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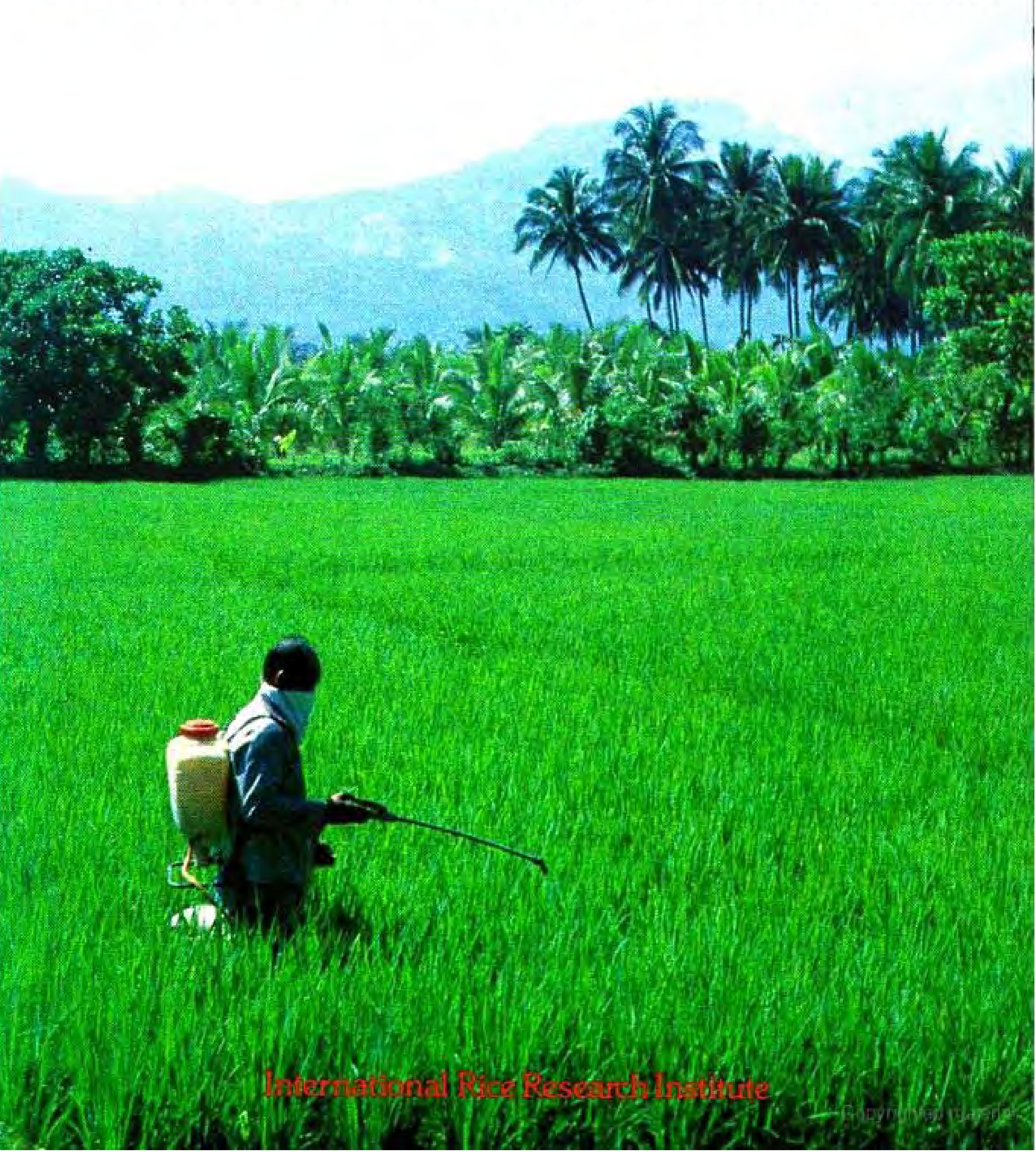

International Rice Research Institute

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Contents

Foreword

During the past decade insecticides have played a major role in the management of rice insect pests. They have helped bring under control major rice pest outbreaks and have become well established as essential tools in insect pest management.

Research on alternative means of rice pest management has also been fruitful. Remarkable progress has been made in developing new high-yielding rice varieties with genetic resistance to insect pests. Likewise, antifeedants and biological control mechanisms are being explored and show much promise.

Despite the potential of these alternative pest management practices, it is recognized that pesticides will continue to be vital components of effective integrated pest management systems. Consequently, there is a continuing need for effective pesticide research. Insecticides that are effective against target pests but ensure a margin of safety to natural enemies must be identified and minimum effective rates, optimum time of application, and most effective application methods determined.

Since late 1962, when Dr. M. D. Pathak first established IRRI's insecticide evaluation program, the Institute has developed a variety of methodologies for insecticide research ranging from unique procedures for insect rearing to data-recording analysis. Some of these techniques are described in this manual. They are regularly used in the IRRI insecticide evaluation programs but most have not been published and are generally not known to rice entomologists.

The authors in the preparation of this manual have drawn upon extensive experience in insecticide studies. Dr. E. A. Heinrichs, head of the Department of Entomology and leader of the IRRI insecticide program, had experience in insecticide evaluation studies in the USA, Brazil, and India before he joined IRRI in 1975. Dr. S. Chelliah, professor of Tamil Nadu Agricultural University in Coimbatore, India, has many years of experience in insecticide evaluation and was a post-doctoral fellow at IRRI conducting research on brown planthopper resurgence during the preparation of this manual. Mr. Steve Pickin from Imperial College, Berkshire, England, conducted his doctoral research on the physical assessment of spraying systems at IRRI. G. B. Aquino, S. Valencia, L. T. Fabellar, and M. B. Arceo, research staff of the Department of Entomology, have contributed to the development of many of the techniques described in the manual. Dr. G. A. Matthews, Imperial College, Berkshire, England, and Dr. K. A. Gomez and Dr. M. de Ramos of the IRRI Department of Statistics reviewed the manuscript. W. G. Rockwood, editor, and E. Cervantes, editor's assistant, edited the manual,

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About this manual

Rice production has increased in many countries since the introduction of the modern high-yielding varieties. The shorter growth duration of these varieties and the development of irrigation systems allowed increased cropping intensity. That increased intensity, plus factors such as high tillering of varieties, closer spacing, and more intensive use of fertilizer are believed responsible for an increase in severity of damage by some rice insects. Yield losses due to rice insect pests are estimated to be about 30% in Asia (Cramer 1967). Oka (1979) reports that the average loss to the brown planthopper was 46% in severely affected fields in Indonesia from 1974 to 1976. In the Philippines the application of insecticides often increases yield by 1 t/ha.

Despite significant advances in the development of insect-resistant varieties and other insect control methods, insecticides remain a common control method for rice insect pests. But those insecticides will become more expensive because of increased costs of raw materials and development. That calls for insecticides that are effective and that will provide a high benefit-cost ratio. Other factors greatly affect insecticide research:

- Government regulations relating to the development and use of insecticides are becoming more strict in many developing countries. More data on the merits and demerits of insecticides being recommended for use in national agricultural production programs are required.
- National governments spend huge sums for rice insect control. Some countries provide loans for the purchase of insecticides for rice insect control, others provide insecticides free to the farmer. Recommending ineffective insecticides wastes resources.
- There may be *hidden costs* when certain insecticides are recommended. One is pest resurgence after insecticide application, which damages a crop more than if no insecticide is applied. Development of insecticide resistance is another hidden cost.

Thus, it is mandatory that entomologists in national rice improvement programs identify effective insecticides, critical time of application, and correct dosages and application methods to achieve an effective, economical, and practical pest control. Because of varying conditions and varying formulations and concentrations of available insecticides, it is desirable that every country or region develop its own insecticide evaluation program. The program should involve laboratory, insectary, and field testing. Standard evaluation techniques should be simple, accurate, and. easily adoptable. We hope that this manual stimulates entomologists to do effective insecticide research and provides the extension agent with information needed to effectively advise rice farmers.

This manual is based on methods developed and tested at the International Rice Research Institute (IRRI) during more than 15 years. It presents techniques in evaluating insecticides in the laboratory, insectary, and field. It explains in detail the methodology used in the laboratory and insectary to determine the resistance levels of insects to insecticides and the relative toxicity of insecticides such as contact and stomach poisons and fumigants.

This manual also includes the methodology for field experiments to determine the activity of insecticides using various application methods. Examples of statistical analyses are given to assist the reader in the analysis and preparation of data.

Some of the techniques presented may already be practiced in many stations. This compilation, however, presents many new ideas and will lead to standardizing existing techniques to facilitate comparison of the results from different research stations.

Additional information which may be of value to the reader is included in the appendices. Included are a list of selected publications that report results of rice insecticide testing, a list of equipment and supplies and names of some suppliers, a list of useful reference books, reference tables for determining insecticide rates, and a conversion table. A glossary has been provided to acquaint the reader with terms used in the manual.

chapter 1

PLANNING INSECTICIDE EVALUATION STUDIES

Proper planning is essential to ensure success in conducting laboratory, insectary, and field insecticide studies. Poor planning may result in failure to realize the objectives of the study and in waste of time and money. Proper planning involves

- selecting a relevant problem,
- conducting a literature review, and
- developing a written research plan.

SELECTING A PROBLEM

A good knowledge of the conditions that farmers face in rice insect control will help in selecting problems that are realistic and useful and will provide you with possible research topics. Some of the more commonly conducted rice insecticide studies are:

- comparison of the efficacy of coded and named insecticides,
- comparison of formulations,
- rate studies,
- comparison of the number of applications,
- comparison of various application methods,
- determination of yield losses in protected and unprotected plots, and
- determination of yield losses at various plant growth stages.

Studies to determine the efficacy of insecticides are necessary so that recommendations can be made for the control of a certain insect. In some cases minor pests have become major pests and control recommendations have become necessary. But no efficacy tests have yet been conducted. Where do you start your studies in this case? Knowledge of similar research conducted elsewhere is extremely valuable as an aid in developing research plans. This requires a close communication with other rice scientists involved in insecticide studies and a knowledge of the literature on the particular pest.

LITERATURE REVIEW

By reviewing the literature you acquaint yourself with previous research along a certain field. In some cases results of research conducted elsewhere can be utilized in making temporary recommendations until you finish your study and make recommendations based on your own work. *Importing* information is common when a production program is initially developed. *The Review of Applied Entomology, Rice Abstracts, The International Bibliography of Rice Research,* and the publications listed in Appendix B can be consulted for sources of literature on rice insecticide studies.

A review of the literature will often provide ideas on methodology that can be utilized in your study and may also provide you with information on the biology and behavior of the pest which can be extremely important, For example, you may want to determine, in field conditions, insecticides that are effective against the green leafhopper vector of tungro virus. You fail to protect the seedlings in the nursery and make the first insecticide application 5 days after transplanting (DT). Two weeks after application the plants begin to show symptoms of tungro virus. You conclude that none of the insecticides tested provided control of the vector. Had you known more about the insect's behavior you would have realized that the plants could already have been infested before the insecticide application — perhaps by leafhoppers that attacked the seedlings in the nursery or in the newly transplanted field. This example illustrates the importance of knowledge of the pest, which can often be obtained from a review of the literature.

Many research stations have limited library facilities. In such cases you should contact other scientists conducting similar work, or larger libraries, for reprints of pertinent articles. When contacting libraries specify the information you want. Do not, for example, request all the literature on the control of the green leafhopper. A more specific request would be for the literature on the evaluation of granular insecticides for field control of the green leafhopper *Nephotettix virescens* on rice. Specific requests generally get more favorable results than do general requests. It is costly to photocopy and send articles. For large requests a fee may be assessed.

DEVELOPING A RESEARCH PLAN

Develop a written research plan to serve as your guide in conducting the experiment. A good understanding of how to conduct the various phases of the experiment is essential in writing the plan. It gives a good indication of the feasibility of the experiment in relation to cost, time, and personnel required. Your plan can be reviewed by colleagues for possible improvement, and by a statistician to determine whether the experimental design is correct or can possibly be improved to provide for more appropriate analysis.

Items to include in a research plan vary depending on the experiment but the following are generally included.

- Title
- Background information
- Objective(s)
- Site
- Research staff
- Experimental procedure
  - -Treatments
  - -Experimental design and layout
- Agronomic practices
- Special instructions
- Equipment and supplies needed
- Observations and sampling dates

An example of a research plan is given in Appendix C.

Title

Your title should be clear and concise and should indicate what the experiment is about. Avoid general titles such as *Chemical control of the brown planthopper* because most likely the study does not cover all aspects of chemical control. A title such as *Laboratory evaluation of three carbamate insecticides for the control of the brown planthopper* gives a more concise description of the study.

Background information

The background information should briefly state what the problem is, what has been done to solve the problem, and how the information obtained from the experiment will be used.

Objectives

The research objectives, which will determine the design of the experiment, should be well thought out. In determining the objectives of problem-oriented research, consider the farmers' needs. Do not try to achieve too many objectives in one experiment. The result may be a large amount of data that cannot be properly analyzed and from which conclusions cannot be drawn. The objectives should clearly state what you expect to learn from the study.

Site

Information on the site should indicate whether the experiment will be conducted in the laboratory, insectary, or in the field. For field experiments, include the research station or farmer's field where the study is to be conducted; for field experiments in an experiment station, specify the field number.

Research staff

List the individuals involved in conducting the experiment in order of authorship if the study is to be published.

Experimental procedure

Briefly describe how the experiment is to be conducted.

Treatments. The type of treatments depends on your objectives, Do not attempt to answer too many questions in one experiment. It is, for example, possible to compare various insecticides, rates, and application methods simultaneously but it may be difficult to interpret the results properly and form conclusions once the experiment is completed. It may be best to conduct several simple experiments instead of one extremely complicated experiment.

When evaluating new insecticides for effectiveness, include a standard insecticide for comparison. The standard should be a highly effective insecticide currently recommended.

Experimental design and layout. Include a layout indicating the position of the various treatments. Seek the help of a statistician or refer to Gomez (1972) in selecting the proper experimental design. The randomized complete block design (RCBD) is commonly used in both laboratory and field experiments. A split-plot design is commonly used for a factorial experiment, When yield data are recorded, block in the direction of the fertility gradient. Another important factor you should consider in field studies is the pattern of insect distribution. Distribution is affected by the manner of migration and may not be random. In this case, block in the direction of the insect density gradient.

The number of replications depends on the amount of variance expected. In most laboratory or insectary and field insecticide evaluation studies four replications are used. In determining the number of replications choose a number that will provide at least 10 degrees of freedom for estimating experimental error.

Plot size must be considered in field studies. Because of the variability in insect distribution and insect damage, plot sizes for insecticide evaluation studies are often larger than for agronomy experiments. Plot sizes may vary from 25 to 100 m^2 or even larger depending on the size and shape of the field. At IRRI plot size is usually 4 × 9 m (36 m^2). This size provides room for 40 plots 4 × 8 m with 1-m alleys between plots. Regardless of the size and shape of the plot, it is necessary to have a 5-m^2 area, excluding borders, for yield measurements. For ultralow-volume studies, use plots that are at least 10 m wide because of insecticide drift.

Agronomic practices

For field insecticide evaluation studies, follow the agronomic practices commonly recommended for the area. However, you may use modifications such as plant spacing and fertilizer rates to promote high insect populations for more effective evaluation.

Special instructions

Here include all instructions that cannot be appropriately included elsewhere in the research plan. These instructions are extremely important and should be understood by those conducting the study. Failure to follow them can jeopardize the study. For example: *It is important to construct levees between plots to prevent the interplot movement of insecticide.*

Equipment, supplies, and personnel needed

Include the major items needed in the experiment. Preparing the materials before the start of the experiment will help ensure that the necessary items are available on the date needed. Long range planning is especially important if some of the required materials must be imported. If insecticides must be imported, notify the chemical company at least 5 months in advance. Appendix D lists some commonly used equipment and supplies, and suppliers. Appendix E lists chemical companies that include rice insecticides in their research and development program. In soliciting insecticide samples it is generally best to contact a representative of the company residing in your country if one is available.

The number of laborers and technical staff and the amount of labor hours required must also be considered. Do not conduct more experiments than your staff can effectively handle. Field experiments that require extensive insect sampling are extremely time-consuming.

Observations and sampling dates

List the procedures for insect counts and estimating of insect damage, which are used to measure the relative efficacy of the insecticide treatments, and days after transplanting at which observations are to be made. It may be difficult but try to adhere to the sampling date listed as closely as possible. During the course of the experiment take note of additional observations which were unexpected and thus not included in the experiment outline.

chapter 2

REARING OF TEST INSECTS

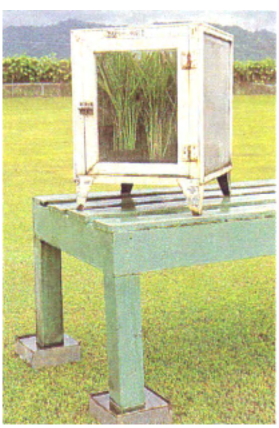
Rearing of test insects is a major input for insecticide evaluation studies in a laboratory or insectary. It requires adequate planning to have sufficient test insects of the right age and sex at the right time. Because rearing conditions influence the reaction of an insect to an insecticide (Sun 1960) it is important that insects used in the tests be as physiologically similar as possible. Proper rearing technique will assure low insect mortality in the untreated control and decrease variation in successive tests.

An efficient insect-rearing program is also valuable in field studies of insecticides. Field populations of insects are often not sufficiently large to provide valid data and cultured insects can be used to artificially infest plants when field populations are low.

Methods of rearing the striped stem borer *(Chilo suppressalis),* yellow stem borer (*Tryporyza incertulas*), brown planthopper (*Nilapavarta lugens*), whitebacked planthopper (*Sogatella furcifera*), green leafhopper (*Nephotettix virescens*), leaf folder (*Cnaphalocrocis medinalis*), caseworm (*Nymphula depunctalis*), and rice bug (*Leptocorisa oratorius*) have been developed at IRRI.

PLANTHOPPERS AND LEAFHOPPERS

An initial population of field-collected insects is used to start cultures of the brown planthopper (BPH), whitebacked planthopper (WBPH), and green leafhopper (GLH). It is preferable to grow the population from a single pair of insects. The three species are cultured on the susceptible rice variety Taichung Native 1 (TN1). In the tropics the hoppers multiply well under open shade throughout the year.



1. Cage for the rearing of leafhoppers and planthoppers. The front and top are covered with glass and the back and two sides with metal, nylon, or fiberglass screen. Bench legs are placed in trays with water to prevent ants from entering the cage.

The hopper-rearing cage is detailed in Figure 1. TN1 plants are grown continuously for the rearing of the hoppers.

Plant six 10-day-old seedlings in clay pots 10 cm in diameter. Add ammonium sulfate fertilizer (2g) to each pot at 15 DT. Plants 25-35 days old are ideal for feeding and oviposition by hoppers. Eight potted plants in each cage will maintain 600-800 hoppers. Maintain separate cages (of the type shown in Fig. 1) for oviposition and rearing of the hoppers. Allow 4 days for oviposition before transferring plants to the hopper-rearing cage.

A person well trained in rearing work can easily maintain 10,000 hoppers of different stages at a time. Periodic examination of cages for the presence of predators and other insect species and prompt removal of these predators are necessary for effective rearing. You should build a fresh culture of insects from a field population at least once in 2 years to avoid *inbreeding depression.*

STEM BORERS

Three methods will provide stem borer larvae for testing.

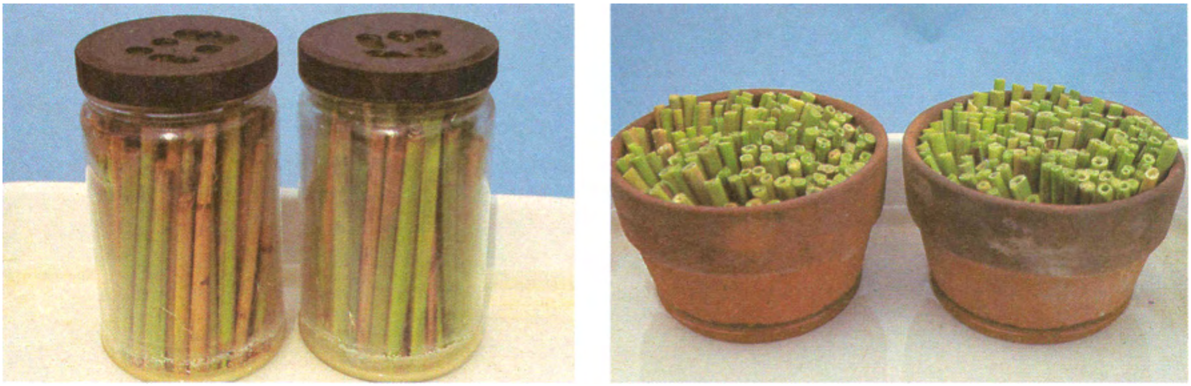
1. For either striped or yellow stem borers, collect borer moths with a sweep net in the rice fields during the day or during the night in light traps or at lights near buildings. Place the moths in vials and return them to the laboratory where they are confined in wooden cages similar to the hopper-rearing cage (Fig. 1). Feed the moths with 10% sucrose solution soaked in cotton wool. Place potted TN1 plants, 40-50 days old, in the cage for oviposition.

Collect the egg masses deposited by the moths daily, by cutting off the leaf section with eggs. Place the leaf sections on moist filter paper in petri dishes and store them at room temperature until the eggs are at the blackhead stage (about 5 days). Place the eggs in an incubator at 15ºC where they can be kept for 10 days without affecting hatching. This permits accumulation of a large number of egg masses that will hatch at the same time. Prior to use, expose the eggs to room temperature. Use the hatched larvae for the tests.

2. Striped stem borer larvae can be mass reared in the laboratory, using cut stalks or by an artificial diet. In the cut-stalk method developed by Kamran (1970), stalks of a susceptible rice variety are cut in 12- to 15-cm sections in such a way that each cut stalk has a node about 2 to 3 cm from the bottom. The stalks are packed tightly in clay pots and placed in metal trays with 2 cm water (Fig. 2). The water keeps out ants and permeates the bottom of the clay pots and provides high relative humidity whereas the upper halves of the pots remain relatively dry. The borers thus have a gradient of humidity.

The use of clay pots provides advantages over the use of other containers such as glass jars (Fig. 2) in that relative humidity is maintained at a favorable level. Also, absence of free water inside the pots gives the borers freedom to crawl about when they leave the old stalks and crawl to the pot rim.

Six egg masses are placed between the rice stalks in each pot. The emerging borers bore into the stems at their cut ends. Later the stalks become brown and dry and the borers leave the stalks and crawl to the rims of the pot in search of food. At this stage, they are picked up with a fine camel's hair brush (older larvae can be picked up with soft forceps) and transferred to pots containing fresh stalks. Stalks are changed



2. Glass jars (left) and clay pots (right) with cut rice stalks for the rearing of rice stem borer larvae. Jars and pots are kept in a metal tray with 2 cm water. Moisture can be better regulated in the clay pots than in the glass jars (Kamran 1970). Glass jars are satisfactory when infesting the cut stalks with late instar larvae but young larvae get caught in the moisture on the glass side.

about 2 times a week. Dissection of old stalks is unnecessary. The adults are allowed to emerge directly from the dried stalks in which they pupate. The moths are confined in cages containing rice plants on which they oviposit. Eggs are transferred to the cut stalks in clay pots for culture maintenance and excess insects are used for insecticide testing.

3. A modification of an artificial diet developed by Kamano (1971) can be used to rear striped stem borer larvae. The diet is prepared as follows.

Ingredients

I.	Cellulose powder	1.0 g
	Wheat bran	2.0 g
II.	Agar powder	1.0 g
	Glucose	0.5 g
	Sucrose	0.5 g
	Casein	1.5 g
	Dry yeast	1.0 g
	Becks salt mixture	0.2 g
	Cholesterol	0.02 g
III.	a) Choline chloride	0.05 g
	b) Sodium dehydroacetate	0.01 g
	c) Water	50.0 ml
IV.	a) Sodium ascorbate	0.2 g
	b) 1% Formalin solution	2.0 ml

Quantities given are sufficient for one 250-ml Erlenmeyer flask.

Preparation

1. Place ingredients I in a flask.
2. Grind and mix II thoroughly in mortar. Place the mixture in the flask.
3. Place IIIa and IIIb in a beaker. Add water and stir to dissolve.
4. Add solution III to the flask and shake slightly to mix ingredients.

5. Autoclave immediately at 112°C and 0.6 kg/cm^2 pressure for 30 minutes.
6. Dissolve IVa in IVb. After autoclaving, transfer flask into a hood for cooling. Then add solution IV to the flask.
7. Take out flask from hood, and shake slightly while immersed in cold water to solidify the diet and attain uniform distribution of ingredients. Keep flasks in a refrigerator at 15°C until ready for inoculation with larvae.

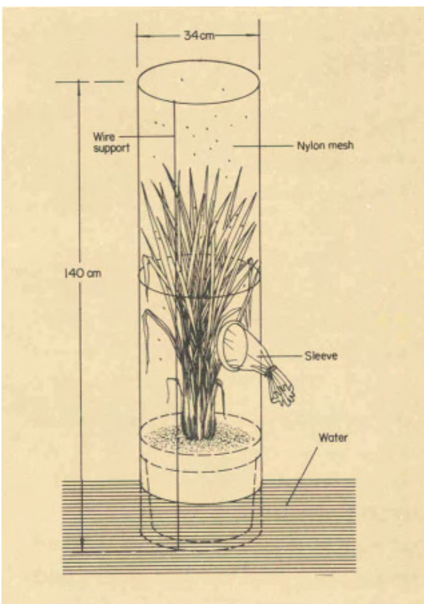
To obtain larvae collect egg masses in the field or collect moths and allow them to lay eggs on wax paper in cages (Fig. 1). Place eggs in a petri dish with moist filter paper and maintain them at a temperature of 25-280°C. When the eggs are at the blackhead stage, place the wax paper containing about 30 eggs on the glass in front of the diet in the flask which is lying on its side. Plug flask opening with sterile cotton and keep it in a clean room at 25–280°C. Insects can be removed from the diet in the later instars and used for insecticide evaluation studies. A few larvae can be allowed to pupate and become adults to maintain the stem borer culture.

LEAF FOLDER

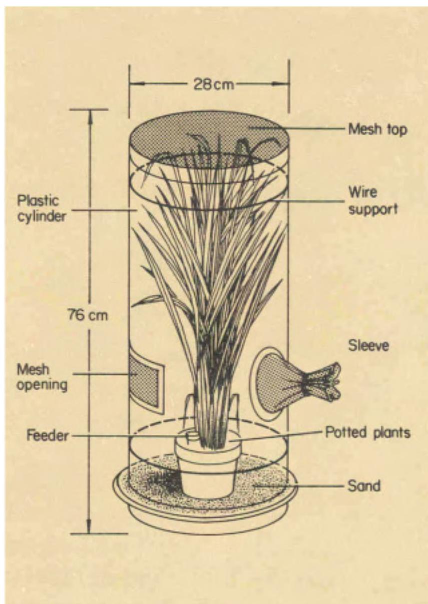
A method of rearing leaf folder larvae was developed by Waldbauer and Marciano (1979).

Start your initial culture from partly grown larvae collected in the field. Place the larvae on potted (clay pots 30 cm in diameter and 28 cm tall) plants in the insectary and place a cage over the plants (Fig. 3). Each pot holds 30 plants with about 125 tillers. Place the pots in the insectary in a metal tray with water about 13 cm deep. Place the adults that emerge in an oviposition cage (Fig. 4) for egg laying.

Place potted 60-day-old TN1 plants in the cages for oviposition. Put them in an earthenware tray (30 cm in diameter and 5 cm deep) filled with wet sand. Feed the moths with 25% honey in water placed in a vial with cotton. Change the feeder every



3. Leaf folder larvae-rearing cage. A cylindrical frame of heavy wire (l40 cm × 34 cm in diam) supports a nylon mesh cage of similar dimension. The mesh extends into the water to prevent insect escape. A 43 cm × 19 cm diam sleeve attached 80 cm from the cage bottom allows access to the cage (Waldbauer and Marciano 1979).



4. Leaf folder oviposition cage. The mylar film or plastic cylinder is supported by two wires. The sand can be wetted to regulate moisture. The cotton fader is soaked with honey to provide nourishment for the moths (Waldbauer and Marciano 1979).

2 days to avoid fungal infection. The cage is designed to provide high relative humidity necessary for normal survival of the moths.

Eggs are laid singly or in rows and are generally concentrated at the tip portion of the leaves. Cut the leaf bits with eggs with scissors and place them on moist filter paper in petri dishes, 300-400 eggs/dish. The eggs hatch in 4 days with about 90% viability. The hatched larvae can be used for experimental purposes.

Transfer the newly hatched larvae daily to plants in the rearing cage (Fig. 3). Transfer singly with a fine, pointed, wet camel's hair brush. Leaf bits to which larvae cling can also be wedged in the axils of plants with forceps.

Place a cylindrical frame of heavy wire over each infested pot to support a nylon mesh cylinder of similar dimensions. The open bottom of the nylon mesh must extend below the water to prevent insect escape. Access to the cylinder is through a nylon mesh side sleeve, which must be tied shut when not in use.

Each pot will support the complete development of at least 50 larvae. You can raise as many as 75 larvae in 1 cage if additional plants in small pots are introduced as needed, beginning 14 days after infestation. To avoid inbreeding, collect larvae in the field and introduce them into the culture annually.

Pupation occurs and adults emerge from plants in the cages at 22-23 days after infestation. The average survival from the first instar to adult is about 87%.

Collect the adults that emerge and place them in vials at 5 adults/vial. Sort them by sex. Release groups of 20-25 moths with about 1:1 sex ratio into the oviposition cage (Fig. 4).

RICE BUG

1. To start the culture, collect adults in the field and place them in wooden cages (Fig. 1) containing rice plants with panicles in the milky stage.

2. Take them back to the rearing facility and transfer them into oviposition cages (1 × 2 × 1.5 m) containing 9 No. 4 (6" in diameter) clay pots, each containing 1 hill.

3. Remove newly laid eggs daily by cutting the leaf portion on which they are laid. Place them in a petri dish with moist filter paper and keep them in the laboratory for 5 days at room temperature (24–30°C).

4. Place the petri dishes with the filter paper and the eggs in a rearing cage on top of a pot at the base of the plants. Immediately after hatching the nymphs move up and begin feeding within 1-2 hours.

5. Change the food plants in the milky dough stage weekly.

6. Nymphs become adults in about 1 month. Use the 2-day-old adults for insecticide screening, and keep the others to maintain the culture.

CASEWORM

The caseworm-rearing technique developed by Bandong and Litsinger (1981) will yield about 5,400 eggs every 4 days of which 97% are used for insecticide studies and the rest to maintain the culture. The procedure follows:

1. Set up an oviposition cage indoors or in an insectary. The cage consists of a mylar film cylinder 25 cm in diameter and 54 cm tall with the top made of nylon mesh. A nylon mesh window and a sleeve are located on the side. The sleeve, located near the base, facilitates placing of leaves and insects into the cage. The bottom of the cage is immersed in about 5 cm of water. Because the moths oviposit on the

undersides of floating leaves, place about 30 10-cm-long leaf sections from about 3-week-old plants in the water.

2. Collect moths in infested fields to start the culture. Place the moths in the oviposition cage.

3. Remove the egg-infested leaf sections daily and place them in a small tray with water keeping the eggs submerged. Replace fresh leaves in the oviposition cage.

4. Eggs hatch in 3 days. Upon hatching, transfer about 160 larvae on leaves into the larvae-rearing cage. Place 6 No. 4 pots, each containing 8 20- to 30-day-old plants in a metal tray on an insectary bench containing about 12 cm water (sufficient to cover the pots). Cover with a cage constructed of a wire frame cover and with nylon mesh or fiberglass screen. Allow the larvae to feed for 17-20 days. The larvae will pupate in the leaf sheaths of the potted plants.

5. At pupation, remove the potted plants with pupae from the larvae–rearing cage. cut tops of plants and place them in the adult emergence cage. The adult emergence cage is similar to the oviposition cage except that it has a sleeve near the top, rather than near the bottom, to facilitate collection of the moths which congregate near the top of the cage.

6. Adults emerge in about 1 week. This completes 1 cycle. In the second cycle place 40 adults of each sex in the oviposition cage and continue the cycle as previously described. Larvae can be taken from the egg-hatching tray at hatching or as later instars from the larvae-rearing cage for insecticide studies.

chapter 3

DETERMINING LD_{50} VALUES OF INSECTICIDES

The initial screening of new insecticides and tests for resistance to insecticides are done in the insectary and laboratory. Field trials require expensive labor and land and are subject to many variables. Insectary studies narrow the number of chemicals to a few promising compounds, which can then be tested in the field.

We include here the methodology for determining the 50% lethal dose (LD_{50} values) of insecticides in the laboratory. LD_{50}, studies give an accurate indication of the contact toxicity of an insecticide and are especially useful in estimating level of resistance to insecticides. The test starts with simple bracketing in nonreplicated experiments. Final tests use at least three replications.

BRACKETING

To start bracketing, prepare serial dilutions of five concentrations of a technical grade insecticide in acetone solution. For leafhoppers and planthoppers, apply a dose of 0.2 μl of the insecticide solution on the thoracic tergites of each test insect with a calibrated microapplicator and microsyringe (Fig. 1). For spiders and for larger insects such as stem borer larvae apply 1 μl. Prepare serial dilutions and calibrate syringe as follows:

1. *Serial dilution.* Because the active ingredient (% a.i.) of technical insecticides varies, standardize the dilution to provide uniform concentrations. This is done as follows:

- Determine by ratio and proportion the weight of insecticide needed to have a 100% stock solution (SS).
- Compute the weight of insecticide needed with the desired volume of SS.

For example, you have a technical insecticide with 99.5% a.i. To determine the weight of technical insecticide needed to have a 100% SS, calculate as follows:

First determine the correction factor (CF).

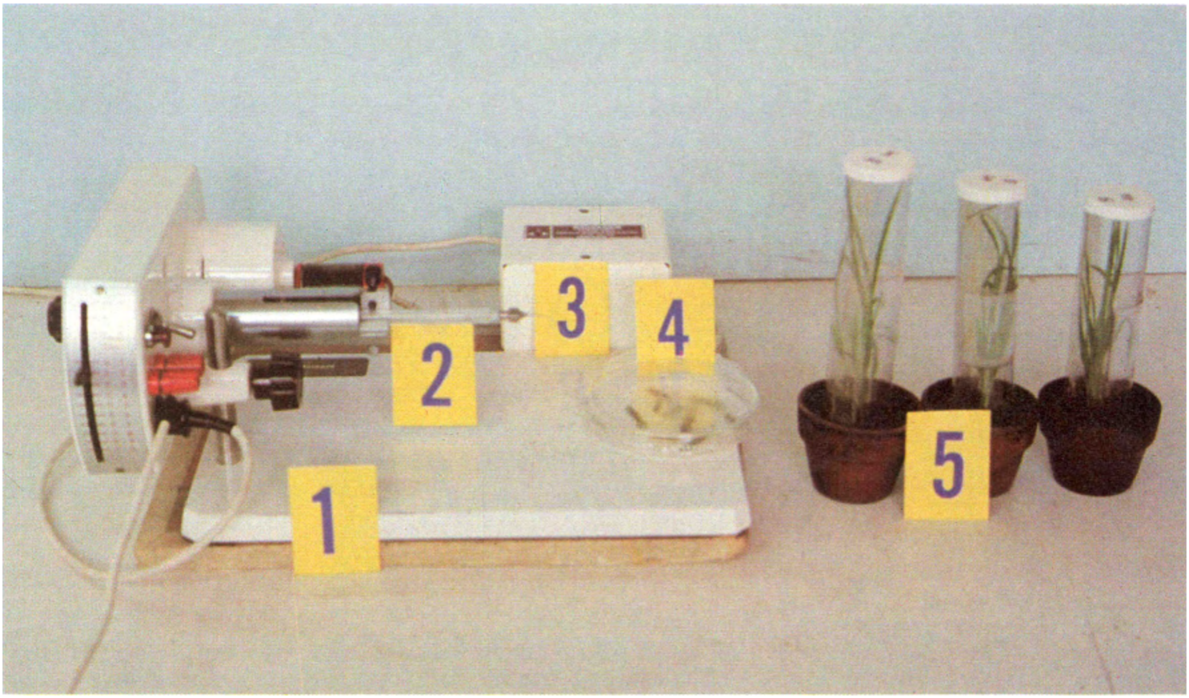
$$CF = \frac{100\%}{\%\ \text{a.i. in technical insecticide}} = \frac{100}{99.5} = 1.005$$

Next, using the CF, determine the weight of technical insecticide required to prepare a given volume of a given concentration:

$$\text{Concentration of insecticide needed} \times \text{volume of insecticide needed} \times \text{CF}$$

For example, to prepare 25 ml of a 1,000 μg/ml concentration,

$$\begin{aligned} &= 1{,}000\ \mu\text{g/ml} \times 25\ \text{ml} \times 1.005 \\ &= 25{,}125\ \mu\text{g} \\ &= 25.125\ \text{mg} \\ &= .0251\ \text{g} \end{aligned}$$



1. Microapplicator for the topical application of insecticide and cages used in LD_{50} studies. 1) bearing block, 2) glass syringe, 3) transformer, 4) petri dish containing test insects, 5) potted plants in mylar film cages 15 cm high and 3.5 cm in diam.

Weigh 0.0251 g or 25.125 mg of the technical insecticide and dissolve it in a volumetric flask by adding analytical reagent (AR) acetone to a 25-ml volume. Make a serial dilution from the SS using the equation:

$$C_1V_1 = C_2V_2;$$

where

C_1 = initial concentration,
C_2 = final concentration.
V_1 = initial volume, and
V_2 = final volume.

To prepare 10 ml of 5 μg/ml (= 5 ppm) from 1,000 μg/ml (= 1,000 ppm)

$$C_1V_1 = C_2V_2$$

$$1{,}000\,(X) = 5(10)$$

$$X = \frac{50}{1{,}000}$$

$$X = 0.05 \text{ ml of SS.}$$

To make 10 ml add the 0.05 ml of SS to 9.95 ml of solvent.

2. *Calibration of syringe.* Unless the microapplicator and syringe are of the same brand, the syringe to be used should be calibrated to provide uniform application of insecticides. To do that:

- Place mercury (Hg) in the syringe and set the selector level arbitrarily. Using the 1-ml syringe, make 10 deliveries (about 10 drops of Hg).

- Weigh the 10 drops of Hg and compute the weight of 1 drop.
- Find the volume of Hg using the equation

$$V = \frac{wt}{d}$$

where

V = volume (ml),
d = 13.6 g/ml, and
wt = weight (g).

- At the given setting, compute the delivery (μl) by multiplying the volume by 1,000.
- Use ratio and proportion to determine the setting that will deliver 1 μl.

For example:

$$\begin{aligned} \text{Setting} &= 1.0 \\ \text{Weight of Hg} &= 0.0022725\ \text{g/drop} \\ V &= \frac{wt}{d} \\ &= \frac{0.0022725\ \text{g}}{13.6\ \text{g/ml}} \\ &= 0.000167\ \text{ml} \\ \text{Delivery (in } \mu\text{l)} &= V \times 1{,}000 \\ &= 0.000167\ \text{ml} \times 1{,}000\ \mu\text{l/ml} \\ &= 0.167\ \mu\text{l} \end{aligned}$$

The setting that will deliver 0.2 μl = 1:0.167 as X:0.2

$$X = \frac{0.2}{0.167} = 1.198$$

3. *Preliminary test.* The preliminary test to approximate the doses needed is called bracketing. Bracketing is usually done with only one replication. select 5 dillutions usually ranging from 1 to 100 parts per million (ppm). To facilitate handling of test insects, anesthetize them for 40-45 seconds with carbon dioxide at a flow rate of 10 ml/13 seconds (Fig.2). Treat control insects with analytical reagent acetone alone.

Place the treated insects on 2-week-old TN1 rice seedlings and cover with small mylar cages (Fig. 1). Place the caged plants in an incubator with a temperature of 27-30° C, 60-80% RH, and 16 hours illumination/day.

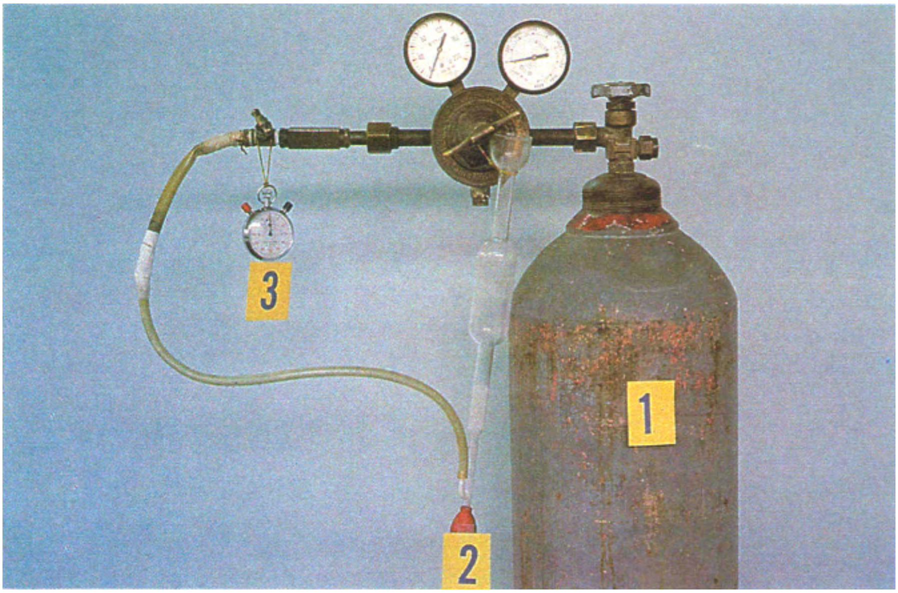
Record insect mortality 24 hours after treatment and convert it to percentage of mortality using the formula:

$$\text{Percentage of mortality} = \frac{\text{dead insects}}{\text{total insects treated}} \times 100$$

The percentage of mortality is corrected by Abbott's (1925) formula:

$$\text{\% Corrected Mortality} = \frac{\text{\% test mortality} - \text{\% control mortality}}{100 - \text{\% control mortality}} \times 100$$

Record insect body weight. Anesthetize representative individuals from the test insect population with ethyl ether and weigh about 20 insects individually (using a



2. Equipment for the anesthetization of test insects. I) CO_2 cylinder, 2) soap film flow meter, 3) stopwatch.

I-g capacity Mettler balance) or in 3 batches of 20 insects (using a lag capacity Mettler balance).

4. *Final test.* In the final test choose from the preliminary test at least 5 mortality points ranging from 5 to 95%. Prepare a serial dilution of the doses and conduct the final test with a minimum of 3 replications using 20 insects/replication.

5. *Probit analysis.* Computer programs have been developed for probit analysis (Daum 1970, Russell et a1 1977). In the absence of computer facilities, probit analysis can be conducted with the aid of a simple calculator. There are 29 basic steps in the mathematical estimation of the LD_{SO} and probit regression line as modified from Finney (1962). They are:

1) Enter in column 1 of the Probit Table (Table 1) the treatment doses (ppm), from the highest to the control concentration.
2) Enter in column 2 the logarithm of the doses (from Appendix A Table 1). The doses may be multiplied or divided by 10 to have small positive values of its logarithm. These are adjusted at the end to be able to express the results in the original unit of measurement.
3) Enter in column 3 the total number of insects tested for each dose.
4) Enter in column 4 the total number of dead insects for each dose.
5) Record in column 5 the computed mortality percentages.
6) Record in column 6 the computed percentage of corrected mortality using Abbott's formula.
7) Enter in column 7 the corresponding probit of % corrected mortality, given in Appendix A Table 2. Use values correct to two decimal places.
8) If you are using the normal squared paper, plot the empirical probit (column 7) against log of dose (column 2) and draw a provisional eye fitted line. However,

Table 1. Mathematical estimation of LD_{50}.

Insecticide A

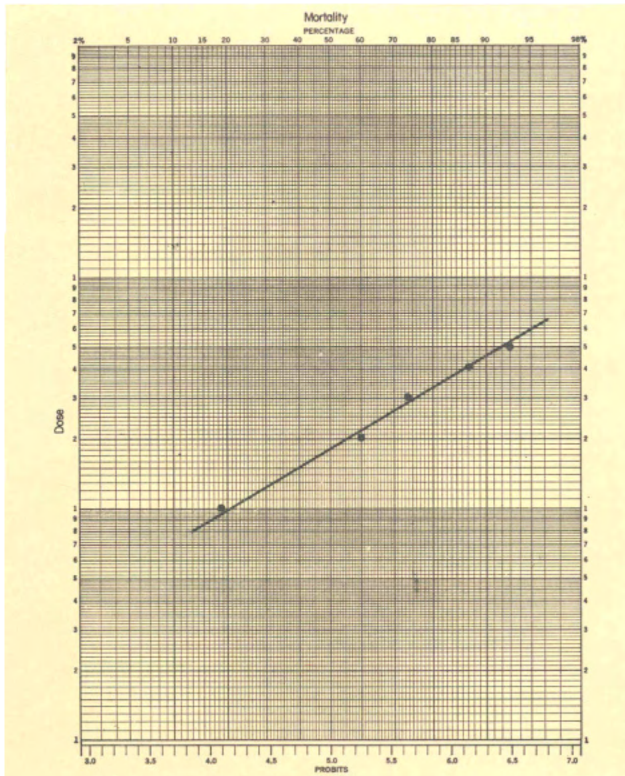
Species N.lugens

Sex Female

Dose[a]	Log of dose *x*	Total in-sects *n*	No. dead insects *r*	% Mor-tality *p*	% Cor-retted Mort.	Empi-rical probit	Ex-pected probit *Y*	Weight-ing Coef. *w*	Weight *nw*	Work-ing probit *y*	*nwx*	*nwy*	nwx^2	*nwxy*	nwy^2
50	1 70	60	56	93.33	93.10	6.48	6.45	0.285	17.100	6.47	29.070	110.637	49.41900	188.08290	715.82139
40	1.60	60	53	88.33	87.93	6.17	6.12	0.398	23.880	6.17	38.208	147.340	61.13280	235.74336	909.08780
30	1.48	60	45	75.00	74.14	5.64	5.72	0.526	31.560	5.64	46.709	177.998	69.12932	263.43876	1,003.90870
20	1.30	60	37	61.67	60.34	5.26	5.18	0.628	37.680	5.25	48.984	197.820	63.67920	257.16600	1,038.55500
10	1.00	60	13	21.67	18.96	4.12	4.20	0.503	30.180	4.12	30.180	124.342	30.18000	124.34160	512.28904
0		60	2	3.33											
									140.400	27.65	193.151	758.137	273.54032	1,068.7726	4,179.66180

Snw	140.400	$Snwx^2$	273.54032	k-2 (df)	3
Snwx	193151	*Snwxy*	1,068.7726	χ^2 tabular	7.8
Snwy	758.137	$Snwy^2$	4,179.66180		

[a] Expressed in parts per million and multiplied by 10 to avoid fractions that will result in a negative log value.



3. Dose-mortality response curve of an insecticide against *N. lugens* plotted on probability paper.

if you are using a logarithmic probability paper such as in Figure 3, you can plot the dose (column 1) and % corrected mortality (column 6) directly. Read the values of the provisional line and enter those in column 8.

9) Enter in column 9 the weighting coefficient values from Appendix A Table 3 corresponding to expected probit *(Y).*

10) Enter in column 10 the product of the weighting coefficient *(w)* and number of insects tested *(n).* Use values correct to three decimal places.

11) For column 11, you can determine the working probit *(y)* in two ways depending on the value of expected probit *(Y).*

- If the lowest *Y* value is 2.0 or more and the highest *Y* value is 7.9 or less, refer to Appendix A Table 4 and enter in column 11 the working probit values.
- If *Y* is less than 2.0 or greater than 7.9, use the minimum-maximum working Probit Table (Appendix A Table 5).

Assuming $Y = 1.90$ use the following formula:

$$y = \text{minimum working probit} + (\text{\% kill} \times \frac{1}{Z})$$

where the minimum working probit and $\frac{1}{Z}$ (range)

are taken from Appendix A Table 5 and the % kill = % corrected mortality on Table 1.
Thus, assuming Y = 1.90 and % kill = 0.10,

$$y = 1.6038 + (0.0010 \times 306.1)$$
$$y = 1.91$$

Assuming Y = 8.0, use the following formula:

$$y = \text{maximum working probit} - (\% \text{ alive} \times \frac{1}{Z})$$

Again the maximum working probit and 1/Z are taken from Appendix A Table 5 and % alive = (100 - % corrected mortality).
Thus, assuming Y = 8.0 and % kill is 99.87 (% alive = 0.13),

$$y = 8.3046 - (0.0013 \times 225.6)$$
$$y = 8.01$$

For both, the maximum and minimum working probits use values correct to two decimal places, if $n < 200$, and 3 decimal places if $n > 200$.

12) Enter in columns 12 to 16 the product of computed values from respective columns as indicated in each column heading. Use values correct to 3 decimal places for columns 12 and 13 and values correct to 5 decimal places for columns 14 to 16.

13) Compute the summation of columns 10 to 16.

14) Divide the sum of *nwx* by the sum of *nw* to compute the mean value of *x.* Use values correct to four decimal places.

$$\bar{x} = \frac{Snwx}{Snw.}$$
$$\frac{193.151}{140.400}$$
$$= 1.3757$$

15) Divide the sum of *nwy* by the sum of *nw* to compute the mean value of *y.* Use values correct to four decimal places.

$$\frac{Snwy}{Snw}$$
$$= \frac{758.137}{140.400}$$
$$= 5.3998$$

$$\bar{y} = \frac{Snwy}{Snw}$$
$$= \frac{758.137}{140.400}$$
$$= 5.3998$$

16) Compute *Syy* using the equation

$$Syy = Snwy^2 \frac{(Snwy)^2}{Snw}$$
$$= 4{,}179.6618 - \frac{(758.137)^2}{140{,}400}$$
$$= 4{,}179.6618 - 4{,}093.8155$$
$$= 85.84630$$

17) Compute *Sxy* using the equation

$$Sxy = Snwxy - \frac{(Snwx)\ (Snwy)}{Snw}$$

$$= 1{,}068.7726 - \frac{(193.151)\ (758.137)}{140.400}$$

$$= 1{,}068.7726 - 1{,}042.9838$$

$$= 25.78880$$

18) Compute *Sxx* using the equation

$$Sxx = Snwx^2 - \frac{(Snwx)^2}{Snw}$$

$$= 273.54032 - \frac{(193.151)^2}{140.400}$$

$$= 273.54032 - 265.72157$$

$$= 7.81875$$

19) Compute the slope or regression coefficient (*b*).

$$b = \frac{Sxy}{Sxx}$$

$$= \frac{25.78900}{7.81875}$$

$$= 3.29835$$

20) Substitute the values in the equation to compute the probit regression line.

$$Y = \bar{y} + b\ (x - \bar{x})$$

$$= 5.3998 + 3.29835\ (x - 1.3757)$$

$$= 0.86226 + 3.29835x$$

Select three concentrations (highest, middle, and lowest log of dose) and substitute for x in the equation. Plot the three Y values obtained from the probit regression line. Compare the calculated values of x with the expected probit *(Y).* If the values do not differ by more than 0.2 in any case, the provisional line may be considered adequate. In our example for x = 1.70, 1.48, and 1.00, we have the following three calculations, respectively:

$$Y = 0.86226 + (3.29835)\ (1.70) = 6.47$$

$$Y = 0.86226 + (3.29835)\ (1.48) = 5.74$$

$$Y = 0.86226 + (3.29835)\ (1.00) = 4.16$$

None of the computed values of Y differ from the expected probit Y by more than 0.2. Thus, the provisional line is considered adequate.

On the other hand, if the computed Y and expected probit differ by more than 0.2, there is a need for second cycle computations. In this case consider the computed values of Y as improved expected probits Y^1 and plot them on logarithmic probability paper. Draw another provisional eye-fitted line. From the line record the improved expected probits in column 8 Table 1. For column 9, recalculate the weighting coefficient for Y^1 and repeat calculations in columns 10-16.

21) Find the variance of individual observations *(Va)* to at least seven decimal places.

$$Va = \frac{1}{Snw}$$
$$= \frac{1}{140.400}$$
$$= 0.0071225$$

22) Find the variance of slope *(b)* from the reciprocal of *Sxx.*

$$Vb = \frac{1}{Sxx}$$
$$= \frac{1}{7.81875}$$
$$= 0.1278976$$

23) Compute the Chi square (x^2) value using equation

$$\chi^2 = Syy - \frac{(Sxy)^2}{Sxx}$$
$$= 85.84630 - \frac{(25.78880)^2}{7.81875}$$
$$= 85.84630 - 85.059914$$
$$= 0.786386$$

24) Compare the computed x^2 value with the tabulated x^2 in Appendix A Table 6 at the level of 0.05 probability. The degrees of freedom (df) are equal to the number of concentrations (doses) (k) minus 2. From the table the x^2 for 3 df at 0.05 probability is equal to 7.8 and is greater than the computed x^2 value. Thus, the probit regression line in Figure 3 satisfactorily represents the results of the experiment.

25) Find the standard error of the slope *(b)* from the square root of the reciprocal of *Sxx.*

$$s.e.b. = \sqrt{\frac{1}{Sxx}}$$
$$= \sqrt{\frac{1}{7.81875}}$$
$$= \sqrt{0.127898}$$
$$= 0.3576278$$

26) Find the variance of *m,* the estimated log LD_{50}, as the value $\bar{x}$, which gives $Y = 5$. The estimated log LD_{50} is

$$m = \bar{x} + \frac{(5-\bar{y})}{b}$$
$$= 1.3757 + \frac{(5-5.3998)}{3.29835}$$
$$= 1.3757 - 0.121212$$
$$= 1.2545$$

27) Find the antilog of 1.2545 (see Antilog, Appendix A Table 7). Because the doses are multiplied by 10, divide the antilog by 10 to set the original units of measurement.

$$\text{Antilog} = \frac{17.97}{10}$$
$$= 1.797\ \mu g/ml$$

28) Calculate for LD_{50}. The lethal dose varies with the size of the insect and, for purposes of comparison, is expressed in µg/g body weight of the insect.

$$LD_{50}(\mu g/g \text{ body weight}) = \frac{\text{Conc. of insecticide} \times \text{delivery}}{\text{Weight of insect}}$$

Convert the concentration of insecticide (µg/ ml), taken from step 27 of probi analysis, to µg/µl by dividing by 1,000 as

$$1\mu 1 = \frac{1\ ml}{1{,}000}$$

In our example: 1.797 µg/ml= 0.001797 µg/µl.
Delivery is expressed in µl/insect weight in grams.

$$\frac{0.001797\ \mu g/\mu l \times 0.2}{0.00255 g}$$
$$= \frac{0.0003594}{0.00255}$$
$$= 0.141\ \mu g/g$$

29) Compute g for the probability level at which fiducial limits are required using the equation

$$g = \frac{t^2 Vb}{b^2}$$

where t = 1.96 at > 120 df and at 0.05 probability (Appendix A Table 8).

$$g = \frac{(1.96)^2 \times 0.1279}{(3.29835)^2}$$
$$= \frac{0.4913}{10.8791}$$
$$= 0.0452$$

If g is less than the product of t and standard error of m(s.e.m.), calculate the fiducial limits using the equation

$$\log LD_{50} \pm t\ s.e.m.$$

The log LD_{50} has been computed (see step 26). Get the value of t from the t-values in Appendix A Table 8. Compute the standard error of m(s.e.m.) from the square root of the variance of m(Vm). Because the value of Vm is unknown, compute first for Vm using the equation

$$
\begin{aligned}
Vm &= \frac{1}{b^2}[Va + (m - \bar{x})^2\ Vb] \\
&= \frac{1}{(3.29835)^2}[0.0071225 + (1.2545 - 1.3757)^2\ (0.1279)] \\
&= 0.0919192\ [0.0071225 + 0.0018787] \\
&= 0.0919192\ (0.0090012) \\
&= 0.0008273
\end{aligned}
$$

$$
\begin{aligned}
s.e.m. &= \sqrt{Vm} \\
&= \sqrt{0.0008273} \\
&= 0.0287628 \\
t\ s.e.m. &= 1.96\ (0.0287628) \\
&= 0.056375
\end{aligned}
$$

Because g (0.0452) is less than t s.e.m. (0.056375), use the following formula:

$$
\begin{aligned}
\text{Fiducial limits} &= \text{Log } LD_{50} \pm t\ s.e.m. \\
&= 1.2545 \pm (1.96)\ (0.0287628) \\
&= 1.2545 + 0.056375 \\
&= 1.310875 \\
&= 1.2545 - 0.056375 \\
&= 1.198125
\end{aligned}
$$

Convert the values to their antilogs (see Appendix A Table 7) and correct for dosage multiplication of 10. Thus,

$$
\begin{aligned}
\text{antilog of } 1.310875 &= 20.46 \\
\text{antilog of } 1.198125 &= 15.78 \\
\text{Fiducial limits} &= \frac{20.46}{10} \text{ to } \frac{15.78}{10} \\
&= 2.046\ \mu g/ml \text{ to } 1.578\ \mu g/ml
\end{aligned}
$$

Next convert the values to µg/ ml concentration of insecticide per g body weight of the insect using the following formula:

$$\frac{\mu g/ml \times \text{delivery } (\mu l/\text{insect})}{\text{weight of insect (g)}}$$

$$= \frac{2.046 \times \frac{0.2}{1{,}000}}{0.00255} \text{ to } \frac{1.578 \times \frac{0.2}{1{,}000}}{0.00255}$$

$$= 0.1605\ \mu g \text{ to } 0.1238\ \mu g/g$$

The information on toxicity as obtained in this example can be reported in tabular form.

Insecticide	LD_{50}		Slope (from step 19)	SE Slope (from step 25)
	LD_{50} μg/g	Fiducial limits (from step 29)		
A	0.141	0.12–0.16	3.30	0.36

If g is greater than t *s.e.m.,* calculate the fiducial limits using the formula:

$$m + \frac{g}{1-g}(m-\bar{x}) \pm \frac{t}{b(1-g)} \sqrt{\frac{1-g}{Snw} + \frac{(m-\bar{x})^2}{Sxx}}$$

chapter 4

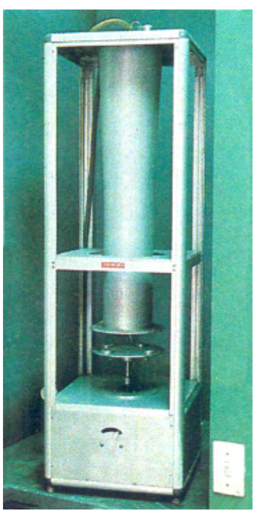
INSECTARY EVALUATION OF INSECTICIDES

Indoor evaluation of insecticides in semicontrolled conditions is a rapid and accurate method of obtaining initial information on the comparative effectiveness (knockdown and residual activity) of candidate insecticides. Most of the candidate insecticides are eliminated from further evaluation in the insectary testing process and only the most promising are further evaluated in the more expensive and time-consuming field tests. Insecticides can kill insects in several ways. In this section we discuss the following tests which are designed to determine the activity of the insecticides through the various routes:

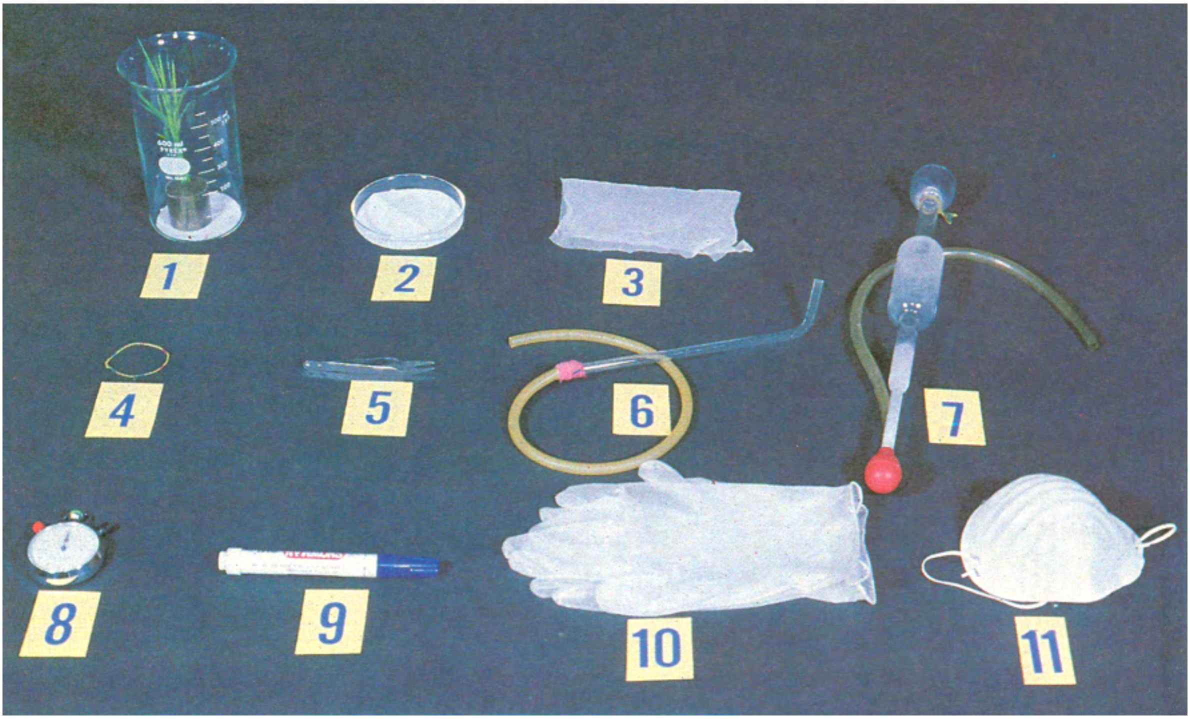
- contact toxicity studies with precision spraying
- foliar sprays
- broadcast application of granules
- root zone application
- antifeedant activity
- ovicidal activity
- fumigation activity
- resurgence activity

PRECISION SPRAYING ON INSECTS

For hoppers, precision spraying of insecticides directly on the body of the insect is done with a Potter's spray tower (Fig. 1). The spray tower provides a uniform mist over a given area and can be used for applying insecticides directly on insects and for



1. Potter's spray tower. An exhaust fan in the cabinet removes the fumes after spraying.



2. Materials for precision spraying studies. 1) 500-ml beaker with rice seedlings in a plastic cup, 2) petri dish with filter paper, 3) nylon mesh cloth to cover beaker, 4) rubber band to secure nylon mesh cloth on beaker, 5) forceps, 6) mouth aspirator for handling insects, 7) flow meter, 8) stopwatch, 9) marking pen, 10) disposable polyethylene gloves, 11) disposable mask.

deposition of residual films. Like the microapplicator the technique provides precise preliminary data on the relative effectiveness of insecticides applied as a spray. The Potter's spray tower must always be used in a fume hood which removes toxic fumes from the work area.

Preparation of plants and cages

Plant 5- to 10-day-old TN1 seedlings in plastic cups (3.5 cm in diameter and 5 cm high) at the rate of 20 to 30 seedlings per cup. Use glass beakers (500 ml) as cages for insects. Put a filter paper (7 cm in diameter) at the bottom of each beaker and place a plastic cup with seedlings on it (Fig. 2, no. 1). Use a minimum of 4 replications for each treatment. Keep the cages at a 25–27°C temperature, 60-80% relative humidity, and 12 h/day light.

Preparation of test insects

Collect hoppers from rearing cages by a mouth aspirator. Collect 25 adult hoppers for each replication and place them in glass tubes 11 cm long and 2.5 cm in diameter, with screen caps and ventilated lids. Anesthetize the test insects as follows:

- Attach a flow rate meter to the outlet of carbon dioxide.
- With a stopwatch, regulate gas flow of a carbon dioxide tank at the rate of 2.5 ml CO_2/second.
- Expose insects in each tube to the darbon dioxide flow for 20 seconds.

- Close the tube mouth with the thumb for 20 seconds.
- Transfer anesthetized hoppers to a petri dish (10 cm in diameter) that has a filter paper at the bottom. Arrange the hoppers on the filter paper in a natural position.

Computation of insecticide required

The rate of insecticide for the Potter's spray tower is expressed in % concentration. In assessing the quantity of test chemical required, consider field concentration of the insecticide recommended (% basis) and volume of spray fluid required (liters/ ha). Determine the volume of spray fluid required in the tower by the use of a dye in water with volume increased until there is good coverage of the petri dish. Use about 2 ml to spray each petri dish. Also, consider the volume of spray solution to be prepared (a standard procedure is to prepare 0.2 liters of spray solution of each insecticide) and the concentration of the commercial product (% a.i.). Two examples are given:

1. Wettable powder (WP)

Example:	Volume of spray fluid required	=	200 ml(0.2 liter)
	Recommended concentration	=	0.04 %
	Carbaryl 85 WP	=	85% WP

Solution:

$$\text{WP required (kg)} = \frac{\text{\% concentration desired} \times \text{required spray vol. (liters)}}{\text{\% a.i. in commercial product}}$$

$$\text{Carbaryl required} = \frac{0.04 \times 0.2}{85} = 0.0000941 \text{ kg or } 94.1 \text{ mg}$$

2. Emulsifiable concentrate (EC)

Example:	Spray volume required	=	200 ml (0.2 liter)
	Recommended concentration	=	0.025%
	Methyl parathion 50 EC	=	50% EC

Solution:

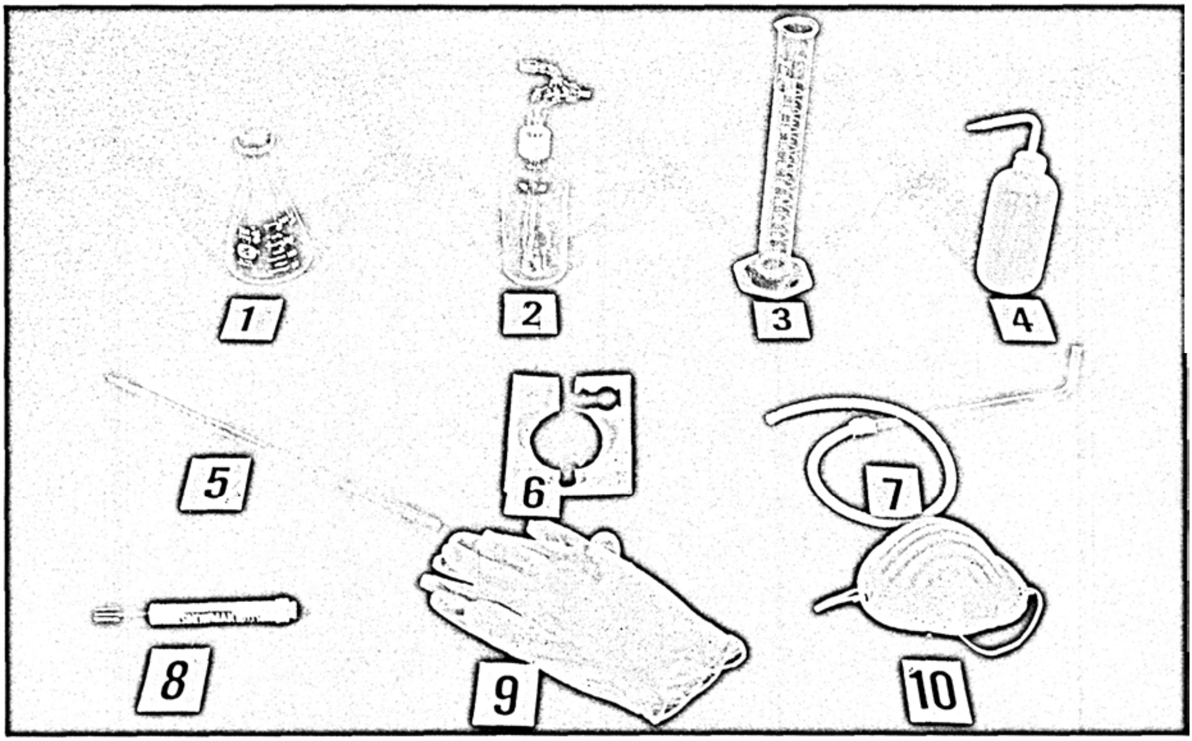
$$\text{EC required (liters)} = \frac{\text{\% conc. desired} \times \text{required spray vol. (liters)}}{\text{\% a.i. in commercial product}}$$

$$\text{Methyl parathion required} = \frac{0.025 \times 0.2}{50} = 0.0001 \text{ liter or } 0.1 \text{ ml}$$

Preparation of spray fluid

After computing the quantity of insecticide required, prepare the spray fluid as follows:

- Prepare the required number of 250-ml Erlenmeyer flasks. Clean the inner portion with acetone and air dry. Label the flasks with the name of the treatment.
- Measure 200 ml of distilled water or clean tap water with a graduated cylinder and transfer it to each flask.
- Measure the required quantity of insecticide with a pipette and a suction bulb, and transfer the insecticide to respective flasks.



3. Materials for insectary foliar spray tests. 1) 250-ml Erlenmeyer flask with rubber cork, 2) glass atomizer, 3) graduated cylinder, 4) wash bottle containing acetone. 5) pipette, 6) rubber suction bulb, 7) mouth aspirator, 8) marking pen, 9) disposable polyethylene gloves, IO) disposable mask.

- Close the flasks tightly with a rubber stopper and shake the contents to mix them thoroughly.

Insecticide treatment

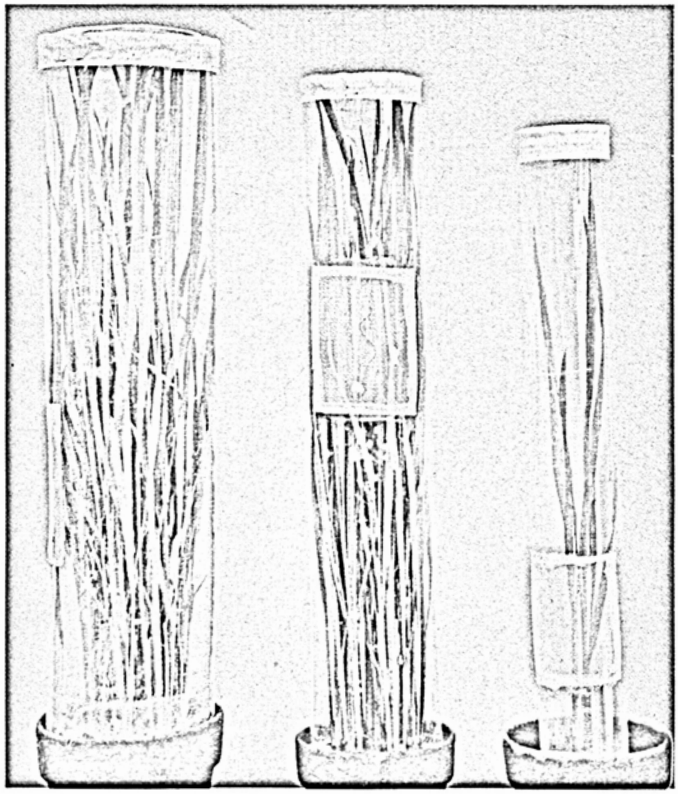
Place the petri dish with the anesthetized insects at the bottom of the Potter's spray tower (Fig. 1). Place 2 ml of the test insecticide in the insecticide reservoir at the top of the tower. Release the spray lever and spray the insects directly at a pressure of 0.703 kg/cm^2. Transfer sprayed insects on 5-day-old seedlings in 500-ml beakers (see Fig. 2, no. 1) and cover the beakers with nylon cloth. Spray a control group of insects with distilled water.

Mortality assessment

Record insect mortality at 1, 4, 24, and 48 hours after treatment and correct the percentage of mortality using Abbott's formula. Express the data in either graph or tabular form.

FOLIAR SPRAY TEST

Foliar spraying is a common method of applying insecticides such as wettable powders, soluble powders, emulsifiable concentrates, and flowable formulations. The method remains popular despite the laborious task of carrying large amounts of spray solution to the field for the commonly used high-volume knapsack sprayer.



4. Mylar film cages (about 54 cm high and 8-14 cm in diam) for confining test insects in foliar spray tests.

Rice insecticide evaluation programs should include an insectary test to identify effective chemicals applied as foliar sprays.

The materials required for the foliar spray test are shown in Figure 3.

Preparation of plants and cages

Use three 30- to 40-day-old plants of a susceptible variety/pot for the test. Clean test plants by removing the dead lower leaves, washing them with water, and shade drying them before foliar spraying. After spraying confine the insects on the plants in cylindrical (about 54 cm tall and 8 cm in diameter) mylar film cages (Fig. 4).

Computation of insecticide required

Assess the quantity of insecticide required. The quantity required to spray the plants in each pot is based on the volume of the spray fluid used in the field and population of plants in a hectare, with a given spacing. For plants at maximum tillering, 500 liters of spray fluid applied with a high volume sprayer is adequate to provide uniform distribution of the insecticide on a hectare. With a 25 × 25 cm spacing, there will be 160,000 hills/ha. Spray 4 pots with 4 plants each simultaneously on a revolving table, treating each pot as a hill. Calculate the quantity of spray fluid for the 4 pots as follows:

$$\text{Quantity} = \frac{\text{Volume of spray fluid/hectare (ml)}}{\text{No. of hills/hectare}} \times \text{No. of hills to be sprayed}$$
$$= \frac{500{,}000}{160{,}000} \times 4$$
$$= 12.5 \text{ ml}$$

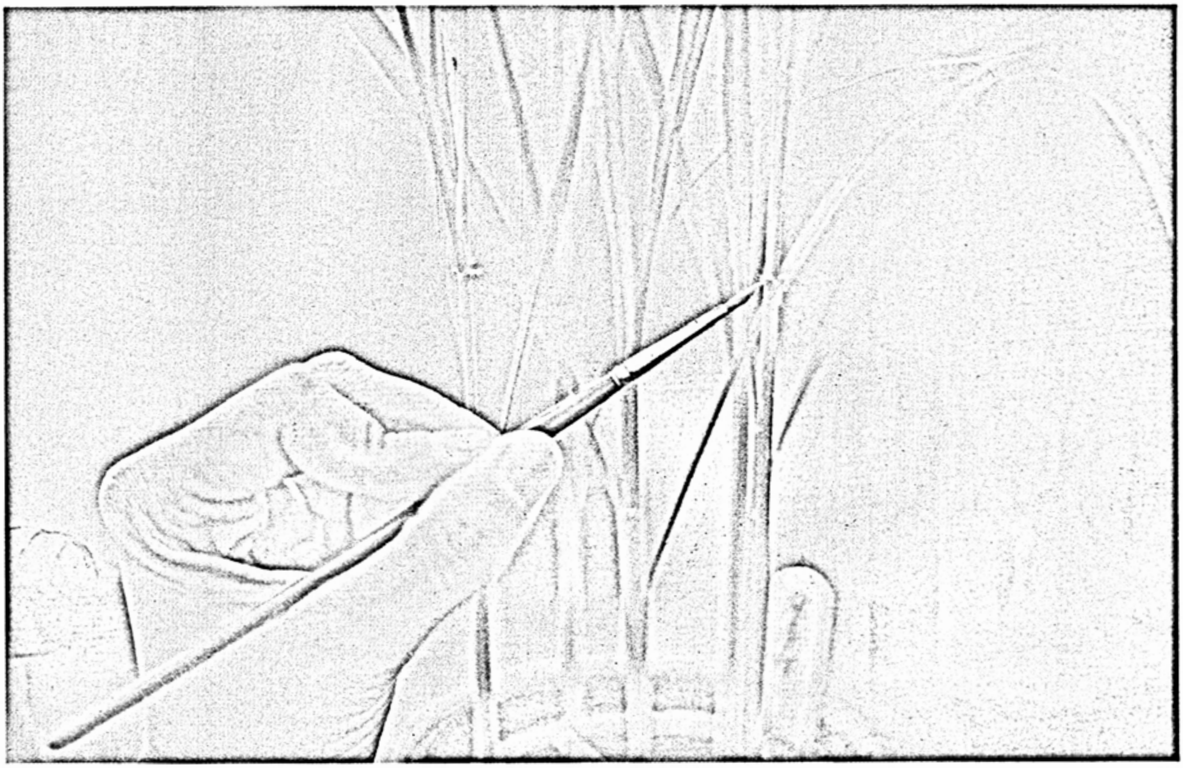
Insecticide treatment

Treatment differs according to insect being used in the tests:

Hoppers and stem borers. Four replications are normally used for each treatment. Spray the control plants with water. Place pots (4 clean plants/pot) of each treatment at an equal distance from the outer rim of an electrically operated revolving table (Fig. 5). Place the quantity of spray fluid in a bottle atomizer and spray the insecticide uniformly on the plants with a pressure of 0.703 kg/cm^2. A constant speed of the revolving table will allow a uniform distribution of the spray fluid on the test plants.

Place the sprayed plants in shade for the spray droplets to dry and then transfer them to an insectary with a controlled temperature (27 ± 1°C), 60-80% relative humidity, and 12 hours light/day.

5. Revolving table used for an even distribution of spray deposits in insectary foliar spray studies.



6. A leaf folder larva being placed on the auricle of a rice plant with a camel's hair brush 2 weeks before spraying the plant.

Leaf folders. The leaf folder is an example of a foliage-feeding insect. Thin plants to 5 tillers/pot. Infest 25- to 30-day-old potted TN1 plants or any other susceptible variety with newly hatched larvae by placing 2 larvae each on the auricle of the leaf (Fig. 6). The usual requirement is 10 larvae/pot (5 tillers at 2 larvae each). Each pot is a replication. When all leaves are folded (about 2 weeks after infestation) spray the potted plants and place them in a controlled environment as indicated for hoppers and stem borers.

Caseworm. Transplant 14-day-old seedlings in no. 4 clay pots at 3 hills/pot and 2 plants/hill. Place one pot in each plastic tray and add water to cover pot. Place 10 second-instar larvae from the larvae-rearing cage in each tray 2 weeks after transplanting. Cover with mylar film cage. Remove the mylar film cage 1 day after larvae are established on the plants. Place the plastic tray with the potted plant in water on the revolving table and spray. After spraying, cover pot with a mylar cage and place the tray in a controlled environment.

Rice bug. Place field-grown plants with panicles in the milky grain stage in pots. Put 4 pots on a revolving table and spray them with 12 ml of the spray solution. Remove the sprayed panicles from each plant and place them in a specially designed mylar cage (Fig. 7) located in a controlled environment as indicated for hoppers and stem borers. Place 20 rice bugs in each cage 1 day after spraying. Each cage is a replication.

7. Cage for evaluating foliar-sprayed insecticides for rice bug control. The mylar film cage has a plastic top that is secured when the bugs have been placed in the cage, and a plastic bottom that rests on a container with water. The upper portion of the culm consisting of the flag leaf and panicle (grains in milky stage) is cut and the base secured in the water container.

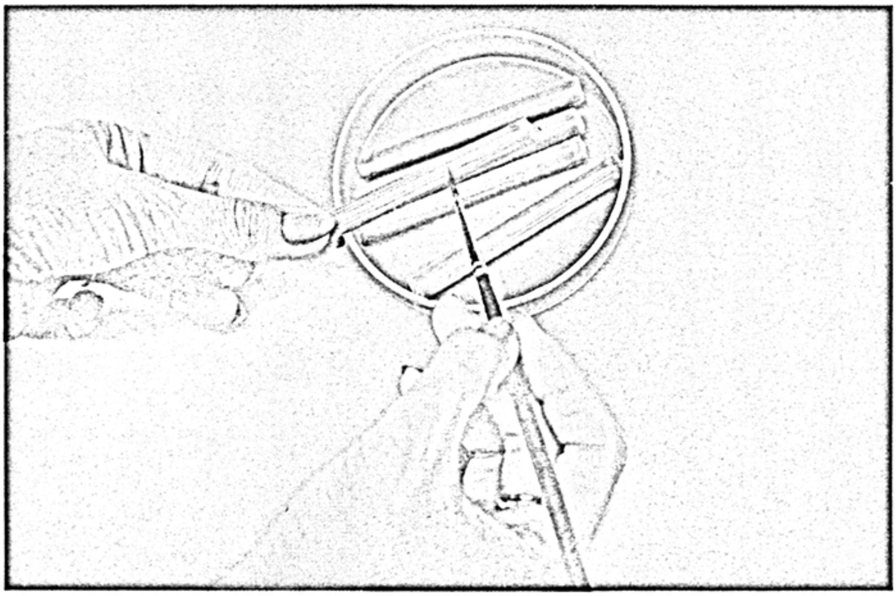
Mortality assessment

Hoppers. Assess the toxicity of foliar-sprayed insecticides beginning at 1 day after spraying and continue observations at 5-day intervals until mortality in best treatment drops below 40%. Collect 20 adult hoppers with a mouth aspirator and release them on test plants by inserting glass tube of aspirator through the slit in the mylar cage. Assess their mortality after 48 hours. Remove all insects from the cage after each mortality assessment. Adjust percentage of mortality using Abbott's formula and express data in graph or tabular form.

Stem borers. At 1 day after spraying cut the stems of sprayed plants at a length of about 75 mm. Seal both ends by dipping them in hot paraffin. That forces the larvae to enter through the portion of the stem containing the deposit of insecticide. Infest sealed stems by hand with 10 first-instar larvae each (Fig. 8). Place 1 infested stem in a glass vial 20 × 95 mm. Each vial serves as a replication. Place a modified screw cap cover with a fine wire mesh top over the end of the tube. Leave the vials of infested stems in a temperature-controlled environment. Two days after infestation dissect cut stems under a microscope and record the number of living and dead larvae and determine percentage of mortality. Repeat infestation of cut stems with larvae at 5-day intervals until mortality in best treatment drops below 40%. Convert mortality figures by Abbott's formula.

Leaf folder. Two days after spraying place the plants on a table, open the folded leaves, and record living and dead larvae to determine percentage of mortality. Convert these figures by Abbott's formula.

Caseworm. Forty-eight hours after spraying remove the cases and larvae without cases from the tray and place them in a petri dish containing water. Live larvae can be identified by their movement. Where no movement is observed, open the case to



8. Infesting first-instar striped stem borer larvae on insecticide-treated rice stem pieces. To prevent larvae from entering ends of the cut stems, the stems are dipped in hot paraffin.

verify that a larva is in the case. If some larvae are missing check the bottom of the tray. Count the living and dead larvae to determine percentage of mortality. To determine the residual activity of insecticides, fresh larvae can be added at various intervals.

Rice bug. For mass screening make 1 mortality recording 48 hours after placing the bugs on the treated panicles. For studies that require information on knock-down rate, make mortality readings at 1, 4, 8, 24, and 48 hours after infestation. The percentage of mortality is based on the number of living and dead bugs. Convert these figures by Abbott's formula.

BROADCAST APPLICATION OF INSECTICIDE GRANULES

Preparation of plants

For tests with insecticide granules, use porcelain pots 20 cm tall and 15.5 cm in diameter. First, sow TN1 seeds in clay pots at the rate of 2-3 seeds/pot. Transfer 25- to 30-day-old seedlings from the clay pots to the porcelain pots at the rate of 1 hill/pot. A week after planting, apply the insecticides in pots with 2 cm standing water.

Computation of insecticide required

Compute the quantity of insecticide required using the formula

$$\text{Granules required (kg)} = \frac{\text{Quantity of a.i. desired (kg/ha)} \times \text{area (m}^2\text{)}}{\text{\% a.i. in commercial product} \times 100}$$

Example:

Carbofuran 3G = 3% G

Recommended rate = 0.75 kg a.i., ha

Area to be treated (area of porcelain pot) = 0.02544 m^2

Solution:

$$\text{Carbofuran granules required (kg)} = \frac{0.75 \times 0.02544}{3 \times 100}$$

$$= 0.0000636 \text{ kg or } 63.6 \text{ mg}$$

After computing the quantity of the insecticide, weigh it on a precision balance and fold it in aluminum foil sheets.

Application of insecticides

Broadcast insecticide granules on the standing water in the porcelain pots. Give no treatment to control plants. After insecticide application, cover the plants with cylindrical mylar cages.

Mortality assessment

Mortality assessment differs for hoppers, stem borers, leaf folders, and caseworms.

Hoppers. Release 20 adult hoppers/ cage 1, 5, 10, and 15 days after granule application. Assess the mortality of the hoppers 48 hours after caging.

Stem borers. Remove the plants from the porcelain pots at 1, 5, 10, and 15 days after application of granules (as long as mortality remains above 40%), and cut and seal the stems with paraffin. Infest plants with larvae and record mortality as indicated in the foliar spray test on page 32.

Leaf folders. Apply granules to the standing water of potted plants about 2 weeks after plants are infested with first-instar larvae (after leaves are rolled). Take mortality readings 2 days after insecticide application.

Caseworm. Transplant 3 hills of 2 14–day-old seedling each into the soil in a plastic tray. After 2 weeks place 10 second-instar larvae in each tray and cover with a mylar film cage with open top. After a day broadcast granules into the water within the mylar film cage, rate of insecticide is based on the surface area of the water within the mylar film cage. Record mortality 2 days after application.

ROOT ZONE APPLICATION OF INSECTICIDES

Because of the rapid degradation and the loss of insecticides due to heavy rainfall, insecticides applied as foliar sprays or broadcast as granules have a short residual activity in the tropics. Studies have indicated that an application of a systemic insecticide, such as carbofuran, into the soil near the rice roots provides insect control equal or superior to that of several broadcast or foliar spray applications. Because of the significant savings in insecticide cost, root zone application is growing in popularity. Rice insecticide evaluation programs should include this test to determine the effectiveness of insecticides applied to the root zone.

Preparation of plants

Preparation, maintenance, and caging of plants are similar to those for broadcast application.

Computation of insecticide required

Calculate the insecticide required on a kilogram ai./hectare basis. The experimental area in this case is the area of the porcelain pot which is 0.02544 m^2.

- For insecticide granules use the same calibration as for broadcast application.
- For flowable formulations:

$$\text{Quantity required (kg)} = \frac{\text{Recommended rate (kg a.i. / ha)} \times \text{area (m}^2\text{)}}{\text{\% a.i. in commercial product} \times 100}$$

Example:

Carbofuran 2 F = 20.3% F
Recommended rate = 1.0 kg a.i./ha
Area to be treated = 0.02544 m^2

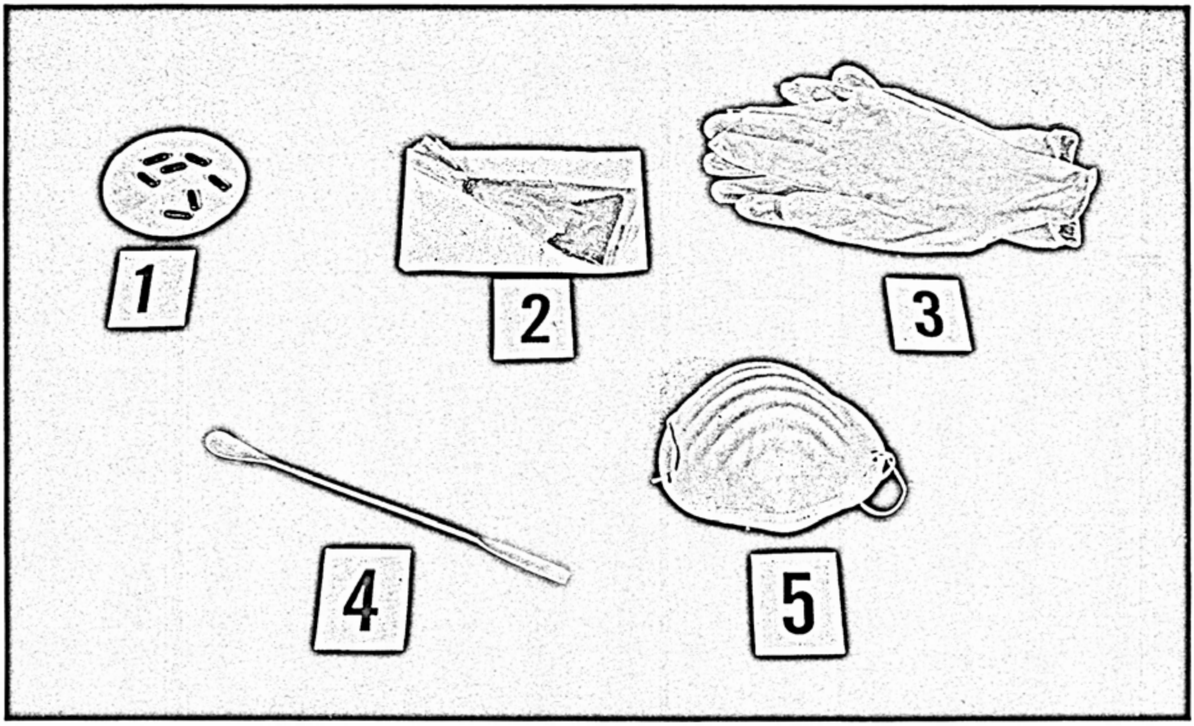
The quantity of flowable formulation required (kg):

$$= \frac{1.0 \times 0.02544}{20.3 \times 100}$$

$$= .0000126 \text{ kg or } 12.6 \text{ mg}$$

Preparation of insecticides

For insecticide granules weigh the required quantity of insecticide and place in a gelatin capsule (Fig. 9). For flowable formulation, measure the required quantity of flowable insecticide and place in a clean glass beaker.



9. Materials for preparing capsules containing insecticides for the evaluation of insecticidal activity when applied in the root zone. 1) empty gelatin capsules. 2) insecticide, 3) disposable polyethylene gloves, 4) spatula for handling insecticide, 5) disposable mask.

Application of insecticides

Place insecticide granules in no. 2 gelatin capsules and place capsules individually by hand near the root zone of the rice plants (2 cm below the soil surface and 2 cm away from the stem). Inject flowable, wettable powder or emulsifiable concentrate formulations as a prepared insecticide solution (1 ml/pot) under the root system of the plant. Use a glass syringe. Cover the plants with mylar cages for both granular and liquid treatments.

Mortality assessment

As in other insectary methods release 20 BPH, GLH, or WBPH in each cage at 1, 5, 10, and 15 days after treatment and assess the mortality rate after 48 hours. Adjust percentage of mortality using Abbott's formula. Other insects can also be used as mentioned under broadcast application of insecticide granules.

Antifeedants. Antifeedants are chemicals that neither kill nor drive away, but prevent insects from feeding normally. Antifeedants are of interest to entomologists because some are nontoxic to natural enemies. Oil extracted from the seed of the neem tree, *Azadirachta indica,* and various fungicides and insecticides have shown antifeedant activity against rice insects. The properties of some antifeedant chemicals have been tested against planthoppers, leafhoppers, and leaf folders. The test method for planthoppers follows.

Preparation of plants

Use 30- to 40-day-old TN1 plants in clay pots. Retain one tiller in each pot. Maintain 20 replications for each treatment.

Preparation of spray fluid

Neem oil is an antifeedant against brown planthopper and is used as an example here. Compute the quantity of neem oil required as follows:

$$C_1V_1 = C_2V_2$$

where

C_1 = recommended spray concentration (%),
V_1 = spray volume required,
C_2 = % a.i. in commercial formulation, and
V_2 = quantity of commercial formulation required.

For neem oil,

C_2 = 100% (assumed), C_1 = 12% and V_1 = 200 ml.

$$V_2 = \frac{C_1 \times V_1}{C_2} = \frac{12 \times 200}{100} = 24 \text{ ml}$$

Mix 24 ml neem oil with 200 ml water, and add a few drops of liquid detergent. Shake the mixture thoroughly to get a good emulsion.

Application of antifeedants

Arrange potted plants on a revolving table and spray with the spray solution as in the foliar spray test.

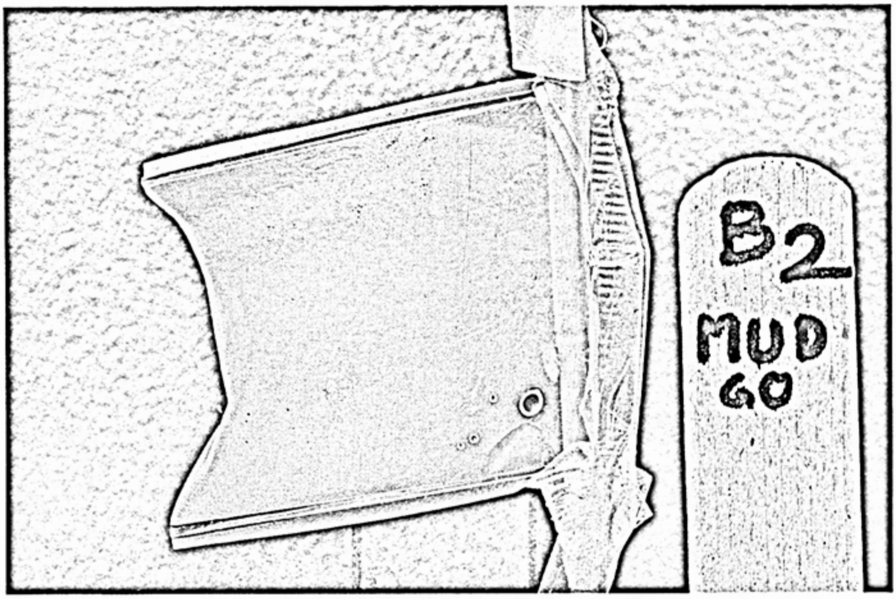
Feeding test

Use newly emerged adult hoppers for the feeding test. Collect the insects from rearing cages and starve them for 4 hours before the test.

Two techniques for determining feeding activity — the *parafilm sachet* and *ninhydrin* methods — are described. Both are used to determine the amount of honeydew excreted. These methods assess the feeding rate because feeding of the hopper is directly related to the quantity of honeydew excreted.

For the sachet method fix the parafilm sachet (5 cm X 2.5 cm) tightly around the basal part of the stem for planthoppers and leaf for leafhoppers to allow a minimum of air to enter (Fig. 10). Release 1 to 5 starved hoppers in each sachet and confine for 24 hours.

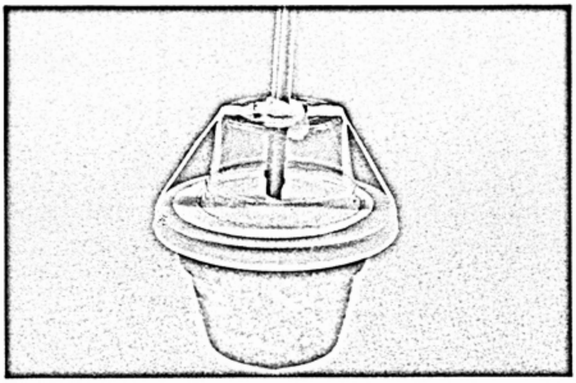
As the insects feed they excrete honeydew, which is seen as clear droplets on the inner walls of the sachet. Remove the sachet after 24 hours by cutting it parallel to the stem. Remove the insect and weigh the sachet with the honeydew on a balance with a sensitivity of 1 μg. Blot out the honeydew with a filter paper and weigh the sachet alone. Determine the weight of the honeydew by the difference in weight of

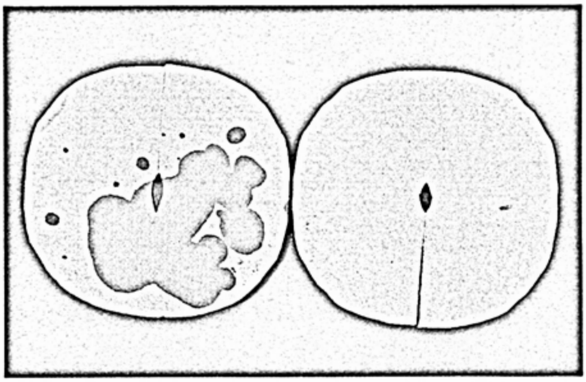


10. Parafilm sachet for measuring the amount of honeydew excreted by hoppers. After placing the hopper in the sachet, the sachet is closed around the culm. Note the brown planthopper feeding on the culm and the honeydew droplet on the sachet.

the sachet before and after removing the honeydew. If the hopper excretes honeydew on the plant the replication is rejected. Use only the sachets on which all of the honeydew is excreted for evaluation.

For the ninhydrin method place a feeding chamber consisting of an inverted plastic cup over a filter paper resting on a petri dish (Fig. 11). Place 52-day-old female BPH previously starved for about 4 hours into the chamber through a hole at the top of the cup. Place a cotton wad in the hole to prevent escape of the insects. Allow the insects to feed for 12 or 24 hours. Collect the filter papers and treat with 0.001% ninhydrin in acetone solution. Ovendry for 5 minutes at 100ºC. The honeydew spots appex purple or violet. Trace the spots on tracing paper within 12 hours. Place the tracing paper over mm square graph paper and count the number of squares. Feeding activity is based on the area (mm^2) of the honeydew spots.





11. Left—Apparatus used in the ninhydrin method of determining feeding activity. A plastic cup is placed over the filter paper sitting on an inverted plastic petri dish. The hoppers are placed through a hole in the top which is then plugged with cotton. The cage can also be used as a planthopper oviposition cage in studies on the ovicidal activity of insecticides. Right—Ninhydrin-treated filter paper showing the area of honeydew excretion (purple) and an unexposed filter paper.

OVICIDAL TESTS

Insecticides that kill eggs in addition to insects at other stages in the life cycle are desirable for rice insect pest management. Foliar sprays have little effect against stem borers once the eggs have hatched and the larvae begin feeding within the stem. Timing of brown planthopper control would be less critical if insecticides with effective ovicidal action, in addition to toxicity to nymphs and adults, could be identified. Thus, insecticide evaluation programs should include testing for ovicidal action.

A method to determine ovicidal activity of insecticides against the BPH follows.

Preparation of plants

Use 30- to 40-day-old potted TN1 plants for oviposition. Maintain a single tiller in each pot. Put a plastic cup around the plant, as shown in Figure 11. That confines a restricted stem area of the plant inside the cage, and facilitates easy location of the eggs. Release 2 gravid BPH in each cage and confine them for 24 hours.

Insecticide treatment

Prepare insecticide spray fluids as in foliar spray tests. After 24 hours remove the insect and the cage from the plants. Place the potted plants with BPH eggs on a revolving table and spray them with insecticide using an atomizer and a pressure pump. Spray the untreated check plants with distilled water. Replicate each treatment at least four times. Confine the sprayed plants individually inside mylar film cages.

Egg mortality assessment

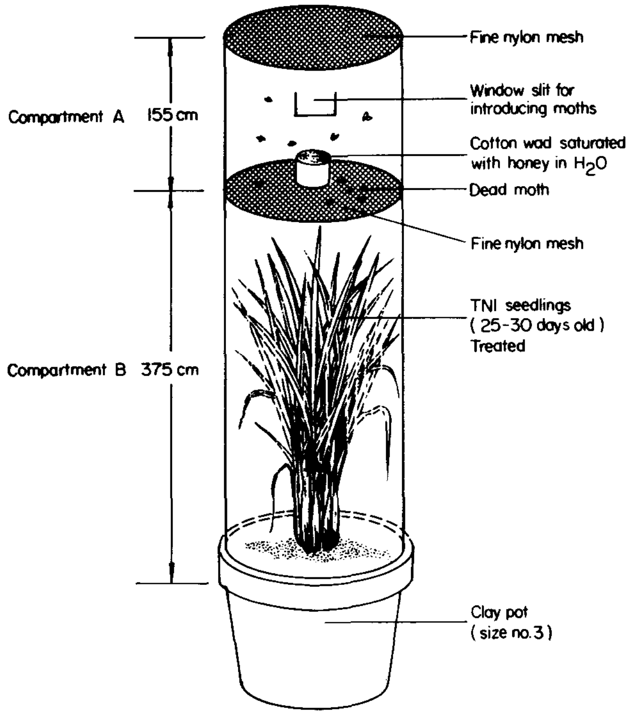
The first set of nymphs will start emerging 6 days after caging. For 14 days from first emergence, count the hatched nymphs daily and remove them from the plants. When hatching terminates, determine the number of unhatched eggs by dissecting the plants under a stereoscopic microscope. Count the eggs dying after embryonic development, those with embryonic death, and the dead eggs with no development to assess the ovicidal action of the test chemicals in relation to the total number of eggs laid by the following formula:

$$\% \text{ hatch} = \frac{\text{No. of unhatched eggs} \times 100}{\text{Total eggs laid (no. of unhatched eggs + no. of nymphs hatched)}}$$

Assess the ovicidal effect of granular insecticides by the same technique.

FUMIGATION ACTIVITY OF FOLIAR-SPRAYED AND PADDY-WATER-APPLIED INSECTICIDES

Some insecticides used in controlling rice insect pests kill by fumigation, in addition to contact and feeding toxicity. Insecticides with fumigant action are preferable because they provide effective control when rice plants are in the late vegetative or early flowering phase. At that stage, the canopy is so thick that it is difficult to cover the lower plant parts with a foliar spray. The thick canopy also increases the concentration of insecticide fumes.



12. Mylar film cage used to evaluate the fumigation activity of insecticides against leaf folder and stem borer moths. By replacing the honey container at the top with rice seedlings, the same cage can be used for fumigation studies on hoppers.

Fumigation effect of foliar spray

Spray insecticides on 20- to 25-day-old potted TN1 plants, at the desired concentration, as in the foliar spray test. Cover the potted plants with a special cylindrical mylar cage, which has an upper and lower compartment (Fig. 12).

Twenty-four hours after spraying, place 1 plastic cup containing about 20 5-day-old seedlings in the upper compartment of each cage to serve as a food source for hoppers. Use a 25% honey solution soaked in cotton wool as a food source for stem borer or leaf folder moths. Release 10 BPH, GLH, WBPH, or stem borer or leaf folder moths in the upper compartment. Record mortality of the test insects 24 and 48 hours after release.

Fumigation effect of insecticide granules

The test with granules is similar to that for foliar sprays. Apply the required quantity of insecticide granules in standing water in porcelain pots. Release the test insects 24 hours after insecticide application and record the mortality 24 and 48 hours after release.

RESURGENCE TEST

Resurgence of the BPH after the application of certain insecticides is often a serious problem for the rice farmer. Resurgence occurs when the insect population in the treated areas significantly exceeds that in an untreated control. Various insecticides are known to cause BPH resurgence (Chelliah and Heinrichs 1980a,b). Although several factors may be involved, some insecticides have been shown to stimulate insect reproduction. It is extremely important that national programs establish testing programs to identify insecticides capable of causing resurgence. Such insecticides should not be included in national insect control recommendations.

Resurgence of BPH following application of insecticide sprays and granules can be assessed from the comparison of reproductive rate of BPH on the treated and untreated plants by the following formula:

$$\text{Resurgence ratio} = \frac{\text{No. of insects on treated plants}}{\text{No. of insects on untreated plants}}$$

An analysis of variance comparing all treatments to determine if the number of insects in a particular treatment is significantly greater than that in the untreated check is also conducted. It is desirable to conduct resurgence tests where the temperature (27° ± 1°C), relative humidity (60-80%), and light (12 hours/day) can be regulated.

Foliar spray

Plant 10-day-old TN1 seedlings in clay pots 10 cm in diameter at the rate of 2 seedlings/pot and keep them insect-free. Do the first spraying 20 days after planting. Prepare the spray fluid in water from commercial formulations of wettable powders or emulsifiable concentrates at 0.04% concentration (except synthetic pyrethroids wherein 0.002% is used). The quantity of spray fluid per pot and the spraying procedure are similar to those described in the foliar spray test. Repeat spraying 30 and 40 days after planting. Cover the plants in each pot with mylar film cages. Each pot is a replication. Use at least 4 replications.

Fifteen days after the third spraying (55th day), release 2 gravid, 7-day-old BPH per pot. Maintain a sufficient population of test insects of the same age on TN1 plants to replace dead insects, daily if necessary. Remove the insects after 7 days. Assess the insect's reproductive rate during the period of their confinement on test plants by counting the nymphs that emerged from the plants. Count nymphs daily and remove them with an aspirator. Continue counting until hatching terminates. Counting of the nymphs will give an indirect measure of fecundity. Dissecting the part of the leaf sheath exposed to oviposition after hatching terminates and counting the unhatched eggs, although more laborious, gives a more accurate measure of fecundity. In this case,

$$\text{Fecundity} = \text{nymphs hatched} + \text{unhatched eggs}$$

Granules

With the development of granular insecticides such as BHC, diazinon, and carbofuran, granular insecticides for rice insect control have gained popularity. Unlike foliar sprays, granular insecticides require no equipment or water to apply and can be applied on windy days because they are less subject to drift. Because of these factors many rice insecticides are currently marketed in a granular formulation and new granular compounds are continually being produced. The various granular insecticides can rapidly be evaluated in the insectary before field testing.

The method for determining resurgence from use of insecticide granules is similar to that for foliar sprays. Use porcelain pots 20 cm tall, 15.5 cm in diameter. Granule application is based on the rate normally used in the field (0.5 to 1.0 kg a.i./ha). Calculate the quantity for each pot on the basis of surface area of the pot as indicated in the section *Broadcast application of insecticide granules.* Keep minimum water in the pot, and incorporate the granules into the soil around the plants 20 and 35 DT. Thirty days after the second application, release gravid BPH females on the plants and assess their reproductive rate as described in the foliar spray test for resurgence.

You can use the same techniques to evaluate insecticides for inducement of whitebacked planthopper resurgence.

chapter 5

FIELD EVALUATION OF INSECTICIDES

CONDUCTING FIELD EXPERIMENTS

Insecticides found effective in insectary screening should be selected for further testing in the field. In selecting insecticides for field testing consider those that cause 80% or higher insect mortality in the insectary screening studies. Effectiveness in the field is usually considerably lower than in indoor screening because of various biological and physical factors. Insecticides that perform effectively in the field screening at the experiment station should be further evaluated in farmers' fields before they are recommended.

Because of the many variables involved in the field evaluation of insecticides proper techniques should be followed. The process of developing a research plan was discussed in Chapter 1.

Selection of a site

Choose a site near your headquarters that will provide the necessary conditions to meet your objectives. For experiments in farmers' fields select farmers who manage their fields properly, are willing to cooperate, and will not superimpose their own treatments in the experiment. It is generally best to have the farmer sign a contract that clearly delineates the responsibilities of both parties and indicates how the farmer will be paid for the use of his land. Consider the following characteristics in selecting your site:

1. Field size sufficient;
2. Representative of the surrounding area;
3. Easily accessible so that it can be visited often during the term of the experiment;
4. Weather conditions favorable;
5. Level and uniform in fertility;
6. Irrigation water and drainage adequate;
7. Security;
8. Previous fertilizer and other agronomic practices compatible with the aims of the experiment; and
9. Population of test insects sufficiently high so as to provide reliable results.

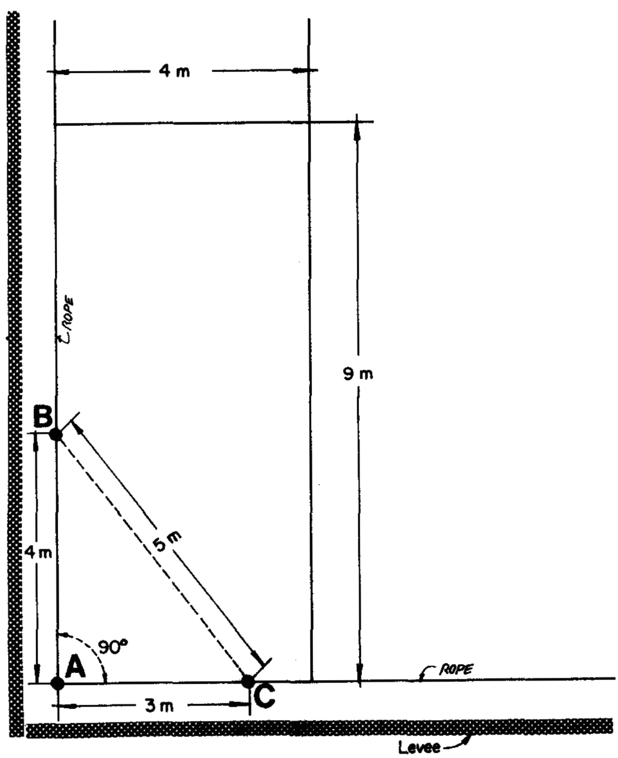
Field plot layout

Plot size depends on the behavior of the test insect, treatment to be applied, and frequency of sampling. Before laying out the plots prepare the land properly. The *Training manual for rice production* by Xuan and Ross (1976) describes the techniques for land preparation before transplanting. To ensure that the plots are of the same size and shape and with square corners, the following method is suggested.

1. First, establish the baseline (see Fig. 1). The baseline is usually parallel to the border levees. To establish the first baseline (A-B), place stake at reference point A. Place another stake at point B 4 m from point A.
2. Establish the A-C baseline by placing a stake at point C 3 m from point A.
3. Establish a right angle between the two baselines by applying the Pythagorean equation. The distance between B and C should equal the square root of the sum of the squares of both baselines. For our example the distance between B and C

$$= \sqrt{3^2 + 4^2}$$
$$= 5$$

4. Thus, move the stakes at points B and C until the distance between them is 5 m. Now we have a square corner at point A.
5. Establish the boundaries of the experiment by stretching a rope along the length of the field parallel to points A-B and mark with stakes. Repeat the process parallel to points A-C.
6. Mark the individual plots and alleyways with stakes. In our example, we have laid out 4 × 9 m plots with 1-m alleys between plots. Establish levees around each plot for both foliar spray and granular applications.



1. Procedure to obtain square corners in laying out field plots. The figure illustrates a 4 × 9 m plot.

Planting

Transplant seedlings of an insect-susceptible variety at two seedlings/ hill. Choose a recommended spacing for the variety which is usually 20 × 20 or 25 × 25 cm. Replace missing hills up to 10 DT.

Plot identification

Prepare labels of sturdy paper. Write the replication number and treatment on them with waterproof ink. Dip in molten wax and staple to a bamboo or wood stake. Use only the code number, instead of the complete description of each plot, to identify your plots. That will prevent bias when observations are made. When using the RCB design, use the 3-digit number system for convenience — the first number to refer to the replication number and the next two to the plot within the replication (see example). In our example 304 refers to plot number 4 in replication 3.

Another technique is to number all plots consecutively.

3-digit-no. method					Replications	Consecutive-no. method				
406	407	408	409	410	IV	40	39	38	37	36
401	402	403	404	405		31	32	33	34	35
306	307	308	309	310	III	30	29	28	27	26
301	302	303	304	305		21	22	23	24	25
206	207	208	209	210	II	20	19	18	17	16
201	202	203	204	205		11	12	13	14	15
106	107	108	109	110	I	10	9	8	7	6
101	102	103	104	105		1	2	3	4	5

Application of insecticides

Insecticide application is an essential part of the experiment. Before going to the field to apply insecticides, consider the following points.

1. Make a checklist of necessary items. This should include a copy of the field book that contains the details of the experiment. Refer to this list before going to the field for the application.
2. Accurately weigh out all insecticides and place in labeled packets. Make sure you use fresh insecticides.
3. Verify the availability of equipment and make sure the equipment functions properly. When applying insecticides:
   - use clean and calibrated equipment;
   - wash equipment between applications of different chemicals;
   - avoid drift by spraying early in the morning;
   - make two passes over each plot to increase the accuracy of insecticide distribution.

Method of increasing insect populations

Sufficient populations of the target insect are necessary to obtain reliable measurements of insecticide effectiveness. Many field insecticide studies fail because of insufficient insect populations. Several methods can be used to increase the level of insect infestation and damage.

1. Artificial infestation. Insects are reared in the insectary, released in the field plots, and allowed to build up populations. Or cultured insects are placed on caged plants in the field after insecticide application and mortality assessed by counting the number of dead insects in the cages (see Chapter 7).
2. Planting time. Many insect species that attack rice have population peaks and field tests should coincide with those peaks. Analysis of available light-trap data would be useful in determining when the population is expected to peak.
3. Site. Certain sites are known as *hotspots* for certain species. Select sites where facilities are satisfactory and transportation is not a limiting factor.
4. Fertility. High nitrogen levels are beneficial to some rice insects especially to hoppers and leaf folders.
5. Plant spacing. Close spacing is generally favorable to brown planthopper and wide spacing increases whorl maggot damage.
6. Lights. Most rice insects, especially the stem borers, hoppers, and gall midge are attracted to lights. Make sure the lights are evenly distributed throughout the experimental area to ensure an even distribution of the insects. Fluorescent, incandescent, or kerosene lamps can be used.
7. Insecticides. Certain insecticides, when applied at a low rate to the canopy, increase brown planthopper populations. We have used methyl parathion and decamethrin to increase brown planthopper populations to a level at which reliable results are possible. To use this technique, plant a planthopper-susceptible variety and spray every 2 weeks beginning at 35 DT. Make weekly counts by tapping the plants and conduct the insecticide screening trial when the hopper population is at least 30 insects/ hill.

APPLICATION METHODS

There are several methods of insecticide application. Application methods are based on the type of insect being controlled and the formulations available. Entomologists are developing new application methods that will increase the effectiveness of insecticides. Foliar sprays and the paddy water application of granules are the most common methods used by rice farmers in the tropics but several methods of root zone application are in various stages of development and use by farmers.

Root zone application

Gelatin capsules

1. Compute the quantity of the commercial granular insecticide required for the experimental field (see *Soil incorporation of granules).*
2. Compute the quantity of insecticide to be placed in a gelatin capsule. If the planting space is 25 × 25 cm, you will need 160,000 capsules at the rate of 1 capsule/hill.

$$\text{kg commercial formulation/capsule} = \frac{\text{kg a.i./ha rate} \times 100}{160{,}000 \times \text{\% a.i. in commercial formulation}}$$

3. Fill the capsules with the calculated quantity of the insecticide granules. Place the capsules about 2 cm to the side of the plant and below the surface of the soil, near the roots, at the rate of 1 capsule/hill.
4. Place capsules in dry container when not in use. They stick together and are destroyed under high humidity.

Root soak. Pests that infest rice seedlings immediately after transplanting can be controlled by soaking the seedling roots in an insecticide suspension for at least 12 hours.

- You need 150 liters of insecticide solution to soak 160,000 seedlings, the number needed to plant 1 ha at 25 × 25 cm spacing.
- A dosage rate of 1,000 ppm is recommended.

Calculate the quantity of commercial formulation required as follows:

Example:

Parts insecticide = 1,000 ppm
Vol. of solution desired = 150 liters
% a.i. in commercial formulation = 12

Solution:

$$\text{Quantity of commercial formulation required (liters)} = \frac{\text{Insecticide (ppm)} \times \text{recommended volume of spray solution (liters)}}{\text{\% a.i. in commercial formulation} \times 10{,}000}$$

$$= \frac{1{,}000 \times 150}{12 \times 10{,}000}$$

$$= 1.25 \text{ liters}$$

Mix the calculated quantity of insecticide with water and stir thoroughly with a bamboo stick. Dip the seedling roots in the insecticide suspension for 12 hours. Transplant the seedlings.

Root-coat treatment. Wash the seedling roots well and dip for a few minutes in a warm mixture of 89 parts water, 6 parts gelatin, and 5 parts of a flowable insecticide formulation. Gelatin is added so that the insecticide will stick to the roots. Transplant the seedlings in the field and test the efficacy of the root coat. Caution transplanter about the danger of touching treated roots over a long period. Use of polyethylene gloves is advisable.

Liquid spot injector. A 10-row IRRI-designed liquid injector (Fig. 2) places insecticide or fertilizer 5-10 cm below the soil surface by spot injection. The injector can be used as a row marker for transplanting while injecting chemicals, and it can be used up to 20 DT. A peristaltic pump metering assembly attached to a wooden frame pumps the chemical from a backpack container through 10 discharge nozzles housed in steel tubes which penetrate the soil. The pump meters the correct amount of chemical. The back-and-forth movement of the hand lever activates the pump through a rachet. After the injections, the hills are transplanted at the marks left by

2. Applying a systemic insecticide into the root-zone area with a liquid spot injector. The machine also marks rows to serve as a guide in transplanting.

the injector tube and the roots are thus in contact with the chemical. This type of application is advantageous over soil incorporation because the insecticide is concentrated near the roots allowing the plant to take up the chemical. To calibrate the 10-row liquid spot injector:

- Fill the backpack tank with water and connect it to the injector pump.
- Fill delivery nozzles with water by continuously rotating the peristaltic pump. Stop pumping when all the delivery tubes are filled with water.
- Detach backpack container from the pump assembly. Drain the remaining water from the container and pour in a known volume of water. Connect the container to the injector unit.
- Mark the field crosswise with the injector without operating the pump. Pull the injector along the length of the field and inject the solution at the point where the marked crosswise line is reached. Continue until 100 such injections are completed.
- Measure the amount of water left in the container and calculate the volume.

$$\text{Quantity (liters) of solution required/hectare} = \frac{(\text{volume before injection} - \text{volume after injection}) \times \text{plant density/hectare}}{\text{no. of nozzles} \times \text{frequency of injections}}$$

Example:

Volume before injection = 5 liters
Volume after injection = 4.5 liters
No. of nozzles = 10
No. of injections = 100
Plant density/hectare at a 25 × 25 cm spacing = 160,000

$$\text{liters/ ha} = \frac{(5.0-4.5) \times 160{,}000}{10 \times 100}$$

$$= \frac{0.5 \times 160{,}000}{1{,}000}$$

$$= 0.5 \times 160$$
$$= 80 \text{ liters}$$

Note: Injector discharge/ hectare varies with plant density/ hectare. For a 20 × 20 cm spacing, number of hills is 250,000/ha.

- Now calculate the quantity of commercial formulation required per backpack tankload when the amount of insecticide recommended = 0.5 kg a.i./ha; liters/tank load = 10; % a.i. in commercial formulation = 0.12; volume (liters) of insecticide solution/ hectare = 80.

$$\text{Amount of commercial insecticide formulation required (liters or kilograms)/tank load} = \frac{\text{kg a.i. recommended/ha} \times \text{liters/tank load} \times 100}{\text{\% a.i. in commercial formulation} \times \text{volume (liters/ha)}}$$

$$= \frac{0.5 \times 10 \times 100}{12 \times 80}$$

$$= 0.521$$

Thus, we add 0.521 liters of the commercial insecticide formulation to 9.479 liters of water for each tank load which covers 1,250 m^2.

Soil incorporation of granules. Calculate the quantity of commercial insecticide required to protect a given area.

Formula:

Recommended rate
Area to be treated (ha)
% a.i. in the commercial formulation

$$\text{Quantity of commercial formulation required (kilograms)} = \frac{\text{Recommended rate (kg ai./ha)} \times \text{area to be treated (ha)} \times 100}{\text{\% a.i. in commercial formulation}}$$

Example:

Recommended rate = 1.0 kg a.i./ha
Area to be treated = 3,000 m^2
% a.i. in commercial formulation = 10

$$\text{Quantity required} = \frac{1.0 \times \frac{3{,}000}{10{,}000} \times 100}{10}$$

$$= 3.0 \text{ kg}$$

Method:

1) Calculate the area to be treated. Using the formula given above compute the quantity of insecticide required. Weigh and place the insecticide in a suitable container.
2) Keep levees closed. Maintain 2-4 cm water in the field. Check for any seepage and repair levees if necessary.
3) Broadcast granules by hand as evenly as possible. Skill in equal distribution of granules can be developed with sufficient experience.
4) Broadcast across wind, never against the wind.
5) Incorporate the granules preferably with a rototiller or a minicultivator. Run the cultivator crosswise and level the field. If a harrow is used, run harrow crosswise and lengthwise.
6) Wash hands thoroughly with soap after application.
7) Transplant the day after incorporating the granules.
8) Impound water for at least 3 days after application.

Paddy water application

Follow steps 1-4 of methods, *Soil incorporation of granules.*

Foliar spray

Foliar spray is a common method of insecticide application in rice. Applying the correct rate when spraying is, however, complicated and incorrect rates are often applied. In this section we discuss the mathematics involved in determining the correct rates of foliar spray applied with a knapsack and the ULV rotary sprayer.

We also discuss the methodology for assessing the effect of foliar sprays on hopper egg parasites and BPH resurgence.

Knapsack. To calculate the quantity of insecticide required when using a knapsack sprayer, you need to know the following:

a. *When the recommendations are based on active ingredient per hectare:*
   1) recommended rate (kg a.i./ ha)
   2) % a.i. in the commercial formulation, and
   3) area to be treated (ha)

Formula:

$$\text{Amount of commercial formulation required (kg)} = \frac{\text{Recommended rate} \times \text{area to be treated} \times 100}{\text{\% a.i. in the commercial formulation}}$$

Example:

Recommended rate = 0.75 kg a.i./ha
% a.i. in the commercial formulation = 60
Area to be treated = 0.5 ha

Solution:

$$\text{Amount of commercial formulation required} = \frac{0.75 \times 0.5 \times 100}{60}$$
$$= 0.625 \text{ kg}$$

b. *When the recommendations are based on % concentration of the spray fluid:*
   1) recommended concentration,
   2) volume of spray fluid/ha,
   3) % a.i. in commercial formulation, and
   4) area to be treated (ha)

Formula:

$$\text{Amount of commercial formulation required (kg)} = \frac{\text{\% recommended concentration} \times \text{amount of spray fluid required} \times \text{area to be treated}}{\text{5 a.i. in commercial formulation}}$$

Example:

Recommended concentration = 0.04%

Volume of spray fluid hectare = 250 liters

% a.i. in commercial formulation = 45

Area to be treated = 0.5 ha

Solution:

$$\text{Amount of commercial formulation required} = \frac{0.04 \times 250 \times 0.5}{45}$$

$$= 0.111 \text{ liters}$$

Calculate the number of sprayer loads of the spray solution required to treat a given area as follows:

$$\text{No. of sprayer loads required} = \frac{\text{Total spray volume (liters/ha)} \times \text{area to be treated (ha)}}{\text{Capacity of the sprayer (liters)}}$$

Example:

Amount of spray fluid required ha = 300 liters

Area to be treated = 0.5 ha

Capacity of the sprayer = 10 liters

Solution:

$$\text{No. of sprayer loads required} = \frac{300 \times 0.5}{10}$$

$$= 15 \text{ sprayer loads}$$

Calculate the quantity of commercial formulation to be mixed in each sprayer load as follows:

$$\text{Amount of commercial formulation required per sprayer load} = \frac{\text{Capacity of sprayer} \times \text{spray concentration}}{\text{\% a.i. in the commercial formulation}}$$

Example:

Capacity of sprayer = 10 liters

Spray concentration = 0.04%

% a.i. in the commercial formulation = 45

Solution:

$$\text{Amount of commercial formulation required per sprayer load} = \frac{10 \times 0.04}{45}$$

$$= 0.009 \text{ liters}$$

Ultralow-volume (ULV) spraying. Hand-held ULV spraying is usually associated with the battery-operated, rotary sprayer first introduced by E. J. Bals of Micron Sprayers Ltd, Three Mills, Bromyard, Hereford, England. The ULV concept has also been applied to mist blowers.

Plot size. Plots should be square to allow spraying in any direction depending on the wind. Because ULV spraying uses the wind to carry the finely atomized spray across the swath, large plots are necessary to minimize interplot contamination. This is particularly true before the rice canopy has closed over (30 DT) when the spray cloud is capable of drifting well over 10 m. At later growth stages, the largeleaf area presented by the crop filters out the majority of the spray over the first 5 m.

The plots should be big enough to enable at least 3 spray passes of about 7 m each. For applications before 30 DT you should have as large a plot size as possible for example, 441 m^2 per plot (21 × 21 m) where the swath width is 7 m. Applications later in the season can be made on plots as small as 225 m^2 (15 × 15 m) when a swath width of 3 to 5 m can be used. The spray path should be parallel to the prevailing wind direction.

Sprayer calibration and conditions for spraying. Most rotary sprayers come with a mechanism for changing the flow rate to the disc, because formulations vary in viscosity and hence flow rate. The rate should always be maintained between 30 and 100 ml/min; a higher rate will flood the disc and destroy the narrow droplet-size spectrum the machines are designed to produce. The flow rate can be measured easily by removing the disc and inverting the sprayer over a 100-ml measuring cylinder and determining how many milliliters per second flow into the cylinder.

When making up your own water-based spray solutions, you can only approximate the flow rate when you are computing the concentration required for a given dosage rate (the concentration will affect the flow rate). The flow rate is approximated based on the flow rate of water. The walking speed can be subsequently readjusted to compensate for any differences as follows:

Flow rate (estimated) = 1.0 ml/second
Swath width = 3 m
Walking speed = 0.5 m/ second
Dosage rate = 500 g a.i. / ha

a) Volume rate:

$$\text{Volume rate (ml/ha)} = \frac{10{,}000}{\text{Walking speed (m/second)} \times \text{Swath width (m)}} \times \text{Flow rate (ml/second)}$$

Example:

$$\text{Volume rate} = \frac{10{,}000}{0.5 \times 3} \times 1.0$$

$$= 6{,}666.7 \text{ ml/ha or } 6.61 \text{ liters/ha.}$$

b) Concentration of spray solution:

$$\begin{array}{c}\text{Amount of formulated}\\ \text{product (ml) to make up}\\ \text{1 liter spray solution}\end{array} = \frac{\text{Final vol. of spray mixture (liters)}}{\text{Val. rate (liters/ha)}} \times \frac{\text{Dosage rate (g a.i./ha)}}{\text{Concentration in formulation (g a.i./ 100 ml)}} \times 100$$

Example:

Concentration of sprayable formulation = 30 g a.i./ 100 ml

$$\text{To make up 1 liter of spray solution} = \frac{1}{6.67} \times \frac{500}{30} \times 100$$

= 250 ml of formulated product is required

Add 250 ml of formulated product to the spray bottle and make up to 1 liter with water.

c) Flow rate:

Now measure the flow rate of the spray mixture. Flow rate of most rotary sprayers can be altered by changing the restrictor size. If flow rate still lies outside the desired range after changing the restrictor, change walking speed. In most cases a combination of flow rate and walking speed is used to obtain the selected dosage and volume rate. Flow rate should lie within ± 0.2 ml/ second of the estimated value. To measure flow rate, remove the disc and invert the spray head over a 100-ml graduated cylinder and determine the volume (ml) that flows into the cylinder per second. If the estimated volume does not lie within the ± 0.2 ml/second range, change the restrictor or walking speed. Determine the correct walking speed as follows:

Flow rate (measured) = 0.7 ml second
Swath width = 3 m
Walking speed = X m/second
Dosage rate = 500 g a.i./ha
Volume rate = 6.667 liters/ha

From the volume rate equation above:

$$\frac{10{,}000}{X \times 3} \times 0.7 = 6{,}667 \text{ (ml)}$$

$$X = \frac{0.7}{6{,}667} \times \frac{10{,}000}{3}$$

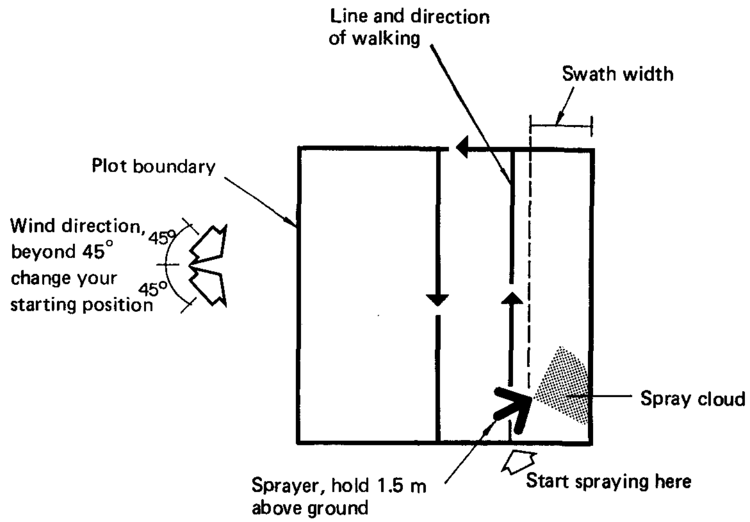
Walking speed = 0.35 m/second

For best results, time each spray pass to ensure a constant walking speed. If oil formulations are used, the flow rate of the sprayer still needs to be measured but the percentage of concentration of the spray solution is predetermined, and so all the adjustments must come from changing the restrictor of the sprayer, or altering the walking speed, to achieve the chosen dosage and volume rate.

When spraying a plot, always begin at the downwind edge and walk in a line at right angles to the wind direction, with the sprayer pointing downward (Fig. 3). The swath width before 30 DT should be between 5 and 10 m; after 30 DT, swath width should be between 3 and 5 m.

Spray in overcast conditions with light winds sufficient to flutter the leaves. Avoid calm and very hot periods of the day when convective currents interfere with spray deposition.

Maintenance of the sprayers. A disadvantage of the ULV rotary sprayers is that



3. Spray path to follow when applying an insecticide with a rotary ultralow-volume sprayer.

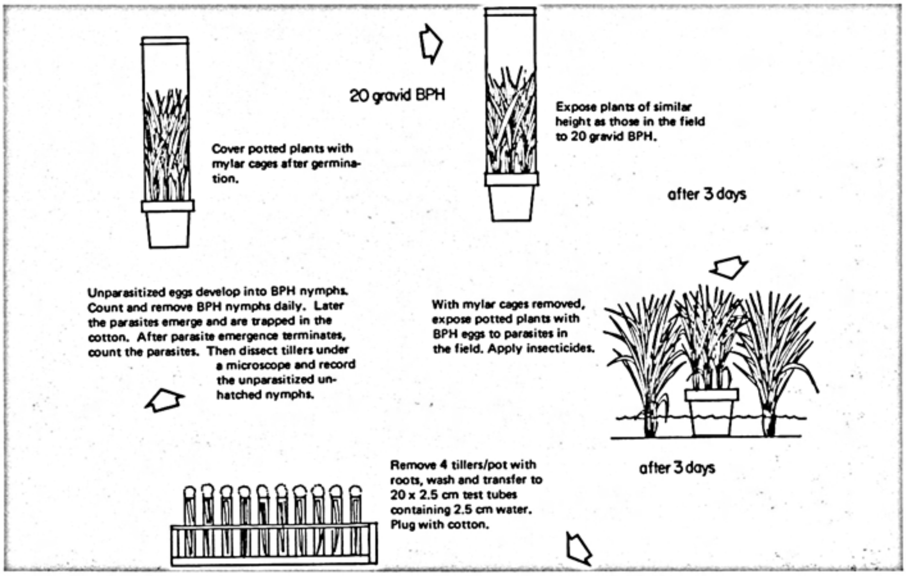
they are less durable than the knapsack type. The rotor, a delicate part of the ULV sprayer, can easily fracture when you drop the machine. It also has a serrated edge, to aid in droplet formation, which is easily destroyed if the machine touches the ground while the rotor is still revolving.

Remove the batteries after a spray operation. Replace the complete set after 3 to 5 hours of spray time. Wash the feed stem and disc thoroughly by running water through them. If oil-formulated insecticides have been sprayed, use a strong solution of detergent for cleaning. Do not totally immerse the spray head in water; it will destroy the electric motor.

Evaluating effect of foliar sprays on egg parasites. The effect of foliar-sprayed insecticides on the egg parasites of hoppers can be evaluated by a special technique (Fig. 4). Plant susceptible rice seedlings, preferably TN1, in clay pots 15 cm in diameter at the rate of 4 seedlings/ pot. When the plants are 30-40 days old, release 20 gravid BPH in each pot and confine them in a cylindrical mylar cage for 24 hours. Remove the hoppers and place the potted plants with the hopper eggs at random in experimental plots in the field, at the rate of 3 to 5 pots/ plot, depending on the plot size. Spray insecticides on field plots containing the potted plants. Expose the plants with BPH eggs for 2 to 3 days for parasitization and put them back in the greenhouse.

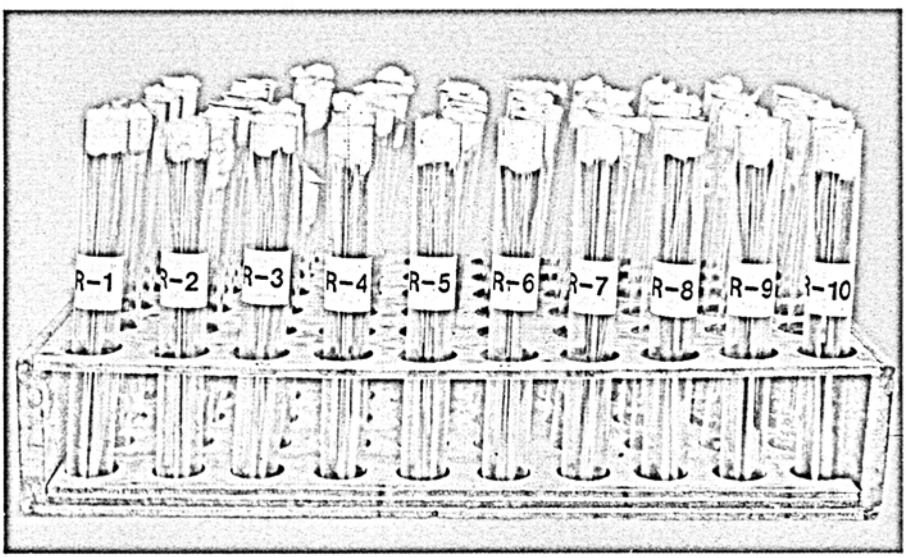
Remove 3 tillers with roots from each pot. Wash and trim the roots, and transfer the plant to glass tubes (20 cm long and 2.5 cm wide) with 2.5 cm water to soak the roots (Fig. 5). Plug the tube mouth with cotton.

Count the number of BPH nymphs that hatch from each set of tillers daily and then remove the nymphs. The BPH generally hatch 10 days after oviposition. The

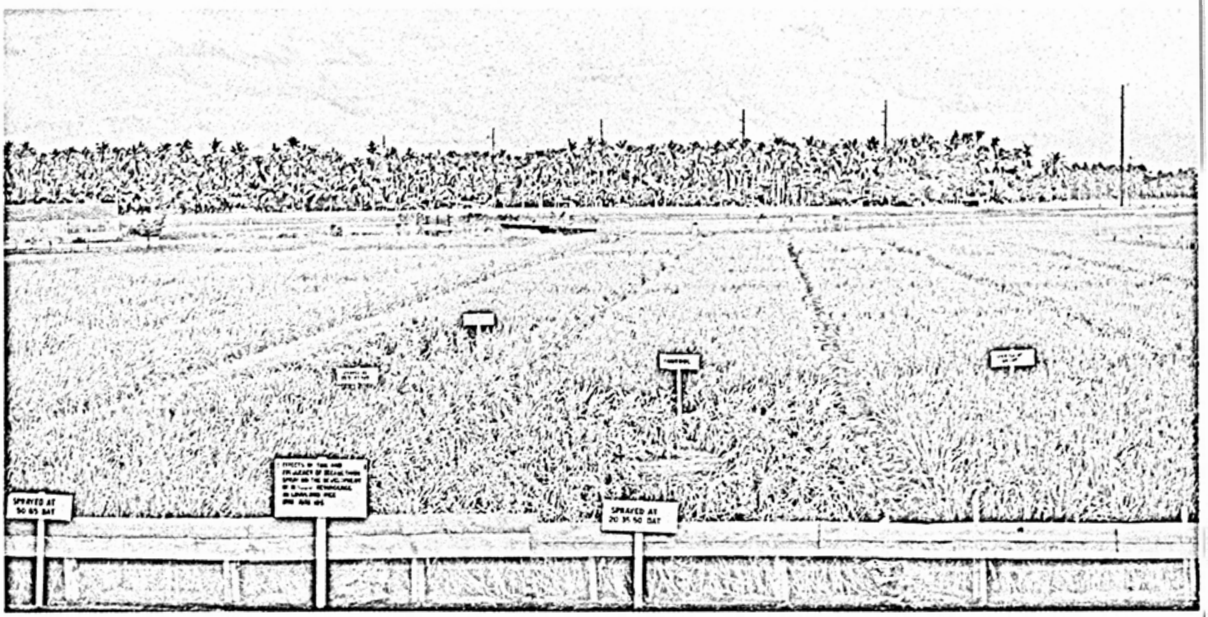


4. Procedure for the field evaluation of insecticides for their effects on the parasites of brown planthopper eggs. The same general procedure can be used to evaluate effects of insecticides on egg parasites of other rice insects.

BPH egg parasites emerge later. They try to move through the cotton wool and get trapped and die. Continue your observations until no more parasites emerge. Count the number of each parasite species in each tube with a stereoscopic microscope. Dissect the tillers under the stereoscopic microscope using needles mounted in wood. This way you get the number of parasitized eggs and of healthy unhatched eggs. With these data, you can assess the total number of eggs laid in each group of plants and the percentage of parasitization by different species. That will give you a relative idea of the activity of egg parasites in insecticide-treated field plots.



5. Test tubes (20 X 2.5 cm) containing rice tillers infested with brown planthopper eggs. The tillers had been exposed to egg parasites in the field. When egg parasites emerge they move up and are caught in the cotton plug and are easily counted and removed from the tubes.



6. Field evaluation of insecticides for brown planthopper resurgence activity. Hopperburned plot in the center foreground was treated with a resurgence-inducing insecticide. The green and undamaged plot behind it is the untreated check plot.

To determine the residual effect of insecticide application on parasite activity in the field, expose potted plants with hopper eggs at different intervals after spraying.

BPH resurgence. To identify insecticides that induce BPH resurgence in the field, plant a BPH-susceptible variety. Spray the fields 4 times at 15-day intervals beginning at 30 DT. Direct the spray to the canopy. Spraying the fourth and fifth instars is preferred to get maximum resurgence. Test rates of about 5-40 g a.i./ha for the synthetic pyrethroids and about 200-700 g a.i./ha for the other insecticide classes. Figure 6 shows field screening of insecticides to determine BPH resurgence activity.

- *Rare of resurgence assessment.* Count the BPH weekly. If hopperburn (complete drying) occurs, record the percentage of plants in each plot that show hopperburn. Begin recording when hopperburn is first observed and continue taking records 2 times/week until there is no longer an increase in the hopperburned area.
- *Data presentation.* Make a statistical analysis of the data. Illustrate graphically or tabularly the number of BPH in each treatment and the percentage of hopperburned area on each observation date. The ratio of the number of BPH in the treated plots and that in the control plots indicates the degree of resurgence.

chapter 6

PHYSICAL ASSESSMENT OF SPRAYING SYSTEMS

Because of the high cost of spraying insecticides we should fully understand and improve the efficiency of the application technique. A meaningful measure of efficiency is the amount of chemical deposited on the target area of the rice plant which is determined by measuring the recovery rate. Any improvement of efficiency should subsequently reduce chemical input.

The recovery rate can be measured by using a dye as a tracer. Make up a solution in the spray tank or reservoir, spray it onto the crop, and wash off any part of the rice plant in a known volume of water. The concentration is subsequently determined colorimetrically.

COLORIMETRIC TECHNIQUE FOR DETERMINING INSECTICIDE RECOVERY RATE

The following colorimetric technique, devised at IRRI, is only one method of determining recovery rate concentration (other methods include gas chromatography of insecticide residues extracted from plants and the use of paper sampling targets). The method, which is relatively simple and gives precise quantitative data, involves the following steps:

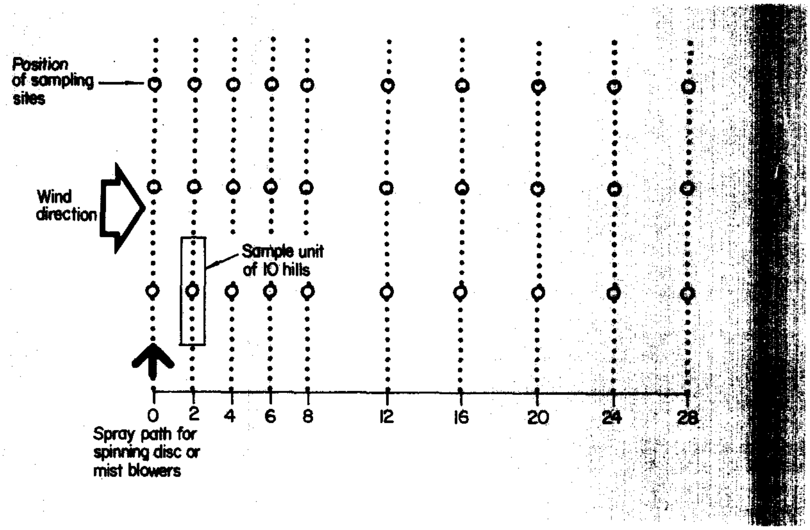
1. *Making up the dye solution.* Make a spray solution of dye in water. Use about 0.1% concentration for high volume spraying (knapsack and mist blowers) and as high as 1% for ultralow-volume. 'Croceine' scarlet, which is available at Skillbeck Ltd, 55-57 Glengall Rd, London S.E. 15, England, is the best dye to use because it is stable in bright sunlight and highly soluble in water. You can use other dyes but make sure they are photostable and easy to wash off the plant.

Before spraying, save a small sample of the dye solution, so that the exact concentration can be measured colorimetrically. You will need the concentration in calculating the volume recovery rate.

2. *Spraying.* For an accurate determination of the recovery rate, spray only along a single spray line of between 5 and 10 m. It will be necessary to make several sprayings along the same line to build up a sufficient deposit and to ensure that the concentration of the wash lies in the range for colorimetry. This is especially true for ULV applications which use low volume rates and which require as many as 8 passes.

Measure the flow rate of the sprayer with the dye solution and record the walking speed.

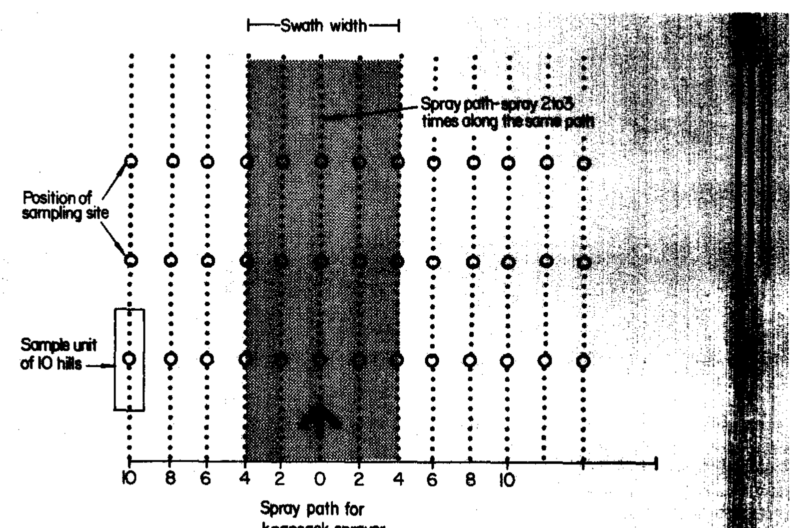
3. *Sampling.* A sample unit for washing should contain 10 hills before 30 DT. At later growth stages only 5 hills are required because the leaf area is greater. Cut the sample units at 0, 2, 4, 6, 8, 12, and 16 rows downwind and thereafter until no more deposit is encountered (Fig. 1). It is important to have both zero points (plants with no dye directly underneath and downwind from the applicator) to determine the



1. Proper location of sampling sites in field plots treated with a rotary ultralow-volume or mist blower sprayer when measuring insecticide recovery rates. Numbers indicate number of rows from the applicator.

amount of spray recovered. For knapsack and related sprayers, cut 2-row spaced samples across the 2-m swath (Fig. 2). Take several rows of sample units per treatment to obtain a good average.

4. *Washing off the dye from the sample unit.* Bind the individual hills of a sample unit together with a rubber band and wash as a whole in one liter of water, moving them up and down repeatedly to ensure that all the spray deposit is washed off the plants. If necessary, separate the leaves, leaf sheath, and panicles and wash them as separate components. It is important to maximize the concentration of the dye. Record the total volume of water the sample was washed in. From the wash, put a



2. Proper location of sampling sites in field plots treated with a knapsack sprayer when measuring insecticide recovery rates. Numbers indicate number of rows from the applicator.

Table 1. Table for making up the calibration curve.

A Serial dilution	B % concentration of serial dilution	C % transmittance of B	D Log concentration (log of B)
1	3.09×10^{-4}	78.0	0.49
2	6.18×10^{-4}	56.5	0.79
3	12.30×10^{-4}	28.2	1.08
4	24.70×10^{-4}	7.0	1.39

subsample into a test tube for colorimetry. Up to this stage, the whole operation can be done in the field. Only test tubes containing the subsamples need to be carried back to the laboratory.

5. *Cleanup of the sample.* Many soil particles will be present in the subsample. To remove these particles centrifuge each sample or leave it to stand overnight. But even then, plant pigments will remain. Adjust the colorimeter when measuring the percentage of transmittance of the subsamples so that 100% transmittance corresponds to a blank which consists of a centrifuged washing of unsprayed rice.

6. *Measuring the percentage of concentration of the sample.* To determine the concentration of the dye in the subsamples obtained from washing the plants (in water) in the field:

a) Make a stock solution by weighing a known amount of dye and adding it to a known volume of water in a volumetric flask.

b) Turn on the colorimeter, allow it to warm up for 15 minutes, and adjust it to read 0% transmittance. Insert a colorimetric tube with distilled water and adjust the colorimeter to read 100% transmittance. From the stock solution, make 4 serial dilutions and record the concentration of each, as in column B, Table 1.

c) Determine the percentage of transmittance of each of the four serial dilutions and record as in column C, Table 1.

d) Log the whole number values of B to obtain log concentration values (see Log Table, Appendix A Table 1, as indicated in column D, Table 1).

e) Plot the log concentration values obtained in D against the percentage of transmittance expressed in step C (see Fig. 3).

f) You can now correlate the transmittance of the subsamples from the field with the percentage of concentration of the dye present. You can thus measure the transmittance percentage of the treated samples as follows.

- First, determine the percentage of transmittance of each sample that has been returned from the field and record as indicated in Table 2.
- Next, take the log concentration for each sample as based on the percentage of transmittance from the calibration curve (Fig. 3). Now determine the actual concentration (not log) by making the antilog of the low concentration for the respective percentage of transmittance from Appendix A Table 7. For example: The percentage of transmittance for the sample taken at 8 rows downwind is 67 (see Table 2). The percentage of concentration at 67% transmittance is determined by taking the antilogarithm of the log concentration value from the calibration curve (Fig. 3). Thus, the antilogarithm of the log concentration 0.61

Table 2. Determination of the volume of spray solution in each sample unit.

	Rows (no.) downwind									
	0	2	4	6	8	12	16	20	24	28
% transmittance	100	99	85	72	67	70	78	89	89	100
% conc. × 10^{-4}	0	0	2.23	3.46	4.07	3.71	2.95	1.86	1.86	0
ml/ 10 hills	0	0	0.27	0.43	0.50	0.46	0.36	0.23	0.23	0

is 4.07 (see antilogarithm table Appendix A Table 7). The actual concentration is therefore 4.07 × 10^{-4}.

Record as in Table 2.

7. *Recovery check from the washing procedure.* Make a recovery check from the washing procedure by spiking an untreated sample unit (or component of, i.e. leaf, leaf sheath, or panicle) with a known volume of spray solution. Repeat the washing procedure and estimate the percentage of concentration of the wash. For example:

0.5 ml of a 1.04% dye solution was pipetted onto the canopy of 10 hills bound together with a rubber band, and washed in 1 liter of water.

$$\text{For 100\% recovery the concentration of the wash} = \text{Volume of dye solution pipetted on plants} \; \frac{\text{Concentration of dye solution}}{\text{Volume of wash water (ml)}}$$

$$= 0.5 \times \frac{1.04}{1{,}000}$$

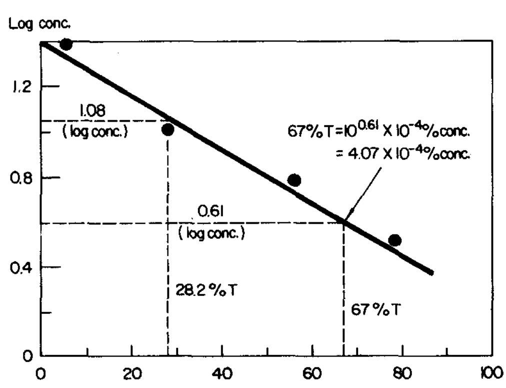
$$= 5.2 \times 10^{-4}\%$$

The percentage of transmittance of the spiked sample is 67. The log concentration at 67% (see Fig. 3) = 0.61. Take the antilog of 0.61 to compute the actual concentration. The actual concentration is 4.07 × 10^{-4}.

$$\text{Efficiency of the washing procedure} = \frac{\text{Conc. of actual recovery}}{\text{Conc. at 100\% recovery}}$$

For example:

$$\frac{4.07 \times 10^{-4}}{5.20 \times 10^{-4}} \times 100 = 78.3\%$$



3. Calibration curve of the concentration of croceine scarlet (weight/volume) against % transmittance.

One should aim to mimic the spray deposit as close to actual spraying conditions as possible. During spraying, keep the volume applied to the sample in the range you expect (0.5 ml to 1.0 ml/10 hills). Pipette the volume in small drops throughout the sample unit. Before washing off the deposit leave the sample outside for the approximate time it takes between cutting and washing the sample under actual field condition.

8. *Calculations.* Now we want to determine the volume of spray solution/ 10 hills. To do this, we use the following formula:

$$\text{Vol. of spray solution, 10 hills} = \frac{\text{\% conc. of subsample}}{\text{\% conc. of spray solution}} \times \text{Vol. (ml) used to wash the sample unit} \times \frac{100}{\text{Efficiency}}$$

Say we want to determine the volume of spray solution (ml)/10 hills at 8 rows downwind (see Table 2). Thus, using the information noted below:

Vol. used for washing the sample units = 1,000 ml

Percentage of efficiency for the washing procedure = 78.3

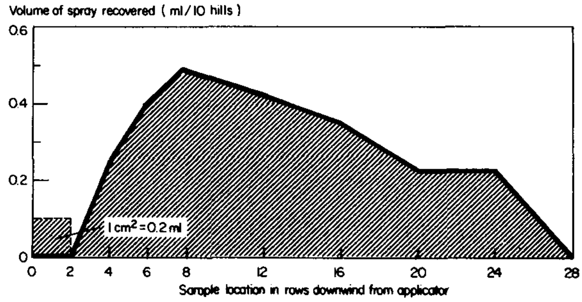
% conc. of subsample = 4.07×10^{-4} (from the calibration curve, Fig. 3)

% conc. of spray solution = 1.04

$$\text{Volume of spray solution, 10 hills} = \frac{4.07 \times 10^{-4}}{1.04} \times 1{,}000 \times \frac{100}{78.3}$$

$$= 0.50 \text{ ml}$$

Do these calculations for all sample units and record as in Table 2. Now we can plot the volume of spray recovered (ml)/10 hills from Table 2 for each sample row downwind for ULV and mist blowers or across the swath for knapsack sprayers as indicated in Figure 4. The area under the curve is the total volume of spray recovered (ml) over the entire sample area (10 × 28 hills). The area under the curve can be estimated by counting squares of graph paper, using a planimeter or cutting the curve out, and weighing it. For this example, the area was determined by cutting the curve out and weighing it. The area can be calculated if the weight/cm^2 of graph



4. Volume of spray recovered at each sampling site as indicated by the number of rows downwind from the applicator.

paper is known as 1 cm^2 = 0.2 ml (two 10 hill units at 0.1 ml each). For the example in Figure 4, do the following computations:

First, determine the volume of spray recovered over the distance equivalent to 10 hills of spraying.

Wt of graph paper cut out = 400 mg

1 cm^2 of graph paper = 8.89 mg

$$\text{Area under curve} = \frac{\text{Wt of paper cut out}}{\text{Wt of 1 cm}^2\text{ of paper}} = \frac{400}{8.89} = 44.99\ \text{cm}^2$$

1 cm^2 of graph paper = 0.2 ml of spray solution

Vol. of spray recovered (ml)/ 10 hills of spraying = 44.99 × 0.2 = 9.00 ml

Next, determine the volume of spray emitted over the distance equivalent to 10 hills of spraying. For this we need the following information:

Flow rate	= 0.79 ml/second
Walking speed	= 0.47 m/second
No. of spray passes	= 6
No. of hills/sample unit	= 10 hills
Hill spacing	= 0.25 × 0.25 m

The distance equivalent to 10 hills of spraying = 0.25 m × 10 hills

= 2.50 m

$$\text{Time (seconds) to walk 2.5 m at 0.47 m/second} = \frac{2.50}{0.47}$$

= 5.32 seconds

$$\text{Vol. of spray emitted (ml) over 2.5 m} = \frac{\text{Time (seconds) to walk 2.5 m} \times \text{flow}}{\text{rate x no. of spray passes}}$$

= 5.32 × 0.79 × 6

= 25.22 ml

Now determine the recovery:

$$\text{\% spray volume recovered} = \frac{\text{Vol. of spray recovered}}{\text{Vol. of spray emitted}} \times \text{loo}$$

$$= \frac{9.00}{25.22} \times 100$$

= 35.69%

The recovery is a measure of the dosage rate on the canopy, leaf sheath, or panicles. From the present example, if a dosage rate of 500 g a.i./ha was applied, only 35.7% or 179 g a.i./ha is deposited on the plants.

Precautions in using the colorimetric technique

A common fault in the colorimetric technique is the failure to get a sufficiently high concentration of dye when washing the sample unit, which tends to occur when the sample unit is separated into leaf sheaths or panicles and treated separately. This can be remedied by:

1) Increasing the concentration of the dye in the spray solution;
2) Spraying a larger number of spray passes; and
3) Decreasing the volume of water the samples are washed in.

If all these fail, then re-examine the dye that has been used. Common failures are due to photodegradation or absorption of the dye onto soil particles within the sample.

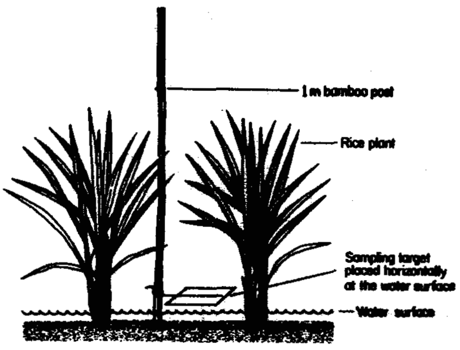
Uses of the colorimetric technique in developing insecticide application recommendations

By determining the quantity of the deposit, the technique pinpoints where the chemical is going and how much is deposited on a particular sector of the rice plant. As such, it can be used for:

- Recommending the most efficient type of sprayer for the control of a particular pest. For example, a spraying system that maximizes the deposit on the leaf sheath is recommended for brown planthopper control.
- For a given spraying system, it can be used for producing recommendations for spraying, i.e. swath width determination or the correct range of wind speeds under which spraying is feasible.
- Minimizing the applied dosage rate, i.e. if 30% of the applied 500 g a.i./ha lands on the canopy, and this level controls a stem borer, doubling this recovery rate to 60% (by modifying the sprayer or spraying practice) will enable a decrease in the applied dosage rate to 250 g a.i./ha.
- Determining the environmental hazards imposed by spraying. For example, if the total deposit on all parts of the rice plant accounts for 40% of the applied 500 g a.i./ha, 300 g a.i./ha contaminates the environment and is lost to the water or air.

Determination of the amount of insecticide lost to drift

A further refinement is to determine the amount of insecticide that contaminates the water surface and that which is lost as drift beyond the treated area by placing targets of either 4 cm × 1 cm pieces of fixed, glazed photographic paper (or glass slides) at the level of the water surface (Fig. 5). The targets can be glued to a piece of wire and attached to a bamboo stake.



5. Sampling target used to determine the amount of spray deposited on the water surface. The target consists of glazed photographic paper or glass slides attached to a bamboo post with a wire at water surface level.

The stakes should be placed where the sample units in Figures 1 and 2 were taken from. Wash the deposit off the targets in a test tube, in as small a volume as possible (about 5 ml). Measure the concentration colorimetrically and follow exactly the same computational procedures as with direct washings from the plant to determine environmental contamination.

1. Wash off the deposit on the sampling surface in 5 ml of water in a small petri dish or test tube.
2. Take the percentage of transmittance for the wash solution to determine the percentage of concentration for each sample.

	Rows (no.) downwind						
	0	2	4	6	8	12	16
% transmittance	100	97	86	14	74	92	100
% concentration × 10^{-4}	0	1.28	2.43	3.33	3.33	1.45	0

To convert the percentage of transmittance readings to percentage of concentration, follow the same computational procedures as previously shown (see Fig. 3 and step 6, this chapter).

3. Compute the volume of spray solution per area of the sampling target using the percentage of concentration of the wash:

$$\text{ml/ area of sampling target} = \frac{\text{\% concentration of wash} \times \text{Vol. used for washing off the deposit (ml)}}{\text{\% concentration of spray solution}}$$

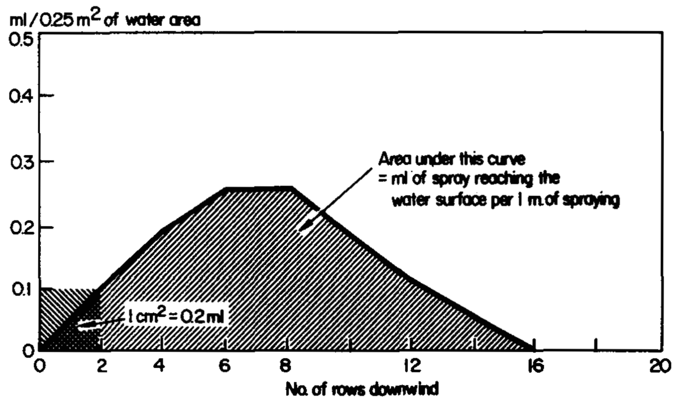
For example, at 8 rows downwind:

$$\text{\% concentration of wash} = 3.33 \times 10^{-4}$$
$$\text{Area of sampling target (m}^2\text{)} = 0.01 \times 0.04 = 4.00 \times 10^{-4}\text{ m}^2$$
$$\text{Volume of wash} = 5\text{ ml}$$
$$\text{\% concentration of spray solution} = 4.0$$
$$\text{ml}/4.00 \times 10^{-4}\text{ m}^2 = \frac{3.33 \times 10^{-4} \times 5}{4.0}$$
$$= 4.16 \times 10^{-4}$$

Follow this step for every sample and tabulate as follows:

	Rows (no.) downwind						
	0	2	4	6	8	12	16
% concentration × 10^{-4}	0	1.28	2.43	3.33	3.33	1.45	0
ml/area of sampling target	0	1.60	3.04	4.16	4.16	1.81	0

4. The area of the sampling target is equivalent to the same area of water surface exposed to the spray deposit. In our case 4.0×10^{-4} m^2 of sampling target is equivalent to 4.0×10^{-4} m^2 of the water surface. To compute the total deposit reaching the water surface, plot the volume/m^2 of water surface for each sampling point against the area of water surface exposed downwind (Fig. 6). The area under this curve will represent the total deposit on the water surface.



6. Volume of spray material recovered at the water surface at each sampling site downwind.

In our example, the distances downwind are expressed as number of rows. To make these numbers equivalent to the water area exposed, consider the row spacing.

$$\text{Hill spacing} = 0.25 \times 0.25 \text{ m}$$

$$\text{For spraying 1 meter of a row} = 1 \text{ row} \times 0.25 \text{ m} \times 1 \text{ m of spraying}$$

$$= 0.25 \text{ m}^2 \text{ of water surface}$$

For ease of computation, convert the volume of spray solution/target area to volume/area of water surface exposed at 1 row downwind for 1 m of spraying:
At 8 rows downwind

$$\text{m1}/4.0 \times 10^{-4} \text{ m}^2 = 4.16 \times 10^{-4}$$

$$\text{m1}/0.25 \text{ m}^2 = 4.16 \times 10^{-4} \times \frac{0.25}{4.0 \times 10^{-4}}$$

$$= 0.26 \text{ ml}$$

Follow this step for each sample site.

	Rows (no.) downwind						
	0	2	4	6	8	12	16
ml × 10^{-4}/ 4.0×10^{-4} m^2	0	1.60	3.04	4.16	4.16	1.81	0
ml/0.25 m^2	0	0.1	0.19	0.26	0.26	0.11	0

5. The volume of spray solution/0.25 m^2 of water surface can now be plotted against the number of rows downwind for each sampling site (Fig. 6).

The area under this curve will give the total volume of spray solution recovered at the water surface for 1 m of spraying. The curve is cut out and weighed to estimate the area.

$$\text{Wt of paper cut out} = 140 \text{ mg}$$

$$1 \text{ cm}^2 \text{ of graph paper} = 8.89 \text{ mg}$$

$$\text{Area under the curve} = \frac{140}{8.89}$$

$$= 15.75 \text{ cm}^2$$

One row downwind is equivalent to 0.25 m^2 of water surface per 1 m of spraying. As the volume on the Y axis of Figure 6 is expressed as ml/0.25 m^2 of water surface:

$$1 \text{ cm}^2 \text{ of graph paper} = \frac{0.1 \text{ ml}}{0.25 \text{ m}^2} \times 2 \text{ rows} \times 0.25 \text{ m}^2$$

$$= 0.2 \text{ ml}$$

The total volume deposited on the water surface per 1 m of spraying:

$$15.75 \times 0.2 = 3.15 \text{ ml of spray solution}$$

6. From the flow rate and walking speed recorded for the spraying procedure, the volume of spray solution emitted over 1 m of spraying can be computed. The volume deposited divided by the volume emitted gives the percentage of spray solution deposited on the water surface.

Walking speed = 0.47 m/second

Flow rate = 0.79 ml/second

No. of spray passes = 6

$$\text{Volume emitted (ml)/ 1 m of spraying} = \frac{1}{\text{Walking speed}} \times \text{Flow rate} \times \text{No. of spray passes}$$

$$= \frac{1}{0.47} \times 0.79 \times 6$$

$$= 10.09 \text{ ml}$$

$$\text{\% spray solution deposited on the water surface} = \frac{\text{Vol. deposited/1 m of spraying}}{\text{Vol. emitted/1 m of spraying}}$$

Volume deposited/1 m of spraying = 3.15 ml

Volume emitted/1 m of spraying = 10.09 ml

$$\text{\% spray solution deposited on the water surface} = \frac{3.15}{10.09} \times 100$$

$$= 31.22\%$$

7. By simple addition, the amount of spray lost as drift outside the treatment area can be estimated.

% deposited on the canopy (see step 8, *Calculations,* this chapter) = 35.69

% deposited on the water surface = 31.22

66.91

Therefore, 100 – 66.91 = 33.09% lost as drift outside the treatment area.

chapter 7

SAMPLING INSECT POPULATIONS AND ESTIMATING INSECT DAMAGE IN FIELD EXPERIMENTS

Various techniques to measure the efficacy of insecticides by measuring the insect population and the amount of plant damage caused by the insects have been developed. A high natural infestation of insects is desirable but sometimes the insects are too few to provide reliable field testing of insecticides. In this case artificial infestations can be utilized.

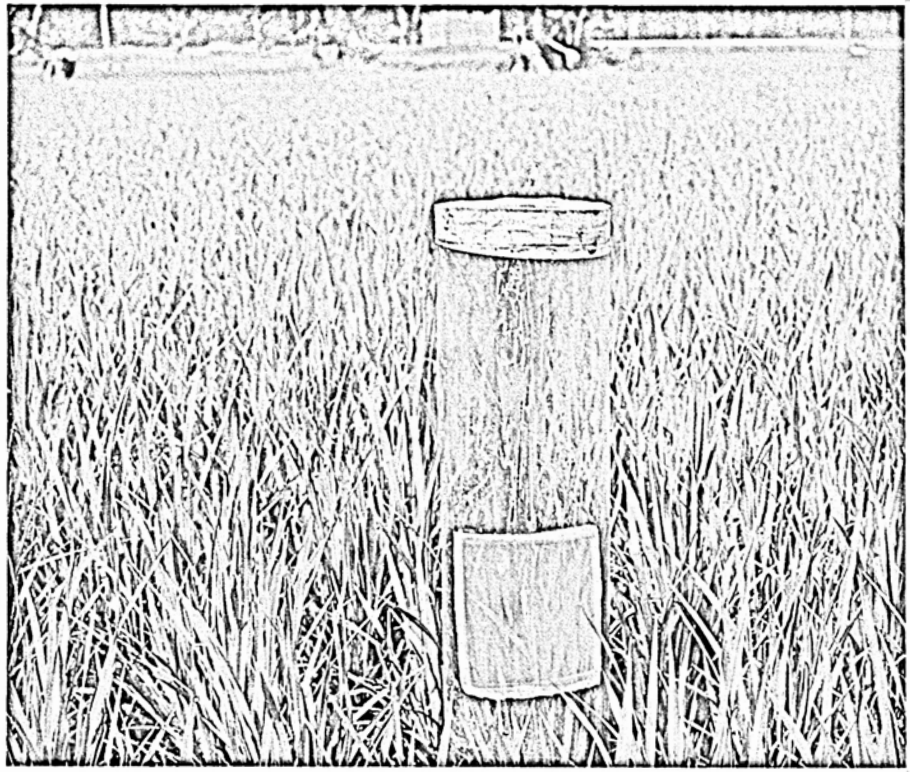
ARTIFICIAL INFESTATION WITH INSECTS

The toxicity of field-applied insecticides on pests at different intervals after application can be measured accurately by caging insecticide-treated plants in the field and releasing insects in the cages at specific intervals after spraying. The technique is especially useful when natural field infestations are low and detailed observations are required. A method for leafhoppers and planthoppers follows. The same method, but with slight modification, can be used for stem borers, leaf folders, rice bugs, and other rice insects.

In each experimental plot, cage 1–2 hills individually in cylindrical mylar film cages (Fig. 1). Place the cages randomly in each plot, 1 day after insecticide application. To infest with planthoppers, place young female adults in a glass vial whose open end is plugged with cotton, and transport them to the field. Release 20 hoppers into each mylar cage through a slit. To study the residual activity of an insecticide, release hoppers at 1, 5, 10, 15, and 20 days after application, or until mortality is less than 30% after adjustment using Abbott's formula. If mortality in. the untreated check is more than 20% consider the test invalid. Make mortality readings 48 hours after infestation and remove the insects.

A modification of the field-caging technique described is to take treated and control plants from the field to the insectary for infestation. This technique can be used for stem borers and leaf folders where mortality in the control plots is often high in the field. Two methods can be used.

- Take potted plants that are as tall as those in the test plots from the insectary or untreated fields to the field before treatment. After spraying, take the plants back to the insectary at various time intervals for insect infestation. If foliar sprays are used and potted plants are removed immediately after spraying, you can use the same portion of the field repeatedly for application of several different insecticides. This technique is especially useful for evaluating various droplet sizes, rates, etc., with the ULV applicator which, because of excessive drift, requires large plots which are not always available.
- Remove the plants directly from the test plots at,various intervals after treatment and take them to the insectary for infestation. The potted-plant method



1. Field caging hoppers for insecticide evaluation studies. The mylar film cage is placed over the plants after spraying and the insects are inserted through a slot on the sides of the cage with a mouth aspirator.

can be used only when foliar sprays or dusts are applied whereas the second method can also be used with granules.

NATURAL INFESTATIONS

Whorl maggot

The damage rating is usually made 20 DT and repeated 30 DT. By then maximum damage is usually visible. The damage is estimated visually and described using the standard evaluation system with a 0 to 9 scale.

Scale	*Damage*
0	No damage
1	Zero to one leaf/hill damaged
3	Two or more leaves/hill damaged but less than 1/3
5	One-third to 1/2 of the leaves damaged
7	More than 1/2 of the leaves damaged but no broken leaves
9	More than 1/2 of the leaves damaged with some broken leaves

Estimate the damage using the following steps.

1. Select a hill from the plot at random.
   a. Count the leaves.
   b. Count the damaged leaves.
   c. Note any broken leaves.

2. Mentally work out the ratio of damaged leaves to total number of leaves.
3. Refer the ratio to the rating system and select the correct scale.
4. Record the scale in your data sheet.
5. Follow the same steps for other hills until you complete 10 hills, selected randomly for each plot.
6. Compute the average scale for 10 hills. That represents the rating scale for the plot.

It is easier to rate the damage if you memorize the scale and the corresponding damage. This can be achieved by practice.

Stem borer

Sampling for stem borer damage is done in a 10-m^2 area at the center of each plot. A 25 × 25 cm spacing will give you 160 hills in the sampling area. To compensate for missing or virus-infested hills, substitute the hills outside the 10-m^2 area. Assess deadheart damage as follows:

1. Observe all the hills. Count the infested ones. Examine each infested hill and
   - count all the tillers, and
   - count those with deadhearts.

   To distinguish the number of deadhearts from the total number of tillers in each infested hill, record the numbers as a fraction, the number of deadhearts as the numerator and the number of tillers as the denominator.
2. Follow the same steps for other infested hills.
3. Compute the percentage of deadhearts by the following formula:

$$\%\ \text{deadhearts} = \frac{\text{No. of deadhearts in infested hills}}{\text{Total no. of tillers observed in infested hills}} \times \frac{\text{No. of infested hills}}{\text{Total hills observed (160)}} \times 100$$

For computing the percentage of whiteheads, use the same steps, substituting panicles for tillers and whiteheads for deadhearts.

$$\%\ \text{whiteheads} = \frac{\text{No. of whiteheads}}{\text{Total no. of panicles observed}} \times \frac{\text{No. of infested hills}}{\text{Total no. (160) of plants observed}} \times 100$$

Gall midge

To assess infestation by gall midge, follow the same steps as for the stem borer.

$$\begin{array}{c}\%\ \text{galled tillers} \\ \text{(silver or onion shoot)}\end{array} = \frac{\text{No. of galled tillers}}{\text{Total no. of tillers observed}} \times \frac{\text{No. of infested hills}}{\text{Total no. of hills observed}} \times 100$$

Planthoppers (BPH and WBPH)

Several sampling methods can be used depending on the population of hoppers.

Counting

1. *Visual sampling.* Depending on the size of the experimental plot, sample 10 to 20 hills selected at random. Adequate standing water in the field is necessary in

counting the floating hoppers. Shake each hill and count the hoppers that fall on the water. This method is useful when there are up to 50 insects on each hill.

2. *Suction machines*

a. *D-Vac.* The machine is operated by a gasoline-powered motor (Fig. 2). The machine sucks the insects from rice plants by vacuum pressure. The insects are collected in plastic bags and counted later in the laboratory. Sampling is usually done in 10 randomly selected hills/plot or from the plants in a 6-linear-meter row.

2. D-vac suction machine for collecting rice insect pests and natural enemies.

3. A Univac suction machine in operation. The intake is much smaller and more flexible than that of the D-vac.

b. *Univac.* In working principle, this machine is similar to D-Vac but the collecting hose is smaller, allowing more versatility (Fig. 3).

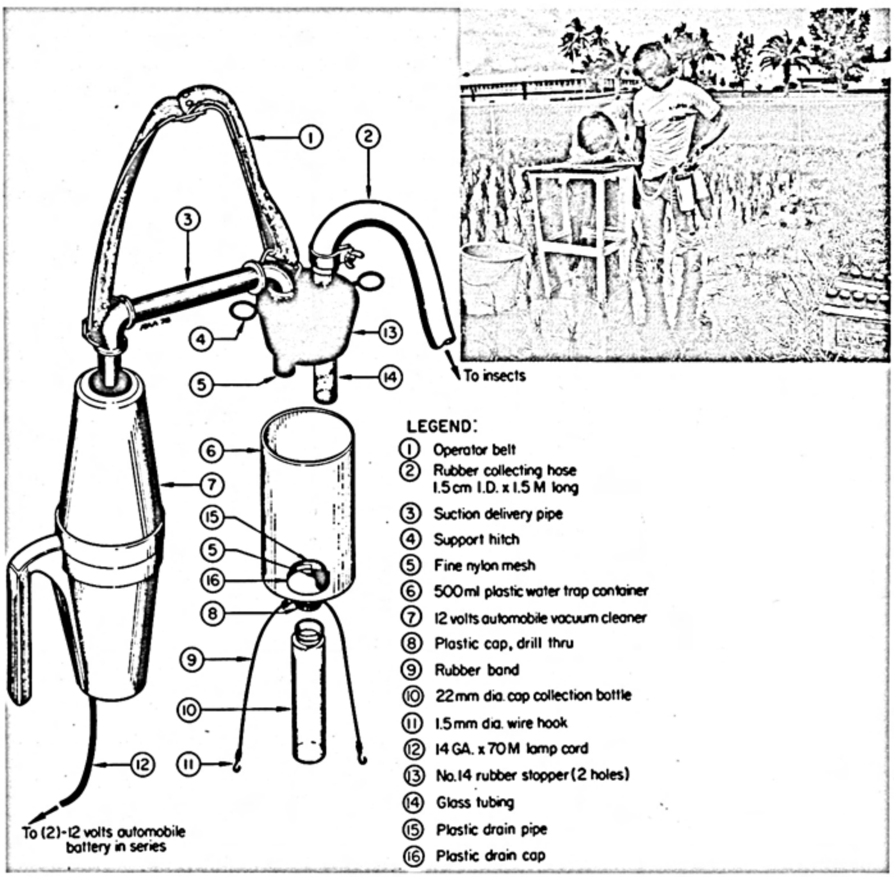
c. *FARMCOP.* An insect-collection device developed at IRRI (Fig. 4), the machine consists of a modified insect aspirator attached to an automobile vacuum cleaner, operated by automobile batteries. A hood with iron frame and mylar film walls is used to confine the individual hills. The insects are collected from the plants and water surface by vacuum pressure.

Among the available suction samplers, FARMCOP is the most efficient for insects on the water surface-such as *Microvelia* spp.

Damage. Record the percentage of hopperburned plants in each plot beginning when a hopperburned plant is observed and continue at 5day intervals. Hopper-burned plants are those whose leaves are all brown and are dead.

Leafhoppers

Sweep-net sampling is the most common method of sampling leafhopper adults. For sampling nymphs, visual counting is good. Suction machines can also be used for efficient sampling.



4. The FARMCOP suction machine (insert) for collecting insects and spiders from rice hills and off the water surface (Cariño et al. 1979). A mylar fdm cag is placed over the hill before inserting the suction machine. That prevents the insects from escaping when the machine is in operation. Details of the FARMCOP are shown in the drawing.

In using the sweep nets, do the following steps:

1. Hold the sweep net near the end of the handle.
2. Begin sweeping at the center of the plot.
3. Swing the pole with both arms forming a semicircle. Keep the circular frame of the open end of the net perpendicular to the ground and pointing to the direction of the swing.
4. Walk normally and swing the net steadily touching the leafy portion of the plant. Do not swing the net up and down. Close net mouth as soon as sweeping action terminates.
5. Sweep 10 timeslplot.
6. Put the collected insects in plastic bags and label with tags.
7. Identify and count the insects in the laboratory.

Leaf folder

Twenty hills selected at random can be examined in each plot, for infestation by leaf folder. The damage is assessed based on the percentage of leaves infested.

$$\%\ \text{leaves damaged} = \frac{\text{No. of damaged leaves/20 hills}}{\text{Total number of leaves/20 hills}} \times 100$$

The same method can be used for evaluating damage by caseworm, green homed caterpillar, and other defoliators. Percentage of leaf area eaten can also be used as a criterion for assessing damage by these insects but is much more difficult.

Rice bug

Two techniques can be used to assess for rice bug control: counting the bugs and measuring the feeding activity on the panicle.

Counting. Count the rice bugs preferably early in the morning because they are not very active at this time. Choose a 1-m^2 area at 4 different sites in each plot and record the number of bugs in each site.

Damage. At harvest, feeding activity can be assessed by counting the number of stylet sheaths left in the grains by rice bug. To see the stylet sheath, stain grains as described by Bowling (1979). Make up a staining solution containing 1 part each of phenol, lactic acid and distilled water, and 2 parts glycerine plus sufficient acid fuchsin to produce a dark red color. Immerse the grains from the various insecticide treatments in the solution for about an hour, remove, and rinse in tap water. Stylet sheaths left in the grain by *Leptocorisa* spp. appear dark red. Count the stylet sheaths with the aid of a binocular microscope.

Insect-transmitted virus diseases

Select a 10-m^2 area at the middle of each plot and record the total number of hills and virus-infected (grassy stunt, ragged stunt, and tungro) hills. Assess the percentage of virus-infected hills using the following formula.

$$\%\ \text{virus-infected hills} = \frac{\text{No. of virus-infected hills in the sample area}}{\text{Total number of hills observed in the sample area}} \times 100$$

Assessment can be made 20, 40, and 60 DT.

chapter 8

STATISTICAL ANALYSIS OF INSECT POPULATIONS AND PLANT DAMAGE

To gain a detailed knowledge on the various types of experimental layouts to evaluate insecticides, we suggest that researchers refer to the publication by Gomez and Gomez (1976). Some statistical procedures useful for analyzing data from insecticide evaluation experiments based on this publication follows.

EXAMPLE I.
ANALYSIS BASED ON ACTUAL VALUES

A field experiment is designed to evaluate the efficacy of 9 insecticides in the control of BPH. Ten treatments (9 insecticides + 1 untreated check) are used. The treatments are replicated 4 times in a randomized complete block (RCB) design (see Appendix C for typical field layout). There are 40 (10 treatments × 4 replications) plots. The grain yield in the individual plots is presented in Table 1.

Table 1. Grain yield (kg/ha) in field plots treated with insecticides.

Treatment no.	Block I	Block II	Block III	Block IV	Treatment total	Treatment mean
1	3845	4169	4988	4896	17898	4475
2	4245	4467	4087	4809	17608	4402
3	4898	4467	4722	5140	19227	4807
4	4555	4329	4540	4764	18188	4547
5	4247	4899	4473	4466	18085	4521
6	4619	4758	4879	4837	19093	4773
7	3764	3313	5051	4266	16394	4099
8	4251	4416	4541	4206	17414	4354
9	3950	4230	3428	4110	15718	3930
10 (check)	3831	3708	3605	3563	14707	3677
Block Total	42205	42 755	44314	45057	174332 (Grand total)	
Block Mean	4220.5	4275.6	4431.4	4505.7		4358.3 (Grand mean)

Analysis of variance

The computation of the analysis of variance for the data given in Table 1 involves the following steps:

Step 1. Group the data by treatment and block. Compute the treatment totals, treatment means, block totals, block means, grand total, and grand mean as shown in Table 1.

Step 2. Calculate the degrees of freedom (df) for each source of variation. The df is calculated as follows:

Total df = total number of observations - 1 = 40 - 1 = 39
Treatment df = total number of treatments - 1 = 10 - 1 = 9
Block df = total number of blocks - 1 = 4 - 1 = 3
Error df = total df - treatment df - block df = 39 - 9 - 3 = 27

Step 3. Compute the correction factor (C.F.) as

$$\text{C.F.} = \frac{(\text{Grand total})^2}{\text{Total no. of observations}} = \frac{(174{,}332)^2}{40} = 759{,}791{,}155.5$$

Step 4. Compute the sum of squares (SS) for each source of variation as follows:
i. Total sum of squares (TSS) = Sx^2 - C.F., where,

Sx^2 = Sum of square of individual plot observations

$$\text{TSS} = (3{,}845)^2 + (4{,}245)^2 + \ldots + (3{,}563)^2 - 759{,}791{,}155.5$$
$$= 8{,}644{,}222.5$$

ii. Block sum of squares (BSS)

$$= \sum \frac{(\text{Block total})^2}{\text{No. of treatments}} - \text{C.F.}$$
$$= \frac{(42{,}205)^2 + (42{,}756)^2 + (44{,}314)^2 + (45{,}057)^2}{10} - 759{,}791{,}155.5$$
$$= 528{,}985.1$$

iii. Treatment sum of squares (Trt SS)

$$= \sum \frac{(\text{Treatment total})^2}{\text{No. of blocks}} - \text{C.F.}$$
$$= \frac{(17{,}898)^2 + (17{,}608)^2 + \ldots (14{,}707)^2}{4} - 759{,}791{,}155.5$$
$$= 4{,}667{,}049.5$$

iv. Error sum of squares (ESS)

$$= \text{TSS} - \text{BSS} - \text{Trt SS}$$
$$= 8{,}644{,}222.5 - 528{,}985.1 - 4{,}667{,}049.5$$
$$= 3{,}448{,}187.9$$

Step 5. Calculate the mean squares (MS) by dividing each SS by its corresponding df.

$$\text{Block MS} = \frac{\text{block SS}}{\text{block df}} = \frac{528{,}985.1}{3} = 176{,}328.4$$

$$\text{Treatment MS} = \frac{\text{treatment SS}}{\text{treatment df}} = \frac{4{,}667{,}049.5}{9} = 518{,}561.1$$

$$\text{Error MS} = \frac{\text{error SS}}{\text{error df}} = \frac{3{,}448{,}187.9}{27} = 127{,}710.7$$

Step 6. Compute the F value.

$$\text{Block F} = \frac{\text{block MS}}{\text{error MS}} = \frac{176{,}328.4}{127{,}710.7} = 1.38$$

$$\text{Treatment F} = \frac{\text{treatment MS}}{\text{error MS}} = \frac{518{,}561.1}{127{,}710.7} = 4.06$$

Step 7. Get the tabular F-values from Appendix A Table 9. For blocks, use the block df as f_1 and the error df as f_2. The tabular F-values for block with 3 and 27 df at 5% and 1% levels of significance are 2.96 and 4.60, respectively. For treatment, use the treatment df as f_1 and the error df as f_2 . The tabular F-values for treatment with 9 and 27 df at 5% and 1% levels of significance are 2.25 and 3.14, respectively.

Step 8. Construct the analysis of variance table and enter all the computed values as shown in Table 2.

Table 2. Analysis of variance.

Source of variation	Df	SS	MS	Observed F	Tabular F	
					1%	5%
Block	3	528985.1	176328.4	1.38ns	4.60	2.96
Treatment	9	4667049.5	518561.1	4.06**	3.14	2.25
Error	27	3448187.9	12771 0.7			
Total	39	8644222.5				

ns = not significant, ** =significant at the 1% level, Df = degrees of freedom, SS = sum of squares, MS = mean square.

Step 9. Compare the observed F-value with the tabular F-values based on the following decision rules:

1. If the observed F is as large as, or larger than, the tabular Fat the 1% level, the differences among treatment means are considered highly significant. Indicate this result by placing two asterisks on the observed F-value.
2. If the observed F-value is as large as, or larger than, the tabular F at the 5% level but smaller than the tabular F at the 1% level, the differences among treatments are significant. Indicate this by placing one asterisk on the observed F-value.
3. If the observed F is smaller than the tabular F at the 5% level, the differences among treatments are not significant. Indicate this by placing *ns* on the observed F-value.

In the present model, we conclude that there are no significant differences among the blocks because the computed F-value for block is less than the tabulated F-value at the 5% level.

For treatments, we conclude that the differences among treatments are highly significant because the computed F-value is larger than the tabular F at 1% level. In other words, chances are less than 1 in 100 that all the observed differences among treatment means could be due to chance.

Comparison of treatment means

Duncan's Multiple Range Test (DMRT) is used to make comparisons among treatment means. The steps involved are as follows:

Step 1. Rank the treatment means in descending order as follows.

Treatment no.	Rank	Mean
3	1	4,807
6	2	4,773
4	3	4,547
5	4	4,521
1	5	4,475
2	6	4,402
8	7	4,354
7	8	4,099
9	9	3,930
10	10	3,677

Step 2. Compute the standard error of treatment mean (s.e.m.) as:

$$\text{s.e.m. } (S_{\bar{x}}) = \sqrt{\frac{\text{Error mean square}}{\text{No. of blocks}}}$$

$$= \sqrt{\frac{127{,}710.7}{4}}$$

$$= 178.7$$

Step 3. From the table of significant studentized ranges (SSR) (Appendix A Table 10), with an error df of 27 and 5% level of significance, list out the SSR values for p = 2 to 10.

Step 4. Compute the *Least Significant Range* (R_p) using the formula

$$LSR = R_p = (a\,p)\ (S_x) \text{ for each value of p}$$

$$R2 = (2.90)\ (178.7) = 518.2;\ \ldots\ R10 = (3.38)\ (178.7) = 604.0$$

Value of p	2	3	4	5	6	7	8	9	10
SSR = a p	2.90	3.05	3.14	3.20	3.26	3.30	3.34	3.36	3.38
LSR = R_p	518.2	545.0	561.1	571.8	582.6	589.7	596.9	600.4	604.0

Step 5. Rank the means.

T10	T9	T7	T8	T2	T1	T5	T4	T6	T3
3,677	3,930	4,099	4,354	4,402	4,475	4,521	4,547	4,773	4,807

Step 6. Test the differences as follows: largest minus smallest, largest minus second smallest, largest minus second largest, second largest minus smallest, second largest minus second smallest, and so on, up to the second smallest minus the smallest.

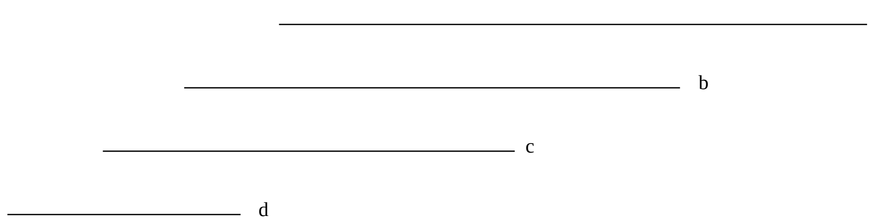
From the LSR in the table under Step 4 we see that because T3 to T10 is a range of 10 means, it must be 604.0 or greater to be significant, and because T6 to T4 is a range of 2 means, it must be 518.2 or greater to be significant, etc.

This procedure is illustrated below:

T3 - T10 = 1,130 > 604.0 = significant
T3 - T9 = 877 > 600.4 = significant
T3 - T8 = 453 < 589.7 = not significant
T6 - T7 = 683 > 589.7 = significant
T6 - T8 = 419 < 582.6 = not significant
T9 - T10 = 253 < 518.2 = not significant

Step 7. Draw lines under all means that are not significantly different. Different letters can be placed under means that are significantly different.

T10	T9	T7	T8	T2	T1	T5	T4	T6	T3
3,677	3,930	4,090	4,354	4,402	4,475	4,521	4,547	4,773	4,807



Step 8. In presenting the results adopt the letter designation to represent the significant differences between treatments. Present the results as follows:

Treatment	Grain yield (kg/ha)[a]	Statistical significance[b]
T1	4,475	abc
T2	4,402	abc
T3	4,807	a
T4	4,547	ab
T5	4,521	ab
T6	4,773	a
T7	4,099	bcd
T8	4,354	abc
T9	3,930	cd
T10	3,677	d

[a]Av of 4 replications. [b]Means followed by a common letter are not significantly different at the 5% level by DMRT.

Based on the statistical analysis, the following conclusions are drawn:

i. Of the nine insecticides tested, two — T7 and T9 — did not give significant yield increase over the untreated check.

ii. Among the other insecticide treatments — TI, T2, T3, T4, T5, T6, and T8 — there was no significant difference in their yields.

EXAMPLE II. ANALYSIS USING SQUARE ROOT TRANSFORMATION

Square root transformation is applied when the data collected consist of small[1] whole numbers or for percentage data where the range is between 0 and 30% or 70 and 100% but not both. In applying the square root transformation, the square root value of each observation is computed and all computations are based on these square root values. If most of the values are small, especially when zeros are present, use

$$\sqrt{x + 0.5}.$$

Illustration: The percentage of deadhearts caused by the stem borer in 10 treatments is presented in Table 3.

Because the data are within the 0-19 range and because there are 0 values, the

$$\sqrt{x + 0.5}$$

transformation will be used. For each observation, increase the value by 0.5 and take the square root.

For example, for treatment 1 in Replication 1 where the original observed value is 5, the square root transformed value is

$$\sqrt{5 + 0.5} = \sqrt{5.5} = 2.35$$

The transformed values for the original values in Table 3 are presented in Table 4.

Compute the analysis of variance and make comparison of means following the procedure illustrated in Example I, using transformed values in Table 4.

Table 3. Percentage of deadhearts in rice varieties.

Treatment no.	Replication I	II	III	IV	Total
1	5	7	9	6	27
2	11	16	13	9	49
3	12	11	19	15	57
4	17	17	12	16	62
5	8	5	4	4	21
6	9	10	8	10	37
7	3	4	2	0	9
8	1	0	1	1	3
9	0	2	1	2	5
10	3	1	0	0	4

[1]When data consist of whole numbers that cover a wide range such as number of BPH per hill or per unit area, the logarithmic transformation is used.

Table 4. Square root transformed values of the percent deadhearts.

Treatment no.	Replication I	II	III	IV	Total	Mean
1	2.35	2.74	3.08	2.55	10.72	2.68
2	3.39	4.06	3.67	3.08	14.20	3.55
3	3.54	3.39	4.42	3.94	15.29	3.82
4	4.18	4.18	3.54	4.06	15.96	3.99
5	2.92	2.35	2.12	2.12	9.51	2.38
6	3.08	3.24	2.92	3.24	12.48	3.12
7	1.87	2.12	1.58	0.71	6.28	1.57
8	1.23	0.71	1.23	1.23	4.40	1.10
9	0.71	1.58	1.22	1.58	5.09	1.27
10	1.87	1.23	0.71	0.71	4.52	1.13
Block total	25.14	25.60	24.49	23.22	98.45 (Grand total)	
Block mean	2.514	2.560	2.449	2.322		2.46 (Grand mean)

EXAMPLE III. ANALYSIS USING ARCSIN TRANSFORMATION

The arcsin transformation is used when the data represent proportions expressed either as decimal fractions or percentages. For the percentage data, the following rules are to be followed:

1. Only the percentage data derived from the ratio of count data (e.g. ratio of deadhearts, which is derived from the ratio of infested tillers to total number of tillers) should be transformed to arcsin values.
2. Percentage data in the 31-69% range need no transformation.
3. For percentage data in the 0-30% range or 70-100% range, but not both, square root transformation should be used.
4. For percentage data that do not follow 2 or 3, arcsin transformation should be used.
5. Substitute $\frac{1}{(4\,n)}$ for 0% values, and 100 - $\frac{1}{(4\,n)}$ for 100% values, where n is the number of units on which the percentage data were based (i.e. the denominator used in computing the percentages).

Illustration: The percentage of mortality of BPH on rice plants sprayed with different insecticides is presented in Table 5. In each plant, 20 insects are released and the percentage of survival is presented.

Number of units on which the % is arrived at = 20 insects. Thus, n = 20.

Substitute 0 with $\frac{1}{4\,n} = \frac{1}{(4 \times 20)} = \frac{1}{80} = 0.0125$

Substitute 100 with $100 - \frac{1}{4n} = 100 - \frac{1}{80} = 99.9875$

Table 5. Percentage of mortality of BPH on rice plants sprayed with different insecticides.

Treatment	Replication			
	I	II	III	IV
1	90	85	90	85
2	95	95	100	100
3	55	60	50	45
4	40	40	35	45
5	30	35	40	25
6	100	95	90	100
7	80	85	75	85
8	90	95	90	85
9	100	100	95	100
10	95	90	90	85
11	65	60	70	55
12	5	10	10	0

After substituting 0 and 100% values in Table 5, transform the percentages to arcsin values using Appendix A Table 11. The arcsin transformed data are presented in Table 6.

The arcsin transformed values can be analyzed as illustrated in Example 1.

Table 6. Arcsin transformed values of data in Table 5.

Treatment	Replication				Total	Mean
	I	II	III	IV		
1	71.56	67.21	71.56	67.21	277.54	69.39
2	77.08	77.08	89.29	89.29	332.74	83.19
3	47.87	50.77	45.00	42.13	185.77	46.44
4	39.23	39.23	35.87	42.13	156.46	39.12
5	33.21	35.87	39.23	30.00	138.31	34.58
6	89.29	77.08	71.56	89.29	327.22	81.81
7	63.44	67.21	60.00	67.21	257.86	64.47
8	71.56	77.08	71.56	67.21	287.41	71.85
9	89.29	89.29	77.08	89.29	344.95	86.24
10	77.08	71.56	71.56	67.21	287.41	71.85
11	53.73	50.77	56.79	47.87	209.16	52.29
12	12.92	18.44	18.44	0.63	50.43	12.61
Block total	726.26	721.59	707.94	699.47	2,855.26 (Grand total)	
Block mean	60.52	60.13	59.00	58.29		59.49 (Grand mean)

chapter 9

DATA REPORTING AND MAKING INSECT CONTROL RECOMMENDATIONS

In a successful insecticide evaluation program, data are promptly analyzed and the results formally reported to other researchers and to committees responsible for developing insect control recommendations.

The development of an insecticide from synthesis to marketing involves many steps.

1. Synthesis and formulation;
2. Tests for insecticidal activity in the chemical company's laboratory and insectary;
3. Determination of the mode of action and toxicological studies by the chemical company;
4. Laboratory, insectary, and field trials in international and national rice research programs;
5. Registration;
6. Production; and
7. Marketing.

Approximately 1 out of 10,000 synthesized compounds is suitable for practical use. Once a compound has been identified as having insecticidal activity in initial laboratory and insectary testing by the chemical company, toxicological and ecological studies are conducted. The compound is then made available to international agricultural centers such as IRRI and to national and provincial rice production programs for evaluation. A delay in the laboratory, insectary, and field tests, or in the summarization and data reporting of these tests lengthens the entire development period.

DATA REPORTING

Data resulting from insecticide evaluation tests should be summarized and interpreted, and reported yearly. The information is of value to chemical companies, researchers in other rice production programs, and committees responsible for making insect control recommendations.

Insecticide evaluation is a major step in the development of an insecticide by a chemical company. Compounds are thus generally supplied to many scientists working in different environmental regions. The performance of a chemical against various insect species in the worldwide testing program determines whether further development is justified. The industry depends on their collaborators for these results and thus a systematic method of reporting by collaborators should be followed.

Rapid communication among scientists in various countries helps speed the development of new compounds. National and provincial programs with limited funding for insecticide evaluation can select for testing only those compounds that have provided effective control in tests conducted in international centers or in other national or provincial programs that have a large insecticide evaluation program. Where land and financial resources are limiting factors, this is a much more effective use of resources than mass screening a large number of compounds annually. To facilitate communication among scientists, a report is necessary.

Committees responsible for rice insect control recommendations rely mostly on the reports of insecticide evaluation studies conducted in their region. Insect pest problems in rice are dynamic and their control methods constantly under review. Thus, relevant data must be provided to these review committees. There are various means of reporting the results of insecticide evaluation programs. Results are often presented in reports given at meetings. Oral reports supported by handouts are often used when an insecticide is submitted to a recommending body by a chemical company or a government scientist. An active insecticide evaluation program should publish reports of testing annually. This information is of value to the chemical company personnel who are monitoring the performance of their candidate insecticides on a diverse variety of crops and to entomologists in rice research programs. It is important to maintain a mailing list to facilitate distribution of the report.

The results of insecticide testing at IRRI are annually reported in the publication *Insecticide evaluation.* This publication contains a brief summary describing the major results and tables and figures giving the details of all tests conducted in a given year.

Some insecticide-testing data, especially those that provide new information on application methods, timing, formulations, etc., are worthy of publishing in scientific journals. A list of selected publications that publish such studies is given in Appendix B. The *Insecticide and acaricide tests,* a widely circulated publication of the Entomological Society of America, is an annual publication that reports on insecticide screening by entomologists in the USA and other countries and includes reports of tests against rice insects.

MAKING RECOMMENDATIONS

When recommendations are made for the first time, all available information on insecticide tests conducted in the region must be considered. If a review of this information reveals insufficient data on a certain pest, data from other countries or regions can be considered. It is not uncommon to *import* information when the research program in a country is newly established or when a new pest occurs in the country. In the latter case, data from its point of origin may be available.

In making recommendations for rice insect control, the insecticide recommendations must be considered in the broader sense of insect pest management. The chemical recommendations should be integrated with other control methods such as resistant varieties and cultural methods, and applications should be based on economic thresholds where such information is available.

The committee to review the performance of a candidate insecticide for inclusion in official recommendations should consist of members of the various research agencies involved in insecticide testing, a medical doctor, and extension personnel.

In determining whether a candidate insecticide should be recommended and in indicating how the chemical is to be used by the farmer, the committee must consider the following:

- Validity of the tests conducted;
- Efficacy against target pests;
- Effect on natural enemies, livestock, and fish;
- Human toxicity;
- Phytotoxicity;
- Compatibility with other pesticides;
- Cost;
- Formulations available; and
- Overall comparison with insecticides currently recommended.

Items to consider in determining the validity of the data are the experimental design (proper replications, etc.), number of tests and test sites, and the insect pressure. It is desirable to conduct field tests at 3 sites before recommending an insecticide. However, there are pests for which field testing methods have not been developed. In this case, it is necessary to rely on insectary studies if a recommendation must be made. Low insect populations are often a major handicap when field tests are conducted. Generally, numerous tests have to be conducted before reliable results can be obtained. Testing in diverse sites provides an opportunity to observe the performance of the chemical in various climatic regions and soil types. For example, rainfall and soil conditions can greatly affect the performance of granular formulations.

Of major importance is the efficacy of the insecticide against target pests. The candidate insecticide should be compared with a standard check so that the review committee has an understanding of its relative effectiveness. The recommendations must be made on a pest basis and the effect of the insecticide against each pest evaluated. Various dosages should be tested so that the committee may select the minimum effective dosage. Information on the relative toxicity to the target pests and predators and parasites, although difficult to obtain, is extremely useful in reviewing the acceptability of a candidate insecticide. Data on mammalian toxicity and toxicity to fish and livestock are provided by the company and are necessary considerations in making a recommendation. It must also be well established that the insecticide does not cause phytotoxicity and that it is compatible with recommended herbicides. Cost of the insecticide on an application basis may be considered but this factor is usually given little importance in making recommendations. If the cost prevents the commercial viability of an insecticide the company will not submit it for recommendation.

The insecticide must be available in formulations needed by the farmer. If the committee is looking for an insecticide that can be incorporated in the soil, a granular formulation of the chemical should be available for recommendation. The availability of proper application equipment at the farmer level must be considered. For example, if a ULV formulation is considered, ULV application equipment must be available to the farmer.

In light of the various factors mentioned, the overall comparison of the candidate insecticide with presently recommended insecticides should be determined. If ample effective insecticides for a given pest are already available, it may not be necessary to add another chemical to the list unless it has some distinct advantage.

Recommendations should be evaluated on an annual basis followed by a rapid publication and dissemination. The recommendations should include the common and trade names of the insecticides, rates and formulations that are effective against specific pests, cost/hectare per application, and time of application. Rapid dissemination of the recommendations to extension personnel for use by the farmer is of utmost importance.

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Appendices

Appendix A Table 1. Logarithms.

	0	1	2	3	4	5	6	7	8	9	1 2 3	4 5 6	7 8 9
10	0000	0043	0086	0128	0170						5 9 13	17 21 26	30 34 38
						0212	0253	0294	0334	0374	4 8 12	16 20 24	28 32 36
11	0414	0453	0492	0531	0569						4 8 12	16 20 23	27 31 35
						0607	0645	0682	0719	0755	4 7 11	15 18 22	26 29 33
12	0792	0828	0864	0899	0934						3 7 11	14 18 21	25 28 32
						0969	1004	1038	1072	1106	3 7 10	14 17 20	24 27 31
13	1139	1173	1206	1239	1271						3 6 10	13 16 19	23 26 29
						1303	1335	1367	1399	1430	3 7 10	13 16 19	22 25 29
14	1461	1492	1523	1553	1584						3 6 9	12 15 19	22 25 28
						1614	1644	1673	1703	1732	3 6 9	12 14 17	20 23 26
15	1761	1790	1818	1847	1875						3 6 9	11 14 17	20 23 26
						1903	1931	1959	1987	2014	3 6 8	11 14 17	19 22 25
16	2041	2068	2095	2122	2148						3 6 8	11 14 16	19 22 24
						2175	2201	2227	2253	2279	3 5 8	10 13 16	18 21 23
17	2304	2330	2355	2380	2405						3 5 8	10 13 15	18 20 23
						2430	2455	2480	2504	2529	3 5 8	10 12 15	17 20 22
18	2553	2577	2601	2625	2648						2 5 7	9 12 14	17 19 21
						2672	2695	2718	2742	2765	2 4 7	9 11 14	16 18 21
19	2788	2810	2833	2856	2878						2 4 7	9 11 13	16 18 20
						2900	2923	2945	2967	2989	2 4 6	8 11 13	15 17 19
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2 4 6	8 11 13	15 17 19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2 4 6	8 10 12	14 16 18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2 4 6	8 10 12	14 15 17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2 4 6	7 9 11	13 15 17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2 4 5	7 9 11	12 14 16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2 3 5	7 9 10	12 14 15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2 3 5	7 8 10	11 13 15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2 3 5	6 8 9	11 13 14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2 3 5	6 8 9	11 12 14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1 3 4	6 7 9	10 12 13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1 3 4	6 7 9	10 11 13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1 3 4	6 7 8	10 11 12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1 3 4	5 7 8	9 11 12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1 3 4	5 6 8	9 10 12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1 3 4	5 6 8	9 10 11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1 2 4	5 6 7	9 10 11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1 2 4	5 6 7	8 10 11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1 2 3	5 6 7	8 9 10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1 2 3	5 6 7	8 9 10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1 2 3	4 5 7	8 9 10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1 2 3	4 5 6	8 9 10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1 2 3	4 5 6	7 8 9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1 2 3	4 5 6	7 8 9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1 2 3	4 5 6	7 8 9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1 2 3	4 5 6	7 8 9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1 2 3	4 5 6	7 8 9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1 2 3	4 5 6	7 7 8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1 2 3	4 5 5	6 7 8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1 2 3	4 4 5	6 7 8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1 2 3	4 4 5	6 7 8

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Appendix A Table 1 continued

	0	1	2	3	4	5	6	7	8	9	123	456	789
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1 2 3	3 4 5	6 7 8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1 2 3	3 4 5	6 7 8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1 2 2	3 4 5	6 7 7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1 2 2	3 4 5	6 6 7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1 2 2	3 4 5	6 6 7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1 2 2	3 4 5	5 6 7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1 2 2	3 4 5	5 6 7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1 2 2	3 4 5	5 6 7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1 1 2	3 4 4	5 6 7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1 1 2	3 4 4	5 6 7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1 1 2	3 4 4	5 6 6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1 1 2	3 4 4	5 6 6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1 1 2	3 3 4	5 6 6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1 1 2	3 3 4	5 5 6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1 1 2	3 3 4	5 5 6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1 1 2	3 3 4	5 5 6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1 1 2	3 3 4	5 5 6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1 1 2	3 3 4	5 5 6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1 1 2	3 3 4	4 5 6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1 1 2	2 3 4	4 5 6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1 1 2	2 3 4	4 5 6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1 1 2	2 3 4	4 5 5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1 1 2	2 3 4	4 5 5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1 1 2	2 3 4	4 5 5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1 1 2	2 3 4	4 5 5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1 1 2	2 3 3	4 5 5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1 1 2	2 3 3	4 5 5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1 1 2	2 3 3	4 4 5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1 1 2	2 3 3	4 4 5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1 1 2	2 3 3	4 4 5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1 1 2	2 3 3	4 4 5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1 1 2	2 3 3	4 4 5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1 1 2	2 3 3	4 4 5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1 1 2	2 3 3	4 4 5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1 1 2	2 3 3	4 4 5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1 1 2	2 3 3	4 4 5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1 1 2	2 3 3	4 4 5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0 1 1	2 2 3	3 4 4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0 1 1	2 2 3	3 4 4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0 1 1	2 2 3	3 4 4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0 1 1	2 2 3	3 4 4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0 1 1	2 2 3	3 4 4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0 1 1	2 2 3	3 4 4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0 1 1	2 2 3	3 4 4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0 1 1	2 2 3	3 4 4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0 1 1	2 2 3	3 4 4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0 1 1	2 2 3	3 4 4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0 1 1	2 2 3	3 4 4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0 1 1	2 2 3	3 4 4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0 1 1	2 2 3	3 3 4

Source: Yarwood and Castle (1961).

Appendix A Table 2. Transformation of percentages to probits.

%	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	2	3	4	5
0	—	1.9098	2.1218	2.2522	2.3479	2.4242	2.4879	2.5427	2.5911	2.6344					
1	2.6737	2.7096	2.7429	2.7738	2.8027	2.8299	2.8556	2.8799	2.9031	2.9251					
2	2.9463	2.9665	2.9859	3.0046	3.0226	3.0400	3.0569	3.0732	3.0890	3.1043	For more detail see				
3	3.1192	3.1337	3.1478	3.1616	3.1750	3.1881	3.2009	3.2134	3.2256	3.2376	values for 95–100				
4	3.2493	3.2608	3.2721	3.2831	3.2940	3.3046	3.3151	3.3253	3.3354	3.3454					
5	3.3551	3.3648	3.3742	3.3836	3.3928	3.4018	3.4107	3.4195	3.4282	3.4368	9	18	27	36	45
6	3.4452	3.4536	3.4618	3.4699	3.4780	3.4859	3.4937	3.5015	3.5091	3.5167	8	16	24	32	40
7	3.5242	3.5316	3.5389	3.5462	3.5534	3.5605	3.5675	3.5745	3.5813	3.5882	7	14	21	28	36
8	3.5949	3.6016	3.6083	3.6148	3.6213	3.6278	3.6342	3.6405	3.6468	3.6531	6	13	19	26	32
9	3.6592	3.6654	3.6715	3.6775	3.6835	3.6894	3.6953	3.7012	3.7070	3.7127	6	12	18	24	30
10	3.7184	3.7241	3.7298	3.7354	3.7409	3.7464	3.7519	3.7574	3.7628	3.7681	6	11	17	22	28
11	3.7735	3.7788	3.7840	3.7893	3.7945	3.7996	3.8048	3.8099	3.8150	3.8200	5	10	16	21	26
12	3.8250	3.8300	3.8350	3.8399	3.8448	3.8497	3.8545	3.8593	3.8641	3.8689	5	10	15	20	24
13	3.8736	3.8783	3.8830	3.8877	3.8923	3.8969	3.9015	3.9061	3.9107	3.9152	5	9	14	18	23
14	3.9197	3.9242	3.9286	3.9331	3.9375	3.9419	3.9463	3.9506	3.9550	3.9593	4	9	13	18	22
15	3.9636	3.9678	3.9721	3.9763	3.9806	3.9848	3.9890	3.9931	3.9973	4.0014	4	8	13	17	21
16	4.0055	4.0096	4.0137	4.0178	4.0218	4.0259	4.0299	4.0339	4.0379	4.0419	4	8	12	16	20
17	4.0458	4.0498	4.0537	4.0576	4.0615	4.0654	4.0693	4.0731	4.0770	4.0808	4	8	12	16	19
18	4.0846	4.0884	4.0922	4.0960	4.0998	4.1035	4.1073	4.1110	4.1147	4.1184	4	8	11	15	19
19	4.1221	4.1258	4.1295	4.1331	4.1367	4.1404	4.1440	4.1476	4.1512	4.1548	4	7	11	15	18
20	4.1584	4.1619	4.1655	4.1690	4.1726	4.1761	4.1796	4.1831	4.1866	4.1901	4	7	11	14	18
21	4.1936	4.1970	4.2005	4.2039	4.2074	4.2108	4.2142	4.2176	4.2210	4.2244	3	7	10	14	17
22	4.2278	4.2312	4.2345	4.2379	4.2412	4.2446	4.2479	4.2512	4.2546	4.2579	3	7	10	13	17
23	4.2612	4.2644	4.2677	4.2710	4.2743	4.2775	4.2808	4.2840	4.2872	4.2905	3	7	10	13	16
24	4.2937	4.2969	4.3001	4.3033	4.3065	4.3097	4.3129	4.3160	4.3192	4.3224	3	6	10	13	16
25	4.3255	4.3287	4.3318	4.3349	4.3380	4.3412	4.3443	4.3474	4.3505	4.3536	3	6	9	12	16
26	4.3567	4.3597	4.3628	4.3659	4.3689	4.3720	4.3750	4.3781	4.3811	4.3842	3	6	9	12	15
27	4.3872	4.3902	4.3932	4.3962	4.3992	4.4022	4.4052	4.4082	4.4112	4.4142	3	6	9	12	15
28	4.4172	4.4201	4.4231	4.4260	4.4290	4.4319	4.4349	4.4378	4.4408	4.4437	3	6	9	12	15
29	4.4466	4.4495	4.4524	4.4554	4.4583	4.4612	4.4641	4.4670	4.4698	4.4727	3	6	9	12	14
30	4.4756	4.4785	4.4813	4.4842	4.4871	4.4899	4.4928	4.4956	4.4985	4.5013	3	6	9	11	14
31	4.5041	4.5070	4.5098	4.5126	4.5155	4.5183	4.5211	4.5239	4.5267	4.5295	3	6	8	11	14
32	4.5323	4.5351	4.5379	4.5407	4.5435	4.5462	4.5490	4.5518	4.5546	4.5573	3	6	8	11	14
33	4.5601	4.5628	4.5656	4.5684	4.5711	4.5739	4.5766	4.5793	4.5821	4.5848	3	5	8	11	14
34	4.5875	4.5903	4.5930	4.5957	4.5984	4.6011	4.6039	4.6066	4.6093	4.6120	3	5	8	11	14
35	4.6147	4.6174	4.6201	4.6228	4.6255	4.6281	4.6308	4.6335	4.6362	4.6389	3	5	8	11	13
36	4.6415	4.6442	4.6469	4.6495	4.6522	4.6549	4.6575	4.6602	4.6628	4.6655	3	5	8	11	13
37	4.6681	4.6708	4.6734	4.6761	4.6787	4.6814	4.6840	4.6866	4.6893	4.6919	3	5	8	11	13
38	4.6945	4.6971	4.6998	4.7024	4.7050	4.7076	4.7102	4.7129	4.7155	4.7181	3	5	8	10	13
39	4.7207	4.7233	4.7259	4.7285	4.7311	4.7337	4.7363	4.7389	4.7415	4.7441	3	5	8	10	13
40	4.7467	4.7492	4.7518	4.7544	4.7570	4.7596	4.7622	4.7647	4.7673	4.7699	3	5	8	10	13
41	4.7725	4.7750	4.7776	4.7802	4.7827	4.7853	4.7879	4.7904	4.7930	4.7955	3	5	8	10	13
42	4.7981	4.8007	4.8032	4.8058	4.8083	4.8109	4.8134	4.8160	4.8185	4.8211	3	5	8	10	13
43	4.8236	4.8262	4.8287	4.8313	4.8338	4.8363	4.8389	4.8414	4.8440	4.8465	3	5	8	10	13
44	4.8490	4.8516	4.8541	4.8566	4.8592	4.8617	4.8642	4.8668	4.8693	4.8718	3	5	8	10	13
45	4.8743	4.8769	4.8794	4.8819	4.8844	4.8870	4.8895	4.8920	4.8945	4.8970	3	5	8	10	13
46	4.8996	4.9021	4.9046	4.9071	4.9096	4.9122	4.9147	4.9172	4.9197	4.9222	3	5	8	10	13
47	4.9247	4.9272	4.9298	4.9323	4.9348	4.9373	4.9398	4.9423	4.9448	4.9473	3	5	8	10	13
48	4.9498	4.9524	4.9549	4.9574	4.9599	4.9624	4.9649	4.9674	4.9699	4.9724	3	5	8	10	13
49	4.9749	4.9774	4.9799	4.9825	4.9850	4.9875	4.9900	4.9925	4.9950	4.9975	3	5	8	10	13
50	5.0000	5.0025	5.0050	5.0075	5.0100	5.0125	5.0150	5.0175	5.0201	5.0226	3	5	8	10	13
51	5.0251	5.0276	5.0301	5.0326	5.0351	5.0376	5.0401	5.0426	5.0451	5.0476	3	5	8	10	13
52	5.0502	5.0527	5.0552	5.0577	5.0602	5.0627	5.0652	5.0677	5.0702	5.0728	3	5	8	10	13
53	5.0753	5.0778	5.0803	5.0828	5.0853	5.0878	5.0904	5.0929	5.0954	5.0979	3	5	8	10	13
54	5.1004	5.1030	5.1055	5.1080	5.1105	5.1130	5.1156	5.1181	5.1206	5.1231	3	5	8	10	13
55	5.1257	5.1282	5.1307	5.1332	5.1358	5.1383	5.1408	5.1434	5.1459	5.1484	3	5	8	10	13
56	5.1510	5.1535	5.1560	5.1586	5.1611	5.1637	5.1662	5.1687	5.1713	5.1738	3	5	8	10	13
57	5.1764	5.1789	5.1815	5.1840	5.1866	5.1891	5.1917	5.1942	5.1968	5.1993	3	5	8	10	13
58	5.2019	5.2045	5.2070	5.2096	5.2121	5.2147	5.2173	5.2198	5.2224	5.2250	3	5	8	10	13
59	5.2275	5.2301	5.2327	5.2353	5.2378	5.2404	5.2430	5.2456	5.2482	5.2508	3	5	8	10	13

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Appendix A Table 2 continued

%	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	2	3	4	5
60	5.2533	5.2559	5.2585	5.2611	5.2637	5.2663	5.2689	5.2715	5.2741	5.2767	3	5	8	10	13
61	5.2793	5.2819	5.2845	5.2871	5.2898	5.2924	5.2950	5.2976	5.3002	5.3029	3	5	8	10	13
62	5.3055	5.3081	5.3107	5.3134	5.3160	5.3186	5.3213	5.3239	5.3266	5.3292	3	5	8	11	13
63	5.3319	5.3345	5.3372	5.3398	5.3425	5.3451	5.3478	5.3505	5.3531	5.3558	3	5	8	11	13
64	5.3585	5.3611	5.3638	5.3665	5.3692	5.3719	5.3745	5.3772	5.3799	5.3826	3	5	8	11	13
65	5.3853	5.3880	5.3907	5.3934	5.3961	5.3989	5.4016	4.4043	5.4070	5.4097	3	5	8	11	14
66	5.4125	5.4152	5.4179	5.4207	5.4234	5.4261	5.4289	5.4316	5.4344	5.4372	3	5	8	11	14
67	5.4399	5.4427	5.4454	5.4482	5.4510	5.4538	5.4565	5.4593	5.4621	5.4649	3	6	8	11	14
68	5.4677	5.4705	5.4733	5.4761	5.4789	5.4817	5.4845	5.4874	5.4902	5.4930	3	6	8	11	14
69	5.4959	5.4987	5.5015	5.5044	5.5072	5.5101	5.5129	5.5158	5.5187	5.5215	3	6	9	11	14
70	5.5244	5.5273	5.5302	5.5330	5.5359	5.5388	5.5417	5.5446	5.5476	5.5505	3	6	9	12	14
71	5.5534	5.5563	5.5592	5.5622	5.5651	5.5681	5.5710	5.5740	5.5769	5.5799	3	6	9	12	15
72	5.5828	5.5858	5.5888	5.5918	5.5948	5.5978	5.6008	5.6038	5.6068	5.6098	3	6	9	12	15
73	5.6128	5.6158	5.6189	5.6219	5.6250	5.6280	5.6311	5.6341	5.6372	5.6403	3	6	9	12	15
74	5.6433	5.6464	5.6495	5.6526	5.6557	5.6588	5.6620	5.6651	5.6682	5.6713	3	6	9	12	16
75	5.6745	5.6776	5.6808	5.6840	5.6871	5.6903	5.6935	5.6967	5.6999	5.7031	3	6	10	13	16
76	5.7063	5.7095	5.7128	5.7160	5.7192	5.7225	5.7257	5.7290	5.7323	5.7356	3	7	10	13	16
77	5.7388	5.7421	5.7454	5.7488	5.7521	5.7554	5.7588	5.7621	5.7655	5.7688	3	7	10	13	17
78	5.7722	5.7756	5.7790	5.7824	5.7858	5.7892	5.7926	5.7961	5.7995	5.8030	3	7	10	14	17
79	5.8064	5.8099	5.8134	5.8169	5.8204	5.8239	5.8274	5.8310	5.8345	5.8381	4	7	11	14	18
80	5.8416	5.8452	5.8488	5.8524	5.8560	5.8596	5.8633	5.8669	5.8705	5.8742	4	7	11	14	18
81	5.8779	5.8816	5.8853	5.8890	5.8927	5.8965	5.9002	5.9040	5.9078	5.9116	4	7	11	15	19
82	5.9154	5.9192	5.9230	5.9269	5.9307	5.9346	5.9385	5.9424	5.9463	5.9502	4	8	12	15	19
83	5.9542	5.9581	5.9621	5.9661	5.9701	5.9741	5.9782	5.9822	5.9863	5.9904	4	8	12	16	20
84	5.9945	5.9986	6.0027	6.0069	6.0110	6.0152	6.0194	6.0237	6.0279	6.0322	4	8	13	17	21
85	6.0364	6.0407	6.0450	6.0494	6.0537	6.0581	6.0625	6.0669	6.0714	6.0758	4	9	13	18	22
86	6.0803	6.0848	6.0893	6.0939	6.0985	6.1031	6.1077	6.1123	6.1170	6.1217	5	9	14	18	23
87	6.1264	6.1311	6.1359	6.1407	6.1455	6.1503	6.1552	6.1601	6.1650	6.1700	5	10	15	19	24
88	6.1750	6.1800	6.1850	6.1901	6.1952	6.2004	6.2055	6.2107	6.2160	6.2212	5	10	15	21	26
89	6.2265	6.2319	6.2372	6.2426	6.2481	6.2536	6.2591	6.2646	6.2702	6.2759	5	11	16	22	27
90	6.2816	6.2873	6.2930	6.2988	6.3047	6.3106	6.3165	6.3225	6.3285	6.3346	6	12	18	24	29
91	6.3408	6.3469	6.3532	6.3595	6.3658	6.3722	6.3787	6.3852	6.3917	6.3984	6	13	19	26	32
92	6.4051	6.4118	6.4187	6.4255	6.4325	6.4395	6.4466	6.4538	6.4611	6.4684	7	14	21	28	35
93	6.4758	6.4833	6.4909	6.4985	6.5063	6.5141	6.5220	6.5301	6.5382	6.5464	8	16	24	31	39
94	6.5548	6.5632	6.5718	6.5805	6.5893	6.5982	6.6072	6.6164	6.6258	6.6352	9	18	27	36	45
95	6.6449	6.6546	6.6646	6.6747	6.6849	6.6954	6.7060	6.7169	6.7279	6.7392					
	97	100	101	102	105	106	109	110	113	115					
96	6.7507	6.7624	6.7744	6.7866	6.7991	6.8119	6.8250	6.8384	6.8522	6.8663					
	117	120	122	125	128	131	134	138	141	145					
97	6.8808	6.8957	6.9110	6.9268	6.9431	6.9600	6.9774	6.9954	7.0141	7.0335					
	149	153	158	163	169	174	180	187	194	202					
98.0	7.0537	7.0558	7.0579	7.0600	7.0621	7.0642	7.0663	7.0684	7.0706	7.0727	2	4	6	8	11
98.1	7.0749	7.0770	7.0792	7.0814	7.0836	7.0858	7.0880	7.0902	7.0924	7.0947	2	4	7	9	11
98.2	7.0969	7.0992	7.1015	7.1038	7.1061	7.1084	7.1107	7.1130	7.1154	7.1177	2	5	7	9	12
98.3	7.1201	7.1224	7.1248	7.1272	7.1297	7.1321	7.1345	7.1370	7.1394	7.1419	2	5	7	10	12
98.4	7.1444	7.1469	7.1494	7.1520	7.1545	7.1571	7.1596	7.1622	7.1648	7.1675	3	5	8	10	13
98.5	7.1701	7.1727	7.1754	7.1781	7.1808	7.1835	7.1862	7.1890	7.1917	7.1945	3	5	8	11	14
98.6	7.1973	7.2001	7.2029	7.2058	7.2086	7.2115	7.2144	7.2173	7.2203	7.2232	3	6	9	12	14
98.7	7.2262	7.2292	7.2322	7.2353	7.2383	7.2414	7.2445	7.2476	7.2508	7.2539	3	6	9	12	15
98.8	7.2571	7.2603	7.2636	7.2668	7.2701	7.2734	7.2768	7.2801	7.2835	7.2869	3	7	10	13	17
98.9	7.2904	7.2938	7.2973	7.3009	7.3044	7.3080	7.3116	7.3152	7.3189	7.3226	4	7	11	14	18
99.0	7.3263	7.3301	7.3339	7.3378	7.3416	7.3455	7.3495	7.3535	7.3575	7.3615	4	8	12	16	20
99.1	7.3656	7.3698	7.3739	7.3781	7.3824	7.3867	7.3911	7.3954	7.3999	7.4044	4	9	13	17	22
99.2	7.4089	7.4135	7.4181	7.4228	7.4276	7.4324	7.4372	7.4422	7.4471	7.4522	5	10	14	19	24
99.3	7.4573	7.4624	7.4677	7.4730	7.4783	7.4838	7.4893	7.4949	7.5006	7.5063	5	11	16	22	27
99.4	7.5121	7.5181	7.5241	7.5302	7.5364	7.5427	7.5491	7.5556	7.5622	7.5690	6	13	19	25	32
99.5	7.5758	7.5828	7.5899	7.5972	7.6045	7.6121	7.6197	7.6276	7.6356	7.6437					
99.6	7.6521	7.6606	7.6693	7.6783	7.6874	7.6968	7.7065	7.7164	7.7266	7.7370					
99.7	7.7478	7.7589	7.7703	7.7822	7.7944	7.8070	7.8202	7.8338	7.8480	7.8627					
99.8	7.8782	7.8943	7.9112	7.9290	7.9478	7.9677	7.9889	8.0115	8.0357	8.0618					
99.9	8.0902	8.1214	8.1559	8.1947	8.2389	8.2905	8.3528	8.4316	8.5401	8.7190					

I am indebted to Professor R. A. Fisher and Dr F. Yates, and also to Messrs Oliver and Boyd, Ltd. of Edinburgh, for permission to reprint Table I from Table IX of their book *Statistical Tables for Biological, Agricultural and Medical Research*.

Source: Finney (1971).

Appendix A Table 3. Weighting coefficient ($W = Z^2 / PQ$).

Y[a]	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	0.001	0.001	0.001	0.002	0.002	0.003	0.005	0.006	0.008	0.011
2	0.015	0.019	0.025	0.031	0.040	0.050	0.062	0.076	0.092	0.110
3	0.131	0.154	0.180	0.208	0.238	0.269	0.302	0.336	0.370	0.405
4	0.439	0.471	0.503	0.532	0.558	0.581	0.601	0.616	0.627	0.634
5	0.637	0.634	0.627	0.616	0.601	0.581	0.558	0.532	0.503	0.471
6	0.439	0.405	0.370	0.336	0.302	0.269	0.238	0.208	0.180	0.154
7	0.131	0.110	0.092	0.076	0.062	0.050	0.040	0.031	0.025	0.019
8	0.015	0.011	0.008	0.006	0.005	0.003	0.002	0.002	0.001	0.001

[a] Y =expected probit. Source: Finney (1962).

Appendix A Table 4. Working probits.

(Y = 2·0–2·9; 0–50% kill)

% kill	Expected probit, Y 2·0	2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9
0	1·695	1·787	1·877	1·967	2·057	2·146	2·234	2·321	2·408	2·494
1	3·951	3·467	3·141	2·927	2·793	2·716	2·681	2·674	2·690	2·721
2	6·207	5·147	4·404	3·886	3·529	3·287	3·127	3·027	·972	·949
3	8·463	6·827	5·667	4·846	4·265	·857	·574	·380	3·254	3·176
4	—	8·507	6·931	5·806	5·002	4·428	4·020	·733	·536	·403
5	—	—	8·194	6·765	·738	·998	·467	4·080	·818	·631
6	—	—	9·458	7·725	6·474	5·569	4·913	4·440	4·099	3·858
7	—	—	—	8·684	7·210	6·139	5·360	·793	·381	4·085
8	—	—	—	9·644	·946	·710	·806	5·146	·663	·313
9	—	—	—	—	8·683	7·280	6·253	·499	·945	·540
10	—	—	—	—	9·419	·851	·699	·852	5·227	·767
11	—	—	—	—	—	8·421	7·146	6·205	5·509	4·995
12	—	—	—	—	—	·992	·592	·558	·791	5·222
13	—	—	—	—	—	9·562	8·039	·911	6·073	·449
14	—	—	—	—	—	—	·486	7·264	·355	·677
15	—	—	—	—	—	—	·932	·617	·636	·904
16	—	—	—	—	—	—	9·379	7·970	6·918	6·132
17	—	—	—	—	—	—	·825	8·323	7·200	·359
18	—	—	—	—	—	—	—	·676	·482	·586
19	—	—	—	—	—	—	—	9·029	·764	·814
20	—	—	—	—	—	—	—	·382	8·046	7·041
21	—	—	—	—	—	—	—	9·735	8·328	7·268
22	—	—	—	—	—	—	—	—	·610	·496
23	—	—	—	—	—	—	—	—	·892	·723
24	—	—	—	—	—	—	—	—	9·173	·950
25	—	—	—	—	—	—	—	—	·455	8·178
26	—	—	—	—	—	—	—	—	9·737	8·405
27	—	—	—	—	—	—	—	—	—	·633
28	—	—	—	—	—	—	—	—	—	·860
29	—	—	—	—	—	—	—	—	—	9·087
30	—	—	—	—	—	—	—	—	—	·315
31	—	—	—	—	—	—	—	—	—	9·542
32	—	—	—	—	—	—	—	—	—	·769
33	—	—	—	—	—	—	—	—	—	·997
34	—	—	—	—	—	—	—	—	—	—
35	—	—	—	—	—	—	—	—	—	—

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Appendix A Table 4 continued

(Y = 3·0–3·9; 0–50 % kill)

% kill	Expected probit, Y 3·0	3·1	3·2	3·3	3·4	3·5	3·6	3·7	3·8	3·9
0	2·579	2·662	2·745	2·826	2·906	2·984	3·061	3·135	3·207	3·277
1	2·764	2·815	2·872	2·932	2·996	3·061	3·127	3·193	3·259	3·323
2	·949	·967	·998	3·039	3·086	·139	·194	·252	·310	·369
3	3·134	3·120	3·125	·145	·176	·216	·261	·310	·362	·415
4	·319	·272	·252	·251	·267	·293	·328	·369	·413	·461
5	·505	·424	·378	·358	·357	·370	·395	·427	·465	·507
6	3·690	3·577	3·505	3·464	3·447	3·447	3·461	3·485	3·516	3·553
7	·875	·729	·632	·570	·537	·525	·528	·544	·568	·599
8	4·060	·882	·758	·677	·627	·602	·595	·602	·619	·645
9	·246	4·034	·885	·783	·717	·679	·662	·660	·671	·690
10	·431	·186	4·012	·889	·808	·756	·728	·719	·722	·736
11	4·616	4·339	4·138	3·996	3·898	3·834	3·795	3·777	3·774	3·782
12	·801	·491	·265	4·102	·988	·911	·862	·835	·825	·828
13	·986	·644	·391	·208	4·078	·988	·929	·894	·877	·874
14	5·172	·796	·518	·315	·168	4·065	·996	·952	·928	·920
15	·357	·948	·645	·421	·258	·142	4·062	4·010	·980	·966
16	5·542	5·101	4·771	4·527	4·348	4·220	4·129	4·069	4·031	4·012
17	·727	·253	·898	·634	·439	·297	·196	·127	·083	·058
18	·913	·406	5·025	·740	·529	·374	·263	·185	·134	·104
19	6·098	·558	·151	·846	·619	·451	·330	·244	·186	·149
20	·283	·710	·278	·953	·709	·528	·396	·302	·237	·195
21	6·468	5·863	5·405	5·059	4·799	4·606	4·463	4·361	4·289	4·241
22	·653	6·015	·531	·165	·889	·683	·530	·419	·340	·287
23	·839	·168	·658	·272	·979	·760	·597	·477	·392	·333
24	7·024	·320	·785	·378	5·070	·837	·664	·536	·443	·379
25	·209	·472	·911	·484	160	·914	·730	·594	·495	·425
26	7·394	6·625	6·038	5·591	5·250	4·992	4·797	4·652	4·546	4·471
27	·580	·777	·165	·697	·340	5·069	·864	·711	·598	·517
28	·765	·930	·291	·803	·430	·146	·931	·769	·649	·563
29	·950	7·082	·418	·910	·520	·223	·997	·827	·701	·608
30	8·135	·234	·545	6·016	·610	·300	5·064	·886	·752	·654
31	8·320	7·387	6·671	6·122	5·701	5·378	5·131	4·944	4·804	4·700
32	·506	·539	·798	·229	·791	·455	·198	5·002	·855	·746
33	·691	·692	·925	·335	·881	·532	·265	·061	·907	·792
34	·876	·844	7·051	·441	·971	·609	·331	·119	·958	·838
35	9·061	·996	·178	·548	6·061	·687	·398	·177	5·010	·884
36	9·247	8·149	7·305	6·654	6·151	5·764	5·465	5·236	5·061	4·930
37	·432	·301	·431	·760	·242	·841	·532	·294	·113	·976
38	·617	·454	·558	·867	·332	·918	·599	·353	·164	5·022
39	·802	·606	·685	·973	·422	·995	·665	·411	·216	·068
40	·987	·758	·811	7·079	·512	6·073	·732	·469	·267	·113
41	—	8·911	7·938	7·186	6·602	6·150	5·799	5·528	5·319	5·159
42	—	9·063	8·065	·292	·692	·227	·866	·586	·370	·205
43	—	·216	·191	·398	·782	·304	·932	·644	·422	·251
44	—	·368	·318	·505	·873	·381	·999	·703	·473	·297
45	—	·520	·445	·611	·963	·459	6·066	·761	·525	·343
46	—	9·673	8·571	7·717	7·053	6·536	6·133	5·819	5·576	5·389
47	—	·825	·698	·824	·143	·613	·200	·878	·628	·435
48	—	·978	·825	·930	·233	·690	·266	·936	·679	·481
49	—	—	·951	8·036	·323	·767	·333	·994	·731	·527
50	—	—	9·078	·143	·414	·845	·400	6·053	·782	·572

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Appendix A Table 4 continued

(Y = 4·0–4·9; 0–50 % kill)

% kill	Expected probit, Y 4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9
0	3·344	3·408	3·469	3·525	3·577	3·624	3·664	3·698	3·724	3·741
1	3·386	3·446	3·503	3·557	3·607	3·652	3·691	3·724	3·750	3·766
2	·427	·487	·538	·589	·637	·680	·719	·751	·775	·791
3	·468	·521	·572	·621	·667	·709	·746	·777	·801	·816
4	·510	·559	·607	·653	·697	·737	·773	·803	·826	·841
5	·551	·596	·641	·685	·727	·766	·800	·829	·852	·867
6	3·592	3·634	3·676	3·717	3·757	3·794	3·827	3·856	3·878	3·892
7	·634	·671	·710	·749	·787	·822	·854	·882	·903	·917
8	·675	·709	·745	·781	·817	·851	·882	·908	·929	·942
9	·716	·747	·779	·813	·847	·879	·909	·934	·954	·967
10	·758	·784	·814	·845	·877	·908	·936	·960	·980	·993
11	3·799	3·822	3·848	3·877	3·907	3·936	3·963	3·987	4·005	4·018
12	·840	·859	·883	·909	·937	·964	·990	4·013	·031	·043
13	·882	·897	·917	·941	·967	·993	4·017	·039	·057	·068
14	·923	·934	·952	·973	·997	4·021	·044	·065	·082	·093
15	·964	·972	·986	4·005	4·027	·050	·072	·092	·108	·119
16	4·006	4·010	4·021	4·038	4·057	4·078	4·099	4·118	4·133	4·144
17	·047	·047	·056	·070	·087	·106	·126	·144	·159	·169
18	·088	·085	·090	·102	·117	·135	·153	·170	·184	·194
19	·130	·122	·125	·134	·147	·163	·180	·196	·210	·219
20	·171	·160	·159	·166	·177	·192	·207	·223	·236	·245
21	4·212	4·198	4·194	4·198	4·207	4·220	4·235	4·249	4·261	4·270
22	·253	·235	·228	·230	·237	·248	·262	·275	·287	·295
23	·295	·273	·263	·262	·267	·277	·289	·301	·312	·320
24	·336	·310	·297	·294	·297	·305	·316	·327	·338	·345
25	·377	·348	·332	·326	·327	·334	·343	·354	·363	·370
26	4·419	4·385	4·366	4·358	4·357	4·362	4·370	4·380	4·389	4·396
27	·460	·423	·401	·390	·387	·391	·397	·406	·415	·421
28	·501	·461	·435	·422	·417	·419	·425	·432	·440	·446
29	·543	·498	·470	·454	·447	·447	·452	·459	·466	·471
30	·584	·536	·504	·486	·477	·476	·479	·485	·491	·496
31	4·625	4·573	4·539	4·518	4·507	4·504	4·506	4·511	4·517	4·522
32	·667	·611	·573	·550	·537	·533	·533	·537	·542	·547
33	·708	·649	·608	·582	·567	·561	·560	·563	·568	·572
34	·749	·686	·642	·614	·597	·589	·588	·590	·594	·597
35	·791	·724	·677	·646	·627	·618	·615	·616	·619	·622
36	4·832	4·761	4·711	4·678	4·657	4·646	4·642	4·642	4·645	4·648
37	·873	·799	·746	·710	·687	·675	·669	·668	·670	·673
38	·915	·836	·780	·742	·717	·703	·696	·695	·696	·698
39	·956	·874	·815	·774	·747	·731	·723	·721	·721	·723
40	·997	·912	·849	·806	·777	·760	·750	·747	·747	·748
41	5·039	4·949	4·884	4·838	4·807	4·788	4·778	4·773	4·773	4·774
42	·080	·987	·918	·870	·837	·817	·805	·799	·798	·799
43	·121	5·024	·953	·902	·867	·845	·832	·826	·824	·824
44	·163	·062	·988	·934	·897	·873	·859	·852	·849	·849
45	·204	·099	5·022	·966	·927	·902	·886	·878	·875	·874
46	5·245	5·137	5·057	4·998	4·957	4·930	4·913	4·904	4·900	4·900
47	·287	·175	·091	5·030	·987	·959	·941	·931	·926	·925
48	·328	·212	·126	·062	5·017	·987	·968	·957	·952	·950
49	·369	·250	·160	·094	·047	5·015	·995	·983	·977	·975
50	·411	·287	·195	·126	·078	·044	5·022	5·009	5·003	5·000

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Appendix A Table 4 continued

($Y = 5{\cdot}0$–$5{\cdot}9$; 0–50 % kill)

% kill	5·0	5·1	5·2	5·3	5·4	5·5	5·6	5·7	5·8	5·9
	Expected probit, *Y*									
0	3·747	3·740	3·719	3·680	3·620	3·536	3·422	3·272	3·079	2·834
1	3·772	3·765	3·744	3·706	3·647	3·564	3·452	3·304	3·114	2·871
2	·797	·790	·770	·732	·675	·593	·482	·336	·148	·909
3	·822	·816	·795	·758	·702	·621	·512	·368	·183	·946
4	·847	·841	·821	·785	·729	·650	·542	·400	·217	·984
5	·872	·866	·846	·811	·756	·378	·572	·433	·252	3·021
6	3·897	3·891	3·872	3·837	3·783	3·706	3·602	3·465	3·287	3·059
7	·922	·916	·898	·863	·810	·735	·632	·497	·321	·097
8	·947	·942	·923	·890	·838	·763	·662	·529	·356	·134
9	·972	·967	·949	·916	·865	·792	·692	·561	·390	·172
10	·997	·992	·974	·942	·892	·820	·722	·593	·425	·209
11	4·022	4·017	4·000	3·968	3·919	3·848	3·752	3·625	3·459	3·247
12	·047	·042	·025	·994	·946	·877	·782	·657	·494	·284
13	·073	·068	·051	4·021	·973	·905	·812	·689	·528	·322
14	·098	·093	·077	·047	4·000	·934	·842	·721	·563	·360
15	·123	·118	·102	·073	·028	·962	·872	·753	·597	·397
16	4·148	4·143	4·128	4·099	4·055	3·990	3·902	3·785	3·632	3·435
17	·173	·168	·153	·126	·082	4·019	·932	·817	·666	·472
18	·198	·194	·179	·152	·109	·047	·962	·849	·701	·510
19	·223	·219	·204	·178	·136	·076	·992	·881	·735	·548
20	·248	·244	·230	·204	·163	·104	4·022	·913	·770	·585
21	4·273	4·269	4·256	4·230	4·191	4·132	4·052	3·945	3·804	3·623
22	·298	·294	·281	·257	·218	·161	·082	·977	·839	·660
23	·323	·320	·307	·283	·245	·189	·112	4·009	·873	·698
24	·348	·345	·332	·309	·272	·218	·142	·041	·908	·735
25	·373	·370	·358	·335	·299	·246	·172	·073	·942	·773
26	4·398	4·395	4·383	4·362	4·326	4·275	4·202	4·105	3·977	3·811
27	·423	·420	·409	·388	·353	·303	·232	·137	4·011	·848
28	·449	·445	·435	·414	·381	·331	·262	·169	·046	·886
29	·474	·471	·460	·440	·408	·360	·292	·201	·080	·923
30	·499	·496	·486	·466	·435	·388	·322	·233	·115	·961
31	4·524	4·521	4·511	4·493	4·462	4·417	4·352	4·265	4·149	3·999
32	·549	·546	·537	·519	·489	·445	·382	·297	·184	4·036
33	·574	·571	·563	·545	·516	·473	·412	·329	·219	·074
34	·599	·597	588	·571	·544	·502	·442	·361	·253	·111
35	·624	·622	·614	·598	·571	·530	·472	·393	·288	·149
36	4·649	4·647	4·639	4·624	4·598	4·559	4·502	4·425	4·322	4·186
37	·674	·672	·665	·650	·625	·587	·532	·457	·357	·224
38	·699	·697	·690	·676	·652	·615	·562	·489	·391	·262
39	·724	·723	·716	·702	·679	·644	·592	·521	·426	·299
40	·749	·748	·742	·729	·706	·672	·622	·553	·460	·337
41	4·774	4·773	4·767	4·755	4·734	4·701	4·652	4·585	4·495	4·374
42	·799	·798	·793	·781	·761	·729	·682	·617	·529	·412
43	·825	·823	·818	·807	·788	·757	·712	·649	·564	·450
44	·850	·849	·844	·833	·815	·786	·742	·682	·598	·487
45	·875	·874	·869	·860	·842	·814	·772	·714	·633	·525
46	4·900	4·899	4·895	4·886	4·869	4·843	4·802	4·746	4·667	4·562
47	·925	·924	·921	·912	·897	·871	·832	·778	·702	·600
48	·950	·949	·946	·938	·924	·899	·862	·810	·736	·637
49	·975	·975	·972	·965	·951	·928	·892	·842	·771	·675
50	5·000	5·000	·997	·991	·978	·956	·922	·874	·805	·713

Continued on next page

Appendix A Table 4 continued

($Y = 6{\cdot}0$–$6{\cdot}9$; 0–50 % kill)

% kill	Expected probit, Y 6·0	6·1	6·2	6·3	6·4	6·5	6·6	6·7	6·8	6·9
0	2·523	2·132	1·643	1·030	0·261	—	—	—	—	—
1	2·564	2·178	1·694	1·088	0·327	—	—	—	—	—
2	·606	·224	·746	·146	·394	—	—	—	—	—
3	·647	·270	·797	·205	·461	—	—	—	—	—
4	·688	·316	·849	·263	·528	—	—	—	—	—
5	·730	·362	·900	·321	·595	—	—	—	—	—
6	2·771	2·408	1·952	1·380	0·661	—	—	—	—	—
7	·812	·454	2·003	·438	·728	—	—	—	—	—
8	·854	·500	·055	·496	·795	—	—	—	—	—
9	·895	·546	·106	·555	·862	—	—	—	—	—
10	·936	·591	·158	·613	·928	0·067	—	—	—	—
11	2·978	2·637	2·209	1·671	0·995	0·144	—	—	—	—
12	3·019	·683	·261	·730	1·062	·221	—	—	—	—
13	·060	·729	·312	·788	·129	·299	—	—	—	—
14	·102	·775	·364	·846	·196	·376	—	—	—	—
15	·143	·821	·415	·905	·262	·453	—	—	—	—
16	3·184	2·867	2·467	1·963	1·329	0·530	—	—	—	—
17	·226	·913	·518	2·022	·396	·607	—	—	—	—
18	·267	·959	·570	·080	·463	·685	—	—	—	—
19	·308	3·005	·621	·138	·530	·762	—	—	—	—
20	·350	·050	·673	·197	·596	·839	—	—	—	—
21	3·391	3·096	2·724	2·255	1·663	0·916	—	—	—	—
22	·432	·142	·776	·313	·730	·993	0·062	—	—	—
23	·474	·188	·827	·372	·797	1·071	·152	—	—	—
24	·515	·234	·879	·430	·864	·148	·243	—	—	—
25	·556	·280	·930	·488	·930	·225	·333	—	—	—
26	3·598	3·326	2·982	2·547	1·997	1·302	0·423	—	—	—
27	·639	·372	3·033	·605	2·064	·379	·513	—	—	—
28	·680	·418	·085	·663	·131	·457	·603	—	—	—
29	·721	·464	·136	·722	·197	·534	·693	—	—	—
30	·763	·509	·188	·780	·264	·611	·784	—	—	—
31	3·804	3·555	3·239	2·838	2·331	1·688	0·874	—	—	—
32	·845	·601	·291	·897	·398	·766	·964	—	—	—
33	·887	·647	·342	·955	·465	·843	1·054	0·050	—	—
34	·928	·693	·394	3·014	·531	·920	·144	·156	—	—
35	·969	·739	·445	·072	·598	·997	·234	·262	—	—
36	4·011	3·785	3·497	3·130	2·665	2·074	1·324	0·369	—	—
37	·052	·831	·548	·189	·732	·152	·415	·475	—	—
38	·093	·877	·600	·247	·799	·229	·505	·581	—	—
39	·135	·923	·651	·305	·865	·306	·595	·688	—	—
40	·176	·969	·703	·364	·932	·383	·685	·794	—	—
41	4·217	4·014	3·754	3·422	2·999	2·460	1·775	0·900	—	—
42	·259	·060	·806	·480	3·066	·538	·865	1·007	—	—
43	·300	·106	·857	·539	·132	·615	·955	·113	0·035	—
44	·341	·152	·909	·597	·199	·692	2·046	·219	·162	—
45	·383	·198	·960	·655	·266	·769	·136	·326	·289	—
46	4·424	4·244	4·012	3·714	3·333	2·846	2·226	1·432	0·415	—
47	·465	·290	·063	·772	·400	·924	·316	·538	·542	—
48	·507	·336	·115	·830	·466	3·001	·406	·645	·669	—
49	·548	·382	·166	·889	·533	·078	·496	·751	·795	—
50	·589	·428	·218	·947	·600	·155	·586	·857	·922	—

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Appendix A Table 4 contlnued

(Y = 3·0–3·9; 51–100% kill)

% kill	3·0	3·1	3·2	3·3	3·4	3·5	3·6	3·7	3·8	3·9
	Expected probit, Y									
51	—	—	9·205	8·249	7·504	6·922	6·467	6·111	5·834	5·618
52	—	—	·331	·355	·594	·999	·534	·170	·885	·664
53	—	—	·458	·462	·684	7·076	·600	·228	·937	·710
54	—	—	·585	·568	·774	·154	·667	·286	·988	·756
55	—	—	·711	·674	·864	·231	·734	·345	6·040	·802
56	—	—	9·838	8·781	7·954	7·308	6·801	6·403	6·091	5·848
57	—	—	·965	·887	8·045	·385	·868	·461	·143	·894
58	—	—	—	·993	·135	·462	·934	·520	·194	·940
59	—	—	—	9·100	·225	·540	7·001	·578	·246	·986
60	—	—	—	·206	·315	·617	·068	·636	·297	6·031
61	—	—	—	9·312	8·405	7·694	7·135	6·695	6·349	6·077
62	—	—	—	·419	·495	·771	·201	·753	·400	·123
63	—	—	—	·525	·585	·848	·268	·811	·452	·169
64	—	—	—	·631	·676	·926	·335	·870	·503	·215
65	—	—	—	·738	·766	8·003	·402	·928	·555	·261
66	—	—	—	9·844	8·856	8·080	7·469	6·986	6·606	6·307
67	—	—	—	·950	·946	·157	·535	7·045	·658	·353
68	—	—	—	—	9·036	·234	·602	·103	·709	·399
69	—	—	—	—	·126	·312	·669	·162	·761	·445
70	—	—	—	—	·216	·389	·736	·220	·812	·491
71	—	—	—	—	9·307	8·466	7·803	7·278	6·864	6·536
72	—	—	—	—	·397	·543	·869	·337	·915	·582
73	—	—	—	—	·487	·621	·936	·395	·967	·628
74	—	—	—	—	·577	·698	8·003	·453	7·018	·674
75	—	—	—	—	·667	·775	·070	·512	·070	·720
76	—	—	—	—	9·757	8·852	8·136	7·570	7·121	6·766
77	—	—	—	—	·848	·929	·203	·628	·173	·812
78	—	—	—	—	·938	9·007	·270	·687	·224	·858
79	—	—	—	—	—	·084	·337	·745	·276	·904
80	—	—	—	—	—	·161	·404	·803	·327	·950
81	—	—	—	—	—	9·238	8·470	7·862	7·379	6·995
82	—	—	—	—	—	·315	·537	·920	·430	7·041
83	—	—	—	—	—	·393	·604	·978	·482	·087
84	—	—	—	—	—	·470	·671	8·037	·533	·133
85	—	—	—	—	—	·547	·738	·095	·585	·179
86	—	—	—	—	—	9·624	8·804	8·154	7·636	7·225
87	—	—	—	—	—	·701	·871	·212	·688	·271
88	—	—	—	—	—	·779	·938	·270	·739	·317
89	—	—	—	—	—	·856	9·005	·329	·791	·363
90	—	—	—	—	—	·933	·072	·387	·842	·409
91	—	—	—	—	—	—	9·138	8·445	7·894	7·454
92	—	—	—	—	—	—	·205	·504	·945	·500
93	—	—	—	—	—	—	·272	·562	·997	·546
94	—	—	—	—	—	—	·339	·620	8·048	·592
95	—	—	—	—	—	—	·405	·679	·100	·638
96	—	—	—	—	—	—	9·472	8·737	8·151	7·684
97	—	—	—	—	—	—	·539	·795	·203	·730
98	—	—	—	—	—	—	·606	·854	·254	·776
99	—	—	—	—	—	—	·673	·912	·306	·822
100	—	—	—	—	—	—	·739	·970	·357	·868

Continued on next page

Appendix A Table 4 continued

(*Y* = 4·0–4·9; 51–100% kill)

% kill	Expected probit, *Y* 4·0	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9
51	5·452	5·325	5·229	5·158	5·108	5·072	5·049	5·035	5·028	5·025
52	·493	·363	·264	·190	·138	·101	·076	·062	·054	·051
53	·535	·400	·298	·222	·168	·129	·103	·088	·079	·076
54	·576	·438	·333	·254	·198	·157	·131	·114	·105	·101
55	·617	·475	·367	·286	·228	·186	·158	·140	·131	·126
56	5·659	5·513	5·402	5·318	5·258	5·214	5·185	5·167	5·156	5·151
57	·700	·550	·436	·351	·288	·243	·212	·193	·182	·177
58	·741	·588	·471	·383	·318	·271	·239	·219	·207	·202
59	·783	·626	·505	·415	·348	·299	·266	·245	·233	·227
60	·824	·663	·540	·447	·378	·328	·294	·271	·258	·252
61	5·865	5·701	5·574	5·479	5·408	5·356	5·321	5·298	5·284	5·277
62	·907	·738	·609	·511	·438	·385	·348	·324	·310	·303
63	·948	·776	·643	·543	·468	·413	·375	·350	·335	·328
64	·989	·814	·678	·575	·498	·441	·402	·376	·361	·353
65	6·031	·851	·712	·607	·528	·470	·429	·402	·386	·378
66	6·072	5·889	5·747	5·639	5·558	5·498	5·456	5·429	5·412	5·403
67	·113	·926	·781	·671	·588	·527	·484	·455	·437	·429
68	·155	·964	·816	·703	·618	·555	·511	·481	·463	·454
69	·196	6·001	·851	·735	·648	·583	·538	·507	·489	·479
70	·237	·039	·885	·767	·678	·612	·565	·534	·514	·504
71	6·279	6·077	5·920	5·799	5·708	5·640	5·592	5·560	5·540	5·529
72	·320	·114	·954	·831	·738	·669	·619	·586	·565	·555
73	·361	·152	·989	·863	·768	·697	·647	·612	·591	·580
74	·402	·189	6·023	·895	·798	·725	·674	·638	·617	·605
75	·444	·227	·058	·927	·828	·754	·701	·665	·642	·630
76	6·485	6·265	6·092	5·959	5·858	5·782	5·728	5·691	5·668	5·655
77	·526	·302	·127	·991	·888	·811	·755	·717	·693	·680
78	·568	·340	·161	6·023	·918	·839	·782	·743	·719	·706
79	·609	·377	·196	·055	·948	·868	·809	·770	·744	·731
80	·650	·415	·230	·087	·978	·896	·837	·796	·770	·756
81	6·692	6·452	6·265	6·119	6·008	5·924	5·864	5·822	5·796	5·781
82	·733	·490	·299	·151	·038	·953	·891	·848	·821	·806
83	·774	·528	·334	·183	·068	·981	·918	·874	·847	·832
84	·816	·565	·368	·215	·098	6·010	·945	·901	·872	·857
85	·857	·603	·403	·247	·128	·038	·972	·927	·898	·882
86	6·898	6·640	6·437	6·279	6·158	6·066	6·000	5·953	5·923	5·907
87	·940	·678	·472	·311	·188	·095	·027	·979	·949	·932
88	·981	·716	·506	·343	·218	·123	·054	6·006	·975	·958
89	7·022	·753	·541	·375	·248	·152	·081	·032	6·000	·983
90	·064	·791	·575	·407	·278	·180	·108	·058	·026	6·008
91	7·105	6·828	6·610	6·439	6·308	6·208	6·135	6·084	6·051	6·033
92	·146	·866	·644	·471	·338	·237	·162	·110	·077	·058
93	·188	·903	·679	·503	·368	·265	·190	·137	·102	·084
94	·229	·941	·713	·535	·398	·294	·217	·163	·128	·109
95	·270	·979	·748	·567	·428	·322	·244	·189	·154	·134
96	7·312	7·016	6·783	6·600	6·458	6·350	6·271	6·215	6·179	6·159
97	·353	·054	·817	·632	·488	·379	·298	·242	·205	·184
98	·394	·091	·852	·664	·518	·407	·325	·268	·230	·210
99	·436	·129	·886	·696	·548	·436	·353	·294	·256	·235
100	·477	·166	·921	·728	·578	·464	·380	·320	·281	·260

Continued on opposite page

Appendix A Table 4 continued

($Y = 5{\cdot}0$–$5{\cdot}9$; 51–100% kill)

%	Expected probit, Y									
kill	5·0	5·1	5·2	5·3	5·4	5·5	5·6	5·7	5·8	5·9
51	5·025	5·025	5·023	5·017	5·005	4·985	4·953	4·906	4·840	4·750
52	·050	·050	·048	·043	·032	5·013	·983	·938	·874	·788
53	·075	·075	·074	·069	·059	·041	5·013	·970	·909	·825
54	·100	·100	·100	·096	·087	·070	·043	5·002	·943	·863
55	·125	·126	·125	·122	·114	·098	·073	·034	·978	·901
56	5·150	5·151	5·151	5·148	5·141	5·127	5·103	5·066	5·012	4·938
57	·175	·176	·176	·174	·168	·155	·133	·098	·047	·976
58	·201	·201	·202	·201	·195	·183	·163	·130	·082	5·013
59	·226	·226	·227	·227	·222	·212	·193	·162	·116	·051
60	·251	·252	·253	·253	·250	·240	·223	·194	·151	·088
61	5·276	5·277	5·279	5·279	5·277	5·269	5·253	5·226	5·185	5·126
62	·301	·302	·304	·305	·304	·297	·283	·258	·220	·164
63	·326	·327	·330	·332	·331	·325	·313	·290	·254	·201
64	·351	·352	·355	·358	·358	·354	·343	·322	·289	·239
65	·376	·378	·381	·384	·385	·382	·373	·354	·323	·276
66	5·401	5·403	5·406	5·410	5·412	5·411	5·403	5·386	5·358	5·314
67	·426	·428	·432	·437	·440	·439	·433	·418	·392	·351
68	·451	·453	·458	·463	·467	·467	·463	·450	·427	·389
69	·476	·478	·483	·489	·494	·496	·493	·482	·461	·427
70	·501	·504	·509	·515	·521	·524	·523	·514	·496	·464
71	5·526	5·529	5·534	5·541	5·548	5·553	5·553	5·546	5·530	5·502
72	·551	·554	·560	·568	·575	·581	·583	·578	·565	·539
73	·577	·579	·585	·594	·603	·609	·613	·610	·599	·577
74	·602	·604	·611	·620	·630	·638	·643	·642	·634	·615
75	·627	·630	·637	·646	·657	·666	·673	·674	·668	·652
76	5·652	5·655	5·662	5·673	5·684	5·695	5·703	5·706	5·703	5·690
77	·677	·680	·688	·699	·711	·723	·733	·738	·737	·727
78	·702	·705	·713	·725	·738	·752	·763	·770	·772	·765
79	·727	·730	·739	·751	·765	·780	·793	·802	·806	·802
80	·752	·755	·764	·777	·793	·808	·823	·834	·841	·840
81	5·777	5·781	5·790	5·804	5·820	5·837	5·853	5·866	5·875	5·878
82	·802	·806	·816	·830	·847	·865	·883	·898	·910	·915
83	·827	·831	·841	·856	·874	·894	·913	·930	·944	·953
84	·852	·856	·867	·882	·901	·922	·943	·962	·979	·990
85	·877	·881	·892	·908	·928	·950	·973	·995	6·014	6·028
86	5·902	5·907	5·918	5·935	5·956	5·979	6·003	6·027	6·048	6·066
87	·927	·932	·943	·961	·983	6·007	·033	·059	·083	·103
88	·953	·957	·969	·987	6·010	·036	·063	·091	·117	·141
89	·978	·982	·995	6·013	·037	·064	·093	·123	·152	·178
90	6·003	6·007	6·020	·040	·064	·092	·123	·155	·186	·216
91	6·028	6·033	6·046	6·066	6·091	6·121	6·153	6·187	6·221	6·253
92	·053	·058	·071	·092	·118	·149	·183	·219	·255	·291
93	·078	·083	·097	·118	·146	·178	·213	·251	·290	·329
94	·103	·108	·122	·144	·173	·206	·243	·283	·324	·366
95	·128	·133	·148	·171	·200	·234	·273	·315	·359	·404
96	6·153	6·159	6·174	6·197	6·227	6·263	6·303	6·347	6·393	6·441
97	·178	·184	·199	·223	·254	·291	·333	·379	·428	·479
98	·203	·209	·225	·249	·281	·320	·363	·411	·462	·517
99	·228	·234	·250	·276	·309	·348	·393	·443	·497	·554
100	·253	·259	·276	·302	·336	·376	·423	·475	·531	·592

Continued on next page

(Y = 6·0–6·9; 51–100% kill)

% kill	Expected probit, Y 6·0	6·1	6·2	6·3	6·4	6·5	6·6	6·7	6·8	6·9
51	4·631	4·473	4·269	4·006	3·667	3·233	2·677	1·964	1·049	—
52	·672	·519	·321	·064	·734	·310	·767	2·070	·175	0·022
53	·713	·565	·372	·122	·800	·387	·857	·176	·302	·175
54	·755	·611	·424	·181	·867	·464	·947	·283	·429	·327
55	·796	·657	·475	·239	·934	·541	3·037	·389	·555	·480
56	4·837	4·703	4·527	4·297	4·001	3·619	3·127	2·495	1·682	0·632
57	·879	·749	·578	·356	·068	·696	·218	·602	·809	·784
58	·920	·795	·630	·414	·134	·773	·308	·708	·935	·937
59	·961	·841	·681	·472	·201	·850	·398	·814	2·062	1·089
60	5·003	·887	·733	·531	·268	·927	·488	·921	·189	·242
61	5·044	4·932	4·784	4·589	4·335	4·005	3·578	3·027	2·315	1·394
62	·085	·978	·836	·647	·401	·082	·668	·133	·442	·546
63	·127	5·024	·887	·706	·468	·159	·758	·240	·569	·699
64	·168	·070	·939	·764	·535	·236	·849	·346	·695	·851
65	·209	·116	·990	·823	·602	·313	·939	·452	·822	2·004
66	5·251	5·162	5·042	4·881	4·669	4·391	4·029	3·559	2·949	2·156
67	·292	·208	·093	·939	·735	·468	·119	·665	3·075	·308
68	·333	·254	·145	·998	·802	·545	·209	·771	·202	·461
69	·375	·300	·196	5·056	·869	·622	·299	·878	·329	·613
70	·416	·346	·248	·114	·936	·700	·390	·984	·455	·766
71	5·457	5·392	5·299	5·173	5·003	4·777	4·480	4·090	3·582	2·918
72	·499	·437	·351	·231	·069	·854	·570	·197	·709	3·070
73	·540	·483	·402	·289	·136	·931	·660	·303	·835	·223
74	·581	·529	·454	·348	·203	5·008	·750	·409	·962	·375
75	·623	·575	·505	·406	·270	·086	·840	·516	4·089	·528
76	5·664	5·621	5·557	5·464	5·336	5·163	4·930	4·622	4·215	3·680
77	·705	·667	·608	·523	·403	·240	5·021	·728	·342	·832
78	·747	·713	·660	·581	·470	·317	·111	·835	·469	·985
79	·788	·759	·711	·639	·537	·394	·201	·941	·595	4·137
80	·829	·805	·763	·698	·604	·472	·291	5·047	·722	·290
81	5·870	5·851	5·814	5·756	5·670	5·549	5·381	5·154	4·849	4·442
82	·912	·896	·866	·815	·737	·626	·471	·260	·975	·594
83	·953	·942	·917	·873	·804	·703	·561	·366	5·102	·747
84	·994	·988	·969	·931	·871	·780	·652	·473	·229	·899
85	6·036	6·034	6·020	·990	·938	·858	·742	·579	·355	5·052
86	6·077	6·080	6·072	6·048	6·004	5·935	5·832	5·685	5·482	5·204
87	·118	·126	·123	·106	·071	6·012	·922	·792	·609	·356
88	·160	·172	·175	·165	·138	·089	6·012	·898	·735	·509
89	·201	·218	·226	·223	·205	·166	·102	6·004	·862	·661
90	·242	·264	·278	·281	·272	·244	·192	·111	·988	·814
91	6·284	6·310	6·329	6·340	6·338	6·321	6·283	6·217	6·115	5·966
92	·325	·355	·381	·398	·405	·398	·373	·323	·242	6·118
93	·366	·401	·432	·456	·472	·475	·463	·430	·368	·271
94	·408	·447	·484	·515	·539	·553	·553	·536	·495	·423
95	·449	·493	·535	·573	·605	·630	·643	·642	·622	·576
96	6·490	6·539	6·587	6·631	6·672	6·707	6·733	6·749	6·748	6·728
97	·532	·585	·638	·690	·739	·784	·824	·855	·875	·880
98	·573	·631	·690	·748	·806	·861	·914	·961	7·002	7·033
99	·614	·677	·741	·807	·873	·939	7·004	7·068	·128	·185
100	·656	·723	·793	·865	·939	7·016	·094	·174	·255	·338

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(Y = 7·0–7·9; 51–100 % kill)

% kill	Expected probit, Y 7·0	7·1	7·2	7·3	7·4	7·5	7·6	7·7	7·8	7·9
51	—	—	—	—	—	—	—	—	—	—
52	—	—	—	—	—	—	—	—	—	—
53	—	—	—	—	—	—	—	—	—	—
54	—	—	—	—	—	—	—	—	—	—
55	—	—	—	—	—	—	—	—	—	—
56	—	—	—	—	—	—	—	—	—	—
57	—	—	—	—	—	—	—	—	—	—
58	—	—	—	—	—	—	—	—	—	—
59	—	—	—	—	—	—	—	—	—	—
60	0·013	—	—	—	—	—	—	—	—	—
61	0·198	—	—	—	—	—	—	—	—	—
62	·383	—	—	—	—	—	—	—	—	—
63	·568	—	—	—	—	—	—	—	—	—
64	·753	—	—	—	—	—	—	—	—	—
65	·939	—	—	—	—	—	—	—	—	—
66	1·124	—	—	—	—	—	—	—	—	—
67	·309	0·003	—	—	—	—	—	—	—	—
68	·494	·231	—	—	—	—	—	—	—	—
69	·680	·458	—	—	—	—	—	—	—	—
70	·865	·685	—	—	—	—	—	—	—	—
71	2·050	0·913	—	—	—	—	—	—	—	—
72	·235	1·140	—	—	—	—	—	—	—	—
73	·420	·367	—	—	—	—	—	—	—	—
74	·606	·595	0·263	—	—	—	—	—	—	—
75	·791	·822	·545	—	—	—	—	—	—	—
76	2·976	2·050	0·827	—	—	—	—	—	—	—
77	3·161	·277	1·108	—	—	—	—	—	—	—
78	·347	·504	·390	—	—	—	—	—	—	—
79	·532	·732	·672	0·265	—	—	—	—	—	—
80	·717	·959	·954	·618	—	—	—	—	—	—
81	3·902	3·186	2·236	0·971	—	—	—	—	—	—
82	4·087	·414	·518	1·324	—	—	—	—	—	—
83	·273	·641	·800	·677	0·175	—	—	—	—	—
84	·458	·868	3·082	2·030	·621	—	—	—	—	—
85	·643	4·096	·364	·383	1·068	—	—	—	—	—
86	4·828	4·323	3·645	2·736	1·514	—	—	—	—	—
87	5·014	·551	·927	3·089	·961	0·438	—	—	—	—
88	·199	·778	4·209	·442	2·408	1·008	—	—	—	—
89	·384	5·005	·491	·795	·854	·579	—	—	—	—
90	·569	·233	·773	4·148	3·301	2·149	0·581	—	—	—
91	5·754	5·460	5·055	4·601	3·747	2·720	1·317	—	—	—
92	·940	·687	·337	·854	4·194	3·290	2·054	0·356	—	—
93	6·125	·915	·619	5·207	·640	·861	·790	1·316	—	—
94	·310	6·142	·901	·560	5·087	4·431	3·526	2·275	0·542	—
95	·495	·369	6·182	·914	·533	5·002	4·262	3·235	1·806	—
96	6·681	6·597	6·464	6·267	5·980	5·572	4·998	4·194	3·069	1·493
97	·866	·824	·746	·620	6·426	6·143	5·735	5·154	4·333	3·173
98	7·051	7·051	7·028	·973	·873	·713	6·471	6·114	5·596	4·853
99	·236	·279	·310	7·326	7·319	7·284	7·207	7·073	6·859	6·533
100	·421	·506	·592	·679	·766	·854	·943	8·033	8·123	8·213

Source: Finney (1962).

Appendix A Table 5. Minimum and maximum working probits and ranges.

Minimum working probits			Maximum working probits	
Expected probit Y	$y_0 = Y - P/Z$	Range $1/Z$	$y_{100} = Y + Q/Z$	Expected probit Y
1·1	0·8579	5034	9·1421	8·9
1·2	0·9522	3425	9·0478	8·8
1·3	1·0462	2354	8·9538	8·7
1·4	1·1400	1634	8·8600	8·6
1·5	1·2334	1146	8·7666	8·5
1·6	1·3266	811·5	8·6734	8·4
1·7	1·4194	580·5	8·5806	8·3
1·8	1·5118	419·4	8·4882	8·2
1·9	1·6038	306·1	8·3962	8·1
2·0	1·6954	225·6	8·3046	8·0
2·1	1·7866	168·00	8·2134	7·9
2·2	1·8772	126·34	8·1228	7·8
2·3	1·9673	95·96	8·0327	7·7
2·4	2·0568	73·62	7·9432	7·6
2·5	2·1457	57·05	7·8543	7·5
2·6	2·2339	44·654	7·7661	7·4
2·7	2·3214	35·302	7·6786	7·3
2·8	2·4081	28·189	7·5919	7·2
2·9	2·4938	22·736	7·5062	7·1
3·0	2·5786	18·5216	7·4214	7·0
3·1	2·6624	15·2402	7·3376	6·9
3·2	2·7449	12·6662	7·2551	6·8
3·3	2·8261	10·6327	7·1739	6·7
3·4	2·9060	9·0154	7·0940	6·6
3·5	2·9842	7·7210	7·0158	6·5
3·6	3·0606	6·6788	6·9394	6·4
3·7	3·1351	5·8354	6·8649	6·3
3·8	3·2074	5·1497	6·7926	6·2
3·9	3·2773	4·5903	6·7227	6·1
4·0	3·3443	4·1327	6·6557	6·0
4·1	3·4083	3·7582	6·5917	5·9
4·2	3·4687	3·4519	6·5313	5·8
4·3	3·5251	3·2025	6·4749	5·7
4·4	3·5770	3·0010	6·4230	5·6
4·5	3·6236	2·8404	6·3764	5·5
4·6	3·6643	2·7154	6·3357	5·4
4·7	3·6982	2·6220	6·3018	5·3
4·8	3·7241	2·5573	6·2759	5·2
4·9	3·7407	2·5192	6·2593	5·1
5·0	3·7467	2·5066	6·2533	5·0
5·1	3·7401	2·5192	6·2599	4·9
5·2	3·7186	2·5573	6·2814	4·8
5·3	3·6798	2·6220	6·3202	4·7
5·4	3·6203	2·7154	6·3797	4·6
5·5	3·5360	2·8404	6·4640	4·5
5·6	3·4220	3·0010	6·5780	4·4
5·7	3·2724	3·2025	6·7276	4·3
5·8	3·0794	3·4519	6·9206	4·2
5·9	2·8335	3·7582	7·1665	4·1
6·0	2·5230	4·1327	7·4770	4·0
6·1	2·1324	4·5903	7·8676	3·9
6·2	1·6429	5·1497	8·3571	3·8
6·3	1·0295	5·8354	8·9705	3·7
6·4	0·2606	6·6788	9·7394	3·6
6·5	−0·7052	7·7210	10·7052	3·5

The working probit, y, may be obtained as $y = (Y - P/Z) + p/Z$ or $y = (Y + Q/Z) - q/Z$, whichever is the more convenient, where $p(= 1 - q)$ is the observed proportion killed.

Source: Finney (1962).

Appendix A Table 6. Values of x^2.

df	Probability of a larger value of x^2				
	100	.050	.025	.010	.005
1	2.71	3.84	5.02	6.63	7.88
2	4.61	5.99	7.38	9.21	10.6
3	6.25	7.81	9.35	11.3	12.8
4	7.78	9.49	11.1	13.3	14.9
5	9.24	11.1	12.8	15.1	16.7
6	10.6	12.6	14.4	16.8	18.5
7	12.0	14.1	16.0	18.5	20.3
8	13.4	15.5	17.5	20.1	22.0
9	14.7	16.9	19.0	21.7	23.6
10	16.0	18 3	20.5	23.2	25.2
11	17.3	19.7	21.9	24.7	26.8
12	18.5	21.0	23.3	26.2	28.3
13	19.8	22.4	24.7	27.7	29.8
14	21.1	23.7	26.1	29.1	31.3
15	22.3	25.0	27.5	30.6	32.8
16	23.5	26.3	28.8	32.0	34.3
17	24.8	27.6	30.2	33.4	35.7
18	26.0	28.9	31.5	34.8	37.2
19	27.2	30.1	32.9	36.2	38.6
20	28.4	31.4	34.2	37.6	40.0
21	29.6	32.7	35 5	38.9	41.4
22	30.8	33.9	36.8	40.3	42.8
23	32.0	35.2	38.1	41.6	44.2
24	33.2	36.4	39.4	43.0	45.6
25	34.4	37.7	40.6	44.3	46.9
26	35.6	38.9	41.9	45.6	48.3
27	36.7	40.1	43.2	47.0	49.6
28	37.9	41.3	44.5	48.3	51.0
29	39.1	42.6	45.7	49.6	52.3
30	40.3	43.8	47.0	50.9	53.7
40	51.8	55.8	59.3	63.7	66.8
50	63.2	67.5	71.4	76.2	79.5
60	74.4	79.1	83.3	88.4	92.0

Adapted from Steel and Torrie (1960).

Appendix A Table 7. Antilogarithms.

	0	1	2	3	4	5	6	7	8	9	123	456	789
·00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0 0 1	1 1 1	2 2 2
·01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0 0 1	1 1 1	2 2 2
·02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0 0 1	1 1 1	2 2 2
·03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0 0 1	1 1 1	2 2 2
·04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0 1 1	1 1 2	2 2 2
·05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0 1 1	1 1 2	2 2 2
·06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0 1 1	1 1 2	2 2 2
·07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0 1 1	1 1 2	2 2 2
·08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0 1 1	1 1 2	2 2 3
·09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0 1 1	1 1 2	2 2 3
·10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0 1 1	1 1 2	2 2 3
·11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0 1 1	1 2 2	2 2 3
·12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0 1 1	1 2 2	2 2 3
·13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0 1 1	1 2 2	2 3 3
·14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0 1 1	1 2 2	2 3 3
·15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0 1 1	1 2 2	2 3 3
·16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0 1 1	1 2 2	2 3 3
·17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0 1 1	1 2 2	2 3 3
·18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0 1 1	1 2 2	2 3 3
·19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0 1 1	1 2 2	3 3 3
·20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0 1 1	1 2 2	3 3 3
·21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0 1 1	2 2 2	3 3 3
·22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0 1 1	2 2 2	3 3 3
·23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0 1 1	2 2 2	3 3 4
·24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0 1 1	2 2 2	3 3 4
·25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0 1 1	2 2 2	3 3 4
·26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0 1	2 2 3	3 3 4
·27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0 1 1	2 2 3	3 3 4
·28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0 1 1	2 2 3	3 4 4
·29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0 1 1	2 2 3	3 4 4
·30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0 1 1	2 2 3	3 4 4
·31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0 1 1	2 2 3	3 4 4
·32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0 1 1	2 2 3	3 4 4
·33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0 1 1	2 2 3	3 4 4
·34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1 1 2	2 3 3	4 4 5
·35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1 1 2	2 3 3	4 4 5
·36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1 1 2	2 3 3	4 4 5
·37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1 1 2	2 3 3	4 4 5
·38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1 1 2	2 3 3	4 4 5
·39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1 1 2	2 3 3	4 5 5
·40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1 1 2	2 3 4	4 5 5
·41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1 1 2	2 3 4	4 5 5
·42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1 1 2	2 3 4	4 5 6
·43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1 1 2	3 3 4	4 5 6
·44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1 1 2	3 3 4	4 5 6
·45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1 1 2	3 3 4	5 5 6
·46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1 1 2	3 3 4	5 5 6
·47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1 1 2	3 3 4	5 5 6
·48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1 1 2	3 4 4	5 6 6
·49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1 1 2	3 4 4	5 6 6

Continued on opposite page

Appendix A Table 7 continued

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
·50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
·51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
·52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
·53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
·54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
·55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
·56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
·57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
·58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
·59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
·60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
·61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
·62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
·63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
·64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
·65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
·66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
·67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
·68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
·69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6	7	8	9	10
·70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6	7	8	9	11
·71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
·72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
·73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
·74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
·75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
·76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
·77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
·78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
·79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
·80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
·81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
·82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
·83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
·84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
·85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8	10	12	13	15
·86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
·87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
·88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
·89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	5	7	9	11	13	14	16
·90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
·91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
·92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
·93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
·94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
·95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
·96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11	13	15	17	19
·97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
·98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
·99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20

Source: Yarwood and Castle (1961).

Appendix A Table 8. Values of *t*.

df	Probability of a larger value of *t*, sign ignored								
	0.5	0.4	0.3	0.2	0.1	0.05	0.02	0.01	0.001
1	1.000	1.376	1.963	3.078	6.314	12.706	31.821	63.657	636.619
2	.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	31.598
3	.765	.978	1.250	1.638	2.353	3.182	4.541	5.841	12.941
4	.741	.941	1.190	1.533	2.132	2.776	3.747	4.604	8.610
5	.727	.920	1.156	1.476	2.015	2.571	3.365	4.032	6.859
6	.718	.906	1.134	1.440	1.943	2.447	3.143	3.707	5.959
7	.711	.896	1.119	1.415	1.895	2.365	2.998	3.499	5.405
8	.706	.889	1.108	1.397	1.860	2.306	2.896	3.355	5.041
9	.703	.883	1.100	1.383	1.833	2.262	2.821	3.250	4.781
10	.700	.879	1.093	1.372	1.812	2.228	2.764	3.169	4.587
11	.697	.876	1.088	1.363	1.796	2.201	2.718	3.106	4.437
12	.695	.873	1.083	1.356	1.782	2.179	2.681	3.055	4.318
13	.694	.870	1.079	1.350	1.771	2.160	2.650	3.012	4.221
14	.692	.868	1.076	1.345	1.761	2.145	2.624	2.977	4.140
15	.691	.866	1.074	1.341	1.753	2.131	2.602	2.947	4.073
16	.690	.865	1.071	1.337	1.746	2.120	2.583	2.921	4.015
17	.689	.863	1.069	1.333	1.740	2.110	2.567	2.898	3.965
18	.688	.862	1.067	1.330	1.734	2.101	2.552	2.878	3.922
19	.688	.861	1.066	1.328	1.729	2.093	2.539	2.861	3.883
20	.687	.860	1.064	1.325	1.725	2.086	2.528	2.845	3.850
21	.686	.859	1.063	1.323	1.721	2.080	2.518	2.831	3.819
22	.686	.858	1.061	1.321	1.717	2.074	2.508	2.819	3.792
23	.685	.858	1.060	1.319	1.714	2.069	2.500	2.807	3.767
24	.685	.857	1.059	1.318	1.711	2.064	2.492	2.797	3.745
25	.684	.856	1.058	1.316	1.708	2.060	2.485	2.787	3.725
26	.684	.856	1.058	1.315	1.706	2.056	2.479	2.779	3.707
27	.684	.855	1.057	1.314	1.703	2.052	2.473	2.771	3.690
28	.683	.855	1.056	1.313	1.701	2.048	2.467	2.763	3.674
29	.683	.854	1.055	1.311	1.699	2.045	2.462	2.756	3.659
30	.683	.854	1.055	1.310	1.697	2.042	2.457	2.750	3.646
40	.681	.851	1.050	1.303	1.684	2.021	2.423	2.704	3.551
60	.679	.848	1.046	1.296	1.671	2.000	2.390	2.660	3.460
120	.677	.845	1.041	1.289	1.658	1.980	2.358	2.617	3.373
∞	.674	.842	1.036	1.282	1.645	1.960	2.326	2.576	3.291
	0.25	0.2	0.15	0.1	0.05	0.025	0.01	0.005	0.0005
df	Probability of a larger value of *t*, sign considered								

SOURCE: This table is abridged from Table III of Fisher and Yates, *Statisticaly Tables for Biological, Agricultural, and Medical Research,* published by Oliver and boyd Ltd., Edinburgh 1949, by permission of the authors and publisher

Source: Steel and Torrie (1960).

Appendix A Table 9. Distribution of *f*.

f_2	*f*. Degrees of freedom (for greater mean square)																								f_2
	1	2	3	4	5	6	7	8	9	10	11	12	14	16	20	24	30	40	50	75	100	200	500	∞	
1	161	200	216	225	230	234	237	239	241	242	243	244	245	246	248	249	250	251	252	253	253	254	254	254	1
	4,052	**4,999**	**5,403**	**5,625**	**5,764**	**5,859**	**5,928**	**5,981**	**6,022**	**6,056**	**6,082**	**6,106**	**6,142**	**6,169**	**6,208**	**6,234**	**6,261**	**6,286**	**6,302**	**6,323**	**6,334**	**6,352**	**6,361**	**6,366**	
2	18.51	19.00	19.16	19.25	19.30	19.33	19.36	19.37	19.38	19.39	19.40	19.41	19.42	19.43	19.44	19.45	19.46	19.47	19.47	19.48	19.49	19.49	19.50	19.50	2
	98.49	**99.00**	**99.17**	**99.25**	**99.30**	**99.33**	**99.36**	**99.37**	**99.39**	**99.40**	**99.41**	**99.42**	**99.43**	**99.44**	**99.45**	**99.46**	**99.47**	**99.48**	**99.48**	**99.49**	**99.49**	**99.49**	**99.50**	**99.50**	
3	10.13	9.55	9.28	9.12	9.01	8.94	8.88	8.84	8.81	8.78	8.76	8.74	8.71	8.69	8.66	8.64	8.62	8.60	8.58	8.57	8.56	8.54	8.54	8.53	3
	34.12	**30.82**	**29.46**	**28.71**	**28.24**	**27.91**	**27.67**	**27.49**	**27.34**	**27.23**	**27.13**	**27.05**	**26.92**	**26.83**	**26.69**	**26.60**	**26.50**	**26.41**	**26.35**	**26.27**	**26.23**	**26.18**	**26.14**	**26.12**	
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.93	5.91	5.87	5.84	5.80	5.77	5.74	5.71	5.70	5.68	5.66	5.65	5.64	5.63	4
	21.20	**18.00**	**16.69**	**15.98**	**15.52**	**15.21**	**14.98**	**14.80**	**14.66**	**14.54**	**14.45**	**14.37**	**14.24**	**14.15**	**14.02**	**13.93**	**13.83**	**13.74**	**13.69**	**13.61**	**13.57**	**13.52**	**13.48**	**13.46**	
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.78	4.74	4.70	4.68	4.64	4.60	4.56	4.53	4.50	4.46	4.44	4.42	4.40	4.38	4.37	4.36	5
	16.26	**13.27**	**12.06**	**11.39**	**10.97**	**10.67**	**10.45**	**10.29**	**10.15**	**10.05**	**9.96**	**9.89**	**9.77**	**9.68**	**9.55**	**9.47**	**9.38**	**9.29**	**9.24**	**9.17**	**9.13**	**9.07**	**9.04**	**9.02**	
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.03	4.00	3.96	3.92	3.87	3.84	3.81	3.77	3.75	3.72	3.71	3.69	3.68	3.67	6
	13.74	**10.92**	**9.78**	**9.15**	**8.75**	**8.47**	**8.26**	**8.10**	**7.98**	**7.87**	**7.79**	**7.72**	**7.60**	**7.52**	**7.39**	**7.31**	**7.23**	**7.14**	**7.09**	**7.02**	**6.99**	**6.94**	**6.90**	**6.88**	
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.63	3.60	3.57	3.52	3.49	3.44	3.41	3.38	3.34	3.32	3.29	3.28	3.25	3.24	3.23	7
	12.25	**9.55**	**8.45**	**7.85**	**7.46**	**7.19**	**7.00**	**6.84**	**6.71**	**6.62**	**6.54**	**6.47**	**6.35**	**6.27**	**6.15**	**6.07**	**5.98**	**5.90**	**5.85**	**5.78**	**5.75**	**5.70**	**5.67**	**5.65**	
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.34	3.31	3.28	3.23	3.20	3.15	3.12	3.08	3.05	3.03	3.00	2.98	2.96	2.94	2.93	8
	11.26	**8.65**	**7.59**	**7.01**	**6.63**	**6.37**	**6.19**	**6.03**	**5.91**	**5.82**	**5.74**	**5.67**	**5.56**	**5.48**	**5.36**	**5.28**	**5.20**	**5.11**	**5.06**	**5.00**	**4.96**	**4.91**	**4.88**	**4.86**	
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.13	3.10	3.07	3.02	2.98	2.93	2.90	2.86	2.82	2.80	2.77	2.76	2.73	2.72	2.71	9
	10.56	**8.02**	**6.99**	**6.42**	**6.06**	**5.80**	**5.62**	**5.47**	**5.35**	**5.26**	**5.18**	**5.11**	**5.00**	**4.92**	**4.80**	**4.73**	**4.64**	**4.56**	**4.51**	**4.45**	**4.41**	**4.36**	**4.33**	**4.31**	
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.97	2.94	2.91	2.86	2.82	2.77	2.74	2.70	2.67	2.64	2.61	2.59	2.56	2.55	2.54	10
	10.04	**7.56**	**6.55**	**5.99**	**5.64**	**5.39**	**5.21**	**5.06**	**4.95**	**4.85**	**4.78**	**4.71**	**4.60**	**4.52**	**4.41**	**4.33**	**4.25**	**4.17**	**4.12**	**4.05**	**4.01**	**3.96**	**3.93**	**3.91**	
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.86	2.82	2.79	2.74	2.70	2.65	2.61	2.57	2.53	2.50	2.47	2.45	2.42	2.41	2.40	11
	9.65	**7.20**	**6.22**	**5.67**	**5.32**	**5.07**	**4.88**	**4.74**	**4.63**	**4.54**	**4.46**	**4.40**	**4.29**	**4.21**	**4.10**	**4.02**	**3.94**	**3.86**	**3.80**	**3.74**	**3.70**	**3.66**	**3.62**	**3.60**	
12	4.75	3.88	3.49	3.26	3.11	3.00	2.92	2.85	2.80	2.76	2.72	2.69	2.64	2.60	2.54	2.50	2.46	2.42	2.40	2.36	2.35	2.32	2.31	2.30	12
	9.33	**6.93**	**5.95**	**5.41**	**5.06**	**4.82**	**4.65**	**4.50**	**4.39**	**4.30**	**4.22**	**4.16**	**4.05**	**3.98**	**3.86**	**3.78**	**3.70**	**3.61**	**3.56**	**3.49**	**3.46**	**3.41**	**3.38**	**3.36**	
13	4.67	3.80	3.41	3.18	3.02	2.92	2.84	2.77	2.72	2.67	2.63	2.60	2.55	2.51	2.46	2.42	2.38	2.34	2.32	2.28	2.26	2.24	2.22	2.21	13
	9.07	**6.70**	**5.74**	**5.20**	**4.86**	**4.62**	**4.44**	**4.30**	**4.19**	**4.10**	**4.02**	**3.96**	**3.85**	**3.78**	**3.67**	**3.59**	**3.51**	**3.42**	**3.37**	**3.30**	**3.27**	**3.21**	**3.18**	**3.16**	
14	4.60	3.74	3.34	3.11	2.96	2.85	2.77	2.70	2.65	2.60	2.56	2.53	2.48	2.44	2.39	2.35	2.31	2.27	2.24	2.21	2.19	2.16	2.14	2.13	14
	8.86	**6.51**	**5.56**	**5.03**	**4.69**	**4.46**	**4.28**	**4.14**	**4.03**	**3.94**	**3.86**	**3.80**	**3.70**	**3.62**	**3.51**	**3.43**	**3.34**	**3.26**	**3.21**	**3.14**	**3.11**	**3.06**	**3.02**	**3.00**	
15	4.54	3.68	3.29	3.06	2.90	2.79	2.70	2.64	2.59	2.55	2.51	2.48	2.43	2.39	2.33	2.29	2.25	2.21	2.18	2.15	2.12	2.10	2.08	2.07	15
	8.68	**6.36**	**5.42**	**4.89**	**4.56**	**4.32**	**4.14**	**4.00**	**3.89**	**3.80**	**3.73**	**3.67**	**3.56**	**3.48**	**3.36**	**3.29**	**3.20**	**3.12**	**3.07**	**3.00**	**2.97**	**2.92**	**2.89**	**2.87**	
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.45	2.42	2.37	2.33	2.28	2.24	2.20	2.16	2.13	2.09	2.07	2.04	2.02	2.01	16
	8.53	**6.23**	**5.29**	**4.77**	**4.44**	**4.20**	**4.03**	**3.89**	**3.78**	**3.69**	**3.61**	**3.55**	**3.45**	**3.37**	**3.25**	**3.18**	**3.10**	**3.01**	**2.96**	**2.98**	**2.86**	**2.80**	**2.77**	**2.75**	
17	4.45	3.59	3.20	2.96	2.81	2.70	2.62	2.55	2.50	2.45	2.41	2.38	2.33	2.29	2.23	2.19	2.15	2.11	2.08	2.04	2.02	1.99	1.97	1.96	17
	8.40	**6.11**	**5.18**	**4.67**	**4.34**	**4.10**	**3.93**	**3.79**	**3.68**	**3.59**	**3.52**	**3.45**	**3.35**	**3.27**	**3.16**	**3.08**	**3.00**	**2.92**	**2.86**	**2.79**	**2.76**	**2.70**	**2.67**	**2.65**	
18	4.41	3.55	3.16	2.93	2.77	3.66	2.58	2.51	2.46	2.41	2.37	2.34	2.29	2.25	2.19	2.15	2.11	2.07	2.04	2.00	1.98	1.95	1.93	1.92	18
	8.28	**6.01**	**5.09**	**4.58**	**4.25**	**4.01**	**3.85**	**3.71**	**3.60**	**3.51**	**3.44**	**3.37**	**3.27**	**3.19**	**3.07**	**3.00**	**2.91**	**2.83**	**2.78**	**2.71**	**2.68**	**2.62**	**2.59**	**2.57**	
19	4.38	3.52	3.13	2.90	2.74	2.63	2.55	2.48	2.43	2.38	2.34	2.31	2.26	2.21	2.15	2.11	2.07	2.02	2.00	1.96	1.94	1.91	1.90	1.88	19
	8.18	**5.93**	**5.01**	**4.50**	**4.17**	**3.94**	**3.77**	**3.63**	**3.52**	**3.43**	**3.36**	**3.30**	**3.19**	**3.12**	**3.00**	**2.92**	**2.84**	**2.76**	**2.70**	**2.63**	**2.60**	**2.54**	**2.51**	**2.49**	
20	4.35	3.49	3.10	2.87	2.71	2.60	2.52	2.45	2.40	2.35	2.31	2.28	2.23	2.18	2.12	2.08	2.04	1.99	1.96	1.92	1.90	1.87	1.85	1.84	20
	8.10	**5.85**	**4.94**	**4.43**	**4.10**	**3.87**	**3.71**	**3.56**	**3.45**	**3.37**	**3.30**	**3.23**	**3.13**	**3.05**	**2.94**	**2.86**	**2.77**	**2.69**	**2.63**	**2.56**	**2.53**	**2.47**	**2.44**	**2.42**	
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.28	2.25	2.20	2.15	2.09	2.05	2.00	1.96	1.93	1.89	1.87	1.84	1.82	1.81	21
	8.02	**5.78**	**4.87**	**4.37**	**4.04**	**3.81**	**3.65**	**3.51**	**3.40**	**3.31**	**3.24**	**3.17**	**3.07**	**2.99**	**2.88**	**2.80**	**2.72**	**2.63**	**2.58**	**2.51**	**2.47**	**2.42**	**2.38**	**2.36**	
22	4.30	3.44	3.05	2.82	2.66	2.55	2.47	2.40	2.35	2.30	2.26	2.23	2.18	2.13	2.07	2.03	1.98	1.93	1.91	1.87	1.84	1.81	1.80	1.78	22
	7.94	**5.72**	**4.82**	**4.31**	**3.99**	**3.76**	**3.59**	**3.45**	**3.35**	**3.26**	**3.18**	**3.12**	**3.02**	**2.94**	**2.83**	**2.75**	**2.67**	**2.58**	**2.53**	**2.46**	**2.42**	**2.37**	**2.33**	**2.31**	
23	4.28	3.42	3.03	2.80	2.64	2.53	2.45	2.38	2.32	2.28	2.24	2.20	2.14	2.10	2.04	2.00	1.96	1.91	1.88	1.84	1.82	1.79	1.77	1.76	23
	7.88	**5.66**	**4.76**	**4.26**	**3.94**	**3.71**	**3.54**	**3.41**	**3.30**	**3.21**	**3.14**	**3.07**	**2.97**	**2.89**	**2.78**	**2.70**	**2.62**	**2.53**	**2.48**	**2.41**	**2.37**	**2.32**	**2.28**	**2.26**	
24	4.26	3.40	3.01	2.78	2.62	2.51	2.43	2.36	2.30	2.26	2.22	2.18	2.13	2.09	2.02	1.98	1.94	1.89	1.86	1.82	1.80	1.76	1.74	1.73	24
	7.82	**5.61**	**4.72**	**4.22**	**3.90**	**3.67**	**3.50**	**3.36**	**3.25**	**3.17**	**3.09**	**3.03**	**2.93**	**2.85**	**2.74**	**2.66**	**2.58**	**2.49**	**2.44**	**2.36**	**2.33**	**2.27**	**2.23**	**2.21**	
25	4.24	3.38	2.99	2.76	2.60	2.49	2.41	2.34	2.28	2.24	2.20	2.16	2.11	2.06	2.00	1.96	1.92	1.87	1.84	1.80	1.77	1.74	1.72	1.71	25
	7.77	**5.57**	**4.68**	**4.18**	**3.86**	**3.63**	**3.46**	**3.32**	**3.21**	**3.13**	**3.05**	**2.99**	**2.89**	**2.81**	**2.70**	**2.62**	**2.54**	**2.45**	**2.40**	**2.32**	**2.29**	**2.23**	**2.19**	**2.17**	
26	4.22	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22	2.18	2.15	2.10	2.05	1.99	1.95	1.90	1.85	1.82	1.78	1.76	1.72	1.70	1.69	26
	7.72	**5.53**	**4.64**	**4.14**	**3.82**	**3.59**	**3.42**	**3.29**	**3.17**	**3.09**	**3.02**	**2.96**	**2.86**	**2.77**	**2.66**	**2.58**	**2.50**	**2.41**	**2.36**	**2.28**	**2.25**	**2.19**	**2.15**	**2.13**	

Continued on next page

Appendix A Table 9 continued

f_2	f_1 Degrees of freedom (for greater mean square)																								f_2
	1	2	3	4	5	6	7	8	9	10	11	12	14	16	20	24	30	40	50	75	100	200	500	∞	
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.30	2.25	2.20	2.16	2.13	2.08	2.03	1.97	1.93	1.88	1.84	1.80	1.76	1.74	1.71	1.68	1.67	27
	7.68	**5.49**	**4.60**	**4.11**	**3.79**	**3.56**	**3.39**	**3.26**	**3.14**	**3.06**	**2.98**	**2.93**	**2.83**	**2.74**	**2.63**	**2.55**	**2.47**	**2.38**	**2.33**	**2.25**	**2.21**	**2.16**	**2.12**	**2.10**	
28	4.20	3.34	2.95	2.71	2.56	2.44	2.36	2.29	2.24	2.19	2.15	2.12	2.06	2.02	1.96	1.91	1.87	1.81	1.78	1.75	1.72	1.69	1.67	1.65	28
	7.64	**5.45**	**4.57**	**4.07**	**3.76**	**3.53**	**3.36**	**3.23**	**3.11**	**3.03**	**2.95**	**2.90**	**2.80**	**2.71**	**2.60**	**2.52**	**2.44**	**2.35**	**2.30**	**2.22**	**2.18**	**2.13**	**2.09**	**2.06**	
29	4.18	3.33	2.93	2.70	2.54	2.43	2.35	2.28	2.22	2.18	2.14	2.10	2.05	2.00	1.94	1.90	1.85	1.80	1.77	1.73	1.71	1.68	1.65	1.64	29
	7.60	**5.42**	**4.54**	**4.04**	**3.73**	**3.50**	**3.33**	**3.20**	**3.08**	**3.00**	**2.92**	**2.87**	**2.77**	**2.68**	**2.57**	**2.49**	**2.41**	**2.32**	**2.27**	**2.19**	**2.15**	**2.10**	**2.06**	**2.03**	
30	4.17	3.32	2.92	2.69	2.53	2.42	2.34	2.27	2.21	2.16	2.12	2.09	2.04	1.99	1.93	1.89	1.84	1.79	1.76	1.72	1.69	1.66	1.64	1.62	30
	7.56	**5.39**	**4.51**	**4.02**	**3.70**	**3.47**	**3.30**	**3.17**	**3.06**	**2.98**	**2.90**	**2.84**	**2.74**	**2.66**	**2.55**	**2.47**	**2.38**	**2.29**	**2.24**	**2.16**	**2.13**	**2.07**	**2.03**	**2.01**	
32	4.15	3.30	2.90	2.67	2.51	2.40	2.32	2.25	2.19	2.14	2.10	2.07	2.02	1.97	1.91	1.86	1.82	1.76	1.74	1.69	1.67	1.64	1.61	1.59	32
	7.50	**5.34**	**4.46**	**3.97**	**3.66**	**3.42**	**3.25**	**3.12**	**3.01**	**2.94**	**2.86**	**2.80**	**2.70**	**2.62**	**2.51**	**2.42**	**2.34**	**2.25**	**2.20**	**2.12**	**2.08**	**2.02**	**1.98**	**1.96**	
34	4.13	3.28	2.88	2.65	2.49	2.38	2.30	2.23	2.17	2.12	2.08	2.05	2.00	1.95	1.89	1.84	1.80	1.74	1.71	1.67	1.64	1.61	1.59	1.57	34
	7.44	**5.29**	**4.42**	**3.93**	**3.61**	**3.38**	**3.21**	**3.08**	**2.97**	**2.89**	**2.82**	**2.76**	**2.66**	**2.58**	**2.47**	**2.38**	**2.30**	**2.21**	**2.15**	**2.08**	**2.04**	**1.98**	**1.94**	**1.91**	
36	4.11	3.26	2.86	2.63	2.48	2.36	2.28	2.21	2.15	2.10	2.06	2.03	1.98	1.93	1.87	1.82	1.78	1.72	1.69	1.65	1.62	1.59	1.56	1.55	36
	7.39	**5.25**	**4.38**	**3.89**	**3.58**	**3.35**	**3.18**	**3.04**	**2.94**	**2.86**	**2.78**	**2.72**	**2.62**	**2.54**	**2.43**	**2.35**	**2.26**	**2.17**	**2.12**	**2.04**	**2.00**	**1.94**	**1.90**	**1.87**	
38	4.10	3.25	2.85	2.62	2.46	2.35	2.26	2.19	2.14	2.09	2.05	2.02	1.96	1.92	1.85	1.80	1.76	1.71	1.67	1.63	1.60	1.57	1.54	1.53	38
	7.35	**5.21**	**4.34**	**3.86**	**3.54**	**3.32**	**3.15**	**3.02**	**2.91**	**2.82**	**2.75**	**2.69**	**2.59**	**2.51**	**2.40**	**2.32**	**2.22**	**2.14**	**2.08**	**2.00**	**1.97**	**1.90**	**1.86**	**1.84**	
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.07	2.04	2.00	1.95	1.90	1.84	1.79	1.74	1.69	1.66	1.61	1.59	1.55	1.53	1.51	40
	7.31	**5.18**	**4.31**	**3.83**	**3.51**	**3.29**	**3.12**	**2.99**	**2.88**	**2.80**	**2.73**	**2.66**	**2.56**	**2.49**	**2.37**	**2.29**	**2.20**	**2.11**	**2.05**	**1.97**	**1.94**	**1.88**	**1.84**	**1.81**	
42	4.07	3.22	2.83	2.59	2.44	2.32	2.24	2.17	2.11	2.06	2.02	1.99	1.94	1.89	1.82	1.78	1.73	1.68	1.64	1.60	1.57	1.54	1.51	1.49	42
	7.27	**5.15**	**4.29**	**3.80**	**3.49**	**3.26**	**3.10**	**2.96**	**2.86**	**2.77**	**2.70**	**2.64**	**2.54**	**2.46**	**2.35**	**2.26**	**2.17**	**2.08**	**2.02**	**1.94**	**1.91**	**1.85**	**1.80**	**1.78**	
44	4.06	3.21	2.82	2.58	2.43	2.31	2.23	2.16	2.10	2.05	2.01	1.98	1.92	1.88	1.81	1.76	1.72	1.66	1.63	1.58	1.56	1.52	1.50	1.48	44
	7.24	**5.12**	**4.26**	**3.78**	**3.46**	**3.24**	**3.07**	**2.94**	**2.84**	**2.75**	**2.68**	**2.62**	**2.52**	**2.44**	**2.32**	**2.24**	**2.15**	**2.06**	**2.00**	**1.92**	**1.88**	**1.82**	**1.78**	**1.75**	
46	4.05	3.20	2.81	2.57	2.42	2.30	2.22	2.14	2.09	2.04	2.00	1.97	1.91	1.87	1.80	1.75	1.71	1.65	1.62	1.57	1.54	1.51	1.48	1.46	46
	7.21	**5.10**	**4.24**	**3.76**	**3.44**	**3.22**	**3.05**	**2.92**	**2.82**	**2.73**	**2.66**	**2.60**	**2.50**	**2.42**	**2.30**	**2.22**	**2.13**	**2.04**	**1.98**	**1.90**	**1.86**	**1.80**	**1.76**	**1.72**	
48	4.04	3.19	2.80	2.56	2.41	2.30	2.21	2.14	2.08	2.03	1.99	1.96	1.90	1.86	1.79	1.74	1.70	1.64	1.61	1.56	1.53	1.50	1.47	1.45	48
	7.19	**5.08**	**4.22**	**3.74**	**3.42**	**3.20**	**3.04**	**2.90**	**2.80**	**2.71**	**2.64**	**2.58**	**2.48**	**2.40**	**2.28**	**2.20**	**2.11**	**2.02**	**1.96**	**1.88**	**1.84**	**1.78**	**1.73**	**1.70**	
50	4.03	3.18	2.79	2.56	2.40	2.29	2.20	2.13	2.07	2.02	1.98	1.95	1.90	1.85	1.78	1.74	1.69	1.63	1.60	1.55	1.52	1.48	1.46	1.44	50
	7.17	**5.06**	**4.20**	**3.72**	**3.41**	**3.18**	**3.02**	**2.88**	**2.78**	**2.70**	**2.62**	**2.56**	**2.46**	**2.39**	**2.26**	**2.18**	**2.10**	**2.00**	**1.94**	**1.86**	**1.82**	**1.76**	**1.71**	**1.68**	
55	4.02	3.17	2.78	2.54	2.38	2.27	2.18	2.11	2.05	2.00	1.97	1.93	1.88	1.83	1.76	1.72	1.67	1.61	1.58	1.52	1.50	1.46	1.43	1.41	55
	7.12	**5.01**	**4.16**	**3.68**	**3.37**	**3.15**	**2.98**	**2.85**	**2.75**	**2.66**	**2.59**	**2.53**	**2.43**	**2.35**	**2.23**	**2.15**	**2.06**	**1.96**	**1.90**	**1.82**	**1.78**	**1.71**	**1.66**	**1.64**	
60	4.00	3.15	2.76	2.52	2.37	2.25	2.17	2.10	2.04	1.99	1.95	1.92	1.86	1.81	1.75	1.70	1.65	1.59	1.56	1.50	1.48	1.44	1.41	1.39	60
	7.08	**4.98**	**4.13**	**3.65**	**3.34**	**3.12**	**2.95**	**2.82**	**2.72**	**2.63**	**2.56**	**2.50**	**2.40**	**2.32**	**2.20**	**2.12**	**2.03**	**1.93**	**1.87**	**1.79**	**1.74**	**1.68**	**1.63**	**1.60**	
65	3.99	3.14	2.75	2.51	2.36	2.24	2.15	2.08	2.02	1.98	1.94	1.90	1.85	1.80	1.73	1.68	1.63	1.57	1.54	1.49	1.46	1.42	1.39	1.37	65
	7.04	**4.95**	**4.10**	**3.62**	**3.31**	**3.09**	**2.93**	**2.79**	**2.70**	**2.61**	**2.54**	**2.47**	**2.37**	**2.30**	**2.18**	**2.09**	**2.00**	**1.90**	**1.84**	**1.76**	**1.71**	**1.64**	**1.60**	**1.56**	
70	3.98	3.13	2.74	2.50	2.35	2.23	2.14	2.07	2.01	1.97	1.93	1.89	1.84	1.79	1.72	1.67	1.62	1.56	1.53	1.47	1.45	1.40	1.37	1.35	70
	7.01	**4.92**	**4.08**	**3.60**	**3.29**	**3.07**	**2.91**	**2.77**	**2.67**	**2.59**	**2.51**	**2.45**	**2.35**	**2.28**	**2.15**	**2.07**	**1.98**	**1.88**	**1.82**	**1.74**	**1.69**	**1.62**	**1.56**	**1.53**	
80	3.96	3.11	2.72	2.48	2.33	2.21	2.12	2.05	1.99	1.95	1.91	1.88	1.82	1.77	1.70	1.65	1.60	1.54	1.51	1.45	1.42	1.38	1.35	1.32	80
	6.96	**4.88**	**4.04**	**3.56**	**3.25**	**3.04**	**2.87**	**2.74**	**2.64**	**2.55**	**2.48**	**2.41**	**2.32**	**2.24**	**2.11**	**2.03**	**1.94**	**1.84**	**1.78**	**1.70**	**1.65**	**1.57**	**1.52**	**1.49**	
100	3.94	3.09	2.70	2.46	2.30	2.19	2.10	2.03	1.97	1.92	1.88	1.85	1.79	1.75	1.68	1.63	1.57	1.51	1.48	1.42	1.39	1.34	1.30	1.28	100
	6.90	**4.82**	**3.98**	**3.51**	**3.20**	**2.99**	**2.82**	**2.69**	**2.59**	**2.51**	**2.43**	**2.36**	**2.26**	**2.19**	**2.06**	**1.98**	**1.89**	**1.79**	**1.73**	**1.64**	**1.59**	**1.51**	**1.46**	**1.43**	
125	3.92	3.07	2.68	2.44	2.29	2.17	2.08	2.01	1.95	1.90	1.86	1.83	1.77	1.72	1.65	1.60	1.55	1.49	1.45	1.39	1.36	1.31	1.27	1.25	125
	6.84	**4.78**	**3.94**	**3.47**	**3.17**	**2.95**	**2.79**	**2.65**	**2.56**	**2.47**	**2.40**	**2.33**	**2.23**	**2.15**	**2.03**	**1.94**	**1.85**	**1.75**	**1.68**	**1.59**	**1.54**	**1.46**	**1.40**	**1.37**	
150	3.91	3.06	2.67	2.43	2.27	2.16	2.07	2.00	1.94	1.89	1.85	1.82	1.76	1.71	1.64	1.59	1.54	1.47	1.44	1.37	1.34	1.29	1.25	1.22	150
	6.81	**4.75**	**3.91**	**3.44**	**3.14**	**2.92**	**2.76**	**2.62**	**2.53**	**2.44**	**2.37**	**2.30**	**2.20**	**2.12**	**2.00**	**1.91**	**1.83**	**1.72**	**1.66**	**1.56**	**1.51**	**1.43**	**1.37**	**1.33**	
200	3.89	3.04	2.65	2.41	2.26	2.14	2.05	1.98	1.92	1.87	1.83	1.80	1.74	1.69	1.62	1.57	1.52	1.45	1.42	1.35	1.32	1.26	1.22	1.19	200
	6.76	**4.71**	**3.88**	**3.41**	**3.11**	**2.90**	**2.73**	**2.60**	**2.50**	**2.41**	**2.34**	**2.28**	**2.17**	**2.09**	**1.97**	**1.88**	**1.79**	**1.69**	**1.62**	**1.53**	**1.48**	**1.39**	**1.33**	**1.28**	
400	3.86	3.02	2.62	2.39	2.23	2.12	2.03	1.96	1.90	1.85	1.81	1.78	1.72	1.67	1.60	1.54	1.49	1.42	1.38	1.32	1.28	1.22	1.16	1.13	400
	6.70	**4.66**	**3.83**	**3.36**	**3.06**	**2.85**	**2.69**	**2.55**	**2.46**	**2.37**	**2.29**	**2.23**	**2.12**	**2.04**	**1.92**	**1.84**	**1.74**	**1.64**	**1.57**	**1.47**	**1.42**	**1.32**	**1.24**	**1.19**	
1000	3.85	3.00	2.61	2.38	2.22	2.10	2.02	1.95	1.89	1.84	1.80	1.76	1.70	1.65	1.58	1.53	1.47	1.41	1.36	1.30	1.26	1.19	1.13	1.08	1000
	6.66	**4.62**	**3.80**	**3.34**	**3.04**	**2.82**	**2.66**	**2.53**	**2.43**	**2.34**	**2.26**	**2.20**	**2.09**	**2.01**	**1.89**	**1.81**	**1.71**	**1.61**	**1.54**	**1.44**	**1.38**	**1.28**	**1.19**	**1.11**	
∞	3.84	2.99	2.60	2.37	2.21	2.09	2.01	1.94	1.88	1.83	1.79	1.75	1.69	1.64	1.57	1.52	1.46	1.40	1.35	1.28	1.24	1.17	1.11	1.00	∞
	6.64	**4.60**	**3.78**	**3.32**	**3.02**	**2.80**	**2.64**	**2.51**	**2.41**	**2.32**	**2.24**	**2.18**	**2.07**	**1.99**	**1.87**	**1.79**	**1.69**	**1.59**	**1.52**	**1.41**	**1.36**	**1.25**	**1.15**	**1.00**	

Source: Gomez and Gomez (1976).

Appendix A Table 10. Significant studentized ranges for 5% and 1% level new multiple-range test.

Error *df*	Protection level	*p* = number of means for range being tested													
		2	3	4	5	6	7	8	9	10	12	14	16	18	20
1	.05	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	.01	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
2	.05	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09
	.01	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
3	.05	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
	.01	8.26	8.5	8.6	8.7	8.8	8.9	8.9	9.0	9.0	9.0	9.1	9.2	9.3	9.3
4	.05	3.93	4.01	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02
	.01	6.51	6.8	6.9	7.0	7.1	7.1	7.2	7.2	7.3	7.3	7.4	7.4	7.5	7.5
5	.05	3.64	3.74	3.79	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83
	.01	5.70	5.96	6.11	6.18	6.26	6.33	6.40	6.44	6.5	6.6	6.6	6.7	6.7	6.8
6	.05	3.46	3.58	3.64	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68
	.01	5.24	5.51	5.65	5.73	5.81	5.88	5.95	6.00	6.0	6.1	6.2	6.2	6.3	6.3
7	.05	3.35	3.47	3.54	3.58	3.60	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61
	.01	4.95	5.22	5.37	5.45	5.53	5.61	5.69	5.73	5.8	5.8	5.9	5.9	6.0	6.0
8	.05	3.26	3.39	3.47	3.52	3.55	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
	.01	4.74	5.00	5.14	5.23	5.32	5.40	5.47	5.51	5.5	5.6	5.7	5.7	5.8	5.8
9	.05	3.20	3.34	3.41	3.47	3.50	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
	.01	4.60	4.86	4.99	5.08	5.17	5.25	5.32	5.36	5.4	5.5	5.5	5.6	5.7	5.7
10	.05	3.15	3.30	3.37	3.43	3.46	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.48
	.01	4.48	4.73	4.88	4.96	5.06	5.13	5.20	5.24	5.28	5.36	5.42	5.48	5.54	5.55
11	.05	3.11	3.27	3.35	3.39	3.43	3.44	3.45	3.46	4.46	3.46	3.46	3.46	3.47	3.48
	.01	4.39	4.63	4.77	4.86	4.94	5.01	5.06	5.12	5.15	5.24	5.28	5.34	5.38	5.39
12	.05	3.08	3.23	3.33	3.36	3.40	3.42	3.44	3.44	3.46	3.46	3.46	3.46	3.47	3.48
	.01	4.32	4.55	4.68	4.76	4.84	4.92	4.96	5.02	5.07	5.13	5.17	5.22	5.24	5.26
13	.05	3.06	3.21	3.30	3.35	3.38	3.41	3.42	3.44	3.45	3.45	3.46	3.46	3.47	3.47
	.01	4.26	4.48	4.62	4.69	4.74	4.84	4.88	4.94	4.98	5.04	5.08	5.13	5.14	5.15
14	.05	3.03	3.18	3.27	3.33	3.37	3.39	3.41	3.42	3.44	3.45	3.46	3.46	3.47	3.47
	.01	4.21	4.42	4.55	4.63	4.70	4.78	4.83	4.87	4.91	4.96	5.00	5.04	5.06	5.07
15	.05	3.01	3.16	3.25	3.31	3.36	3.38	3.40	3.42	3.43	3.44	3.45	3.46	3.47	3.47
	.01	4.17	4.37	4.50	4.58	4.64	4.72	4.77	4.81	4.84	4.90	4.94	4.97	4.99	5.00
16	.05	3.00	3.15	3.23	3.30	3.34	3.37	3.39	3.41	3.43	3.44	3.45	3.46	3.47	3.47
	.01	4.13	4.34	4.45	4.54	4.60	4.67	4.72	4.76	4.79	4.84	4.88	4.91	4.93	4.94
17	.05	2.98	3.13	3.22	3.28	3.33	3.36	3.38	3.40	3.42	3.44	3.45	3.46	3.47	3.47
	.01	4.10	4.30	4.41	4.50	4.56	4.63	4.68	4.72	4.75	4.80	4.83	4.86	4.88	4.89
18	.05	2.97	3.12	3.21	3.27	3.32	3.35	3.37	3.39	3.41	3.43	3.45	3.46	3.47	3.47
	.01	4.07	4.27	4.38	4.46	4.53	4.59	4.64	4.68	4.71	4.76	4.79	4.82	4.84	4.85
19	.05	2.96	3.11	3.19	3.26	3.31	3.35	3.37	3.39	3.41	3.43	3.44	3.46	3.47	3.47
	.01	4.05	4.24	4.35	4.43	4.50	4.56	4.61	4.64	4.67	4.72	4.76	4.79	4.81	4.82
20	.05	2.95	3.10	3.18	3.25	3.30	3.34	3.36	3.38	3.40	3.43	3.44	3.46	3.46	3.47
	.01	4.02	4.22	4.33	4.40	4.47	4.53	4.58	4.61	4.65	4.69	4.73	4.76	4.78	4.79
22	.05	2.93	3.08	3.17	3.24	3.29	3.32	3.35	3.37	3.39	3.42	3.44	3.45	3.46	3.47
	.01	3.99	4.17	4.28	4.36	4.42	4.48	4.53	4.57	4.60	4.65	4.68	4.71	4.74	4.75
24	05	2.92	3.07	3.15	3.22	3.28	3.31	3.34	3.37	3.38	3.41	3.44	3.45	3.46	3.47
	.01	3.96	4.14	4.24	4.33	4.39	4.44	4.49	4.53	4.57	4.62	4.64	4.67	4.70	4.72
26	.05	2.91	3.06	3.14	3.21	3.27	3.30	3.34	3.36	3.38	3.41	3.43	3.45	3.46	3.47
	.01	3.93	4.11	4.21	4.30	4.36	4.41	4.46	4.50	4.53	4.58	4.62	4.65	4.67	4.69
28	.05	2.90	3.04	3.13	3.20	3.26	3.30	3.33	3.35	3.37	3.40	3.43	3.45	3.46	3.47
	.01	3.91	4.08	4.18	4.28	4.34	4.39	4.43	4.47	4.51	4.56	4.60	4.62	4.65	4.67
30	.05	2.89	3.04	3.12	3.20	3.25	3.29	3.32	3.35	3.37	3.40	3.43	3.44	3.46	3.47
	.01	3.89	4.06	4.16	4.22	4.32	4.36	4.41	4.45	4.48	4.54	4.58	4.61	4.63	4.65
40	.05	2.86	3.01	3.10	3.17	3.22	3.27	3.30	3.33	3.35	3.39	3.42	3.44	3.46	3.47
	.01	3.82	3.99	4.10	4.17	4.24	4.30	4.34	4.37	4.41	4.46	4.51	4.54	4.57	4.59
60	.05	2.83	2.98	3.08	3.14	3.20	3.24	3.28	3.31	3.33	3.37	3.40	3.43	3.45	3.47
	.01	3.76	3.92	4.03	4.12	4.17	4.23	4.27	4.31	4.34	4.39	4.44	4.47	4.50	4.53
100	.05	2.80	2.95	3.05	3.12	3.18	3.22	3.26	3.29	3.32	3.36	3.40	3.42	3.45	3.47
	.01	3.71	3.86	3.98	4.06	4.11	4.17	4.21	4.25	4.29	4.35	4.38	4.42	4.45	4.48
∞	.05	2.77	2.92	3.02	3.09	3.15	3.19	3.23	3.26	3.29	3.34	3.38	3.41	3.44	3.47
	.01	3.64	3.80	3.90	3.98	4.04	4.09	4.14	4.17	4.20	4.26	4.31	4.34	4.38	4.41

SOURCE: Abridged from D. B. Duncan, "Multiple range and multiple *F* tests," *Biometrics*, **11**: 1–42 (1955), with the permission of the editor and the author.

Source: Steel and Torrie (1960).

Appendix A Table 11. The arcsin $\sqrt{\text{percentage}}$ transformation.

Transformation of binomial percentages, in the margins, to angles of equal information in degrees. The + or - signs following angles ending in 5 are for guidance in rounding to one decimal.

%	0	1	2	3	4	5	6	7	8	9
0.0	0	0.57	0.81	0.99	1.15 –	1.28	1.40	1.52	1.62	1.72
0.1	1.81	1.90	1.99	2.07	2.14	2.22	2.29	2.36	2.43	2.50
0.2	2.56	2.63	2.69	2.75 –	2.81	2.87	2.92	2.98	3.03	3.09
0.3	3.14	3.19	3.24	3.29	3.34	3.39	3.44	3.49	3.53	3.58
0.4	3.63	3.67	3.72	3.76	3.80	3.85 –	3.89	3.93	3.97	4.01
0.5	4.05 +	4.09	4.13	4.17	4.21	4.25 +	4.29	4.33	4.37	4.40
0.6	4.44	4.48	4.52	4.55 +	4.59	4.62	4.66	4.69	4.73	4.76
0.7	4.80	4.83	4.87	4.90	4.93	4.97	5.00	5.03	5.07	5.10
0.8	5.13	5.16	5.20	5.23	5.26	5.29	5.32	5.35 +	5.38	5.41
0.9	5.44	5.47	5.50	5.53	5.56	5.59	5.62	5.65 +	5.68	5.71
1	5.74	6.02	6.29	6.55 –	6.80	7.04	7.27	7.49	7.71	7.92
2	8.13	8.33	8.53	8.72	8.91	9.10	9.28	9.46	9.63	9.81
3	9.98	10.14	10.31	10.47	10.63	10.78	10.94	11.09	11.24	11.39
4	11.54	11.68	11.83	11.97	12.11	12.25 –	12.39	12.52	12.66	12.79
5	12.92	13.05 +	13.18	13.31	13.44	13.56	13.69	13.81	13.94	14.06
6	14.18	14.30	14.42	14.54	14.65 +	14.77	14.89	15.00	15.12	15.23
7	15.34	15.45 +	15.56	15.68	15.79	15.89	16.00	16.11	16.22	16.32
8	16.43	16.54	16.64	16.74	16.85 –	16.95 +	17.05 +	17.16	17.26	17.36
9	17.46	17.56	17.66	17.76	17.85 +	17.95 +	18.05 –	18.15 –	18.24	18.34
10	18.44	18.53	18.63	18.72	18.81	18.91	19.00	19.09	19.19	19.28
11	19.37	19.46	19.55 +	19.64	19.73	19.82	19.91	20.00	20.09	20.18
12	20.27	20.36	20.44	20 53	20.62	20.70	20.79	20.88	20.96	21.05 –
13	21.13	21.22	21.30	21.39	21.47	21.56	21.64	21.72	21.81	21.89
14	21.97	22.06	22.14	22.22	22.30	22.38	22.46	22.55 –	22.63	22.71
15	22.79	22.87	22.95 –	23.03	23.11	23.19	23.26	23.34	23.42	23.50
16	23.58	23.66	23.73	23.81	23.89	23.97	24.04	24.12	24.20	24.27
17	24.35	24.43	24.50	24.58	24.65 +	24.73	24.80	24.88	24.95 +	25.03
18	25.10	25.18	25.25 +	25.33	25.40	25.48	25.55 –	25.62	25.70	25.77
19	25.84	25.92	25.99	26.06	26.13	26.21	26.28	26.35 –	26.42	26.49
20	26.56	26.64	26.71	26.78	26.85 +	26.92	26.99	27.06	27.13	27.20
21	27.28	27.35 –	27.42	27.49	27.56	27.63	27.69	27.76	27.83	27.90
22	27.97	28.04	28.11	28.18	28.25 –	28.32	28.38	28.45 +	28.52	28.59
23	28.66	28.73	28.79	28.86	28.93	29.00	29.06	29.13	29.20	29.27
24	29.33	29.40	29.47	29.53	29.60	29.67	29.73	29.80	29.87	29.93
25	30.00	30.07	30.13	30.20	30.26	30.33	30.40	30.46	30.53	30.59
26	30.66	30.72	30.79	30.85 +	30.92	30.98	31.05 –	31.11	31.18	31.24
27	31.31	31.37	31.44	31.50	31.56	31.63	31.69	31.76	31.82	31.88
28	31.95 –	32.01	32.08	32.14	32.20	32.27	32.33	32.39	32.46	32.52
29	32.58	32.65 –	32.71	32.77	32.83	32.90	32.96	33.02	33.09	33.15 –
30	33.21	33.27	33.34	33.40	33.46	33.52	33.58	33.65 –	33.71	33.77
31	33.83	33.89	33.96	34.02	34.08	34.14	34.20	34.27	34.33	34.39
32	34.45 –	34.51	34.57	34.63	34.70	34.76	34.82	34.88	34.94	35.00
33	35.06	35.12	35.18	35.24	35.30	35.37	35.43	35.49	35.55 –	35.61
34	35.67	35.73	35.79	35.85 –	35.91	35.97	36.03	36.09	36.15 +	36.21
35	36.27	36.33	36.39	36.45 +	36.51	36.57	36.63	36.69	36.75 +	36.81
36	36.87	36.93	36.99	37.05 –	37.11	37.17	37.23	37.29	37.35 –	37.41
37	37.47	37.52	37.58	37.64	37.70	37.76	37.82	37.88	37.94	38.00
38	38.06	38.12	38.17	38.23	38.29	38.35 +	38.41	38.47	38.53	38.59
39	38.65 –	38.70	38.76	38.82	38.88	38.94	39.00	39.06	39.11	39.17
40	39.23	39.29	39.35 –	39.41	39.47	39.52	39.58	39.64	39.70	39.76
41	39.82	39.87	39.93	39.99	40.05 –	40.11	40.16	40.22	40.28	40.34
42	40.40	40.46	40.51	40.57	40.63	40.69	40.74	40.80	40.86	40.92
43	40.98	41.03	41.09	41.15 –	41.21	41.27	41.32	41.38	41.44	41.50
44	41.55 +	41.61	41.67	41.73	41.78	41.84	41.90	41.96	42.02	42.07
45	42.13	42.19	42.25 –	42.30	42.36	42.42	42.48	42.53	42.59	42.65 –
46	42.71	42.76	42.82	42.88	42.94	42.99	43.05 –	43.11	43.17	43.22
47	43.28	43.34	43.39	43.45 +	43.51	43.57	43.62	43.68	43.74	43.80
48	43.85 +	43.91	43.97	44.03	44.08	44.14	44.20	44.25 +	44.31	44.37
49	44.43	44.48	44.54	44.60	44.66	44.71	44.77	44.83	44.89	44.94

SOURCE: This table appeared in *Plant Protection* (Leningrad), 121 67 (1937), and is reproduced with permission of the author, C. I. Bliss.

Continued on opposite page

Appendix A Table 11 continued

%	0	1	2	3	4	5	6	7	8	9
50	45.00	45.06	45.11	45.17	45.23	45.29	45.34	45.40	45.46	45.52
51	45.57	45.63	45.69	45.75 –	45.80	45.86	45.92	45.97	46.03	46.09
52	46.15 –	46.20	46.26	46.32	46.38	46.43	46.49	46.55 –	46.61	46.66
53	46.72	46.78	46.83	46.89	46.95 +	47.01	47.06	47.12	47.18	47.24
54	47.29	47.35 +	47.41	47.47	47.52	47.58	47.64	47.70	47.75 +	47.81
55	47.87	47.93	47.98	48.04	48.10	48.16	48.22	48.27	48.33	48.39
56	48.45 –	48.50	48.56	48.62	48.68	48.73	48.79	48.85 +	48.91	48.97
57	49.02	49.08	49.14	49.20	49.26	49.31	49.37	49.43	49.49	49.54
58	49.60	49.66	49.72	49.78	49.84	49.89	49.95 +	50.01	50.07	50.13
59	50.18	50.24	50.30	50.36	50.42	50.48	50.53	50.59	50.65 +	50.71
60	50.77	50.83	50.89	50.94	51.00	51.06	51.12	51.18	51.24	51.30
61	51.35 +	51.41	51.47	51.53	51.59	51.65 –	51.71	51.77	51.83	51.88
62	51.94	52.00	52.06	52.12	52.18	52.24	52.30	52.36	52.42	52.48
63	52.53	52.59	52.65 +	52.71	52.77	52.83	52.89	52.95 +	53.01	53.07
64	53.13	53.19	53.25 –	53.31	53.37	53.43	53.49	53.55 –	53.61	53.67
65	53.73	53.79	53.85 –	53.91	53.97	54.03	54.09	54.15 +	54.21	54.27
66	54.33	54.39	54.45 +	54.51	54.57	54.63	54.70	54.76	54.82	54.88
67	54.94	55.00	55.06	55.12	55.18	55.24	55.30	55.37	55.43	55.49
68	55.55 +	55.61	55.67	55.73	55.80	55.86	55.92	55.98	56.04	56.11
69	56.17	56.23	56.29	56.35 +	56.42	56.48	56.54	56.60	56.66	56.73
70	56.79	56.85 +	56.91	56.98	57.04	57.10	57.17	57.23	57.29	57.35 +
71	57.42	57.48	57.54	57.61	57.67	57.73	57.80	57.86	57.92	57.99
72	58.05 +	58.12	58.18	58.24	58.31	58.37	58.44	58.50	58.56	58.63
73	58.69	58.76	58.82	58.89	58.95 +	59.02	59.08	59.15 –	59.21	59.28
74	59.34	59.41	59.47	59.54	59.60	59.67	59.74	59.80	59.87	59.93
75	60.00	60.07	60.13	60.20	60.27	60.33	60.40	60.47	60.53	60.60
76	60.67	60.73	60.80	60.87	60.94	61.00	61.07	61.14	61.21	61.27
77	61.34	61.41	61.48	61.55 –	61.62	61.68	61.75 +	61.82	61.89	61.96
78	62.03	62.10	62.17	62.24	62.31	62.37	62.44	62.51	62.58	62.65 +
79	62.72	62.80	62.87	62.94	63.01	63.08	63.15 –	63.22	63.29	63.36
80	63.44	63.51	63.58	63.65 +	63.72	63.79	63.87	63.94	64.01	64.08
81	64.16	64.23	64.30	64.38	64.45 +	64.52	64.60	64.67	64.75 –	64.82
82	64.90	64.97	65.05 –	65.12	65.20	65.27	65.35 –	65.42	65.50	65.57
83	65.65 –	65.73	65.80	65.88	65.96	66.03	66.11	66.19	66.27	66.34
84	66.42	66.50	66.58	66.66	66.74	66.81	66.89	66.97	67.05 +	67.13
85	67.21	67.29	67.37	67.45 +	67.54	67.62	67.70	67.78	67.86	67.94
86	68.03	68.11	68.19	68.28	68.36	68.44	68.53	68.61	68.70	68.78
87	68.87	68.95 +	69.04	69.12	69.21	69.30	69.38	69.47	69.56	69.64
88	69.73	69.82	69.91	70.00	70.09	70.18	70.27	70.36	70.45 –	70.54
89	70.63	70.72	70.81	70.91	71.00	71.09	71.19	71.28	71.37	71.47
90	71.56	71.66	71.76	71.85 +	71.95 +	72.05 –	72.15 –	72.24	72.34	72.44
91	72.54	72.64	72.74	72.84	72.95 –	73.05 –	73.15 +	73.26	73.36	73.46
92	73.57	73.68	73.78	73.89	74.00	74.11	74.21	74.32	74.44	74.55 –
93	74.66	74.77	74.88	75.00	75.11	75.23	75.35 –	75.46	75.58	75.70
94	75.82	75.94	76.06	76.19	76.31	76.44	76.56	76.69	76.82	76.95 –
95	77.08	77.21	77.34	77.48	77.61	77.75 +	77.89	78.03	78.17	78.32
96	78.46	78.61	78.76	78.91	79.06	79.22	79.37	79.53	79.69	79.86
97	80.02	80.19	80.37	80.54	80.72	80.90	81.09	81.28	81.47	81.67
98	81.87	82.08	82.29	82.51	82.73	82.96	83.20	83.45 +	83.71	83.98
99.0	84.26	84.29	84.32	84.35 –	84.38	84.41	84.44	84.47	84.50	84.53
99.1	84.56	84.59	84.62	84.65 –	74.68	84.71	84.74	84.77	84.80	84.84
99.2	84.87	84.90	84.93	84.97	85.00	85.03	85.07	85.10	85.13	85.17
99.3	85.20	85.24	85.27	85.31	85.34	85.38	85.41	85.45 –	85.48	85.52
99.4	85.56	85.60	85.63	85.67	85.71	85.75 –	85.79	85.83	85.87	85.91
99.5	85.95 –	85.99	86.03	86.07	86.11	86.15 –	86.20	86.24	86.28	86.33
99.6	86.37	86.42	86.47	86.51	86.56	86.61	86.66	86.71	86.76	86.81
99.7	86.86	86.91	86.97	87.02	87.08	87.13	87.19	87.25 +	87.31	87.37
99.8	87.44	87.50	87.57	87.64	87.71	87.78	87.86	87.93	88.01	88.10
99.9	88.19	88.28	88.38	88.48	88.60	88.72	88.85 +	89.01	89.19	89.43
100.0	90.00									

Source: Steel and Torrie (1960).

Appendix A Table 12. Quantity of commercial liquid formulation of insecticide required for different recommended rates

Recommended rate (kg a.i./ha)	% a.i. in commercial formulation																		
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
	Quantity of commercial formulation required (liters or kg/ha)																		
0.05	0.500	0.333	0.250	0.200	0.166	0.143	0.125	0.111	0.100	0.091	0.083	0.077	0.071	0.067	0.063	0.059	0.056	0.053	0.05
0.1	1.000	0.667	0.500	0.400	0.333	0.286	0.250	0.222	0.200	0.182	0.167	0.154	0.143	0.133	0.125	0.118	0.111	0.105	0.10
0.2	2.000	1.333	1.000	0.800	0.667	0.571	0.500	0.444	0.400	0.364	0.333	0.308	0.286	0.267	0.250	0.235	0.222	0.211	0.20
0.3	3.000	2.000	1.500	1.200	1.000	0.857	0.750	0.667	0.600	0.545	0.500	0.462	0.429	0.400	0.375	0.353	0.333	0.316	0.30
0.4	4.000	2.666	2.000	1.600	1.333	1.143	1.000	0.889	0.800	0.727	0.667	0.615	0.571	0.533	0.500	0.471	0.444	0.421	0.40
0.5	5.000	3.333	2.500	2.000	1.667	1.429	1.250	1.112	1.000	0.909	0.833	0.769	0.714	0.667	0.625	0.588	0.556	0.526	0.50
0.6	6.000	4.000	3.000	2.400	2.000	1.174	1.500	1.334	1.200	1.091	1.000	0.923	0.857	0.800	0.750	0.706	0.667	0.632	0.60
0.7	7.000	4.667	3.500	2.800	2.333	2.000	1.750	1.556	1.400	1.273	1.167	1.077	1.000	0.933	0.875	0.824	0.778	0.737	0.70
0.8	8.000	5.333	4.000	3.200	2.667	2.286	2.000	1.778	1.600	1.455	1.333	1.231	1.142	1.067	1.000	0.941	0.889	0.842	0.80
0.9	9.000	6.000	4.500	3.600	3.000	2.571	2.250	2.000	1.800	1.636	1.500	1.385	1.286	1.200	1.125	1.059	1.000	0.947	0.90
1.0	10.000	6.667	5.000	4.000	3.333	2.857	2.500	2.222	2.000	1.818	1.667	1.538	1.429	1.333	1.250	1.176	1.111	1.053	1.00
2.0	20.000	13.333	10.000	8.000	6.667	5.714	5.000	4.444	4.000	3.636	3.333	3.077	2.857	2.667	2.500	2.353	2.222	2.105	2.00
3.0	30.000	20.000	15.000	12.000	10.000	8.571	7.500	6.667	6.000	5.455	5.000	4.615	4.286	4.000	3.750	3.529	3.333	3.158	3.00

a.i. = active ingtredient

Appendix A Table 13. Quantity of commercial granular formulation of insecticide required for different recommended rates.

Recommended rate (kg a.i./ha)	% a.i. in commercial formulation																
	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
	Quantity of commercial formulation required (kg/ha)																
0.1	5.000	4.000	3.333	2.857	2.500	2.222	2.000	1.818	1.667	1.538	1.429	1.333	1.250	1.176	1.111	1.053	1.000
0.2	10.000	8.000	6.667	5.714	5.000	4.444	4.000	3.636	3.333	3.077	2.857	2.667	2.500	2.353	2.222	2.105	2.000
0.3	15.000	12.000	10.000	8.571	7.500	6.667	6.000	5.455	5.000	4.615	4.286	4.000	3.750	3.529	3.333	3.158	3.000
0.4	20.000	16.000	13.333	11.429	10.000	8.889	8.000	7.273	6.667	6.154	5.714	5.333	5.000	4.706	4.444	4.211	4.000
0.5	25.000	20.000	16.667	14.286	12.500	11.111	10.000	9.091	8.333	7.692	7.143	6.667	6.250	5.882	5.556	5.263	5.000
0.75	37.500	30.000	25.000	21.429	18.750	16.667	15.000	13.636	12.500	11.538	10.714	10.000	9.375	8.826	8.826	7.895	7.500
1.00	50.000	40.000	33.333	28.571	25.000	22.222	20.000	18.181	16.667	15.385	14.286	13.333	12.500	11.765	11.111	10.530	10.000
1.5	75.000	60.000	50.000	42.857	37.500	33.333	30.000	27.273	25.000	23.077	21.429	20.000	18.750	17.647	16.667	15.789	15.000
1.75	87.500	70.000	58.333	50.000	43.750	38.890	35.000	31.818	29.167	26.923	25.000	23.333	21.875	20.588	19.444	18.421	17.500
2.00	100.000	80.000	66.667	57.143	50.000	44.444	40.000	36.364	33.333	30.769	28.571	26.667	25.000	23.529	22.222	21.053	20.000
2.50	125.000	100.000	83.333	71.429	62.500	55.556	50.000	45.455	41.667	38.462	35.714	33.333	31.250	29.412	27.778	26.316	25.000
3.00	150.000	120.000	100.000	85.714	75.000	66.667	60.000	54.545	50.000	46.154	42.857	40.000	37.500	35.294	33.333	31.579	30.000

a.i. = active ingredient.

Appendix A Table 14. Quantity of commercial formulation required for preparing different percentages of spray fluid. Calculations made at 500 liters of spray fluid/ha.

Recommended rate (% spray fluid)	% a.i. in commercial formulation																		
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
	Quantity of commercial formulation required (liters or kg/ha)																		
0.01	0.500	0.333	0.250	0.200	0.167	0.143	0.125	0.111	0.100	0.091	0.083	0.077	0.071	0.067	0.063	0.059	0.056	0.053	0.050
0.02	1.000	0.667	0.500	0.400	0.333	0.286	0.250	0.222	0.200	0.182	0.167	0.154	0.143	0.133	0.125	0.118	0.111	0.105	0.100
0.03	1.500	1.000	0.750	0.600	0.500	0.429	0.375	0.333	0.300	0.273	0.250	0.231	0.214	0.200	0.188	0.176	0.167	0.158	0.150
0.04	2.000	1.333	1.000	0.800	0.667	0.571	0.500	0.444	0.400	0.364	0.333	0.308	0.286	0.267	0.250	0.235	0.222	0.211	0.200
0.05	2.500	1.667	1.250	1.000	0.833	0.714	0.625	0.556	0.500	0.455	0.417	0.385	0.357	0.333	0.313	0.294	0.278	0.263	0.250
0.06	3.000	2.000	1.500	1.200	1.000	0.857	0.750	0.667	0.600	0.545	0.500	0.462	0.429	0.400	0.375	0.353	0.333	0.316	0.300
0.07	3.500	2.333	1.750	1.400	1.167	1.000	0.875	0.778	0.700	0.636	0.583	0.538	0.500	0.467	0.438	0.412	0.389	0.368	0.350
0.075	3.750	2.500	1.875	1.500	1.250	1.071	0.938	0.833	0.750	0.682	0.625	0.577	0.536	0.500	0.469	0.441	0.417	0.395	0.375
0.08	4.000	2.667	2.000	1.600	1.333	1.143	1.000	0.889	0.800	0.727	0.667	0.615	0.571	0.533	0.500	0.471	0.444	0.421	0.400
0.1	5.000	3.333	2.500	2.000	1.667	1.429	1.250	1.111	1.000	0.909	0.833	0.769	0.714	0.667	0.625	0.588	0.556	0.526	0.500
0.2	10.000	6.667	5.000	4.000	3.333	2.857	2.500	2.222	2.000	1.818	1.667	1.538	1.429	1.333	1.250	1.176	1.111	1.053	1.000

a.i. = active ingredient.

Appendix A Table 15. Common equivalents and conversion factors.[a]

Approximate common equivalents		Conversions accurate to parts per million[b]	
1 inch	= 25 millimeters	inches × 25.4*	= millimeters
1 foot	= 0.3 meter	feet × 0.3048*	= meters
1 yard	= 0.9 meter	yards × 0.9144*	= meters
1 mile	= 1.6 kilometers	miles × 1.609 34	= kilometers
1 sq inch	= 6.5 sq centimeters	sq in × 6.451 6*	= sq centimeters
1 sq foot	= 0.09 sq meter	sq ft × 0.092 903	= sq meters
1 sq yard	= 0.8 sq meter	sq yards × 0.836 127	= sq meters
1 acre	= 0.4 hectare	acres × 0.404 686	= hectares
1 cu inch	= 16 cu centimeters	cu inches × 16.3871	= cu centimeters
1 cu foot	= 0.03 cu meter	cu feet × 0.028 31 6	= cu meters
1 cu yard	= 0.8 cu meter	cu yards × 0.764 555	= cu meters
1 quart	= 1 liter	quarts (1 g) × 0.946 353	= liters
1 gallon	= 0.004 cu meter	gallons × 0.003 785 41	= cu meters
1 ounce (avdp)	= 28 grams	ounces (avdp) × 28 3495	= grams
1 pound (avdp)	= 0.45 kilogram	pounds (avdp) × 0.453 592	= kilograms
1 millimeter	= 0.04 Inch	millimeters × 0.039 370 1	= inches
1 meter	= 3.3 feet	meters × 3.280 84	= feet
1 meter	= 1.1 yards	meters × 1.093 61	= yards
1 kilometer	= 0.6 mile	kilometers × 0.621 371	= miles
1 sq centimeter	= 0.1 6 sq Inch	sq centimeters × 0.155 000	= sq inches
1 sq meter	= 11 sq feet	sq meters × 10.7639	= sq feet
1 sq meter	= 1.2 sq yards	sq meters × 1.95 99	= sq yards
1 hectare	= 2.5 acres	hectares × 2.471 05	= acres
1 cu centimeter	= 0.06 cu inch	cu centimeter × 0.061 207 7	= cu inches
1 cu meter	= 1.3 cu yards	cu meters × 1.307 95	= cu yards
1 cu meter	= 35 cu feet	cu meters × 35.3147	= cu feet
1 liter	= 1 quart	liters × 1.056 69	= quarts
1 cu meter	= 250 gallons	cu meters × 264.1 72	= gallons
1 gram	= 0.035 ounce	grams × 0.035 274 0	= ounces
1 kilogram	= 2.2 pounds	kilograms × 2.204 62	= pounds
1 ton	= 1.016 047 metric tons or 1,016.0470 kilograms		

[a] United States Department of Commerce, National Bureau of Standards (1970). [b] * = exact.

Appendix B. Selected publications that report studies on rice insecticides.

Bangladesh

Bangladesh Journal of Agricultural Sciences
Bangladesh Rice Research Institute (BRRI) Annual Report
Bangladesh Rice Research Institute (BRRI), Miscellaneous Activities of the Entomology Division

Brazil

Agronomia Sulriograndense
Anais da Sociedade Entomologica Brasileira
Pesquisa Agropecuaria Brasileira

Britain

Bulletin of Entomological Research

China

Acta Entomologica Sinica
Pesticide Science
Journal of South China Agricultural College — Kwangchou
Entomological Knowledge — Peking
Journal of Plant Protection
Plant Protection Bulletin
Kwangtung Agricultural Science

Fiji

Fiji Agricultural Journal

India

Aduthurai Reporter
All-India Coordinated Rice Improvement Project (AICRIP), Hyderabad, Annual Report
Andhra Pradesh Agricultural Journal
Annamulai University Agricultural Research Annuals
Central Rice Research Institute (CRRI, Cuttack) Annual Reports
Current Science
Entomon
Haryana Agricultural Journal
Indian Agriculturist
Indian Journal of Agricultural Science
Indian Journal of Entomology
Indian Journal of Plant Protection
Indian Phytopathology
Journal of Entomological Research
Kerala Agricultural Research Journal
Madras Agricultural Journal
Marathurada Agricultural Journal
Mysore Journal of Agricultural Sciences
Oryza
Pantnagar Journal of Research
Pesticides
Pestology
Punjab Agricultural University Research Journal
Science and Culture

Continued on opposite page

Appendix B continued

Indonesia

Agrlcultural Cooperation Indonesia - the Netherlands Research Reports, 1968-1974. Section II Technical Contributions
CRIA Annual Reports, Bogor
CRIA, Reports of Staff Meetings, Bogor
Kongres Entomologi
Maros Research Institute for Agriculture Bulletin
Rapot Keloprob

Iran

Applied Entomology and Phytopathology

Italy

Il Riso

Japan

Biological Science
Botyu-Kogaku
Bulletin of the Chugoku Agricultural Experiment Station
Bulletin of the Institute of Agricultural Research, Tohoku University
Bulletin of the Ishikawa Agricultural Experiment Station
Bulletin of the Kyushu Agricultural Experiment Station
Bulletin of National Agricultural Science, Series C.
Bulletin of the Shiga Prefecture Agricultural Experiment Station
Bulletin of the Tohoku National Agrlcultural Experiment Station
Chugoku Agricultural Research
Hokkaido Agricultural Experiment Station Reports
Japan Pesticide Information
Japanese Journal of Applied Entomology and Zoology
JARQ
Journal of Pesticide Science
Kyushu Agricultural Experiment Station Annual Report
Kyushu Agrlcultural Research
Memoirs of the Faculty of Agriculture, Kagoshima University
National Institute of Agricultural Science Bulletin
Oyo Knotyu
Proceedings of the Hokuriku Association of Plant Protection
Proceedings of the Kansai Plant Protection Society
Proceedings of the Kanto-Tosan Plant Protection Society
Proceedings of the Kyushu Association of Plant Protection
Proceedings of the Sikoku Association of Plant Protection

Korea

Korean Journal of Entomology
Korean Journal of Plant Protectton
Korea Office of Rural Development Research Reports

Malaysia

Malaysia Agricultural Journal
Malaysia Agricultural Research and Development Institute (MARDI) Annual Reports
Malaysia Agrlcultural Research and Development Institute Research Bulletin

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Appendix B continued

Nepal

Ministry of Food and Agriculture, Department of Agriculture, Entomology Division Annual Reports
Nepalese Journal of Agriculture

Pakistan

Agriculture Pakistan
Pakistan Journal of Science

Philippines

Araneta Research Journal
Bureau of Plant Industries Annual Reports
Philippine Agriculturist
Philippine Entomologist

Spain

Arroz

Sri Lanka

Administration Reports of the Director of Agriculture
Central Agricultural Research Institute (CARI), Division of Entomology Annual Reports
Tropical Agriculturist

Taiwan

Agricultural Research Journal
Plant Protection Bulletin
Taiwan Agricultural Quarterly
Taiwan Journal of Plant Protection
Memoirs of College of Agriculture, National Taiwan University

Thailand

Department of Agriculture, Entomology-Zoology Division, Rice Pest Branch. Annual Repori
Thai Journal of Agricultural Science

USA

Arkansas Agricultural Experiment Station Progress Report
California Agricultural Experiment Station Progress Report
Environmental Entomology
Insecticide and Acaricide Tests
Journal of Economic Entomology
Louisiana Rice Experiment Station Annual Progress Report
Rice Journal
Texas Agricultural Experiment Station Bulletin and Progress Reports

Vietnam

Ministry of Agriculture Annual Reports of Studies in Agricultural Science

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Appendix B continued

International Organizations

- Centre for Overseas Pest Research Miscellaneous Report Series
- PANS
- International Institute of Tropical Agriculture (IITA) Annual Report
- International Rice Research Institute
  - Annual Report
  - Insecticide Evaluation
  - International Rice Research Newsletter
  - IRRI Research Paper Series
- Office de la Recherche Scientifique et Technique d' Outre-Mer (ORSTOM) Reports
- West Africa Rice Development Association (WARDA) Research Report and Annual Report

Appendix C. Outline of an experiment on stem borer control.

Title: FIELD EVALUATION OF GRANULAR INSECTICIDES FOR YELLOW STEM BORER CONTROL

Background information: The yellow stem borer, *Tryporyza incertulas,* is a pest that, in the Philippines, frequently causes deadheart damage above the economic injury level, Because varietal resistance is only of a moderate level, insecticides are commonly used for control. The effectiveness of currently recommended insecticides must be verified before revising current recommendations. Also new insecticides need to be tested to find additional effective insecticides. Data obtained will be evaluated by the Pesticide Technical Committee of the Masagana 99 program when current recommendations are revised.

Objectives: To determine which of the currently recommended insecticides should be delisted and whether any new chemicals should be added.

Site: Maligaya Rice Research and Training Center (MRRTC), Muñoz, Nueva Ecija, Philippines

Research staff: E. A. Heinrichs and L. Antonio, IRRI, and M. Elesanco, Maligaya Rice Research and Training Center

Experimental procedure: Nine insecticides will be applied 5 times, in a field experiment, 10, 25, 45, 60, and 75 DT as a paddy water granular broadcast at 1.0 kg a.i./ha. Deadheart counts will be made twice and whiteheads will be counted at harvest. Data on additional insects will be recorded. Yields will be recorded.

Treatments

1. Carbofuran (Furadan) 3 G
2. Diazinon 10 G
3. Gamma BHC 6 G
4. Endosulfan (Thiodan) 5 G
5. Gamma BHC + Carbaryl (Sevidol) 6 + 4 G
6. Bendiocarb (Ficam) 5 G
7. Gamma BHC + MlPC (Gamma Hytox) 6 + 4 G
8. Gamma BHC + MTMC (Dolmix) 6 + 3 G
9. Isazophos (Miral) 10 G
10. Untreated check

Experimental design and layout

Randomized complete block with 4 replications (see field layout)
Plot size = 4 × 9 m

Agronomic practices

Variety	- IR29
Planting	- Plant 14-day-old dapog-grown seedlings at 2 seedlings/hill on 15 November 1980
Spacing	- 25 × 25 cm
Fertilizer/ha	- Basal = 14 kg N + 14 kg P + 14 kg K
	- 25-30 days after transplanting (DT) = 23 kg N
	- Panicle initiation = 23 kg N
Weeding	- Hand weed when necessary

FIELD LAYOUT

Block I		Block II	
4	7	9	3
1	6	5	2
9	2	1	6
10	8	10	4
3	5	7	8
1	6	4	8
5	8	3	2
9	2	1	9
3	7	5	7
10	4	10	6
Block III		**Block IV**	

Continued on next page

Appendix C continued

Special instructions:
1. Use insecticides not more than 1 year from date of manufacture.
2. Before the first insecticide application, make levees to separate each plot and maintain them throughout the experiment.
3. Maintain 2-4 cm of water in plots at all times.
4. Do not apply insecticide during heavy rains or winds.
5. Control rats as per recommended method.
6. Control birds.

Equipment, supplies, and personnel needed:

Equipment and supplies	*Personnel*
Power tiller	Plot preparation – 5 labor days
Meter tape	Transplanting – 10 persons for 2 hours
Seedlings	Plot maintenance – 1 person for 2 days per week
Abaca twine	
Fertilizer	Observations – 3 persons on sampling date
Insecticides	
Balance (50 g sensitivity)	
Sweep nets	
Data sheets	
Bamboo stakes	

Observations and sampling dates:
1. Whorl maggot damage rating at 20 and 30 DT. Check 20 randomly selected hills per plot.
2. Deadheart count sat 20 and 40 DT. Check 20 randomly selected hills per plot. Dissect stems to determine percentage of each borer species present.
3. Whitehead counts at harvest. Check 20 randomly selected hills per plot.
4. Other insects. If populations of other insects or insect damage warrant, record as follows:
   Green leafhoppers – Make 10 sweeps/plot.
   Planthoppers – Shake insects off the plants by tapping 10 plants/plot and count the insects that fall.
   Leaf folder and caseworm – Estimate percentage of damaged leaves on 10 hills/plot.
5. Yield data. Take sample from a 3 × 4 m area in the center of each plot.

Appendix D. Equipment and supplies used in insecticide evaluation studies, with names and addresses of suppliers.

Items	*Suppliers*[1]
abaca twine/coin rope	22
aluminum foil	22
aspirator	4, 6
atomizer	11
balance	35
camel's hair brush	6, 22
chemicals and reagents	14, 16, 17, 28, 38, 45
cotton	22
counters (hand tally)	17
dessicator	3, 11
filter paper	17
flow meter (soap film)	11
forceps	4, 6
gas regulator	11
gelatin capsules	50
glassware - beakers, flasks, funnels, graduated cylinders, petri dishes, screw cap vials, test tubes, volumetric flasks	6, 11
gloves (disposable)	4, 11
goggles (protective)	1, 46
grain moisture tester	9
granular spot applicator	24
granule spreader (for broadcast application)	41
hose (plastic)	11
hygrothermograph	47
incubator, growth chamber	11, 20
leaf area meter	31
magnifier	11
masking tape	22
masks (protective)	11, 18, 33, 39
microapplicator	8, 27
microscope (stereo)	11, 48
mylar film	19, 32, 44
nozzles (spray)	5, 13, 43
nutritional biochemicals	14, 38
nylon mesh	22
parafilm	11
pots (porcelain/plastic)	29
Potter's spray tower	8
propipette	3, 11, 17
respirator	7, 37
rubber bands	22
scissors	3, 4
spatula	3

Continued on next page

Appendix D continued

sprayers - hand operated	2, 5, 10, 12, 21, 25, 34, 40, 42
– motorized mistblowers	21, 23, 25, 34, 40, 42
– ULV (hand held, battery operated)	36
stopwatch	11
suction samplers (motorized)	
FARMCOP (moulinex model 237 car cleaner)	30
D-vac	15
Univac	8
sweep net	6, 46
tubing (rubber)	11
turntable (for foliar spraying)	26
vacuum pump	11
vials	6
wire mesh	22

[1] Includes only those with which we are familiar. This is not in anyway an endorsement of these companies nor a recommendation of their products. Numbers correspond to the numbers in the accompanying *Names and addresses of suppliers.*

Appendix D continued

Names and Addresses of Suppliers

1. American Optical Co.
Safety Products Division, Southbridge, Massachusetts 01 550 USA

2. American Spring and Pressing Works
Post Box No. 7602, Malad, Bombay 64NB, India

3. Arthur Thomas Co.
Vine Street at Third
P. O. Box 779, Philadelphia, Pennsylvania 19105 USA

4. Australia Entomological Supplies
35 Kiwong St., Yowie Bay
N. S. W. 2228 Australia

5. B & G Equipment Co.
Plumsteadville, Pennsylvania 18949 USA

6. Bioquip Products
P. O. Box 61, Sta. Monica, California 90406 USA

7. Birger Carlson Co., AB
Kaptensgatan 6, Stockholm, Sweden

8. Burkard Scientific (Sales) Ltd.
Woodcock Hill, Rickmansworth, Herts WD3 IPJ, England

9. Burrows Equipment Co.
1316 Shelman Ave., Evanston, Illinois 60204 USA

10. China Agricultural Machinery Co., Ltd.
4th Floor, Tun-Hwa Road South, Taipei, Taiwan, Republic of China.

11. Cole Parmer Instrument Co.
7425 North Oak Park Ave., Chicago, Ilinois 60648 USA

12. Cooper, Pegler & Co.. Ltd
Burgess Hill, Sussex RH1 5 9LA, England

13. Delawan Mfg. Co.
811 4th St., West Des Moines, Iowa 50265 USA

14. Difco Laboratories
P.O. Box 1058-A
920 Henry St., Detroit, Michigan 48201 USA

15. D-Vac Co.
P. O. Box 2095, Riverside, California, 92506 USA

16. Carlo lrba
Milano 20159 via C. lmbonati 24
P. O. Box 399, Milano, Italy

17. Fischer Scientific Co.
711 Forbes Ave., Pittsburgh, Pennsylvania 15219 USA

18. Flexo Products Inc.
24864 Detroit Rd., Westlake, Ohio 44145 USA

19. Garware Plastics Ltd.
50a Central Salsette Rd.-57, Bombay, India

20. GCA Precision Scientific Co.
3737 West Cortland St., Chicago, Illinois 60647 USA

21. Gebruder Holder Mashinen Fabrik
7418 Maichingen bei Stuttgart, Postfach 20, West Germany

22. General stores in many sites

23. Hatsuta Industrial Co. Ltd.
59-1 Chome, Chifune-Higashi, Nishi-Yodagawa-ku, Osaka, Japan

24. Horstine Farmery Ltd.
North Newbald, York Y04, 3SP, England

25. H. D. Hudson Mfg. Co.
500 N. Michigan Ave., Chicago, Illinois 60611 USA

Appendix D continued

26. lhedarica Co., Ltd.
    2-15-12 Iwamoto-cho
    Chiyoda-ku
    Tokyo, 101 Japan

27. Instrumentation Specialist Co.
    P. O. Box 5347, Lincoln, Nebraska
    68505 USA

28. ICN Pharmaceuticals, Inc.
    K & K Labs Division
    Life Sciences Group
    121 Express Street, Plainview
    New York 11803 USA

29. Kiya Seisakusho Co., Ltd.
    1-20-8 Mukogaoka, Bunkyo-ku, Tokyo
    113, Japan

30. Richard Kwan Oriental Supplier Ltd.
    G.P.O. 3341, Hongkong

31. Lambda Instruments Corp.
    Box 4425, Lincoln, Nebraska 68504
    USA

32. N. A. Lim Commercial
    674 E. de Los Santos Ave., Pasay, Metro
    Manila, Philippines

33. Matindale Electric Co.
    1375 Hiid Ave., Cleveland,
    Ohio 44107 USA

34. Mauryama Mfg. Co., Ltd.
    4-15 San-Chome, Uchi-karida, Chiyoda-
    ku, Tokyo, Japan

35. Mettler Instruments AC
    CH-8606 Greinfensee-Zurich,
    Switzerland

36. Micron Sprayers, Ltd.
    Three Hills, Bromyard, Hereford, England

37. Mine Safety Appliances Co.
    400 Penn. Center Blvd., Pittsburgh,
    Pennsylvania 15235 USA

38. Nutritional Biochemicals Corp.
    26201 Miles Road, Cleveland, Ohio
    44128 USA

39. Pulmosan Safety Equipment Corp.
    30-48 Linden Place, Flushing, New York
    11354 USA

40. Root-Lowell Corp.
    1000 Foremian Road, Lowell, Missouri
    49331 USA

41. Seymour Mfg. Co.
    500 N. Broadway, Seymour, Indiana
    47274 USA

42. Solo Kleinmotoren GMBH
    7034 Maichingen bei Stuttgart, Postfach
    20, Germany

43. Spraying Systems Co.
    3201 Randolph St., Bellwood, Illinois
    60104 USA

44. Transilwrap Co.
    274 Harbor way, San Francisco.
    California 94080 USA

45. United States Biochemical Corp.
    Corporate Offices
    P. O. Box 22400, Cleveland, Ohio
    441 22, Plant - 2100 Miles Parkway,
    Cleveland, Ohio 44128 USA

46. Wards Natural Science Establishment
    Incorporation
    P. O. Box 1749, Monterey, California
    93940 USA

47. Weather Measure Corporation
    P. O. Box 41257, Sacramento, California
    95841 USA

48. Wild Heerbrugg Instruments Inc.
    465 Smith Str., Farmingdale, Long
    Island, New York 11735 USA

49. K. Arano & Co. Ltd.
    C. P. O. Box 1701, Tokyo 100-91. Japan

50. Eli Lilly and Co.
    Elanco Products Co. Division,
    Indianapolis, Indiana 46206 USA

Appendix E. Chemical companies with research and development on rice insecticides. [1]

Agricultural and Veterinary Products Division, ABBOTT LABORATORIES
North Chicago, Illinois 60064, USA

BASF AKTIENGESELLSCHAFT
Landwirtschaftliche Versuchsstation, D-703 Limburgerhos and Pfalz, Federal Republic of Germany

BAYER AG, Sparte Pflanzenschutz Anwendungstechnik/Biologische Entwicklung, 5090 Leverkusen, Bayerwerk, West Germany

CHEVRON CHEMICAL INTERNATIONAL INC.
Agric. Chemicals Division, 940 Hensley Street, Richmond, California 94804 USA

CIBA-GEIGY LIMITED
Agrochemicals Division, Research and Development, CH-4002 Basle, Switzerland

CYANAMID INTERNATIONAL
P. O. Box 400, Princeton, New Jersey 08540 USA

DIAMOND SHAMROCK CHEMICAL COMPANY
Agricultural Chemicals Division, 300 Union Commerce Building, Cleveland, Ohio 44115 USA

DOW CHEMICAL
Gammon House, 12 Harcourt Road, Hongkong

DUPONT COMPANY
Wilmington, Delaware 19898 USA

FMC CORPORATION
Agricultural Chemicals Division, 2000 Market St., Philadelphia, Pennsylvania 19107 USA

FISONS LIMITED
Hauxton, Cambridge, CB2 5HU, England

HOECHST
Aktiengesellschaft, Verkauf Landwirtschaft, 6000 Frankfurt 71, Lyoner Strasse 30, (M) Germany

HOKYO CHEMICAL INDUSTRY COMPANY LIMITED
Mitsui Building No. 2, 4-2 Nihonbashi Hongoku-cho, Chuo-ku, Tokyo, Japan

HOOKER CHEMICALS AND PLASTICS CORPORATION
Agricultural Chemicals, International Division, Stamford, Connecticut 06905 USA

ICI PLANT PROTECTION LIMITED
Jealotts Hill Research Station, Bracknell RG12 EY Berks, England

ELANCO PRODUCTS COMPANY
Lilly Research Laboratories, P.O. Box 708, Greenfield, Indiana 46140 USA

DR. R. MAGG LTD
Agrochemics, CH-8157, Dielsdorf, Switzerland

MITSUI TOATSU CHEMICALS, INC.
Agricultural Chemicals Department, Kasumigaseki Bldg., P.O. Box 83, Tokyo 100, Japan

MITSUBISHI CHEMICAL INDUSTRIES LIMITED
Agricultural Chemicals Department, 5-2 Marunouchi
2-Chome, Chiyoda-ku
Tokyo 100, Japan
Central P.O. Box No. 245

MOBIL CHEMICAL COMPANY
Post Office Box 26683, Richmond, Virginia 22261 USA

MONSANTO COMMERCIAL PRODUCTS CO.
Agricultural Division, 800 N. Lindbergh Boulevard, St. Louis, Missouri 63166 USA

MONTEDISON S.P.A.
Via Bonfadini 148, 20138 Milano, Italy

MURPHY CHEMICAL LTD.
Wheathampstead, St. Albans, Hertfordshire, England AL4 8QU

Continued on next page

Appendix E continued

NIHON NOHYAKU
2-5 Nihonbashi, 1-Chome, Chuo-ku, Tokyo, Japan

NIPPON KAYAKU CO., LTD.
New Kaijo Building, No. 2-1, 1-Chome, Marunouchi, Chiyoda-ku, Tokyo, Japan

PHILIPS-DUPHAR B.V.
Agricultural Development Department, Gooilust, Zuidereinde 419, 's-Graveland, The Netherlands

RHONE-POULENC
Division Phytosanitaire, 14 Rue Pierre Baizer B.P., B.P. 9163 Lyon 09-69263, Lyon Cedet, France

ROHM AND HAAS COMPANY
Agricultural Division, Independence Mall West, Philadelphia, Pennsylvania 19105 USA

SANDOZ LIMITED
Agro Division-Research, Basle, Switzerland

SANKYO COMPANY, LTD.
No. 10-17, Ginza 3-Chome, Chuo-ku, Tokyo 104, Japan

SCHERING AKTIENGESSELLSCHAFT
Agrochemical Division, D-1 Berlin 65, West Germany

SHELL INTERNATIONAL
Agrochemicals Division, Shell Centre, London SE1 7PG, England

STAUFFER CHEMICAL COMPANY
P.O. Box 760, Mt. View, California 94042 USA

TAKEDA CHEMICAL INDUSTRIES, LIMITED
Agricultural Chemicals Division, 2-12-10 Nihonbashi, Chuo-ko Tokyo 103, Japan

UNION CARBIDE
Agricultural Products Division, 7825 Baymeadows Way, P. O. Box 17610, Jacksonville, Florida 32216 USA

UNIROYAL CHEMICAL
Agricultural Chemical Section, 74 Amity Road, Bethany, Connecticut 06525 USA

UPJOHN INTERNATIONAL, INC.
Agricultural-Veterinary Division, Kalamazoo, Michigan 49001 USA

VELSICOL CHEMICAL CORPORATION
341 East Ohio St., Chicago, Illinois 60611 USA

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[1] Includes only those companies with which IRRI has cooperated in insecticide evaluation studies.

Appendix F. Some useful reference books on insecticide evaluation methods, pesticide formulations, data analysis, and application equipment.

Busvine, J. R. 1957. A critical review of the techniques for testing insecticides. Commonwealth Agricultural Bureau. Eastern Press Ltd., London. 208 p.

Campbell, L. F., and F. T. Moulton, eds. 1943. Laboratory procedures in studies of the chemical control of insects. American Association for the Advancement of Science, Smithsonian Institution Bldg., Washington, D. C. 206 p.

Deutsch, A. E., ed. 1976. Manufacturers of pesticide application equipment. Publication 19-A-76. International Plant Protection Center, Oregon State University, Corvallis, Oregon. 55 p.

Deutsch, A. E., and A. P. Poolee, eds. 1972. Manual of pesticide application equipment. International Plant Protection Center, Oregon State University. Corvallis, Oregon.

Farm Chemicals Handbook. Meister Publishing Co.. Willcughby, Ohlo. USA. (published annually)

Finney, D. J. 1962. Probit analysis. 2d ed Cambridge University Press. 318 p.

Finney, D. J. 1964. Statistical methods in biological assay. 2d ed. Hafner Publishing Co., New York. 668 p.

Finney, D. J. 1971. Probit analysis. 3d ed. Cambridge University Press, London. 333 p.

Gomez, K. A. 1972. Techniques for field experiments with rice. International Rice Research Institute, Los Baños, Philippines. 46 p.

Kenaga, E. E., and C. S. End. 1974 Commercial and experimental organic insecticides. Entom-olcgical Society of America. Spec. Publ. 74-177 p.

Lewallen, L. L. 1962. A glossary of insect toxicology. Erdmans. Ann Arbor, Michigan. 29 p.

Matthews, G. A. 1979. Pesticide application methods. Longman, London. 334 p.

Shepard, H. H., ed. 1958 Methods of testing chemicals on insects. Vol. I. Burgess Publishing Co., Minneapolis, Minnesota. 356 p.

Shepard, H. H., ed. 1960. Methods of testing chemicals on insects. Vol II. Burgess Publishing Co., Minneapolis, Minnesota. 248 p.

Thomson, W. J. 1973. Agricultural chemicals Book 1. Insecticides, acaricides, and ovicides. Thomson Publicatlons, P. O. Box 50160, Indianapolis, Indiana, USA.

Volkenburg, W. V., ed. 1973. Pesticide formulations. Marcel Decker Inc., New York. 481 p.

Wiswesser, W. J., ed. Pesticide Index. Entomological Society of America, College Park, Maryland.

Glossary

Abbott's formula — mathematical formula used to correct for mortality in the untreated check, e.g.

$$\frac{\text{\% mortality in treatment - \% mortality in check}}{100 - \text{\% mortality in check}} \times 100$$

Active ingredient (a.i.) — the portion of a pesticide preparation that is biologically active in contrast to the carrier which is inert.

Adsorption — a process in which molecules or ions of one substance cling to the surface of another substance.

Analytical reagent (AR) — reagents that are pure and are used for quantitative analysis.

Anesthetize — process of immobilizing an insect by exposing it to carbon dioxide.

Antifeedants — chemicals that are neither toxic nor repel insects but prevent them from feeding normally.

Arcsin transformation — used to transform data in proportions with the range of 0 to 30% and 70 to 100%.

Artificial infestation — infestation of plants with insects by placing them directly on plants by hand or by releasing them into a cage, in contrast to natural infestation where a natural field population is depended on for testing an insecticide.

Atomizer — device used to break up a liquid spray into small droplets.

Benefit-cost ratio — ratio formed by dividing the benefit in terms of increased crop value when a pesticide is used, by the cost of the insecticide treatment;

$$\frac{\text{value of treated crop - value of untreated crop}}{\text{cost of insecticide application to treated crop}}$$

Biological control — in applied entomology, the control of insect pests by employing natural means such as predators, parasites, or insect pathogens.

Blackhead stage — stage in the development of insect eggs wherein the head can be observed as a black spot through the chorion.

Block — an experimental unit in which each treatment occurs the same number of times.

BPH — brown planthopper *Nilaparvata lugens.*

Broadcast application — application of insecticide granules by hand or machine over a surface area.

Calibration — to check the graduation of an instrument so that accurate measurements in definite units can be made.

Calibration curve — standard curve showing the relationship between concentration and transmittance.

Canopy — cover formed by the upper leaves of the rice crop after maximum tillering has been completed.

Centrifugation — separation of solids from liquids or liquids of different specific gravities by using a high-speed rotary machine.

Chemical property of an insecticide — the ability of the insecticide to undergo or induce a chemical change.

Chi square — a statistic used to test the goodness of fit of the fitted probit-log dosage regression line.

Coded insecticide — unnamed insecticide but having a code which identifies it and the manufacturer.

Colorimetric analysis — determination of the amounts of substances by comparing the intensity of color produced by them with specific reagents in comparison to the intensity of color produced by a standard solution with the same reagents. It is based on the fact that the color intensity of a solution is proportional to the concentration of the solute.

Commercial insecticide — formulated insecticide sold in the market.

Concentration — the quantity of solute (dissolved substance) in a given solvent.

Contact insecticide — an insecticide that kills insects by contacting and entering their bodies directly through the body wall into the blood.

Cultural (agronomic) practice — in rice production, the local practices involved in land preparation, fertilization, pest control, and harvesting.

DAT — days after treatment.

Deadheart — death of the growing shoot due to attack of stem borer which cuts its base.

Defoliator — any chewing insect that feeds on the leaves of the plant.

Dissection for eggs — cutting the plant tissue to expose insect eggs for counting.

Dosage — quantity of insecticide in the environment wherein the insect is present with a fixed exposure time.

Dose — known quantity of a substance given to an individual insect such as in topical application.

Drift — movement of airborne pesticide particles away from the intended area of application.

DT — days after transplanting.

Duncan’s Multiple Range Test (DMRT) — in statistics, a mathematical calculation used to make comparisons among all possible pairs of treatments regardless of the number of treatments involved.

Egg parasite — an insect that lives in the eggs of its host (other insects).

Embryonic death — death during the egg stage of the insect.

Embryonic development — development of the egg stage.

Emergence — stage when the adult insect leaves the pupal case or the last nymphal skin.

Emulsifiable concentrate (EC) — consists of a toxicant and an emulsifying agent in a water-insoluble organic solvent. An emulsion is formed when water is added which is an opaque liquid.

Emulsion — suspension of minuscle droplets of one liquid in another.

Environmental hazard — the relative likelihood of insecticides producing undesirable effects on the environment.

Expected probit — the probit value based on the provisional eye fitted line.

Experimental design — includes the plan and the actual procedure of laying out the experiment to have a valid analysis of results and efficient estimation of treatment effects.

Factorial experiments — experiments characterized by treatments that are composed of all possible combinations of levels in each of two or more factors, e.g. in insecticide studies where two insecticides are applied at three rates.

Fiducial limits — the lower and upper values for the estimate of LD_{50} or LD_{90} computed from the probit regression equation at a given reliability coefficient, say, 95% or 99%.

Flowable formulation — insecticide plus a dust diluent that is blended in a small quantity of water, resulting in a thick paste called a wet blend that has the same settling characteristics as wettable powder.

Foliar spray — application of a chemical preparation by spraying the foliage of plants.

Formulation — the form in which a pesticide is sold for use, i.e. dusts, granules, wettable powder, emulsifiable concentrate, etc.

Fumigant — gaseous poisons used to kill insects in which the gas enters the body wall through the spiracles during respiration.

Fumigation — exposure of insects to poison gases.

Gas chromatography — the separation of components of a sample by selective adsorption on a stationary phase and gas being the mobile phase.

Gelatin capsules — capsules filled with insecticides for use as a root-zone application.

GLH — green leafhopper *Nephotettix virescens.*

Granular insecticide — small pellets formed from various inert clays or sand impregnated with an insecticide and which are usually broadcasted.

Grassy stunt — virus transmitted by BPH.

Gravid — an insect containing fertilized eggs.

Hidden costs — undetected costs resulting from insecticide application which cannot always be immediately calculated, e.g. resurgence of primary and secondary pests, insecticide resistance, environmental pollution, and poisoning cases.

Hills — one or more plants directly adjacent to each other.

Holometabolous insects — insects that undergo complete metamorphosis.

Honeydew — liquid excretion produced by insects such as leafhoppers and planthoppers.

Hopperburn — drying up of rice plants due to the feeding of leaf- and planthoppers.

Hotspot — site where the natural infestation of a particular insect is high, providing sufficient pressure for reliable results in insecticide evaluation tests.

Inbreeding depression — the result of inbreeding as in the continued rearing of insects without the occasional introduction of field-collected insects where the continuous breeding of genetically related individuals affects the biology, i.e. decrease in reproductive capacity.

Insectary — a building where insects are cultured and studied; often consisting of a roof and screened walls.

Insecticide — a substance for killing insects.

Insecticide resistance — the degree to which a species of insect tolerates a toxic substance. The degree of resistance is based on LD_{50} values of a population that has been previously exposed to insecticides, compared to those of a population that has not.

Insect pest management — an ecologically based strategy of maintaining insect pest populations below the economic injury level by the use of any or all control techniques that are economically, ecologically, and socially acceptable.

Instar — the stage of an insect between successive molts, the first instar being the stage between hatching and the first molt.

Knapsack sprayer — a light sprayer constructed to fit the back of the operator. It is fitted with a hydraulic pump actuated by a hand-operated lever.

Knockdown activity — ability of the pesticide to manifest an effect on the insect within a short time (4 hours or less after application).

Larva (pl. larvae) — the immature stage between the egg and pupa of holometabolous insects.

LD_{50} — the dose of a toxicant producing 50% mortality in a population in a given period of time. In insect toxicology studies, the LD_{50} is expressed in µg insecticide g body weight of the insect.

Leaf sheath — the lower part of the leaf, originating from a node and enclosing the culm above the node.

Logarithm — the ten base logarithm of a number is the power to which ten must be raised to give that number.

Neem oil — oil extracted from the seed of the neem tree, *Azadirachta indica.*

Microapplicator — instrument used to apply small quantities of insecticide to the body of insects in LD_{50} studies.

Mist blower — a motorized sprayer that forces a blast of air against the spray material, forming fine droplets that are carried to the target by the air blast.

Mouth aspirator — device used for capturing small insects alive by sucking through a mouth piece, and drawing insects into a glass vial.

Mylar film — trade name for a plastic-like film used in making insect cages for insecticide studies.

Natural enemy — parasites, predators, and pathogens which attack various life stages of insects.

Nymph — an immature stage (following hatching) of an insect that has incomplete metamorphosis.

Oil formulation — oil-based preparations of insecticide formulations.

Ovicide — a chemical that kills eggs.

Oviposition — the process of laying or depositing eggs.

Paddy water application — broadcast application of the granular formulation of insecticides into paddy water.

Panicle — branching inflorescence made up of a group of spikelets.

Parafilm sachet — sac-like structure made of parafilm to enclose a sucking insect on a plant part for the purpose of collecting honeydew to estimate feeding activity.

Parasites — insects that develop in another insect, eventually killing the host. Most of the life cycle is spent on the host.

Photodegradation — the conversion of the molecules of an insecticide into simpler molecules due to the action of light.

Physical property of an insecticide — characteristics of an insecticide that are not observed in the course of a chemical reaction, e.g., color, odor, state, density, solubility, etc.

Potter's spray tower — instrument used for precision spraying of insecticides. It provides a uniform mist over a given area.

ppm — parts per million.

Precision spraying — uniform spraying of insecticides directly on the bodies of insects.

Predator — relative to insects, a predator is an animal that feeds on any or all stages of the insect host and usually requires several host insects to complete development.

Probit analysis — a statistical procedure of transforming percentage mortality data into another variate called probit and then finding the regression function of probit with log dosage in order to estimate LD_{50} or LD_{90}.

Probit regression line — equation of the line showing the relationship between % mortality and dose or dosage; used to calculate LD_{50}.

Pupa — the apparently inactive stage in all holometabolous insects; the intermediate stage between the larva and the adult.

Pupation — the process of becoming a pupa.

Pythagorean equation — $C^2 = a^2 + b^2$. In a right-angled triangle, the square of the hypotenuse is equal to the sum of the squares of the other sides. Used as an aid in making right-angled corners when laying out field plots.

Randomized complete block design — an experimental design in which the experimental area is divided into blocks and all of the treatments are randomly arranged within each block.

Ragged stunt — virus disease of rice transmitted by BPH.

Rate of insecticide — amount of active ingredient (a.i.) of insecticide in weight/area such as kilogram per hectare.

Recovery rate — amount of insecticide recovered in relation to the amount applied.

Regression coefficient — slope of the regression line.

Relative humidity (RH) — the ratio of the water vapor in the air at a given temperature to the maximum amount of water vapor air can hold at that temperature.

Replication — repetition of the same treatment so that it appears two or more times in an experiment.

Residual activity — the insecticidal activity resulting from the presence of an insecticide and its metabolites on or in a treated site after an insecticide is applied.

Residue — the quantity of a pesticide which remains in or on the surface of a crop after insecticide application.

Resurgence — significantly more damage or more insects in an insecticide-treated crop after application than in an untreated crop.

Root coat — coating the roots of rice seedlings by dipping into a liquid formulation of an insecticide that contains a sticking agent such as gelatin which causes the insecticide to stick to the roots.

Root soak — placement of rice seedling roots in a solution of insecticide and given a sufficient period (12 hours or more) to take up insecticide through the roots.

Root-zone application — application of a systemic insecticide into the anaerobic layer of soil about 2-10 cm below the soil surface where the rice roots are located.

Rotary sprayer — a sprayer with a spinning disc that forms small droplets (about 50- 150 µ) when the spray solution passes onto it; the droplets are carried to the target by the wind.

Sampling — taking a small portion of a substance, which is representative of the entire lot, for a test or analysis.

Serial dilution — preparation of a series of gradient solutions step by step from a concentrated stock solution.

Silver shoot onion shoot — the gall produced by an abnormal growth of the leaf sheath in response to the attacks of the gall midge, *Orseolia oryzae* larva.

Slope regression coefficient — slope of the probit regression line showing Dy/Dx (i.e. change in y per unit change in x).

Soil incorporation — broadcasting of a granulated insecticide which is then incorporated into the top several centimeters of the soil.

Soluble powder — a technical grade of insecticide plus a small amount of wetting agent that dissolves in water to form a true solution and does not settle out as wettable powder does. Usually contains a high concentration of the insecticide.

Spiked sample — sample inoculated with a known concentration and volume of insecticide which is used as a standard for comparison in insecticide residue studies.

Split plot design — an experimental design in which one type of treatment is assigned to main plots and another type to plots within the main plot (subplots).

Spray deposit — the pesticide that remains on a sprayed surface after the spray droplets have dried.

Square root transformation — transformation appropriate for data in small whole numbers or for percentage data with the range of 0-30% or 70-100% but not both.

Stomach poison — an insecticide that, when eaten by an insect, is toxic.

Stylet sheath — a sheath formed in the plant from the saliva that is released by the stylets of hoppers during feeding.

Subsample — a part or fraction of a sample.

Swath width — area covered by the spray deposits when passing through the field.

Synthetic pyrethroids — synthetic pyrethrin-like compounds produced in attempts to duplicate the activity of natural pyrethrin from pyrethrum flowers.

Systemic — compound that is absorbed by the roots, stem, or leaves and is translocated throughout the plant.

Technical insecticide — the pesticide chemical in nearly pure form (usually 95-100% active ingredient) as it is manufactured by a chemical company before being used in formulating a commercial formulation.

Tergite — a sclerite (hardened plate of the insect cuticle) located on the tergum (dorsal part of the body).

Thoracic tergites — sclerites (hardened plate) on the dorsal part of the thorax.

Tiller — shoot arising from the main culm.

Treatment — a factor varied in an experiment such as the rate of an insecticide.

Tungro — a rice disease believed to be a virus, which is transmitted by GLH, *Nephotettix virescens.*

Ultralow-volume (ULV) spray — application of 4 liters or less per hectare. ULV sprays are often applied in an undiluted formulation.

Varietal resistance — property of a variety to avoid, tolerate, or recover from injury by insect populations that would cause greater damage to other varieties in similar environmental conditions.

Viability — in seeds, the ability to germinate and grow.

Viscosity — the resistance offered by a fluid to flow; it is due to the combined effect of cohesive and adhesive forces.

WBPH — whitebacked planthopper, *Sogatella furcifera.*

Wettable powder (WP) — a powdered preparation containing a toxic insecticide dust and a wetting agent which mix readily with water to form a suspension.

Whitehead — white empty panicles due to the attack of stem borer which cut the inner portion of the culm.

µg — symbol for microgram; equivalent to 0.001 milligram.

µl — symbol for microliter; equivalent to 0.001 milliliter.