# COMPATIBILITY OF INSECTICIDE AND FUNGICIDE USED FOR THE CONTROL OF INSECT PESTS AND DISEASES OF RICE

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THESIS

submitted in partial fulfilment of the requirement for the degree

**MASTER OF SCIENCE IN AGRICULTURE**

Faculty of Agriculture

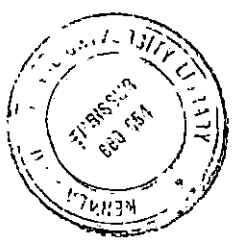
**KERALA AGRICULTURAL UNIVERSITY**

**DEPARTMENT OF ENTOMOLOGY**

**COLLEGE OF AGRICULTURE**

VELLAYANI - TRIVANDRUM

**1988**



# D E C L A R A T I O N

I hereby declare that this thesis entitled 'Compatibility of insecticide and fungicide used for the control of insect pests and diseases of rice' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

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Vellayani,

22-11-1988.

# C E R T I F I C A T E

Certified that this thesis, entitled 'Compatibility of insecticide and fungicide used for the control of insect pests and diseases of rice' is a record of research work done independently by Sri. K. Babu 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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ACKNOWLEDGEMENTS

The author places on record his deep sense of gratitude and indebtedness to:

Sri. P. Reghunath, Assistant Professor, Department of Entomology who was also the Chairman of the Advisory Board for suggesting the problem and for the guidance in the conduct of this research programme and in the preparation of the thesis.

Dr. N. Mohan Das, Professor and Head, Department of Entomology for his kind attention and help extended to this research programme.

Dr. K.I. Wilson, Professor and Head, Department of Plant Pathology for the help rendered in the studies.

Dr. P. Saraswathy, Associate Professor, Department of Agricultural Statistics for the help rendered in the analysis of data.

Sri. C. Gokulapalan, Asst. Professor, Department of Plant Pathology for the help extended for the conduct of the pathological aspect of the study.

Sri. Thomas Biju Mathew and Sri. C. Nandakumar, Assistant Professors in Entomology for their sincere help and encouragement given in conducting the research programme.

The Director of Agriculture, Kerala, for awarding deputation to undergo the course.

The Dean, College of Agriculture, Vellayani, for the facilities provided.

K. BABU.

# C O N T E N T S

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# INTRODUCTION

# INTRODUCTION

The introduction of high yielding varieties of crops necessitated the intensive use of plant protection measures to control the pest problems and to ensure the realization of yield potential. The phenomenal green revolution in foodgrain crops became a reality only with the adoption of intensive plant protection measures.

The application of pesticides in fixed schedule at different growth stages of crops, irrespective of the incidence of pests and diseases, was the strategic plant protection technology adopted for a long time. In these schedules, combinations of insecticides and fungicides had high relevance. The application of pesticides in schedule led to the culmination of undesirable side effects of pesticide use like the emergence of the resistant strains of insect pests and disease causing organisms, occurrence of pest resurgence, emergence of secondary pests, contamination of agricultural products, hazardous effects on non-target organisms and environmental pollution. The realization of these inherent limitations of pesticide use gave rise to the emergence of intensive research for evolving safer and effective alternate technologies of pest control. This new approach was the basis for the concept of integrated pest management. Even in areas where techniques other than chemical control of pests for evolving integrated control programmes were not available, intensive use of pesticides in schedule had been given up in favour of a need-based

treatment strategy. Thus the application of plant protection chemicals was resorted to only when the pest population reached critical threshold levels. Specific pesticides are now being recommended for use in the field against individual pest or disease as and when they occur in the field. In this plant protection technology, the relevance of insecticide-fungicide combinations is less.

Even in need-based pest control programmes, the necessity for the application of a fungicide and insecticide at close intervals may arise in field situations. Simultaneous incidence of insects like leaf roller, brown plant hopper, stem borer, rice bug or thrips and diseases like blast, brown leaf spot and sheath blight is often observed in later stages of paddy crop (Nair, 1978; Nair and Menon, 1983; Kerala Agricultural University, 1984, 1986, 1987). In such situations, use of insecticides and fungicides in combination will obviously reduce the cost and time required for application. The desirability of adopting combination sprays had been stressed by earlier authors too (Rose, 1963; Mehta and Verma, 1968; Nene and Thapliyal, 1979; Sharvelle, 1979; Wood, 1983).

This technology will particularly be advantageous in a state like Kerala where the cost of labour is very high. For recommending a combined application of fungicide and insecticide, a thorough knowledge about their interaction is highly essential.

Sharvelle (1979) observed that physical incompatibility (the formation of unstable mixture), chemical incompatibility (loss of chemical properties causing toxicity), phytotoxic incompatibility (causing injury to host plant) or placement incompatibility (incorrect placement of the components) may arise in the combined use of insecticides and fungicides." Synergistic effect of insecticide-fungicide combination (Kerala Agricultural University, 1981, 1982) and antagonistic effect of combinations (Chakraborty and Mutatkar, 1979; Gradis and Sutton, 1981) have also been reported.

The basic information available on the above aspects, especially with reference to the pesticides on rice, is inadequate. Hence, detailed investigations were taken up to study the compatibility of insecticides and fungicides more widely used in Kerala for the control of paddy pests. The experiment included (i) laboratory evaluation of insecticides and fungicides and their interaction (ii) pot culture experiments to evaluate promising combinations and (iii) pot culture experiments to evaluate the keeping quality of insecticide-fungicide mixtures.

# 1. REVIEW OF LITERATURE

The literature available on areas related to the different aspects covered in the present investigation have been reviewed here briefly.

## 1.1. Incidence of brown planthopper and sheath blight on rice and their control

Brown planthopper, Nilaparvata lugens (Stal.), (Delphacidae), which has been taken as a test insect in the studies, is a major pest of rice in most tracts of India (Rai and Zutrhi, 1969; Abraham and Nair, 1975). Under favourable conditions the pest occurs in all the growth stages of the crop, but usually causes serious damage when they infest the crop at booting and hard dough stages (Alam et al., 1978; Natarajan and Palchamy, 1978; Sogawa and Kusumayadi, 1984). Since the planthoppers show negative phototaxis and prefer high humidity they congregate in areas of more luxuriant plant growth. They feed and multiply near the basal parts of the plant (Caresche, 1933; Pathak, 1968).

Sheath blight, a serious disease of rice covered in these studies, also occurs at the basal parts of the plant. The disease is caused by Rhizoctonia solani Kuhn. (PS. Thanatephorus cucumeris (Frank) Donk). Occurrence of the pest and disease simultaneously in the field is very common (Kerala Agricultural University, 1984, 1986, 1987).

Various chemicals have been evaluated against brown plant hopper. Monocrotophos was reported effective by many workers (Lim, 1971; Mani and Jayaraj, 1976; Skaria and Das, 1981; Rao et al., 1984; Patel et al., 1986). However, Katanyukul and Budhasamai (1983) concluded from their experiments that the effectiveness of monocrotophos require further assessment. Manila and Lapis (1977) observed that monocrotophos predisposed rice plants to rice blast incidence.

Effectiveness of quinalphos in controlling BPH was reported by many workers (Balasubrahamonian and Michael, 1976; Rao et al., 1976; Mani and Jayaraj, 1976; Skaria and Das, 1981; Rao et al., 1984). But its use against BPH was questioned by Chandy et al. (1980), Ye et al. (1981) and Sasmal et al. (1984).

HCH was also found effective against BPH (Das et al., 1972; Sathyanandan and Subramanian, 1984). But HCH was reported ineffective in preventing the hatching of BPH eggs (Basilo and Heinrichs, 1981).

In vitro studies using various fungicides against R.solani showed that the fungus was highly sensitive to carbendazim and other methyl benzimidazole compounds (Behra et al., 1982; Kesavan, 1984; Martin et al., 1984; Prasad and Hiremath, 1985; Lakshmanan and Nair, 1986; Sha, 1986; Jones et al., 1987). The effectiveness of ediphenphos against R. solani

was stressed by Lulu Das (1986). Captafol + PCNB (Kesavan, 1984) and captafol alone (Prasad and Hiremath, 1985; Lulu Das, 1986) were also reported effective against R. solani. Captafol at 50 ug/g soil was found effective in controlling the sclerotia of the fungus (Lakshmanan and Nair, 1986).

Superiority of carbendazim and other methyl benzimidazole compounds against R. solani was proved in field also (Chin, 1977; Jagannathan and Kannaiyan, 1978; Mukherjee, 1978; Varadarajan and Rajan, 1978; Kannaiyan and Prasad, 1979; Dev and Satyarajan, 1980; Leshmanan et al., 1980; Lee and Courtney, 1981; Reddy et al., 1981; Roy, 1981; Arunyanart et al., 1986; Dev and Mary, 1986; Telan and Lapis, 1986).

Ediphenphos was also reported as very effective treatment for controlling sheath blight in field by many workers (Jagannathan and Kannaiyan, 1978; Mukherjee, 1978; Varadarajan and Rajan, 1978; Kannaiyan and Prasad, 1979; Rajan et al., 1979; Lakshmanan et al., 1980; Gokulapalan, 1981; Roy, 1981; Lulu Das, 1986; Annie Thomas, 1987).

Varadarajan and Rajan (1978) reported captafol to be effective against sheath blight. But Roy (1981) considered this chemical to be less effective compared to carbendazim and ediphenphos.

Fungicidal action of insecticides and insecticidal action of fungicides

In laboratory studies crude BHC dust (Simkover and Shenefelt, 1951), carbaryl at 125 ppm (Naquib, 1968), Metasystox and other related organo-phosphate insecticides (Ryan and Clare, 1972), Lebaycid (Yamaguchi, 1974), aldicarb (Tisserat et al., 1977), Sevidol and Thimet (Lakshmanan and Nair, 1980) were found to inhibit the fungus R. solani.

According to John et al. (1982) the fungicide zineb had antifeedant activity on the fourth instar larvae of Spodoptera mauritia Boisd. Medrano et al. (1984) reported that a spray of 0.1% ediphenphos reduced hatching of brown plant hopper by 34% and also killed all nymphs.

Compatibility of insecticides and fungicides

Chlorinated hydrocarbons and fungicides

Seed treatment by a formulation containing 20% HCH and 60% thiram against the disease caused by Ascochyta fabae Speg., Fusarium oxysporum Schlecht and Uromyces fabae (Pers.) in bean (Chekalinskaya, 1963), ascochytosis of pea (Balashova and Babak, 1964) and beetles infesting wheat and barley (Baicu et al., 1983) was reported very effective. The above combination used for root treatment against cabbage root fly was effective, but the treatment resulted in harmful effects on plants. Combinations of HCH and a fungicide was reported effective against coffee borer (Hypothenemus hampei (Ferrari))

and the fungus Corticium on coffee (Liceras and Farge, 1975) and flea beetle and fungal diseases of fibre flax (Zhuravlev et al., 1976). Ermilova (1965) reported that granusan and mercuran when applied with HCH controlled wheat smut more effectively than when the fungicide was applied alone. According to Chatrath et al. (1977) fungicidal property of benomyl and Vitavax was unaffected when applied in combination with HCH, against loose smut of wheat. Application of lindane at 1 g ai/l combined with captafol at 1.5 g ai/l was effective against inflorescence die back of cashew (Olunloyo, 1983).

Compatibility of heptachlor and thiram applied @ 2.5 g and 3 g respectively per kg of seed, as a seed treatment against Tanymecus of maize was reported by Tanase and Paulian (1973). Aldrin EC 30 and Vitavax (carboxin) controlled Ustilago hordei (Pers.) Lagerh of barley (Mathur and Bhatnagar, 1986) and endosulfan in combination with karathane was effective against pod borer, Etiella zinckenella Treit. and powdery mildew, Erysiphe polygoni DC. of field pea (Sukla and Lal, 1988). In the case of endosulfan and karathane the combination gave synergistic effect.

Organophosphorus insecticides and fungicides

Application of quinalphos with Bordeaux mixture or zineb against the larvae of Clysia and powdery mildew of

grape vines (Nedyalkov, 1975), with ediphenphos against leaf folder (Cnaphalocrocis medinalis Guen.), rice whorl maggot (Hydrellia sp.), green leafhopper (Nephotettix virescens Dist.), rice leafhopper (Tettigoniella spectra Dist.) and the leaf spot disease of rice (Bhaskaran et al., 1976), and with Bordeaux mixture against Coccus viridis (Green) of coffee (Chacko et al., 1977) did not adversely affect the efficacy of constituent chemicals. Quinalphos used with thiram or Fytolan or Dithane M 45 was reported to have synergistic effect (Kerala Agricultural University, 1981), but with Dithane Z-78, Bayer 5072, Bordeaux mixture, Hinosan and Kitazin the effect was inconsistent against Phytophthora palmivora Butler (Kerala Agricultural University, 1983).

Monocrotophos was reported to be compatible with Thiram, Fytolan and Dithane M-45 (Kerala Agricultural University, 1981). Combined application of monocrotophos and fungicides against Aphis craccivora Koch., Spodoptera litura (Fb.), Aproaeremia and Lamprosema and three species of fungus in peanut was reported to be effective than applying either fungicide or insecticide alone (Schiller et al., 1982). There were also reports of compatibility of monocrotophos with the fungicides Cuman, Bavistin and Dithane (Kerala Agricultural University, 1984). Samalo and Parida (1983) reported that monocrotophos 0.05% and chlorothalonil (Daconil) 0.225% when applied in combination against thrips, cicadellids, aphids and Aproaerema

resulted in maximum net return. Leaf folder of rice was shown to be more effectively controlled by a combined spray of monocrotophos and Bavistin or Hinosan (Kerala Agricultural University, 1986). Sukla and Lal (1988) reported that monocrotophos and sulfex or Bavistin were not only compatible but also superior in controlling pod borer (E. zinckenella) and powdery mildew (E. polygoni) of field pea than when applied independently. The efficacy was inconsistent when monocrotophos was mixed with Dithane Z-78, Bayer 5072, Bordeaux mixture, Hinosan and Kitazin and used against P. palmivora (Kerala Agricultural University, 1983).

Methyl parathion in combination with Bordeaux mixture or zineb effectively controlled the insect Clysia and the powdery mildew of grape vine (Nedyalkov, 1975) and with ediphenphos, Helminthosporium leaf spot and many insect pests of rice were effectively controlled (Bhaskaran et al., 1976). Mixing of methyl parathion 0.03% with Bordeaux mixture did not affect the efficacy of the insecticide in containing C. viridis of coffee (Chacko et al., 1977).

Malathion when applied in combination with captan or thiram on apple for the control of complex pest and disease no ill effects were noticed on plant (Murphy et al., 1961). Malathion 0.05% sprayed with Bordeaux mixture was found to be as effective against C. viridis of coffee as the

insecticide used alone (Chacko et al., 1977). Chatrath et al. (1977) reported that fungicidal property of benomyl and Vitavax was unaffected when they were mixed with malathion and used against loose smut (Ustilago nuda (Jens.) Rostr.) of wheat.

According to Chacko et al. (1977) the combined application of fenthion 0.04% and Bordeaux mixture did not reduce the efficacy of fenthion. When used with Dithane Z-78, Bayer 5072, Bordeaux mixture, Hinosan and Kitazin the fungicidal effect against P. palmivora was seen inconsistent (Kerala Agricultural University, 1983).

Chakraborty and Mutatkar (1979) reported that maximum tuber yield was obtained when dimethoate and captafol were applied in combination on potato than when the treatments were given independently. However, with benomyl and blitox, dimethoate did not combine well. According to Minoiu and Dragan (1982) use of fungicides in combination with dimethoate was superior for the control of diseases and pests of apple orchards than their independent application.

Mixing of dilor and zineb (1 : 1) had a synergistic effect when used against the fungus Phytophthora on tomato (Udilov and Borisova, 1976). According to Kurilov (1983) the insecticide dilor at 0.4 kg/ha and the fungicide cuprazan at 2.5 kg/ha when combined and applied was highly

effective against colarado potato beetle (Leptinotarsa decemlineata Say.) and phytophthorosis.

Phosalone applied in combination with ediphenphos controlled leaf folder, whorl maggot, green leafhopper and white leafhopper of rice more effectively than when the insecticide was applied alone (Bhaskaran et al., 1976). Combined treatments against the incidence of pests, diseases and weeds on apple and grapes using DNOC, chlorophos, phosalone, Dicofol, etc. was found highly beneficial (Atadzhanov and Dubrovina, 1977).

The activity of maneb, zineb, ziram and mancozeb was found enhanced and that of triforine, imugan, ethirimol and afugan reduced on mixing with insecticide (Svampa et al., 1974).

Primiphos methyl was found compatible with benomyl, carbendazim and dinocap and gave good control of Lobesia and pathogenic fungi like Plasmopara viticola Berk & Curt., Uncinula necator (Schw.) Burr. and Botryotinia of grape vine (Mirica et al., 1981). The fungicidal and fungistatic action of mancozeb and captan was found reduced when they were mixed with phosmet and azinphos methyl and used against Botryosphaeria dothidea (Moug Fr.) and Glomerella cingulata (Stonem.) Spauld & Schrenk (Gradis and Sutton, 1981). Mixing of Folithion with Fytolan resulted in a synergistic action and complete inhibition of fungal growth was noted in the mixture (Kerala Agricultural University, 1982).

# MATERIALS AND METHODS

## 2. MATERIALS AND METHODS

### 2.1. Raising rice plants for mass rearing of N. lugens and for pot culture studies

Rice variety TN 1 was raised in clay pots (15 x 15 cm). Wet land soil was collected and dried, homogenised and mixed with dried farm yard manure at appropriate quantity and filled in pots. Ammonium phosphate, urea and muriate of potash were applied in each pot in required quantities to give half nitrogen, full phosphorus and half potash of 90 : 45 : 45 kg/ha of NPK. The remaining quantities of nitrogen and potash were applied in two equal splits at active tillering and panicle initiation stages respectively.

Three week old rice seedlings were transplanted at the rate of one seedling per pot. The water level in each pot was maintained at two cm throughout the growth period of the crop. Ten days after planting the plants were covered with cylindrical cages (75 x 15 cm) made of transparent 250 microns thick polyster film. Each cage was provided with two voile cloth lined ventilators (5 x 10 cm) and the top end was covered with nylon cloth and it was held in position using a rubber band. The caged plants were kept in a glass house under normal temperature, humidity and light intensity.

### 2.2. Rearing of N. lugens

A culture of the test insect was continuously maintained in the laboratory. Potted rice plants prepared as described

in para 2.1 were used for this purpose. The initial population of N. lugens was collected from the field and reared in the laboratory for three to four generations for stabilising the population and this was used as the stock culture. Fifteen to twenty gravid females were transferred from the stock culture, using an aspirator, to each 30 day old caged plant for egg laying. Twenty four hours after exposure the insects were again transferred to fresh caged plants. This ensured that each plant had eggs laid by the insects on the same day and thus the nymphs emerging on each plant were of uniform age. Adequate number of plants were thus set at regular intervals, so as to ensure the availability of sufficient number of test insects of same age for the experiments throughout. When the plants in each cage got dried up due to the feeding of emerging immature stages they were cut at the base and the insects were gently tapped on to fresh plants. One to two day old brachypterous adult females were used in all experiments.

## 2.3. Isolation, culturing and maintenance of R. solani

The isolate of R. solani used in the study was obtained from diseased rice plants collected from rice fields at Vellayani. The sheath portion of infected plants showing characteristic symptoms of attack were cut into small bits, surface sterilised with 0.1% mercuric chloride solution for two minutes and were repeatedly washed in three changes of

sterile water. The sheaths were then planted over potato dextrose agar (PDA) in sterile petri dishes and incubated under sterile conditions. The isolate was purified by repeated hyphal tip planting and the organism was maintained on PDA by subculturing periodically.

## 2.4. Selection of dosages of insecticides for studying their interaction with fungicides

The experiment for the selection of dosages of insecticide was conducted using N. lugens as test insect by adopting standard bioassay techniques (Heinrichs et al., 1981). The insecticides selected were monocrotophos (Nuvacron 36 EC of CIBA-Geigy India Ltd.), quinalphos (Ekalux 25 EC of Sandoz (India) Ltd.) and HCH (BHC 50 WP of A.V. Thomas & Co., Ltd.).

A preliminary test to select doses of each insecticide to give a suitable range of mortality in bioassay (20 to 90%) was done using concentrations at wide ranges. Within such suitable ranges, five to six graded concentrations were worked out and adopted for the experiment. Different concentrations of the insecticides were prepared by diluting the emulsifiable concentrate/wettable powder with water and sprayed on test insects.

Adult female hoppers were collected in batches of 20 from rearing cages using an aspirator and transferred to plastic specimen tubes (8 x 2 cm). They were anaesthetised by exposing

them to a carbondioxide flow at the rate of 2.5 ml $CO_2$/second for 20 seconds. The hoppers were then transferred to a petri dish and sprayed under a Potter's spraying tower. The treated hoppers were transferred to 15 day old TN 1 seedling grown in ice cream cup (7 x 3.5 cm) and maintained in a glass chimney. Mortality of the insects was observed 24 hours after treatment. Three replications were maintained for each treatment. The percentages of mortality were calculated from the data and they were corrected using Abbott's (1925) formula. The data were subjected to probit analysis (Finney, 1952) and the regression equations were worked out. Using these equations the $LC_{50}$, $LC_{25}$ and $LC_{75}$ values of each insecticide were estimated.

2.5. Selection of concentrations of fungicides for studying their interation with insecticides

The experiments for the selection of suitable concentrations of fungicides were conducted using R. solani as test fungus by adopting the poisoned food technique of Zentmyer (1955).

The fungicides selected were captafol (Foltaf 80 W of Rallis (India) Ltd.), carbendazim (Bavistin 50 WP of BASF (India) Ltd.) and ediphenphos (Hinosan 50 EC of Bayer (India) Ltd.).

Stock solutions of each of these chemicals were prepared using sterile water. From these, the required quantities to give graded concentrations were added to sterilised molten potato dextrose agar media, (so as to make 50 ml gross) mixed well and poured into sterile petri plates at the rate of 15 ml per plate. Mycelial discs of 10 mm diameter were cut out from actively growing culture of the fungus and each of them was placed in the centre of each petri dish. The petri dishes were incubated at room temperature. Mycelial discs placed in petri dishes containing the media alone (no fungicide) served as control. The colony diameter was measured when the growth in the control fully covered the medium in the petri dish. The percentage inhibition was calculated by using the formula $(C - T) \times 100 / C$ where C and T were the colony diameters in control and treatment respectively.

In preliminary trials using the fungicides in wide ranges of concentrations, the levels causing 40 to 100% inhibition were chosen. For each fungicide six graded concentrations were selected and the percentages of inhibition of growth in the concentrations were assessed. Concentrations likely to give 50, 75 and 100 per cent inhibition were selected for the experiments.

2.6. Assessment of the effect of combining the selected concentrations of insecticides and fungicides on their insecticidal and fungicidal properties in the laboratory using N. lugens and R. solani as test organisms

The experiment was conducted adopting a completely randomised design, and each treatment was replicated thrice. The concentrations of insecticides and fungicides selected (para 2.4 and 2.5) and their combinations were included in the treatments (vide Tables 3 to 11). The insecticidal and fungicidal action of the insecticides, fungicides and their combinations were assessed adopting the bioassay technique described in para 2.4 and 2.5.

2.7. Assessment of the effect of combining insecticides and fungicides on the control of sheath blight and N. lugens

It was a pot culture experiment and completely randomised design was adopted for the experiment. The concentrations of insecticides selected were concentrations recommended for field use of monocrotophos and HCH and the recommended and half the recommended concentrations of quinalphos. In the case of fungicides the recommended and half the recommended concentrations of all the three fungicides viz. captafol, ediphenphos and carbendazim were used. There were thus 24 combinations.

The insecticides and fungicides were included independently also in the treatments. Total treatments thus came to 35 including control (vide Table 12). Each treatment was replicated thrice.

Caged TN 1 plants at panicle initiation stage, prepared as described in para 2.1, were selected for the experiment. The plants were inoculated with sclerotia on the inner surface of leaf sheath and the inoculated portions were covered with wet cotton. Characteristic symptoms of the disease appeared in two days around the point of inoculation. Each of the above potted plants to be sprayed was kept at the centre of an electrically operated revolvolite machine. The quantity of spray fluid required to give complete coverage of the stem and leaf portion of the plants at panicle initiation stage was fixed as ten ml by repeated trials. The spray fluid (10 ml) was sprayed with an atomiser connected to an electrically operated pressure pump maintained at 0.6 $kg/cm^2$ pressure. A constant speed of revolving table and a steady vertical motion of the atomiser nozzle from the bottom to the top of the plant ensured a uniform distribution of the toxicant on the plant. Control plants were similarly treated with water.

Treated plants were allowed to dry under shade. Twenty five adult hoppers were transferred to each treated plant and kept caged.

The insecticidal effect of the treatments was assessed in terms of the mortality of N. lugens noted 24 hours after releasing the insects. The intensity of the disease was assessed three weeks after treatment adopting the Standard Evaluation System for Rice Diseases (International Rice Research Institute, 1976) with 0 - 9 scale viz.

Scale

1 Lesions limited to lower 1/4 of leaf sheaths

3 Lesions present on lower 1/2 of leaf sheaths

5 Lesions present on more than 1/2 of leaf sheaths. Slight infection on lower (3rd or 4th) leaves

7 Lesions present on more than 3/4 of leaf sheaths. Severe infection on lower leaves and slight infection on upper leaves (flag and 2nd leaf)

9 Lesions reaching top of tillers, severe infection on all leaves.

The data on the mortality of hoppers and on the disease indices were subjected to statistical analysis after suitable transformation.

## 2.8. Assessment of the effect of applying fungicides and insecticides in sequence and in combination on the control of sheath blight and N. lugens

A pot culture experiment, adopting a completely randomised design was conducted. The insecticide-fungicide combinations tried were those mentioned in para 2.7. There were 24 combinations. Applications of insecticide followed by fungicide and fungicide followed by insecticide were also included as treatments. There were thus 73 treatments including control (vide Table 13 and 14). Each treatment was replicated thrice. Test plants were prepared as described in para 2.7. Method of treatment was as described in para 2.7.

## 2.9. Assessment of the effect of spraying fungicide-insecticide combinations, at different intervals after formulation, on the control of sheath blight and N. lugens

The study was carried out as a pot culture experiment adopting completely randomised design. The combinations of the insecticides and fungicides selected were those mentioned in para 2.7. Each combination was tried at four intervals after formulation viz. 0, 4, 8 and 24 hours. They were prepared in advance and applied simultaneously. There were 97 treatments including control (vide Table 15 and 16). Each treatment was replicated thrice. The procedure of the

experiment was the same as described in para 2.7. Data on the disease score and insect mortality collected from the experiment were subjected to statistical analysis.

## 2.10. Assessment of the effect of insecticide-fungicide combinations on the control of sheath blight in field

A field trial was conducted in a farmer's field at Alleppey in April 1988. The crop was in its flowering stage. There was a heavy and uniform incidence of sheath blight. However, no insect pest was observed in the season.

Combinations of fungicides and insecticides used were those tried in the pot culture experiments. There were 35 treatments in the experiment (vide Table 17). The experiment was laid out in a randomised block design. Each treatment was replicated twice.

Two blocks having uniform incidence of sheath blight were selected in the field and 35 plots of 3 x 3 m size each were peg marked. A buffer area of 1 m width was left on all sides of each plot to avoid the effect of drift in treatment. A pretreatment score was taken from all the plots. Forty five ml each of the required spray fluid was sprayed in each plot. Plots sprayed with water alone were maintained as controls.

Three weeks after the treatment the disease intensity was scored on 25 randomly selected hills in each plot and the indices were calculated as described in para 2.7.

# RESULTS

# 3. RESULTS

## 3.1. Selection of suitable concentrations of insecticides and fungicides for the assessment of their interaction in the laboratory

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 1. Concentrations of monocrotophos required to give 25, 50 and 75 per cent mortality of the test insect were 0.002, 0.007 and 0.03 per cent respectively. The corresponding values for quinalphos were 0.005, 0.02 and 0.05 per cent respectively and for HCH the values were 0.026, 0.071 and 0.2 per cent respectively.

The results relating to the bioassay of fungicides are presented in Table 2. The concentrations of captafol to give 50, 75 and 100 per cent inhibition of the fungus, as assessed by repeated experiments, were 250 ppm, 750 ppm and 2000 ppm respectively. The corresponding values for carbendazim were 1 ppm, 2.5 ppm and 5 ppm respectively and for ediphenphos the concentrations required were 20 ppm, 50 ppm and 100 ppm respectively.

Table 1. Suitable dosages of insecticides selected for the assessment of their interaction with fungicides in the laboratory

| Insecticides | Heterogeneity | Regression equation* | $LC_{50}$ (%) | Fiducial limits | $LC_{25}$ (%) | $LC_{75}$ (%) |
|---|---|---|---|---|---|---|
| Monocrotophos | $\chi^2_{(5)} = 0.7599$ | $y = 1.18x + 2.82$ | 0.007 | 0.0148<br>0.0033 | 0.002 | 0.03 |
| Quinalphos | $\chi^2_{(4)} = 1.2029$ | $y = 1.3x + 2.17$ | 0.02 | 0.0312<br>0.0074 | 0.005 | 0.05 |
| HCH | $\chi^2_{(4)} = 1.0852$ | $y = 1.56x + 2.11$ | 0.071 | 0.119<br>0.0043 | 0.026 | 0.2 |

* Regression equation of probit mortality (y) on log concentration (x).

Table 2. Suitable dosages of fungicides selected for the assessment of their interaction with insecticides in the laboratory

| Fungicides | Concentration (ppm) | Mean colony diameter (mm) | Per cent inhibition over control |
|---|---|---|---|
| Captafol | 250 | 36.2 | 59.7 |
| | 750 | 19.3 | 78.5 |
| | 2000 | 0.0 | 100.0 |
| Carbendazim | 1.0 | 36.67 | 59.26 |
| | 2.5 | 23.67 | 73.70 |
| | 5.0 | 0.0 | 100.0 |
| Ediphenphos | 20 | 39.8 | 55.7 |
| | 50 | 22.0 | 75.5 |
| | 100 | 0.0 | 100.0 |

## 3.2. Effect of combining various concentrations of insecticides and fungicides on their insecticidal and fungicidal properties assessed in the laboratory using N. lugens and R. solani as test organisms

### 3.2.1. Combinations of monocrotophos and captafol

Data relating to the experiment are presented in Table 3. Captafol at 2000 ppm, 750 ppm and 250 ppm gave low mortality of N. lugens ranging from 13.01 to 16.36 per cent. The mortality caused by monocrotophos 0.03 per cent alone and in combination with the three concentrations of captafol ranged from 60.04 to 68.96 per cent and they were statistically on par, and in the case of monocrotophos 0.007% the mortalities ranged from 48.33 to 56.69 per cent and they were on par. Monocrotophos 0.002% in combination with the three concentrations of captafol gave mortalities ranging from 24.88 to 28.30 per cent and they were also on par.

Monocrotophos 0.03, 0.007 and 0.002 per cent gave 53.71, 42.21 and 44.79 per cent inhibition of the fungus respectively. While captafol 2000 ppm gave 100% inhibition of the fungus, the combinations with the three concentrations of monocrotophos gave inhibition ranging from 85.97 to 89.30 per cent only, the variation among these treatments being statistically not significant. When captafol 750 ppm was mixed with 0.03% monocrotophos, inhibition did not vary significantly (75.55

Table 3. Effect of combining various doses of monocrotophos and captafol on their insecticidal and fungicidal properties assessed in the laboratory using N.lugens and R.solani as test organisms

| Insecticidal effect | | Fungicidal effect | |
|---|---|---|---|
| Treatments | Mean percentage mortality of N.lugens | Treatments | Mean percentage inhibition of R.solani over control |
| Captafol 2000 ppm | 16.21 (23.73) | Monocrotophos 0.03% | 53.71 (47.11) |
| ,, 750 ,, | 16.36 (23.85) | ,, 0.007% | 42.21 (40.50) |
| ,, 250 ,, | 13.01 (21.14) | ,, 0.002% | 44.79 (42.00) |
| Monocrotophos 0.03% | 68.96 (56.12) | Captafol 2000 ppm | 100.00 (90.00) |
| ,, + captafol 2000 ppm | 63.35 (52.72) | ,, + monocrotophos 0.03% | 89.30 (70.88) |
| ,, + ,, 750 ,, | 60.04 (50.77) | ,, + ,, 0.007% | 85.63 (67.70) |
| ,, + ,, 250 ,, | 61.68 (51.73) | ,, + ,, 0.002% | 85.97 (67.97) |
| Monocrotophos 0.007% | 56.69 (48.83) | Captafol 750 ppm | 75.55 (60.34) |
| ,, + captafol 2000 ppm | 48.33 (44.03) | ,, + monocrotophos 0.03% | 76.53 (61.00) |
| ,, + ,, 750 ,, | 48.33 (44.03) | ,, + ,, 0.007% | 59.36 (50.38) |
| ,, + ,, 250 ,, | 50.00 (44.98) | ,, + ,, 0.002% | 59.36 (50.38) |
| Monocrotophos 0.002% | 28.30 (32.13) | Captafol 250 ppm | 48.90 (44.35) |
| ,, + captafol 2000 ppm | 26.63 (31.06) | ,, + monocrotophos 0.03% | 75.98 (60.63) |
| ,, + ,, 750 ,, | 28.30 (32.13) | ,, + ,, 0.007% | 53.74 (47.12) |
| ,, + ,, 250 ,, | 24.88 (29.91) | ,, + ,, 0.002% | 62.21 (52.04) |
| C.D. for comparison | 6.6 | C.D. for comparison | 5.4 |

Figures in parentheses are angular transformations. CD. at 0.05 level

and 76.53 per cent respectively). When mixed with monocrotophos at concentrations of 0.007 and 0.002 per cent the percentages of inhibition were significantly reduced (59.36 per cent inhibition in both). Captafol 250 ppm mixed with monocrotophos 0.007 per cent gave no reduction in the inhibition of the fungus (48.90 and 53.74 per cent respectively). When the fungicide at the above concentration was mixed with monocrotophos 0.002 and 0.03 per cent the inhibitions resulted were significantly higher than the extent of inhibition in fungicide treatment alone (62.21 and 75.98 per cent respectively).

3.2.2. Combinations of monocrotophos and ediphenphos

The data relating to the bioassay of these combinations against N. lugens and R. solani are presented in Table 4. Ediphenphos 100 ppm, 50 ppm and 20 ppm gave mortalities of N. lugens ranging from 19.84 to 33.17 per cent. The insecticidal effects of monocrotophos 0.03 per cent (mortality of N. lugens ranging from 68.96 per cent) and monocrotophos 0.007% (56.69 per cent) were not significantly affected by mixing the insecticide with the three concentrations of ediphenphos. But in the case of monocrotophos 0.002 per cent (28.30 per cent mortality) there was less kill of test organism than in its combinations with the three concentrations of fungicide (mortality ranging from 36.67 to 48.33 per cent).

Table 4. Effect of combining various doses of monocrotophos and ediphenphos on their insecticidal and fungicidal properties assessed in the laboratory using N.lugens and R.solani as test organisms

| Insecticidal effect | | Fungicidal effect | |
|---|---|---|---|
| Treatments | Mean percentage mortality of N.lugens | Treatments | Mean percent inhibition R.solani over c. |
| Ediphenphos 100 ppm | 33.17 (35.15) | Monocrotophos 0.03% | 53.71 (47.11) |
| ,, 50 ,, | 29.92 (33.15) | ,, 0.007% | 42.21 (40.50) |
| ,, 20 ,, | 19.84 (26.44) | ,, 0.002% | 44.79 (42.00) |
| Monocrotophos 0.03% | 68.96 (56.12) | Ediphenphos 100 ppm | 100.00 (90.00) |
| ,, + ediphenphos 100 ppm | 76.71 (61.12) | ,, + monocrotophos 0.03% | 100.00 (90.00) |
| ,, + ,, 50 ,, | 71.70 (57.84) | ,, + ,, 0.007% | 87.81 (69.54) |
| ,, + ,, 20 ,, | 73.48 (58.98) | ,, + ,, 0.002% | 68.95 (56.11) |
| Monocrotophos 0.007% | 56.69 (48.83) | Ediphenphos 50 ppm | 77.43 (61.61) |
| ,, + ediphenphos 100 ppm | 56.74 (48.86) | ,, + monocrotophos 0.03% | 100.00 (90.00) |
| ,, + ,, 50 ,, | 60.32 (50.94) | ,, + ,, 0.007% | 83.67 (66.13) |
| ,, + ,, 20 ,, | 58.33 (49.81) | ,, + ,, 0.002% | 49.96 (44.96) |
| Monocrotophos 0.002% | 28.30 (32.13) | Ediphenphos 20 ppm | 47.37 (43.47) |
| ,, + ediphenphos 100 ppm | 48.33 (44.01) | ,, + monocrotophos 0.03% | 92.76 (74.36) |
| ,, + ,, 50 ,, | 36.67 (37.24) | ,, + ,, 0.007% | 84.75 (66.97) |
| ,, + ,, 20 ,, | 41.67 (40.18) | ,, + ,, 0.002% | 55.96 (48.40) |
| C.D. for comparison | 7.5 | C.D. for comparison | 5.9 |

Figures in parentheses are angular transformations. CD. at 0.05 level

Ediphenphos 100 ppm when mixed with monocrotophos 0.03 per cent did not reduce the inhibition of the fungus, but the fungicide when mixed with monocrotophos 0.007 and 0.002 per cent the inhibitions were significantly reduced (87.81 and 68.95 per cent respectively). Ediphenphos 50 ppm mixed with monocrotophos at 0.03 per cent gave significantly higher inhibition (100 per cent) while with monocrotophos 0.007 per cent the effect was statistically on par and with monocrotophos 0.002 per cent, gave significantly lower level of inhibition (49.96 per cent). In the case of ediphenphos 20 ppm the inhibition of the fungus was 47.37 per cent over control while in combination with the three concentrations of monocrotophos the inhibition was significantly raised and it was positively correlated with the increasing concentrations of the insecticide (55.96, 84.75 and 92.76 per cent respectively).

3.2.3. Combinations of monocrotophos and carbendazim

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 5. Carbendazim 5 ppm, 2.5 ppm and 1 ppm gave mortalities of *N. lugens* ranging from 8.33 to 11.67 per cent. The mortality caused by monocrotophos 0.03 per cent (68.96 per cent) was significantly reduced by the mixing of insecticide with carbendazim at all the three concentrations, (mortality ranging from 43.33 to 45.0 per cent, all on par). But at

Table 5. Effect of combining various doses of monocrotophos and carbendazim on their insecticidal and fungicidal properties assessed in the laboratory using N.lugens and R.solani as test organisms

| Insecticidal effect. | | Fungicidal effect | |
|---|---|---|---|
| Treatments | Mean percentage mortality of N.lugens | Treatments | Mean percentage inhibition of R.solani over control |
| Carbendazim 5 ppm | 11.67 (19.88) | Monocrotophos 0.03% | 53.71 (47.11) |
| ,, 2.5 ,, | 8.33 (16.20) | ,, 0.007% | 42.21 (40.50) |
| ,, 1 ,, | 11.67 (19.88) | ,, 0.002% | 44.79 (42.00) |
| Monocrotophos 0.03% | 68.96 (56.12) | Carbendazim 5 ppm | 100.00 (90.00) |
| ,, + carbendazim 5 ppm | 43.33 (41.15) | ,, + monocrotophos 0.03% | 58.51 (49.88) |
| ,, + ,, 2.5 ,, | 45.00 (42.11) | ,, + ,, 0.007% | 47.75 (43.69) |
| ,, + ,, 1 ,, | 45.00 (42.11) | ,, + ,, 0.002% | 38.82 (38.52) |
| Monocrotophos 0.007% | 56.69 (48.83) | Carbendazim 2.5 ppm | 74.84 (59.87) |
| ,, + carbendazim 5 ppm | 53.34 (46.90) | ,, + monocrotophos 0.03% | 100.00 (90.00) |
| ,, + ,, 2.5 ,, | 56.69 (48.83) | ,, + ,, 0.007% | 65.55 (54.04) |
| ,, + ,, 1 ,, | 61.68 (51.73) | ,, + ,, 0.002% | 38.82 (38.52) |
| Monocrotophos 0.002% | 28.30 (32.13) | Carbendazim 1 ppm | 48.86 (44.33) |
| ,, + carbendazim 5 ppm | 35.00 (36.26) | ,, + monocrotophos 0.03% | 100.00 (90.00) |
| ,, + ,, 2.5 ,, | 36.65 (37.24) | ,, + ,, 0.007% | 71.13 (57.48) |
| ,, + ,, 1 ,, | 33.17 (35.15) | ,, + ,, 0.002% | 47.76 (43.70) |
| C.D. for comparison | 6.0 | C.D. for comparison | 3.8 |

Figures in parentheses are angular transformations. CD. at 0.05 level

the lower concentration of 0.007 and 0.002 per cent of monocrotophos, mixing with different concentrations of carbendazim did not affect the toxicity to N. lugens as revealed from the mortality of test insect, (ranging from 53.34 to 61.68 per cent at 0.007 per cent concentration and from 28.3 to 36.65 per cent with 0.002 per cent concentration).

The inhibition of the fungus caused by carbendazim 5 ppm was 100 per cent while in combination with the three doses of monocrotophos the inhibitions were significantly reduced (ranging from 38.82 to 58.51 per cent, the effect being positively correlated with the doses of insecticide). Carbendazim 2.5 ppm gave 74.84 per cent inhibition while in combination with monocrotophos 0.03 per cent there was 100 per cent inhibition of the fungus but with the lower concentrations of insecticide the inhibitions were significantly reduced (38.82 and 65.55 per cent). At the lowest concentration of 1 ppm, carbendazim gave 48.86 per cent inhibition and it was on par with the inhibition of the fungicide combined with monocrotophos 0.002 per cent. But with higher concentrations of monocrotophos 0.007 and 0.03 per cent, the percentages of inhibition were significantly higher viz. 71.13 and 100 per cent respectively.

3.2.4. Combinations of quinalphos and captafol

Data relating to the interaction of quinalphos and captafol are presented in Table 6. Captafol 2000 ppm, 750 ppm

Table 6. Effect of combining various doses of quinalphos and captafol on their insecticidal and fungicidal properties assessed in the laboratory using N.lugens and R.solani as test organisms

| Insecticidal effect | | Fungicidal effect | |
|---|---|---|---|
| Treatments | Mean percentage mortality of N.lugens | Treatments | Mean percentage inhibition of R.solani over control |
| Captafol 2000 ppm | 16.21 (23.73) | Quinalphos 0.05% | 92.63 (74.22) |
| ,, 750 ,, | 16.36 (23.85) | ,, 0.02% | 83.68 (66.15) |
| ,, 250 ,, | 13.01 (21.14) | ,, 0.005% | 72.57 (58.39) |
| Quinalphos 0.05% | 76.99 (61.31) | Captafol 2000 ppm | 100.00 (90.00) |
| ,, + captafol 2000 ppm | 85.24 (67.38) | ,, + quinalphos 0.05% | 100.00 (90.00) |
| ,, + ,, 750 ,, | 96.72 (79.53) | ,, + ,, 0.02% | 100.00 (90.00) |
| ,, + ,, 250 ,, | 87.44 (69.21) | ,, + ,, 0.005% | 100.00 (90.00) |
| Quinalphos 0.02% | 46.65 (43.06) | Captafol 750 ppm | 75.55 (60.84) |
| ,, + captafol 2000 ppm | 93.14 (74.79) | ,, + quinalphos 0.05% | 99.37 (85.43) |
| ,, + ,, 750 ,, | 87.44 (69.21) | ,, + ,, 0.02% | 100.00 (90.00) |
| ,, + ,, 250 ,, | 85.24 (67.38) | ,, + ,, 0.005% | 100.00 (90.00) |
| Quinalphos 0.005% | 26.44 (30.93) | Captafol 250 ppm | 48.90 (44.35) |
| ,, + captafol 2000 ppm | 66.69 (54.73) | ,, + quinalphos 0.05% | 96.27 (78.83) |
| ,, + ,, 750 ,, | 65.06 (53.74) | ,, + ,, 0.02% | 99.51 (85.95) |
| ,, + ,, 250 ,, | 63.35 (52.72) | ,, + ,, 0.005% | 88.20 (69.88) |
| C.D. for comparison | 9.9 | C.D. for comparison | 6.3 |

Figures in parentheses are angular transformations. CD. at 0.05 level

and 250 ppm gave mortalities of N. lugens ranging from 13.01 to 16.36 per cent. Quinalphos 0.05 per cent when mixed with captafol 2000 ppm gave a mortality of 85.24 per cent of N. lugens and this was on par with the mortality caused by quinalphos alone. With captafol 750 ppm and 250 ppm, the mortalities were significantly higher (96.72 and 87.44 per cent respectively). Quinalphos 0.02 per cent combined with all the three concentrations of captafol gave significantly higher per cent kill of N. lugens (85.24 to 93.14 per cent), the differences being directly proportional to the concentrations of fungicide. In the case of quinalphos 0.005 per cent also the same trend was observed (26.44 per cent kill observed in quinalphos alone got enhanced to the range of 63.35 to 66.69 per cent in the combinations).

Quinalphos was found to have significant fungicidal effect also. With the three concentrationsof 0.05, 0.02 and 0.005 per cent tried in this experiment, the percentages of inhibitions of R. solani were 92.63, 83.68 and 72.57 respectively. The fungicide at 2000 ppm and its combination with all the concentration of insecticide gave 100 per cent inhibition of the fungus. Captafol 750 ppm gave 75.55 per cent inhibition of the fungus only, while in combination with quinalphos 0.05, 0.02 and 0.005 per cent, the inhibition rose to 99.37, 100 and 100 per cent respectively.

Captafol 250 ppm gave only 48.90 per cent inhibition while in combination with 0.05, 0.02 and 0.005 per cent, the percentages of inhibition were raised to the levels of 96.27, 99.51 and 88.20 respectively.

3.2.5. Combinations of quinalphos and ediphenphos

The data relating to the experiment are presented in Table 7. Ediphenphos 100 ppm, 50 ppm and 20 ppm gave 33.17, 29.92 and 19.84 per cent kill of N. lugens respectively and were statistically on par. The kill of N. lugens caused by quinalphos 0.05 per cent and its combination with ediphenphos 50 ppm and 20 ppm were on par (76.99 to 84.77 per cent), whereas in combination with 100 ppm the mortality was significantly higher (93.51%). Quinalphos 0.02 per cent alone gave 46.65 per cent kill while in combination with the three concentrations of ediphenphos, the mortalities were significantly enhanced (60.13 to 91.84 per cent). With reference to the lowest concentration of 0.005 per cent also the same trend was noted in combination with the fungicide. The insecticide alone caused only 26.44 per cent kill while in combination with the fungicide the mortalities ranged from 55.07 to 58.54 per cent.

Ediphenphos 100 ppm gave 100 per cent inhibition of the fungus while in combination with three concentrations of insecticide the inhibition got significantly reduced (84.04 to 88.25 per cent). Ediphenphos 50 ppm gave 77.43 per cent

Table 7. Effect of combining various doses of quinalphos and ediphenphos on their insecticidal and fungicidal properties assessed in the laboratory using N.lugens and R.solani as test organisms

| Insecticidal effect | | Fungicidal effect | |
|---|---|---|---|
| Treatments | Mean percentage mortality of N.lugens | Treatments | Mean percentage inhibition of R.solani over control |
| Ediphenphos 100 ppm | 33.17 (35.15) | Quinalphos 0.05% | 92.63 (74.22) |
| ,, 50 ,, | 29.92 (33.15) | ,, 0.02% | 83.68 (66.15) |
| ,, 20 ,, | 19.84 (26.44) | ,, 0.005% | 72.57 (58.39) |
| Quinalphos 0.05% | 76.99 (61.31) | Ediphenphos 100 ppm | 100.00 (90.00) |
| ,, + ediphenphos 100 ppm | 93.51 (75.21) | ,, + quinalphos 0.05% | 88.25 (69.93) |
| ,, + ,, 50 ,, | 84.77 (67.00) | ,, + ,, 0.02% | 84.04 (66.42) |
| ,, + ,, 20 ,, | 78.65 (62.45) | ,, + ,, 0.005% | 84.98 (67.17) |
| Quinalphos 0.02% | 46.65 (43.06) | Ediphenphos 50 ppm | 77.43 (61.91) |
| ,, + ediphenphos 100 ppm | 91.84 (73.37) | ,, + quinalphos 0.05% | 83.68 (66.15) |
| ,, + ,, 50 ,, | 83.79 (66.23) | ,, + ,, 0.02% | 75.55 (60.34) |
| ,, + ,, 20 ,, | 60.13 (50.82) | ,, + ,, 0.005% | 71.47 (57.69) |
| Quinalphos 0.005% | 26.44 (30.93) | Ediphenphos 20 ppm | 47.37 (43.47) |
| ,, + ediphenphos 100 ppm | 58.54 (49.90) | ,, + quinalphos 0.05% | 100.00 (90.00) |
| ,, + ,, 50 ,, | 55.07 (47.89) | ,, + ,, 0.02% | 70.01 (56.77) |
| ,, + ,, 20 ,, | 55.18 (47.95) | ,, + ,, 0.005% | 66.33 (54.51) |
| C.D. for comparison | 10.5 | C.D. for comparison | 5.1 |

Figures in parentheses are angular transformations. CD. at 0.05 level

inhibition while with the highest concentration of quinalphos the inhibition of the fungus was higher (83.68%) and with middle and lowest concentrations the inhibitions were on par (75.55 and 71.47 per cent respectively. In the case of ediphenphos 20 ppm, the inhibition was 47.37 per cent only while in combination with the three concentrations of insecticide the inhibition got significantly enhanced to the range of 66.33 to 100 per cent.

3.2.6. Combinations of quinalphos and carbendazim

Data relating to this experiment are presented in Table 8. The percentage kill of N. lugens caused by carbendazim 5 ppm, 2.5 ppm and 1 ppm were 11.67, 8.33 and 11.67 per cent respectively. Quinalphos 0.05 per cent gave 76.99 per cent kill of N. lugens while in combination with the three concentrations of carbendazim the mortalities ranged from 72.02 to 78.38 per cent, there being no statistical difference among them. With reference to quinalphos 0.02 per cent and its combination with carbendazim, the mortality ranged from 46.65 to 58.39 per cent and these were all on par. At the lowest dose of 0.005 per cent, quinalphos gave 26.44 per cent kill, while its combination with the different concentrations of fungicide gave mortalities ranging from 44.93 to 51.72 per cent, there being no significant difference among the combinations.

Table 8. Effect of combining various doses of quinalphos and carbendazim on their insecticidal and fungicidal properties assessed in the laboratory using N.lugens and R.solani as test organisms

| Insecticidal effect | | Fungicidal effect | |
|---|---|---|---|
| Treatments | Mean percentage mortality of N.lugens | Treatments | Mean percentage inhibition of R.solani over control |
| Carbendazim 5 ppm | 11.67 (19.88) | Quinalphos 0.05% | 92.63 (74.22) |
| ,, 2.5 ,, | 8.33 (16.20) | ,, 0.02% | 83.68 (66.15) |
| ,, 1 ,, | 11.67 (19.88) | ,, 0.005% | 72.57 (58.39) |
| Quinalphos 0.05% | 76.99 (61.31) | Carbendazim 5 ppm | 100.00 (90.00) |
| ,, + carbendazim 5 ppm | 72.02 (58.04) | ,, + quinalphos 0.05% | 100.00 (90.00) |
| ,, + ,, 2.5 ,, | 73.00 (58.66) | ,, + ,, 0.02% | 100.00 (90.00) |
| ,, + ,, 1 ,, | 78.38 (62.26) | ,, + ,, 0.005% | 100.00 (90.00) |
| Quinalphos 0.02% | 46.65 (43.06) | Carbendazim 2.5 ppm | 74.84 (59.87) |
| ,, + carbendazim 5 ppm | 50.00 (44.68) | ,, + quinalphos 0.05% | 100.00 (90.00) |
| ,, + ,, 2.5 ,, | 58.39 (49.81) | ,, + ,, 0.02% | 100.00 (90.00) |
| ,, + ,, 1 ,, | 55.07 (47.89) | ,, + ,, 0.005% | 90.05 (71.56) |
| Quinalphos 0.005% | 26.44 (30.93) | Carbendazim 1 ppm | 48.86 (44.33) |
| ,, + carbendazim 5 ppm | 44.93 (42.07) | ,, + quinalphos 0.05% | 100.00 (90.00) |
| ,, + ,, 2.5 ,, | 51.72 (45.97) | ,, + ,, 0.02% | 100.00 (90.00) |
| ,, + ,, 1 ,, | 51.67 (45.93) | ,, + ,, 0.005% | 85.20 (67.35) |
| C.D. for comparison | 9.5 | C.D. for comparison | 1.7 |

Figures in parentheses are angular transformations. CD. at 0.05 level

Carbendazim 5 ppm as well as its combinations with all the concentrations of quinalphos gave 100 per cent inhibition of R. solani. Carbendazim at 2.5 ppm gave 74.84 per cent inhibition of fungus while its combination with 0.005 per cent quinalphos gave significantly higher level of inhibition (90.05 per cent). When combined with quinalphos 0.05 and 0.02 per cent there was 100 per cent inhibition of the fungus. Carbendazim 1 ppm gave 48.86 per cent inhibition of fungus while its combination with the lowest concentration of insecticide gave 85.20 per cent inhibition, which was significantly higher. In combination with the other two concentrations of the insecticide also carbendazim gave 100 per cent inhibition of the fungus.

3.2.7. Combinations of HCH and captafol

The results relating to the experiment and statistical analysis of the data are presented in Table 9. Captafol 2000 ppm, 750 ppm and 250 ppm gave mortalities of N. lugens ranging from 13.01 to 16.36 per cent. HCH 0.2 per cent gave 76.71 per cent kill of N. lugens while in combination with the three concentrations of captafol the mortality fell to the range of 41.61 to 55.02 per cent. HCH 0.071 per cent and that in combination with captafol 2000 ppm were statistically on par (48.31 and 53.34 per cent respectively). The effects in combination with captafol 750 ppm and 250 ppm

Table 9. Effect of combining various doses of HCH and captafol on their insecticidal and fungicidal properties assessed in the laboratory using N.lugens and R.solani as test organisms

| Insecticidal effect | | Fungicidal effect | |
|---|---|---|---|
| Treatments | Mean percentage mortality of N.lugens | Treatments | Mean percentage inhibition of R.solani over control |
| Captofol 2000 ppm | 16.21 (23.73) | HCH 0.2% | 100.00 (90.00) |
| ,, 750 ,, | 16.36 (23.85) | ,, 0.071% | 100.00 (90.00) |
| ,, 250 ,, | 13.01 (21.14) | ,, 0.026% | 79.83 (63.29) |
| HCH 0.2% | 76.71 (61.20) | Captafol 2000 ppm | 100.00 (90.00) |
| ,, + captafol 2000 ppm | 55.02 (47.86) | ,, + HCH 0.2% | 100.00 (90.00) |
| ,, + ,, 750 ,, | 48.33 (44.03) | ,, + ,, 0.071% | 100.00 (90.00) |
| ,, + ,, 250 ,, | 41.61 (40.15) | ,, + ,, 0.026% | 100.00 (90.00) |
| HCH 0.071% | 48.31 (44.02) | Captafol 750 ppm | 75.55 (60.84) |
| ,, + captafol 2000 ppm | 53.34 (46.89) | ,, + HCH 0.2% | 100.00 (90.00) |
| ,, + ,, 750 ,, | 39.96 (39.20) | ,, + ,, 0.071% | 100.00 (90.00) |
| ,, + ,, 250 ,, | 36.60 (37.21) | ,, + ,, 0.026% | 100.00 (90.00) |
| HCH 0.026% | 24.53 (29.67) | Captafol 250 ppm | 48.90 (44.35) |
| ,, + captafol 2000 ppm | 34.94 (36.22) | ,, + HCH 0.2% | 100.00 (90.00) |
| ,, + ,, 750 ,, | 38.28 (38.21) | ,, + ,, 0.071% | 100.00 (90.00) |
| ,, + ,, 250 ,, | 36.65 (37.24) | ,, + ,, 0.026% | 100.00 (90.00) |
| C.D. for comparison | 6.7 | C.D. for comparison | 2.5 |

Figures in parentheses are angular transformations. CD. at 0.05 level

were on par between themselves (39.96 and 36.60 per cent respectively) and both were inferior to the effect caused by insecticide alone. At the lowest concentration of 0.026 per cent the mortality caused by HCH was inferior to the combinations involving the three concentrations of fungicide (24.53 to 38.28 per cent), which were statistically on par among themselves.

HCH was found to have significant fungicidal effect also. The three concentrations of 0.2, 0.071 and 0.026 per cent gave 100, 100 and 79.83 per cent inhibition of R. solani. The inhibitions by captafol at 2000 ppm, 750 ppm and 250 ppm in combination with all the three concentrations of HCH reached the level of 100 per cent.

3.2.8. Combinations of HCH and ediphenphos

The results of the experiment and the statistical analysis of the data are presented in Table 10. Ediphenphos 100 ppm, 50 ppm and 20 ppm gave 33.17, 29.92 and 19.84 per cent kill of N. lugens respectively and treatments were statistically on par. The mortality caused by HCH 0.2 per cent (76.71 per cent) came on par with the mortality caused by the insecticide in combination with three concentrations of ediphenphos (71.70 to 81.73 per cent). HCH 0.071 per cent caused 48.31 per cent kill of insects, while the mortality caused by the three concentrations of insecticide in combination with ediphenphos were significantly higher and on par

Table 10. Effect of combining various doses of HCH and ediuphenphos on their insecticidal and fungicidal properties assessed in the laboratory using N.lugens and R.solani as test organisms

| Insecticidal effect | | Fungicidal effect | |
|---|---|---|---|
| Treatments | Mean percentage mortality of N.lugens | Treatments | Mean percentage inhibition of R.solani over control |
| Ediphenphos 100 ppm | 33.17 (35.15) | HCH 0.2% | 100.00 (90.00) |
| ,, 50 ,, | 29.92 (33.15) | ,, 0.071% | 100.00 (90.00) |
| ,, 20 ,, | 19.84 (26.44) | ,, 0.026% | 79.83 (63.29) |
| HCH 0.2% | 76.71 (61.20) | Ediphenphos 100 ppm | 100.00 (90.00) |
| ,, + ediphenphos 100 ppm | 75.11 (60.05) | ,, + HCH 0.2% | 100.00 (90.00) |
| ,, + ,, 50 ,, | 81.73 (64.67) | ,, + ,, 0.071% | 100.00 (90.00) |
| ,, + ,, 20 ,, | 71.70 (57.84) | ,, + ,, 0.026% | 100.00 (90.00) |
| HCH 0.071% | 48.31 (44.02) | Ediphenphos 50 ppm | 77.43 (61.91) |
| ,, + ediphenphos 100 ppm | 75.11 (60.05) | ,, + HCH 0.2% | 100.00 (90.00) |
| ,, + ,, 50 ,, | 73.56 (59.03) | ,, + ,, 0.071% | 100.00 (90.00) |
| ,, + ,, 20 ,, | 68.49 (55.83) | ,, + ,, 0.026% | 100.00 (90.00) |
| HCH 0.026% | 24.53 (29.67) | Ediphenphos 20 ppm | 47.37 (43.47) |
| ,, + ediphenphos 100 ppm | 68.49 (55.83) | ,, + HCH 0.2% | 100.00 (90.00) |
| ,, + ,, 50 ,, | 65.23 (53.84) | ,, + ,, 0.071% | 100.00 (90.00) |
| ,, + ,, 20 ,, | 60.03 (50.77) | ,, + ,, 0.026% | 100.00 (90.00) |
| C.D. for comparison | 6.7 | C.D. for comparison | 5.0 |

Figures in parentheses are angular transformations. CD. at 0.05 level

among themselves (68.49 to 75.11 per cent). HCH 0.026 per cent gave 24.53 per cent kill of N. lugens while in combination with different concentrations of fungicide the mortalities were significantly higher and on par (60.03 to 68.49 per cent) among themselves.

The inhibition of R. solani by ediphenphos at 100 ppm, 50 ppm and 20 ppm in combination with all the three concentrations of HCH reached the level of 100 per cent.

3.2.9. Combinations of HCH and carbendazim

The result relating to the experiment and statistical analysis of the data are presented in Table 11. The percentage kill of N. lugens caused by carbendazim 5 ppm, 2.5 ppm and 1 ppm were 11.67, 8.33 and 11.67 per cent respectively. HCH 0.2 per cent gave 76.71 per cent kill of the insect. The insecticide in combination with fungicides gave lower kill (63.44 to 66.91 per cent) but the data were on par. Two of the combinations were on par with the insecticide treatment also. The mortality with HCH 0.071 per cent was 48.31 per cent, while in combination with different concentrations of fungicide the mortality ranged from 60.04 to 61.72 per cent. The mortality given by HCH 0.026 per cent was 24.53 per cent. In combination with fungicides the mortalities ranged from 33.31 to 44.98 per cent.

Table 11. Effect of combining various doses of HCH and carbendazim on their insecticidal and fungicidal properties assessed in the laboratory using N.lugens and R.solani as test organisms

| Insecticidal effect | | Fungicidal effect | |
|---|---|---|---|
| Treatments | Mean percentage mortality of N.lugens | Treatments | Mean percentage inhibition of R.solani over control |
| Carbendazim 5 ppm | 11.67 (19.28) | HCH 0.2% | 100.00 (90.00) |
| ,, 2.5 ,, | 8.33 (16.20) | ,, 0.071% | 100.00 (90.00) |
| ,, 1 ,, | 11.67 (19.28) | ,, 0.026% | 79.83 (63.29) |
| HCH 0.2% | 76.71 (61.20) | Carbendazim 5 ppm | 100.00 (90.00) |
| ,, + carbendazim 5 ppm | 66.91 (54.86) | ,, + HCH 0.2% | 100.00 (90.00) |
| ,, + ,, 2.5 ,, | 63.44 (52.77) | ,, + ,, 0.071% | 100.00 (90.00) |
| ,, + ,, 1 ,, | 65.14 (53.79) | ,, + ,, 0.026% | 100.00 (90.00) |
| HCH 0.071% | 48.31 (44.02) | Carbendazim 2.5 ppm | 74.84 (59.87) |
| ,, + carbendazim 5 ppm | 61.72 (51.75) | ,, + HCH 0.2% | 100.00 (90.00) |
| ,, + ,, 2.5 ,, | 60.04 (50.77) | ,, + ,, 0.071% | 100.00 (90.00) |
| ,, + ,, 1 ,, | 61.68 (51.74) | ,, + ,, 0.026% | 100.00 (90.00) |
| HCH 0.026% | 24.53 (29.67) | Carbendazim 1 ppm | 48.86 (44.33) |
| ,, + carbendazim 5 ppm | 39.97 (39.20) | ,, + HCH 0.2% | 100.00 (90.00) |
| ,, + ,, 2.5 ,, | 33.31 (35.24) | ,, + ,, 0.071% | 100.00 (90.00) |
| ,, + ,, 1 ,, | 44.98 (42.10) | ,, + ,, 0.026% | 100.00 (90.00) |
| C.D. for comparison | 6.5 | C.D. ror comparison | 2.2 |

Figures in parentheses are angular transformations. CD. at 0.05 level

The inhibitions of R. solani by carbendazim at 5 ppm, 2.5 ppm and 1 ppm in combination with all the three concentrations of HCH reached the level of 100 per cent.

### 3.3. Effect of combining insecticides and fungicides on the control of N. lugens and sheath blight (pot culture)

Data relating to the experiment and the statistical analysis of the same are presented in Table 12. There was 8.90 per cent mortality of N. lugens in control. In treatments using fungicides alone, the mortality ranged from 7.187 to 24.988 per cent but the data were on par. Mortality of N. lugens in pots treated with monocrotophos 0.05 per cent was 99.556 per cent and in the treatments in which the insecticide was combined with fungicides the percentages of mortality ranged from 89.973 to 100 per cent. The data were on par. Quinalphos 0.05 per cent gave 100 per cent kill of insect. In combination with fungicide, the mortality percentages ranged from 95.52 to 100 per cent. These treatments were also on par. Quinalphos 0.025 per cent gave 74.196 per cent mortality and the mortality obtained in the application of the insecticide combined with carbendazim 1000 ppm and 500 ppm also came on par (88.199 and 91.274 per cent respectively). In the remaining treatments in which quinalphos 0.025 per cent was combined with ediphenphos and captafol the percentages of

Table 12. Effect of combining insecticides and fungicides on the control of sheath blight and N.lugens (Pot culture)

| Treatments | Mean indices of sheath blight incidence* | Per cent mortality of N.lugens** |
|---|---|---|
| Monocrotophos 0.05% | 4.277 (2.068) | 99.556 (86.144) |
| Quinalphos 0.05% | 4.860 (2.204) | 100.000 (90.000) |
| Quinalphos 0.025% | 4.277 (2.068) | 74.196 (59.447) |
| HCH 0.2% | 4.860 (2.204) | 82.943 (65.580) |
| Captafol 3000 ppm | 3.610 (1.900) | 14.481 (22.357) |
| ,, + monocrotophos 0 | 3.610 (1.900) | 93.643 (75.366) |
| ,, + quinalphos 0.0 | 1.548 (1.244) | 100.000 (90.000) |
| ,, + ,, 0.0 | 4.277 (2.068) | 99.556 (86.144) |
| ,, + HCH 0.2% | 2.214 (1.488) | 93.643 (75.366) |
| Captafol 1500 ppm | 4.277 (2.068) | 7.187 (15.544) |
| ,, + monocrotophos 0.05% | 1.548 (1.244) | 94.550 (76.469) |
| ,, + quinalphos 0.05% | 3.000 (1.732) | 100.000 (90.000) |
| ,, + ,, 0.025% | 3.610 (1.900) | 93.776 (75.522) |
| ,, + HCH 0.2% | 3.610 (1.900) | 91.740 (73.268) |
| Carbendazim 1000 ppm | 1.000 (1.000) | 12.945 (21.079) |
| ,, + monocrotophos 0.05% | 1.000 (1.000) | 89.973 (75.150) |
| ,, + quinalphos 0.05% | 2.742 (1.656) | 96.623 (79.378) |
| ,, + ,, 0.025% | 1.548 (1.244) | 88.199 (69.880) |
| ,, + HCH 0.2% | 4.277 (2.068) | 88.905 (70.515) |
| Carbendazim 500 ppm | 1.000 (1.000) | 10.027 (18.454) |
| ,, + monocrotophos 0.05% | 1.548 (1.244) | 96.398 (79.027) |
| ,, + quinalphos 0.05% | 2.742 (1.656) | 95.520 (77.748) |
| ,, + ,, 0.025% | 1.548 (1.244) | 91.274 (72.789) |
| ,, + HCH 0.2% | 2.742 (1.656) | 95.520 (77.748) |
| Ediphenphos 1000 ppm | 1.000 (1.000) | 24.988 (29.980) |
| ,, + monocrotophos 0.05% | 1.000 (1.000) | 99.556 (86.144) |
| ,, + quinalphos 0.05% | 1.548 (1.244) | 100.000 (90.000) |
| ,, + ,, 0.025% | 2.214 (1.488) | 97.383 (80.657) |
| ,, + HCH 0.2% | 4.277 (2.068) | 93.214 (82.288) |
| Ediphenphos 500 ppm | 3.610 (1.900) | 19.576 (26.250) |
| ,, + monocrotophos 0.05% | 1.548 (1.244) | 100.000 (90.000) |
| ,, + quinalphos 0.05% | 1.548 (1.244) | 100.000 (90.000) |
| ,, + ,, 0.025% | 3.610 (1.900) | 98.626 (83.235) |
| ,, + HCH 0.2% | 1.548 (1.244) | 98.626 (83.235) |
| Control | 6.296 (2.509) | 8.900 (17.350) |
| C.D. for comparison | 0.707 | 15.15 |

Disease incidence was assessed in 0 - 9 scale

* Figures in parentheses are squareroot transformations

** Figures in parentheses are angular transformations

CD. at 0.05 level

insect kill were higher (93.776 to 99.556 per cent). HCH alone gave 82.943 per cent kill of insect. This and the mortalities caused by the combinations of HCH with captafol and carbendazim came on par (88.90 to 95.52 per cent). When combined with ediphenphos 1000 ppm and 500 ppm the kill of the insect were found to be high, 93.214 and 98.626 per cent respectively.

The disease index in control plant was 6.296. The application of the insecticides monocrotophos, quinalphos and HCH did not significantly reduce the disease incidence (incidence ranged from 4.277 to 4.860 only). The disease index in captafol 3000 ppm treated pot was 3.610. The indices in treatments in which captafol 3000 ppm was combined with the above insecticides came on par among themselves and with the index in fungicide treatment alone (4.277 to 1.548). The disease index in pots treated with captafol 1500 ppm was 4.277. When combined with HCH 0.2, quinalphos 0.05 and 0.025 per cent the indices were slightly reduced but all were on par. The disease index in pots treated with the fungicide in combination with monocrotophos was found to be lower compared to the fungicide treatment alone (1.548 and 4.277 respectively).

The disease index in the case of carbendazim 1000 ppm, the combinations with monocrotophos and two concentrations of quinalphos ranged from 1 to 2.742 and were on par but with

HCH the disease index was higher (4.277). The disease index in pots treated with carbendazim 500 ppm as well as its combinations with various insecticides ranged from 1 to 2.742 and were on par.

The disease indices in pots treated with ediphenphos 1000 ppm and its combinations with monocrotophos and quinalphos ranged from 1 to 2.214 and were on par. But the disease index in pots treated with ediphenphos and HCH was higher (4.277). The disease index in the pots treated with ediphenphos 500 ppm and its combinations with various insecticides ranged from 1.548 to 3.610 and came on par.

### 3.4. Effect of applying insecticide and fungicide in sequence and in combination on the control of *N. lugens* and sheath blight (pot culture)

The data of the experiment and the statistical analysis of the same presented in Table 13 showed that the mortality of *N. lugens* caused by the application of the fungicide followed by the insecticide was found to be significantly higher than the mortality in treatment with insecticide followed by fungicide or the combined application of the chemicals in the case of monocrotophos 0.05% and captafol 3000 ppm only.

The application of the fungicide followed by the insecticide or the combined application of the chemicals were found on par and significantly superior to the application of

Table 13. Effect of applying insecticides and fungicides in sequence and in combination on the control of N.lugens

| Treatments | Mean percentage mortality of N. lugens after applying | | |
|---|---|---|---|
| | Insecticide followed by fungicide | Fungicide followed by insecticide | Insecticide and fungicide combined |
| Monocrotophos 0.05% and captafol 3000 ppm | 81.78 (64.71) | 99.10 (84.51) | 93.64 (75.37) |
| ,, and ,, 1500 ,, | 99.10 (84.51) | 97.64 (81.14) | 99.55 (76.47) |
| ,, and carbendazim 1000 ,, | 94.69 (76.65) | 89.97 (71.51) | 89.97 (71.51) |
| ,, and ,, 500 ,, | 94.55 (76.47) | 97.64 (81.14) | 96.40 (79.03) |
| ,, and ediphenphos 1000 ,, | 96.62 (79.38) | 91.27 (72.79) | 99.56 (86.14) |
| ,, and ,, 500 ,, | 99.10 (84.51) | 78.87 (62.61) | 100.00 (90.00) |
| Quinalphos 0.05% and captafol 3000 ppm | 82.16 (65.00) | 98.14 (82.13) | 100.00 (90.00) |
| ,, and ,, 1500 ,, | 85.52 (67.61) | 95.52 (77.75) | 100.00 (90.00) |
| ,, and carbendazim 1000 ,, | 94.46 (76.36) | 78.87 (62.61) | 96.62 (79.38) |
| ,, and ,, 500 ,, | 97.64 (81.14) | 86.59 (68.49) | 95.52 (77.75) |
| ,, and ediphenphos 1000 ,, | 98.14 (82.13) | 98.63 (83.23) | 100.00 (90.00) |
| ,, and ,, 500 ,, | 93.88 (75.65) | 91.27 (72.79) | 100.00 (90.00) |
| Quinalphos 0.025% and captafol 3000 ppm | 78.87 (62.61) | 75.01 (59.98) | 99.56 (86.14) |
| ,, and ,, 1500 ,, | 65.42 (53.96) | 73.36 (58.90) | 93.78 (75.52) |
| ,, and carbendazim 1000 ,, | 60.09 (50.80) | 73.78 (59.18) | 88.20 (69.88) |
| ,, and ,, 500 ,, | 75.01 (59.98) | 96.62 (79.38) | 91.27 (72.79) |
| ,, and ediphenphos 1000 ,, | 98.63 (83.23) | 98.63 (83.23) | 97.38 (80.66) |
| ,, and ,, 500 ,, | 96.62 (79.38) | 79.76 (63.23) | 98.63 (83.23) |
| H C H 0.2% and captafol 3000 ppm | 82.16 (65.00) | 82.77 (65.45) | 93.64 (75.37) |
| ,, and ,, 1500 ,, | 75.46 (60.28) | 72.24 (58.18) | 91.74 (73.27) |
| ,, and carbendazim 1000 ,, | 73.59 (59.05) | 85.52 (67.61) | 88.90 (70.52) |
| ,, and ,, 500 ,, | 69.45 (56.43) | 76.32 (60.85) | 95.52 (77.75) |
| ,, and ediphenphos 1000 ,, | 73.78 (59.18) | 83.46 (65.98) | 98.21 (82.29) |
| ,, and ,, 500 ,, | 65.42 (53.96) | 98.14 (82.13) | 98.63 (83.23) |
| Control | 8.90 (17.35) | | |
| C.D. for comparing treatments as well as sequence of application | | 14.67 | |

Figures in parentheses are angular transformations.
CD. at 0.05 level

the insecticide followed by the fungicide in the treatments, quinalphos 0.05% + captafol 3000 ppm, quinalphos 0.025 + carbendazim 1000 ppm, quinalphos 0.025% + carbendazim 500 ppm and HCH 0.2% + ediphenphos 500 ppm.

Application of insecticide followed by the fungicide or the combined application of the chemicals were found on par and significantly superior to the application of fungicide followed by insecticide in the case of following treatments viz. quinalphos 0.05% + carbendazim 1000 ppm, quinalphos 0.05% + ediphenphos 500 ppm and quinalphos 0.025% + ediphenphos 500 ppm.

Combined application of the insecticide and fungicide was found significantly superior than the application of chemicals in sequence in the case of quinalphos 0.05% + captafol 1500 ppm, quinalphos 0.025% + captafol 3000 ppm, quinalphos 0.025% + captafol 1500 ppm, HCH 0.2% + carbendazim 500 ppm and HCH 0.2% + ediphenphos 1000 ppm. The other treatments in the experiment did not show significant variation in the data.

The disease indices (Table 14) in pots treated with the fungicide followed by the insecticide or with the simultaneous application of the chemicals were on par and significantly superior to the indices in plants treated with the insecticide followed by the fungicide in the treatments carbendazim 1000 ppm + monocrotophos 0.05%, carbendazim 1000 ppm +

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Table 14. Effect of applying fungicides and insecticides in sequence and in combination on the control of sheath blight

| Treatments | Mean indices of sheath blight incidence after applying | | |
|---|---|---|---|
| | Fungicide followed by insecticide | Insecticide followed by fungicide | Fungicide and insecticide combined |
| Captafol 3000 ppm and monocrotophos 0.05% | 2.21 (1.488) | 2.74 (1.656) | 3.61 (1.900) |
| ,, and quinalphos 0.05% | 2.74 (1.656) | 2.74 (1.656) | 1.55 (1.244) |
| ,, and ,, 0.025% | 4.28 (2.068) | 5.00 (2.236) | 4.28 (2.068) |
| ,, and HCH 0.2% | 3.00 (1.732) | 3.61 (1.900) | 2.21 (1.488) |
| Captafol 1500 ppm and monocrotophos 0.05% | 4.28 (2.068) | 5.00 (2.236) | 1.55 (1.244) |
| ,, and quinalphos 0.05% | 4.28 (2.068) | 2.21 (1.488) | 3.00 (1.732) |
| ,, and ,, 0.025% | 4.28 (2.068) | 3.00 (1.732) | 3.61 (1.900) |
| ,, and HCH 0.2% | 3.61 (1.900) | 3.61 (1.900) | 3.61 (1.900) |
| Carbendazim 1000 ppm and monocrotophos 0.05% | 1.00 (1.000) | 2.74 (1.656) | 1.00 (1.000) |
| ,, and quinalphos 0.05% | 1.00 (1.000) | 1.00 (1.000) | 2.74 (1.656) |
| ,, and ,, 0.025% | 5.00 (2.236) | 2.21 (1.488) | 1.55 (1.244) |
| ,, and HCH 0.2% | 2.74 (1.656) | 1.55 (1.244) | 4.28 (2.068) |
| Carbendazim 500 ppm and monocrotophos 0.05% | 1.55 (1.244) | 4.28 (2.068) | 1.55 (1.244) |
| ,, and quinalphos 0.05% | 3.61 (1.900) | 4.28 (2.068) | 2.74 (1.656) |
| ,, and ,, 0.025% | 2.21 (1.488) | 5.00 (2.236) | 1.55 (1.244) |
| ,, and HCH 0.2% | 4.28 (2.068) | 3.00 (1.732) | 2.74 (1.656) |
| Ediphenphos 1000 ppm and monocrotophos 0.05% | 1.00 (1.000) | 3.00 (1.732) | 1.00 (1.000) |
| ,, and quinalphos 0.05% | 1.00 (1.000) | 1.00 (1.000) | 1.55 (1.244) |
| ,, and ,, 0.025% | 2.21 (1.488) | 3.00 (1.732) | 2.21 (1.488) |
| ,, and HCH 0.2% | 5.00 (2.236) | 4.28 (2.068) | 4.28 (2.068) |
| Ediphenphos 500 ppm and monocrotophos 0.05% | 1.55 (1.244) | 3.00 (1.732) | 1.55 (1.244) |
| ,, and quinalphos 0.05% | 2.74 (1.656) | 2.21 (1.488) | 1.55 (1.244) |
| ,, and ,, 0.025% | 4.28 (2.068) | 4.28 (2.068) | 3.61 (1.900) |
| ,, and HCH 0.2% | 4.28 (2.068) | 4.28 (2.068) | 1.55 (1.244) |
| Control | 6.296(2.509) | | |
| C.D. for comparing treatments as well as sequence of application | | 0.569 | |

Figures in parentheses are squareroot transformations.

Disease incidence was assessed on 0 - 9 scale.

CD. at 0.05 level

quinalphos 0.05%, carbendazim 500 ppm + monocrotophos 0.05%, carbendazim 500 ppm + quinalphos 0.05% and ediphenphos 1000 ppm + monocrotophos 0.05%.

The application of the insecticide followed by the fungicide as well as the simultaneous application of the chemicals were found on par and significantly superior to the application of the fungicide followed by the insecticide in the case of carbendazim 1000 ppm + quinalphos 0.025% only.

The sequential application of the insecticide followed by the fungicide or vice versa were found on par and significantly superior to simultaneous application in treatments carbendazim 1000 ppm + quinalphos 0.05% and carbendazim 1000 ppm + HCH 0.2%.

The simultaneous application of insecticide and fungicide was found significantly superior to the sequential application of the chemicals in treatments, captafol 1500 ppm + monocrotophos 0.05% and ediphenphos 500 ppm + HCH 0.2%. The data relating to the remaining treatments in the experiment did not show statistically significant variations.

3.5. Effect of spraying insecticide-fungicide combinations, after keeping the mixture for different durations on the control of N. lugens and sheath blight

The data relating to the effect of keeping the formulations for varying durations before the application on the

insecticidal effect of chemicals are presented in Table 15. In comparison with the mortality of N. lugens caused by the formulations immediately after preparation, significant drop in the insecticidal activity was observed in the formulations kept for four hours or for greater durations in the case of quinalphos 0.025% + captafol 3000 ppm, HCH 0.2% + captafol 3000 ppm, HCH 0.2% + captafol 1500 ppm, HCH 0.2% + ediphenphos 1000 ppm and HCH 0.2% + ediphenphos 500 ppm. In the remaining combinations there was no reduction in the insecticidal activity of the formulations kept up to 24 hours after preparation.

The data relating to the effect of keeping the formulations for varying durations before application on the fungicidal effect of chemicals are presented in Table 16. Notable fall in the fungicidal effect of the spray formulations kept for varying durations after preparation was observed only in a limited number of treatments. The reduction was observed in the formulations of captafol 1500 ppm + monocrotophos 0.05%, ediphenphos 500 ppm + quinalphos 0.025%, carbendazim 1000 ppm + monocrotophos 0.05% and carbendazim 500 ppm + HCH 0.2% kept for 4 hours or for greater durations after preparation. Data relating to the remaining treatments did not show significant variation.

Table 15. Effect of spraying insecticide-fungicide combinations after keeping the mixture for different durations on the control of N.lugens

| Treatments | Mean percentage mortality of N. lugens when applied after keeping the mixture for different durations (h) | | | |
|---|---|---|---|---|
| | 0 | 4 | 8 | 24 |
| Monocrotophos 0.05% + captafol 3000 ppm | 93.64 (75.37) | 92.33 (73.89) | 97.38 (80.66) | 84.14 (66.50) |
| ,, + ,, 1500 ,, | 94.55 (76.47) | 94.46 (76.36) | 89.43 (71.00) | 82.71 (65.40) |
| ,, + carbendazim 1000 ppm | 89.97 (71.51) | 96.62 (79.38) | 92.81 (74.42) | 94.69 (76.65) |
| ,, + ,, 500 ,, | 96.40 (79.03) | 90.10 (71.63) | 85.95 (67.96) | 94.81 (76.80) |
| ,, + ediphenphos 1000 ppm | 99.56 (86.14) | 96.62 (79.38) | 92.67 (74.26) | 99.56 (86.14) |
| ,, + ,, 500 ,, | 100.00 (90.00) | 90.27 (71.80) | 98.21 (82.29) | 99.56 (86.14) |
| Quinalphos 0.05% + captafol 3000 ppm | 100.00 (90.00) | 97.38 (80.66) | 99.10 (84.51) | 99.10 (84.51) |
| ,, + ,, 1500 ,, | 100.00 (90.00) | 95.52 (77.75) | 89.97 (71.51) | 100.00 (90.00) |
| ,, + carbendazim 1000 ppm | 96.62 (79.38) | 85.38 (67.49) | 94.69 (76.65) | 97.13 (80.21) |
| ,, + ,, 500 ,, | 95.52 (77.75) | 94.81 (76.80) | 94.69 (76.65) | 92.33 (73.89) |
| ,, + ediphenphos 1000 ppm | 100.00 (90.00) | 99.56 (86.14) | 99.10 (84.51) | 95.52 (77.75) |
| ,, + ,, 500 ,, | 100.00 (90.00) | 95.52 (77.75) | 95.89 (72.28) | 98.21 (82.29) |
| Quinalphos 0.025% + captafol 3000 ppm | 99.56 (86.14) | 89.39 (70.97) | 85.95 (67.96) | 87.05 (68.88) |
| ,, + ,, 1500 ,, | 93.78 (75.52) | 95.18 (77.28) | 86.59 (68.49) | 82.94 (65.58) |
| ,, + carbendazim 1000 ppm | 88.20 (69.88) | 95.89 (78.28) | 92.33 (73.89) | 95.52 (77.75) |
| ,, + ,, 500 ,, | 91.27 (72.79) | 83.10 (65.70) | 90.27 (71.79) | 88.20 (69.88) |
| ,, + ediphenphos 1000 ppm | 97.38 (80.66) | 95.52 (77.75) | 98.63 (83.24) | 99.10 (84.51) |
| ,, + ,, 500 ,, | 98.63 (83.23) | 97.64 (81.14) | 94.81 (76.80) | 94.81 (76.80) |
| H C H 0.2% + captafol 3000 ppm | 93.64 (75.37) | 76.66 (61.09) | 76.49 (60.97) | 73.36 (58.90) |
| ,, + ,, 1500 ,, | 91.34 (73.27) | 74.77 (59.82) | 73.59 (59.05) | 68.04 (55.56) |
| ,, + carbendazim 1000 ppm | 88.90 (70.52) | 82.71 (65.40) | 84.37 (66.68) | 85.95 (67.96) |
| ,, + ,, 500 ,, | 95.52 (77.75) | 95.52 (77.75) | 95.18 (77.28) | 91.27 (72.79) |
| ,, + ediphenphos 1000 ppm | 98.21 (82.29) | 25.18 (30.10) | 27.76 (31.78) | 22.56 (28.35) |
| ,, + ,, 500 ,, | 98.63 (83.23) | 26.64 (31.06) | 22.64 (28.40) | 27.94 (31.90) |
| Control | 8.90 (17.35) | | | |
| C.D. for comparing treatments as well as the durations of keeping mixture | 13.73 | | | |

Figures in parentheses are angular transformations.

CD. at 0.05 level

Table 16. Effect of spraying fungicide-insecticide combinations after keeping the mixture for different durations on the control of sheath blight

| Treatments | | Mean indices of sheath blight incidences when applied after keeping the mixture for different durations (h) | | | |
|---|---|---|---|---|---|
| | | 0 | 4 | 8 | 24 |
| Captafol 3000 ppm | + monocrotophos 0.05% | 3.61 (1.900) | 4.28 (2.068) | 4.28 (2.068) | 5.00 (2.236) |
| ,, | + quinalphos 0.05% | 1.55 (1.244) | 2.74 (1.656) | 3.61 (1.900) | 3.33 (1.824) |
| ,, | + quinalphos 0.025% | 4.28 (2.068) | 4.28 (2.068) | 4.28 (2.068) | 5.00 (2.236) |
| ,, | + H C H 0.2% | 2.21 (1.488) | 2.74 (1.656) | 3.33 (1.824) | 4.28 (2.068) |
| Captafol 1500 ppm | + monocrotophos 0.05% | 1.55 (1.244) | 4.28 (2.068) | 5.00 (2.236) | 5.00 (2.236) |
| ,, | + quinalphos 0.05% | 3.00 (1.732) | 2.74 (1.656) | 3.61 (1.900) | 3.61 (1.900) |
| ,, | + quinalphos 0.025% | 3.61 (1.900) | 3.61 (1.900) | 4.28 (2.068) | 4.28 (2.068) |
| ,, | + H C H 0.2% | 3.61 (1.900) | 4.28 (2.068) | 4.28 (2.068) | 4.28 (2.068) |
| Ediphenphos 1000 ppm | + monocrotophos 0.05% | 1.00 (1.000) | 1.55 (1.244) | 1.55 (1.244) | 1.55 (1.244) |
| ,, | + quinalphos 0.05% | 2.74 (1.656) | 2.74 (1.656) | 2.74 (1.656) | 2.74 (1.656) |
| ,, | + quinalphos 0.025% | 1.55 (1.244) | 1.00 (1.000) | 1.55 (1.244) | 1.00 (1.000) |
| ,, | + H C H 0.2% | 4.28 (2.068) | 4.28 (2.068) | 3.61 (1.900) | 3.61 (1.900) |
| Ediphenphos 500 ppm | + monocrotophos 0.05% | 1.55 (1.244) | 2.21 (1.488) | 2.74 (1.656) | 2.74 (1.656) |
| ,, | + quinalphos 0.05% | 2.74 (1.656) | 4.28 (2.068) | 4.28 (2.068) | 4.28 (2.068) |
| ,, | + quinalphos 0.025% | 1.55 (1.244) | 2.21 (1.488) | 4.28 (2.068) | 4.28 (2.068) |
| ,, | + H C H 0.2% | 2.74 (1.656) | 3.61 (1.900) | 3.61 (1.900) | 3.61 (1.900) |
| Carbendazim 1000 ppm | + monocrotophos 0.05% | 1.00 (1.000) | 3.00 (1.732) | 3.00 (1.732) | 2.74 (1.656) |
| ,, | + quinalphos 0.05% | 1.55 (1.244) | 2.21 (1.488) | 2.21 (1.488) | 2.21 (1.488) |
| ,, | + quinalphos 0.025% | 2.21 (1.488) | 1.55 (1.244) | 2.21 (1.488) | 2.21 (1.488) |
| ,, | + H C H 0.2% | 4.28 (2.068) | 4.28 (2.068) | 5.00 (2.236) | 5.00 (2.236) |
| Carbendazim 500 ppm | + monocrotophos 0.05% | 1.55 (1.244) | 1.55 (1.244) | 1.55 (1.244) | 1.55 (1.244) |
| ,, | + quinalphos 0.05% | 1.55 (1.244) | 1.55 (1.244) | 1.55 (1.244) | 1.55 (1.244) |
| ,, | + quinalphos 0.025% | 3.61 (1.900) | 3.00 (1.732) | 4.28 (2.068) | 4.28 (2.068) |
| ,, | + H C H 0.2% | 1.55 (1.244) | 2.21 (1.488) | 3.61 (1.900) | 4.28 (2.068) |
| Control | | 6.296 (2.509) | | | |
| C.D. for comparing treatme duration of keeping t | as well as ixture | 0.616 | | | |

Figures in parentheses are squareroot transformations

Disease incidence was assessed on 0 - 9 scale.

CD. at 0.05 level

## 3.6. Effect of combined application of fungicide and insecticide in the field on the control of sheath blight

Results of the experiment and statistical analysis of the data are presented in Table 17. The disease indices in plots treated with monocrotophos, HCH or quinalphos came on par with that of control (5.63 to 5.67). All the treatments with the fungicide combinations reduced the disease indices significantly when compared to control (1.40 to 4.52).

The disease index in plots treated with captafol 3000 ppm was 3.48. In plots treated with fungicide in combination with quinalphos 0.025 per cent or HCH 0.2 per cent, the disease index was 3.04. Both were on par. The disease index in plots treated with the fungicide in combination with quinalphos 0.05 per cent or monocrotophos 0.05 per cent were on par and better than the other three treatments (2.88 and 2.49 respectively). The index in plots treated with captafol 1500 ppm alone was 4.52. The fungicide in combination with the two doses of quinalphos as well as HCH came on par (4.08 to 4.32). The fungicide combined with monocrotophos 0.05 per cent showed the least incidence (3.56).

Carbendazim 1000 ppm alone showed the least disease index of 1.40 and it came on par with the index in plots treated with the fungicide in combination with monocrotophos

Table 17. Effect of combined application of fungicide and insecticide in the field on the control of sheath blight

| Treatments | Mean indices of sheath blight incidence | |
|---|---|---|
| | Before treatment | Three weeks after treatment |
| Monocrotophos 0.05% | 2.52 (1.58) | 5.74 (2.397) |
| Quinalphos 0.05% | 2.88 (1.69) | 5.63 (2.373) |
| Quinalphos 0.025% | 3.32 (1.81) | 5.97 (2.443) |
| H C H 0.2% | 1.48 (1.21) | 5.90 (2.428) |
| Captafol 3000 ppm | 2.84 (1.68) | 3.48 (1.865) |
| Captafol 3000 ppm + monocrotophos 0.05% | 3.20 (1.79) | 2.88 (1.697) |
| ,, + quinalphos 0.05% | 1.76 (1.31) | 2.49 (1.578) |
| ,, + ,, 0.025% | 2.36 (1.53) | 3.04 (1.743) |
| ,, + H C H 0.2% | 2.98 (1.72) | 3.04 (1.743) |
| Captafol 1500 ppm | 1.64 (1.28) | 4.52 (2.126) |
| ,, + monocrotophos 0.05% | 2.06 (1.42) | 3.56 (1.886) |
| ,, + quinalphos 0.05% | 1.44 (1.20) | 4.08 (2.020) |
| ,, + ,, 0.025% | 2.54 (1.59) | 4.32 (2.078) |
| ,, + H C H 0.2% | 2.08 (1.43) | 4.28 (2.069) |
| Carbendazim 1000 ppm | 2.04 (1.41) | 1.40 (1.184) |
| ,, + monocrotophos 0.05% | 1.52 (1.23) | 1.64 (1.279) |
| ,, + quinalphos 0.05% | 2.88 (1.69) | 3.56 (1.887) |
| ,, + ,, 0.025% | 3.00 (1.72) | 4.19 (2.046) |
| ,, + H C H 0.2% | 3.20 (1.78) | 3.76 (1.939) |
| Carbendazim 500 ppm | 2.54 (1.59) | 1.66 (1.249) |
| ,, + monocrotophos 0.05% | 1.64 (1.28) | 2.48 (1.574) |
| ,, + quinalphos 0.05% | 2.52 (1.58) | 4.38 (2.093) |
| ,, + ,, 0.025% | 1.76 (1.81) | 4.38 (2.093) |
| ,, + H C H 0.2% | 2.36 (1.53) | 4.20 (2.043) |
| Ediphenphos 1000 ppm | 3.20 (1.78) | 1.56 (1.249) |
| ,, + monocrotophos 0.05% | 2.68 (1.63) | 1.40 (1.183) |
| ,, + quinalphos 0.05% | 2.08 (1.43) | 1.36 (1.166) |
| ,, + ,, 0.025% | 3.32 (1.81) | 2.68 (1.636) |
| ,, + H C H 0.2% | 2.54 (1.59) | 2.35 (1.534) |
| Ediphenphos 500 ppm | 2.36 (1.53) | 3.28 (1.812) |
| ,, + monocrotophos 0.05% | 2.80 (1.66) | 1.91 (1.382) |
| ,, + quinalphos 0.05% | 1.48 (1.21) | 2.54 (1.594) |
| ,, + ,, 0.025% | 2.08 (1.43) | 2.84 (1.685) |
| ,, + H C H 0.2% | 3.20 (1.79) | 4.25 (2.061) |
| Control | 2.84 (1.68) | 5.97 (2.443) |
| C.D. for comparison | NS | 0.161 |

Disease incidence was assessed on 0 - 9 scale

NS - Nonsignificant at 0.05 level

Figures in parentheses are squareroot transformations

0.05 per cent. The other combinations of carbendazim 1000 ppm and insecticides were less effective and on par (3.56 to 4.19). The disease index in plots treated with carbendazim 500 ppm was the least (1.66) and it was the better treatment compared to others. The combination of the fungicide and monocrotophos 0.05 per cent came as the second in ranking (2.48). Combinations of the fungicide with HCH or the two doses of quinalphos came on par (4.20 to 4.38).

The disease index in plots treated with ediphenphos 1000 ppm was 1.56. The fungicide combined with quinalphos 0.05 per cent and monocrotophos 0.05 per cent showed slightly lower indices (1.36 and 1.40 respectively) and all the three were on par. The fungicide combined with HCH 0.2 per cent and quinalphos 0.025 per cent were on par and less effective (2.35 and 2.68 respectively). The disease index in plots treated with ediphenphos 500 ppm was 3.28. The fungicide combined with quinalphos 0.025 per cent came on par with the fungicide alone (2.84). The combinations of the fungicide with quinalphos 0.05 per cent or monocrotophos 0.05 per cent were found to be better than the treatments with fungicide alone (2.54 and 1.91 respectively). The combination with HCH 0.2 per cent was found inferior to the treatment with fungicide alone (4.25).

# DISCUSSION

## DISCUSSION

Results presented in para 3.2.1, 3.2.2 and 3.2.3 showed that the insecticidal effect of monocrotophos on N. lugens was not significantly altered, when used in combination with captafol, ediphenphos or carbendazim in widely varying proportions. The results obtained in pot culture studies also were in agreement with the observations in the laboratory. Precise bioassay studies covering the interaction of the above insecticide and fungicides have not been reported so far. But the results reported earlier from field studies have indicated that the spraying of monocrotophos in combination with fungicides was more effective than the application of the insecticide alone in controlling some insect pests (Schiller et al., 1982; Samalo and Parida, 1983; Kerala Agricultural University, 1986; Sukla and Lal, 1988). The lack of enhancement of insecticidal effect of monocrotophos on N. lugens when used in combination with fungicides as observed in present investigations may be due to the varying response of the test organisms to the toxicants.

The data presented in para 3.2.4 showed that quinalphos when used in combination with captafol resulted in a higher kill of N. lugens than when the insecticide was used alone. The variations in the dosages of fungicides used in the combinations were not generally altering the enhancement in insecticidal activity significantly. In the case of combinations with ediphenphos also, a synergistic effect was

observed (para 3.2.5). But the enhancement was positively correlated with the dosage of fungicide used in the combinations in a limited number of cases. The results thus indicated the possibility of exploiting the combined application of quinalphos and captafol or ediphenphos more advantageously for the control of N. lugens provided the proportion of the constituents in the mixture is judiciously fixed. The insecticidal activity of quinalphos 0.05% and 0.02% was not seen altered significantly when combined with carbendazim (para 3.2.6) at all the three doses (5 ppm, 2.5 ppm and 1 ppm). But the combinations of the insecticide at 0.002% and the three doses of the fungicide showed a synergistic effect. This favourable ratio of insecticide fungicide combinations is not feasible in the field since the dose of the fungicide required for the control of R. solani under field conditions ranged from 500 to 1000 ppm (Kerala Agricultural University, 1986).

Since the mortality of N. lugens was enhanced when quinalphos was used in combination with fungicides, the efficacy of the insecticide was evaluated at two doses in the pot culture studies. At the higher dose of 0.05 per cent, the insecticidal effect of quinalphos came on par with the mortality in the insecticide-fungicide combinations mixed in varying proportions. But at the lower concentration of 0.025 per cent, the mortality in combination of quinalphos with captafol or ediphenphos (at two levels each) came on par and significantly superior to the mortality in pots treated with quinalphos 0.025 per cent alone (para 3.3). But the combination of the insecticide and

carbendazim came on par with the treatment with insecticide alone. These results indicated the possibility of reducing the dosage of quinalphos for the control of N. lugens under field condition when the insecticide was used in combination with captafol or ediphenphos for the control of sheath blight and BPH concurrently. There was also a report of field study on the synergistic effect of fungicides on the insecticidal effect of quinalphos (Kerala Agricultural University, 1981).

The interaction of HCH and captafol presented in para 3.2.7 showed that at 0.2 per cent concentration the insecticidal effect of HCH was significantly reduced by the combination with fungicide while at 0.026 per cent the combination was found more favourable. In the pot culture experiment the insecticide and its combination with two doses of captafol came on par. The fumigant effect of HCH which exerted greater influence in the laboratory experiments might have failed to exert any influence in the field and hence the variations in the result. In the laboratory, HCH 0.2 per cent used alone was found on par with the combinations with the three doses of ediphenphos while in lower doses the insecticide-fungicide combinations were significantly superior to the treatment with the insecticide alone. In pot culture studies also the same result was observed. In the HCH-carbendazim combinations while there was significant reduction in activity of higher dose of HCH, the combinations with lower doses of HCH showed synergism.

In pot culture studies the combinations came on par with the use of HCH alone. The enhancement of insecticidal activity of HCH when used in combination with fungicides have not been reported in earlier studies though the combinations have been found effective in controlling insect pest and disease incidence occurring simultaneously (Chatrath et al., 1977; Olunloyo, 1983).

The laboratory studies (para 3.2.1) showed that the fungicidal effect of monocrotophos was fairly high, the percentages inhibition of R. solani at the three doses being in the range of 42.21 to 53.71. Monocrotophos used in combination with the fungicides showed an antagonistic effect at higher levels of captafol, ediphenphos and carbendazim, while at lower concentrations there was an enhancement of the fungicidal effect.

The fungicidal effect of quinalphos was also observed to be quite high in the laboratory, percentages of inhibition of R. solani being in the range of 72.57 to 92.63 at the different doses used. In combinations with captafol 750 and 250 ppm, the combination treatments had significantly higher fungicidal effect than the treatment with the corresponding doses of fungicide alone (para 3.2.4). In the case of ediphenphos and carbendazim also the insecticides when combined with lower doses of fungicides showed synergistic effect while with the higher doses there was either lack of synergism or antagonistic effect.

The fungicidal effect of HCH observed in the laboratory was very high, the inhibition of R. solani caused by the three doses used in the experiment being 100, 100 and 79.83 per cent respectively (para 3.2.7). Though the three doses of the three fungicides showed a range in the percentage of inhibition of R. solani in the laboratory, the combination with the varying doses of HCH tried in the experiment, the inhibition of the fungus was raised to 100 per cent level.

In the pot culture and field experiments the fungicidal effect of captafol, ediphenphos and carbendazim each at two levels and monocrotophos 0.05 per cent, quinalphos 0.05 and 0.025 per cent and HCH 0.2 per cent as well as their combinations were tried. Fungicides were taken in two doses since they showed a general enhancement of fungicidal effect in the laboratory when used in combination with insecticides.

In the pot culture study, among the insecticide-fungicide combinations, captafol 1500 ppm + monocrotophos combination alone was found to be the better one compared to the treatments with fungicides alone. When used with carbendazim 1000 ppm and ediphenphos 1000 ppm, HCH 0.2 per cent showed antagonistic effect on disease control (para 3.3). Though the insecticides showed high fungicidal activity in the laboratory studies, there was no reduction in the disease in pots treated with the insecticide alone. Laboratory studies and pot culture experiments in the above lines have not been reported earlier.

The data presented in para 3.6 showed that the insecticides which showed significant fungicidal activity in the laboratory did not reduce the disease incidence in the field. Monocrotophos 0.05 per cent when combined with captafol 3000 ppm or 1500 ppm or ediphenphos 500 ppm and quinalphos combined with captafol 3000 ppm and ediphenphos 500 ppm alone gave higher control of the disease than the treatments in which the fungicides were used alone. HCH combined with captafol did not show any antagonistic effect while in combination with ediphenphos and carbendazim, there was antagonistic action as manifested by the disease indices.

Results obtained from laboratory studies, pot culture experiments and the field experiment showed that insecticides when combined with fungicides may not affect the fungicidal effect of the latter in some cases while in some combinations there may be synergistic or antagonistic effect. Monocrotophos and quinalphos could be combined with captafol and ediphenphos without antagonistic effect or even with synergistic effect while carbendazim is compatible with monocrotophos only and that too in the recommended field doses of the components. The laboratory studies revealed that the proportion in which the fungicides and insecticides are mixed play an important role in deciding the favourable influence in the combination. When the different doses of the insecticides were mixed with

the lower doses of fungicides the synergistic effect was being manifested prominently. This showed that synergism will be more in combinations having higher proportion of insecticides. In the pot culture and field experiments also this trend was seen. In the treatment combinations in which the concentrations of the fungicides by themselves were sufficient to give the maximum possible suppression of the fungus, the insecticides did not manifest their fungicidal effect and when the lower doses of fungicides did not give full control of the fungus the fungicidal effect of the insecticides contributed to the suppression of disease. This result also indicated the possibility of lowering the dosage of fungicides in treatments if insecticide-fungicide combinations are used.

In the pot culture experiment, the reduced dose of captafol (1500 ppm) was not found effective, but in combination with monocrotophos and quinalphos, captafol 1500 ppm came on par with captafol higher dose and its combinations. In the case of carbendazim and ediphenphos the higher and lower doses came on par and hence the combination effect could not be assessed.

In the field experiment also captafol 1500 ppm and ediphenphos 500 ppm were less effective for the control of sheath blight when compared to their higher doses of 3000 and 1000 ppm respectively. But in combination with monocrotophos the lower doses of fungicide came on par with the higher dose used alone.

In the case of captafol, the combinations containing its lower dose and quinalphos or HCH also came on par with the higher doses of the fungicide. These results thus indicate the feasibility of saving the cost of fungicides by reducing their doses when used in combination with insecticides. Since the ratio of the components in the mixtures were found to influence their toxicity the optimum level of reduction of fungicides has to be worked out through repeated field experiments. In the case of HCH, though it showed significant stimulatory effect on fungicidal action in the laboratory, no such effects were found in pot culture and field experiments. With carbendazim and ediphenphos there was even antagonism.

The compatibility of captafol with monocrotophos or quinalphos had not been reported earlier. But its compatibility with HCH (Olunloyo, 1983), with malathion (Murphy et al., 1961) and with dimethoate (Chakraborty and Mutatkar, 1979) was observed earlier. The compatibility of ediphenphos and insecticides was reported by Bhaskaran et al. (1976) and also by Kerala Agricultural University (1986) and carbendazim or benomyl was reported compatible with HCH (Chatrath et al., 1977) and monocrotophos (Kerala Agricultural University, 1984, 1986; Sukla and Lal, 1988). The effect of combining the toxicants in various proportions on the fungicidal and insecticidal effects was studied for the first time and the possibility for reducing the quantity of fungicides in combinations has also been made as a fresh contribution from the present investigations.

The data presented in para 3.4 showed that, in the control of N. lugens the combined application of insecticide and fungicide was found superior in five out of 24 treatments in the experiment, than applying the pesticides in sequence (insecticide followed by fungicide or vice-versa). Insecticide application followed by fungicide was better in three cases and fungicide followed by insecticide was so in five cases. Eleven treatments did not show any variations.

In the control of sheath blight, combined application was found superior in two treatments only. Application of fungicide followed by insecticide was better in five cases and insecticide followed by fungicide was so in one case. Fourteen treatments did not show any variation.

The results thus showed that the sequence in the application of fungicide and insecticide in a field where a pest and disease problem coexist is in general not likely to influence the control of the insect or fungus.

The necessity for storing the combined formulations for completing the spraying operations in the field may arise as a problem and hence the keeping quality of the mixtures was studied up to a period of 24 hours after formulation. Only five out of 24 treatments showed significant reduction in the insecticidal effect of the mixture. Similarly

fungicidal effect was found decreased only in five out of twenty four treatments. The data as a whole did not show statistically significant variations. It may hence be concluded that the mixtures stored upto 24 hours after formulation generally do not lose the insecticidal/fungicidal effect.

The major conclusions from the different experiments are the following:

1. The laboratory studies showed that the insecticidal property of monocrotophos was not significantly altered when combined with captafol, ediphenphos and carbendazim. Insecticidal effect of quinalphos had a synergistic effect when combined with captafol and ediphenphos but not with carbendazim. HCH also showed the synergistic effect when its lower doses were combined with the fungicide while at higher dose a general antagonism was observed.

2. The fungicidal effect of captafol, ediphenphos and carbendazim was enhanced when combined with all the three insecticides.

3. The interaction of the fungicides and insecticides was significantly influenced by the dosage of the toxicants in the combination, the synergistic effects being prominently seen at lower concentrations. The insecticidal effect was enhanced when combined with fungicides in higher proportions

and fungicidal effect was enhanced when combined with insecticides in higher proportion. Optimum proportions for maximum advantage have to be worked out, for the combined use of an insecticide and fungicide in the field.

4. The insecticidal effect of combinations obtained in pot culture studies was in conformation with the result obtained in laboratory studies.

5. In pot culture studies the fungicidal effect of captafol or ediphenphos in combination with monocrotophos or quinalphos was either not altered or showed a general enhancement of action, while the combinations of ediphenphos or carbendazim with HCH showed a general decrease of action.

6. The result obtained in field studies with respect to the fungicidal effect of combinations was in conformation with the result obtained in pot culture study.

7. By virtue of the synergistic action on the efficacy of fungicides, when mixed with insecticides, the dosage of the former in mixtures may be reduced in some combinations. This trend was seen when captafol or ediphenphos was mixed with monocrotophos or quinalphos.

8. The application of insecticides in combination with fungicides is as effective as applying them in sequence for the control of insects and diseases occurring concurrently and hence this practice may be adopted as an improved technology to save cost of plant protection treatment.

9. The mixtures of insecticides and fungicides do not lose their efficacy when kept up to 24 hours after preparation and prior to the application in field.

# SUMMARY

## SUMMARY

Experiments were conducted in the laboratory and as pot culture at the Agricultural College, Vellayani and in farmer's fields at Alleppey during 1986-88 to ascertain the compatibility of insecticides and fungicides commonly used for the control of insect pests and diseases of rice. In the laboratory, suitable dosages of insecticides and fungicides were selected for studying their interactions using N. lugens and R. solani as test organisms. Standard bioassay technique was adopted for studying the toxicity to the insect N. lugens and poisoned food technique was adopted for studying the toxicity to the fungus R. solani. The concentration of monocrotophos required to give 20, 50 and 75 per cent mortality was found as 0.002, 0.007 and 0.03 per cent respectively. The corresponding values for quinalphos were 0.005, 0.02 and 0.05 per cent respectively and for HCH 0.026, 0.071 and 0.2 per cent respectively. The concentration of captafol to give 50, 75 and 100 per cent inhibition was found as 250, 750 and 2000 ppm respectively. The corresponding values for carbendazim were 1, 2.5 and 5 ppm respectively and for ediphenphos, the concentration required were 20, 50 and 100 ppm respectively. The interation of insecticides and fungicides when mixed in the above doses, in all possible combinations, was studied with reference to their fungicidal and insecticidal effect assayed with the above test organisms.

Pot culture studies were carried out to assess the effect of (i) combining insecticides and fungicides on the control of BPH and sheath blight, (ii) applying fungicides and insecticides in sequence and in combination on the control of BPH and sheath blight and (iii) spraying fungicide and insecticide combinations at different intervals after preparing the mixture on the control of BPH and sheath blight. The potted plants kept on a revolvolite were sprayed with the required quantities of pesticide formulations using an atomiser connected to a pressure pump working at a constant pressure of 0.6 $kg/cm^2$ thus giving a very uniform coverage on all plants treated.

The results obtained in the laboratory and pot culture experiments were tested in a field experiment conducted in a farmer's field at Alleppey. The experiment was conducted in a field where the incidence of sheath blight was noted in sufficient intensity and uniform spread. The treatments were done in plots, peg marked, adopting a randomised block design.

Laboratory studies revealed that the insecticidal effect of monocrotophos on N. lugens was not significantly altered when used in combination with captafol, ediphenphos or carbendazim in widely varying proportions. The same trend was observed in pot culture experiments also.

Quinalphos when used in combination with captafol resulted in a higher kill of N. lugens than when the

insecticide was used alone. The variation in doses of fungicide used in combination with each dose of insecticide did not alter the enhancement of insecticidal activity significantly. A synergistic effect was observed in the case of combinations with ediphenphos also and the enhancement was positively correlated with the dosage of fungicide used in the combinations with some doses of the insecticide. Enhancement of action of lower dose of quinalphos in combination with captafol and ediphenphos was observed in pot culture study also. Combined application of quinalphos and captafol or ediphenphos by judiciously fixing the proportion of constituents in the mixture may be more advantageous for the control of N. lugens. There was enhancement in the insecticidal activities of quinalphos 0.002% when combined with carbendazim at 5 ppm, 2.5 ppm and 1 ppm, but not at 0.05 and 0.005 per cent. The favourable ratio of insecticide-fungicide combination is not possible in the field since the dose of fungicide required for the control of R. solani, under the field conditions, ranges from 500 - 1000 ppm.

The insecticidal effect of HCH 0.2% was significantly reduced in the laboratory when combined with captafol. But with 0.026% of HCH the combination was found favourable. In pot culture experiment the insecticide and its combinations with two doses of captafol came on par. The lower doses of HCH and ediphenphos, carbendazim combinations were significantly

superior to the treatment with insecticide alone. In pot culture studies the above combinations came on par with the treatment of HCH alone.

In the laboratory studies the fungicidal effect of monocrotophos was found to be fairly high. Monocrotophos used in combination with fungicides showed antagonistic effect at higher levels of captafol, ediphenphos and carbendazim while at lower concentrations there was an enhancement of fungicidal effect.

The fungicidal effect of quinalphos observed in laboratory was very high. When combined with captafol 750 ppm and 250 ppm quinalphos caused enhanced fungicidal effect. In the case of ediphenphos and carbendazim when combined with lower dose of fungicide, the insecticide showed synergistic effect while with higher doses there was either lack of synergism or antagonistic effect.

The fungicidal effect of HCH was very high in the laboratory at all doses. The three doses of the three fungicides tried in the laboratory in combination with the varying doses of HCH gave inhibition of the fungus to 100% level.

In pot culture experiments and in field experiment the fungicidal effect of captafol, ediphenphos and carbendazim each at two levels and monocrotophos at 0.05%, quinalphos 0.05 and 0.025% and HCH 0.2% as well as their combinations

were tried. Quinalphos was taken in two doses since the insecticidal activity of the chemical in the laboratory was observed to be synergised in combinations with fungicide. Similarly fungicides at their lower doses showed a general enhancement of fungicidal effect when used in combination with insecticides.

In pot culture study among the insecticide-fungicide combinations, captafol 1500 ppm and monocrotophos 0.05% was the better one compared to the treatment with fungicides alone. Significant antagonistic effect in disease control was observed where HCH 0.2% was combined with carbendazim 1000 ppm or ediphenphos 1000 ppm.

In the field experiment, monocrotophos 0.05% when combined with captafol 3000 ppm or 1500 ppm, ediphenphos 500 ppm and quinalphos combined with captafol 3000 ppm and ediphenphos 500 ppm gave better control of the disease than the treatments in which the fungicides were used alone. The combination of HCH 0.2% with captafol did not show any antagonistic effect but in combination with ediphenphos and carbendazim, there was significant antagonistic action. Monocrotophos and quinalphos could be combined with captafol and ediphenphos without any antagonistic effect or even with synergistic effect when combined in suitable proportions. With carbendazim, monocrotophos alone was found compatible.

The synergism noted in the experiments was more conspicuous in combinations having higher proportions of the insecticides. This indicated the possibility of lowering the quantity of fungicides in treatments using compatible insecticide and fungicide in combination.

The application of insecticide and fungicide in sequence (fungicide followed by insecticide or vice-versa) or in combination, in a field where a pest and disease, occur together did not in general affect the efficacy of the treatment. It was further seen that keeping of mixtures up to 24 hours after formulation did not affect the insecticidal and fungicidal properties and hence can be kept for the required length of time after preparation to finish the spraying operation in the field without any adverse effect on toxicity.

# REFERENCES

## REFERENCES


Abraham, C.C. and Nair, M.R.G.K. (1975). The brown plant hopper outbreak in Kerala. Rice Entomol. NewsL. 2 : 36.

Alam, S., Alam, M.S. and Choudhary, M.A. (1978). Brown plant hopper situation in Bangladesh. Int. Rice Res. NewsL. 3(4) : 17-18.

Annie Thomas. Studies on insect pests and diseases of rice earhead and their control. M.Sc.(Ag.) Thesis. Kerala Agricultural University, (1987), pp. 118.

Arunyanart, P., Surin, A., Rojanahasadin, W., Dhitikiattipong, R. and Distthaporn, S. (1986). Chemical control of Sheath blight (Sh B). Int. Rice Res. NewsL. 11(2) : 20.

Atadzhanov, M.A. and Dubrovina, V.A. (1977). An experiment in the protection of fruit trees and vines. Zashch. Rast. 7 : 24.

Baicu, T., Nagler, M., Rascanescu, M. and Paulian, F. (1983). Seed treatment of cereals with fungicide and mixed products. Ana. Inst. Cercet. Prot. Plant. 9 : 425-431. (Cf: Rev. Plant Path. 63 : 1103).

Balashova, N.N. and Bebak, N.M. (1964). Combined seed treatments and nystatin in the control of ascochytosis of garden pea. Tr. Mold. Nauchno-Issled. 6(1) : 200-205. (Cf: Rev. Appl. Myco. 46 : 1146).

Balasubrahamonian, M. and Michael, R.K.P.M. (1976). Effect of insecticides and certain other pesticides on the pests of rice. Madras Agric. J. 63 (5-7) : 288-291.

Basilo, R.P. and Heinrichs, E.A. (1981). Insecticides sprayed on brown plant hopper eggs. Int. Rice Res. NewsL. 6(3) : 16-17.

Behera, B., Dash, S.C. and Mishra, D. (1982). In vitro evaluation of fungicides against Corticium sesakii causing sheath blight of rice. Pesticides 16(11) : 5-6.

Bhaskaran, P., Narayanaswamy, P., Balasubrahamonian, M. and Reghunathan, V. (1976). Field evaluation of insecticide-fungicide spray combinations against rice pests. Rice Entomol. NewsL. 4 : 37.

Caresche, L. (1933). Note sur less insects appeles "pucerons du riz" dons le sud. Undochinois et les moyens de dutte a leur opposer. Bull. Econ. Indochina 36 : 488-510. (Cf: Rev. Appl. Entomol. 22 : 16).

Chacko, M.J., Muthappa, B.N. and Ramanarayan, E.P. (1977). Performance of four insecticides with Bordeaux mixture. J. Coffee Res. 7(1) : 9-14.

Chakraborty, D.P. and Mutatkar, V.K. (1979). Rogor (dimethoate) its application, toxicity and efficacy with urea on various crops under field conditions. xiii-xvii, Planning and Development Division, Fertilizer Promotion and Agricultural Research Centre, Sindri, Bihar.

Chandy, K.C., Sadakathulla, S. and Mohan, J. Chandra. (1980). Resurgence of brown plant hopper. Pestology 4(7) : 34.

Chatrath, M.S., Gupta, J.D. and Sethi, G.R. (1977). Compatibility of systemic seed dressing fungicides with insecticides. Pesticides 11(8) : 40-41.

Chekalinskaya, N.I. (1963). Disease of broad bean. Bot. Issled Minsk. 5 : 210-216. (Cf: Rev. Appl. Myco. 46 : 194).

Chin, K.M. (1977). Chemical control of leaf blight disease of rice caused by Thanatephorus cucumeris (Frank) Donk. Malay. Agric. J. 51(2) : 238-243.

Das, N.M., Mammen, K.V. and Christudas, S.P. (1972). Occurrence of Nilaparvata lugens Stal. as a serious pest of paddy in Kerala. Agric. Res. J. Kerala 10(2) : 191-192.

Dev, V.P.S. and Mary, C.A. (1986). Sheath blight control. Int. Rice Res. NewsL. 11(1) : 22.

Dev, V.P.S. and Satyarajan, P.K. (1980). Efficiency of certain fungicides in the control of sheath blight disease of rice. Agric. Res. J. Kerala 18(1) : 113-115.

Ermilova, V.M. (1965). Differential use of fungicides in the control of wheat bunt in N. Kazakhstan. Tr. Kaz. Nauchno-Issled. 9 : 237-243. (Cf: Rev. Appl. Myco. 46 : 2688).

Finney, D.J. (1952). Probit Analysis - A statistical treatment of the sigmoid response curve. 2nd Ed. Cambridge University Press, Cambridge, pp.318.

Gokulapalan, C. Role of the rice root nematode (Heirschmanniella oryzae) in the incidence of sheath blight disease of rice in Kerala. M.Sc.(Ag.) Thesis. Kerala Agricultural University, (1981), pp. 92.

Gradis, W.H. and Sutton, T.B. (1981). Effect of insecticides, nutrients and adjuvants on *in vitro* fungistatic and fungicidal activity of captan and mancozeb. *Plant Dis.* 65(4) : 356-358.

Heinrichs, E.A., Chelliah, S., Valencia, S.L., Arceo, M.B., Fabellar, L.T., *et al.* (1981) *Mannual for testing insecticides on rice*. 1st Ed. International Rice Research Institute, Manila pp.134.

International Rice Research Institute (1976). *Standard evaluation system for rice*. International Rice Research Institute, Laguna, Philippines. pp.64.

Jagannathan, R. and Kannaiyan, S. (1978). Studies on the chemical control of sheath blight disease of rice. *Indian J. Plant Prot.* 6(1) : 31-32.

John, P., Dale, D. and Mathew, J. (1982). Insect antifeedant action of some fungicides. *Angew. Entomol.* 94(1) : 32-34. (Cf: *Rev. Appl. Entomol.* 70 : 7338).

Jones, R.K., Belmar, S.B. and Jeger, M.J. (1987). Evaluation of benomyl and propiconazole for controlling sheath blight of rice caused by *Rhizoctonia solani*. *Plant Dis.* 71 : 3.

Kannaiyan, S. and Prasad, N.N. (1979). Effect of foliar spray of certain fungicides on the control of sheath blight disease of rice. *Res. Bull. Macco Agric. Dig.* 4(7) : 3-6.

Katanyukul, W. and Budhasamai, T. (1983). Granular insecticides for control of major rice insects in Thailand. *Int. Rice Res. NewsL.* 8(1) : 17-18.

Kerala Agricultural University (1981). *Research Report 1979-80*. Directorate of Research, Vellanikkara 680654, Trichur, India.

Kerala Agricultural University (1982). *Annual Report 1981-82*. Directorate of Extension, Vellanikkara 680654, Trichur, India.

Kerala Agricultural University (1983). *Research Report 1980-81*. Directorate of Research, Vellanikkara 680654, Trichur, India.

Kerala Agricultural University (1984). *Research Report 1982-83*. Directorate of Research, Vellanikkara 680654, Trichur, India.

Kerala Agricultural University (1986). *Research Report 1983-84*. Directorate of Research, Vellanikkara 680654, Trichur, India.

Kerala Agricultural University (1986). Package of Practices Recommendations 1986. Directorate of Extension, Vellanikkara, 680654, Trichur, India.

Kerala Agricultural University (1987). Research Report 1984-85. Directorate of Research, Vellanikkara 680654, Trichur, India.

Kesavan, R. (1984). In vitro efficacy of certain fungicides against Rhizoctonia solani and Sclerotium rofsii. Fitopatol. Brass. 9(3) : 627-630. (Cf: Rev. Plant Path. 64 : 2315).

Kurilov, V.I. (1983). The effectiveness of combined treatments. Zaschch. Rast. 6 : 32-33. (Cf: Rev. Appl. Entomol. 72 : 3925).

Lakshmanan, P. and Nair, M.C. (1980). In vitro toxicity of granular insecticides against Rhizoctonia solani Kuhn. Madras Agric. J. 67 : 59-60.

Lakshmanan, P. and Nair, M.C. (1986). Effects of soil fungicides on Rhizoctonia solani Kuhn. Pesticides 20(3) : 35-38.

Lakshmanan, P., Nair, M.C. and Menon, M.R. (1980). Comparative efficacy of certain fungicides on the control of sheath blight of rice. Pesticides 14(10) : 31-32.

Lee, F.N. and Courtney, N.L. (1981). Foliar fungicide testing for rice sheath blight control. Ark. Farm Res. 30(3) : 11. (Cf: Rev. Plant Path. 63 : 620).

Liceras, Z.L. and Farge, G.G. (1975). Chemical control of the coffee borer with early and late applications in Tingo Maria. Rev. Peru. Entomol. 17(1) : 78-80. (Cf: Rev. Appl. Entomol. 66 : 2788).

Lim, G.S. (1971). Screening of insecticides against Nilaparvata lugens Stal. Malays. Agric. J. 48(2) : 104-121.

Lulu Das. Effect of application of plant protection chemicals on the survival of Rhizoctonia solani Kuhn. Ph.D. Thesis. Kerala Agricultural University, (1986), pp. 108.

Mani, M.S. and Jayaraj, S. (1976). Effectiveness of insecticides against brown plant hopper infesting rice in Tamil Nadu. Pesticides 10(3) : 46-47.

Manila, C.E. and Lapis, D.B. (1977). Severity of rice blast, bacterial blight and sheath blight in rice after application with herbicides and insecticides. Philipp. Agricu. 61(1/2) : 1-11, (Cf: Rev. Plant Path. 58 : 202).

Martin, S.B., Lucas, L.T. and Cambell, C.L. (1984). Comparative sensitivity of Rhizoctonia solani and Rhizoctonia like fungi to selected fungicides in vitro. Phytopathology 74 : 778-781.

Mathur, A.K. and Bhatnagar, G.C. (1986). Studies on the compatibility of Vitavax with aldrin EC. Pesticides 20(9) : 53.

Medrano, F., Heinrichs, E.A. and Aguda, R. (1984). Control of Metarrhizium anisopliae in brown plant hopper rearing. Int. Rice Res. NewsL. 9(3) : 15-16.

Mehta, P.R. and Verma, B.K. (1968). Plant Protection. 1st Ed. Ministry of Food and Agriculture, Government of India, New Delhi, pp.587.

Minoiu, N. and Dragan, N. (1982). Studies on the control of disease and pests in fruiting apple orchards in northern Transylvania. Probl. Prot. Plant 10(1) : 1-25. (Cf: Rev. Appl. Entomol. 72 : 5924).

Mirica, A., Baltac, M. and Mirica, I. (1981). Compatibility and biological effectiveness of some pesticide mixtures used in the control of principal pests and diseases of grapevine. Ana. Inst. Cercet. Prot. Plant 16 : 405-409. (Cf: Rev. Appl. Entomol. 70 : 2109).

Mukherjee, N. (1978). Sheath blight of rice (Thanatephorus cucumeris) and its control possibilities. Pesticides 12(8) : 39-40.

Murphy, F.E., Briant, M.A., Dodds, L.M., Fagerson, I.S., Kirkpatrick, E.M. and Wiley, R.C. (1961). Effect of insecticides and fungicides on the flavour quality of fruits and vegetables. J. Agric. Fd. Chem. 9(3) :214-223. (Cf: Rev. Appl. Myco. 40 : 657.

Nair, M.C. and Menon, M.R. (1983) Diseases of crop plants of Kerala 1st Ed. Kerala Agricultural University, Trichur, pp.277.

Nair, M.R.G.K. (1978). A monograph of crop pests of Kerala and their control 1st Ed. Kerala Agricultural University, Trichur, pp.150.

Naquib, M.I. (1968). Effect of Sevin on the metabolism of Rhizoctonia solani. J. Bot. UAR. 11 : 7-18. (Cf: Rev. Plant Path. 49 : 3649).

Natarajan, K. and Palchamy, A. (1978). Outbreak of rice case worm and brown plant hopper in Madurai, Tamil Nadu, India. Int. Rice Res. NewsL. 3(3) : 17.

Nedyalkov, K. (1975). Clysia ambiguella and its control. Rost. Zashch. 23(3) : 30-31. (Cf: Rev. Appl. Entomol. 64 : 1999).

Nene, Y.L. and Thapliyal, P.N. (1979) Fungicides in Plant Disease Control. 2nd Ed. Oxford and IBH Publishing Co., Bombay, pp.507.

Olunloyo, O.A. (1983). Results of three years of spraying with fungicide-insecticide combination against inflorescence die-back disease of cashew. Plant Dis. 67(12) : 1319-1320.

Patel, V.S., Patel, B.H. and Desai, N.D. (1986). Relative damage and loss due to insect pests of paddy crop. Pesticides 20(8) : 24-26.

Pathak, M.D. (1968). Ecology of common insect pests of rice. Annu. Rev. Entomol. 13 : 257-294.

Prasad, C.K.P.S. and Hiremath, P.C. (1985). Varietal screening and chemical control in fenugreek against foot rot and damping off caused by Rhizoctonia solani. Pesticides 19(5) : 34-36.

Rajan, K.M., Nair, P.V. and Nair, S.S. (1979). Field evaluation of certain proprietory fungicides against sheath blight of paddy. Agric. Res. J. Kerala 17(2) : 253-255.

Rai, L. and Zutrhi, M.K. (1969). Efficacy of Thimet 10 G in controlling some major paddy insect pests. Plant Prot. Inform. 2 : 1-5. (Cf: Rev. Appl. Entomol. 62 : 3164).

Rao, P.R.M., Dani, R.C. and Rao, P.S.P. (1976). Recent studies on the chemical control of rice pests. Madras Agric. J. 63 (5-7) : 281-287.

Rao, P.R.M., Rao, P.S. and Prakash (1984). Relative toxicity of some insecticides to brown plant hopper, Nilaparvata lugens Stal. Pesticides 18(10) : 55-57.

Reddy, A.P.K., Bhaktavatsalam, G. and John, V.T. (1981). Sheath blight of rice: relationship between disease severity and yield. Pesticides 15(7) : 11-12.

Rose, G.J. (1963) Crop Protection. 2nd Ed. Leonard Hill (Books) Ltd., London, pp.490.

Roy, A.K. (1981). Efficacy of few fungicides on the control of sheath blight of rice. Res. Assam Agric. Univ. 2(2) : 177-181.

Ryan, C.C. and Clare, B.G. (1972). Insecticides - a cautionary tale of plant pathologist. Aust. Plant Path. Soc. NewsL. 1(3) : 20. (Cf: Rev. Plant Path. 54 : 2148).

Samalo, A.P. and Parida, P.B. (1983). Pest and disease management of groundnut. Indian Farming 33(6) : 34-35.

Sasmal, S., Kulshrestha, J.P. and Dani, R.C. (1984). Re-evaluation of some of the commercially available insecticides for the control of brown plant hopper on rice. Pesticides 18(10) : 30-31.

Sathyanandan, V.K.R. and Subramanian, A. (1984). Evaluation of certain candidate insecticides against rice brown plant hopper (Nilaparvata lugens Stal.) Pesticides 18(5) : 37-38.

Schiller, J.M., Sampoapol, R. and Thirathon, S. (1982). Interdependence of disease and insect pest control in rainfed peanut production. Thai J. Agric. Sci. 15(1) : 33-50.

Sha, L.R. (1986). In vitro studies on the efficacy of certain fungicies against R. solani Kuhn. blight of rape seed and mustard. Int. Rice Res. NewsL. 20(10) : 31.

Sharvelle, G. Eric (1979). Plant Disease Control. 1st Ed. AVI Publishing Company, Inc., Connecticut, pp.331.

Simkover, H.G. and Shenefelt, R.D. (1951). Effect of benzene hexachloride and chlordane on certain soil organisms. J. Econ. Entomol. 44 : 426-427.

Skaria, B.P. and Das, N.M. (1981). Contact toxicity of different insecticides to third and fifth instar nymphs of brown plant hopper Nilaparvata lugens Stal. (Delphacidae : Homoptera). Agric. Res. J. Kerala 19(2) : 33-38.

Sogawa, K. and Kusumayadi, A. (1984). Monitoring brown plant hopper biotypes by rice garden in North Sumatra. Int. Rice Res. NewsL. 9(6) : 15-16.

Sukla, P. and Lal, S.S. (1988). Effect of combined application of fungicides and insecticides on the powdery mildew and pod borer of field pea. Pesticides XXII(3) : 5-7.

Svampa, G., Brunelli, A. and Tosatti, E.M. (1974). Plant chemical mixtures - effect on insecticides and fungicides. Inf. Fito Patol. 24(12) : 5-10. (Cf: Rev. Plant Path. 55 : 548).

Tanase, V. and Paulian, F. (1973). New results in the prevention of attack by Tanymecus dilaticollis Gyll. by treatment of maize seed. Probl. Prot. Plant. 1(1) : 111-123. (Cf: Rev. Appl. Entomol. 64 : 1350).

Telan, I.F. and Lapis, D.B. (1986). Foliar spray to control sheath blight (ShB). Int. Rice Res. NewsL. 11(6) : 18.

Tisserat, N., Altman, J. and Campell, C.L. (1977). Pesticide plant disease interactions, the influence of Aldicarb on growth of R. solani and damping off of sugar beet seedlings. Phytopathology 67 : 791-793.

Udilov, O.F. and Borisova, S.F. (1976). The compatibility of fungicides with the insecticide Dilor in tests against the causal agent of Phytophthorosis of tomato. Zakh. Rosl. 23 : 94-99. (Cf: Rev. Plant Path. 56 : 5195).

Varadarajan nair, P. and Rajan, K.M. (1978). Operational research on sheath blight control. Int. Rice Res. NewsL. 3(4) : 14.

Wood, P.A. (1983) Weed Science : Principles. 2nd Ed. West Publishing Company, New York, pp.655.

Yamaguchi, T. (1974). Control of rice diseases by fine granular formations. Jpn. Pestic. Inf. 19 : 9-13.

Ye, X.X., Lin, K., Wang, T.X., Shi, G.Q. and Wu, Y.Y. (1981). Effect of insecticides on population fluctuation of plant hoppers and their predators in rice fields. Zhejung Nongye Kexue 5 : 222-225. (Cf: Rev. Appl. Entomol. 70 : 5287).

Zentmyer, C.A. (1955). A laboratory method for testing soil fungicides with Phytophthora cinnamoni as test organism. Phytopathology 45 : 398-404.

Zhuravlev, A.P., Karpunia, Yu, T. and Komarov, A.M. (1976). An integrated system of protection of fibre flax. Zashch. Rast. 5 : 20-23. (Cf: Rev. Appl. Entomol. 65 : 3350).

# ABSTRACT

# COMPATIBILITY OF INSECTICIDE AND FUNGICIDE USED FOR THE CONTROL OF INSECT PESTS AND DISEASES OF RICE

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ABSTRACT OF A THESIS

submitted in partial fulfilment of the requirement for the degree

**MASTER OF SCIENCE IN AGRICULTURE**

Faculty of Agriculture

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**DEPARTMENT OF ENTOMOLOGY**

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## ABSTRACT

Experiments were conducted in the laboratory, pots and field during 1986-88 to ascertain the compatibility of insecticides and fungicides commonly used for the control of insect pests and diseases of rice. Standard bioassay technique and poisoned food technique were adopted in the laboratory studies using N. lugens and R. solani as test organisms. Based on these, concentrations to give 25, 50 and 75 per cent mortality of insect and 50, 75 and 100 per cent inhibition of the fungus were selected. The interaction of the insecticides and fungicides when mixed in the above doses, in all possible combinations, was studied with reference to their fungicidal and insecticidal effect assayed with the above test organisms.

Pot culture experiments were conducted for the assessment of effect of (i) combining insecticides and fungicides on the control of sheath blight and BPH, (ii) applying fungicides and insecticides in sequence and in combination on the control of sheath blight and N. lugens and (iii) spraying fungicide – insecticide in combinations at different intervals after preparing the mixture, on the control of sheath blight and N. lugens.

A field trial was also laid out for assessing the efficacy of fungicide-insecticide combinations for the control of sheath blight.

The insecticidal effect of monocrotophos on N. lugens was not significantly altered when used in combination with captafol, ediphenphos or carbendazim in widely varying proportions. A synergistic effect was observed when quinalphos was combined with captafol or ediphenphos. Enhancement of action of lower dose of quinalphos when combined with captafol and ediphenphos was observed in pot culture study also.

Enhancement in the insecticidal activity of quinalphos in the laboratory in combination with carbendazim (at 1 ppm, 2.5 ppm and 5 ppm) was limited to lower doses of the insecticide. With higher dose of the insecticide there was no significant synergism. This favourable ratio of insecticide fungicide combination is not possible in the field since the dose of fungicide required in the field for the control of R. solani ranges from 500 - 1000 ppm.

Laboratory studies showed that the insecticidal effect of HCH 0.2% was significantly reduced when combined with captafol. But at 0.071 and 0.026% the combinations showed no antagonistic effect. In the pot culture experiment the insecticide and its combinations with two doses of captafol came on par. The lower dose of HCH and ediphenphos combinations were superior to the treatment with insecticide alone. The same result was obtained when HCH was combined with carbendazim in the laboratory. In pot culture studies the combinations did not show any difference with the use of HCH alone for the control of N. lugens.

Laboratory studies showed fairly high fungicidal effect for monocrotophos. Monocrotophos used in combination with fungicides showed antagonistic effect at higher levels of captafol, ediphenphos and carbendazim. But with lower concentrations there was an enhancement of fungicidal effect.

In the laboratory the fungicidal effect of quinalphos was observed to be high. While no antagonistic effect was observed when it was used in combination with higher levels of captafol and carbendazim, the combinations with lower levels of all the three fungicides showed synergistic effect. In the case of ediphenphos, combination of quinalphos with the higher level of fungicide showed antagonistic effect.

The fungicidal effect of HCH was very high in the laboratory at all the three doses tried. The three doses of HCH in combination with varying doses of fungicides gave 100% inhibition of the fungus in the laboratory.

In the pot culture experiment among the treatments, captafol 1500 ppm and monocrotophos 0.05% alone was found to be better in fungicidal action compared to the treatments with fungicides alone. Antagonistic effect in disease control was observed where HCH 0.2% was combined with carbendazim 1000 ppm and ediphenphos 1000 ppm.

In the field experiment, higher control of the disease was obtained in combinations of monocrotophos 0.05% with captafol

3000 ppm, or 1500 ppm, ediphenphos 500 ppm and quinalphos combined with captafol 3000 ppm and ediphenphos 500 ppm. Combination of HCH with captafol did not show any antagonistic effect, but antagonistic action was observed in combination with ediphenphos and carbendazim.

Overall assessment of the data obtained from the laboratory, pot culture and field experiments showed that monocrotophos and quinalphos could be combined with captafol and ediphenphos without any antagonistic effect or even with synergistic effect. With carbendazim, monocrotophos alone is compatible. The synergism will be more in combinations in which higher proportion of insecticides were used. The possibility of lowering the quantity of fungicide in treatments when compatible insecticides and fungicides were used in combination for the control of diseases also was indicated in the experiment.

When the application of fungicides and insecticides in sequence (fungicide followed by insecticide and vice-versa) was compared to the combined application, it was found that in general the treatments were all on par. It was further seen that keeping of mixtures up to 24 hours after formulation did not affect the insecticidal and fungicidal properties of the mixtures and hence they can be kept for the required length of time after preparation to finish the spraying operation in the field without any adverse effect on toxicity.