FACTORS RESPONSIBLE FOR THE POPULATION BUILD UP OF RICE BUG, *LEPTOCORISA ACUTA* THUNB AND THE CONTROL OF THE PEST

By

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DECLARATION

I hereby declare that this thesis entitled "Factors responsible for the population build up of rice bug, *Leptocorisa acuta* Thunb. and the control of the pest" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled "Factors responsible for the population build up of rice bug, Leptocorisa acuta Thunb. and the control of the pest" is a record of research work done independently by Sri. Krishna Kumar, R. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

The rice bug Leptocorisa acuta Thunb. is a major pest of rice in India occurring in epidemic forms in many parts of the country sporadically. The loss caused by the bug infestation ranges from 10 to 40 per cent (Israel and Rao, 1961) and at times in severe infestations total loss of the crop occurs (Srivastava and Saxena, 1960; Smith 1981). The genus Leptocorisa was first reported by Atkinson in 1886 occurring in Pakistan, Gorakpur in U.P., Nagpur and Assam. Subsequently Distant (1902) recorded it from various parts of India. It has been reported as a serious pest of rice from different regions of India (Ayyar, 1917, 1924, 1933; Venkitachalam, 1940; Akbar, 1957; Israel and Rao, 1961 and Rai, 1983).

Much work has been undertaken on the life cycle, bionomics, alternate hosts, effect of climatic factors on the population and control of the bug under different agro-ecological conditions in India; much remains to be known about these factors under subtropical and equable climatic conditions existing in Kerala. For example biological investigations relating to the response of the insect to different varieties of rice in the different agro-climatic zones and the suitability of the weed fauna of the different zones for the completion of the life cycle of the bugs during off-seasons have to be studied. The impact of different weather factors prevalent in the different agro-climatic zones on the population build up of the bug has to be studied. A comprehensive idea on the factors responsible for the population build up will help in evolving appropriate systems for keeping the pest population under control.

The feeding habits of the bug are closely associated with the damage caused to the crop as the bug attacks the earheads. Studies have to be made to understand these associations precisely. Rice bug is one pest which is known to select strains resistant to toxicity of insecticides. So there is need to examine the phenomomena by appropriate toxicological studies both in the laboratory and in the field. There exists a lacuna in our information on this aspect because the work done on this line is quite scanty especially under epidemic conditions of *L. acuta*.

The economic threshold level for rice bug has not been worked out in India so far. The threshold recommended is based mainly on the finding of Dyck (1978) from IRRI, Philippines. Hence the economic threshold has to be worked out under the Kerala conditions.

In the light of the position detailed above a programme of investigations on the following aspects of *L. acuta* was undertaken during 1983 to 1985.

(1) Biology of *L. acuta* on different varieties of rice.

(2) Suitability of rice land weed fauna present in the rice fields as alternate hosts.

(3) Estimation of damage of *L. acuta* at different stages of development of grains.

(4) Assessment of economic threshold level of rice bug.

(5) The relative toxicity of different insecticides to *L. acuta* bugs.

(6) Persistent toxicity of insecticides to the bug.

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(8) Estimation of residues in the grain.

(9) The factors influencing population build up of *L. acuta* in the field.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

<u>Biology of *L. acuta* on different varieties of rice</u>

Uichanco (1921) and Corbett (1930) observed that the female of *L. acuta* (Thunb.) mates when it is 7 - 25 days old. Austin (1923) and Misra (1968) reported that mating generally occurs in the morning. Akbar (1957), Lim Guan Soon (1971) and Kalode and Yadava (1976) observed that the males generally are ready for copulation soon after emergence but the female takes about 8 - 14 days to attain sexual maturity. Misra (1969) reported that pre-copulation period was found to variesfrom 12 - 15 days.

The copulation was found to last for 4 to 5½ hours (Misra, 1969), 6 - 7 hours (Kalode and Yadava, 1976) and 2 - 6 hours (Rai, 1983).

A single female laid about 250 - 300 eggs which are placed in rows on leaf blades of rice or grass (Anon., 1928). Corbett (1930) observed that the eggs are laid 9 - 41 days after the female has reached the adult stage and the total egg laying period ranged from 11 - 60 days. Biswas (1953) observed that pre-oviposition period vary from 10 - 25 days. Akbar (1957) stated that the mated female starts laying eggs 3 - days after copulation.

Lim Guan Soon (1971) found that oviposition generally commences 9 - 41 days after the female has become adult and average oviposition days for a female lasted for 52 days. Kalode and Yadava (1975) reported that eggs were laid during night, approximately 17 hours after completion of mating. A single gravid female laid eggs for 8 - 14 days with a daily mean oviposition of 3 - 23 eggs. Rai (1983) observed that pre-oviposition period lasted for 1 - 5 days and oviposition period for 2 - 15 days. Female laid a maximum of 45 eggs. The eggs were laid on the upper surfaces of leaves, usually close to midrib in rows of 6 to 18.

Lefroy (1906) reported that the eggs of Leptocorisa are oval, almost black and somewhat flattened. The egg period was reported to vary from 6 - 8 days (Anon., 1919, 1928; Corbett, 1930 and Vander Goot, 1949). Variations in the incubation period of 5 - 8 days have also been reported (Srivastva and Saxena, 1960; Misra, 1969; Lim Guan Soon, 1971; Kalode and Yadava, 1975 and Rai, 1983).

Since 1921 scientists reported that there were five nymphal instars and the nymphal period of rice bug lasted for 17 - 33 days (Uichanco, 1921), three weeks (Corbett, 1930), 21 - 22 days (Van der Goot, 1949), 14 - 25 days (Biswas, 1953), 16 - 17 days (Akbar, 1957; Sen Gupta and Behura, 1952), 16 - 25 days (Srivastva and Saxena, 1960), 14 - 20 days (Misra, 1969), 18 days (Rothshield, 1970), 13 - 17 days (Kalode and Yadava, 1975) and 14 - 23 days by Rai (1983).

The longevity of *L. acuta* was reported to vary from 3 - 4 months (Anon., 1919, 1928) and Austin (1923). According to Van der Goot (1949) adults survived up to 4 - 6 months on rice and 6 - 8 months in grasses. The longevity was also observed to vary from 33 - 55 days (Akbar, 1957), 45 - 60 days (Srivastva and Saxena, 1964), 45 - 70 days (Misra, 1969) and 23 - 63 days (Rai, 1983).

Suitability of weeds as alternate hosts of bug

Various workers have described a number of hosts as food plants of *L. acuta*. Most of these plants belong to the families of Graminae and Cyperaceae. When paddy is not in the earhead stage, the insects feed on various other food plants.

The weeds reported are *Andropogan annulatus* (Lefroy, 1906 & 1908; Corbett, 1923; Srivastva and Saxena, 1960, 1964), *Cyperus iria* and *Cyperus rotundus* (Srivastva and Saxena, 1960, 1964), *Digitaria bifusculata* and *D. barginata* (Corbett, 1923, 1930; Srivastva and Saxena, 1964), *Digitaria sanuinalis* (Ghose *et al.*, 1960; Israel and Rao, 1961), *Eichinochloa pilosa* and *E. colonum* (Sen, 1955; Srivastva and Saxena, 1960, 1964), *Eleusine aegyptiaca* and *E. corocana*

(Corbett, 1923; Ghose et al., 1960; Sen, 1961 and Israel and Rao, 1961), *Eragrostis pilosa* and *Fimbristylis miliacea* (Corbett, 1923; Srivastva and Saxena, 1964), *Ischaemum rugosum*, *Panicum barbatum*, *P. miliare* and *P. miliaceum* (Chopra, 1928; Sen, 1955; Ghose *et al.*, 1960; Srivastva and Saxena, 1960, 1964 and Israel and Rao, 1961), *Paspalam scrobiculatum*, *Paspalidium flavidum* and *Pennisetum typhodeum* (Hutson, 1920; Srivastva and Saxena, 1960; Israel and Rao, 1961; Kalode and Yadava, 1969; Misra, 1968 and Kalode and Yadava, 1975).

Besides the graminaceous and cyperaceous plants as alternate hosts of the rice bug other crops like rubber (Anonymous, 1919 and Puttarudriah, 1961), *Amaranthus* sp. (Hutson, 1920; Puttarudriah, 1961; Sen, 1961; Srivastva and Saxena, 1960 & 1964), screwpine (Pillai, 1923), *Psidium guajaba* (Puttarudriah, 1961), *Solanum melongena* (Puttarudriah, 1961), *Saccharum officinarum*, *Zea mays*, *Apluda* sp. and *Sorghum* (Srivastva and Saxena, 1960 & 1964), *Mangifera indica* (Sen, 1961) and medicinal plants like *Grevia hirsuta* and *Blumea lacera* (Lal and Mukherji, 1977) were also been reported.

Studies on the damage done to rice crop by *L. acuta*

Uichanco (1921) observed that the insect feeds by inserting a part of its stylet into the interior of rice grain in milky stage through a weak spot at the place where the edges of the large glumes meet to form the hull.

Dresner (1955) noticed the losses reaching 50 to 100% in some flooded fields and losses always exceeding 10 - 20% in flooded and non-flooded fields respectively.

Rothschild (1970) observed that an average of four fully milk ripe grains were probed by an adult per day but this increased to nearly 8 per day when the ears were at the early post flowering stage. There was positive correlation between the number of grains in any one ear and the number probed but only about 10% of the available grains were attacked. Grains attacked at the fully milk ripe stage were able to produce only 40 - 60% of their normal endosperm content. It was tentatively suggested that 25% yield loss would result from the feeding activity of 1,00,000 adults/acre or in terms of feeding potential on equivalent number of nymphs. Under severe cases 90% rice grains remained unfilled (Sands, 1977) whereas complete destruction of the crop was noticed by Smith (1981)

Assessment of E.T. level of rice bug

Halterson & Sama (1976) observed that the studies conducted in South Sulawesi, Indonesia, showed that the population density expressed as bug/m^2 on logarithmic scale was significantly related to the percentage infestation (on yield loss) on an arithmetic scale. It indicated that 1 - 2 bugs/square metre shortly after flowering justified the application of chemical sprays. Dyck (1978) studied E.T. level of rice bug and fixed the threshold as 2 - 4 bugs/sq.m. Bandong (1977) observed E.T. as 4 bugs/sq.m.

Persistence of insecticide residues sprayed on rice plant against *L. acuta*

The persistence of insecticide residues on rice plant against *L. acuta* using insecticides fenthion, phosphamidon, endosulfan, endrin, EPN, parathion, diazinon, malathion and gammaxene was observed (Anon., 1969) and it was found that fenthion had showed maximum persistence followed by phosphamidon, endosulfan, endrin, EPN, parathion, diazinon, malathion, and gammaxene in the decreasing order.

Insecticidal control of *L. acuta*

In the early periods the control of rice bug was achieved using inorganic insecticides like lead chromate (Sen, 1919) and calcium cyanide (Brittain, 1926). Then the use of derris and pyrethrum were reported by Corbett (1937) and Tateishi (1939) for rice bug control. The use of chlorinated hydrocarbons like DDT (Baptist, 1947; Kanagarathanam, 1956; Mirchandani, 1956; Srivastva and Saxena, 1964 and Banerjee, 1975), BHC (Baptist, 1947; Ramachandran, 1948; Saxena, 1954; Israel and Rao, 1954;

Rao and Basheer, 1957; Srivastva and Saxena, 1964 and Banerjee, 1975), chlordane (Mirchandani, 1956; Israel and Rao, 1961; Srivastva and Saxena, 1964 and Banerjee, 1975), toxaphene (Rivera and Calora, 1956; Srivastva and Saxena, 1964), Aldrin andDieldrin (Srivastva and Saxena, 1964 and Banerjee, 1975) were also tried with success against L. acuta.

Regarding the use of organophosphorus compounds, Sen and Srivastva (1955) found that when systox was applied the plants remained bug free. Rivera and Calora (1956) reported that TEPP and parathion were found to be effective in the control of rice bug. Veluswamy *et al*. (1977) observed that fenthion, phosphamidon, monocrotophos and dichlorovos were found effective than BHC and carbaryl when an outbreak of *L. acuta* occurred at Olappalayam in Coimbatore District. Jayaraman and Veluswamy (1977) found that malathion, fenthion, folidol and carbaryl were effective in controlling rice bug in paddy experiment station, Ambasamudram, Tirunelveli. Pillai *et al*. (1983) reported that carbosulfan and deltamethrin sprays kept the *Leptocorisa* populations low throughout the seasons. Argente and Heinrichs (1983) proved monocrotophos applied at 0.75 kg ai/ha was the most effective insecticide against rice bug, lindane providing control for one day and carbaryl being ineffective.

Residues of insecticides in grains of rice plants sprayed against *L. acuta*

Jain *et al.* (1980) conducted a field study to determine the residues of disulfoton and phorate broadcast one week after transplanting to control early pest complex of rice and sprays of HCH, lindane, endosulfan, malathion, fenitrothion, chlorpyrifos, applied at the time of earhead emergence to control rice bug *L. acuta*. No residues of the compounds were detected in the grain or straw on 75th day when the plants were harvested; the only compound found in plants at harvest was lindane with 0.15 ppm of residues in the grains.

Effect of climatic factors on the population build up of *L. acuta*

It was stated that *Leptocorisa* was more active in September-October (McKay, 1916) and November-December (Uichanco, 1921 and Austin, 1922) towards the end of rainy season, in presence of cloudy weather and its activity stops abruptly with the intervention of heavy rainfall.

Sen (1954), Ghose *et al.* (1960), Srivastva and Saxena (1964), Israel and Rao (1961), Singh and Chandra (1967), Misra (1969) observed that when early summer rains of short duration with high temperature in April to June-July occur the pest feeds on various millets and grasses; therefore chances of damage to paddy are greater in subsequent months.

Garg and Sethi (1981) observed during Khariff seasons in New Delhi that weekly averages of 28.59°C temperature, 69.55% R.H. and 0 - 71.7 mm rainfall favoured the population build up of rice bugs.

MATERIALS AND METHODS

MATERIALS AND METHODS

Mass rearing of rice bug *Leptocorisa acuta* (Thunb.) in the laboratory.

Leptocorisa acuta was cultured in the laboratory on 'Jaya' variety of rice. The plants were grown in pots (6 cm x 15 cm) and enclosed in cylindrical rearing cages (0.75 m x 1 m), of nylon mesh, with top closed with muslin cloth. A pair of *L. acuta* adults was released in each cage when the grains had reached the milky stage. The eggs laid by the insect were allowed to hatch in the cages and the emerging nymphs also permitted to feed on the milky grains. The plants in the cages were replaced with fresh ones having milky grains as and when found necessary. The first instar nymphs and adults required for the various experiments were taken from these cultures.

Assessment of the effect of rice varieties as hosts on biology of *L. acuta*.

Different rice varieties viz. Jaya, Jyothi, Triveni, Pavizhom and Karthika were raised in pots (6 cm x 15 cm) and when the grains attained milky stage, the plants were enclosed in cages mentioned above. One first instar nymph collected from the culture maintained in the laboratory was introduced in each cage and ten such replications were maintained for each variety.

The effect of the varieties on the biological features of the insect was assessed in terms of duration of different stages, survival of different instars, pre-oviposition and oviposition periods, fecundity and longevity. Fresh plants were provided at intervals of 3 days (Heinrichs *et al* 1982).

<u>Biology of *L. acuta* on alternate weed hosts found in paddy fields</u>

The common rice-land weeds were collected from the field and planted in pots (6 cm x 15 cm). At the end of one or two weeks the plants were enclosed in cages as done in the case of rice mentioned above. Different instars of the insect were confined individually on the potted weed plants. Survival and duration of different life stages as well as the longevity and fecundity of the adults were recorded.

<u>Estimation of damage caused by *L. acuta* to rice earhead at different stages of grain formation</u>

With a view to ascertaining the nature of damage on the grains at various stages of growth, adult bugs starved overnight were individually confined on the panicles at the respective growth stages. In each cage grains formed from flowers opening on the same day were retained and the unopened florets were clipped off with scissors. A single bug was allowed to feed for 24 hours and then it was removed from the cages.

There were three replications for each growth stage of grains. The earheads exposed to the feeding of the insects were allowed to remain in the confined conditions. The grains harvested were grouped into full grains and chaff. Another set of rice plants in the flowering stage were kept simultaneously without exposure to the bugs which served as control.

The actual damage caused by the pest was also determined on the basis of stylet sheaths in the grains detected by the Acid-Fuchsine Staining Technique of Litsinger _et al._ (1981). The grains were stained in a medium containing 1 part each of phenol, lactic acid and water; 2 parts of glycerine and enough acid-fuchsine dye, for 10 minutes. The stained grains were then washed in water to remove excess stain. When examined under the microscope the stylet sheaths present could be seen as minute tubes stained red.

Determination of economic threshold of _L. acuta_ on rice

A field experiment was conducted at the Cropping Systems Research Station, Karamana to determine the economic threshold level of L. acuta. Field cages (1 m x 1 m x 1 m) were used for these studies. The different levels of insect populations were maintained in the cages by introducing definite number of adults in the cages. The levels of population maintained were 0, 1, 2, 3 and 4 bugs.

There were four replications for each population level. The insects released into these cages were carefully watched and dead ones, if any, were replaced. When the grains reached maturity, the crop was harvested. The grains were sorted into full grain and chaff. The possible yield gain per hectare was computed. The cost of pesticide application was also worked out. Economic threshold was assessed on the basis of the cost of pesticide applications and the resultant gain for the cultivators (Gittinger, 1976) and the benefit cost ratio was calculated on the basis of the cost of control operations and the gain in yield.

Assessment of the relative toxicity of different insecticides to *L. acuta*

The relative toxicity of the commonly available insecticides to adults of *L. acuta* was assessed in the laboratory by bioassay. The insecticides used were the commercial formulations. Graded concentrations from the emulsifiable concentrate, formulations of the insecticides were prepared by addition of required quantities of water.

The insects were taken inside petri dishes and covered with wire nets of 40 mesh, sprayed with one ml each of the spray fluid under a Potter's Tower; they were allowed to dry under a fan and the bugs transferred to cylindrical jars of size 20 cm x 20 cm containing fresh rice earhead, held within specimen tubes containing water. Mortality observations on the bugs were recorded after 24 hours of spraying and the data were subjected to probit analysis (Finney, 1962) after correcting for the mortality using Abbot's formula (Abbot, 1925).

<u>Assessment of persistent toxicity of different insecticides sprayed on rice crop to *L. acuta*</u>

A pot culture experiment was carried out to study the persistent toxicity of insecticides sprayed on rice plants to *L. acuta*. The potted plants at the ear bearing stage were sprayed with different insecticides with a knapsack sprayer at the recommended dosage. Ten one-day-old adult bugs were released on each plant at different intervals after spraying and the bugs were confined on the plants with the help of wire mesh cages. The mortality of the bugs was recorded 24 hours after the release. There were three replications for each treatment. Plants sprayed with water alone served as control. The sprayed plants were subjected to weathering and the persistent toxicity was ascertained as described above at different intervals after spraying. The persistent toxicity was determined by calculating PT index following the method of Pradhan (1967).

<u>Relative efficacy of insecticides in the control of *L. acuta* in the field</u>

Two field experiments were laid out adopting R.B.D. in an infested field at Vellayani, to find out the effectiveness of 12 insecticides (Table 6). The insecticides used were applied in the field on need basis.

Observations on pre-treatment and post-treatment populations of the bugs were made. The population was assessed by sudden trapping of the bugs in a cylindrical cage of 50 cm diameter and 125 cm height covered on the side and top with polythene sheet. Ten such lots were trapped from each plot and counted. The grain : chaff ratio based on the weight at harvest was assessed and cost - benefit ratio was also worked out.

<u>Estimation of residues of insecticides in the grain</u>

The residues of the insecticides, malathion, methyl parathion and fenthion in the harvested grains were estimated colorimetrically following the method of Gets and Watts (1962).

<u>Observations on the environmental factors on the population of *L. acuta*</u>

Observational data were collected for the two crop seasons of 1983-84 and 1984-85 on the population fluctuation of *L. acuta* in the Trivandrum District. For this two contiguous 'elas' in each of the three subdivisions of the District were selected and the data on the area cultivated, the time of planting, varieties cultivated, the population fluctuation and the infestation pattern of *L. acuta* in these fields, and on the other host plants, yield based on crop cutting surveys and the weather parameters like temperature, relative humidity, rainfall, etc. were collected. Correlations were worked out between the weather factors and the population of the bug, the results of which are presented in detail.

RESULTS

RESULTS

Effect of different varieties of rice when used as host on the biology of *Leptocorisa acuta*

The various biological features of *L. acuta* as observed when reared on different varieties of rice are presented below (Table 1).

Mating and oviposition

It is observed that the adults mate 2 - 3 days after emergence and the mating of each pair continues for 4 - 5 hours. The pre-oviposition period is found to vary from 3.5 - 4.4 days on an average on different varieties and the oviposition period from 51.40 days to 54.20 days on an average. The pre-oviposition period is found to be higher when reared on Pavizham (4.40 days) followed in the descending order by Jaya with 3.90 days, Karthika with 3.70 days, Jyothi and Triveni with 3.50 days each on an average.

As regards oviposition period of adult bugs it varies from the lowest 48 days in Jaya to the highest 57 days in Triveni. Relatively the oviposition period is highest when reared on Triveni with an average of 54.20 days followed in the descending order by Pavizham with 53.60 days, Jyothi with 53.50 days, Karthika with 52.00 days and Jaya with 51.40 days.

Table 1. Duration of different stages (in days)* of L. acuta on different varieties of rice.

Variety	Preovi-position period	Ovi-position period	Fecundity	Egg period	Nymphal periods						Adult longevity	
					I	II	III	IV	V	Total	Male	Female
Jaya	3.90 (2-5)	51.40 (48-54)	160.00 (158-163)	6.20 (4-7)	2.50 (2-4)	3.80 (3-5)	3.00 (2.5-4)	3.50 (3-5)	5.50 (4-6)	18.50	70.40 (68-72)	79.60 (77-81)
Jyothi	3.50 (2-5)	53.50 (50-55)	161.00 (157-164)	6.40 (5-7)	3.30 (2.5-5	3.20 (3-4)	3.10 (2-4)	4.40 (3-6)	4.20 (3-6)	18.20	71.00 (68-72)	80.50 (79-81)
Triveni	3.50 (3-4)	54.20 (53-57)	161.50 (157-164)	5.90 (4-7)	3.10 (2-4)	3.30 (3-5)	4.40 (3-5)	4.30 (3-6)	4.80 (3-6)	19.40	72.50 (69-72)	81.00 (79-83)
Pavizham	4.40 (3-6)	53.60 (52-56)	159.20 (157-164)	6.00 (4-7)	2.50 (2-4)	4.50 (3-5)	3.20 (3-4)	4.50 (3-6)	5.50 (4-6)	19.20	70.70 (68-71)	81.40 (80-83)
Karthika	3.70 (3-5)	52.00 (50-55)	160.30 (159-162)	5.50 (4-6)	3.30 (2-5)	3.10 (2.5-4)	4.20 (3.5-4)	4.20 (3-6)	4.20 (3-6)	19.00	70.80 (68-71)	79.60 (77-81)

* Means of ten replications. Range in durations are given in parentheses.

A N O V A

	Source	df	ss	MSS	f
(Preoviposition period)	Treatment	45	6.66	0.1488	
	Error	4	777.23÷	194.25	0.0076
	Total	49	787.68		
(Oviposition period)	Treatment	45	38.77	0.866	
	Error	4	478.85	119.25	0.0096
	Total	49	517.62		
(Fecundity)	Treatment	45	42.11	0.9333	
	Error	4	571.44	127.75	0.0073
	Total	49	613.55		
(Egg period)	Treatment	45	8.77	0.200	
	Error	4	678.77	169.75	0.0111
	Total	49	687.54		
(1st instar nymph period)	Treatment	45	11.22	0.267	
	Error	4	818.12	204.54	0.0013
	Total	49	829.34		
(2nd instar nymph period)	Treatment	45	6.44	0.1444	
	Error	4	796.55	199.2	0.0072
	Total	49	802.99		

	Source	df	ss	MSS	f
(3rd instar nymph period)	Treatment	45	5.58	0.120	
	Error	4	798.22	199.5	0.0068
	Total	48	804.60		
(4th instar nymph period)	Treatment	45	6.81	0.1511	
	Error	4	729.19	182.25	0.0085
	Total	49	836.00		
(5th instar nymph period)	Treatment	45	4.31	0.0956	
	Error	4	811.15	202.78	0.0005
	Total	49	815.46		
(Male longevity)	Treatment	45	35.11	0.7778	
	Error	4	777.16	194.3	0.0051
	Total	49	812.27		
(Female longevity)	Treatment	45	39.14	0.8667	
	Error	4	771.11	193.0	0.0056
	Total	49	810.25		

The fecundity is observed to be higher in the bugs reared on the variety Triveni (161.50 eggs per bug average) followed by Jyothi (161.00 eggs), Karthika (160.30 eggs), Jaya (160.00 eggs) and finally Pavizham (159.20 eggs) in the decreasing order.

The egg

The eggs are laid in regular rows usually on the upper surface of the leaf but sometimes on the lower surfaces also. The egg is boat shaped or oval, the lower surface being attached to the leaf surface by means of a white gummy substance which hardens on drying. The freshly laid eggs are reddish brown in colour when laid but soon becomes dark brown. The number of eggs laid by a single female varied from 159.20 to 161.50 on an average.

The incubation period of the egg varies in different host varieties, the variation being 5.5 to 6.4 days on an average. It is found to be highest in the case of eggs laid by the bugs reared on the variety Jyothi (6.4 days) followed by Jaya (6.2 days), Pavizham (6.0 days), Triveni (5.9 days) and Karthika (5.5 days).

The nymph

The nymphs are found to moult four times during ~~its~~ their life-cycle and hence passes through five instars. Table 1 shows the duration of different nymphal instars on different varieties of rice, the average total nymphal period is higher in the bugs reared on the variety Triveni (19.4 days) followed by Pavizham (19.2 days), Karthika (19.0 days), Jaya (18.5 days) and Jyothi (18.2 days) in the decreasing order.

The newly emerged hymphs are tiny and yellowish green coloured. The second to fifth instar nymphs are brownish green in colour, the succeeding instars being correspondingly bigger and more brownish. The wing is found to develop from fourth instar. A characteristic buggy odour is emitted from the second instar to the adult stage. The nymphs are sluggish and do not feed 2 - 3 hours before moulting.

The adult

It is observed that (Table 1) the adult longevity also varied depending upon different varieties on which the bugs are reared. The female adults live longer and are stronger fliers than the males. The longevity of female adults varies from 79.6 to 81.4 days on an average. The longevity is higher in the bugs reared on the variety Pavizham (81.4 days on an average) followed by Triveni (81.0 days), Jyothi (80.5 days), Karthika (79.6 days) and Jaya (79.6 days) in the descending order. The male adults live 70.4 days to 72.5 days on an average on the different varieties of rice. The longevity of male adults is high in Triveni (72.5 days on an average)

Table 2. Duration/survival of different stages (in days)* of *L. acuta* on different weed plants

Weed	Fecundity	Egg period	Nymphal periods						Adult longevity	
			I	II	III	IV	V	Total	Male	Female
Echinochloa colonum	61.00 (57-64)	5.00 (4-6)	3.20 (2-4)	3.50 (3-4)	3.30 (3-4)	4.00 (3.5-4.5)	4.50 (4-5)	19.00	54.20 (51-58)	58.50 (55-60)
Echinochloa crusgalli	59.00 (57-61)	4.50 (3-5)	2.50 (2-3.5)	3.30 (3-4)	4.20 (4-5)	4.50 (3.5-5)	5.00 (4-6)	19.50	52.60 (51-54)	56.00 (54-58)
Cyperus iria	0.00	-	0.00	0.00	0.00	0.00	0.50 (0-1)	-	21.50 (20-23)	30.60 (28-32)
Fimbristylis miliacea	0.00	-	0.00	0.00	0.00	0.00	0.60 (0-1)	-	20.30 (18-21)	28.20 (27-29)
Cyperus rotundus	0.00	-	0.00	0.00	0.00	0.00	0.80 (0-2)	-	31.00 (30-32)	34.50 (35-36)
Camelina sp.	0.00	-	0.00	0.00	0.00	0.00	0.00	-	5.40 (4-7)	11.00 (10-13)
Ludwigia parvifolia	0.00	-	0.00	0.00	0.00	0.00	0.00	-	7.50 (6-9)	10.50 (9-12)
Monocoria vaginalis	0.00	-	0.00	0.00	0.00	0.00	0.00	-	4.70	10.00
Brachmea ramosa	0.00	-	0.00	0.00	0.00	0.00	0.00	-	10.50 (9-12)	15.40 (14-16)
Cyperus diformis	0.00	-	0.00	0.00	0.00	0.00	0.80 (0-2)	-	29.20 (27-31)	38.30 (37-41)
Panicum repens	1.00 (0-3)	-	0.80 (0-2)	1.00 (0-2)	1.00 (0-2)	1.20 (1-2)	1.80 (1-2)	-	38-50 (37-41)	45.40 (43-47)

* Means of five replications.

followed by Jyothi (71.0 days), Karthika (70.8 days), Pavizham (70.7 days) and Jaya (70.4 days) in the descending order. It is observed that in the very old male and female adults in which the oviposition period is over, there is a distinct colour change of white to yellow on the ventral side of the abdomen. The females can be distinguished from males by their pointed abdomen as compared to the swollen rounded cup shaped abdominal tip of the males. The statistical analysis of the data on biological observations of rice bug on different varieties indicated that there is no significant difference between the different growth stages of the bug in the different varieties.

Effect of different weeds as hosts on the biology and survival of *L. acuta*

The studies show (Table 2), out of eleven species of weeds used as hosts, *L. acuta* can complete its life cycle on *Echinochloa colonum* and *Echinochloa crusgalli* only. A female bug lays on an average 61 eggs on *E. colunum* and 59 eggs on *E. crusgalli*. The incubation period is 5 days on an average (range is 4 - 6 days) on *E. colonum* and 4.5 days (range 3 - 5 days) on *E. crusgalli*. The different instars of nymphs survive and moult to the next instars, the mean durations of the first, second, third, fourth and fifth instar being 3.2, 3.5, 3.3, 4.0 and 4.5 days in E. colonum and 2.5, 3.3, 4.2, 4.5 and 5.0 in E. crusgalli respectively. The total nymphal period lasts for 19 days on an average (15.5 to 21.5 days) on E. colonum and 19.5 days (16.5 to 23.5 days) on E. crusgalli. Regarding the longevity, the female bugs live on an average of 58.50 days on E. colonum and 56.00 days on E. crusgalli. The male bugs live on average of 54.20 days on E. colonum and 52.60 days on E. crusgalli.

On the other weeds namely, Cyperus iria, Cyperus rotundus, Fimbristylis miliacea, Ludwigia parvifolia, Monocoria vaginalis, Brachmea ramosa, Cyperus diformis, Camelina sp. and Panicum repens none of the stages of the nymphs survive on them. However, two pairs of bugs are found to mate on the weed Panicum repens and 0 - 3 eggs are laid, but the eggs failed to hatch.

Different nymphal instars also survive for 1 - 2 days on P. repens, but die without moulting. Tho fifth instar nymphs of L. acuta survive for 1 - 2 days on the weeds Cyperus iria, Fimbristylis miliacea, Cyperus rotundus and Cyperus diformis but there is no further development towards adulthood.

The adult longevity is found to vary from 4.7 days to 38.5 days in the case of males and from 10 days to 45.4 days

Table 3. Damage caused by *L. acuta* to rice grain when exposed to infestation at different occasions after flowering.

Days after flowering	Per cent chaff formed		Treatment means for comparison	Mean stylet sheath number
	Exposed to bug	Control		
3	6.97 (9.99)	6.42 (8.03)	(9.01)	0.00
5	11.17 (15.42)	10.04 (7.39)	(11.41)	0.00
10	27.70 (31.51)	8.90 (17.47)	(24.49)	16.70
15	49.26 (44.81)	7.98 (16.43)	(30.62)	38.20
20	4.50 (11.76)	3.20 (10.27)	(11.02)	1.30
25	5.00 (12.56)	5.04 (12.67)	(12.61)	0.00
30	4.17 (11.47)	3.50 (10.93)	(11.21)	0.00
Mean	(19.64)	(11.88)		

C.D. (1) Between days = 9.7784 (2) Treatment vs. Control = 5.2268

Values in parentheses indicate angles.

A N O V A

Source	df	ss	MSS	f
Treatments	13	4097.80	315.22	4.60
A	1	632.18	632.18	6.06
B	6	2488.01	414.67	9.24
A x B	6	977.61	162.94	2.38
Error	28	1914.95	68.39	
Total	41	6012.75		

S.E. = 4.776

C.D.(A) = 5.227

C.D.(B) = 9.778

C.D. (AxB) = 13.829

in the case of females on the various weeds. The adult longevity is observed to be highest on <u>Panicum repens</u> where the male bugs live for 38.5 days on an average and the female bugs for 45.4 days. This weed was followed by <u>Cyperus rotundus</u> and <u>Cyperus diformis</u> where the male and female bugs live for an average of 31.0 to 29.2 days and 34.5 to 38.3 days respectively. In the case of <u>Fimbristylis meliacea</u> and <u>Cyperus iria</u> longevity of adult male varies from 20.3 to 21.5 days on an average and that of adult female from 28.2 to 30.6 days respectively. In the weeds <u>Camelina</u> sp. <u>Ludwigia parvifolia</u>, <u>Monocoria vaginalis</u> and <u>Brachemea ramosa</u> the longevity is low being 4.7 days to 10.5 days in the case of males and 10 to 15.4 days in the case of female bugs.

<u>Relative susceptibility of rice earheads to attack by L. acuta at different stages after flowering</u>

Results presented (Table 3) show that the maximum number of chaff produced as a result of attack by the adult bug is when the earheads are subjected to attack by the bugs on the 10th and 15th day after flowering. The mean chaff produced by the bug is 27.7 per cent on the 10th day as against 8.9 per cent in control (free from bug infestation) and 49.26 per cent on 15th day as against 7.98 per cent in control. It is thus indicated that the period from 10th to 15th day after flowering is the most vulnerable stage for the attack by the pest.

Table 4. Grain and chaff yield caused by different population of rice bug infesting the earhead

No. of bugs per sq.m.	Mean grain yield (g)	Mean quantity of chaff (g)	Total yield (2+3)	Actual yield* (if protected)	Gain in yield (g)	% yield reduction	Benefit/@ cost ratio for control operations (per ha)
1	2	3	4	5	6	7	8
0	350	20	370	350	0	-	-
1	292	28	320	300	50	8.75	4.72
2	261	55	316	296	54	17.41	5.04
3	142	125	267	247	103	46.82	9.72
4	100	155	255	235	115	60.78	10.85

* Quantity of chaff at '0' level reduced from all values

@ Cost involved for the plant protection operations (per hectare) = Rs. 211/-

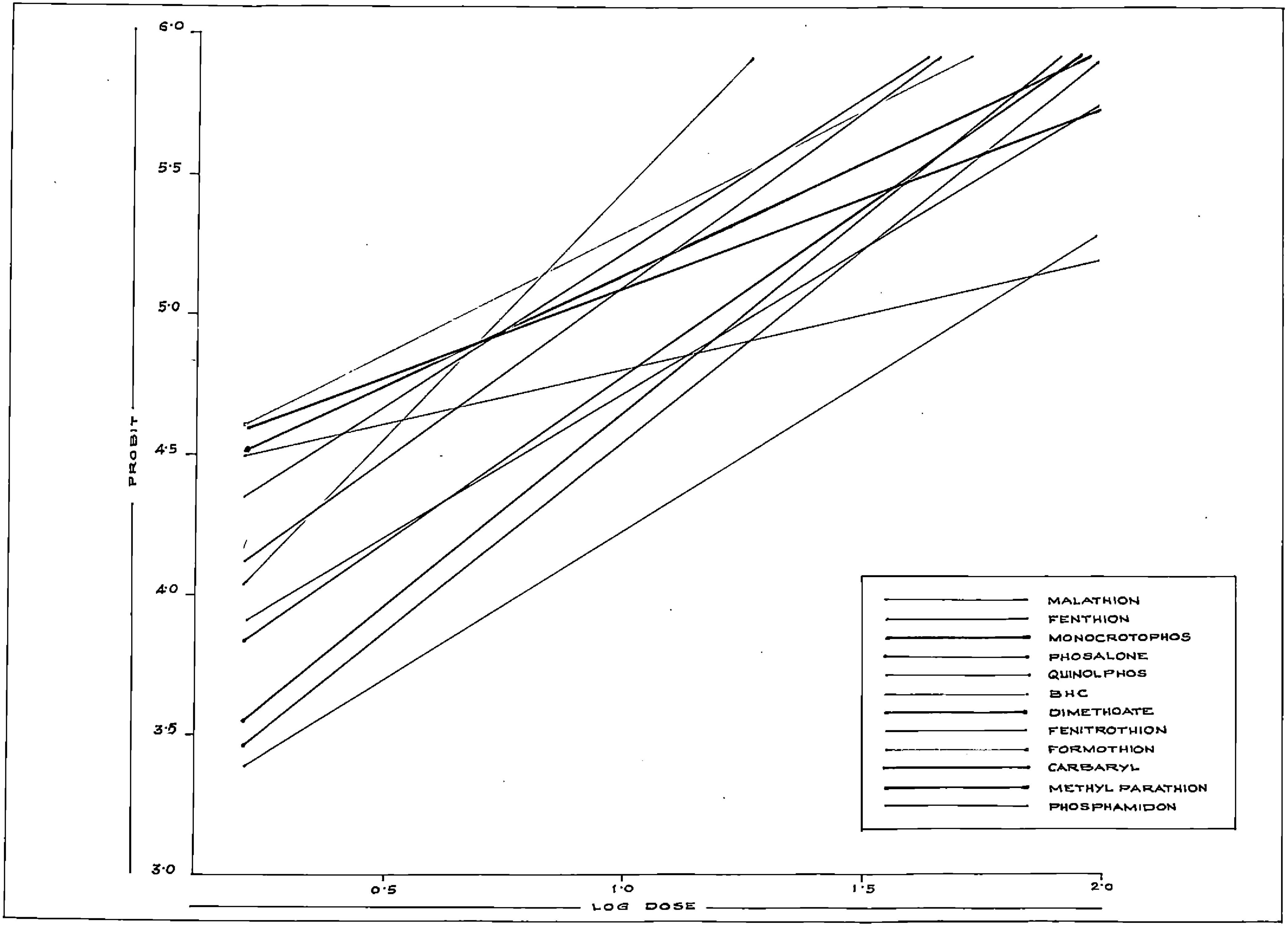
Cost of paddy per kg = Rs. 2/-

Presence of stylet sheaths indicating feeding by the bug on the grains is also seen only on the grains exposed to the bugs on the 10th and 15th day, the mean number of stylet sheath being 16.7 and 38.2 respectively. On the 20th day the number of stylet sheath is very low (1.3 on average). No stylet sheath could be detected on the other occasions.

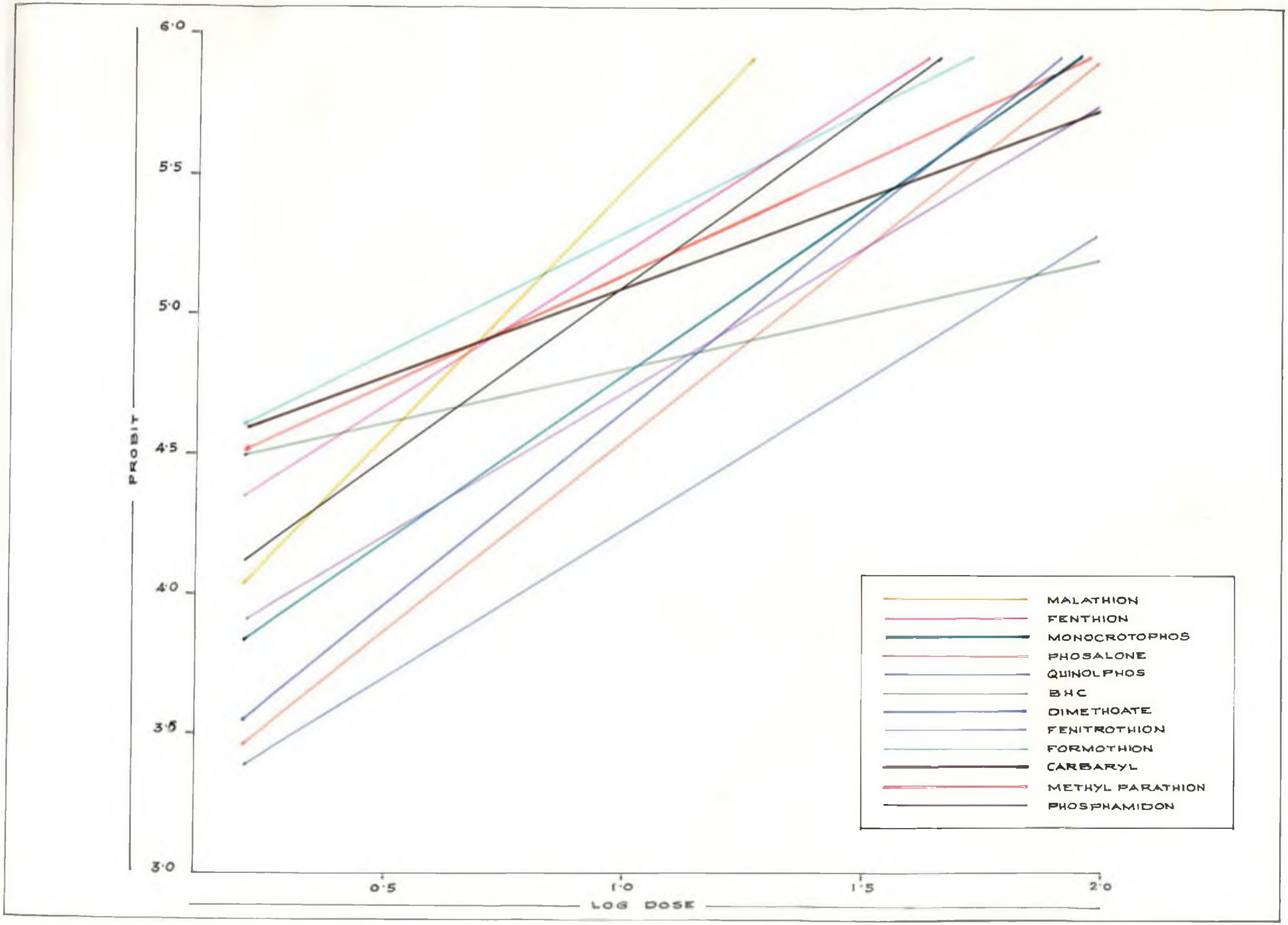
Determination of economic threshold level of *L. acuta* in the field

The results (Table 4) indicate that the yield in the plots completely protected from the bug infestations is maximum with an average of 350 g grains and 20 g of chaff per 1 sq.m of crop. In the plots infested with different population levels of 1, 2, 3 and 4 bugs per plot, the mean grain yields are 292, 241, 142 and 100 g and chaff 28, 55, 125 and 155 g respectively. It is also seen that the percentage reduction in grain yield due to the infestation levels of 1, 2, 3 and 4 bugs/sq.m is 8.75, 17.41, 46.82 and 60.78 respectively. If the crop is protected completely from infestation the gain in yield due to the control operations would be 50 to 115 g per plot as calculated from the above values. The benefit-cost ratio then works out to 4.74, 5.04, 9.72 and 10.85 for the population at 1, 2, 3 and 4 bugs per plot respectively.

Fig. 1. Log dose - probit mortality relationship between different insecticides and adults of rice bug *L. acuta*.



PROBIT
6·0
5·5
5·0
4·5
4·0
3·5
3·0
0·5
1·0
1·5
2·0
LOG DOSE
MALATHION
FENTHION
MONOCROTOPHOS
PHOSALONE
QUINOLPHOS
BHC
DIMETHOATE
FENITROTHION
FORMOTHION
CARBARYL
METHYL PARATHION
PHOSPHAMIDON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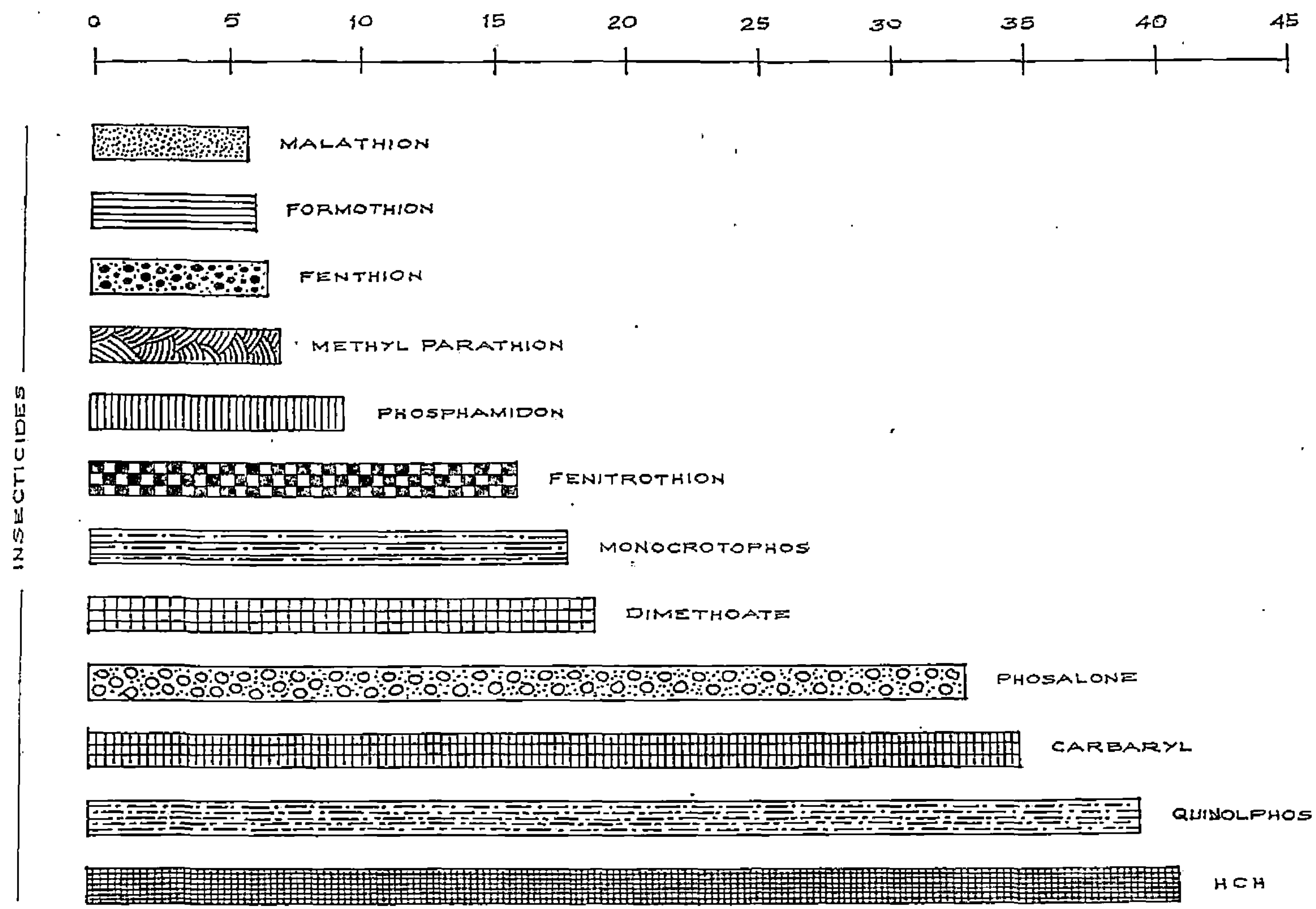
LOG DOSE
MALATHION
FENTHION
MONOCROTOPHOS
PHOSALONE
QUINOLPHOS
BHC
DIMETHOATE
FENITROTHION
FORMOTHION
CARBARYL
METHYL PARATHION
PHOSPHAMIDON

Table 5. Relative toxicity of different insecticides to the adults of rice bug, L. acuta.

Insecticide formulations	Heterogeneity	Regression equation	LC_{50}	Fiducial limits	Relative toxicity
HCH	$x^2 = 2.43$	$y = 1.14x + 3.1609$	0.04180	0.03670 & 0.04872	1
Sevin (carbaryl)	$x^2 = 0.89$	$y = 0.394x + 4.772$	0.03540	0.01853 & 0.4214	1.18
Metacid (methyl parathion)	$x^2 = 1.35$	$y = 1.0357x + 4.107$	0.00729	0.005272 & 0.009350	5.74
Malathion (malathion)	$x^2 = 2.21$	$y = 1.728x + 3.691$	0.00575	0.00475 & 0.00624	7.26
Zolone (phosalone)	$x^2 = 1.46$	$y = 0.996x + 3.491$	0.03282	0.02532 & 0.05162	1.27
Lebaycid (fenthion)	$x^2 = 1.52$	$y = 0.937x + 4.276$	0.00592	0.004821 & 0.006781	7.06
Dimecron (phosphamidon)	$x^2 = 1.68$	$y = 1.392x + 3.643$	0.00952	0.007515 & 0.00994	4.39
Nuvacron (monocrotophos)	$x^2 = 0.98$	$y = 9076x + 3.241$	0.01762	0.01021 & 0.02472	2.37
Ekalux (quinalphos)	$x^2 = 1.31$	$y = 1.327x + 2.894$	0.03911	0.01911 & 0.04921	1.07
Anthio (formothion)	$x^2 = 0.98$	$y = 0.9101x + 4.317$	0.00583	0.004926 & 0.00692	7.42
Rogor (dimethoate)	$x^2 = 1.39$	$y = 1.325x + 3.315$	0.01864	0.01364 & 0.02281	2.24
Sumithion (fenitrothion)	$x^2 = 2.01$	$y = 1.424x + 3.288$	0.01603	0.01137 & 0.02137	2.61

Fig. 2. LC_{50} values of different insecticides against adults of *L. acuta*.



0
5
10
15
20
25
30
35
40
45
INSECTICIDES
MALATHION
FORMOTHION
FENTHION
METHYL PARATHION
PHOSPHAMIDON
FENITROTHION
MONOCROTOPHOS
DIMETHOATE
PHOSALONE
CARBARYL
QUINOLPHOS
HCH

Relative toxicity of different insecticides to L. acuta

Results (Table 5, Fig. 1 and 2) show that malathion is the most highly toxic to the bug with an LC_{50} value of 0.00575 followed in the decreasing order by formothion (0.00583), fenthion (0.00592), methyl parathion (0.00729), phosphamidon (0.00952), fenitrothion (0.01603), monocrotophos (0.01762), dimethoate (0.01864), phosalone (0.03282), carbaryl (0.03540), quinalphos (0.03911), and HCH (0.04180) when their formulations are used against L. acuta. Taking HCH as the standard the insecticides carbaryl, methyl parathion, malathion, phosalone, fenthion, phosphomidon, monocrotophos, quinalphos, formothion, dimethoate and fenitrothion are 1.18, 5.74, 7.26, 1.27, 7.06, 4.39, 2.37, 1.07, 7.42, 2.24 and 2.61 times as toxic as HCH to the bug, respectively.

Persistent toxicity of different insecticides to L. acuta when applied as sprays on plants

Results (Table 6, Fig. 3) show that three days after spraying methyl parathion causes the maximum mortality of 57.49% followed by malathion (54.45%). All the other insecticides produce mortalities ranging from 44.33 to 47.75% are found to be on par.

After five days of treatment malathion, methyl parathion, fenthion and phosphamidon gave the percentage mortality ranging from 46.64 to 51.86. This is followed by phosalone (44.34) which is on par with all the other insecticides.

Table 6. Per cent mortality of L. acuta when exposed to rice plants at different intervals (days)* after spraying with different insecticides

Insecticide	Days after spraying								PT Index
	3 (1)	5 (2)	7 (3)	10 (4)	14 (5)	18 (6)	21 (7)	25 (8)	
Quinalphos	44.34	42.11	36.38	8.47	0	0		0	360.00
Formothion	47.75	41.01	37.58	31.03	18.81	0		0	508.76
Phosalone	47.75	44.34	34.95	36.38	8.47	0		0	540.40
Malathion	54.45	51.86	47.75	44.34	42.11	36.11	1.03	8.50	1092.75
Fenthion	47.75	46.64	43.23	39.89	32.42	30.55	8.50	0	802.41
Dimethoate	44.34	39.81	31.70	8.47	0	0	0	0	367.50
Phosphamidon	47.75	46.64	42.11	36.38	30.55	27.29	8.47	0	726.81
Fenitrothion	44.33	43.27	36.53	35.00	20.69	0	0	0	530.04
BCH	42.12	43.27	37.58	29.16	8.47	0	0	0	530.04
Carbaryl	45.44	41.01	37.58	30.55	8.47	0	0	0	456.68
Methyl parathion	57.49	48.90	46.60	42.11	39.75	32.42	31.03	27.29	1281.25
Monocrotophos	44.34	42.12	42.11	35.00	10.34	0	0	0	540.00
C.D.	3.72	6.35	5.27	11.20	18.08	3.97	10.09	7.43	-

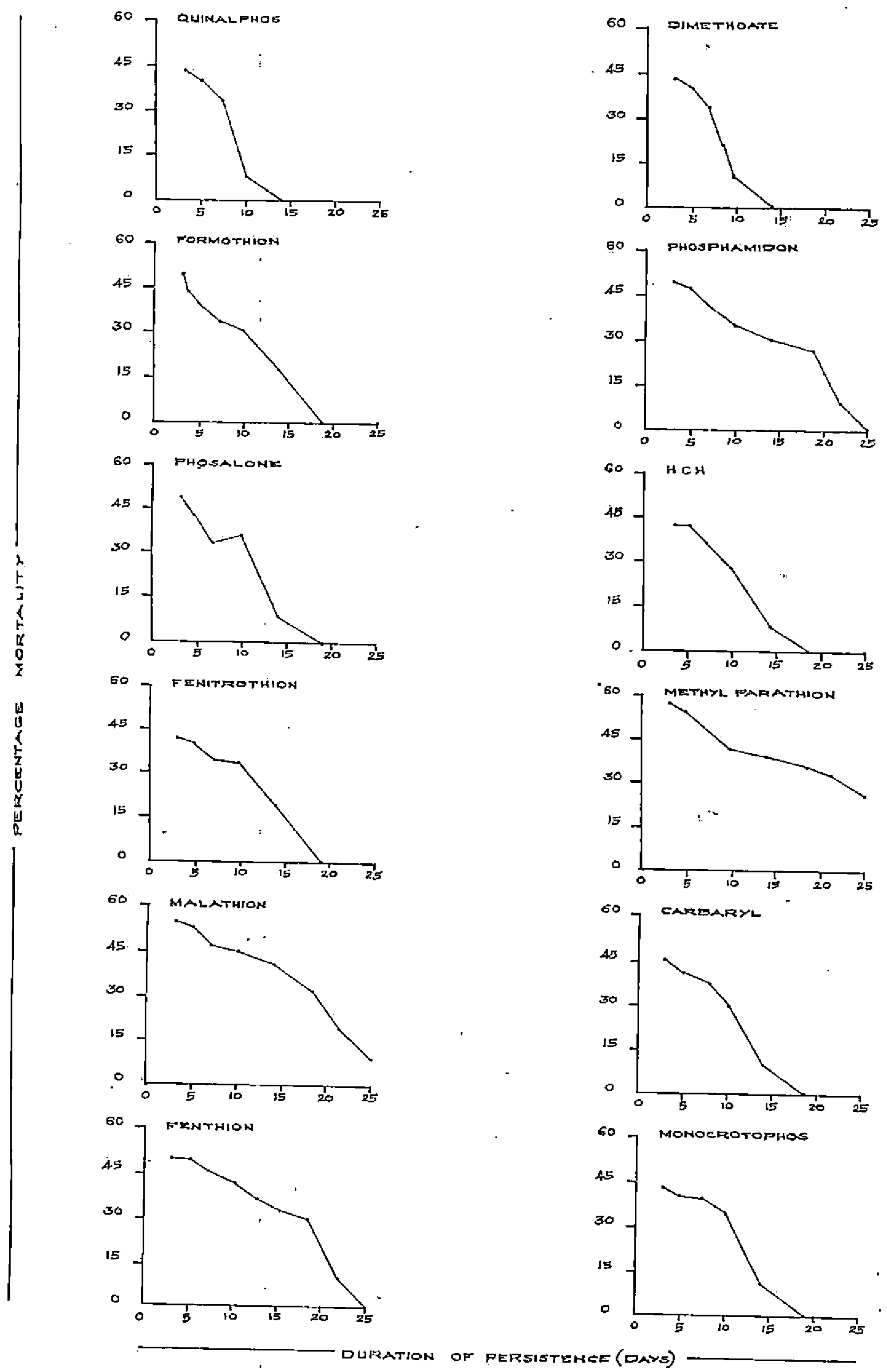
* Means of three replication of percentage mortality.

A N O V A

	Source	df	ss	MSS	f
(1)	Replication	2	3.90	1.95	0.404
	Treatment	11	396.91	36.08	7.47
	Error	22	106.27	4.83	
	Total	35	507.09		
(2)	Replication	2	9.26	4.63	0.329
	Treatment	11	428.34	38.94	2.767
	Error	22	309.64	14.07	
	Total	35	747.24		
(3)	Replication	2	38.57	19.29	1.994
	Treatment	11	742.63	67.51	6.98
	Error	22	212.73	9.67	
	Total	35	993.93		
(4)	Replication	2	704.00	352.00	3.089
	Treatment	11	7215.33	655.94	5.766
	Error	22	2506.84	113.95	
	Total	35	10426.17		

	Source	df	ss	MSS	f
(5)	Replication	2	82.27	41.14	0.9400
	Treatment	11	4459.98	405.45	9.26
	Error	22	962.71	43.76	
	Total	35	5504.96		
(6)	Replication	2	22.74	11.37	2.073
	Treatment	11	8106.57	736.96	134.399
	Error	22	120.63	5.483	
	Total	35	8249.95		
(7)	Replication	2	222.13	111.06	3.130
	Treatment	11	5147.32	467.94	13.110
	Error	22	780.46	35.48	
	Total	35	6149.92		
(8)	Replication	2	29.92	14.96	0.7766
	Treatment	11	2130.95	193.72	10.04
	Error	22	424.42	19.29	
	Total	35	2585.30		

Fig. 3. Persistent toxicity of different insecticides sprayed against adults of *L. acuta*.


PERCENTAGE MORTALITY
QUINALPHOS
DIMETHOATE
FORMOTHION
PHOSPHAMIDON
PHOSALONE
HCH
FENITROTHION
METHYL PARATHION
MALATHION
CARBARYL
FENTHION
MONOCROTOPHOS
DURATION OF PERSISTENCE (DAYS)

Seven days after treatment also a similar trend is shown by malathion, methyl parathion and fenthion with mortality ranging from 43.23 to 47.75%. This is followed by monocrotophos and phosphamidon (each with 42.11%) and formothion, carbaryl and HCH each with 37.58% mortality. Fenitrothion, quinalphos, phosalone and dimethoate produce least mortality of 31.70 to 36.38%.

After ten days of the treatment though malathion, methyl parathion and fenthion give 39.89 to 44.34% mortality of the bugs, they are on par with phosphamidon, phosalone, monocrotophos and fenitrothion with mortalities of 35.00 to 36.38%. Formothion, carbaryl and HCH produce low mortality of 29.16 to 31.03 and are on par. Quinalphos and dimethoate are the least toxic on the tenth day.

Almost a similar trend is revealed by the various insecticides on the 14th day after spraying with malathion, methyl parathion, fenthion and phosphamidon, producing mortalities of 30.55 to 42.11%. Formothion, fenitrothion, monocrotophos, phosalone, carbaryl and HCH give mortalities of 8.47 to 20.69% and are on par. Quinalphos and dimethoate have completely lost their toxicity.

On the 18th day after spraying, malathion, methyl parathion, fenthion and phosphamidon show persistent toxicity giving mortalities of 27.29 to 36.11%. They show 8.47 to

Table 7. Per cent reduction in rice bug population in field caused by different insecticide sprays at different intervals after spraying*

Insecticide	Dosage %	1st pre-count	Treatment 1st spraying: Days after spraying 1	3	4	2nd pre-count	Treatment 2nd spraying: Days after spraying 1	3	4	Grain yield	Grain chaff ratio	Cost benefit ratio for control operations
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)		
Malathion	0.1	70	75.72	77.13	86.60	22	90.70	95.76	97.15	200.00	6.00:1	1: 9.525
Methyl parathion	0.05	61	72.71	76.08	78.36	30	92.62	93.52	94.76	180.00	5.00:1	1:11.25
Fenthion	0.1	50	69.92	64.92	64.09	50	68.62	84.36	91.85	180.00	7.50:1	1: 6.25
Phosphamidon	0.05	53	68.98	57.09	59.98	52	66.05	67.87	81.35	170.00	4.10:1	1:11.25
Fenitrothion	0.1	57	69.98	64.92	56.00	48	65.32	70.16	79.20	170.00	4.00:1	1: 6.25
Monocrotophos	0.05	52	56.59	59.55	49.12	40	66.62	71.09	77.78	160.00	3.00:1	1: 6.4
Phosalone	0.07	57	49.13	52.65	48.59	69	72.52	75.44	77.75	150.00	2.60:1	1: 6.3
Dimethoate	0.05	70	47.37	52.79	48.59	50	66.67	68.79	74.64	150.00	3.10:1	1: 6.8
Formothion	0.05	51	40.26	48.91	29.27	48	63.13	66.67	72.13	150.00	3.50:1	1: 5.95
Quinalphos	0.05	52	36.69	28.22	24.95	50	59.60	67.29	70.94	150.00	1.85:1	1: 6.25
Carbaryl	0.2	65	26.30	28.07	19.03	52	63.31	67.61	70.00	148.33	2.85:1	1: 3.2
HCH	0.2	57	16.55	14.55	3.80	39	59.60	64.28	67.65	100.00	1.2 :1	1: 3.95
Control	--	57	16.23	1.65	3.09	42	5.14	11.74	14.79	70.00	0.55:1	--
C.D.	--	--	7.43	6.47	8.29	--	10.63	5.40	6.79	22.90	--	--

* Means of three replications

ANOVA

	Source	df	ss	MSS	f
(2)	Replication	2	100.09	50.05	2.538
	Treatment	12	24789.40	2065.78	104.78
	Error	24	473.15	19.71	
	Total	38	25362.64		
(3)	Replication	2	89.83	44.91	3.04
	Treatment	12	19538.71	1628.23	110.35
	Error	24	354.12	14.755	
	Total	38	19982.66		
(4)	Replication	2	56.53	28.27	1.167
	Treatment	12	26393.96	2199.497	90.83
	Error	24	581.194	24.22	
	Total	38	27031.70		
(6)	Replication	2	106.60	53.30	1.34
	Treatment	12	17381.75	1448.48	36.40
	Error	24	954.97	39.79	
	Total	38	18443.32		

	Source	df	ss	MSS	f
(7)	Replication	2	39.02	19.54	1.9007
	Treatment	12	14666.74	1222.23	118.88
	Error	24	246.75	10.28	
	Total	38	14952.57		
(8)	Replication	2	20.196	10.09	0.0622
	Treatment	12	16315.85	1359.65	83.81
	Error	24	389.35	16.22	
	Total	38	16725.33		
(9)	Replication	2	3886.77	1943.39	10.100
	Treatment	12	15671.95	1305.99	6.787
	Error	24	4617.895	192.412	
	Total	38	24176.57		

31.03% mortality on the 21st day. Methyl parathion produces 27.29% mortality in comparison to malathion with a mortality of 8.5% on the 25th day after the treatment.

The PT index calculations have shown (Table 6) that methyl parathion is most highly persistent with a PT index of 1281.25 followed by malathion (1092.75), fenthion (802.41), phosphamidon (726.81), phosalone (540.40), monocrotophos (540.00), fenitrothion (530.04), formothion (508.76), carbaryl (466.20), HCH (456.68), dimethoate (367.50) and quinalphos (360.00) in the decreasing order.

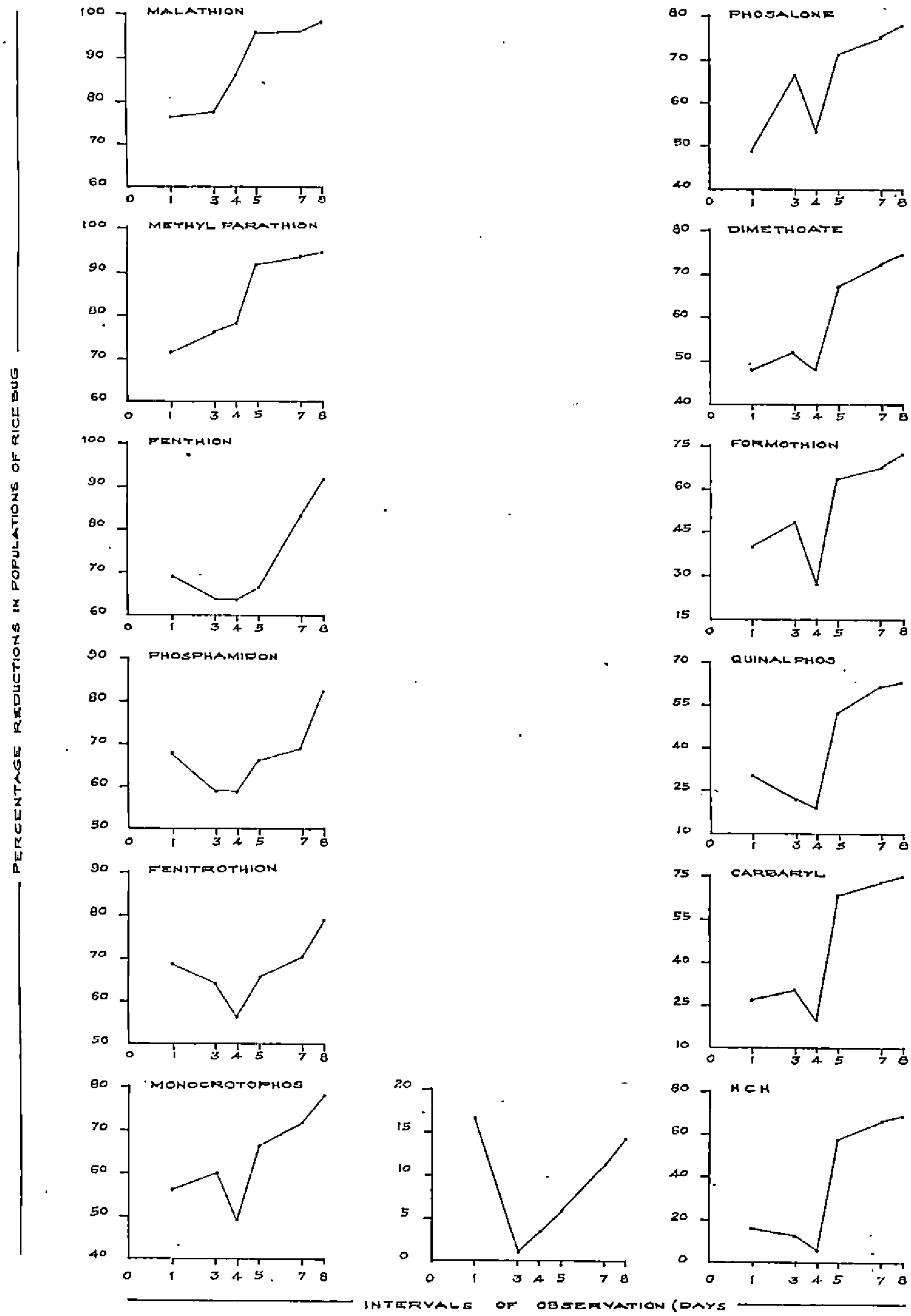
<u>Relative efficacy of insecticides in controlling infestation in the field</u>

Two field experiments are conducted to assess the effectiveness of different insecticides (Tables 7 & 8) in controlling <u>L. acuta</u>. The insecticides are applied as sprays at their recommended field doses, in fields infested heavily with the bug and results are assessed in terms of per cent reduction of the insect population due to the spraying i.e. reduction over pre-application populations.

In the first experiment (Table 7, Fig. 4) one day after the treatment all insecticides are found to reduce the bug population significantly. Among the different insecticides

Fig. 4. Per cent reduction of rice bug population in field caused by different insecticides at different intervals after spraying. (Expt. I)

EXPERIMENT - I



malathion was the most efficacious in controlling the pest closely followed by methyl parathion, fenitrothion, fenthion and phosphamidon all of which are statistically on par with malathion in their effect. Next in efficacy rank monocrotophos, phosalone, dimethoate and formothion. Comparatively quinalphos, carbaryl and HCH are significantly less effective in controlling the pest.

The percentage reductions in the population of the bugs on the third day after the treatment vary from 1.65% to 77.13%. Malathion gave the highest population reduction followed in the decreasing order by methyl parathion, fenthion, fenitrothion, monocrotophos, phosphamidon, dimethoate, phosalone, formothion, quinalphos, carbaryl and HCH, the reduction varying from 76.08% to 14.55%.

It is observed that on the fourth day after treatments the population of the rice bug show an increasing trend over the previous populations under all the treatments except malathion, methyl parathion and phosphamidon. Malathion and methyl parathion are found to be statistically on par in reducing the rice bug populations and are still showing significantly high reductions. HCH is on par with control. So following the principle of need based application of insecticides a second spraying is given on the fourth day following the first application.

One day after the second spraying the percentage population reductions show that malathion and methyl parathion are the best insecticides causing maximum population reductions of rice bug followed by phosalone, fenthion, dimethoate, monocrotophos, phosphamidon, fenitrothion, carbaryl, formothion, quinalphos and HCH in the decreasing order. Here all insecticides are observed to be significantly superior over control.

The insecticides malathion and methyl parathion are found to be producing highest population reductions of rice bug on the 3rd day after the 2nd spraying also. This is found to be followed by fenthion, phosalone, monocrotophos, fenitrothion, dimethoate, phosphamidon, carbaryl, quinalphos, formothion and HCH in the descending order. All the treatments were found to be superior to control.

The percentage population reductions on the 4th day after the 2nd spraying follow the same trend as on the 3rd day with malathion, methyl parathion and fenthion giving maximum population reductions of the bug and is observed to be statistically on par. This is followed by phosphamidon, fenitrothion, monocrotophos, phosalone and dimethoate in the decreasing order and are found to be statistically on par. Formothion, carbaryl and HCH follow the other treatments in causing population reduction in the rice bug populations.

The data (Table 7) on the grain yields from the treated plots reveal that the highest yield is obtained in the malathion treated plots (200 g) which is statistically on par with the yields obtained from the methyl parathion and fenthion (180 g each) treated plots, followed by phosphamidon (170 g), fenitrothion (170 g), monocrotophos (160 g), phosalone (150 g), dimethoate (150 g), formothion (150 g), quinalphos (150 g) and carbaryl (148.33 g) treated ones which are found to be statistically on par among themselves. HCH treated plots give the grain yield of 100 g per plot and control treatments give the least grain yield of 70 g per plot.

Regarding the grain-chaff ratio, it is found to be maximum in the case of fenthion followed by malathion, methyl parathion, phosphamidon, fenitrothion, formothion, dimethoate, monocrotophos, carbaryl, phosalone, quinalphos, HCH and control.

The cost-benefit ratio reveal that methyl parathion and phosphamidon give the maximum returns (1 : 11.25) followed by malathion, dimethoate, monocrotophos, phosalone, fenthion, fenitrothion, quinalphos, formothion, HCH and carbaryl in the descending order, the ratio varying from 1 : 9.5 to 1 : 3.2.

In the second trial in which the population density of the bug is much less than in the first experiment (Table 8, Fig. 5) methyl parathion give the maximum population reduction of the bugs one day after the treatment and this is statistically

Table 8. Per cent reduction in rice bug population in field caused by different insecticide sprays at different intervals after spraying*

Insecticide	Dosage %	Pre-count	Days after spraying 1 (1)	3 (2)	4 (3)	5 (4)	7 (5)	9 (6)	Grain yield (7)	Grain: chaff ratio	Cost:benefit ratio for control operations
Malathion	0.1	11	63.03	67.40	68.50	71.02	81.72	90.61	310	11.20:1	1 : 29.50
Methyl parathion	0.05	10	63.13	63.40	66.21	72.58	81.72	82.72	300	10.69:1	1 : 37.50
Fenthion	0.1	11	54.60	63.43	69.55	69.55	72.58	81.72	295	10.37:1	1 : 20.38
Phosphamidon	0.05	10	49.50	49.56	50.00	60.66	60.66	70.00	250	8.4 :1	1 : 33.78
Fenitrothion	0.1	9	45.56	46.52	49.67	58.52	61.85	68.69	235	7.9 :1	1 : 19.45
Monocrotophos	0.05	10	43.14	45.90	49.30	62.42	62.42	68.19	235	6.7 :1	1 : 20.10
Phosalone	0.07	9	42.73	44.11	44.11	48.49	60.35	68.19	226	6.6 :1	1 : 16.80
Dimethoate	0.05	11	40.73	42.42	42.42	51.02	60.45	67.24	210	5.7 :1	1 : 17.50
Formothion	0.05	9	40.70	41.50	44.44	48.15	49.95	62.22	205	5.5 :1	1 : 14.85
Quinalphos	0.05	10	39.76	40.07	40.30	47.50	50.66	56.77	200	4.9 :1	1 : 16.67
Carbaryl	0.2	8	21.45	30.79	31.05	37.30	40.48	55.93	210	5.2 :1	1 : 17.50
HCH	0.2	9	15.28	20.50	29.43	29.69	36.84	44.60	150	2.5 :1	1 : 23.00
Control	--	12	-13.18	-7.54	-6.59	-5.59	12.78	15.08	105	1.2 :1	--
C.D.	--	--	23.38	16.25	22.35	15.72	13.31	12.34	24.25	--	--

* Means of three replications.

A N O V A

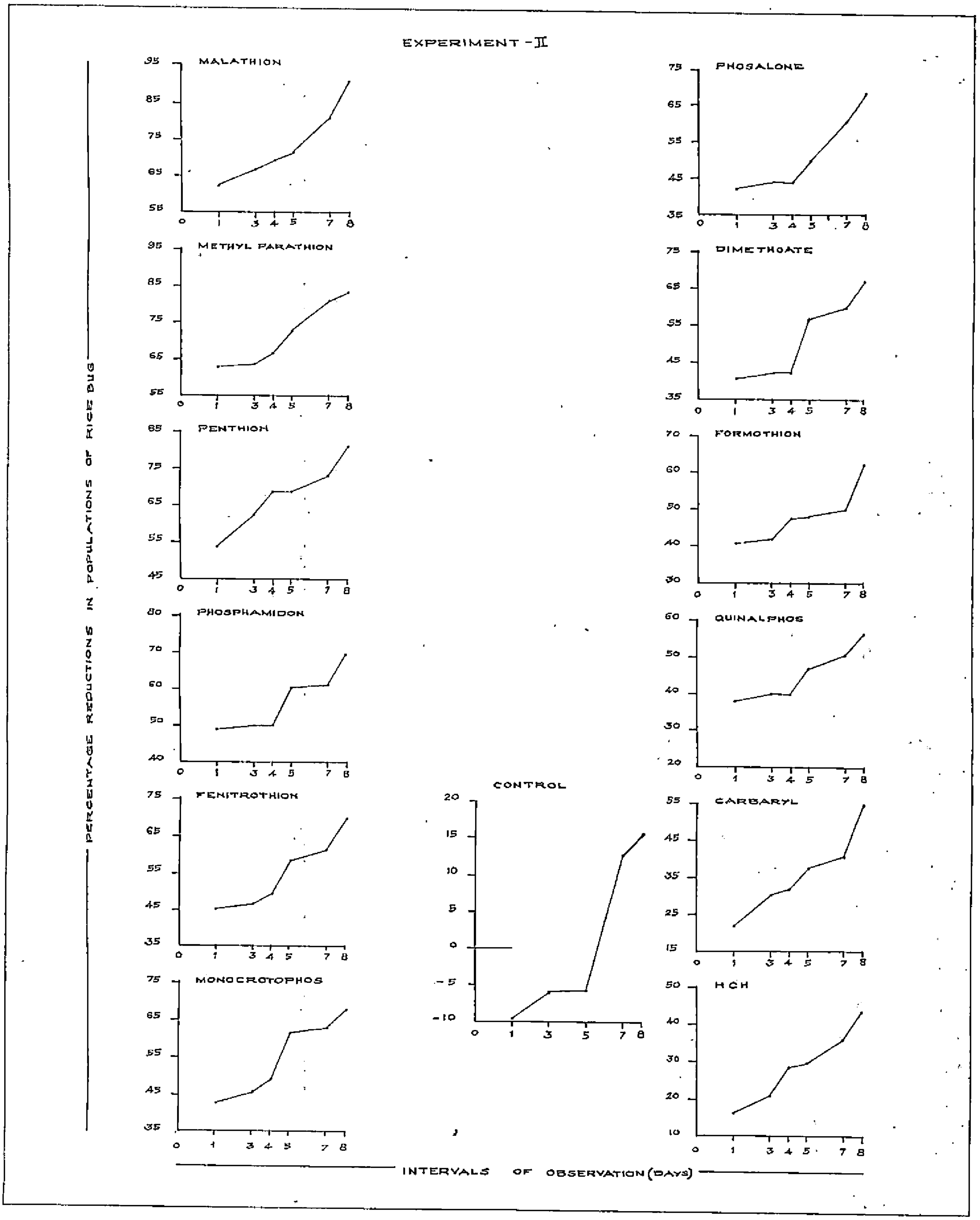
	Source	df	ss	MSS	f
(1)	Replication	2	3886.77	1943.39	10.100
	Treatment	12	15671.95	1305.99	6.787
	Error	24	4617.89	192.41	
	Total	38	24176.57		
(2)	Replication	2	419.58	209.79	2.256
	Treatment	12	9995.08	832.92	8.96
	Error	24	2230.99	92.96	
	Total	39	12645.65		
(3)	Replication	2	1902.67	951.33	5.410
	Treatment	12	1501.55	1251.46	7.118
	Error	24	4219.598	175.81	
	Total	38	21139.82		
(4)	Replication	2	375.71	187.85	2.159
	Treatment	12	15489.31	1290.60	14.840
	Error	24	2087.45	86.98	
	Total	38	17952.47		
(5)	Replication	2	51.96	25.98	4.166
	Treatment	12	21582.18	1781.85	28.57
	Error	24	1496.64	62.36	
	Total	38	22930.78		
(6)	Replication	2	12.937	6.468	0.168
	Treatment	12	24667.48	2055.62	37.112
	Error	24	1329.34	55.39	
	Total	39	26009.76		
(7)	Replication	2	97.44	48.72	0.235
	Treatment	12	70773.08	589.56	28.484
	Error	24	4969.23	207.05	
	Total	38	75839.74		

on par with malathion, fenthion, phosphamidon, fenitrothion, monocrotophos, phosalone, dimethoate, formothion and quinalphos. Carbaryl and HCH could produce only a low population reduction and are statistically on par. All insecticides are significantly superior to control.

The percentage reductions in the population of the bugs on the third day after the treatment was the maximum under malathion (67.4%) followed by fenthion, methyl parathion, phosphamidon, fenitrothion, monocrotophos, phosalone, dimethoate, formothion, quinalphos, carbaryl and HCH in the descending order; the reductions varying from 63.4 to 20.50%. Fenthion cause the maximum population reduction on the 4th day after the spraying followed by malathion, methyl parathion, phosphamidon, fenitrothion, monocrotophos, formothion, phosalone, dimethoate, quinalphos, carbaryl and HCH in the descending order the variation in the reduction being from 29.43 to 68.50.

The percentage reductions on the fifth day after the treatments reveal that methyl parathion cause the maximum population reduction of the bugs and is statistically on par with malathion (71.02%), fenthion (69.55%), monocrotophos (62.42%), phosphamidon (60.66%), fenitrothion (58.52%) and dimethoate (51.02%), phosalone (48.49%) and formothion (48.15%).

Fig. 5. Per cent reduction of rice bug population in field caused by different insecticides at different intervals after spraying.
(Expt. II)


EXPERIMENT - II
MALATHION
METHYL PARATHION
FENTHION
PHOSPHAMIDON
FENITROTHION
MONOCROTOPHOS
CONTROL
PHOSALONE
DIMETHOATE
FORMOTHION
QUINALPHOS
CARBARYL
HCH
PERCENTAGE REDUCTIONS IN POPULATIONS OF RICE BUG
INTERVALS OF OBSERVATION (DAYS)

Quinalphos and carbaryl are found to produce less reduction than the previously mentioned treatments while HCH is found to be causing the least population reductions (29.69%).

Malathion and methyl parathion are equally effective in reducing the population of rice bug on the seventh day after the treatments and they are statistically on par with fenthion (72.58%). The other insecticides monocrotophos, fenitrothion, phosphamidon, dimethoate, phosalone, quinalphos and formothion cause reductions varying from 62.42% to 49.95% and is found to be equal in effect statistically among themselves.

On the eighth day after the spraying the same trend is observed regarding the insecticides malathion, methyl parathion and fenthion, the percentage population reduction being 90.61, 82.72 and 81.72 respectively. The insecticides phosphamidon, fenitrothion, monocrotophos, phosalone, dimethoate and formothion are found to give a population reduction varying from 70.00 to 62.22%. Quinalphos, carbaryl and HCH are observed to produce least effect in the population reduction; however, they are found superior to control.

In the case of grain yields obtained from treated plots, the plots treated with malathion give highest yield (310 g), followed by methyl parathion (300 g), fenthion (295 g), phosphamidon (250 g), fenitrothion (235 g), monocrotophos (235 g), phosalone (226 g), dimethoate (210 g), carbaryl (210 g), formothion (205 g), quinalphos (200 g) and HCH (150 g). The yields obtained from all treated plots are found to be statistically superior than control.

The grain-chaff ratio worked out reveal that it is found to be higher in the case of malathion (11.20 : 1) followed by methyl parathion (10.69 : 1), fenthion (10.37 : 1), phosphamidon (8.4 : 1), fenitrothion (7.9 : 1), monocrotophos (6.7 : 1), phosalone (6.6 : 1), dimethoate (5.7 : 1), formothion (5.5 : 1), carbaryl (5.2 : 1), quinalphos (4.9 : 1), HCH (2.5 : 1) and control (1.2 : 1) in the descending order.

The cost : benefit ratio is worked out for all the different insecticide treatments. It is found that methyl parathion (1 : 37.5) gives highest cost / benefit ratio for control operations followed by phosphamidon, malathion, HCH, fenthion, monocrotophos, fenitrothion, dimethoate, carbaryl, phosalone, quinalphos and formothion in the descending order the ratios varying from 1 : 20.38 to 1 : 14.85.

Residues of insecticides in rice grain

Residues of three of the most effective insecticides under trial in the control of *L. acuta*, namely, malathion, fenthion and methylparathion remaining on the grains are estimated colorimetrically. From the results it is seen that

Table 9. Results of multiple linear regression analysis of population of rice bug on climatic factors.

Independent variables		Partial regression coefficients	S (b)	t values
Max. temp.	(x_1)	0.1181	0.79044	0.14941
Min. temp.	(x_2)	0.6803	1.07066	0.63540
Rainfall	(x_3)	0.0238	9.8649	2.4125*
R.H.	(x_4)	0.6371	0.48497	1.3159

* Significant at 5% level

Reg. Equation at 55% of the variation:

$$y = 54.4344 + 0.1181x_1 + 0.6803x_2 + 0.0238x_3 - 0.6371x_4 \quad (R^2 = 54.87)$$

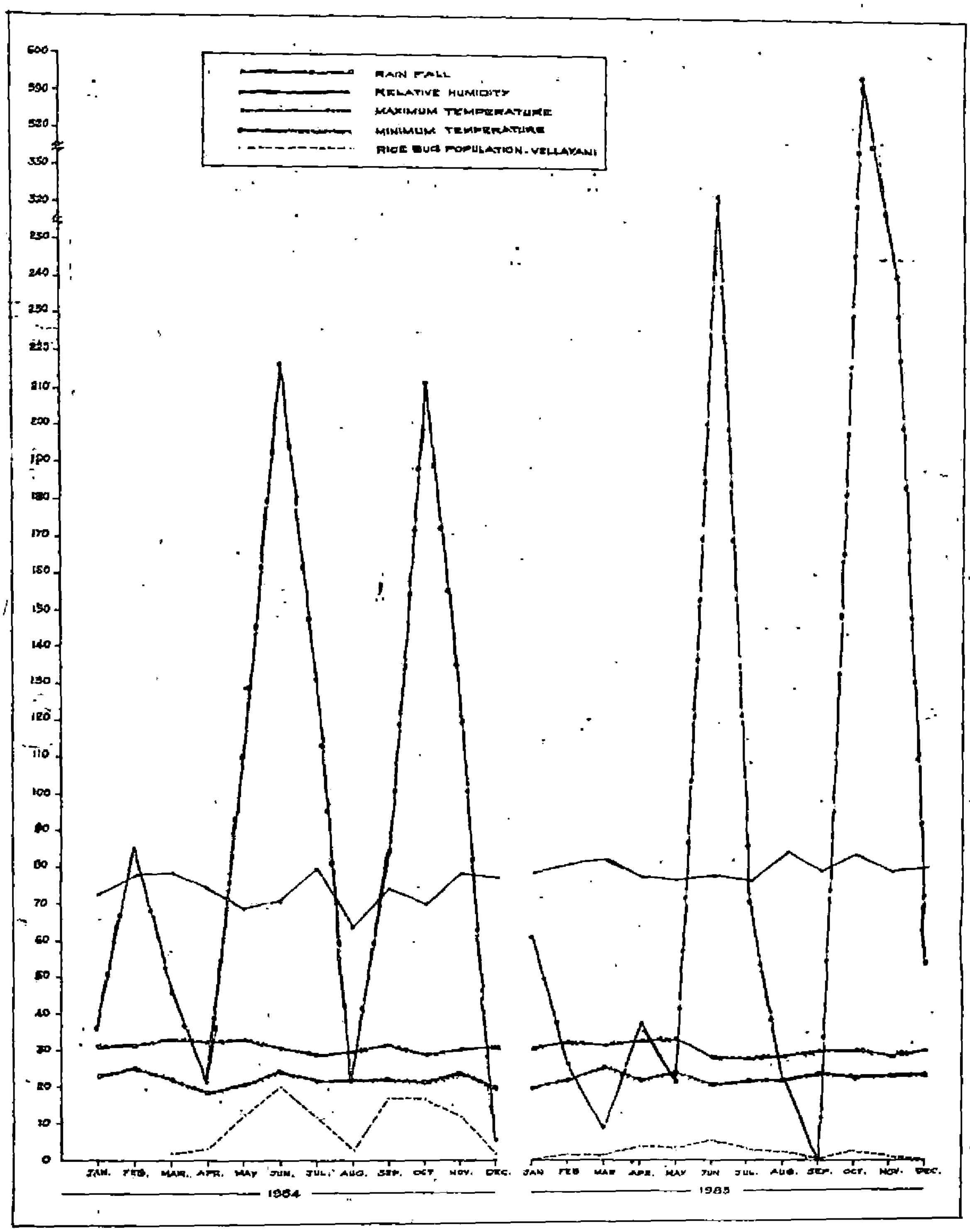
A N O V A

Source	df	SS	MSS	f
Total	11	181.229	16.48	
Regression	4	99.45	24.86	2.1280
Error	7	81.78	11.68	

S (b 1) = 0.7904, S (b 2) = 1.0706, S (b 3) = 9.8649, S (b 4) = 0.4849

(b 1) = 0.1181, (b 2) = 0.6803, (b 3) = 0.0238, (b 4) = -0.6371.

Fig. 6. Population fluctuations of _L. acuta_ with respect to the climatic variations in the fields of Vellayani.



RAIN FALL
RELATIVE HUMIDITY
MAXIMUM TEMPERATURE
MINIMUM TEMPERATURE
RICE BUG POPULATION - VELLAYANI
JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC.
1984
JAN FEB MAR APR. MAY JUN JUL. AUG. SEP. OCT. NOV. DEC.
1985

the residue levels of fenthion in the grains are 0.017 ppm on an average, the range being BDL* to 0.049 ppm. In malathion these values are 0.015 ppm and BDL to 0.039 ppm respectively. The residues of methyl parathion on the grains are found to be below detectable levels only.

Influence of climatic factors on the population fluctuations of *L. acuta* in the field

The results of studies undertaken at Vellayani on the multiple linear regression analysis between the population of rice bug in the field and the climatic parameters are given in Table 9, Fig. 6. The indications are that rainfall alone exerts significant effect on the population of the bug infesting the earheads in the field. Population of the bug is favoured by rainfall and the maximum number of adult bugs on the earheads is observed when the rainfall is high (Appendix I). The other climatic factors such as maximum and minimum temperatures and relative humidity do not show significant effect on the bug population eventhough positive correlation between the climatic factors and bug population is in evidence.

Observations made in other fields at the three Agricultural Sub-divisions of Trivandrum viz. Neyyattinkara, Chirayinkil and Nedumangad, also showed the heavy infestation of the rice earheads by the adult bug during high rainfall periods (Table 10, Fig. 7, Appendix II).

(* Below Detectable level)

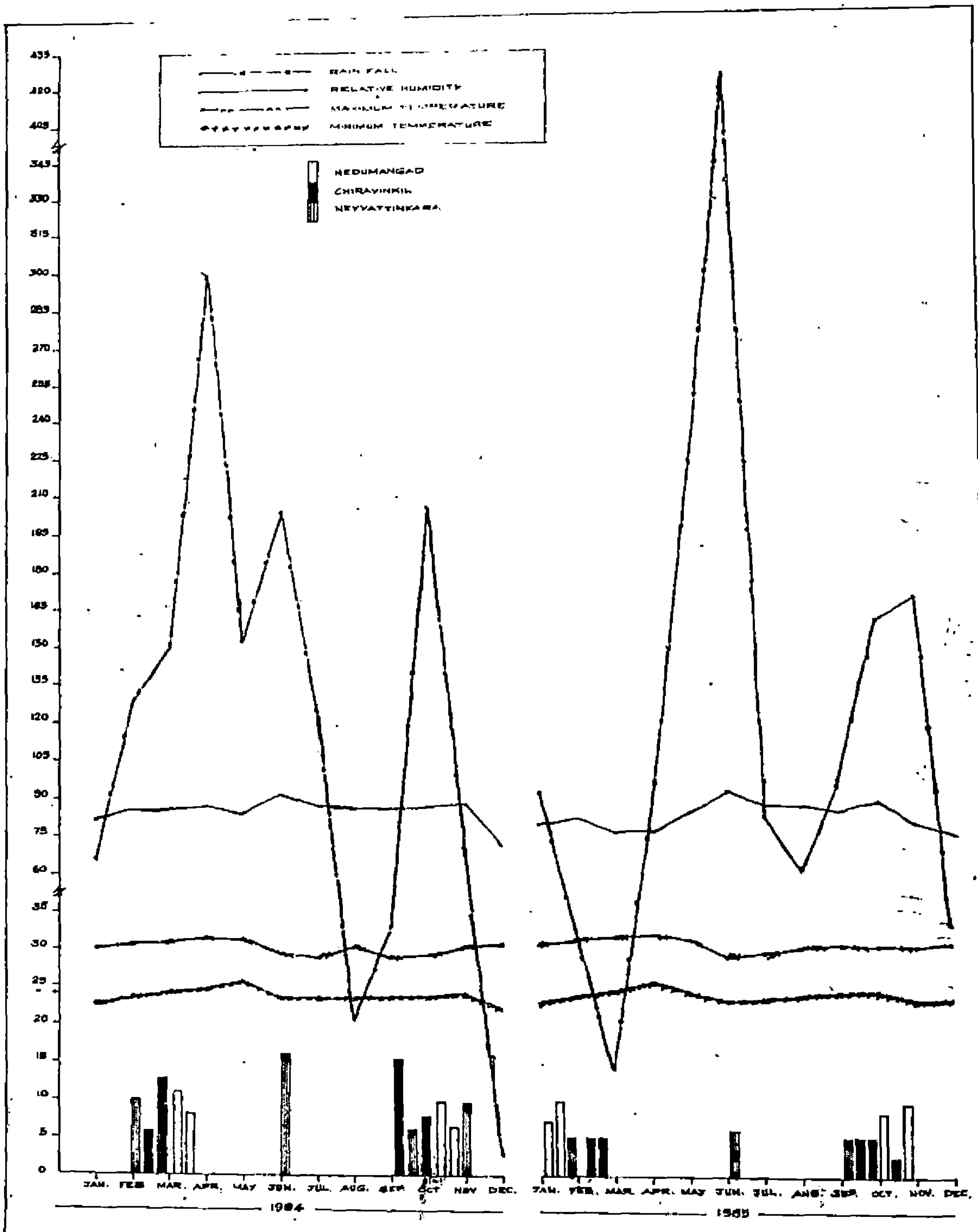
Table 10. Per cent loss in yield in local and high yielding hybrid varieties of rice due to infestation by L. acuta in different tracts and crops

Locality (Area)	Crop varieties and per cent loss							
	1984				1985			
	1st Crop	% loss	2nd Crop	% loss	1st Crop	% loss	2nd Crop	% loss
Kadakam Chirayinkil (15 ha)	Local Ptb-26, Ptb-2 (10)	60	Cheradi, Ptb-20, Kochuvithu (7)	100	Ptb-26, Ptb-2 (4)	20	Cheradi, Ptb-20, Ptb-2 (5)	90
	HYV Bharathi, Jaya (8)	25	Bharathi, Jaya, MO-6 (4)	100	Bharathi, Jaya (2)	30	Bharathi, Jaya, Vyttila 3 & 4 (2)	50
Kishuvalam Chirayinkil (135 ha)	Local Thavalakkanan, Ptb-2 (7)	75	Cheradi, Ptb-20, Lakshmi (12)	100	Ptb-2, Ptb-22 (4)	75	Cheradi, Ptb-20, Ptb-22, Lakshmi (5)	100
	HYV Bharathi, Jaya, Jyothi, MO-6, MO-5 (5)	20	Bharathi, Jyothi, MO-6, MO-7 (4)	50	Bharathi, Jyothi, MO-6 (1)	30	Bharathi, Jyothi, MO-6, MO-7 (3)	70
Kotoor Nedumangadu (5 ha)	Local Ptb-22, Ponni, Ptb-8, Ptb-2, Thulunadan (9)	30	Japancheradi, Kutticheradi, Koottumundakan (10)	50	Suryaprabha, Ptb-2, Thulunadan (6)	30	Japancheradi, Kutticheradi, Koottumundakan (5)	7
	HYV Absent		Absent		Absent		Absent	
Anakode Nedumangadu (10 ha)	Local Kochuvithu, Ptb-4 (7)	40	Ptb-22, Ptb-4, Kochuvithu (7)	50	Ptb-2, Kochuvithu (4)	20	Ptb-2, Ptb-20 (5)	60
	HYV H-4, Mashoori, Jyothi, IR-50 (4)	20	Bharathi, H-4 (4)	20	Mashoori, Bharathi (2)	10	Bharathi, Jyothi (2)	20
Marukil Neyyattinkara (35 ha)	Local Ptb-22, Ptb-2, Ponni, Surya (6)	40	Kutticheradi, Ptb-4, Japancheradi, Koottumundakan (10)	60	Ptb-22, Ptb-2, Ponni, Ptb-4 (4)	20	Ptb-2, Ptb-4, Kutticheradi (5)	50
	HYV Absent		Absent		Absent		Absent	
Pandarakalli Neyyattinkara (56 ha)	Local T-9, Kochuvithu (10)	20	Punja T-9, Kochuvithu (16)	80	T-9, Kochuvithu (2)	--	Punja T-9, Kochuvithu (5)	10
	HYV Bharathi, Jyothi, Jaya, Triveni (4)	10	Bharathi, Jyothi, Jaya, Triveni (7)	40	Bharathi, Jyothi, Jaya, Triveni (2)	--	Bharathi, Jyothi, Jaya, Triveni (2)	5

HYV = High Yielding Variety.

Values in parentheses indicate bug population per earhead or per plant at the particular crop period. (Mean of 10 replications).

Fig. 7. Population fluctuations of *L. acuta* with respect to the climatic variations in different paddy fields of the different agricultural subdivisions of Trivandrum.


RAIN FALL
RELATIVE HUMIDITY
MINIMUM TEMPERATURE
NEDUMANGAD
NEYYATTINKARA
JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC.
1984
JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC.
1985

Observations on the influence of certain biotic environmental factors on infestation by L. acuta in rice fields

1. Overlapping cropping pattern

Availability of irrigation facilities throughout the year and of hybrid photo-insensitive varieties of rice with varying durations (short, medium and long) result in shift in the crop discipline from one of season bound well defined cropping sequence to one of staggered or overlapping pattern of cropping. As a result crops in the earhead stage are present in one or other location of the contiguous 'elas' (fields) always and adult bugs can be observed to occur and breed without any break throughout the year in such areas.

2. Relative loss in yield due to infestation by L. acuta in local and high yielding varieties of rice

In general local varieties of rice like Cheradi, Kochuvithu, Ptb-26, Ptb-2, Ptb-20, Ptb-22, Thavalakkannan, Ptb-4 and Ponni are found to suffer more damage in terms of per cent loss in yield due to attack by the bug than the high yielding hybrid varieties like Bharathi, Jaya, MO-7, MO-6, MO-5, Vytilla-3, Vytilla-4, Jyothi, Mashoori-14 and IR-50, cultivated in the areas observed (Table 10).

3. <u>Observations on the host plants on which the adult bugs survive during off-season</u>

The hosts on which the bugs tide over the interregnum between two crops are found to be the left-over ratoon crop of rice in the field and coconut, guava, banana, cashew, pulses and vegetables growing in the garden bunds bordering the rice tracts. Following is the result of a casual count made on the bugs resting on these plants.

Rice	50 - 60 adults/m^2
Coconut	10 - 20 per leaflet
Guava	4 - 5 per leaf
Banana	7 - 10 per leaf
Cashew	5 - 6 per leaf
Pulses	2 - 4 per leaf
Vegetables	4 - 5 per leaf

These bugs migrated to the paddy fields when crops were raised there in the subsequent season.

DISCUSSION

DISCUSSION

Growing of different varieties of rice with different durations and susceptibilities in continuous and overlapping cropping pattern hase resulted in enormous multiplication of the rice bug in recent years. How far the new high yielding varieties of rice commonly cultivated by the farmers viz. Pavizham, Jaya, Jyothi, Karthika and Triveni have influenced the biological features of L. acuta were examined in laboratory studies.

It has been observed that mating took place 2 - 3 days after emergence of the adults on all these varieties. But Akbar (1957) and Kalode and Yadava (1976) had observed that eventhough the males were ready for copulation soon after emergence, the females took about 8 - 14 days to attain sexual maturity. As regards mating period, it was found to last for 4 - 6 hours which agreed with the finding of Misra (1968).

The preoviposition period of 3.5 to 4.4 days and oviposition period of 51.4 to 54.2 days observed on the different varieties were similar to the findings of Rai (1983) who observed the preoviposition period to last for 1 - 5 days and of Lim Guan Soon (1971) who reported the oviposition period to last for 52 days.

The number of eggs laid by the bugs in the different varieties varied from 159.2 (Pavizham) to 160.3 (Karthika). Kalode and Yadava (1975) reported that a single gravid female laid 24 to 222 eggs during an oviposition period of 8 - 14 days.

The incubation period of eggs laid by the bugs reared in the different varieties varied from 5.5 to 6.4 days which approximated with those reported by Lefroy (1906), Srivastva and Saxena (1960) and other workers who found the egg period to vary from 5 to 8 days (Misra, 1968; Rai, 1983).

The nymphal durations on the different varieties on which the bugs were reared varied from 18.2 days (Jyothi) to 19.4 days (Triveni) the difference being not significant. Variations from 13 to 33 days had been reported by various workers (Uichanco, 1930; Kalode and Yadava, 1975 & Rai, 1983).

The adult longevity of the bug varied from 70.4 to 72.5 days for the males and 79.6 to 81.4 days for the females reared in the different varieties, these were not significant statistically. The longevity was reported to vary from 3 - 7 months (Anon., 1919, 1928), 33-55 days (Akbar, 1957) and 45 - 60 days (Srivastava and Saxena, 1964) and 45 - 70 days (Misra, 1968) and 23 - 63 days (Rai, 1983). Such variations in the adult longevity from 23 days to 4 months in rice may be due to the variations in the climate and other environmental factors like availability of food.

In general, observations on the preoviposition and oviposition periods, fecundity, nymphal durations and adult longevity of the bug reared in the four high yielding varieties did not show any statistically significant variations among the varieties showing that the different varieties of rice did not play any role in changing the biological features of L. acuta.

The biology and survival of L. acuta was studied on twelve different species of weeds commonly occurring in the paddy fields and it was found that the bug would complete the life cycle only on Echinochloa colonum and E. crusgalli. In the case of other weeds none of the stages of the insect could survive on them. Earlier Kalode and Yadava (1975) had also reported that rice bug bred well on E. colonum and not on some other weed hosts. In the Kerala paddy fields E. colonum and E. crusgalli are abundantly found growing on field bunds as well as together with paddy in the main fields. They usually mature earlier than rice crop and the flowers produced by them attract the bugs to the fields and enable them to build up their population. These weeds growing on the field bunds can sustain the population of the bugs in the field environment during the off-season also. Timely removal of these weeds both from the fields and from the environment is thus indicated as an effective component of the integrated pest management system for rice.

The relative susceptibility of rice earheads to attack by L. acuta at different stages after flowering was studied by confining the bugs on the earheads at different intervals. It was found that maximum damage was caused by the 10th and 15th day after flowering as indicated by the percentage of chaff formed (27.7 to 49.3%) in comparison to the bug free earheads (8.9 to 7.98%). The number of stylet sheaths formed also were high during these intervals (Table 3) indicating that milky stagesof the grains were the most vulnerable to attack by the bugs. Similar observations were on record by Gyawali (1981) who noticed more stylet sheaths on the milky stage grains.

Integrated pest management (IPM) has been accepted as the strategy for protection of rice crop from pest infestation all over the World to ensure an economically profitable crop for the farmer and theyby ensure sufficient rice supply for the consumers. An important principle of

IPM is to use insecticide only if there is need for it. The need is fixed in terms of economic threshold levels (ETL). This is the level of population of the pest at which control measures should be adopted to prevent the population reaching economic injury level (EIL) (Stern, 1966). The control measures adopted at this level of the population justify the cost of application needed at the EIL. Based on this the benefit cost ratio was worked out for the different levels of the bug population. Even at a level of one bug per sq.m the ratio was 4.72 which is a substantial return for a rice cultivator. The ratio is artificial, as absolute control of this pest cannot be achieved in the field. But it is sufficient to emphasise that even 1 bug per square metre plot is an economic injury level. So this level of population of 1 bug/sq.m can be accepted as the ETL for rice bug in the pest management programmes in rice. Similar studies conducted by Halterson et al. (1976) suggested 1 - 2 bugs/sq.m as the economic threshold which justified the application of chemical sprays whereas Dyck (1976) fixed the level as 2 - 4 bugs/sq.m in IRRI, Philippines.

The relative toxicity of twelve different insecticides to *L. acuta* was assessed in the laboratory and it was found that malathion was the most toxic (LC_{50} 0.00575) followed by formothion (0.00582), fenthion (0.00592), methyl parathion (0.007285) and phosphamidon (0.009515). The other insecticides fenitrothion, monocrotophos, dimethoate, phosalone, carbaryl, quinalphos and HCH were found to be less toxic with LC_{50} ranging from 0.01762 to 0.0418.

The persistent toxicity of these insecticides wase assessed by spraying potted plants of rice and confining the bugs on the sprayed plants. Among the insecticides methyl parathion and malathion were found to be significantly more toxic than the rest on the 3rd day after spraying.

The persistent toxicity of these insecticides continued to show a similar trend on the 7th, 10th and 14th day after the treatments. The maximum persistent toxicity was exhibited by methyl parathion (27.29%) on the 25th day followed by malathion (8.5%). Fenthion and phosphamidon persisted up to 21 days with mortalities of 8.5 and 8.47 per cent respectively. In general methyl parathion, malathion, fenthion and phosphamidon were found to be more persistent than the other insecticides.

When all these insecticides were applied in the field for the control of L. acuta it was observed that the reduction in population was to the tune of 68.98 per cent to 97.15 per cent in the first experiment (Table 7) and 49.5 to 90.61 per cent in the second experiment (Table 8) which was brought about by malathion, methyl parathion, fenthion and phosphamidon. The reduction in population due to fenitrothion, monocrotophos, phosalone, dimethoate, formothion, quinalphos, carbaryl and HCH, in general was in the descending order.

When a comparative assessment of the insecticides were made in terms of the relative toxicity of these to L. acuta in the laboratory together with the persistent toxicity of these in a pot culture experiment and the evaluation of their bioefficacy in the field under high and low population stresses it was seen that the more effective insecticides were malathion, methyl parathion, fenthion and phosphamidon. The other insecticides except HCH were also found to be effective against the bugs.

Studies conducted (Anonymous, 1963) on the persistence of the residues on rice plant against L. acuta using certain insecticides showed that fenthion had a maximum persistence followed by phosphamidon (Endosulfan, Endrin, SPN), parathion (Diazinon), malathion and gammaxene in the decreasing order. Studies on the control of rice bug conducted by Veluswamy et al. (1977) revealed that sprays of fenthion, phosphamidon, monocrotophos and dichlørovos were more effective than HCH and carbaryl dusts during an outbreak of L. acuta. Heinrichs et al (1982) observed that monocrotophos, endosulfan, chlorøpyrifos, and phosphamidon were found effective against rice bug.

Since insecticides are applied on earheads for rice bug control it is important that the question of toxic residues on the grain is examined thoroughly. Under the present studies the residues of three of the more effective insecticides were estimated on the harvested grain when they were applied on the crop for controlling the pest. These insecticides were malathion, fenthion and methyl parathion. The residues of these three insecticides were estimated colorimetrically. The maximum residue of fenthion remaining in rice grains was 0.049 ppm, the range being BDL to 0.049 ppm. Even the highest value in the range was much below the tolerance limit to 0.05 ppm fixed for fenthion on rice. The residues of malathion on the grain varied from BDL to 0.039 ppm while its tolerance limit on the grain was 10 ppm (Anon., 1969). In the case of methyl parathion, the residues were below detectable levels. Studies conducted by Jain et al. (1980) revealed that no residues of insecticides sprayed at the earhead emergence stage could be detected in grains of crops treated with insecticides for rice bug control. Only lindane left residues to the level of 0.15 ppm. They also found that even at the flowering stage the insecticides applied at the recommended doses did not leave any toxic residues in the grains.

Results of the present studies thus show that sprays of malathion, methyl parathion and fenthion can be recommended for the effective control of rice bug both in respect to toxicity and safety without risk of any toxic residues and even at a high population stress. The other insecticides were also found to give good control of the insect, but based on the cost : benefit ratio and grain : chaff ratio, the best insecticides found most effective for the control of rice were malathion, methyl parathion, fenthion and phosphamidon.

Influence of environmental factors on the population of *L. acuta* in the rice fields

Among the physical factors of the environment in the rice tracts under study, rainfall alone was affecting the population fluctuation of the bug significantly. Thus, high rainfall was found to favour high increase in the bug population and the population was low when the climate was dry. Rainfall has been recorded as favouring multiplication of the bug by DeMel (1937) and Anon. (1928), Israel and Rao (1961), Singh and Chandra (1967) and Misra (1969). Corbett (1930) found, the bug inactive in the drier months and migrating to shady places even before harvest. This did not happen if wet weather prevailed. Contrary observations of injurious effect of rainfall also are on record such as those by Ghose et al. (1960) and Srivastva and Saxena (1964).

Staggered cropping has come to stay as an accepted practice especially where assured water supply is available and also helped by the availability of photo-insensitive varieties of rice. This creates conditions favourable for the bug to multiply uninteroptedly with the assured availability of the food. In general, the local varieties of rice have been found to be damaged more by the bug than the high yielding hybrids in this system of staggered cultivation. This may be due to early harvesting of the high yielding varieties and the migration of the population to the local varieties of larger duration, which were found in the field at the flowering stage.

When no crop is available in the field the heavy population of the adults, which migrate to the various plants in the nearby garden lands. These plants include coconut, guava, banana, cashew, pulses and vegetables. They cluster on the under side of the leaves of these plants apparently under suspended animation. A sustained feeding on the juice of these crops is suspected. They may remain in this aestivating condition till the next crop comes up in the paddy fields. Then they move on to the new crop guided by the draught of odour arising from the rice plants as demonstrated by Kainoh _et al_. (1980).

SUMMARY

SUMMARY

The biology of Leptocorisa acuta Thunb. was studied in the different varieties of rice viz. Jaya, Jyothi, Triveni, Pavizham and Karthika. The pre-oviposition period varied from 4.4 days in Pavizham, 3.9 days in Jaya, 3.7 days in Karthika and 3.5 days each in Jyothi and Triveni. The oviposition period varied from 54.20 days in Triveni followed by Pavizham (53.60 days), Jyothi (53.50 days), Karthika (52.00 days) and Jaya (51.40 days) in the descending order. In the variety Triveni the fecundity of L. acuta was observed to be higher (161.50 eggs per female) than in other varieties which varied from 159.20 to 161.00 eggs per female. The incubation period was found to vary in different varieties the period being 6.4 days in Jyothi, 6.2 days in Jaya, 6.0 days in Pavizham, 5.9 days in Triveni and 5.5 days in Karthika.

The average total nymphal period was found to be higher in the bugs reared on the variety Triveni (19.4 days) followed by Pavizham (19.2 days), Karthika (19.0 days), Jaya (18.5 days) and Jyothi (18.20 days) in the decreasing order.

The longevity of the females varied from 81.4 days in Pavizham, 81.0 days in Triveni, 80.5 days in Jyothi, 79.6 days in Karthika and 79.6 days in Jaya and of the males 72.5 days in Triveni, 71.0 days in Jyothi, 70.8 days in Karthika,

70.7 days in Pavizham and 70.4 days in Jaya on an average. However, there was no significant difference between the different growth stages of the bug in the different varieties.

The common rice land weeds like Echinochloa colonum, E. crusgalli, Cyperus iris, C. rotundus, C. diformis, Fimbristylis miliacea, Camelina sp., Ludwigia parvifolia, Monocoria vaginalis, Brachmea ramosa and Panicum repens were used to study the dration or survival of different life stages of L. acuta. It was observed that only in Echinochloa colonum and E. crusgalli the bugs completed their different life stages. The mean incubation period and the mean durations of the first, second, third, fourth and fifth instar being 5.0, 3.2, 3.5, 3.3, 4.0 and 4.5 days in E. colonum and 4.5, 2.5, 3.3, 4.2, 4.5 and 5.0 days in E. crusgalli respectively. Female adult lived on an average of 58.50 days on E. colonum and 56.00 days on E. crusgalli while male adults lived on an average of 54.20 days on E. colonum and 52.60 days E. crusgalli.

Studies on the estimation of damage by L. acuta to rice earheads at different stages of grain formation showed that the maximum chaff was produced by the bug on the 15th day after flowering (49.26%) followed by 10th day (27.70%). Presence of stylet sheaths also indicated that the most vulnerable stage for the attack was from 10th to 15th day after flowering.

The economic threshold level of *L. acuta* was assessed in the field with the different population levels of the bug ranging from 0 – 4. Based on the benefit cost ratio the economic threshold level was computed and it was found that 1 bug/sq.m was sufficient to cause economic loss to the cultivator.

The relative toxicity of different insecticides to *L. acuta* was found to be 0.00592 for formothion, 0.00575 for malathion, 0.005921 for fenthion, 0.00729 for methyl parathion, 0.0095 for phosphamidon, 0.01603 for fenitrothion, 0.01762 for monocrotophos, 0.01864 for dimethoate, 0.03282 for phosalone, 0.0354 for carbaryl, 0.03911 for quinalphos and 0.04180 for HCH in the descending order.

The persistent toxicity of the different insecticides were assessed by spraying them in potted plants followed by releasing the bugs at different intervals after spraying and observing the mortality of the released bugs. Malathion (8.5%) and methyl parathion (27.29%) were found to produce mortalities up to 25th day after the treatments. The PT index calculations revealed that methyl parathion (1281.28) and malathion (1092.75) produced maximum persistence followed by fenthion (802.41), phosphamidon (726.81), phosalone (540.40), monocrotophos (540.00), fenitrothion (530.04) formothion (508.76), carbaryl

(466.20), HCH (456.68), dimethoate (367.50) and quinalphos (360.00) in the decreasing order.

Two field experiments were conducted to assess the efficacy of different insecticides for controlling L. acuta at different population levels. In the first experiment where there was more of a population stress, the insecticides malathion, methyl parathion and fenthion were found to be more effective in controlling L. acuta, the percentage reduction being from 75.72 to 97.15, 72.71 to 94.76 and 69.92 to 91.85% respectively. In the second experiment with lesser population stress also, the same insecticides showed the maximum effect in controlling L. acuta in the field. The effect of these insecticides was indicated by the higher grain / chaff ratio in all these treatments. The residue of three of the effective insecticides viz. malathion, methyl parathion and fenthion in the grains were also assessed and found that all of them were below detectable levels.

Influence of the climatic factors on the population build up of L. acuta in the field was studied by correlating the climatic factors like rainfall, maximum and minimum temperatures and relative humidity with the population of L. acuta in the fields of Trivandrum District. The multiple linear regression analysis of the collected data revealed that only rainfall was contributing positively to the population build up of L. acuta. Observations on certain biotic environmental factors on population build up of L. acuta in these rice fields showed that overlapping cropping pattern, simultaneous cultivation of local and high yielding varieties and capacity of survival of the adults on the weeds and other host plants growing around the rice lands like cocoa, banana, cashew, coconut, pulses and vegetables also contributed for the population build up of L. acuta.

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* Original not seen

APPENDICES

APPENDIX - I

Climatic parameters and rice bug population during 1984 and 1985 in Vellayani

Year & month	Max. temp. (°C)	Min. temp. (°C)	R.H. (%)	Rainfall (mm)	Rice bug population (bugs/earhead or plant*
<u>1984</u>					
Jan.	30.0	22.0	72	35	-
Feb.	31.0	26.0	78	85	-
Mar.	32.0	23.0	79	45	2
Apr.	31.8	19.0	73	21	3
May	31.5	20.4	67	110	12
Jun.	30.0	26.0	69	218	20
Jul.	29.0	24.0	80	130	10
Aug.	30.0	23.2	65	22	5
Sep.	32.0	22.0	72	85	18
Oct.	30.0	21.0	70	210	18
Nov.	31.0	23.0	80	120	13
Dec.	31.5	20.0	75	5	0
<u>1985</u>					
Jan.	30.0	20.0	79	60	0
Feb.	32.0	22.0	81	28	3
Mar.	31.0	25.0	83	8	2
Apr.	32.0	22.0	75	38	4
May	33.0	23.0	77	22	4
Jun.	28.0	21.0	78	320	8
Jul.	27.0	21.0	74	68	3
Aug.	28.5	21.5	80	23	3
Sep.	30.0	22.0	75	0	0
Oct.	30.0	22.5	80	592	6
Nov.	29.0	22.0	75	238	4
Dec.	30.0	22.0	76	93	0

* Mean of ten replications.

APPENDIX - II

Climatic parameters and rice bug population during 1984 and 1985 in three agricultural subdivisions of Trivandrum

Year & month	Max. temp. (°C)	Min. temp. (°C)	R.H. (%)	Rainfall (mm)	Rice bug population (bug/plant or earhead)
1984					
Jan.	30.0	22.0	81	65.0	-
Feb.	31.0	23.0	85	128.2	10*, 5@, 11§,
Mar.	32.0	24.0	86	151.0	13@, 8§
Apr.	32.0	24.5	86	297.0	-
May	32.0	25.0	84	153.7	-
Jun.	29.0	23.5	91	205.0	16*
Jul.	28.0	22.5	89	126.0	-
Aug.	30.0	23.5	83	21.1	-
Sep.	29.0	23.1	83	40.2	14@, 7*, 9@,
Oct.	29.5	22.8	83	205.1	10§, 7§,
Nov.	30.0	23.3	86	72.0	10*
Dec.	31.0	22.1	72	3.0	-
1985					
Jan.	31.6	22.6	80	91.7	8§, 10§, 5*,
Feb.	32.2	23.3	81	40.2	5@, 5@
Mar.	33.4	24.9	77	13.6	-
Apr.	33.5	25.4	78	87.4	-
May	32.2	24.9	83	223.3	-
Jun.	28.7	22.8	93	424.3	6*
Jul.	29.8	22.9	88	82.5	-
Aug.	30.1	23.3	86	61.8	-
Sep.	30.9	23.6	84	96.8	5@, 5@, 5*, 9§,
Oct.	30.4	23.6	87	152.7	10§, 3*
Nov.	30.1	22.7	83	170.4	-
Dec.	31.7	22.9	76	39.5	-

* Neyyattinkara @ Chirayinkil § Nedumangadu

FACTORS RESPONSIBLE FOR THE POPULATION BUILD UP OF RICE BUG, *LEPTOCORISA ACUTA* THUNB AND THE CONTROL OF THE PEST

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ABSTRACT

The rice bug Leptocorisa acuta Thunb. was reared on the rice varieties Jaya, Jyothi, Triveni, Pavizham and Karthika in order to study the effect of varieties on the insect's biological features. Statistical analysis of the data obtained showed that varieties have no significant influence on the biological features of L. acuta.

Studies made on the duration/survival of L. acuta on eleven common rice land weeds found in paddy fields showed that the bugs could complete their life cycle only on Echinochloa colonum and E. crusgalli. The bugs survived for short periods on a few of the other weed hosts.

In order to find out the most susceptible stage of the rice earhead after flowering to attack by L. acuta, the bugs were confined at different intervals after flowering on the earheads and it was observed that the 10th to 15th days after flowering were the most vulnerable stages of attack.

The economic threshold level of L. acuta was assessed by confining different population levels of the bug on rice earheads in the field and observing the damages caused by the different population levels to the rice grain and computing the cost/benefit ratios. It was found that 1 bug/sq.m was the critical population level for the application of insecticides in controlling L. acuta considering the economic aspects.

The relative toxicity of twelve different insecticides to *L. acuta* was assessed in the laboratory and it was observed that malathion was the most toxic followed by formothion, fenthion, methyl parathion, phosphamidon, fenitrothion, monocrotophos, dimethoate, phosalone, carbaryl, quinalphos and HCH in that descending order.

The persistent toxicity of these insecticides to *L. acuta* was worked out in terms of per cent mortality and PT index. The insecticides methyl parathion and malathion were observed to be most persisting followed by fenthion, phosphamidon, phosalone, monocrotophos, fenitrothion, formothion, carbaryl, HCH, dimethoate and quinalphos in that descending order.

Two field experiments were conducted to study the effectiveness of the different insecticides in the control of *L. acuta* at different population densities. The insecticides malathion, methyl parathion and fenthion were found to be more effective in controlling *L. acuta* in the field at the different population densities. The residues of the more effective insecticides were assayed in the grain and it was observed that the residue in the grains were below detectable levels.

The influence of the climatic factors like temperature, humidity and rainfall in the population build up of *L. acuta* was studied in the different bug infested fields and the regression line obtained from these observations showed that only rainfall influenced the population build up of *L. acuta*.