephate (0.255), ethyl parathion (0.336), dimethoate (0.577), quinalphos (0.700), leptophos (0.713) and carbaryl (0.743) was significantly lower than that in control there being no significant difference among themselves. The other treatments in which the damage remained lower than that of control were fenitrothion (0.962), endosulfan (1.070), methyl parathion (1.089), endrin (1.165), elsan (1.338), monocrotophos (1.396), diazinon (1.440) and phosphamidon (1.482).

Experiment 6

Persistent toxicity of insecticides applied on paddy, to the first instar caterpillars of *C.medinalis*, under field conditions

Experimental details

Insecticides used	:	Same as in Experiment 3
Control	:	Plots sprayed with water alone
Preparation of insecticide dilution	:	As in Experiment 3
Design of the field experiment	:	Randomised Block Design
Test insect used for assessing residual toxicity in laboratory	:	First instar caterpillars of C.medinalis
No. of larvae used in each replication	:	10
No. of replication for each treatment	:	3
Period of experiment	:	26-8-1971 to 16-9-1971
Temperature during the period	:	maximum 29.4 to 31.4°C Av.30.4°C minimum 23.2 to 24.4°C Av.23.8°C
Relative humidity during the period	:	maximum 84.1 to 91.9 per cent Av.88.00 per cent minimum 66.00 to 76.4 per cent Av.69.60 per cent

Rainfall : Nil

Procedure : As described under methods (Page 25)

Results:

The data relating to the persistent toxicity of insecticides calculated for each dose are presented in Tables 7 to 9. A biotogramic representation of the PT indices is presented in Figs. 15A, B and C. It may be seen that persistent toxicity of the various insecticides applied at the lowest doses was in the following descending order: monocrotophos (783.09 PT index), quinalphos (760.4), phosphamidon (709.64), leptophos (706.94), methyl demeton (703.23), carbaryl (671.04), formothion (632.24), ethyl parathion (621.00), carbophenothion (577.62), phorate (493.28), methyl parathion (489.48), fenitrothion (481.23), dimethoate (452.10), acephate (385.20), elsan (355.05), malathion (343.92), endrin (323.35), thiometon (321.60), endosulfan (293.10), trichlorøfon (287.05), diazinon (258.75), fenthion (258.32), BHC (139.64), dichlorvos (105.92). At the middle doses the persistent toxicity was in the following descending order: carbaryl (1477.44), monocrotophos (1408.96), ethyl parathion (993.33), quinalphos (977.06), leptophos (940.52), formothion (830.17),

Table 7 Persistent toxicity of various insecticides sprayed (Highest doses)

Insecticides	Conc.%	Intervals after									
		0.25	0.50	1	2	3	4	5	6	7	8
BHC	0.30	100	100	100	79.0	50.0	20.0				
Endrin	0.06	100	100	100	100	80.0	63.3	88.8	76.7	36.6	7.4
Endosulfan	0.06	100	100	100	80.6	80.0	70.0	45.1	34.5	16.7	
E.parathion	0.06	100	100	100	100	100	100	100	100	86.6	68.7
M.parathion	0.06	100	100	100	100	100	100	81.3	30.7	23.6	20.2
Dichlorvos	0.10	100	81.3	82.0	27.5	26.6	13.3	26.0	7.7		
Carbophenothion	0.06	100	100	100	100	100	100	100	65.2	63.3	54.7
Diazinon	0.06	100	100	100	89.3	63.3	70.0	88.8	26.8	26.6	
Elsan	0.06	100	100	100	100	100	100	100	53.7	50.0	34.3
Fenthion	0.10	100	100	100	100	100	100	100	46.0	56.6	27.5
Malathion	0.10	100	100	100	85.3	80.0	63.3	78.7	72.7	60.0	48.0
Leptophos	0.10	100	100	100	100	100	100	100	84.3	90.0	68.8
Acephate	0.10	100	100	100	100	100	66.7	55.5	53.7	50.0	59.9
Quinalphos	0.10	100	100	100	100	100	100	100	100	93.3	75.6
Carbaryl	0.30	100	100	100	100	100	100	100	100	100	100
Fenitrothion	0.06	100	100	100	100	100	100	90.3	44.1	40.6	48.1
Trichlorfon	0.20	100	100	100	100	86.6	66.6	77.7	26.7	13.3	
Thiometon	0.10	100	100	89.2	72.1	63.3	46.6	36.0			
Phosphamidon	0.06	100	100	100	100	100	100	85.0	80.4	73.3	48.1
Dimethoate	0.10	100	100	100	100	83.3	70.0	14.8	14.8	19.2	
Monocrotophos	0.06	100	100	100	100	100	100	100	100	100	100
Formothion	0.10	100	100	100	100	100	100	100	65.2	70.0	68.8
Phorate	0.06	100	100	100	100	80.0	70.0	44.4	57.5	50.0	17.2
Methyl demeton	0.10	100	100	100	100	100	80.0	62.9	44.8	60.0	51.4

on paddy, to the first instar larvae of C.medinalis, under field conditions

spraying (in days)														
9	10	11	12	13	14	15	16	17	18	19	20	P	T	PT
												4	74.83	299.32
												8	68.38	547.64
												7	69.65	487.55
82.0	37.0	27.5	3.4									12	78.94	947.28
												8	75.58	604.64
												6	45.55	273.30
71.3	18.5	30.9	10.3									12	72.43	869.16
												7	73.86	517.02
46.4	55.5	24.0										11	74.14	815.54
14.3												10	76.76	690.84
12.3	10.0											10	67.52	675.20
46.4	33.3	36.1	41.2	24.0	36.6	46.6	17.2					16	71.36	1141.76
53.5	51.7	62.8	34.3	34.3								13	68.16	886.08
85.5	81.3	65.2	54.6	72.1	26.6	~~14~~						14	84.63	1184.82
100	100	100	100	95.0	86.0	62.0	38.3	22.3	10.7	9.5		19	82.09	1559.80
21.4												9	76.76	690.84
												7	74.54	521.78
												5	72.45	362.25
35.7	44.4	10.3										11	75.16	826.76
												7	66.90	468.30
100	100	90.0	90.0	72.3	79.3	75.6	73.3	59.0	58.5	34.5	15.5	20	84.00	1680.00
28.5	40.7	17.1	10.3									12	71.47	857.64
												8	71.91	575.28
71.3	33.3	30.9	20.6	10.3								13	64.36	836.68

Table 8 Persistent toxicity of various insecticides sprayed (Middle doses)

Insecticides	Conc.%	Intervals after								
		0.25	0.50	1	2	3	4	5	6	7
BHC	0.20	100	100	82.3	82.0	53.3	43.3	22.2		
Endrin	0.40	100	100	100	65.2	63.3	53.3	66.6	11.5	30.00
Endosulfan	0.04	100	100	53.5	48.1	53.3	66.7	29.6	3.8	
E.parathion	0.04	100	100	100	100	100	96.6	97.0	88.2	76.0
M.parathion	0.04	100	100	100	91.6	83.3	83.3	88.8	49.8	26.7
Dichlorvos	0.08	100	14.8	21.4	30.9	20.0	10.0	7.4		
Carbophenothion	0.04	100	96.2	100	100	96.6	96.6	100	42.2	46.6
Diazinon	0.04	100	100	100	92.6	53.3	36.6	70.2	15.3	
Elsan	0.04	100	100	100	100	100	80.0	74.0	61.3	30.0
Fenthion	0.075	100	100	100	100	73.3	43.3	23.3	11.1	10.0
Malathion	0.06	100	100	100	100	63.3	83.3	73.9	30.7	26.6
Leptophos	0.075	100	100	100	100	100	100	100	88.2	63.3
Acephate	0.075	100	100	100	100	83.3	73.3	55.5	34.5	40.0
Quinalphos	0.06	100	100	100	100	100	100	88.7	65.2	36.6
Carbaryl	0.20	100	100	100	100	100	100	100	100	100
Fenitrothion	0.04	100	100	100	100	80.0	86.6	62.9	34.1	23.3
Trichlorfon	0.10	100	100	82.0	72.1	40.0	56.6	70.2	39.1	
Thiometon	0.05	100	88.8	78.5	44.6	46.6	33.3	11.1		
Phosphamidon	0.04	100	100	100	100	90.8	37.0	61.3	50.0	20.6
Dimethoate	0.05	100	100	100	85.8	80.0	63.3	63.3		
Monocrotophos	0.04	100	100	100	100	100	100	100	100	100
Formothion	0.06	100	100	100	100	100	56.6	66.6	65.2	66.6
Phorate	0.04	100	100	100	85.8	76.6	70.0	62.9		
Methyl demeton	0.05	100	100	100	82.5	80.0	73.3	51.7	26.8	66.7

on paddy, to the first instar larvae of C.medinalis, under field conditions

spraying (in days)

8	9	10	11	12	13	14	15	16	17	18	P	T	PT
											5	69.01	345.05
											7	65.54	458.78
											6	56.87	341.22
68.7	60.6	62.9	51.5	41.2	3.4						13	76.41	993.33
10.7											8	73.51	588.08
											5	29.2	146.00
44.6	46.4	29.6	20.6								11	70.72	777.92
											6	71.00	426.00
24.2	25.0	3.7									10	66.51	665.10
[illegible]											7	55.00	385.00
41.2	21.4										9	67.31	605.79
48.1	35.7	33.3	68.8	24.0	10.3	3.3					14	67.18	940.52
30.9	35.7	7.4									10	63.38	633.80
45.6	46.3	77.7	79.0	30.0	34.3	13.3	10.0				14	69.79	977.06
100	100	100	100	95.0	87.0	62.0	40.0	27.0	20.0	10.0	18	82.08	1477.44
27.5	25.0	14.8									10	62.85	628.50
											6	70.00	420.00
											5	57.55	287.75
39.3	22.3	20.6									10	61.82	618.20
											5	80.34	401.70
100	100	100	90.6	90.0	75.8	76.5	46.6	16.6			16	88.06	1408.96
78.5	57.1	66.6	24.0								11	75.47	830.17
											5	85.04	425.20
78.5	39.2	51.5	41.2								11	68.55	754.05

Table 9 Persistent toxicity of various insecticides sprayed (Lowest doses)

Insecticides	Conc.%	Intervals after						
		0.25	0.50	1	2	3	4	5
BHC	0.40	100	13.9	57.1	13.7	13.3	10.0	
Endrin	0.02	100	100	82.0	72.1	30.0	50.0	18.6
Endosulfan	0.02	100	100	46.4	48.1	40.0	50.0	25.9
E.parathion	0.02	100	100	100	100	43.3	40.0	51.7
M.parathion	0.02	100	100	100	100	73.3	90.0	70.2
Dichlorvos	0.04	100	14.8	7.1	13.7	13.3	10.0	
Carbophenothion	0.02	100	100	100	100	86.6	70.0	44.4
Diazinon	0.02	100	100	49.9	37.7	30.3	33.3	11.1
Elsan	0.02	100	100	100	41.2	73.3	56.6	25.9
Fenthion	0.05	100	100	100	30.0	43.3	13.3	
Malathion	0.03	100	100	42.8	37.8	46.6	30.0	33.3
Leptophos	0.05	100	100	100	100	100	63.3	66.6
Acephate	0.05	100	100	100	85.6	62.0	33.3	21.3
Quinalphos	0.03	100	100	100	75.5	90.0	76.6	85.0
Carbaryl	0.10	100	100	100	100	100	80.0	71.3
Fenitrothion	0.02	100	100	100	85.8	70.0	43.3	24.9
Trichlorfon	0.05	100	100	60.6	61.8	43.3	29.6	6.6
Thiometon	0.03	100	85.0	78.5	68.7	60.0	43.3	14.8
Phosphamidon	0.02	100	100	100	100	100	70.0	59.2
Dimethoate	0.03	100	100	100	82.0	79.3	65.0	46.6
Monocrotophos	0.02	100	100	100	100	100	100	100
Formothion	0.03	100	100	100	100	100	86.6	70.2
Phorate	0.02	100	100	100	100	80.0	50.0	25.9
Methyl demeton	0.03	100	100	100	68.7	60.0	43.3	74.0

on paddy, to the first instar larvae of ***C. medinalis***, under field conditions

spraying (in days)										
6	7	8	9	10	11	12	13	P	T	PT
								4	34.66	138.64
								5	64.67	323.35
								5	58.62	293.10
72.1	53.3	41.2	21.4	22.3				10	62.10	621.00
19.2								6	81.58	489.48
								4	26.48	105.92
26.8	33.3	57.8	7.1					9	64.18	577.62
								5	51.75	258.75
								5	71.01	355.05
								4	64.58	258.32
15.3	16.7	7.4						8	42.99	343.92
30.7	40.0	27.5	25.0	3.7	41.2	10.3	7.4	13	54.38	706.94
11.5								6	64.20	385.20
88.2	54.9	46.4	30.0	17.2	10.3	13.1		12	63.37	760.40
66.7	53.3	31.0	17.8					9	74.56	671.04
24.1	20.0	10.0	10.0					9	53.47	481.23
								5	57.41	287.05
								5	64.32	321.60
57.5	56.6	34.3	35.7	18.5	6.9			11	64.51	709.61
29.6								6	75.35	452.10
76.7	73.3	85.8	21.4					9	87.01	783.09
46.0	56.6	30.9						8	79.03	632.24
16.7	36.6	7.4						8	61.66	493.28
88.7	76.7	51.5	36.0	18.5	13.7			11	63.93	703.23

carbophenothion (777.92), methyl demeton (754.05), elsan (665.10), acephate (633.80), fenitrothion (628.50), phosphamidon (618.00), malathion (605.79), methyl parathion (538.08), endrin (458.78), diazinon (426.00), phorate (425.20), trichlorfon (420.00), dimethoate (401.70), fenthion (385.50), BHC (345.05), endosulfan (341.22), thiometon (287.75), dichlorvos (146.00). At the highest doses the persistent toxicity of the insecticides was in the following descending order: monocrotophos (1680.00), carbaryl (1559.71), quinalphos (1184.82), leptophos (1141.76), ethyl parathion (947.28), acephate (886.08), carbophenothion (869.16), formothion (857.64), methyl demeton (836.68), phosphamidon (826.76), elsan (815.54), fenitrothion (690.84), fenthion (690.84), malathion (675.20), methyl parathion (604.64), phorate (575.28), endrin (547.64), trichlorfon (521.78), diazinon (517.02), endosulfan (487.55), dimethoate (468.36), thiometon (362.25), BHC (299.32), dichlorvos (273.30). It is seen that the residues in samples collected at the end of six hours after spraying caused complete mortality of caterpillars in all the treatments. BHC, endrin and endosulfan which are known to have long persistence had much less persistent toxicity to leaf roller larvae than most of the organophosphates which are generally considered as non persistent insecticides. Among the organophosphates the residual toxicity was least for dichlorvos, it being considerably reduced in 48 hours after spraying and totally lost within a period of 6 days after spraying. At the lower doses the residual toxicity was significantly reduced within 12 hours after spraying. Monocrotophos was the most persistent organophosphate. The residues of the insecticide at the three levels caused 100 per cent mortality of the larvae even at 10, 10 and 5 days respectively after spraying and the toxicity persisted upto 20, 16 and 9 days respectively. Insecticides like dichlorvos, diazinon, BHC, thiometon, endosulfan, trichlorfon, dimethoate, endrin, fenthion and phorate also had comparatively low persistent toxicity. Carbaryl had a long persistence almost comparable to that of monocrotophos at the higher doses of 0.3 and 0.2 per cent. In general there was a higher persistence of the insecticides at the higher doses. But the difference in the persistent toxicity between the two higher doses of each insecticide was however not significant.

STUDIES ON THE INSECT-PLANT RELATIONSHIPS BETWEEN *C.MEDINALIS* AND RICE VARIETIES

Experiment 7

Effect of infestation by caterpillars of *C.medinalis* on the yield of rice in relation to the stage of the crop

Experimental details

Varieties of rice used	:	Three varieties of rice viz. IR8, *Annapoorna* and *Kochuvithu* were used
No. of replication for each treatment	:	3
Stage of the crop at which plants were exposed to larvae	:	At weekly intervals from 50 days after sowing
No. of larvae liberated in each replication	:	In sufficiently large numbers to ensure complete feeding of leaves in 48 hours
Control	:	This consisted of plants in three pots unexposed to the larvae
Period of experiment	:	4-3-72 to 14-7-72

Temperature during the period	:	maximum 29.1 to 32.6°C
		minimum 20.8 to 25.5°C
		Av.23.63°C
Relative humidity during the period	:	maximum 83.7 to 93.6 per cent
		Av.88.12 per cent
		minimum 55.3 to 78.0 per cent
		Av.66.99 per cent
Total rainfall	:	627 mm
Procedure	:	As described under methods (Page 26)

Results:

The data on the weight of grains of rice plants exposed to infestation by larvae of *C.medinalis* at different stages of growth are presented in Appendices VII and VIII. Mean percentage of reduction in grain yield as compared to control are given in Table 10 and represented in Fig.16. It may be seen that the infestation at all stages of growth reduced the yield significantly. In the case of IR8 the maximum reduction of 58.16 per cent in grain yield was in plants exposed to the larvae 85 days after sowing. The reduction in yield was less in plants exposed to infestation earlier to or later than this occasion. From the

Fig. 16. Mean percentage reduction in paddy grain yield over control, caused by C.medinalis larvae to different rice varieties at different stages of growth.

Fig. 17. Mean increase in percentage of chaff in the yield of different rice varieties infested by C.medinalis larvae, at various intervals after sowing, over mean percentage of chaff in uninfested control plants.

Fig. 18. The mean percentage reduction in grain yield of different varieties of rice (compared to the yield in control) caused by 3 different levels of larval population of C.medinalis at pre booting stage of the crop.

1.	IR8	10.	Annapoorna (culture.28)
2.	Karuna	11.	Cavery
3.	IR20	12.	Mashoori
4.	Pankaj	13.	Adt27
5.	H4	14.	TKM6
6.	Rohini	15.	Jagannath
7.	Aswathi	16.	Ptb9
8.	Triveni	17.	TKM1
9.	Jaya	18.	Kochuvithu

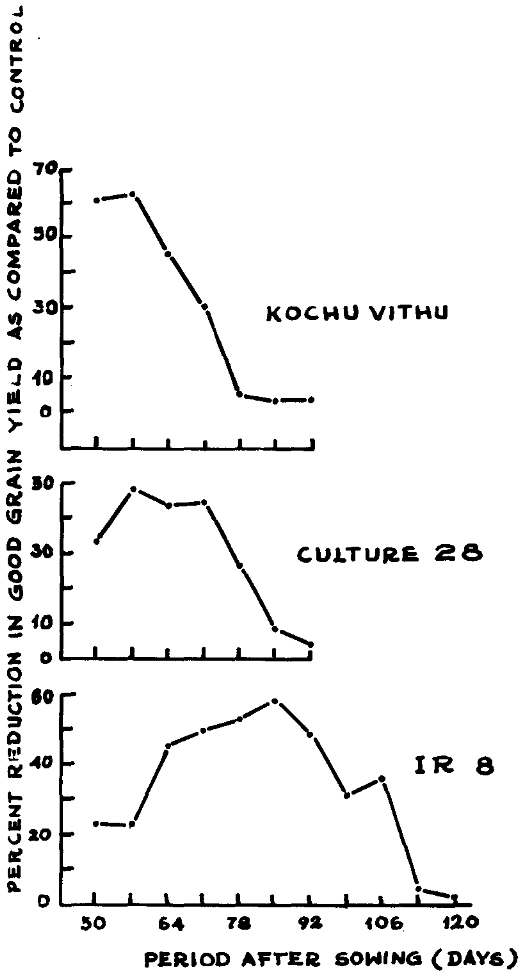


FIG: 16

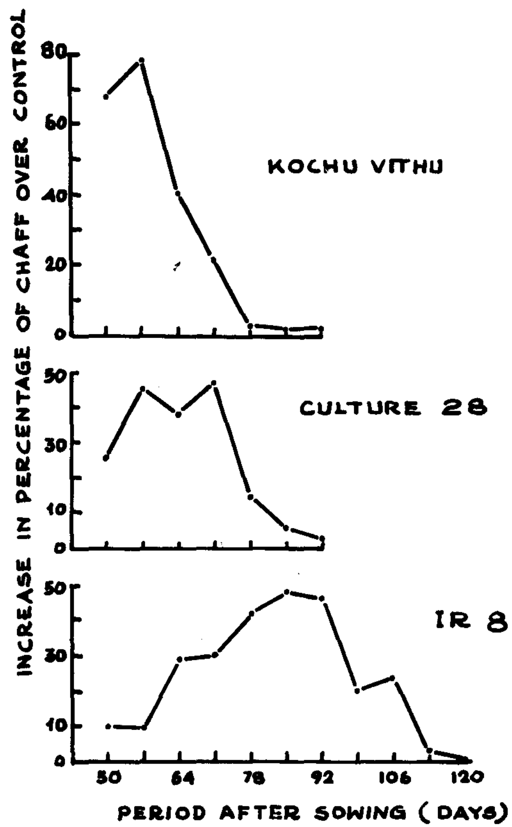


FIG: 17

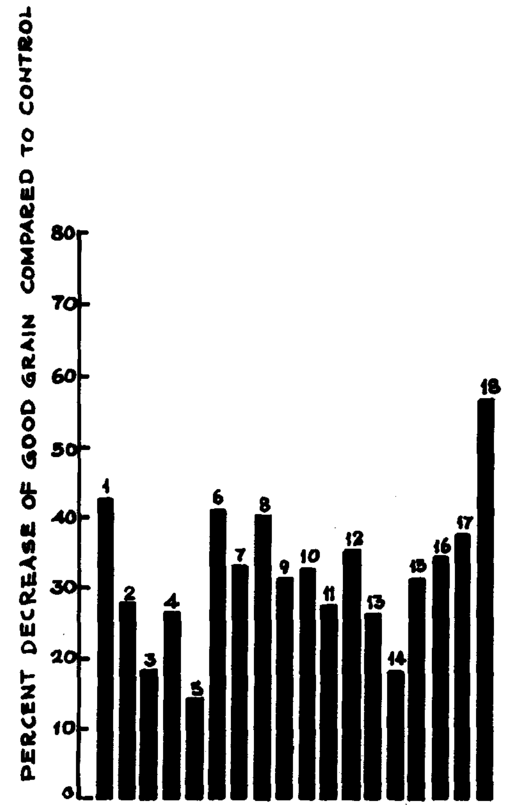


FIG: 18

Table 10 Mean per cent reduction in the good grain yield of 3 varieties of rice exposed to *C.medinalis* infestation at various intervals after sowing over the yield of uninfested plants

Intervals after sowing (in days)	Varieties of rice		
	IR8	Annapoorna	Kochuvithu
50	23.45 (28.96)	35.65 (35.48)	60.10 (50.83)
57	23.13 (28.75)	48.59 (44.18)	62.08 (51.99)
64	45.64 (42.50)	43.21 (41.10)	45.17 (42.23)
71	50.00 (45.00)	44.42 (41.79)	30.03 (33.23)
78	52.72 (46.56)	26.51 (30.99)	4.75 (12.37)
85	58.16 (49.90)	8.50 (16.95)	3.40 (10.60)
92	48.98 (44.52)	4.44 (12.15)	3.37 (10.38)
99	31.56 (34.18)		
106	36.06 (36.91)		
113	4.30 (11.96)		
120	2.73 (9.48)		
CD	(7.76)	(10.72)	(9.16)

Figures in parenthesis are angular transformations of percentages

Analysis of Variance Table

	Source	SS	DF	MS	F
IR8	Total	63553.12	32		
	Treatment	5890.64	10	589.06	28.02
	Error	462.48	22	21.02	
Annapoorna	Total	3406.52	20		
	Treatment	2881.61	6	480.27	12.81
	Error	524.91	14	37.49	
Kochuvithu	Total	9300.45	20		
	Treatment	8917.66	6	1486.26	54.36
	Error	382.79	14	27.34	

85th day occasion to the 130th day occasion, the percentage reduction decreased from 58.16 to 2.73. In general the reduction was substantial in plants exposed to infestation at various intervals from 50th to 106th day, while the yield reduction in plants exposed to the larvae on 113th and 120th days after sowing were negligible.

The maximum reduction in yield of Annapoorna was noted in plants exposed to the larvae on the 57th day after sowing (48.59 per cent) while the yield reduction was less when the plants were subjected to the attack earlier than and later to this occasion. The per cent reduction was 35.65 per cent only at 50th day and it declined to 4.4 per cent at the 92nd day occasion. The yield reduction was substantially high in plants exposed upto 78 days after sowing (range 26.51 to 48.59 per cent); the reduction was negligible in plants subjected to infestation on 85th and 92nd days after sowing.

In the case of 'Kochuvithu' also the maximum reduction in yield was observed in plants exposed on 57th day after sowing (62.08 per cent). At the 50th day infestation the reduction was 60.01 per cent while infestation at various intervals after 57th day showed a progressive decrease in the yield the percentage being 45.17, 30.03, 4.75, 3.40 and 3.37 in plants exposed on 64th, 71st, 78th, 85th and 92nd days respectively after sowing. It is also seen that the infestation from 78th day after sowing did not cause any substantial decrease in yield.

Date on the chaff yield of the plants exposed to the larval infestation at different stages of growth are given in Appendix VIII. Table 11 gives the increase in percentage of chaff yield over those of corresponding controls. Fig.17 represents the same. It may be observed that the infestation resulted in an increase in chaff percentage. In IR8, the maximum increase in chaff percent was in plants subjected to infestation 85 days after sowing. There was a progressive reduction in chaff percentage on either side of this peak point ie. towards the earlier and later periods. From the peak percentage difference of 48.04 on 85th day it dwindled to 9.87 per cent on the 50th day occasion and on the other side it decreased to 0.92 per cent on 120th day. The increase in percentage of chaff produced was high in exposures of infestation from 64th day to 106th day.

In the case of Annapoorna the highest quantity of chaff (46.28 per cent higher than in the control) was found in plants

Table 11 Mean increase in percentage of chaff in the yield of different varieties of rice infested by <u>C.medinalis</u> at various intervals after sowing, over the mean per cent of chaff in uninfested control plants

Intervals after sowing (in days)	Varieties of rice		
	IR8	Annapoorna	Kochuvithu
50	9.87 (18.31)	26.07 (30.66)	67.79 (55.42)
57	9.68 (18.12)	36.28 (42.87)	78.27 (62.22)
64	28.94 (32.54)	38.07 (38.10)	40.49 (39.52)
71	29.43 (32.85)	45.55 (42.45)	21.01 (27.32)
78	41.19 (39.93)	14.66 (22.50)	2.94 (9.86)
85	48.04 (43.87)	6.01 (14.18)	2.09 (8.31)
92	35.97 (36.85)	2.69 (9.40)	2.23 (8.56)
99	19.52 (26.22)		
106	23.27 (28.74)		
113	2.48 (9.01)		
120	0.92 (5.21)		
CD at 5 per cent level	(6.84)	(13.50)	(10.62)

Figures in parenthesis are angular transformations of percentages

<u>Analysis of Variance Table</u>

	Source	SS	DF	MS	F
IR8	Total	4960.66	32		
	Treatment	4601.24	10	460.12	28.16
	Error	359.42	22	16.39	
Annapoorna	Total	4650.40	20		
	Treatment	3816.89	6	636.15	10.69
	Error	833.51	14	59.53	
Kochuvithu	Total	15552.52	20		
	Treatment	15038.39	6	2507.68	68.27
	Error	514.13	14	36.72	

subjected to infestation 57 days after sowing. The chaff production was less due to the infestation on 50th day occasion (26 per cent) and at intervals later to the 57th day occasion. From the 64th day there was a progressive decrease in chaff production, the increase over control declining to 2.69 per cent on the 91st day occasion.

In the rice variety Kochuvithu a very high increase in the quantity of chaff was in evidence due to infestation. It was so in the earlier stage of crop than in the later stages. The peak in chaff production was 78.27 per cent more than in control and it was caused by the infestation on 57th day after sowing. The increase in chaff was less on the 50th day infestation (67.79 per cent) and on the occasions following 57th day ie. 64th, 71st, 78th, 85th and 92nd days; the chaff production at these occasions were in correspondingly decreasing magnitudes ie. 40.49, 21.01, 2.94, 2.09 and 2.23 per cent respectively.

Experiment 8

Effect of different levels of infestation by the larvae of C.medinalis on the yield of different rice varieties

Varieties of rice used : Eighteen varieties listed

No. of plants in each replication	:	3
No, of replication for each treatment	:	3
Stage of crop infested with larvae	:	One week prior to booting stage
Stage of *C.medinalis* larvae liberated	:	First instar within 24 hours after hatching
Levels of infestation	:	i) 1 larva per leaf ii) 2 larvae per leaf iii) 3 larvae per leaf iv) 4 larvae per leaf
Control	:	Plants in pots without larval infestation
Period of experiment	:	20-8-1972 to 4-2-1973
Temperature during the period	:	maximum 28.9 to 31.3°C Av.30.59°C minimum 22.70 to 23.2°C Av.22.91°C
Relative humidity during the period	:	maximum 88.4 to 96.7 per cent Av.90.60 per cent

		minimum 52.1 to 82.3 per cent
		Av.68.79 per cent
Total rainfall during the period	:	826.1 mm
Procedure	:	As described under methods (Page 27)

Results:

The data on the yield of grain in the different rice varieties are presented in Appendix IX. The mean per cent reduction in good grain yield(compared to the corresponding controls) caused by different levels of larval population and their means, are given in Table 12 and Fig. 18. It may be seen that in all the varieties the reduction in yield due to the infestation was directly proportional to the dose of larvae. There were variations in the extent of yield reduction due to infestation in the different varieties of rice as may be seen in the mean reduction values. While among some varieties these differences were significant, among others they were not. In general, it may be observed that the mean yield was least affected in the varieties H_4, TKM6 and IR20 (14.01, 17.84 and 18.00 per cent respectively). The varieties Kochuvithu, IR8, Rohini,

Table 12 Mean per cent reduction in good grain yield of different rice varieties exposed to 4 population levels of *C.medinalis* larvae one week prior booting stage of the crop

Rice varieties	Population levels				
	L1	L2	L3	L4	Mean
IR8	59.81(50.64)	47.24(43.44)	37.00(37.46)	27.02(31.32)	42.52(40.71)
Karuna	46.15(43.01)	34.68(36.08)	21.93(27.92)	11.60(19.91)	27.66(31.73)
IR20	34.16(35.77)	21.20(27.41)	20.26(26.75)	3.31(10.46)	18.00(25.10)
Pankaj	52.28(46.31)	30.79(33.70)	23.61)29.02)	6.18(14.38)	26.29(30.85)
H4	36.00(36.87)	15.27(23.01)	9.92(18.35)	3.07(9.98)	14.01(22.05)
Rohini	58.01(49.67)	52.49(46.43)	35.75(36.82)	18.44(24.43)	40.61(39.59)
Aswathi	47.78(43.73)	37.60(37.82)	34.91(36.22)	14.69(22.54)	33.03(35.08)
Triveni	61.46(51.62)	47.91(43.80)	37.93(38.02)	15.90(23.51)	40.02(39.24)
Jaya	46.01(42.79)	37.33(37.66)	27.44(31.59)	17.36(24.62)	31.45(34.17)
Annapoorna	46.46(42.98)	42.02(40.49)	27.31(31.50)	16.19(23.88)	32.42(34.71)
Cavery	54.75(47.72)	40.64(39.61)	19.44(26.16)	5.49(13.53)	27.20(31.75)
Mashoori	55.16(47.96)	42.90(40.92)	32.01(34.50)	13.98(21.95)	35.10(36.33)
Adt27	45.72(42.56)	35.32(36.46)	19.57(26.26)	8.26(16.70)	25.89(30.49)
TKM6	45.36(42.34)	27.90(31.87)	12.83(21.08)	0.81(4.64)	17.84(24.98)
Jagannath	49.68(44.83)	35.15(36.36)	29.07(32.63)	13.65(21.68)	31.06(33.87)
Ptb9	50.39(45.23)	42.01(40.47)	32.87(34.98)	14.44(22.33)	34.01(35.75)
TKM1	56.77(48.90)	49.80(44.89)	27.22(31.45)	18.99(25.83)	37.51(37.77)
Kochuvithu	75.41(60.24)	65.86(54.25)	51.22(45.70)	33.15(35.17)	56.73(48.84)

Figures in parenthesis are angular transformations of percentages.

Analysis of Variance Table

Source	SS	DF	MS	F
Total	37108.73	215		
Treatment	26558.79	71	374.07	5.11
Error	10549.44	144	73.26	

CD for comparing varieties at 5% level(6.85)

L1 = Four larvae per leaf
L2 = Three larvae per leaf
L3 = Two larvae per leaf
L4 = One larvae per leaf

Triveni, TKM1, Mashoori and PTB9 suffered very high yield loss due to the caterpillar infestation and the mean per cent reduction varied from 56.77 to 34.01. The other varieties occupied intermediate positions with reference to yield reduction. ADT27, Pankaj, Cavery, Karuna, Jagannath, Jaya, Annapoorna and Aswathi may thus be grouped as moderately tolerant to the infestation the per cent reduction being 25.89, 26.29, 27.20, 27.66, 31.06, 31.45, 32.42 and 33.03 respectively.

Experiment 9

Oviposition response of moths of *C.medinalis* in relation to different varieties of rice

Rice varieties used	:	Same as in Experiment 2
Stages of plants exposed for egg laying	:	One month old plants and plants at boot leaf stage were used
No. of leaves kept for oviposition in each replication	:	12
No. of replications for each variety and stage	:	3
Period of exposure to moths for egg laying	:	2 days

Period of experiment	:	(a) On one month old plants: 18-2-1973 to 22-2-1973
		(b) On plants at bootleaf stage: 4-3-1973 to 8-4-1973
Temperature during the period	:	(a) maximum: 31.5 to 33.2°C Av.32.40°C
		minimum: 22.3 to 24.4°C Av.23.20°C
		(b) maximum: 31.5 to 32.9°C Av.30.44°C
		minimum: 22.34 to 24.4°C Av.23.9°C
Relative humidity during the period	:	(a) maximum 88 to 91 per cent Av.89 per cent
		minimum 59 to 69 per cent Av.63.4 per cent
		(b) maximum 83 to 89 per cent Av.87 per cent
		minimum 61 to 70 per cent Av.66 per cent

Rainfall during the period : Nil

Procedure : As described under methods (Page 28)

(Page 28)

Results:

The results are presented in Table 13 and Fig.19. It may be seen that there was considerable variations in the number of eggs laid by C.medinalis moths on different rice varieties. The mean number varied from 14.33 to 30.66 in the case of one month old plants and from 8.00 to 21.00 in the case of plants at the boot leaf stage. The relative preference for the different varieties for egg laying remained more or less same at both the occasions. At the one month old stage minimum number of eggs were found on Kochuvithu the mean number being 14.33 per plant. It was followed in the ascending order by TKM6, TKM1, Adt27, Ptb9, Pankaj, Triveni, H4, Cavery, IR20 Aswathi there being no significant difference among themselves. The mean number of eggs on these varieties were 14.66, 15.66, 16.33, 17.66, 18.33, 18.66, 19.00, 19.66, 19.66 and 20 respectively. Karuna, Jagannath, Annapoorna, Rohini, Mashoori, Jaya and IR8 were preferred for

Fig. 19 A. Mean number of eggs laid by *C.medinalis* moths on one-month-old paddy plants of different varieties.

B. Mean number of eggs laid by *C.medinalis* moths on different rice varieties at boot leaf stage of the crop.

Fig. 20 Mean area of the leaf of different rice varieties scraped by 4th instar caterpillars of *C.medinalis* in 48 hours.

Fig. 21 Larval plus pupal duration of *C.medinalis* reared on different rice varieties.

Fig. 22 Mean per cent mortality of *C.medinalis* during larval plus pupal periods of development.

1. IR8
2. Karuna
3. IR20
4. Pankaj
5. H4
6. Rohini
7. Aswathi
8. Triveni
9. Jaya
10. Annapoorna
11. Cavery
12. Mashoori
13. Adt27
14. TKM6
15. Jagannath
16. Ptb9
17. TKM1
18. Kochuvithu

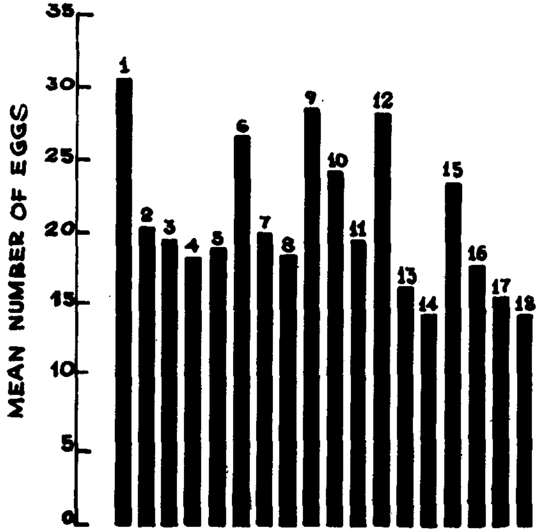


Fig: 19-A

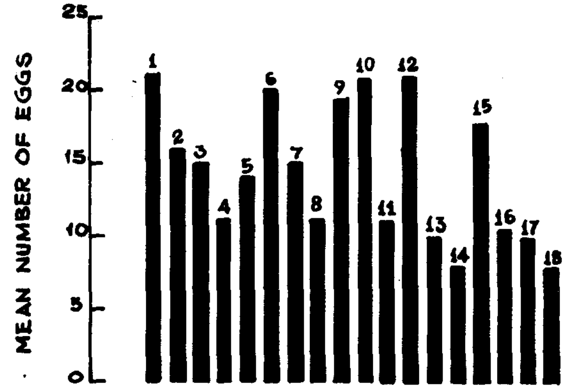


Fig: 19-B

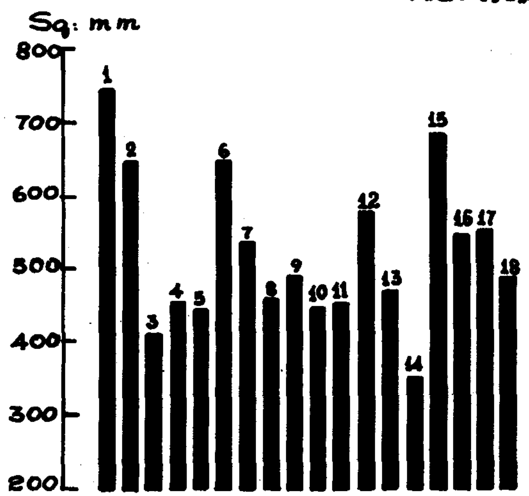


Fig: 20

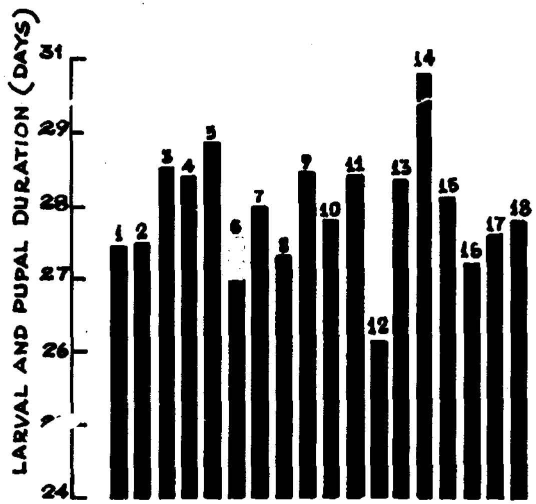


Fig: 21

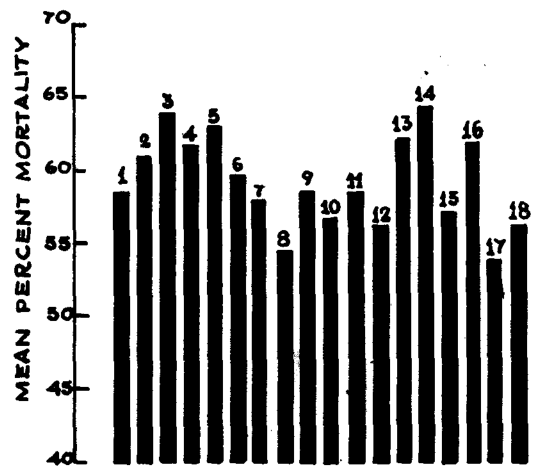


Fig: 22

Table 13 Mean number of eggs of <u>C.medinalis</u> on different rice varieties at different stages of the crop

Rice varieties	Mean number of eggs per plant	
	At one month old stage	At boot leaf stage
IR8	30.66	21.00
Karuna	20.33	16.00
IR20	19.66	15.00
Pankaj	18.33	11.00
H4	19.00	14.00
Rohini	26.66	20.00
Aswathi	20.00	15.00
Triveni	18.66	11.00
Jaya	28.66	18.00
Annapoorna	24.33	21.00
Cavery	19.66	11.00
Mashoori	28.33	21.00
Adt27	16.33	10.00
TKM6	14.66	8.00
Jagannath	23.66	18.00
Ptb9	17.66	10.66
TKM1	15.66	10.00
Kochuvithu	14.33	8.00
C.D. at 5 per cent level	5.877	8.794

<u>Analysis of Variance Table</u>

Source	At one month old stage: Total	Treatment	Error	At boot leaf stage: Total	Treatment	Error
SS	1723.70	1271.00	452.70	2140.80	1126.80	1014.00
DF	53.00	17.00	36.00	53.00	17.00	36.00
MS		74.76	12.58		66.28	28.17
F		5.94			2.35	

oviposition, the mean number of eggs being 20.33, 23.66, 24.33, 26.66, 28.33, 28.66 and 30.66 respectively. At the boot leaf stage also Kochuvithu was least preferred for oviposition and the order of preference for other varieties was also the same as for the plants at one month old stage.

Experiment 10

Effect of varieties of rice on the extent of leaf consumed by caterpillars of *C.medinalis*

Varieties of rice used	:	Same as in Experiment 2
No. of larvae exposed on each replication	:	1
No. of replications for wach variety	:	10
Time allowed for the feeding	:	48 hours
Period of the experiment	:	15-4-73 to 20-4-73
Temperature under which the experiment was carried out	:	29 ± 1°C
Relative humidity under which the experiment was carried out	:	78 ± 4 per cent
Procedure	:	As described under methods (Page 28)

Results:

The data on the leaf area of different rice varieties consumed are presented in Table 14 and Fig. 22. It may be observed from the results (especially with reference to the C.D. values) that the area of leaf surface from which the caterpillar ate the green matter varied significantly in the different varieties. The area of leaf consumed was least in TKM6 (354.5 Sq.mm) and it was closely followed by IR20 (413.8) and H4 (446.5), there being no significant difference among these three varieties. The extent of leaf area eaten in the case of Ptb9, TKM1, Mashoori, Karuna, Rohini, Jagannath and IR8 was considerably high, this being 547.6, 554.2, 578.7, 648.2, 649.4, 685.9 and 748.4 Sq.mm respectively. The varieties Annapoorna, Cavery, Pankaj, Triveni, Adt27, Jaya, Kochuvithu and Aswathi occupied an intermediate position with reference to the leaf area eaten.

Experiment 11

Effect of varieties of rice on the larval plus pupal duration and mortality of *C.medinalis* during development

Varieties of rice used : Same as in Experiment 2

Table 14 Mean area of the boot leaf of different rice varieties eaten by C.medinalis caterpillars in 48 hours

Rice varieties	Mean area of leaf eaten (in Sq.mm)
IR8	748.4
Karuna	648.2
IR20	413.8
Pankaj	457.8
H4	446.5
Rohini	649.4
Aswathi	540.8
Triveni	462.0
Jaya	487.0
Annapoorna	449.6
Cavery	452.7
Mashoori	578.7
Adt27	473.2
TKM6	354.5
Jagannath	685.9
Ptb9	547.6
TKM1	554.2
Kochuvithu	491.1
C.D. at 5 per cent level	90.9

Analysis of Variance Table

Source	SS	DF	MS	F
Total	3575282.5	179		
Treatment	1832009.4	17	107765.26	10.01
Error	1743273.1	162	10760.95	

No. of first instar larvae used in each replication	:	10
No. of replications for each variety (treatments)	:	10
Period of experiment	:	25-4-1973 to 25-6-1973
Temperature under which the experiment was carried out	:	29 ± 2°C
Relative humidity under which the experiment was carried out	:	78 ± per cent
Procedure	:	As described under methods (Page 29)

Results:

Results are presented in Table 15 and in Figs. 21 and 22. The duration of development from hatching to moth emergence varied significantly when the insect was reared on different rice varieties. The duration on TKM6 (30.78) was significantly higher than on all other varieties under test. The duration on H4, ADT27, IR20, Jaya, Pankaj, Cavery, Jagannath, Aswathi, Annapoorna, Kochuvithu and TKM1 ranged from 28.89 to 27.59 days, the difference among themselves not being statistically significant. The duration was least in Mashoori (26.16 days)

Table 15 Duration of larval plus pupal development and per cent mortality of *C.medinalis* reared on different rice varieties

Rice varieties	Larval and pupal duration (in days)	Per cent mortality
IR8	27.45	55.7
Karuna	27.50	60.8
IR20	28.53	63.7
Pankaj	28.41	61.6
H4	28.89	63.2
Rohini	27.07	59.6
Aswathi	28.00	58.1
Triveni	27.27	54.4
Jaya	28.47	58.8
Annapoorna	27.83	56.9
Cavery	28.39	58.8
Mashoori	26.16	56.3
Adt27	28.64	63.3
TKM6	30.78	64.4
Jagannath	28.12	56.9
Ptb9	27.18	62.1
TKM1	27.59	52.7
Kochuvithu	27.78	56.3
C.D. at 5 per cent level	1.39	4.2

Analysis of Variance Table

	Source	SS	DF	MS	F
Larval and pupal duration	Total	2451.8	495		
	Treatment	250.7	17	14.75	3.21
	Error	2201.1	478	4.60	
Per cent mortality during development	Total	71026.7	179		
	Treatment	67512.4	17	3971.32	180.5
	Error	3564.3	162	22.00	

and the remaining varieties based on the length of development duration were in the following descending order: Rohini, Ptb9, Triveni, IR8, Karuna the duration being 26.16, 27.07, 27.18, 27.27, 27.45 and 27.50 days respectively. The difference among these was not statistically significant.

Data on the mortality of immature stages during the larval plus pupal period of *C.medinalis* showed that in general there was high mortality under laboratory conditions. There was also in evidence considerable variations in the percentage mortality of *C.medinalis* when reared on different varieties of rice. The mortality was highest in TKM6 (64.4 per cent). In IR20 and H4 the mortality was 63.7 and 63.1 respectively. The per cent mortality in these three varieties differed significantly from those of the remaining ones while the differences among themselves were not statistically significant. The other varieties were ranked in the following descending order based on the per cent mortality of the larvae Adt27 (63.3), Ptb9 (62.1), Pankaj (61.6), Karuna (60.8), Rohini (59.6), Cavery (58.8) = Jaya (58.8), Aswathi (58.1), Jagannath (56.9) = Annapoorna (56.9), Kochuvithu (56.3) = Mashoori (56.3), IR8 (55.7), Triveni (54.4), TKM1 (52.7).

Experiment 12

Effect of different varieties of rice on the sex ratio and size of moths of C.medinalis reared on them

Varieties of rice used	:	Same as in Experiment 2
No. of moths from each variety used for the determination of sex ratio and size	:	60
Period of experiment	:	30-5-1973 to 15-7-1973
Temperature under which the insect was reared out	:	30 ± 1°C
Relative humidity under which the insects were reared out	:	78 ± 4 per cent
Procedure	:	As described under methods (Page 29)

Results:

Results are presented in Table 16 and Figs. 23 and 24. The size of the moths varied to some extent depending on the variety of rice on which they were reared. The differences were, however, not very remarkable and moths reared on a few varieties alone showed significant difference in size to others under study. The moths reared on Adt27 were the smallest. The other

Fig. 23. Sex ratio of the moths of *C.medinalis* reared out on different rice varieties

Fig. 24. Size of moths of *C.medinalis* reared out on different rice varieties

Fig. 25. Mean longevity of the moths of *C.medinalis* reared out on different rice varieties

1. IR8
2. Karuna
3. IR20
4. Pankaj
5. H4
6. Rohini
7. Aswathi
8. Triveni
9. Jaya
10. Annapoorna
11. Cavery
12. Mashoori
13. Adt27
14. TKM6
15. Jagannath
16. Ptb9
17. TKM1
18. Kochuvithu

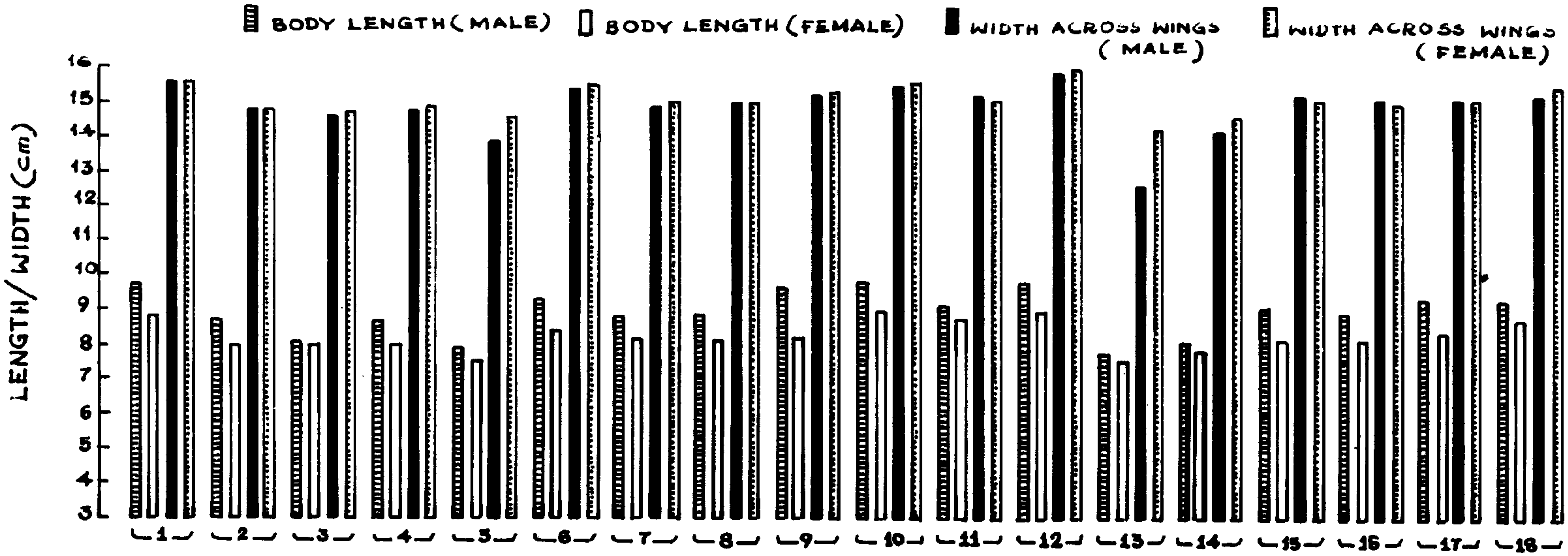


FIG: 24

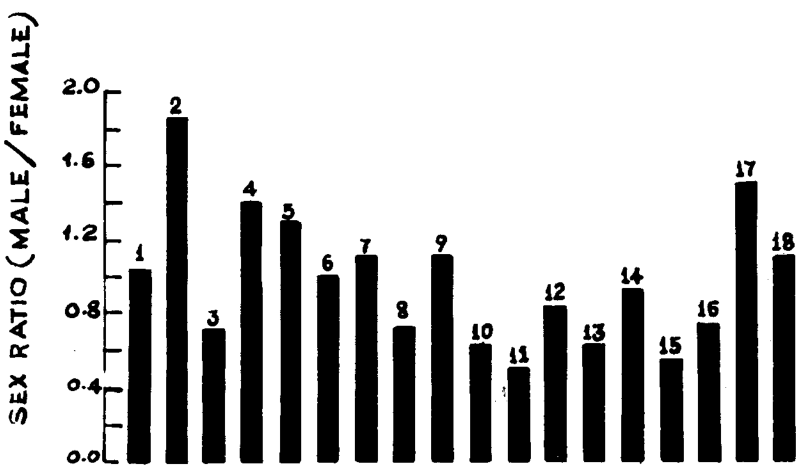


FIG: 23

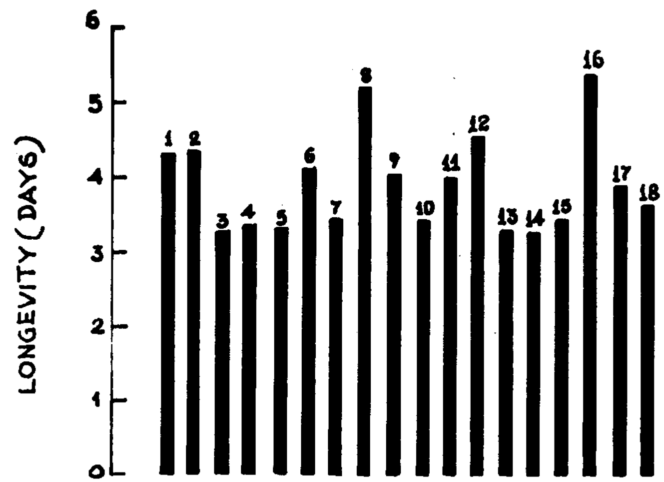


FIG: 25

Table 16 The size and sex ratiom of moths of C.medinalis reared out on different rice varieties

Rice varieties	Body length		Wing expanse		No. of		Sex ratio
	Male	Female	Male	Female	Male	Female	
IR8	9.75	8.82	15.55	15.56	32	28	1.14
Karuna	8.71	8.00	14.79	14.80	39	21	1.86
IR20	8.05	7.93	14.54	14.62	25	35	0.71
Pankaj	8.69	7.97	14.75	14.92	35	25	1.40
H4	7.93	7.51	13.89	14.54	34	26	1.31
Rohini	9.32	8.40	15.40	15.49	30	30	1.00
Aswathi	8.78	8.08	14.81	14.94	32	28	1.14
Triveni	8.80	8.09	14.96	14.94	25	35	0.71
Jaya	9.63	8.15	15.19	15.23	32	28	1.14
Annapoorna	9.73	8.89	15.43	15.52	23	37	0.62
Cavery	9.08	8.71	15.16	15.00	20	40	0.50
Mashoori	9.78	8.86	15.80	15.86	27	33	0.82
Adt27	7.69	7.50	12.57	14.29	23	37	0.62
TKM6	8.03	7.84	14.22	14.57	29	31	0.93
Jagannath	9.00	8.12	15.14	15.00	21	39	0.54
Ptb9	8.88	8.11	15.09	15.00	26	34	0.77
TKM1	9.25	8.31	15.25	15.25	36	24	1.50
Kochuvithu	9.36	8.71	15.41	15.50	32	28	1.14
CD	1.85	0.55	0.63	0.61			

Analysis of Variance Table

	Source	SS	DF	MS	F
Body length of male	Total	610.00	515		
	Treatment	182.90	17	10.759	12.54
	Error	427.10	498	0.858	
Body length of female	Total	552.03	558		
	Treatment	72.60	17	4.270	4.80
	Error	479.43	541	0.890	
Maximum width of male	Total	761.19	519		
	Treatment	229.24	17	13.480	12.74
	Error	531.95	502	1.060	
Maximum width of female	Total	678.17	558		
	Treatment	91.17	17	5.360	4.92
	Error	587.00	541	1.090	

	Source	x^2	DF	
x^2 test for sex ratio	Total	35.27	18	Significant
	Combined data	0.73	1	Not significant
	Heterogenity	34.54	17	Significant

varieties can be ranked in the following ascending order based on the size of moths reared out on them. H4, TKM6, IR20, Pankaj, Karuna, Aswathi, Triveni, Ptb9, Jagannath, Cavery, Jaya, TKM1, Rohini, Kochuvithu, Annapoorna, IR8, Mashoori.

Male: female ratio of the moths of C.medinalis reared on different rice varieties varied significantly male being preponderant over females in Karuna and females proponderant over males in Cavery and Jagannath. Male to female ratio of moths reared from these varieties were 1.86. 0.50 and 0.54 respectively. Based on the male: female ratio the other varieties may be ranked in the following descending order: TKM1 (1.50), Pankaj (1.40), H4 (1.31), IR8 (1.14) = Jaya (1.14) = Kochuvithu (1.14) = Aswathi (1.14), Rohini (1.00), TKM6 (0.93), Mashoori (0.82), Ptb9 (0.77), IR20 (0.71) = Triveni (0.71), Adt27 (0.62) = Annapoorna (0.62). The differences among these varieties were, however, not statistically significant.

Experiment 13

The longevity of moths of C.medinalis reared on different rice varieties, their fecundity and hatching percentage of the eggs laid by them

Varieties of rice used	:	Same as in Experiment 2
No. of moths used for egg laying in each replication	:	20
No. of replications for each rice variety	:	3
Period of experiment	:	15-7-73 to 31-8-73
Temperature under which the experiment was carried out	:	29 $\pm$ 2°C
Relative humidity under which the experiment was carried out	:	78 $\pm$ 4 per cent
Procedure	:	As described under methods (Page 30)

Results:

The results are presented in Table 17 and Figs. 25 to 27. There was considerable difference in the mean number of eggs laid by moths reared out on different rice varieties; these ranged from 35.3 to 144.0 eggs per female. Moths reared out from Adt27 laid the minimum number of eggs and those from Ptb9 laid the maximum. Moths reared out on H4 and IR20 also had low fecundity the mean number of eggs being 37 and 39 respectively. The mean number of eggs laid by moths reared out on TKM6, Aswathi, Pankaj,

Fig. 26. Mean number of eggs laid by *C.medinalis* moths reared out on different rice varieties.

Fig. 27. Mean hatching percentage of eggs laid by *C.medinalis* moths reared out on different rice varieties.

Fig. 28. Mean indices of the leaf damage caused by *C.medinalis* caterpillars on different varieties of rice grown in field.

1.	IR8	10.	Annapoorna
2.	Karuna	11.	Cavery
3.	IR20	12.	Masheeri
4.	Pankaj	13.	Adt27
5.	H4	14.	TKM6
6.	Rohini	15.	Jagannath
7.	Aswathi	16.	Ptb9
8.	Triveni	17.	TKM1
9.	Jaya	18.	Kochuvithu

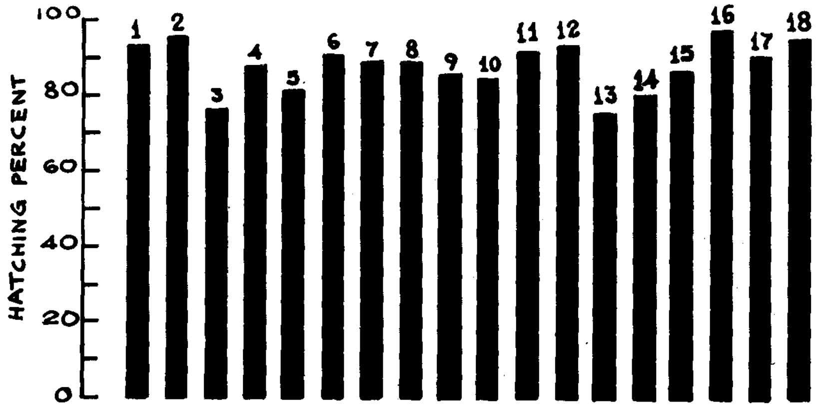


FIG: 27

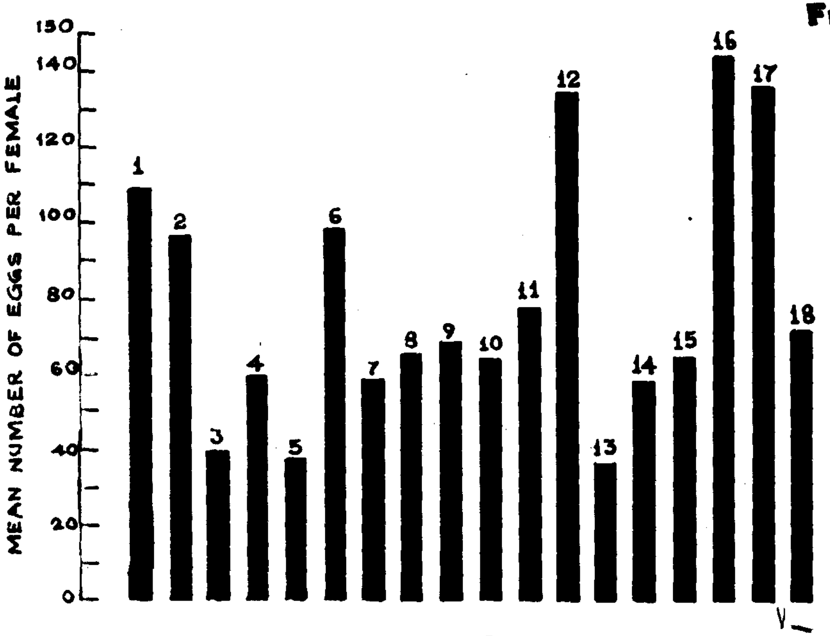


FIG: 26

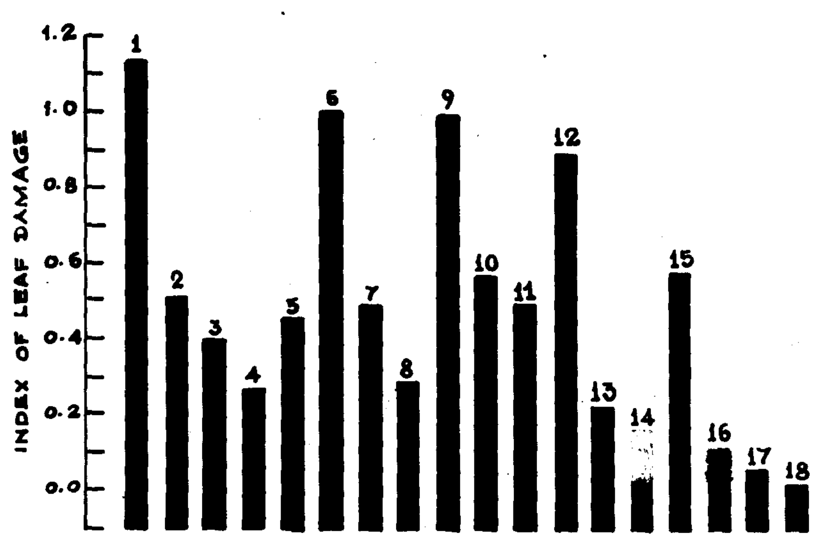


FIG: 28

Table 17 Longevity and fecundity of C.medinalis moths reared out on different rice varieties and the hatching percentage of eggs laid by them .

Rice varieties	Longevity (Days)	Mean No. of eggs per female	Per cent of eggs hatched
IR8	4.30	109.0	92.6
Karuna	4.35	96.0	95.0
IR20	3.27	39.0	76.0
Pankaj	3.35	59.0	87.6
H4	3.30	37.0	81.0
Rohini	4.12	98.3	90.3
Aswathi	3.42	58.0	89.3
Triveni	5.20	65.0	89.3
Jaya	4.02	68.0	85.3
Annapoorna	3.43	64.0	84.0
Cavery	4.00	77.3	90.7
Mashoori	4.56	134.3	93.3
Adt27	3.27	35.3	75.3
TKM6	3.25	58.0	80.3
Jagannath	3.45	64.0	87.6
Ptb9	5.37	144.0	98.3
TKM1	3.88	136.0	90.6
Kochuvithu	3.63	72.0	95.6
C.D. at 5 per cent level	0.08	13.87	5.31

Analysis of Variance Table

	Source	SS	DF	MS	F
Longevity of moths	Total	616.5	1079		
	Treatment	566.2	17	33.31	702.7
	Error	50.3	1062	0.05	
Fecundity of moths	Total	75468.0	53		
	Treatment	72944.1	17	4408.48	62.88
	Error	2523.7	36	70.11	
Per cent of eggs hatched	Total	2488.0	53		
	Treatment	2100.0	17	123.53	11.46
	Error	388.0	36	10.78	

Jagannath, Annapoorna, Triveni, Jaya, Kochuvithu and Cavery were 58, 58, 59, 64, 64, 65, 68, 72 and 77.3 respectively. The remaining varieties viz. Karuna, Rohini, IR8, Mashoori and TKM1 yielded moths having high fecundity the mean number of eggs laid by them being 96, 98.3, 109, 134.3 and 136 respectively.

The data also show that the hatching of the eggs laid by moths reared on different varieties of rice ranged from 75.3 to 98.3 per cent the lowest being in Adt27 and highest in Ptb9. The other varieties may be ranked, based on the hatching percentage of the eggs, in the following descending order: IR20 (76), TKM6 (80.3), H4 (81.0), Annapoorna (84), Jaya (85.3), Pankaj (87.6) = Jagannath (87.6), Triveni (89.3) = Aswathi (89.3), Rohini (90.3), TKM1 (90.6), Cavery (90.7), IR8 (92.6), Mashoori (93.3), Karuna (95), Kochuvithu (95.6).

Experiment 14

Damage caused by larvae of *C. medinalis* to different rice varieties under field conditions

Varieties of rice used	:	Same as in Experiment 2
Design of experiment	:	Random Block Design
No. of replications	:	3

Plot size	:	3 x 3 m
Period of experiment	:	29-10-72 to 26-3-1973
Temperature during the period	:	maximum 28.9 to 32.8°C Av.29.6°C minimum 21.8 to 24.4°C Av.22.8°C
Relative humidity during the period	:	maximum 81.4 to 96.7 per cent Av.91.4 per cent minimum 52.1 to 76.4 per cent Av.65.5 per cent
Total rainfall during the period	:	205.3 mm
Procedure	:	As described under methods (Page 31)

<u>Results:</u>

The data are presented in Table 18 and Fig. 28. In field the least leaf damage was noted in Kochuvithu the index of damage being 0.0127. The extent of damage in TKM6, TKM1, Ptb9, Adt27, Pankaj, Triveni, IR20, H4, Cavery, Karuna, Annapoorna and Jagannath showing the indices of 0.0156, 0.0552, 0.1118, 0.2203, 0.2649, 0.2772, 0.3996, 0.4535, 0.4883, 0.4885 0.5717 and

Table 18 Mean indices of leaf damage caused by <u>C.medinalis</u> larvae to different rice varieties in field

Rice varieties	Indices of damage
IR8	1.1363
Karuna	0.5038
IR20	0.3996
Pankaj	0.2649
H4	0.4535
Rohini	0.9977
Aswathi	0.4885
Triveni	0.2772
Jaya	0.9955
Annapoorna	0.5717
Cavery	0.4883
Mashoori	0.8910
Adt27	0.2203
TKM6	0.0156
Jagannath	0.5760
Ptb9	0.1118
TKM1	0.0552
Kochuvithu	0.0127
C.D.	0.78

Analysis of Variance Table

Source	SS	DF	MS	F
Total	12.6323	53		
Treatment	6.1685	17	0.3629	
Block	1.3544	2	0.6772	2.41
Error	5.1094	34	0.1503	

0.5760 respectively did not differ significantly among themselves or from Kochuvithu. IR8 suffered maximum damage and it was closely followed by Jaya, Rohini and Mashoori. The indices of leaf damage in these varieties did not differ significantly among themselves.

DISCUSSION

DISCUSSION

Results of experiments so far reported on the relative efficacy of various insecticides in controlling rice leaf roller *C.medinalis* are summarised in Table 19. Most of these experiments were aimed at evaluating the efficacy of the insecticides against *C.medinalis* when applied in field in regular schedules. Though a wide range of insecticides have been used in different parts of India, the results obtained are highly variable and inconclusive. It appears that a prophylactic schedule of insecticide treatments will not ensure positive results against *C.medinalis*. This may be due to the characteristic distribution of the pest in patches in the field due to the larval habit of remaining protected in leaf folds and also due to the destruction of the natural enemies by repeated insecticidal application. A need-based and rational use of insecticides which will cause minimum disturbance to the ecosystem is likely to be more advantageous for the long term control of *C.medinalis*. Hence detailed studies on some aspects of the control of this pest were undertaken.

Table 19 Comparative efficacy of various insecticides against C.medinalis as reported from various studies

Sl. No.	Location	Insecticides tried	Effective Insecticides	Reference
1.	Philippines	TEPP, toxaphane and parathion	TEPP, toxaphane and parathion	Calora, 1956 Rivera, 1956
2.	Thaiwan	BHC	BHC	Qu, 1957
3.	Madras	Parathion, endrin followed by BHC	Parathion, endrin, followed by BHC	Abraham, 1958
4.	Kerala	E.parathion, DDT, endrin, sevin dichlorvos, phosphamidon, dimethoate, endosulfan, BHC	Sevin, parathion, DDT	Rajamma & Das, 1969
5.	Rajendra Nagar, Tenali and Aduthurai	Birlane G&EC, Azodrin G&EC, SD 6626G, disulphotonG, endosulfanG, diazinonG, dipterexG, Fenthion G&EC, BHCG, sevidolG, dursbanG&EC, cytrolaneG, phorate+BHC, fenitrothion+malathionEC, phosphamidonEC, DDVPEC, nuvacronEC, fenitrothionEC, SD 6538EC, phosvelEC	MonocrotophosG&EC, SD 6626G, diazinonG, cytrolaneG, dursbanG&EC, phosphamidonEC, fenitrothionEC and phosvel EC gave some control. But data were not conclusive	Anon., 1970a
6.	Punjab	Endrin, malathion, dimethoate, phosphamidon, BHC, DDT and carbaryl - all as sprays. Malathion, carbaryl and BHC - as dusts	All treatments except DDT spray gave very high reductions in pest population	Chaudhary and Bindra, 1970

G.=Granule EC = Emulsifiable concentrate

Sl. No.	Location	Insecticides tried	Effective Insecticides	Reference
7.	Aduthurai, Cuttack, Mandya, Maruteru, Pattambi, Tenali	Parathion, carbaryl, endrin, cytrolane, carbofuran, diazinon	Parathion at Pattambi and Aduthurai. Carbofuran better than cytrolane at some centres. Reverse at other places	Anon.,1971
8.	Pattambi	DusrsbanG, ekaluxG, parathion and carbaryl alternately	Dursban & ekalux parathion and carbaryl alternately	Anon.,1971
9.	Tenali	Phosvel, chlorofevinphos, diacrotophos, phosalone, formothion, quinalphos, methomyl, fenitrothion, malathion, dursban, fenthion, phosphamidon, propoxur, carbaryl, BHC, diazinon, ethyl parathion, endrin	Phosvel, chlorofevinphos, methomyl, dursban & ethyl parathion, Dicrotophos, phosalone, quinalphos, dursban, ambithion and fenthion also gave good control	Anon.,1971
10.	Aduthurai	Cytrolane, carbofuran, lindane, malathion, fenitrothion, diazinon, ethyl parathion, phosphamidon, dichrotophos, formothion, quinalphos, endrin.	Parathion alone was effective	Anon.,1971
11.	Coimbatore	do.	All treatments except dicrotophos, formothion and endrin	do.

Sl. No.	Location	Insecticides tried	Effective Insecticides	Reference
12.	Mandya	Cytrolane, carbofuran, lindane, malathion, fenitrothion, diazinon, e. parathion, phosphamidon, dicrotophos, formothion, quinalphos, endrin	Lindane, phosphamidon, dicrotophos followed by fenitrothion, diazinon and quinalphos	Anon.,1971
13.	Pattambi	do.	Parathion, fenitrothion, dicrotophos and quinalphos	do.
14.	Rajendra Nagar	do.	All treatments - fenitrothion and phosphamidon were slightly better than others	do.
15.	Maharashtra	Endrin and carbaryl	Endrin and carbaryl	Dorge et al., 1971
16.	Aduthurai, Faizabad, Ludhiana	Fenitrothion+malathion, formothion, BHC, dicrotophos, birlane, cytrolane, diazinon, trichlorfon, phosphamidon, dursban, quinalphos, endrin, ethyl parathion, fenitrothion, fenthion, monocrotophos, dichlorvos, carbaryl+BHC, carbaryl, phorate, endosulfan, phosvel.	Phosphamidon, dursban, e. parathion and ekulux were were effective at all centres. Since data were reported differently no further comparison was feasible	Anon., 1972

Sl. No.	Location	Insecticides tried	Effective Insecticides	Reference
17.	Marutheru	Chloropyriphos, fenitrothion, fenthion, MIPC, phorate + BHC, tameron, galecron, vamidothion, chlorofevinphos, carbofuran, acephate, dimethoate, parathion, Fensulfathion, chloropyriphos and leptophos	Galecron, tameron, carbofuran, chlorofevinphos and leptophos were remarkably effective	Anon., 1972
18.	Coimbatore	Diazinon, parathion, endrin, phosphamidon, carbaryl, endosulfan, Dichlorvos, fenthion, fenitrothion, methylparathion+DDT, toxaphane+DDT	Parathion, toxaphane + DDT, methylparathion+DDT	Balasubramoniam *et al.*, 1973
19.	Coimbatore	Diazinon and Sevidol granules, parathion spray	Diazinon and Sevidol granules, parathion spray	Venkitaraman *et al.*, 1973

To accomplish effective control of a pest using insecticides the life stages of the pest prevalent in the field have to be taken into consideration since the relative susceptibility of different stages of an insect to insecticides will vary. The larvae and moths are the two stages of C.medinalis vulnerable to insecticidal pressure in the field. Hence an evaluation of the available insecticides against these two stages has been made.

Relative toxicity of the insecticides to the moths based on LC_{50} values has been studied for the first time. The moths have the habit of remaining on the foliage of rice crop throughout their existence. This habit makes the moths vulnerable to control by the contact action of the insecticides applied. The relative toxicity of insecticides based on LC_{50} values determined by laboratory evaluations will give a picture of the toxicants' effect on the moths under field conditions too.

The results presented show that the insecticides vary considerably in their toxicity to the moths. Ethyl parathion is highly toxic, being 1296.8 times more toxic than BHC (which is taken as standard) while methyl parathion, the next best insecticide is 369.77 times more toxic. Other insecticides having good contact toxicity to the moths are diazinon, elsan, fenitrothion, carbaryl and acephate. The chlorinated compounds, BHC, endrin and endosulfan have very poor toxicity to the moths. The systemics also are not effective.

Studies on dosage-mortality relations between the different insecticides and fourth instar larvae of C.medinalis have also been done for the first time. Results of these studies show a much different picture from what is manifested in the case of moths. Among the 24 insecticides tested, a dozen are highly toxic to the larvae. As in the case of moths, ethyl parathion is the most toxic one. It is closely followed by methyl parathion, elsan and endosulfan in toxicity. Other insecticides which showed significant toxicity to the larvae are acephate, phosphamidon, monocrotophos, dimethoate, diazinon, carbophenothion, quinalphos, fenitrothion and formothion. Though systemic poisons were ineffective against moths, phosphamidon, monocrotophos, dimethoate and formothion manifested good contact toxicity to the larvae. They were more toxic than even the well known contact poisons like BHC, carbaryl, endrin and malathion. But the systemic insecticides, phorate and thiometon did not have any significant contact action. BHC was the least toxic among the insecticides tried. Though endosulfan is 20.47 times as toxic as BHC, endrin which is structurally related to endosulfan is only 7.55 times toxic. In general the effective insecticides were in the organophosphate group.

Since the larvae remain within leaf folds they may not receive the insecticides directly on their body when sprayed in the field. The insecticide deposits and residues on the plants may kill the larvae by contact, when they come out of the folds and try to establish on new leaves. The mortality may also be caused as a result of stomach toxicity. Hence the relative toxicity of the insecticides to the larvae shown in bioassay studies may not correspond to their relative efficacy in field application. This has been revealed in the laboratory studies in which caterpillars of C.medinalis established in leaf folds were sprayed under a precision sprayer (Potter's tower). Each insecticide was evaluated at three graded concentrations. The relative ranks of the insecticides based on the mortality caused by them at the three different concentrations and those based on mean mortality (calculated) are presented in Table 20. There is a general correspondence among the relative ranks of the three concentrations of the different toxicants. But the lowest doses of leptophos, quinalphos and phosphamidon are in 6th, 8th and 5th positions respectively while in the middle doses their positions are 13th, 15th and 12th and in the highest doses they are in 10th, 15th and 11th positions respectively. Dimethoate and formothion have 13th and 16th rank respectively at lower doses, 2nd and 6th positions in the middle doses and 5th and 9th positions respectively at the highest doses. The mean mortality values at the graded doses of each insecticide presented give an overall picture of the relative toxicity of the various insecticides. Ethyl parathion, carbaryl, carbophenothion and methyl parathion were found to be superior to the other insecticides under test in controlling <u>C.medinalis</u> larvae in leaf folds. Endosulfan, malathion, diazinon, trichlorfon, endrin, elsan, BHC and dichlorvos gave very low mortalities. Other treatments were of intermediate toxicity. Among them dimethoate, fenitrothion, fenthion, thiometon, phosphamidon, leptophos, phorate, formothion and quinalphos also may be classed as moderately effective in controlling <u>C.medinalis</u> caterpillars

Table 20 Relative efficacy of various insecticides, at different levels, to larvae of *C.medinalis* established in leaf folds

	INSECTICIDES																							
Rank based on mortality when	BHC	Endrin	Endosulfan	E. parathion	M. parathion	Dichlorvos	Carbophenothion	Diazinon	Elsan	Fenthion	Malathion	Leptophos	Acephate	Quinalphos	Carbaryl	Fenitrothion	Trichlorfon	Thiometon	Phosphamidon	Dimethoate	Monocrotophos	Formothion	Phorate	M. demeton
Applied at lower levels	18	20	23	1	4	19	3	21	17	11	24	6	14	8	2	9	22	10	5	13	12	16	7	15
Applied at middle levels	19	22	24	4	3	17	5	23	18	9	20	13	16	15	1	8	21	7	12	2	14	6	11	10
Applied at higher levels	16	19	24	1	4	18	3	22	21	6	23	10	17	15	2	7	20	8	11	5	13	9	12	14
Mean	18	20	24	1	4	17	3	22	19	7	23	10	16	13	2	6	21	8	9	5	14	12	11	15

in leaf folds.

A comparison of the contact toxicity of the different insecticides to the larvae of <u>C.medinalis</u> and the mortality caused by the same insecticides to the larvae in leaf folds reveals the following (See Fig. 29). Ethyl and methyl parathion which have good contact toxicity are highly effective in killing the larvae in the leaf folds too. On the other hand endosulfan, diazinon and elsan possessing high contact toxicity to the larvae when directly applied were ineffective in killing them within leaf folds. Similarly some insecticides manifesting relatively low contact action cause higher mortality of larvae in leaf folds. Examples are carbophenothion, fenthion, leptaphos, carbaryl, fenitrothion, thiometon, phosphamidon, phorate and methyl demeton. But monocrotophos which is known as a systemic poison maintains a higher rank as a contact poison (7) than as a toxicant killing larvae in leaf folds (14).

Good contact poisons may thus prove ineffective in the field evidently because the larvae remaining in leaf folds do not receive sufficient quantity of the toxicants directly on their body. The insecticides ranking low as contact poisons manifest higher toxicity to the larvae in folds probably through

Fig. 29. Comparison of LC_{50} values of various insecticides to the moths of C.medinalis and per cent mortality of 4th instar caterpillars in leaf folds sprayed with various insecticides.

Fig. 30. Comparison of the mean per cent mortality of C.medinalis caterpillars when sprayed in leaf folds in the laboratory and the reduction of population of the same when sprayed in an infested field.

1.	BHC	13.	Acephate
2.	Endrin	14.	Quinalphos
3.	Endosulfan	15.	Carbaryl
4.	E.parathion	16.	Fenitrothion
5.	M.parathion	17.	Trichlorfon
6.	Dichlorvos	18.	Thiometon
7.	Carbophenothion	19.	Phosphamidon
8.	Diazinon	20.	Dimethoate
9.	Elsan	21.	Monocrotophos
10.	Fenthion	22.	Formothion
11.	Malathion	23.	Phorate
12.	Leptophos	24.	Methyl demeton

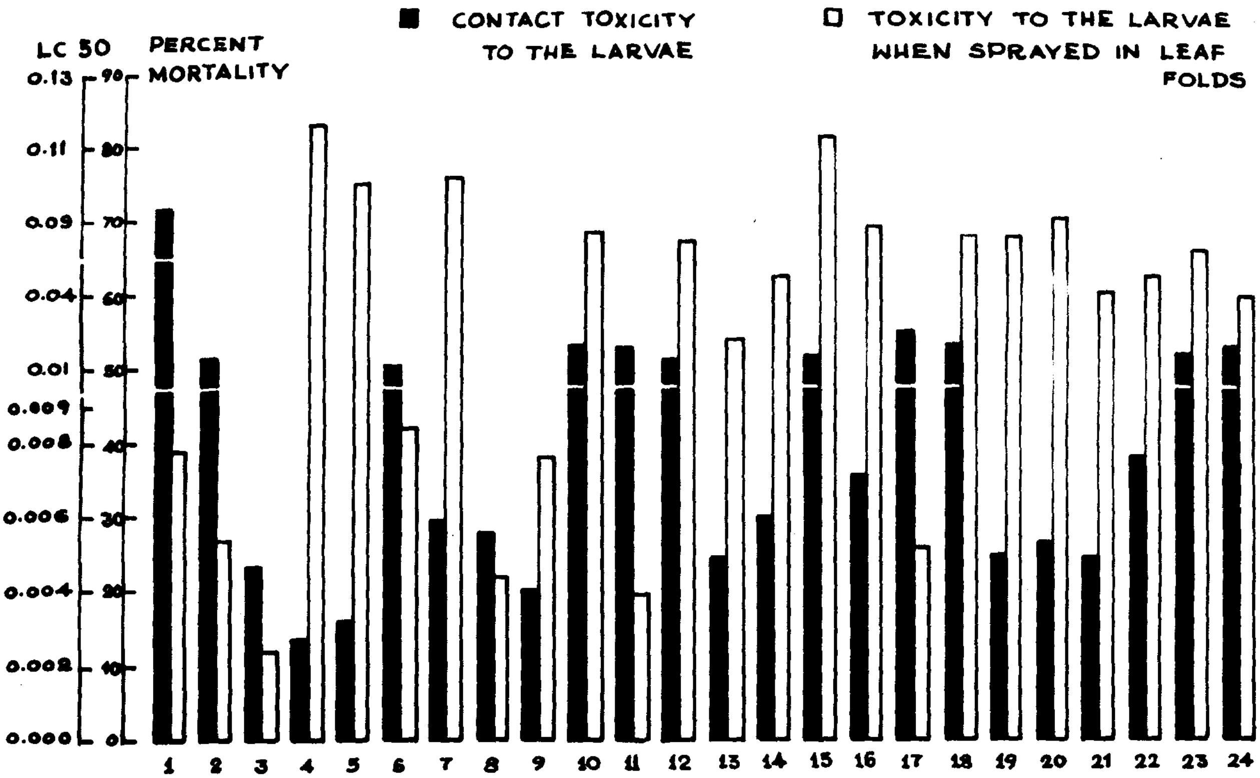

CONTACT TOXICITY TO THE LARVAE
TOXICITY TO THE LARVAE WHEN SPRAYED IN LEAF FOLDS
LC 50
PERCENT MORTALITY
0.13
0.11
0.09
0.04
0.01
0.009
0.008
0.006
0.004
0.002
0.000
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

FIG: 29

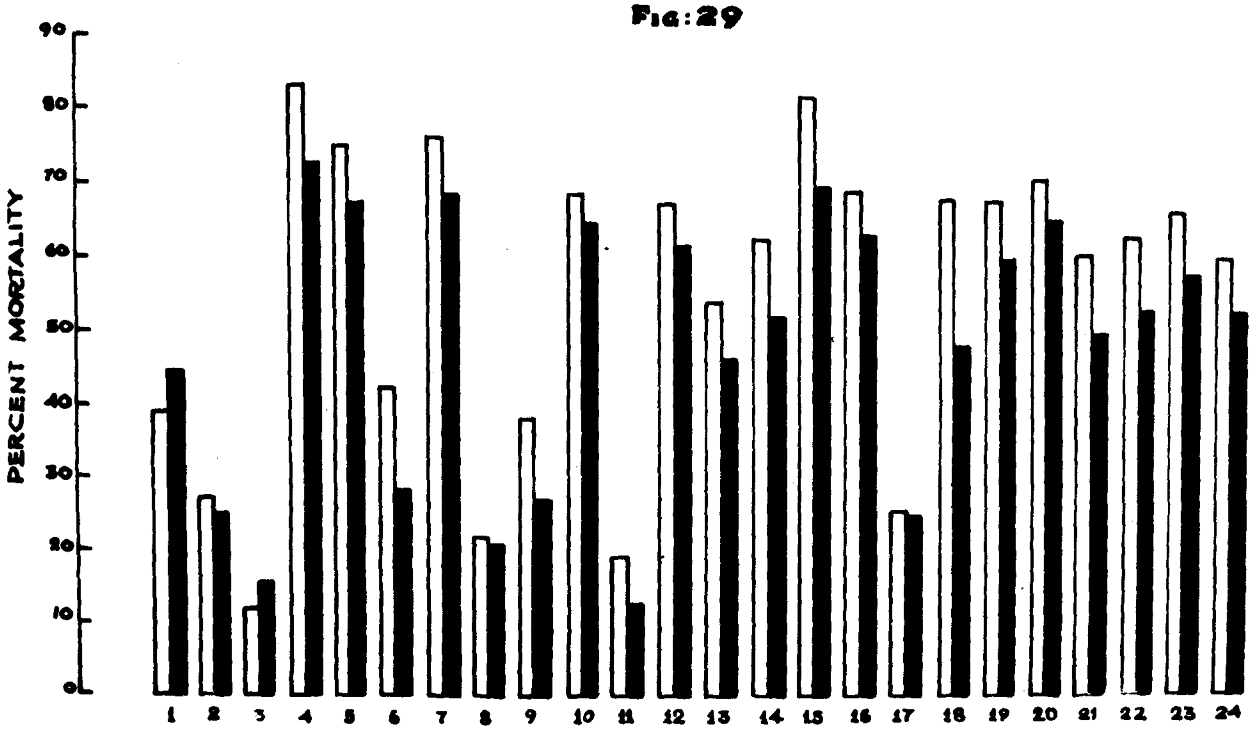

PERCENT MORTALITY
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

FIG: 30

TOXICITY TO THE LARVAE WHEN SPRAYED IN LEAF FOLDS
REDUCTION OF POPULATION WHEN SPRAYED IN FIELD

the stomach and fumigant action of the toxicants which are not manifested in the bioassay of contact toxicity. The penetration of some insecticides into the tissues lying immediately beneath the applied surface also might contribute towards this shift in the relative toxicity of insecticides when applied on the leaf folds harbouring the larvae.

A comparison between the toxicity of the different insecticides to the larvae of C.medinalis in the leaf folds as evaluated in the laboratory and toxicity of insecticides to the larvae on plants in an infested field are presented in Fig. 30. It may be observed that there exists a more or less strict correspondence between the mortality of larvae in leaf folds and the reduction of larval population in the field caused by the different insecticides. This is as expected. Obviously the choice of insecticides for field control of this pest cannot be based on their relative contact toxicity.

Based on the results of the experiments on the toxicity of different insecticides to the larvae of C.medinalis under laboratory and field conditions the insecticides under test can be ranked as follows: ethyl parathion, carbaryl, carbophenothion, methyl parathion, dimethoate, fenthion, leptophos, phosphamidon, phorate, formothion, methyl dimeton, quinalphos. Even the maximum reduction in field population (in plots treated with parathion) was 72.53 per cent only. The earliest report of the relative ranking of insecticides based on pre and post treatment counts of the larvae in field was from Punjab. Choudhary and Bindra (1970) found that malathion, endrin, dimethoate, phosphamidon, BHC and carbaryl as sprays and carbaryl, malathion and BHC as dusts caused significant reduction in the larval population of *C.medinalis* in field, seven days after spraying. All treatments except malathion and DDT sprays gave more than 90% reduction in population. In another report from Punjab (Anon. 1971) the ~~first~~ relative efficacy of the insecticides tested (those insecticides which are not included in the present investigations are omitted) was in the following descending order: phosphamidon, fenitrothion, ethyl parathion, formothion, malathion, endrin. But in the present investigations malathion and endrin are notat all effective against *C.medinalis* caterpillars. The percentage reduction in larval population due to insecticidal treatments have also been reported from some centres of All India Co-ordinated Rice Improvement Project (Anon., 1972).

But these results from different centres could not be compared among themselves since the methods adopted for the evaluation of the efficacy of insecticides were different at the various centres.

As mentioned earlier the results of the prophylactic schedule of treatments of insecticides against C.medinalis are highly variable. These variations may partly be attributed to the inherent defects in the methods adopted for the evaluation of the effect of the insecticidal treatments. The usual method of counting the attacked leaves on randomly selected plants under the treatments does not appear to be reliable as the incidence of this pest often occurs in the field in isolated patches. Further, the mere number of attacked leaves will not reveal the extent of damage since the attack ranges from just a nibbling of the chlorophyll from the leaf surface to the extensive removal of green matter from whole leaf area. The field evaluation of insecticides was hence done eliminating these possible errors. The extent of damage was assessed by counting the total leaves in the treated plots and by rating them on the basis of the extent of chlorophyll eaten by the larvae.

During the first season of this experiment the insecticide treatments did not show any significant effect in controlling the larvae. The leaf damage in all the plots including control was very low. The futility and wastage of insecticidal application in schedule in rainy seasons is thus indicated. In the second and third seasons of the experiment the extent of leaf damage in plots receiving insecticides varied significantly from control. During the second season the damage in plots treated with ethyl parathion, methyl parathion and carbaryl alone was significantly lower than that of control. The other insecticides which reduced the damage to levels lower than in control were quinalphos, leptophos, dimethoate, phorate, methyl demeton, monocrotophos, acephate, phosphamidon, fenitrothion, carbophenothion, malathion and endrin. But there was no significant difference among themselves including control. In the third season the damage in plots treated with acephate, ethyl parathion, dimethoate, quinalphos, leptophos and carbaryl was significantly lower than that in control. The damage in plots treated with fenitrothion, endosulfan, methyl parathion, endrin, elsan, monocrotophos, diazinon and phosphamidon was lower than in control though the difference among themselves including control was not statistically significant. The treatment in which the damage was significantly lower than that of the level of the control in both the seasons were ethyl parathion and carbaryl only. Though methyl parathion was second best during the second season it came to 9th position during the third season. Similarly acephate which was the best during the third season was in the 10th position only during the second season. Dimethoate, quinalphos and leptophos which were in the 3rd, 4th and 5th positions in the third season had fairly high ranks during the second season also, viz. 6th, 4th and 5th respectively. Fenitrothion and monocrotophos which were in the 12th and 9th positions in the second season were maintaining high ranks of 7 and 12 respectively in the third season. The performance of other insecticides varied considerably during the two seasons. Ethyl parathion, carbaryl, methyl parathion, leptophos, acephate, quinalphos and dimethoate sprayed in biweekly schedule may be considered promising in controlling leaf roller, especially with reference to the leaf damage caused by the caterpillars, in the field. Fenitrothion and monocrotophos can be ranked as moderately effective. These insecticides had been reported effective against <u>C.medinalis</u> in some centres of the ACRIP trials also (Table 19). The relative efficacy of the insecticides based on the extent of protection of leaves from damage did not agree with their relative toxicity to the moths and caterpillars. These discrepancies may be attributed to other factors like the persistence of insecticides, impact on natural enemies etc.

Assessment of persistence of insecticides on plants is important for the selection of appropriate insecticides for the control of a pest with minimum disturbance to the agro-eco system. The information on the persistent toxicity of various insecticides to a pest and to its important natural enemies will be of help in formulating an integrated programmes for controlling the insect. Efforts to rear the parasites of C.medinalis in the laboratory were not successful and hence in the present studies persistent toxicity of the insecticides to the larvae of C.medinalis alone could be assessed. A consolidated statement of the PT indices of the different insecticides in the three doses tried and their mean value along with a relative ranking of the toxicants are presented in Table 21. There is a general agreement in the relative ranking of the insecticides based on PT indices in the three different doses. But phosphamidon ranks 10 and 12 at

Table 21 PT indices of various insecticides sprayed at different levels in the field

Treatments	PT indices			Mean
	In lowest doses	In middle doses	In highest doses	
BHC	299.32(23)	345.05(21)	261.03(23)	261.00(23)
Endrin	547.64(17)	458.78(15)	323.35(16)	443.25(17)
Endosulfan	487.55(20)	341.22(22)	293.10(19)	373.96(21)
E.parathion	947.28(5)	993.33(3)	621.00(8)	853.87(5)
M.parathion	604.64(15)	588.08(14)	489.48(11)	560.73(14)
Dichlorvos	273.30(24)	146.00(24)	105.92(24)	175.07(24)
Carbophenothion	869.16(7)	777.92(7)	577.62(9)	741.57(8)
Diazinon	517.02(19)	426.00(16)	258.75(21)	400.59(20)
Elsan	815.54(11)	665.10(9)	355.05(15)	611.90(11)
Fenthion	690.84(13)	385.00(20)	258.32(22)	444.72(16)
Malathion	675.20(14)	605.79(13)	343.92(15)	561.64(13)
Leptophos	1141.76(4)	940.52(5)	706.94(4)	929.74(4)
Acephate	886.08(6)	633.80(10)	385.20(14)	635.03(10)
Quinalphos	1184.82(3)	978.04(4)	760.40(2)	974.42(3)
Carbaryl	1559.80(2)	1477.44(1)	671.04(6)	1236.33(2)
Fenitrothion	690.84(12)	628.50(11)	481.23(12)	600.19(12)
Trichlorfon	521.78(18)	420.00(18)	287.05(20)	409.61(19)
Thiometon	362.25(22)	287.75(23)	321.60(18)	323.87(22)
Phosphamidon	826.76(10)	618.20(12)	709.61(3)	718.19(9)
Dimethoate	440.46(21)	401.70(19)	452.10(13)	431.42(18)
Monocrotophos	1680.00(1)	1408.96(2)	783.09(1)	1290.68(1)
Formothion	857.64(8)	830.17(6)	632.24(7)	773.35(6)
Phorate	575.28(16)	425.20(17)	493.28(10)	497.92(15)
Methyl demeton	836.68(9)	754.05(8)	703.23(5)	754.65(7)

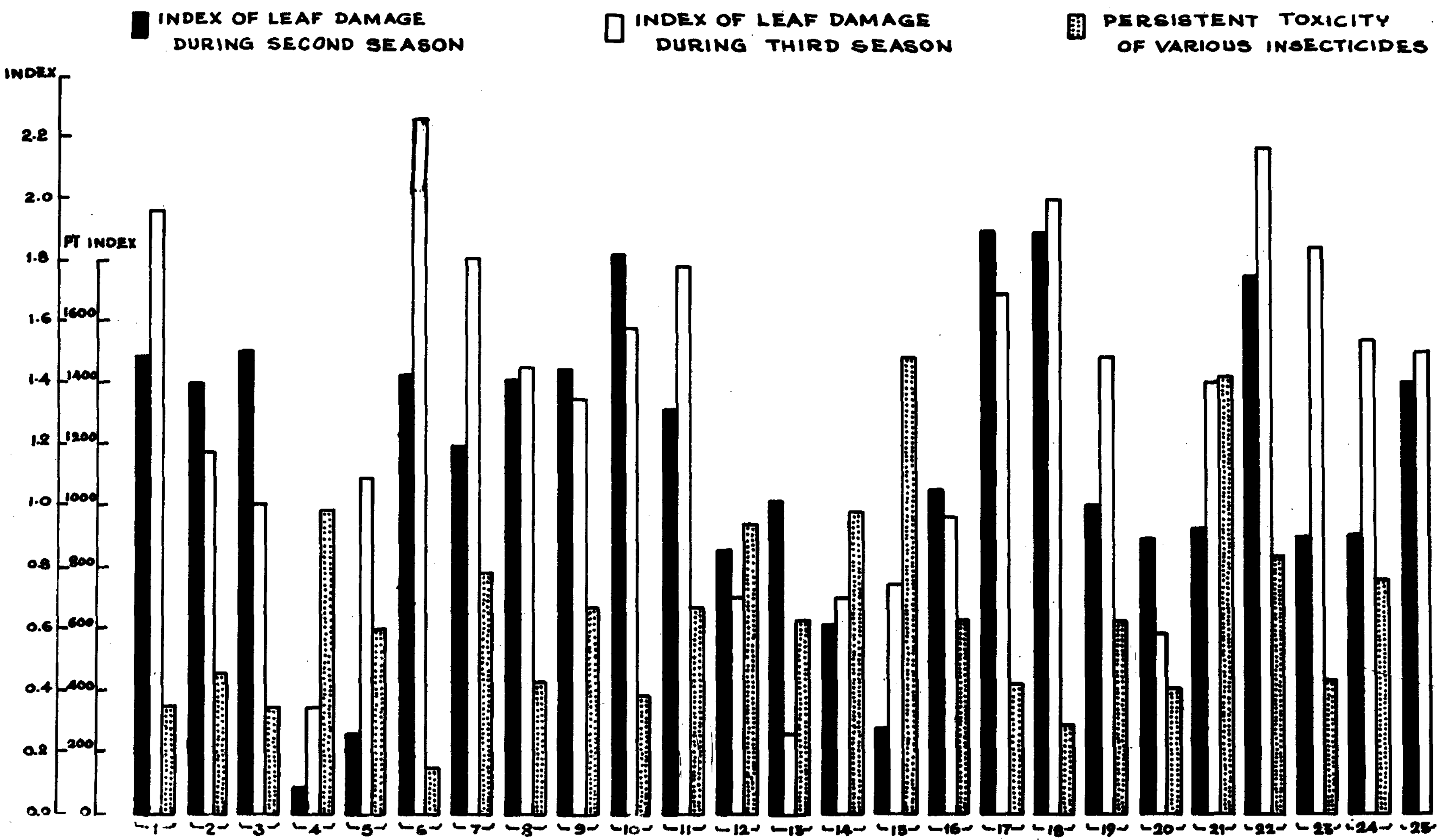
(Relative efficacy is given in parenthesis) middle and lowest doses respectively while in the highest dose it ranks 3. A ranking based on the mean indices can be taken for comparing the persistent toxicity of the various insecticides to C.medinalis.

BHC, endrin and endosulfan which are known as highly persistent insecticides showed very low persistent toxicity to C.medinalis. The persistence of these toxicants is even lower than those of the organophosphates which as a group are considered as nonpersistent insecticides. A rapid deterioration of chlorinated insecticides, even faster than some of the organophosphates, under field conditions in Kerala, have been reported earlier also (Ali et al., 1969; Koshi et al., 1972). Among the 24 insecticides studied monocrotophos had the maximum persistent toxicity to C.medinalis larvae. This was very closely followed by carbaryl, quinalphos, leptophos and ethyl parathion. Those with very low persistence include dichlorvos, BHC, thiometon, endosulfan, diazinon, trichlorfon, and dimethoate. Others showed intermediate degree of persistence.

Fig. 31 reveals a general correlation between the extent of leaf damage as influenced by insecticidal treatments in field in schedule and the persistent toxicity of these insecticides.

Fig. 31. Comparison of the mean indices of leaf damage caused by *C.medinalis* in plots treated with various insecticides at biweekly intervals (two seasons) and the persistent toxicity of various insecticides to 1st instar larvae of *C.medinalis* (in terms of PT indices).

1.	BHC	13.	Acephate
2.	Endrin	14.	Quinalphos
3.	Endosulfan	15.	Carbaryl
4.	E.parathion	16.	Fenitrothion
5.	M.parathion	17.	Trichlorfon
6.	Dichlorvos	18.	Thiometon
7.	Carbophenothion	19.	Phosphamidon
8.	Diazinon	20.	Dimethoate
9.	Elsan	21.	Monocrotophos
10.	Fenthion	22.	Formothion
11.	Malathion	23.	Phorate
12.	Leptophos	24.	Methyl demeton



INDEX OF LEAF DAMAGE DURING SECOND SEASON
INDEX OF LEAF DAMAGE DURING THIRD SEASON
PERSISTENT TOXICITY OF VARIOUS INSECTICIDES
INDEX
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
PT INDEX
1600
1400
1200
1000
800
600
400
200
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

FIG:31

Monocrotophos, carbaryl, quinalphos, leptophos and ethyl parathion which showed high persistent toxicity reduced the leaf damage also significantly. Methyl parathion and fenitrothion which had medium persistence and dimethoate which had little persistence also reduced the leaf damage. These insecticides had high toxicity on leaf roller caterpillars when applied in leaf folds. The higher efficacy of persistent insecticides for schedule application is evidently because the first instar larvae fail to establish due to the residual toxicity of the insecticides. But such insecticides may be harmful in the long run in tracts rich in parasite population.

Table 22 gives the relative efficacy of different insecticides against the leaf roller C.medinalis in relation to the different methods of application. In Table 23 the insecticides found effective against the moths, larvae in leaf folds and field as well as for prophylactic treatment in schedule are grouped as persistent, moderately persistent and non-persistent insecticides. In selecting the best insecticide for the control of C.medinalis, persistent insecticides may be chosen for the tracts where the natural enemies of the pests are scarce and moderately persistent and least persistent insecticides for the

Table 22 Relative efficacy of different insecticides against C.medinalis in relation to different methods of evaluation

Ranks based on	BHC	Endrin	Endosulfan	E.parathion	M.parathion	Dichlorvos	Carbophenothion	Diazinon	Elsan	Fenthion	Malathion	Leptophos	Acephate	Quinalphos	Carbaryl	Fenitrothion	Trichlorfon	Thiometon	Phosphamidon	Dimethoate	Monocrotophos	Formothion	Phorate	M.demeton	Control
LC50 values to the moths	22	23	18	1	2	16	10	3	4	8	12	17	7	9	6	5	24	13	15	19	21	20	14	11	
LC_{50} values to caterpillars	24	17	4	1	2	14	10	9	3	22	19	15	6	11	16	12	23	21	5	8	7	13	18	20	
Mean mortality when sprayed in leaf folds	18	20	24	1	4	17	3	22	19	7	23	10	16	13	2	6	21	8	9	5	14	12	11	15	
Reduction in larval population in field	17	20	24	1	4	18	3	22	19	6	25	8	16	13	2	7	21	15	9	5	14	11	10	12	23
Reduction in leaf damage when applied in schedule (IIseason)	20	15	21	1	2	18	13	17	19	23	14	5	10	4	3	12	24	25	11	6	9	22	7	8	16
Reduction in leaf damage when applied in schedule (IIIseason)	22	10	8	2	9	25	20	13	11	17	19	5	1	4	6	7	18	23	14	3	12	24	21	16	15
Persistent toxicity (Mean of PT indices at 3 doses)	23	17	21	5	13	24	8	20	11	16	14	4	10	3	2	12	19	22	9	18	1	6	15	7	

Table 23 Insecticides found effective against *C.medinalis* in laboratory and field evaluations grouped on the basis of their persistent toxicity

Method of evaluation adopted	Highly persistent	Moderately persistent	Least persistent
LC 50 values against moths	ethyl parathion, carbaryl	methyl parathion, elsan, fenitrothion, acephate	diazinon
Reduction of larval population in field 72 hrs after spraying and the effect of spraying on larvae in leaf folds in the laboratory	ethyl parathion, carbaryl, carbophenothion, leptophos, formothion, methyl demeton, quinalphos	methyl parathion, fenthion, fenitrothion and phosphamidon	dimethoate and phorate
Reduction of leaf damage in field when sprayed in schedule	ethyl parathion, carbaryl, quinalphos, leptophos, monocrotophos	methyl parathion, fenitrothion, acephate	dimethoate

tracts rich in natural enemies and where the artificial colonisation of the parasites will be feasible. The selection of pesticides must also be done with reference to the predominant life stage of the pest in field at the time of insecticidal application.

Studies on the insect-plant relationships between C.medinalis and different rice varieties have yielded very informative results. One of these relates to the effect of the larval infestation on the good grain yield of the plants subjected to the infestation at different growth stages. The infestations applied on plants in these studies were designed to ensure maximum damage to the crop and in effect it resulted in total damage of the leaves at each of the stages of the crop under study. The stages subjected to infestation were spaced at weekly intervals, starting from 50th day after sowing, since natural infestation in field usually occurred in serious proportion only from that stage of the crop.

The results of these studies showed that there was a critical stage at which the infestation by the pest caused the maximum reduction to the grain yield. This critical phase in the case of IR8 was at the 85th day occasion while in the case of Annapoorna and Kochuvithu the critical periods were at 57 days after sowing. IR8 is a medium duration variety (130 days) while the other two are short duration varieties (100 days). It is interesting to note that the critical period in all the varieties corresponded to the booting stage of the crop. The reduction in yield due to the larval infestation progressively declined towards the earlier and later occasions from the booting stage. The complete destruction of leaves at booting stage left the crop without leaves at the heading, flowering, filling and ripening stages. Even then there was considerable filling of grains in all the varieties studied. The constituents utilised for the filling of these grains might have been derived from the materials stored in the culm and sheaths of the plants prior to the destruction of leaves. Earlier studies on physiology of rice plants have indicated such a possibility. In IR8, for instance, it has been reported that starch and dextrin increased in proportions in leaf sheath and culm from 6 to 10 weeks after transplanting with the highest level occurring in the 10th or 11th week. After booting and through flowering and grain development the starch was found depleted presumably getting translocated to the filling grains (Anon., 1970). The larval feeding at the occasions prior to booting appeared to reduce the quantity of ingredients stored in the culm and sheath but these plants were still left with the boot leaf and some top leaves for the rest of their life time. Top leaves of the plants are reported to contribute heavily to the formation of the grains. (Fujiwara and Suzuko, 1957; Mastsushima, 1957). Why the leaf damage occurring prior to booting stage caused lower levels of reduction in yield than leaf damage at booting stage can hence be attributed to this phenomenon.

In general, severe infestation by the larvae as provided in the present studies, brought about highly significant reduction in grain yield from 50th day of sowing onwards. The yield reduction was comparatively low in plants exposed to larval infestation, subsequent to 106th, 85th, and 78th days after sowing in the case of IR8, Annapoorna and Kochuvithu respectively. This may mainly be due to the fact that the filling of grains was completed by that time and subsequent leaf damage did not affect the yield significantly. Further, the damage of the leaves at this stage was not as thorough as in previous occasions since the larvae did not feed as extensively on the older leaves as on younger leaves. It may be presumed that C.medinalis infestation after the filling of grains will not reduce the yield significantly under field conditions too.

Another result which merits mention is the relative magnitude of the loss in yield sustained by the three varieties under test, caused by larval infestation. The variety Kochuvithu suffered the greatest loss in yield due to the pest infestation than the other two varieties. Kochuvithu is a local variety while the others are the improved high yielding strains. The superiority of the high yielders over local strains, in the capacity to compensate the loss due to pest damage, is thus evidenced.

The results on the variations in the production of chaff due to the pest infestation at the different stages show that the pattern of the relationships were similar to those of the good grain but in reverse proportion.

The yield data presented in appendices VII and VIII show an apparent anomaly in that there is a progressive reduction in the mean yield of grains obtained from control plants (uninfested plants) of the various lots corresponding with the advancement of the period of infestation by the larvae. The grain weight fell from 95.6 to 79.8, from 84.5 to 70 and from 62.5 to 51.5

grammes per pot in the case of IR8, Annapoorna and Kochuvithu respectively. This phenomenon appeared to be correlated with the durations for which the plants were kept in the insect proof cage prior to their shifting to the field cages after submission to insect infestations. In the insect proof cages sunlight is shaded to some extent. This adversely affect the plant and the longer is the period spent by the plants within the insect proof cages more will be this adverse effect. Thus the leaf damage caused by the larvae and the shading in the insect proof cages reduce the grain yield. The shade factor was eliminated from this by taking separate controls for each occasion.

The overall observation from the experiment may be summed up as follows:

1. Infestation at the boot leaf stage of the crop causes the maximum reduction in yield.

2. Infestation during the late vegetative phase and in post booting stage, till the filling of the grains, also reduces the yield significantly.

3. There is no significant reduction due to the infestation at post-filling stage of the crop.

4. Severe infestation by leaf roller caterpillars causes substantial reduction in yield in all the varieties under study.

5. Local rice varieties suffer greater reduction in yield than high yielding varieties when leaf damage is intense.

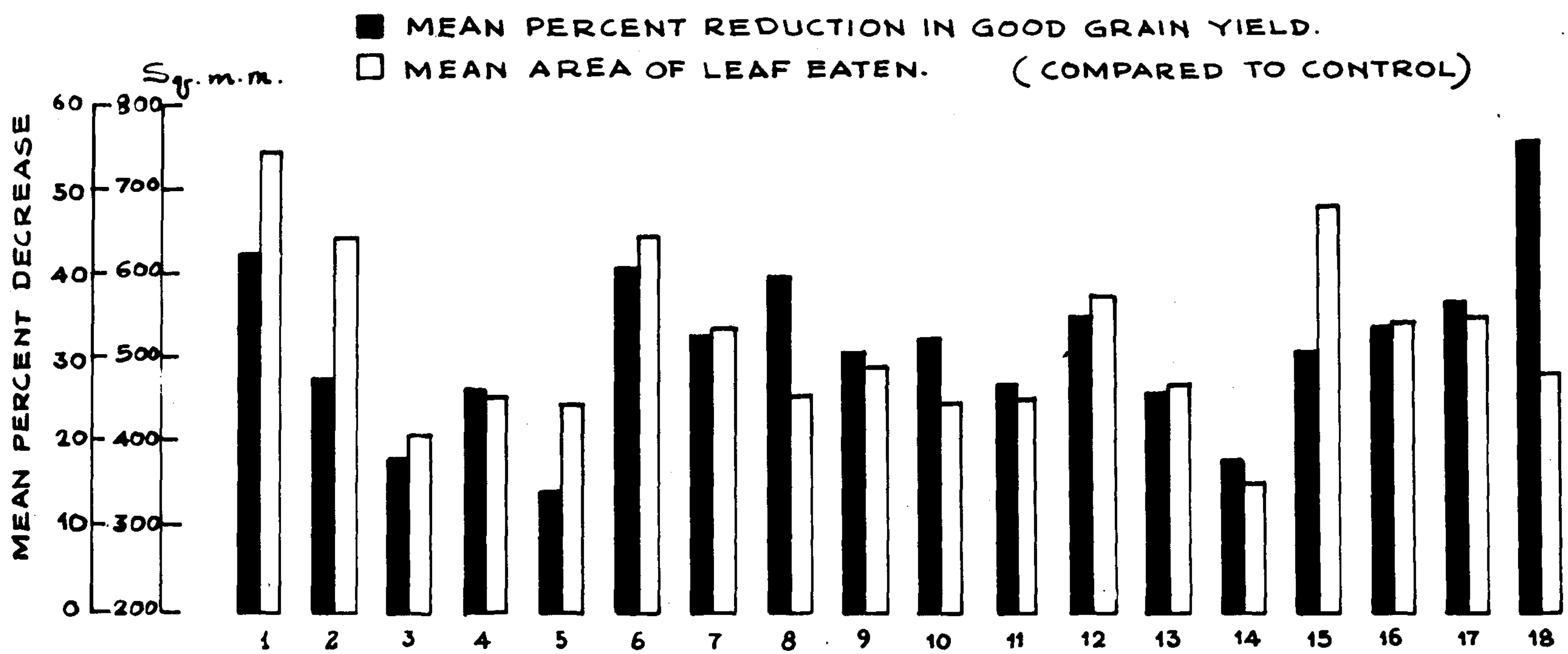
To study the response of different varieties of rice to the attack of leaf roller caterpillars the different varieties were subjected to the same doses of infestation under identical conditions. Four doses of larvae were used for each of the varieties. In general the different varieties responded to each of the levels in a similar pattern. There were variations in the reduction in grain yield in different rice varieties due to the pest infestation even though the plants were subjected to obligatory feeding by the caterpillars. H4, TKM6 and IR20 were observed to suffer the least loss in yield due to the leaf roller infestation (14.01 to 18.00 per cent) and Kochuvithu the local strain suffered the maximum reduction (50.77 per cent). The per cent reduction in yield in the remaining 14 varieties ranged from 26.29 to 43.52. Among these IR8, Rohini, Triveni, TKM1, Mashoori and Ptb9 showed fairly high rate of loss, varying from 34.01 to 43.52 per cent. The other varieties showed moderate resistance with reference to yield reduction.

A comparison of the extent of leaf area of different rice varieties consumed by caterpillars of C.medinalis and the mean reduction in yield sustained by them due to leaf roller infestation, both obligate feeding, shows that these two are closely related (Fig. 32). This indicates that the variations in the reduction in yield is mainly due to the variations in the extent of leaf eaten by the caterpillars on different rice varieties. TKM6, IR20, and H4 in which leaf consumption was less showed the least reduction in grain yield also. On the other hand varieties like IR8, Rohini, Mashoori, TKM1 and Ptb9 which showed higher degree of leaf damage when fed by the larvae sustained considerable reduction in yield also due to larval infestation. There were discrepant cases also which involved varieties like Karuna, Triveni, Annapoorna and Kochuvithu wherein there is no correspondence between the extent of leaf area fed and the percentage reduction in good grain yield. This may be due to other reasons such as the variations in the establishment of the first instar larvae on potted plants, variations in the percentage of mortality of immature stages etc.

Painter (1951, 1958) classified the types of plant

Fig. 32. Comparison of the mean leaf area of different rice varieties eaten by caterpillars of C.*medinalis* in 48 hours and the mean reduction in grain yield of different rice varieties exposed to the larval infestation.

1.	IR8	10.	Annapoorna
2.	Karuna	11.	Cavery
3.	IR20	12.	Mashoori
4.	Pankaj	13.	Adt27
5.	H4	14.	TKM6
6.	Rohini	15.	Jagannath
7.	Aswathi	16.	Ptb9
8.	Triveni	17.	TKM1
9.	Jaya	18.	Kochuvithu



MEAN PERCENT REDUCTION IN GOOD GRAIN YIELD.
MEAN AREA OF LEAF EATEN. (COMPARED TO CONTROL)
Sq. m.m.
MEAN PERCENT DECREASE
60
50
40
30
20
10
0
800
700
600
500
400
300
200
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

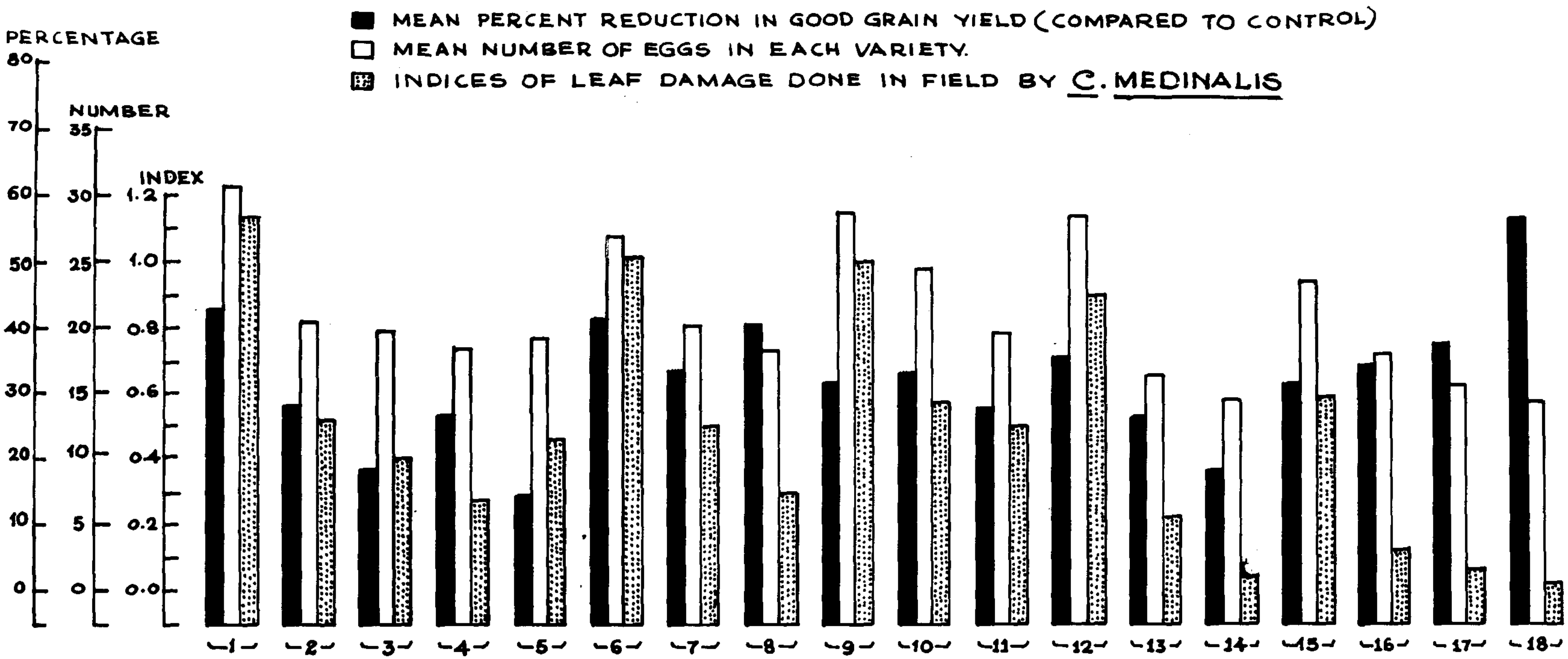
FIG: 32

resistance mechanisms under three categories viz. (a) preference and non-preference (b) antibiosis and (c) tolerance. Beck (1961) recognised non-preference and antibiosis alone as the resistance mechanisms of agricultural importance.

Response of C.medinalis to the different rice varieties reflecting the preference-nonpreference mechanism, was manifested in two experiments. In one ~~of~~ the different varieties were exposed to moths of C.medinalis to ascertain their relative preference, if any, to the rice varieties for oviposition. In the other experiment, the extent of leaf damage sustained by different rice varieties as a result of leaf roller infestation, when grown in random plots in field, was assessed. A combined representation of the results of the two trials is shown in Fig. 33. It is clear that the extent of leaf damage noted in different varieties, when grown in field, was directly proportional to the number of eggs noted in different rice varieties in the other experiment. The varieties which suffered most were those which were preferred by moths for oviposition and vice versa. The preference of caterpillars for feeding does not appear to be operative in the results of the field experiments as may be seen clearly in the comparison given in Fig. 33. Thus the relative resistance

Fig. 33. Comparison of the mean number of eggs laid by C.medinalis moths on one-month-old plants of different rice varieties, the mean indices of leaf damage in different varieties when grown in field and the per cent reduction in grain yield of different varieties exposed to *C.medinalis*.

1.	IR8	10.	Annapoorna
2.	Karuna	11.	Cavery
3.	IR20	12.	Masheori
4.	Pankaj	13.	Adt27
5.	H4	14.	TKM6
6.	Rohini	15.	Jagannath
7.	Aswathi	16.	Ptb9
8.	Triveni	17.	TKM1
9.	Jaya	18.	Kochuvithu



MEAN PERCENT REDUCTION IN GOOD GRAIN YIELD (COMPARED TO CONTROL)
MEAN NUMBER OF EGGS IN EACH VARIETY.
INDICES OF LEAF DAMAGE DONE IN FIELD BY C. MEDINALIS
PERCENTAGE
NUMBER
INDEX
80
70
60
50
40
30
20
10
0
35
30
25
20
15
10
5
0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

FIG: 33

manifested by the varieties when grown in adjacent plots simultaneously is mostly due to oviposition preference than, due to 'antibiosis'. Non-preference has also been recognised as an important factor of resistance by some workers (Pathak, 1971) since such non-preferred varieties usually escaped or developed less infestation.

The question of the possible antibiosis, exerted by the different rice varieties on rice leaf roller was examined with reference to the effect of the varieties on the duration of immature stages, mortality in larval and pupal development, size of the resulting moths, the sex ratio, longevity and fecundity of moths reared out on different varieties and the hatching percentage of the eggs laid by them. The relative ranking of the different rice varieties with reference to these aspects are given in Table 24. In this ranking of varieties, plants with following effects on various biological features of the insect are treated as susceptible ones and those with reverse attributes as relatively resistant ones:-

(a)	Duration of immature stages of the insect	low
(b)	Mortality of immature stages during development	low

Table 24 Relative ranking of different rice varieties based on various aspects of antibiosis to C.medinalis

Criterion adopted	RICE VARIETIES																	
	IR8	Karuna	IR20	Pankaj	H4	Rohini	Aswathi	Triveni	Jaya	Annapoorma	Cageri	Mashoori	Adt27	TKM6	Jagannath	Ptb9	TKM1	Kochuvithu
Larval and Pupal duration (discending scale)	14	13	4	6	2	17	9	15	5	10	7	18	3	1	8	16	12	11
Mortality of immature stages (descending scale)	16	7	2	6	3	8	11	17	10	13	9	15	4	1	12	5	18	14
Size (ascending scale)	17	6	4	5	2	14	7	8	12	16	11	18	1	3	10	9	13	15
Longevity of moths (ascending scale)	14	15	3	5	4	13	6	17	12	7	11	16	2	1	8	18	10	9
Fecundity (ascending scale)	15	13	3	6	2	14	5	9	10	8	12	16	1	4	7	18	17	11
Hatching percentage (ascending scale)	14	16	2	7	4	11	10	9	6	5	13	15	1	3	8	18	12	17

(c)	Male/Female ratios of resulting moths	low
(d)	Longevity of moths	high
(e)	Size of resulting moths	high
(f)	Fecundity of resulting moths	high
(h)	Hatching percentage of the eggs laid by resulting moths	high

Results on sex ratio of the moths reared on different rice varieties showed considerable variations. In Karuna males were significantly higher and in Jagannath and Cavery females were significantly predominant. The variations in the sex ratio of moths reared out from other varieties did not differ significantly among themselves. With reference to all other aspects of 'antibiosis' studied, the variation among the different varieties was highly significant. Rice varieties showing less 'antibiosis' will help the insect in building up the population fast. The ranking in Table 24 shows that the varieties IR8, Mashoori, TKM1 and Kochuvithu were highly favourable for the 'multiplication' of C.medinalis while IR20, Adt27, TKM6, H4 and Pankaj appeared to be highly unfavourable to the insect's multiplication. In varieties such as Karuna, Rohini and Ptb9 though the factors relating to the rate of multiplication (such as longevity of moths, their fecundity and percentage of egg hatch) are high the survival factor remain very low. In varieties like Triveni, Annapoorna and Jagannath the survival percentage remain high while multiplication factors remain low.

SUMMARY

SUMMARY

A series of laboratory and field experiments were conducted to study the relative toxicity of 24 insecticides to moths and larvae of the rice leaf roller, *Cnaphalocrocis medinalis*, the relative efficacy of these insecticides in controlling the pest in the field and the insect-plant relationships between *C.medinalis* and different rice varieties.

Suitable methods for the collection of moths of *C.medinalis* from the field, for the collection of their eggs and first instar larvae in sufficiently large numbers and for rearing the insect in the laboratory, were evolved.

Contact toxicity of 24 insecticides to the moths of *C.medinalis* was assessed for the first time by spraying the moths directly with the insecticides. The LC_{50} of the insecticides ethyl parathion, methyl parathion, diazinon, elsan, fenitrothion, carbaryl, acephate, fenthion, quinalphos, carbophenothion, methyl demeton, malathion, thiometon, phorate, phosphamidon, dichlorvos, leptophos, endosulfan, dimethoate, formothion, monocrotophos, BHC, endrin and trichlorfon were .000016, .000056, .000067, .000105, .000124, .000277, .000522, .001169, .002061, .002178, .002635, .002667, .002825, .004440, .005014, .005370, .006407,

.007413, .012790, .013550, .018840, 0.02084, .026550 and .08337 respectively.

Contact toxicity of the above insecticides to the larvae of C.medinalis was also studied for the first time. The LC_{50} values for ethyl parathion, methyl parathion, elsan, endosulfan, phosphamidon, acephate, monocrotophos, dimethoate, diazinon, carbophenothion, quinalphos, fenitrothion, formothion, dichlorvos, leptophos, carbaryl, endrin, phorate, malathion, methyl demeton, thiometon, fenthion, trichlorfon and BHC were .00264, .003102, .003882, .004539, . 004710, .004753, .004764, .005234, .005346, .005834, .005875, .006966, .007523, .01002, .0114, .01164, .0123, .01259, .01488, .0149, .0152, .01556, .0182 and .0929 respectively.

Relative toxicity of the 24 insecticides to the larvae of C.medinalis established within leaf folds was assessed using a precision spraying technique in the laboratory and by applying each insecticide at 3 doses. Based on means of the percentage of mortalities at the 3 doses, ethyl parathion, carbaryl, carbophenothion and methyl parathion giving 83.14, 80.85, 75.67 and 74.88 per cent mortality respectively were the most effective. Dimethoate, fenitrothion, fenthion, thiometon, phosphamidon, leptophos, phorate, formothion and quinalphos were moderately effective with 69.8, 68.54, 67.87, 67.27, 66.57, 65.90, 65.27, 61.93 and 61.83 per cent mortality respectively and monocrotophos, methyl demeton, acephate, dichlorvos, BHC, elsan, endrin, trichlorfon, diazinon, malathion and endosulfan were the least effective giving 59.98, 59.16, 53.56, 40.20, 38.42, 38.10, 27.09, 25.32, 2204, 18.78 and 13.68 per cent mortality respectively.

Spraying under field conditions, ethyl parathion, carbaryl, carbophenothion, methyl parathion, dimethoate, fenthion, fenitrothion, leptophos, phosphamidon, phorate, formothion, methyl dimeton, quinalphos, monocrotophos, thiometon and acephate were found to be more effective than BHC taken as the standard, giving respectively 72.53, 69.03, 67.64, 66.79, 64.25, 64.20, 62.23, 61.07, 59.04, 57.18, 52.44, 52.18, 51.26, 49.17, 46.78 and 45.97 per cent reduction in larval population. Dichlorvos, elsan, endrin, trichlorfon, diazinon, endosulfan and malathion were less effective than BHC with 28.54, 27.11, 24.84, 24.69, 20.67, 15.81 and 12.35 per cent reduction in larval population respectively; BHC gave a reduction of 44.67 per cent.

Field evaluation of the relative efficacy of different insecticides, applied at biweekly intervals, in controlling leaf damage caused by C.medinalis larvae showed that ethyl parathion, methyl parathion and carbaryl gave the best control in one season, the leaf damage indices being significantly lower in these than in the other treatments. In a second season acephate, ethyl parathion, dimethoate, quinalphos, leptophos and carbaryl showed significant reduction in leaf damage the difference among themselves being statistically insignificant. The damage in plots treated with the other insecticides in both the seasons did not differ significantly from control.

Persistent toxicity of 24 insecticides to the first instar caterpillars of C.medinalis was studied by spraying the insecticides at three different graded doses on rice plants and by exposing the larvae to leaves collected from the treated plants at regular intervals. Based on the means of the PT indices of each insecticide at various doses, monocrotophos had the maximum persistent toxicity and it was closely followed by carbaryl, quinalphos, leptophos and ethyl parathion. The other insecticides came in the following descending order: formothion, methyl demeton, carbophenothion, phosphamidon, acephate, elsan, fenitrothion, methyl parathion, malathion, phorate, fenthion, endrin, dimethoate, trichlorfon, diazinon, endosulfan, thiometon, BHC and dichlorvos.

The experiment to study the effect of leaf damage on the yield of 3 varieties of rice viz. IR8, Annapoorna and Kochuvithu, when subjected to maximum infestation by C.medinalis caterpillars at different growth stages of the crop showed that in all varieties infestation at the bootleaf stage caused the maximum reduction in yield. Infestation at the late vegetative phase and at the post-booting stage till the grains were filled, also reduced the yield significantly. The pest incidence during post-filling stage of the crop, even with heavy population of caterpillars, did not reduce the grain yield significantly. In general, severe infestation by leaf roller caused significant reduction in yield in all the three varieties. But the local variety suffered greater reduction in yield than the hybrid high yielding varieties when subjected to obligatory infestation by the pest.

The response of 18 varieties of rice to infestation by 4 different population levels of C.medinalis larvae was studied in terms of the per cent reduction in yield of grain caused by the infestation. H4, TKM6 and IR20 suffered the least loss in yield. Kochuvithu a local variety suffered the maximum reduction. IR8, Rohini, Triveni, TKM1, Mashoori and Ptb9 were also highly susceptible. Pankaj, Adt27, Cavery, Karuna, Jagannath, Jaya, Annapoorna and Aswathi were moderately tolerant.

The oviposition response of *C. medinalis* moths to the different rice varieties was studied with provision for the moths to choose their favoured varieties. There was significant variation in the number of eggs observed on different varieties. The average number of eggs laid per plant at one-month stage was least on Kochuvithu (14.33) followed by other varieties in the following descending order: TKM6 (14.66), TKM1 (15.66), Adt27 (16.33), Ptb9 (17.66), Pankaj (18.33), Triveni (18.66), H4 (19), Cavery (19.66), IR20 (19.66), Aswathi (20.00), Karuna (20.33), Jagannath (23.66), Annapoorna (24.33), Rohini (26.66), Mashoori (28.33), Jaya (28.66) and IR8 (30.66). The same trend was seen with the varieties at boot leaf stage also.

The extent of leaf area from which the leaf-roller caterpillar fed during 48 hours on different rice varieties was assessed by devising a suitable technique. Taking the limitation in the extent of feeding as an index of resistance, the different varieties of rice tested could be ranked in the following descending order: TKM6, IR20, H4, Annapoorna, Cavery, Pankaj, Triveni, Adt27, Jaya, Kochuvithu, Aswathi, Ptb9, TKM1, Mashoori, Karuna, Rohini, Jagannath, IR8.

The extent of antibiosis shown by different rice varieties to C.medinalis was assessed in terms of the duration of immature stages, mortality during larval and pupal developments and size, the sex ratio, longevity, fecundity and hatching percentage of the eggs of moths reared on different varieties.

Taking longer duration of immature stages of the pest as correlated with resistance of the plants to the larval infestation, the different varieties of rice screened could be ranked in the following descending order: TKM6, H4, Adt27, IR20, Jaya, Pankaj, Cavery, Jagannath, Aswathi, Annapoorna, Kochuvithu, TKM1, Karuna, IR8, Triveni, Ptb9, Rohini and Mashoori.

Relating higher mortality among larvae and pupae to the resistance of varieties to the infestation, the varieties could be ranked in the following descending order: TKM6, IR20, H4, Adt27, Ptb9, Pankaj, Karuna, Rohini, Cavery, Jaya, Aswathi, Jagannath, Annapoorna, Kochuvithu, Mashoori, IR8, Triveni and TKM1.

On the basis of the longevity of the moths reared out on different varieties, the varieties could be ranked as: TKM6, Adt27, IR20, H4, Pankaj, Aswathi, Annapoorna, Jagannath, Kochuvithu, TKM1, Cavery, Jaya, Rohini, IR8, Karuna, Mashoori, Triveni and Ptb9.

The proportion of male moths in the progeny reared on different rice varieties was significantly higher in Karuna only. Females were predominant in Jagannath and Cavery. Though there were differences among the sex ratios in other varieties these were not statistically significant.

With reference to the fecundity of the moths of C.medinalis reared out on different rice varieties, the varieties could be ranked in the following descending order: Adt27, H4, IR20, TKM6, Aswathi, Pankaj, Jagannath, Annapoorna, Triveni, Jaya, Kochuvithu, Caveri, Karuna, Rohini, IR8, Mashoori, TKM1, and Ptb9.

There was statistically significant difference in the hatching percentage of the eggs laid by moths of C.medinalis reared out on different rice varieties. Taking low percentages of hatching as an index of resistance the varieties screened could be ranked in the following descending order: Adt27, IR20, TKM6, H4, Annapoorna, Jaya, Pankaj, Jagannath, Triveni, Aswathi, Rohini, TKM1, Cavery, IR8, Mashoori, Karuna, Kochuvithu and Ptb9.

Taking smaller size of the moths as a factor unfavourable for the population build up of the species the different rice varieties could be ranked in the following descending order: Adt27, H4, TKM6, IR20, Pankaj, Karuna, Aswathi, Triveni, Ptb9, Jagannath, Cavery, Jaya, TKM1, Rohini, Kochuvithu, Annapoorna, IR8 and Mashoori.

The varieties could be ranked in the following descending order based on the extent of leaf damage caused by the pest under field infestation: Kochuvithu, TKM6, TKM1, Ptb9, Adt27, Pankaj, Triveni, IR20, H4, Cavery, Aswathi, Karuna, Annapoorna, Jagannath, Mashoori, Rohini, Jaya and IR8.

Relative toxicity of different insecticides to the larvae of C.medinalis assessed by laboratory bioassay method does not hold good under field conditions; good contact poisons appear ineffective in field and vice versa. The need for field experimentation for choosing effective insecticides for the control of pests like paddy leaf roller is thus indicated.

There is correspondance between the mortality of the larvae in leaf folds when sprayed with various insecticides in the laboratory and the reduction in larval population in an infested field treated with the same insecticides.

There is a general negative correlation between the persistent toxicity of various insecticides on paddy to the first instar larvae of *C.medinalis* and the extent of leaf damage under the insecticidal treatments in field. Carbaryl, quinalphos, leptophos, monocrotophos and ethyl parathion which have longer persistent toxicity cause correspondingly low leaf-roller damage when sprayed in field at biweekly intervals.

Out of the 24 insecticides studied, 12 are effective against *C.medinalis* larvae based on different aspects investigated. These insecticides can be ranked in the following descending order of efficacy: ethyl parathion, carbaryl, carbophenothion, methyl parathion, dimethoate, fenthion, leptophos, phosphamidon, phorate, formothion, methyl demeton and quinalphos. Ethyl parathion, carbaryl, methyl parathion, elsan, fenitrothion, acephate and diazinon are effective in controlling the moths of *C.medinalis*. For prophylactic treatment under conditions in Kerala, ethyl parathion, carbaryl, quinalphos, leptophos, monocrotophos, methyl parathion, fenitrothion, acephate and dimethoate are promising since the extent of leaf damage in plots treated with these insectcides is low.

Among the insecticides found effective in the above trials ethyl parathion, carbaryl, carbophenothion, leptophos, formothion, methyl demeton, quinalphos and monocrotophos have the maximum persistent toxicity to the first instar larvae of *C.medinalis*: methyl parathion, elsan, fenitrothion, acephate, fenthion and phosphamidon are moderately persistent and diazinon, dimethoate and phorate the least persistent. BHC, endrin and endosulfan which are known as highly persistent insecticides show very low persistent toxicity to *C.medinalis* larvae.

Under obligate feeding, there is positive correlation between the leaf area eaten by the larvae of *C.medinalis* (on different rice varieties) and reduction in yield caused by the larval infestation. Under field conditions the extent of leaf damage noted on different rice varieties is correlated to the number of eggs laid on them, when simultaneously offered for oviposition. Hence non-preference of varieties for oviposition makes them less liable to infestation under such situations.

Antibiosis studies have shown that varieties like IR8, Mashoori, TKM1 and Kochuvithu are highly favourable for population build up of *C.medinalis* while IR20, Adt27, TKM6, H4 and Pankaj are highly unfavourable. Among these TKM6 is tall and lodging and is not a high yielder. Hence it can be used in breeding programmes for evolving leaf-roller resistent varieties, while the other resistant varieties may be preferred for tracts showing heavy incidence of *C.medinalis* regularly.

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*Original not seen.

APPENDICES

Appendix I Per cent mortality of C.medinalis moths sprayed

Insecticides / Doses	.000005	.000010	.000020	.000030	.000040	.000045	.000050	.000060	.000067
E.parathion	33.3	40.0	66.7		76.7				
M.parathion				26.7		40.0			56.7
Diazinon					20.0		33.3	46.7	
Carbaryl									
Fenitrothion									

Appendix I Per cent mortality of C.medinalis moths sprayed

Insecticides / Doses	.00030	.00050	.00060	.00070	.00080	.00100	.00120	.00150	.00190
Endosulfan									
Dichlorvos									
Carbophenothion		13.3				30.0			
Elsan		30.0			42.0		60.0		66.7
Fenthion		30.0		43.3		56.6			70.0
Malathion						23.3			
Leptophos									
Acephate	30.0		60.0				70.0		
Quinalphos								20.0	
Thiometon						20.0			
Phosphamidon		10.0				13.3			

Appendix I Per cent mortality of C.medinalis moths sprayed

Insecticides / Doses	.0020	.0025	.0040	.0050	.0060	.0070	.0080	.0100	.01500
BHC								33.3	
Endrin									
Trichlorfan									
Dimethoate					43.3			46.6	50.0
Monocrotophos							20.0	26.7	36.7
Formothion						40.0		43.3	46.7
Phorate		43.3		50.0				66.6	
Methyl demeton	36.7		56.6			76.6			83.3

with different concentrations of various insecticides in the laboratory

.000075	.000080	.000100	.000140	.000150	.000200	.000270	.000300	.000360	.000500	.000600
	83.4									
		76.7		86.7						
	53.3	76.7								
				20.0	33.3	60.0		60.0	73.3	
33.3		43.3	60.0		66.7		66.7			

Contd.

with different concentrations of various insecticides in the laboratory

.00200	.00240	.00250	.00300	.00350	.00400	.00500	.00600	.00700	.00800	.01000	.01500	.01600	.02000
				[illegible]		20.0	40.0	40.0	56.7	70.0			
		20.0		33.3		43.3		66.7		73.3			
50.0					73.3			80.0					
			66.7										
			90.0										
30.0					63.3				76.7			90.0	
			30.0			46.6		53.3		60.0	70.0		
	76.6					83.3							
56.6			76.6			73.3		83.3					
36.6			50.0		63.3	70.0							
			40.0						63.3				80.0

Contd.

with different concentrations of various insecticides in the laboratory

.0200	.0300	.0400	.0500	.0600	.0700	.0800	.1000	.1400	.2400	.4000
60.0	66.6			70.0			76.7		[illegible]	
36.7	56.7		80.0		83.3		90.0		[illegible]	
			40.0			46.7		60.0	76.7	70.0
56.6		60.0								
56.7	66.7									
56.6	70.0									
70.0	76.7									
	86.7									

Appendix II Per cent mortality of 4th instar caterpillars' insecticides

Insecticides	0.0006	0.0007	0.0013	0.0015	0.0020	0.0025	0.0030	0.0035	0.0040	0.0045	0.0050	0.0060
B.H.C.												
Endrin							26.7					40.0
Endosulfan					31.1		37.7				48.8	
E.parathion	28.9		36.6			53.3					60.0	
M.parathion						28.9		60.6			80.0	
Dichlorvos							17.8				24.4	
Carbophenothion									26.7		37.7	46.6
Diazinon						28.9		31.1			35.5	
Elsan		15.5		31.1			53.3				50.0	
Fenthion							20.0				28.8	
Malathion							28.9			28.9		35.5
Leptophos							13.3				22.2	
Acephate						26.7		42.2			60.0	
Quinalphos					17.8				40.0			
Carbaryl					11.1				20.0			
Fenitrothion						22.2		31.1			33.3	
Trichlorfon												28.9
Thiometon						11.1					17.7	
Phosphamidon						22.2			50.0		62.2	
Dimethoate						20.0					50.0	
Monocrotophos					20.0				50.0			
Formothion						40.0					44.4	
Forate						6.7		13.3			15.5	
Methyl demeton											15.5	

of C. *medinalis* sprayed with different concentrations of various

0.0070	0.0080	0.0090	0.0100	0.0120	0.0130	0.0150	0.0160	0.0180	0.0200	0.0250	0.0300	0.0350	0.0500	0.0700	0.1000
										20.0		26.6	33.3	42.2	66.6
				53.3						63.3			66.7		
60.0			73.3												
			60.0												
84.4			86.7												
	37.7		50.0						77.8						
73.3			77.8												
60.0			80.0												
			67.8												
	33.3					51.1				60.0					
			44.4			51.1									
		40.0				60.0				75.5					
64.4			82.2												
62.2					71.1					82.2					
33.3					54.4					73.3					
53.3			62.2												
		28.9		37.7				50.0		60.0					
		22.2					50.0					77.8			
60.0			66.7												
71.1							88.8				97.7				
71.1					88.7					97.7					
		48.9					60.0				66.7				
26.7			66.6												
24.4			57.8	50.0					60.0						

Appendix III Reduction of larval population of *C.medinalis* when different insecticides were sprayed in an infested field

Insecticides	Concentration (Per cent)	No. of live caterpillars per 200 leaf folds collected at random (mean of three plots)	
		Pretreatment	48 hours after treatment
BHC	0.20	66.66	36.00
Endrin	0.04	70.00	52.67
Endosulfan	0.04	73.00	61.66
E.parathion	0.04	72.66	20.33
M.parathion	0.04	65.33	21.66
Dichlorvos	0.08	75.33	54.66
Carbophenothion	0.04	74.00	24.33
Diazinon	0.04	66.00	52.00
Elsan	0.04	69.66	50.79
Fenthion	0.075	65.33	24.00
Melathion	0.06	72.00	63.00
Leptophos	0.075	72.66	28.33
Acephate	0.06	70.33	36.67
Quinalphos	0.06	73.33	36.00
Carbaryl	0.20	70.33	22.33
Fenitrothion	0.04	71.33	26.66
Trichlorfon	0.20	69.00	52.66
Thiometon	0.05	69.33	37.33
Phosphamidon	0.04	66.66	27.00
Dimethoate	0.05	69.00	25.00
Monocrotophos	0.04	68.00	33.33
Formothion	0.06	77.00	37.00
Phorate	0.04	70.00	29.66
Methyl demeton	0.05	70.66	34.00
Control		64.66	59.33

Appendix IV Extent of leaf damage caused by C.medinalis to rice plants treated with different insecticides at biweekly intervals (First season)

Insecticides and concentration (per cent)		Mean number of leaves damaged per plot to the extent of				
		A	B	C	D	E
BHC	0.20	20111.00	857.33	1015.00	191.66	17.33
Endrin	0.04	19877.33	664.00	722.66	220.00	12.33
Endosulfan	0.04	19393.33	545.66	720.33	154.33	22.33
E.parathion	0.04	18685.33	632.66	1228.66	283.33	36.66
M.parathion	0.04	20577.33	724.33	868.33	247.00	10.00
Dichlorvos	0.08	18799.00	1003.33	682.00	178.00	17.66
Carbophenothion	0.04	19288.33	802.33	1263.66	99.33	12.33
Diazinon	0.04	18580.33	1552.00	1256.66	241.66	17.33
Elsan	0.04	13474.66	839.66	732.66	105.00	6.33
Fenthion	0.075	18862.66	892.66	1193.33	125.33	11.66
Malathion	0.06	19552.66	1552.66	1182.33	57.33	-
Phosvel	0.075	18502.33	1179.66	243.66	270.33	142.33
Acephate	0.06	20139.66	940.33	947.33	217.66	37.33
Quinalphos	0.06	19247.33	1074.33	763.33	126.66	-
Carbaryl	0.20	20834.66	826.00	979.66	46.33	19.00
Fenitrothion	0.04	20582.66	920.00	957.00	167.00	39.00
Trichlorfon	0.20	21140.66	615.00	576.66	238.66	9.33
Thiometon	0.05	20584.66	680.66	580.33	185.33	18.00
Phosphamidon	0.04	20587.00	746.33	1453.66	135.00	44.66
Dimethoate	0.05	20661.33	1031.33	782.33	71.33	40.00
Monocrotophos	0.04	20525.00	810.00	707.66	246.66	27.66
Formothion	0.06	20576.66	1175.33	302.33	406.66	9.00
Phorate	0.04	21667.66	1047.33	229.33	371.33	14.00
Methyl demeton	0.05	21184.00	1569.00	117.33	323.33	13.66
Control		21620.00	1624.00	336.33	1214.66	4.00

A = No damage
B = 0 to 25 per cent of leaf area damaged
C = 25 to 50 per cent of leaf area damaged
D = 50 to 75 per cent of leaf area damaged
E = 75 to 100 per cent of leaf area damaged

Appendix V Extent of leaf damage caused by <u>C.medinalis</u> to rice plants treated with different insecticides at biweekly intervals (Second season)

Insecticides and concentration (per cent)		Mean number of leaves damaged per plot to the extent of				
		A	B	C	D	E
BHC	0.2	8926.66	1715.00	1526.66	1625.00	3723.00
Endrin	0.04	9951.66	2175.00	1760.00	1715.66	4027.66
Endosulfan	0.04	9742.66	1790.33	1410.33	1639.00	6752.00
E.parathion	0.04	17668.33	525.00	453.33	66.66	-
M.parathion	0.04	21640.00	751.33	482.66	836.66	549.33
Dichlorvos	0.08	10675.33	1684.00	1838.00	2180.66	4485.66
Carbophenothion	0.04	11036.33	1765.33	1063.00	1800.66	3413.33
Diazinon	0.04	10456.00	1929.33	1511.33	2342.66	4274.00
Elsan	0.04	9367.66	2300.00	1960.00	1874.00	4617.33
Fenthion	0.075	9536.66	1430.00	1546.66	2250.00	6883.33
Malathion	0.06	11026.33	2294.66	2165.33	1674.00	3545.33
Phosvel	0.075	11068.00	1176.66	498.33	1131.66	2055.00
Acephate	0.06	9503.33	1620.00	1533.33	686.66	2573.33
Quinalphos	0.06	15590.00	1583.66	1284.33	1627.00	1010.66
Carbaryl	0.20	18013.33	491.66	460.00	566.66	660.00
Fenitrothion	0.04	12056.66	1331.66	1810.00	2176.66	2220.00
Trichlorfon	0.20	6451.33	3072.66	2532.00	1989.33	5713.00
Thiometon	0.05	6197.33	4847.66	2147.66	2602.00	6272.33
Phosphamidon	0.04	10960.00	1038.33	1533.33	1566.66	2003.33
Dimethoate	0.05	14671.66	1065.00	1736.66	1043.33	2966.66
Monocrotophos	0.04	14139.33	1133.66	977.00	1064.00	2805.33
Formothion	0.06	6636.66	1940.00	1946.66	2043.33	4853.33
Phorate	0.04	12640.00	950.00	353.33	2640.00	1713.33
Methyl demeton	0.05	12383.00	1387.00	1031.66	1292.00	2376.33
Control		9900.00	1446.00	2344.66	1436.00	4422.66

A = No damage
B = 0 to 25 per cent of leaf area damaged
C = 25 to 50 per cent of leaf area damaged
D = 50 to 75 per cent of leaf area damaged
E = 75 to 100 per cent of leaf area damaged

Appendix VI Extent of leaf damage caused by *C.medinalis* to rice plants treated with different insecticides at biweekly intervals (Third season)

Insecticides and concentration (per cent)		Mean number of leaves damaged per plot to the extent of				
		A	B	C	D	E
BHC	0.20	7668.00	2316.66	2573.33	1961.33	3742.66
Endrin	0.04	8057.66	1366.33	1159.33	1063.00	2183.33
Endosulfan	0.04	7173.33	1843.33	1872.66	1212.00	2060.00
E,parathion	0.04	11723.33	1966.66	1366.66	616.66	-
M.Parathion	0.04	8963.33	1873.33	1226.66	1066.66	2460.00
Dichlorvos	0.08	3856.66	1980.00	1520.00	1983.33	5195.00
Carbophenothion	0.04	5778.00	2408.66	1503.00	2380.66	4003.33
Diazinon	0.04	8553.33	2056.66	1580.00	2620.00	2960.00
Elsan	0.04	8842.00	2091.33	1344.66	1455.33	3202.66
Fenthion	0.075	10286.66	1110.00	1448.33	2116.66	4573.33
Malathion	0.06	4463.33	1800.00	1046.66	1860.00	3460.00
Phosvel	0.075	10918.33	755.00	729.00	747.66	1253.33
Acephate	0.06	8840.00	1043.33	2266.66	300.00	86.66
Quinalphos	0.06	8476.00	1983.33	626.66	1123.33	536.66
Carbaryl	0.20	15280.00	1100.00	1013.33	1066.66	2020.00
Fenitrothion	0.04	9103.33	1146.66	1276.66	1840.00	1033.33
Trichlorfon	0.10	6780.00	2133.33	2120.00	1786.66	4180.00
Thiometon	0.05	5256.66	1616.66	1248.33	1476.66	4581.66
Phosphamidon	0.04	7007.33	1282.33	1508.33	1867.33	2950.00
Dimethoate	0.05	13566.66	1165.00	483.33	635.00	1166.66
Monocrotophos	0.04	6958.66	1975.33	1356.66	1264.66	3275.33
Formothion	0.06	4376.66	2303.33	2246.66	2376.66	5993.33
Phorate	0.04	4616.66	2176.66	1760.00	1716.66	4023.33
Methyl demeton	0.05	6786.66	1900.00	1596.66	1993.33	3076.66
Control		6770.00	1136.66	676.66	780.00	3823.33

A = No damage
B = 0 to 25 per cent of leaf area damaged
C = 25 to 50 per cent of leaf area damaged
D = 50 to 75 per cent of leaf area damaged
E = 75 to100 per cent of leaf area damaged

Appendix VII Mean weight of good grains (in g) of different varieties of rice exposed to C.medinalis larvae at various intervals after sowing and the mean yield in corresponding control plants

Interval after sowing (in days)	IR8		Annapoorna		Kochuvithu	
	I	II	I	II	I	II
50	73.10	95.60	55.80	84.50	25.20	62.50
57	73.10	95.20	42.37	82.40	22.97	60.30
64	50.50	93.20	45.27	79.75	31.90	57.90
71	45.10	90.80	39.08	70.50	39.20	56.00
78	42.80	90.50	50.45	68.50	48.86	51.30
85	37.40	89.00	63.60	69.50	50.20	52.00
92	42.00	83.00	66.58	70.00	49.80	51.50
99	55.20	80.50				
106	49.80	78.00				
113	75.57	79.00				
120	77.50	79.80				

I = Infested plants

II = Uninfested plants

Appendix VIII Mean weight of chaff in different varieties of rice exposed to C.medinalis larvae at various intervals after sowing and the mean weight of chaff in corresponding control plants

Interval after sowing (in days)	IR8		Annapoorna		Kochuvithu	
	I	II	I	II	I	II
50	14.41	9.86	31.10	10.09	19.33	6.05
57	14.28	9.87	24.81	10.72	20.42	6.65
64	19.96	10.59	24.01	11.63	17.30	8.15
71	18.50	11.45	25.98	13.97	13.93	9.31
78	22.34	11.44	17.50	13.73	12.24	11.20
85	22.40	11.87	15.87	12.76	11.79	11.10
92	21.01	14.31	15.00	13.82	12.04	11.09
99	19.13	15.44				
106	19.65	16.64				
113	14.26	16.58				
120	13.62	16.67				

I = Infested plants

II = Uninfested plants

Appendix IX Mean weight (in g) of good grain of different rice varieties exposed to <u>C.medinalis</u> larvae at 4 population levels one week prior to booting stage

Rice varieties	Population levels			
	4 larvae per leaf	3 larvae per leaf	2 larvae per leaf	1 larva per leaf
IR8	25.99	33.84	40.35	46.41
Karuna	37.47	45.59	54.66	61.75
IR20	45.39	54.23	54.95	66.37
Pankaj	32.81	47.60	52.39	64.29
H4	41.43	54.99	58.46	63.00
Rohini	22.50	25.52	34.29	44.01
Aswathi	34.12	40.65	42.73	55.07
Triveni	29.52	39.52	47.40	64.15
Jaya	39.49	45.92	53.22	60.66
Annapoorna	33.94	36.69	46.14	53.15
Cavery	31.73	41.55	56.10	66.25
Mashoori	23.92	30.43	35.96	45.85
Adt27	40.16	47.52	59.08	67.62
TKM6	33.80	44.39	53.62	61.50
Jagannath	32.48	41.87	45.82	55.78
Ptb9	26.72	31.12	36.11	45.00
TKM1	22.22	25.86	37.19	41.32
Kochuvithu	12.39	17.19	24.48	33.46

Appendix X Extent of leaf damage caused by *C.medinalis* larvae to different rice varieties grown in field

Rice variety	A	B	C	D	E
IR8	13121.66	1418.66	1511.66	1520.00	3589.00
Karuna	15160.00	446.33	738.33	766.00	1324.00
IR20	15758.33	811.33	750.00	527.33	1018.33
Pankaj	14049.33	180.00	249.33	425.33	698.66
H4	15357.33	304.00	408.66	832.00	1280.33
Rohini	12586.33	1145.00	1448.66	1205.66	2870.66
Aswathi	13459.33	677.00	605.00	609.66	1011.33
Triveni	18422.66	388.00	178.00	196.66	986.00
Jaya	13356.00	948.33	1019.33	9879.33	3161.00
Annapoorna	15469.33	664.00	769.33	810.66	1419.33
Cavery	16258.66	554.66	786.00	866.66	1226.66
Mashoori	13502.00	1535.66	1348.00	2169.00	2168.33
Adt27	16875.00	533.33	443.33	386.66	406.66
TKM6	12986.00	14.66	6.66	25.00	23.66
Jagannath	14218.33	884.33	893.66	818.00	1275.66
Ptb9	11644.66	112.66	151.66	127.00	150.00
TKM1	17869.30	97.66	88.00	125.66	102.66
Kochuvithu	12608.00	18.00	14.00	32.66	6.66

A = No damage
B = 0 to 25 per cent of leaf area damaged
C = 25 to 50 per cent of leaf area damaged
D = 50 to 75 per cent of leaf area damaged
E = 75 to 100 per cent of leaf area damaged