DESIGNING AND DEVELOPMENT OF AN INSECTICIDE APPLICATOR FOR THE CONTROL OF BROWN PLANT HOPPER

By

V. R. RAMACHANDRAN

THESIS

Submitted in partial fulfilment of
the requirement for the degree

Master of Science in Agricultural Engineering

Faculty of Agricultural Engineering
Kerala Agricultural University

Department of Farm Power Machinery and Energy
Kelappaji College of Agricultural Engineering and Technology
Tavanur - Malappuram

1988

DECLARATION

I hereby declare that this thesis entitled "Designing and development of an insecticide applicator for the control of Brown planthopper" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

RAMACHANDRAN, V.R.

Tavanur,

July 1988.

CERTIFICATE

Certified that this thesis, entitled "Designing and development of an insecticide applicator for the control of Brown plant hopper" is a record of research work done independently by Shri. RAMACHANDRAN, V.R. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

Tavanur,
27th July, 1988.

C.P. MUHAMMAD,
Chairman,
Advisory Committee,
Professor and Head,
Dept. of Farm Power
Machinery and Energy.

CERTIFICATE

We, the undersigned members of the Advisory Committee of Shri. RAMACHANDRAN, V.R. a candidate for the degree of Master of Science in Agricultural Engineering agree that the thesis entitled "Designing and development of an insecticide applicator for the control of Brown planthopper" may be submitted by Shri. RAMACHANDRAN, V.R. in partial fulfilment of the requirement for the degree.

C.P.Muhammad,
(Chairman)
Professor and Head (FPM &E),
KCAET, Tavanur

T.P.George,
Dean-in-charge,
KCAET, Tavanur.

Dr.C.C.Abraham,
Associate Director(M&E),
Directorate of Research,
Vellanikkara.

K.John Thomas,
Professor and Head (IDE),
KCAET, Tavanur.

ACKNOWLEDGEMENT

In this endeavour I am greatly indebted to Shri. C.P.Muhammed, Professor and Head, Department of Farm Power, Machinery and Energy, Chairman of the Advisory Committee for his valuable guidance, critical suggestions and help throughout the course of this investigation and in the preparation of this thesis.

My sincere thanks are also due to Shri. T.P.George, Dean-in-charge, Dr.C.C.Abraham, Associate Director of Research (M & E) and Shri. K.John Thomas, Professor and Head (IDE), members of the Advisory Committee for their constant encouragement, constructive suggestions and keen interest at every stage of investigation and preparation of the thesis.

I am greatly indebted to Shri. Jippu Jacob, former Chairman of the Advisory Committee for his valuable guidance and critical suggestions and help throughout the course of this investigation and preparation of the thesis.

I express my heartfelt thanks to the staff members of the Department of Agricultural Engineering, College of Horticulture, Kelappaji College of Agricultural Engineering and Technology, Tavanur, Regional Agricultural Research

Station, Pattambi and to my beloved friends for their tireless co-operation and enthusiastic help from time to time for the completion of this thesis.

Thanks are also due to Shri. Sharad L. Patel, Technical Director, ASPEE Research Institute, Bombay for his valuable guidance.

RAMACHANDRAN, V.R.

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SYMBOLS AND ABBREVIATIONS USED

A	-	Area
ai	-	Active ingradient
Agric.	-	agricultural
Agron.	-	Agronomy
BPH	-	Brown plant hopper
cm	-	Centimetre(s)
contd.	-	Continued
d	-	Droplet diameter
DAS	-	Days after sowing
DAT	-	Days after transplanting
EC	-	Emulsifying content
Entmol.	-	Entomology
Fig.	-	Figure
G.I	-	Galvanised iron
ha	-	Hectare
hr	-	Hour
HV	-	High volume
Ind.	-	India
Int.	-	International
IRRI	-	International Rice Research Institute
J.	-	Journel
kg/cm^2	-	Kilogram per square centimetre
km	-	Kilometre(s)
kmph	-	Kilometre per hour

l	-	Litre(s)
lpm	-	Litre(s) per minute
LV	-	Low volume
m	-	Metre(s)
m^2	-	Square metre(s)
min	-	minute
ml	-	millilitre(s)
mm	-	millimetre(s)
M.S.	-	Mild Steel
MV	-	Medium volume
Newsl.	-	Newsletter
No.	-	Number
p.	-	page
pp	-	pages
Pathol.	-	Pathology
pap.	-	Paper
Rep.	-	Report
Res.	-	Research
Rs.	-	Rupee(s)
S	-	Second(s)
Sci.	-	Science
Sem.	-	Seminar
Stn.	-	Station
W	-	Swath width

μm	-	Micrometer
°	-	Degree
/	-	per
%	-	per cent

Introduction

INTRODUCTION

Rice is the staple food of approximately half of the world's population. Rice produces maximum calories per unit area of land among the cereals and is adaptable to a wide agro-climatic conditions.

Rice is cultivated in about 145 million hectares of land in the world. India, the country having the oldest known rice species of the world is also the second largest rice producer. In India, annual cultivated area of rice is estimated as 38.6 million hectares (Muhammad, 79), and production of 43.8 million tonnes of rice. Thearea under rice in Kerala is about 875000 ha with an average yield of nearly 1900 kg./ha. The rice production can be increased by adopting scientific cultivation methods.

The Brown plant hopper (BPH), Nilaparvata lugens continues to cause devastating damage to rice, because of the unpredictability of its infestation and lack of adequate control measures. This necessitates to improve our pest control technology and to devise an effective pest management strategy.

The outbreak of this pest generally occurs after the formation of a dense canopy of leaves in the rice crop. The adults and nymphs of the pest congregate around the stem, usually 15 to 20 cm from the base, near the water level. The estimated loss caused by BPH to rice in Kerala, from 1973 to 1976 amounted to a total of 12 crore rupees, and that of the world was 312 crore rupees. These are shown in Table 1 and 2. Among the various control measures for BPH, chemical method is reported to be better, provided that an adequate amount of insecticide gets deposited at the correct zone of infestation. The conventional sprayers generally deliver the spray fluid over the plant canopy, and not down enough to cover the lower regions of the rice stems. Besides, these conventional sprayers do not permit their use to deliver the spray fluid around the stem as the movement of their lance through interlocked leaves is difficult. Repeatedly confronted with this problem, the need for designing improved version of sprayers for effective spray of the fluid deep inside the canopy to reach critical zone on the rice plant, has been stressed very much by the Agricultural Scientists. The present studies were taken up in this background.

The objectives of the project is to develop a suitable insecticide applicator for the control of BPH, a major pest of rice. The specific objectives are:

(i) To design and fabricate a suitable applicator to control the Brown planthoppers in paddy fields.

Table 1. Damage to the rice crop caused by the brown planthopper in Kerala, India, from 1973 - 76

Crop year	Season	Affected area Ha.	Affected area % of total rice area	Degree of damage %	Estimated equivalent area of total crop loss (ha.)	Approximate value of crop loss* US $
1973-'74	Mundakan (Aug-Jan)	19,002	5.8	50-100	14,250	4,275,000
	Puncha (Dec-Apr)	48,910	63.4	10-100	19,800	5,940,000
1974-'75	Mundakan	17,150	5.2	0-100	820	246,000
	Puncha	5,148	6.7	0-100	560	168,000
1975-'76	Mundakan	6,087	1.9	0-30	480	144,000
	Puncha	27,356	35.4	0-100	3,230	969,000
Total						11,742,000

* Assuming an expected yield of 2.0 t/ha. and a rough rice price of US $ 150/t.

(Dyck and Thomas, 1979)

Table 2. Summary of approximate total monetry loss cause in recent years by brown plant hopper and grassy stunt damage to rice

Country	Loss (Million US$)
Fiji	0.50
India	20.00
Indonesia	100.00
Japan	100.00
Korea	10.00
Malaysia	1.00
Philippines	26.00
Solomon Island	0.12
Sri Lanka	1.00
Taiwan	50.00
Vietnam	3.00
Total	311.62

(Dyck and Thomas, 1979)

(ii) To evaluate the performance of the applicator for its efficiency and limitations.

Review of Literature

REVIEW OF LITERATURE

The information relating to brown planthopper a notorious rice pest, crop losses caused by it, and its control are reviewed in this chapter. The review is presented in the following headings:

Crop loss

Brown planthopper and its feeding habits

Migration

Control

Rice Oryza sativa is an ancient cereal crop domesticated about 10,000 years ago along the hilly tracts, south of the Himalaya (Kazushige, Segawa 1982). Because of the long history of its cultivation and its widespread dispersal, rice is probably the most genetically diversified among the worlds cereal crops. With the spread of high yielding rice varieties and intensive cultivation, the most destructive of rice pests has been the brown planthopper Nilaparvata lugens stal. (Abraham and Nair, 1975). It causes a severe direct damage to rice by causing hopper-burn and also of grassy stunt indirectly through the transmission of ragged stunt and virus diseases.

2.1 Crop losses

It is reported that the BPH causes incredibly heavy losses to the crop. The minimum crop damage is observed in the dry season. Outbreaks continue to increase with the expansion of irrigated rice growing areas, and with the continuous cultivation of high yielding varieties. The present control measures are not entirely satisfactory.

A severe outbreak of BPH in India occurred in Kerala State at the end of 1973 and early 1974 (Koya 1974; Nalinakumari and Mammen 1975). It mainly occurred in Kole lands of Trichur district and the Kuttanad area of Kottayam and Alleppey districts. The outbreak caused a partial damage to about 50,000 ha of rice fields. Gopalan (1974), reported that about 8000 ha was almost completely wiped out. The loss in grain yield ranged from 10% in moderately affected field to 70% in the severely affected field (Kulshreshtha et al. 1974). The damage to the standing crop some times reached cent percent. The Table 1 shows the area equivalent to that which experienced total loss of rice crop in recent years. According to Dyck, and Thomas (1979), the estimated losses in Kerala from 1973-74 to 1975-76 amounted to US $ 12 million (12 crore rupees) and that in the world was US $ 311.62 million (Table 2).

2.2 Brown planthopper and its feeding habits

Miles (1972) reported that the BPH is a vascular feeder; it primarily sucks the Phloem sap by "Stylet sheath feeding" and secretes a coagulable saliva that forms a tubular lining. Usually nymphs and adults aggregate and feed on the leaf sheath at the basal portion of the rice plant. When adult population is exceptionally high, eggs are found even in the upper parts of rice plants and they are observed to swarm even on flag leaves, the uppermost internodes of panicles and panicle areas. Otherwise eggs are inserted into the leaf sheaths.

2.3 Migration

According to Mechida (1970), nymphs and brechypteyous adults move by walking and hopping, Macropterous adults move by flying, walking and hopping. Asalina and Tsurnoha (1968) states that the BPH can migrate long distances - several hundred kilometers or more.

The BPH severely damages rice plants in the post flowering stage in most rice areas (Kulshreshta, 1974). The typical sucking damage caused by the BPH is commonly referred to as hopper-burn. Usually it occurs on rice plants nearing maturity. The first symptom of hopper-burn injury appears on rice plants as an yellowing of older leaf blades. It extends progressively to all parts of the plant that are above the ground. In the paddy fields, hopper-burn usually appears as a browning of plants in scattered patches. In severe cases, the patches spread rapidly on large scale. The water content of rice plant decreases to cause wilting. The yield loss due to hopper burn varies greatly according to the time of BPH attack. It is reported that, if the plant suffer hopper-burn within 30, 40 and 50 days after booting stage, the yield losses have been estimated at about 85%, 50% and 10%, respectively (Kisimoto, 1976). Hisano (1964) reported that besides the yield loss, higher percentages of dead, immature, and broken grains have been recorded in the infested plants. But, in tropical areas where rice is grown throughout the year in continuous and staggered plantings, the hopper-burn tends to occur at any stage of crop growth (Mochida, and Dyck 1976). Table 3 shows the relationship between degrees of damage by the BPH and the corresponding yield loss in rice.

2.4 Control

The BPH infestation can be controlled by varietial method, biological method, cultural method, and Chemical method.

Table 3. Relationship between degree of damage by the brown planthopper and rice yield loss

Damage	Plant appearance	Panicle damage @ %	Yield loss %
Slight	No withering; little sooty mold	25	10
Low	Little withering; much sooty mold; hopper burned area	40	35
Medium	Withered of lower leaves; severeesooty sooty mold; 60% lodging at the edge of hopper burned areas	45	50
High	Considerable withering; 80% lodging within hopper burned areas	70	65-70
Severe	Completely withered; few fully developed panicles in center of hopper burned areas	90	80

@ Number of panicles with less than 70% ripend grains.

(Suenaga and Nomura, 1970)

2.4.1. Varietial method

Although timely application of insecticides provides effective control, large scale chemical control is difficult and expensive. Repeated spraying may upset the natural balance between the insect and its natural enemies. The logical approach to BPH control by varietal resistance was by the use of host-plant resistance (Kalode, and Krishna 1979).

2.4.2. Biological method

Outbreaks of the BPH are often attributed not only to high plant density, heavy nitrogen fertilisation, and contimuous cropping, but also to the decreasing populations of natural enemies as a consequence of increased use of insecticides. Because those natural enemies are always present in paddy fields, their activities help to reduce the BPH population if they are properly managed.

2.4.3. Cultural method

Cultural methods are needed to reduce the BPH population when resistant varieties and pesticides are inadequate. Simultaneous rice cropping, if practiced over a larger area and rotated with other crops, would reduce chances of uninterrupted multiplication of the pest.

Immediate destruction of rice stubbles and voluntary ratoons from harvested rice crop would also help to keep down the population of the pest. Raising the water level or draining the field would help to destroy the insect population. Wider plant spacing should allow some sunlight to reach the basal portion of the plant.

Higher rates of nitrogenous fertilizers results in more protein and amino acid synthesis by the rice plant. The protein and amino acids are among the essential requirement for growth and development of immature insects and are often needed by adults for the reproductive process. Although reducing the amount of applied nitrogen may lower BPH populations, large amounts are essential for high rice yields. It is therefore, not realistic to recommend less fertilizer use, even if the pest problems are exaggerated (Pathak, 1971). In certain cases, early planting or simultaneous cropping of early maturing rice would keep the crop well clear of attack.

2.4.4. Chemical control

Chemical control is the best method of the above four methods of control, provided, sufficient amount of the insecticide is sprayed at the correct place of infestation (Heinrichs, 1979). To make chemical control of BPH more effective and economical, insecticidal application methods require considerable refinement. Heong (1975) reported that in Malaysia, the BPH could be completely controlled in three days after spraying when the spray fluid was directed towards the plant base. Pest control was only 57% when the spray was directed towards the upper canopy. According to Heinriches and Aquino, (1979) studios at IRRI indicated that insecticides vary in effectiveness depending on the site of application, with performance by 30% when the insecticide were applied to the plant base, instead of the canopy.

2.4.5. Manually operated sprayers

Rice in Kerala is grown in uplands as well as in wet lands, by sowing or transplanting in lines or at random. The conventional manually operated plant protection appliances available in the market are single nozzle single lance sprayers. There are three types of manually operated sprayers widely used by the farmers; they are Pneumatic or Hand compression knapsack sprayer, Rocker sprayer, Hydraulic energy knapsack sprayer.

2.4.5.1. Pneumatic or Hand Compression Knapsack Sprayer

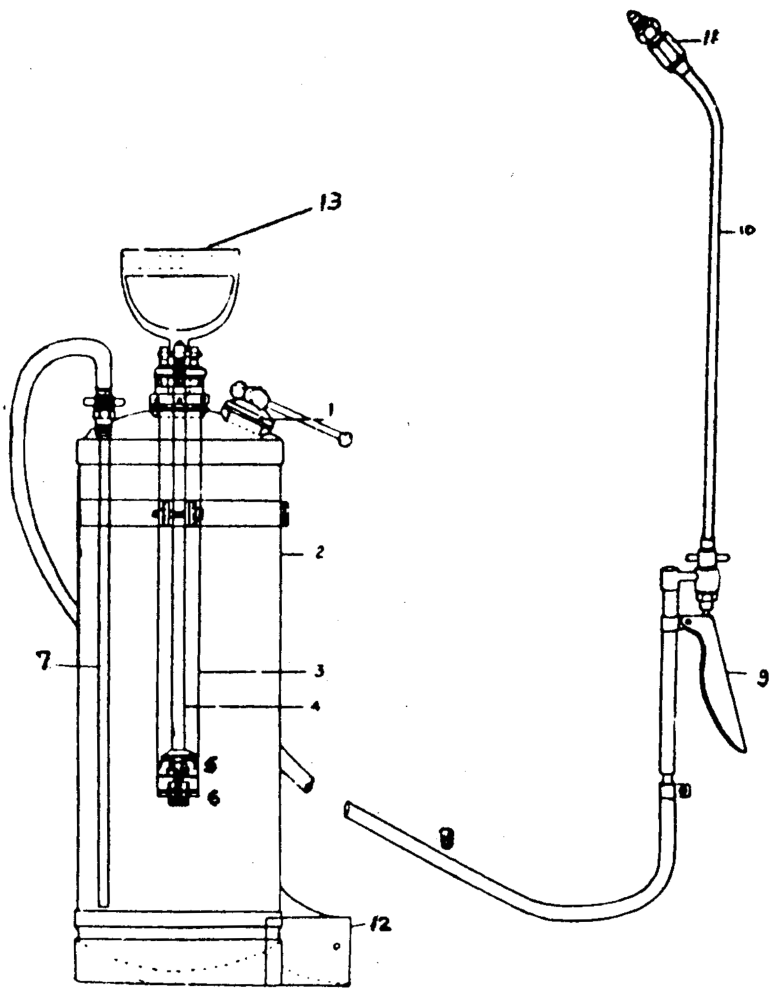
This type of sprayer consists of a metal tank for holding the spray fluid and compressed air, a vertical air pump with a handle, a filler hole, a spray lance with a nozzle and a cut-off device (Fig.1). Besides, it has a metal skirt which protects the bottom of the tank of the sprayer against wear and makes the sprayer stable when placed on the ground. This also serves as a base for the back rest. An adjustable canvas belt is also provided for carrying the sprayer on shoulder.

The capacity of the tank varies from 10 to 20 litres. The liquid chemical is filled two third of the total volume of the tank. On operating the pump for about 50 to 60 full strokes, it developes a pressure of $4g/cm^2$.

The main disadvantage of this sprayer is that the pressure in the tank drops progressively as the spraying proceeds. Compression sprayers are not ideal for applying suspensions, because of the absence of an agitating mechanism.

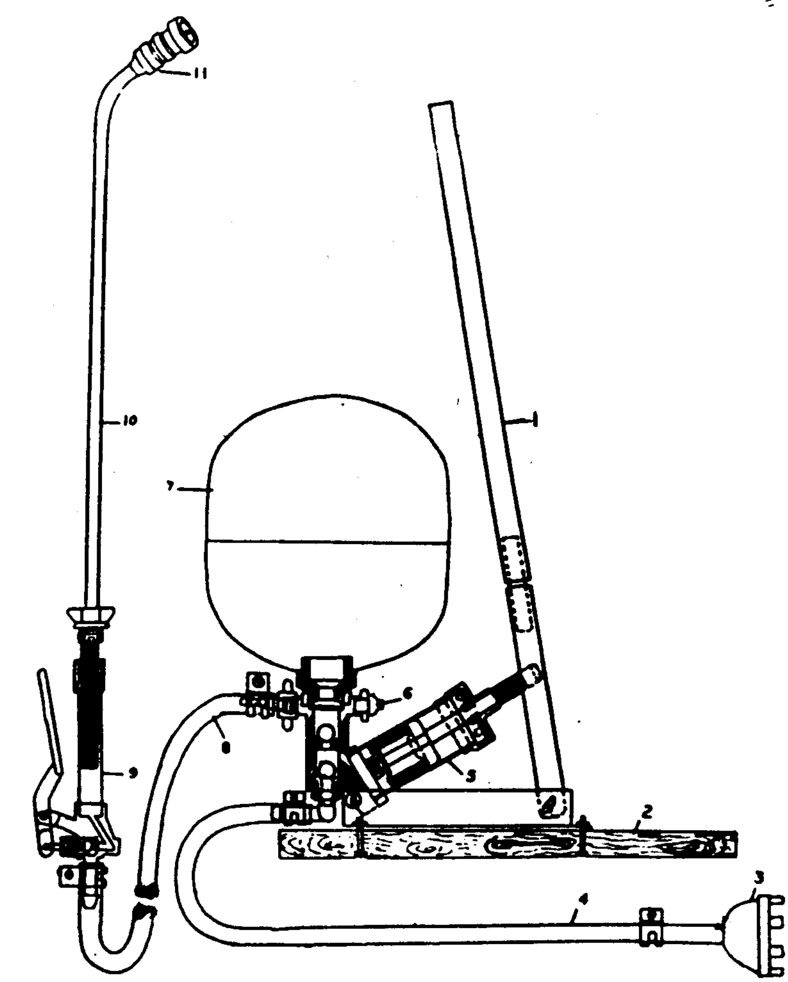
2.4.5.2. Rocker sprayer

The rocker sprayer consists of a pump assembly, a platform, an operating lever, a pressure chamber, a suction hose with strainer, delivery hose, spray lance with nozzle (Fig.2). The rocking movement of the handle



1. filler hole cap, 2. tank, 3. pump barrel, 4. plunger rod, 5. plunger assembly, 6. air-check valve assembly, 7. delivery tube, 8. delivery hose, 9. trigger cutoff valve, 10. spray lance, 11. nozzle, 12. back rest, 13. pump lever.

FIG. 1. HAND COMPRESSION SPRAYER



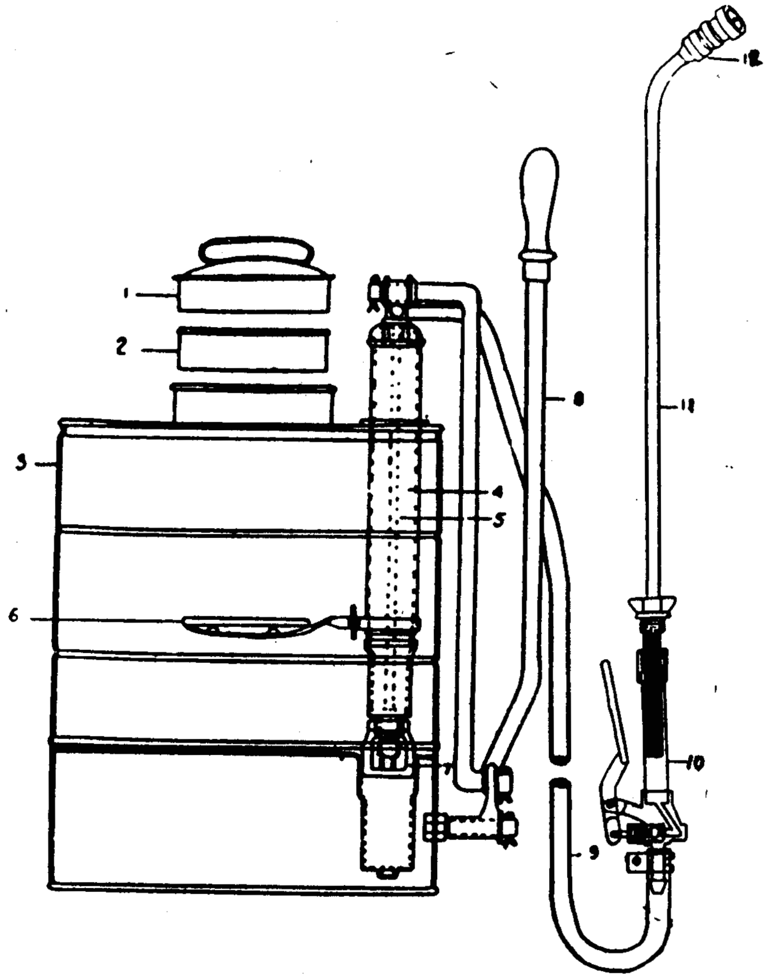
1. lever , 2. platform , 3. strainer , 4. suction hose , 5. pump assembly , 6. closed delivery spout , 7. pressure vessel , 8. delivery hose , 9. trigger cut-off valve with strainer , 10. spray lance , 11. nozzle.

FIG: 2 - ROCKER SPRAYER

operates the piston of the pump. The movement of the piston to the rod end creates a vacuum inside the pump barrel. The liquid in the suction hose which is at the atmospheric pressure flows to the pump barrel. In the return stroke the liquid which was in the pump barrel is pressurised, and the high pressure liquid opens the outlet valve and reaches to the pressure chamber. The pressurised liquid is taken from the outlet of the pressure chamber. There is no built in tank for this sprayer. A maximum pressure of about 36 N/cm^2 can be developed in this sprayer. This is commonly used for spraying tall tree crops. And is not convenient for use in paddy, since a long delivery pipe is to be moved inside the field.

2.4.5.3. Hydraulic energy knapsack sprayer

The hydraulic energy knapsack sprayer has a tank of elliptical or bean-shaped cross section, generally made of galvanised iron, brass, stainless steel or plastic. The filling hole of the tank is usually 12.5 cm in diameter for easy filling without a funnel. The sprayer is so shaped as to conveniently fit on the back of the operator. The tank is provided with a pump, a pressure barrel and mechanical agitator (Fig.3). This can be operated either



1. filler-hole cap, 2. strainer, 3. tank, 4. pressure chamber, 5. delivery tube, 6. mechanical agitator, 7. delivery valve assembly, 8. pump lever, 9. delivery hose, 10. Trigger cutoff valve with strainer, 11. spray lance, 12. nozzle.

FIG. 3. HYDRAULIC ENERGY KNAPSACK SPRAYER

by right hand or left hand. A pressure of 3 to 5 kg/cm^2 can be maintained without much effort. On continuous operation for longer periods the operator gets tired because he has to bear the weight of the sprayer containing the fluid and simultaneously operate the pump lever with one hand and the spray lance with the other hand (Bindra and Harcharan Singh, 1977). As such, the lighter the equipment, less overall effort is needed for the operation. These sprayers require very little maintenance. The advantage of this sprayer is that a constant pressure can be maintained during operation, there by a uniform spray can be obtained. Besides, operator's energy is not wasted by way of compressed air as in the case of hand compression type.

2.4.6. Nozzles

Standard nozzles available in the market are hydraulic energy nozzle. These are the common types used in manually operated sprayers. These nozzles can produce droplets with volume mean diameter of 150 to 400 μm at a minimum pressure of about 1.0 Kg /cm^2, while for the full development of the spray pattern, a pressure of 2 to 3 kg/cm^2 is required (Bindra, and Harcharan singh, 1977). Nozzles are manufactured so as to give various rates of discharge, angles of spray and patterns of spray. These are designed for high pressure or low pressure use, to produce a fan shaped, solid cone, or hollow cone spray patterns (Fig.4). These nozzles give spray angles ranging from straight stream to 100 degrees.

2.4.6.1. Hollow cone nozzles

In the hollow cone nozzle (Fig.5A) the liquid passes through a swirl plate and reaches the disc. When the liquid flows through the swirl plate it achieves a rotating action, and when it is delivered through the disc it gets a hollow cone shape.

2.4.6.2. Solid cone nozzles

In the solid cone nozzle, the liquid passes centrally through the nozzle to fill the air core to produce a solid cone spray pattern. These nozzles are used for the spot spraying of weeds in lawns, because they cover the entire circular area evenly. These nozzles can also be mounted on special booms for a good coverage of the foliage at various heights (Fig. 5B).

2.4.6.3. Triple action nozzles

Triple action nozzle can produce a jet, a solid cone and a hollow cone by adjusting the swirl plate (Fig.5C).

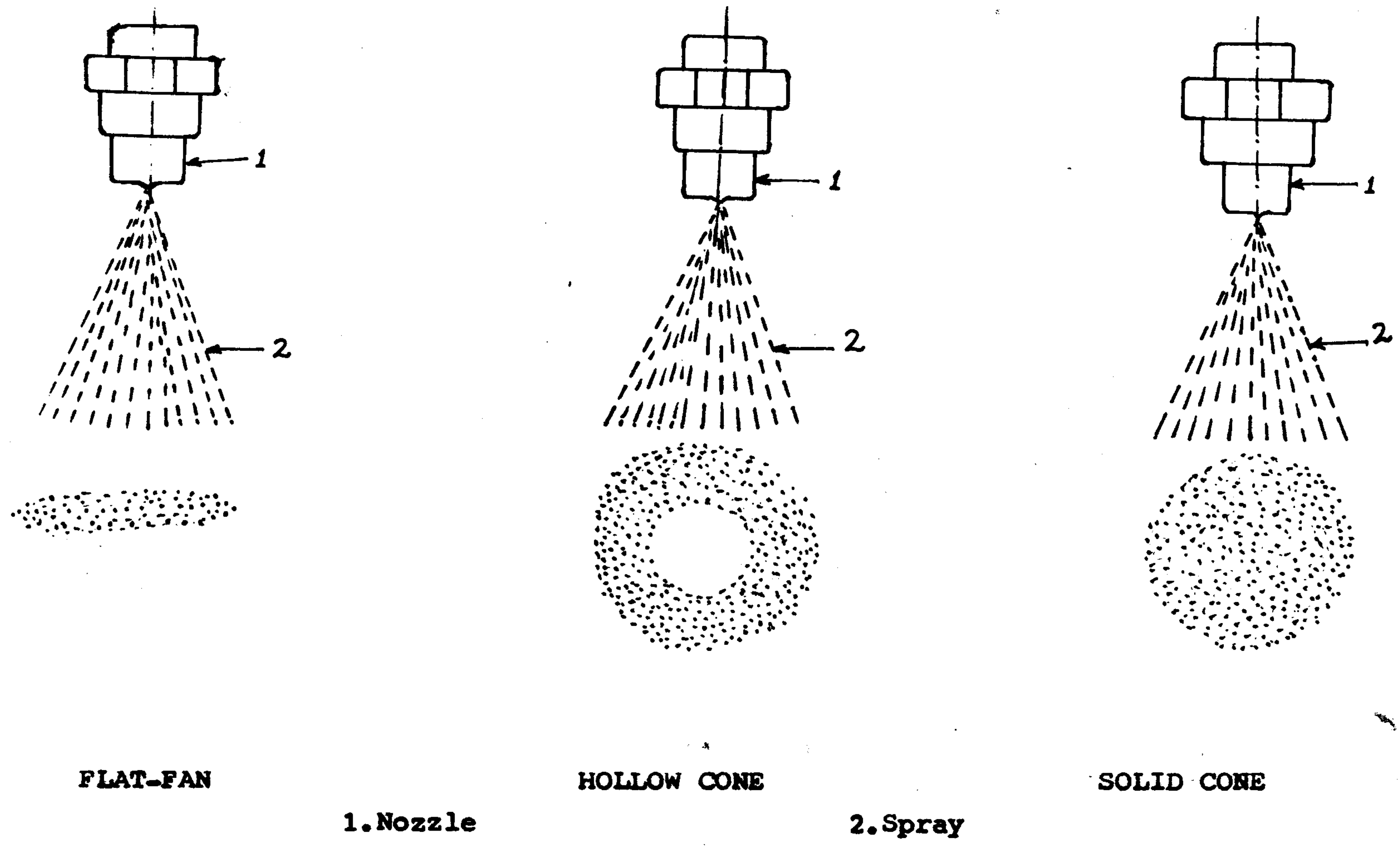


FIG:4. SPRAY PATTERNS

Since the length of nozzle is large compared to the other types this is inconvenient to be moved inside the plant canopy.

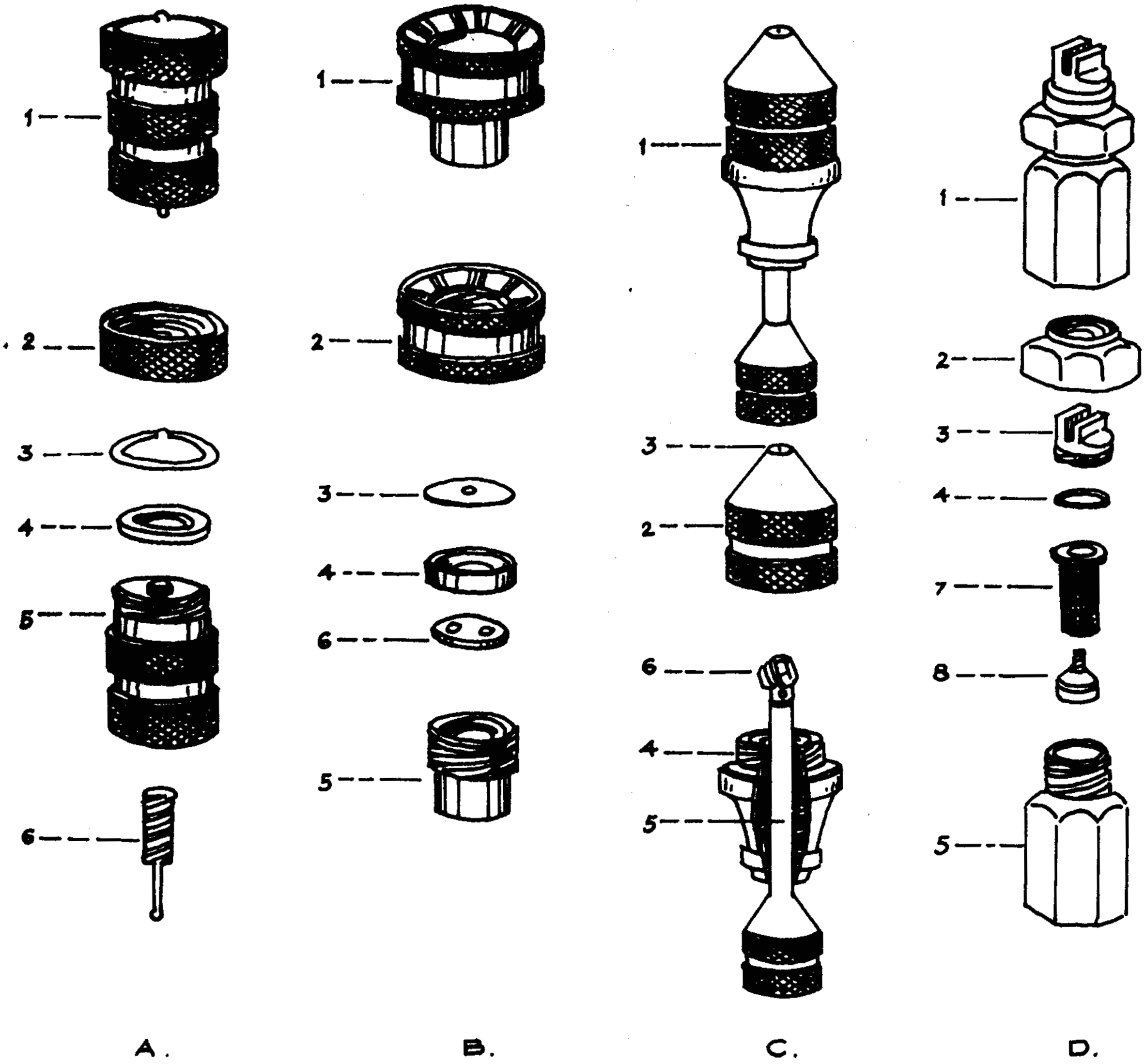
2.4.6.4. Flat-fan nozzle

Flat-fan nozzles are also called fish-tail nozzles (Fig.5D). Their spray pattern is in the form of a triangular flat sheet, with the apex at the nozzle. The internal shape of a fan nozzle permits the travelling of two streams of liquids towards each other inside the nozzle so as to meet behind a single orfice. This produces a flat fan shaped sheet of liquid which disintegrates to form droplets. The spray patterns vary with the spray angles, which range from 45° to 147°. Since there is no swirl plate, the nozzle has low atomizing ability and hence it gives out a coarse spray. These nozzles are, therefore, used for herbicide application.

2.4.6.5. Swivel nozzles

Single swivel nozzle can turn in any angle from 0° to 180°. The joint of the nozzle with the extension rod is swivelling, it can turn in any direction and can be locked at any required angle.

These are available in the single swivel model (SSDN) and Double Swivel (DSDN) model; in the case of a double



A. HOLLOW CONE B. SOLID CONE C. TRIPLE-ACTION
D. FLAT FAN

1. COMPLETE NOZZLE, 2. CAP, 3. DISC; IN D IT IS A NOZZLE TIP, 4. GASKET, 5. BODY, 6. SWIRL PLATE, 7. STRAINER, 8. SCREW RETAINING THE STRAINER GAUGE-ASSEMBLY.

FIG. 5. TYPES OF NOZZLES.

swivel nozzle (Plate 1) there are two nozzles both of which can turn in any direction to spray wider surfaces of plants and bushes. The nozzle size is small compared to other types, and it can be fixed in any position. Therefore, it can move freely under the plant canopy. Moreover, it has two nozzles on each side, so complete coverage is achieved with the minimum number of down pipes.

The existing types of manually operated sprayers are suited for the application of insecticide over the plant canopy only, while the BPH is usually seen on the basel portion of rice plant. Fig.6 shows the position of BPH on plants at the heading stage. For the effective control of BPH, the spray should reach the base of the plant (Fig.7). The design of these sprayers does not permit to use them to penetrate through a dense canopy of rice plants overcoming the resistance offered by the tillers and foliage and to direct the spray to the base of theplants. It is also laborious and time consuming to spray the base of every plant with a single nozzle (Heinriches, 1979). The natural enemies of the BPH which are often found in the foliage are killed when the upper canopy is sprayed. This type of non-selective application causes relaxation

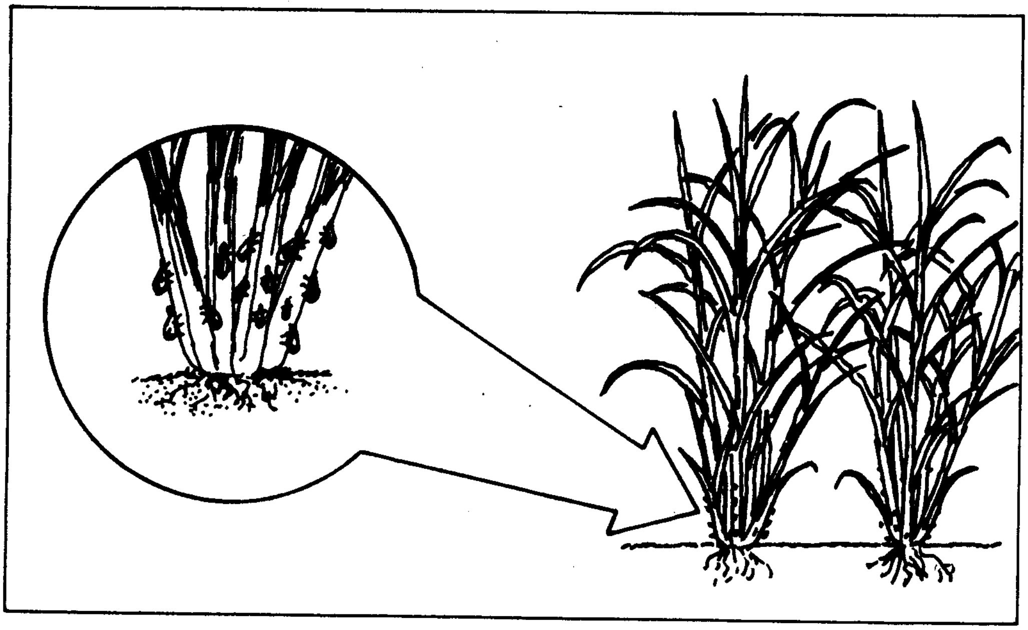


FIG. 6. POSITION OF BROWN PLANT HOPPER ON RICE AT THE HEADING STAGE.

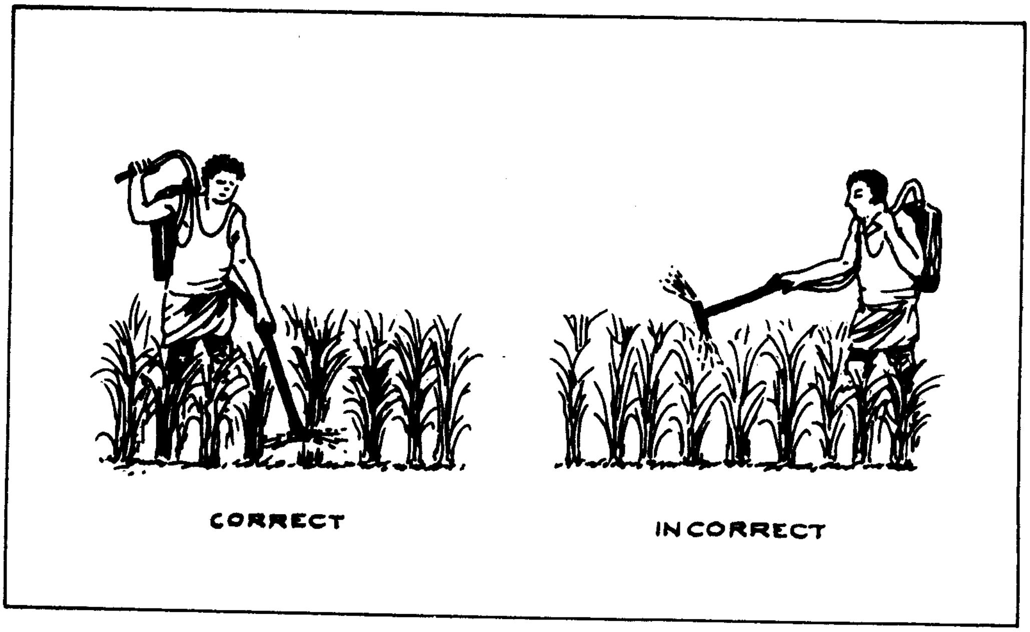


FIG. 7. CORRECT AND INCORRECT METHODS OF SPRAYING FOR BROWN PLANT HOPPER.

in the biotic stress from natural enemies and the resultant population explosion. In order to over come the above problems and to speed up the process of the application, IRRI has developed a six row sprayer with drop nozzles (Fig.8). Its use provided more effective control than the use of canopy sprayers. However, it was advantageous only in rice fields with wider row spacing. Since the nozzles were exposed, and projecting sideways it was disadvantageous in rice fields of India, because of closer spacing. Similarly the shape of the handles did not permit the operators to hold the down pipe vertical while combing, to bring the nozzle in the proximity of the lower region of stem. Besides, all the seven down pipes were connected to a common delivery pipe from just one sprayer, this caused non-uniform application of chemicals from row to row. Therefore it has become necessary to design and develop an insecticide applicator to overcome the difficulties explained and hence this project.

FIG.8. IRRI six row boom for basel
application

Materials and Methods

MATERIALS AND METHODS

This chapter deals with the design aspects and modifications incorporated during the course of development and testing of the new BPH sprayer. These are arranged in the following sub-headings:

1. Objectives and concept
2. Design considerations and the development of the sprayer
3. Preliminary laboratory studies for the selection of the nozzle
4. Main experimental programme
5. Final laboratory test
6. Observations and measurements

3.1. Objectives and concept

A critical review of the existing practices, and methods of applications available, brought out the following facts:

(a) Out of the four methods of control namely, chemical, varietial, Biological, and cultural, the chemical method is the best one, provided sufficient amount of the insecticide is sprayed at the correct place of infestation.

(b) Effectiveness of the insecticide spray vary with the place of application.

(c) The natural enemies of BPH are eliminated when sprayed with conventional sprayers, thereby causing pest population explosion.

(d) The currently available manually operated sprayers can be used effectively for the canopy spraying, while for the effective control of BPH, the spray, should reach around the stem at about 15 to 20 cm. from the field level where the insects are usually confined.

(e) With a single nozzle conventional sprayer and directing the spray at the base of every plant is a laborious and time consuming process.

It was, therefore decided to design a boom type insecticide applicator for the control of brown planthopper in paddy fields to overcome the afore-mentioned drawbacks of the existing practices.

The main objectives of this study were:

(i) Design a suitable spray boom with boom-drops, to be used in conjuction with a pair of knap-sack sprayers.

(ii) Fabrication of the unit designed under (i) above.

(iii) Testing of the above applicator in the field.

(iv) Modification of the applicator to overcome the drawbacks if any and to fit the best nozzle combination.

(v) Evaluation of the modified version for effectiveness and limitations.

3.2 Design considerations and the development of the sprayer

3.2.1. Theoretical considerations

Based upon the entomological aspects and cultural practices, the following fundamental requirements were set for the design of the new BPH sprayer.

1. It should discharge the spray of insecticide at a height of 15 to 20 cm above the ground on the base of the plant.
2. The application rate of the liquid should be 500 litres/ha.
3. The nozzle should be easily moveable through the thickly planted rice.
4. The speed of travel of the operator should be about 1 kmph.
5. The discharge pressure of the nozzle should be about 2 kg/cm^2.
6. It should cause a minimum damage to the crop.
7. It should give only minimum drudgery to operator.
8. It should be portable, cheap, simple and easy for maintenance.

In order to satisfy these a spray boom concept was used. According to Menon (1986) for BPH control, a high volume spraying (400 to 500 litres/ha) is recommended, which were seen 45 days after transplanting (DAT) or 60 days after sowing (DAS). Some of the insecticides recommended for spraying one hectare are:

1. Monocrotophos (Nuvacron) 600 ml of 40 EC
2. Phosmamidon (Dimecron) 250 ml of 100 EC
3. Quinalphos (Ekalux) 1000ml of 25 EC
4. Phosalone 1000 ml of 35 EC

Of the above insecticides, Nuvacron has got persistent long residual action and ovicidal action, so it is more commonly used.

3.2.2. Relations used

Width of boom = 2.5 m (assumed)

Speed of travel = 1 kmph (")

= 1000 m/hr

Application rate = 500 lit./ha

Tank capacity of hydraulic knapsack sprayer = 16 l

Time required for one hectare spraying

$$= \frac{10000\ m^2/ha}{\text{Boom width in m} \times \text{speed of travel in m/hr}}$$

$$= \frac{10000}{2.5 \times 1000} = 4.0\ hr/ha$$

Flow rate of boom in lit/hr = $\frac{\text{boom width in m} \times \text{Application rate in l/ha} \times \text{speed of travel in m/hr}}{10000 \text{ m/ha}}$

$= \frac{2.5 \times 500 \times 1000}{10000} = 125$ lit/hr

Number of tanks per hectare = $\frac{\text{Application rate in lit/ha}}{\text{Tank capacity}}$

$= \frac{500}{16} = 31.25 = 32$ tanks (say)

Number of filling $= \frac{32}{2} = 16$

Time for one filling = 5 min

Total filling time = 16 x 5 = 80 min = 1.33 hr

Assuming an average plot size = 100x50m = 0.5 ha

Number of turnings at the headlands $= \frac{50}{2.5} - 1 = 19$

Time taken for turning at one headland = 1 min

Total turning time for 0.5 ha = 19 x 1.0 = 19 min

Turning time for one hectare = 38 min = 0.63 hr

Total time = spraying time + filling time + turning time

= 4 + 1.96 = 5.96 hrs/ha

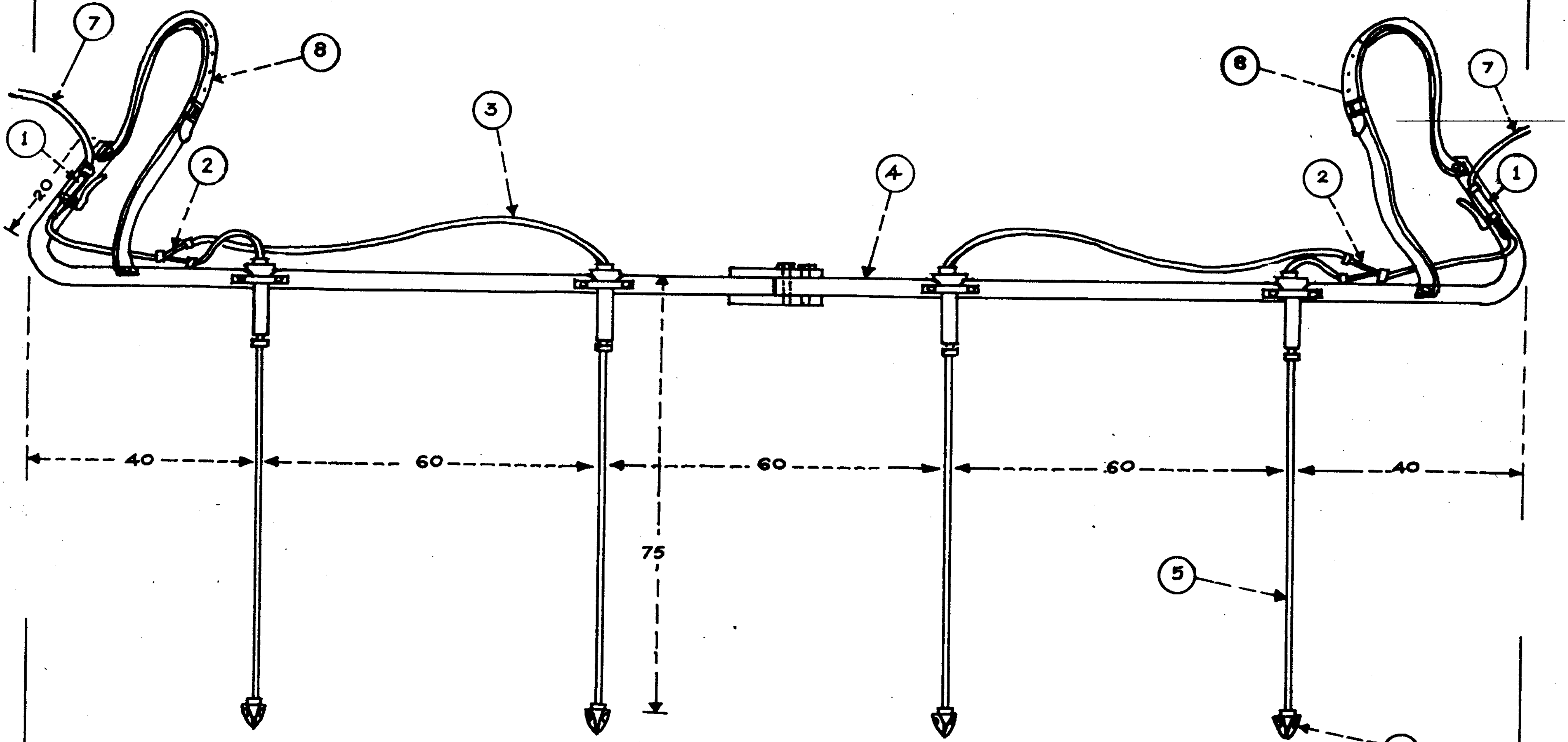
Field efficienty $= \frac{4 \times 100}{5.96} = 67.45\%$

3.2.3. Major components of the boom

The major components of a spray boom are sprayer, hose, boom carrier, cut-off device, downpipe, and nozzle, which are shown in Fig.9.

3.2.3.1. Sprayer

In the existing manually operated sprayers, hydraulic energy knapsack sprayer was found to be more advantageous compared to other types of sprayers as a constant Pressure can be maintained during operation, thereby a uniform spray can be obtained.
The metal tanks are now expensive and the modern



1. TRIGGER CUT-OFF VALVE
2. THREE WAY JOINT
3. HOSE CONNECTION
4. BOOM CARRIER
5. DOWN PIPE
6. NOZZLE WITH COVER
7. CONNECTION TO SPRAYER
8. CANVAS BELT

ALL DIMENSIONS IN cm.
SCALE . 1:10

FIG. 9. BPH APPLICATOR

trend is to use a plastic tank usually moulded from high density polyethylene or poly-propylene incorporating an ultraviolet light inhibitor. The volume of the liquid in the tank is indicated by graduated marks, the translucent plastic material helps for the direct observation of the liquid.

The pressure in this sprayer is developed by an under arm operated piston pump. The pump was connected by a system of linkages to a lever which was pivoted at a lower point on the side of the tank. During the upward operation of the lever liquid was drawn through a flexible piston into the pump barrel. With the return of the lever to the original position, liquid in the pump barrel was forced past outlet valve, into the pressure chamber. An agitator was also fitted to the external casing of the pressure chamber. The compressed liquid from the pressure chamber was delivered to the cut-off device by a flexible hose.

3.2.3.2. Hose

The hose was used for connecting the delivery end of the pressure chamber to the open end of the cut-off device. The outlet end of the cut-off device was connected to the tee-joint by hose pipes. From the tee-joint to the open end of the down pipe, another piece of hose pipe was used, as shown in Fig. 9. The hose should be light, non-absorbent, oil resistant, durable and flexible. According to Bindra and

Harcharan singh (1977) the bursting pressure of hose should be three times greater than the spraying pressure. In the prototype flexible hose with bursting pressure of 7 kg /cm^2, inner diameter of 7mm and wall thickness of 3mm were used. Hose clips were used for tightening the ends of the hose.

3.2.3.3 Boom carrier

Spray lance carrying more than one nozzle is commonly known as spray booms. In this work 18mm galvanised iron pipe of length 3m with two ends bent at right angles were used as the boom carrier. The boom carrier was cut into two halves which were joined together with nuts and bolts. This facilitated easy transportation. Cut-off devices, downpipes and connecting hose, were attached to the boom carrier.

3.2.3.4 Cut-off devices

Cut-off devices were provided to control and cut-off the flow of pressurised liquid from the tank to the nozzle. In the prototype model of the applicator, trigger cut-off valve with pressure regulater was used for reading out the pressure of liquid. But for commercial purpose trigger cut-off valve with strainer is only required.

3.2.3.5 Down pipe

The nozzle is attached to one end of the down pipe. And the other end is connected to the tee joint by the hose. Brass pipes of length 75 cm with wall thickness 0.6 m.m and internal diameter 6 m.m were used as down pipes.

3.2.3.6. Nozzle

The results of the preliminary nozzle testing and also from the review of literature available on nozzles, it was found that Double Swivel Duro Nozzle (DSDN) was better than other types of nozzles.

3.3. Laboratory Studies for the selection of the nozzle

In order to select the most suitable nozzle from the various types available, a laboratory study was conducted.

3.3.1. Initial testing

Initial testing of the nozzle for their performance was done at the Agricultural Engineering Research Workshop, Mannuthy. Since the BPH is usually seen on the lower stem portion, insecticide has to be sprayed at the bottom portion, and hence conventional nozzle testing methods could not be used here. The types of nozzle tested were flat-fan, Triple-action and DSD nozzles.

For testing the nozzle performance, a frame work of size 200 x 150 cm was fabricated making use of angle iron.

In order to study the pattern of droplet discharge along a vertical plane, for spraying at different heights, another table like moveable frame work made out of angled iron having an overall dimensions 160 x 25 x 50 cm. The movable frame work was placed over the frame kept flat on the ground. In this moveable frame work, an angle iron section was provided lengthwise in such a manner that its vertical height from the ground level could be adjusted to the required levels. To simulate the field spraying conditions in which the lance and the nozzle assembly is moved along a vertical axis to reach the base , the laboratory test was conducted with the lance kept vertically downwards and this was gently slided over the angled iron cross bar to deliver the spray from various fixed heights. The spray deposition pattern along the vertical plane at various distances from the nozzle point was studied by collecting the droplets on a large paper sheet of size 150 x 50 cm. The paper was kept vertical with the help of metallic rods welded at one end of the frame in an upright manner. The experimental set up is shown in Plate - II. The liquid was sprayed with flat-fan, hollow cone, solid cone and DSD nozzles.

Black ink was used as dye for spraying. The number of droplets at different heights for different nozzles were counted. The results obtained are presented in Table - 4.

From the observations, the DSD nozzle was found to be better as it gave a solid cone spray pattern which could cover a full area. The droplets formed are fine compared to flat-fan and hollow cone nozzle.

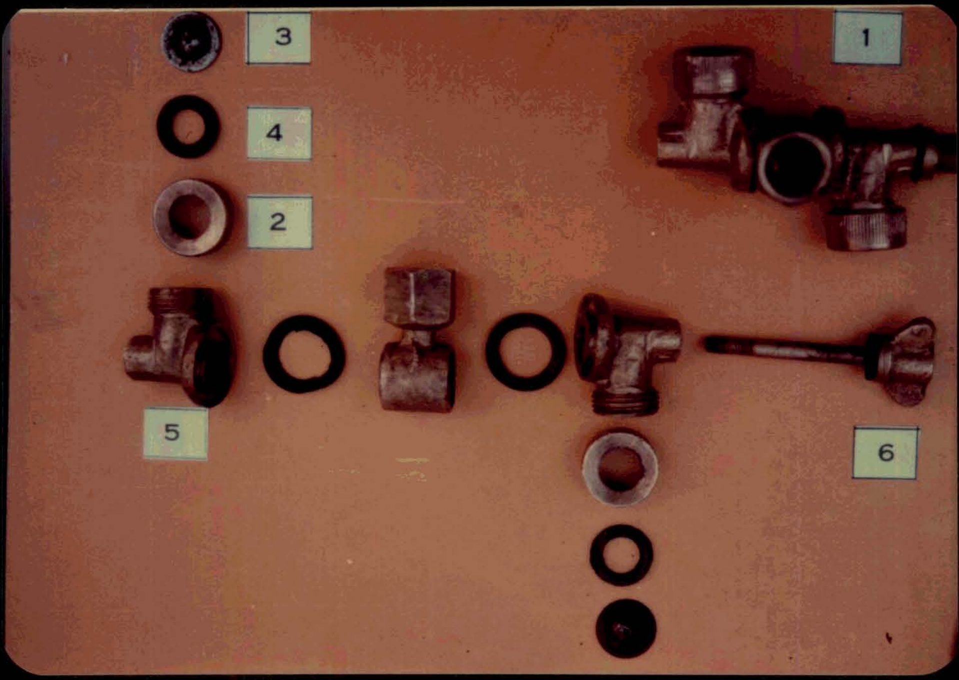
3.3.2. Second stage testing

The experiment was then continued by simulating the field conditions in the laboratory. The set up is shown in Plate - III. Paper was rolled out in open cylindrical shape

Plate I. Double Swivel Duro Nozzle

1. complete nozzle, 2. cap, 3. disc,
4. gasket, 5. body, 6. wing nut.

Plate II. Laboratory testing of nozzle


3
1
4
2
5
6

of about 4 cm in diameter and 25 cm height to represent one hill of paddy plant. They were fixed in the tray at a spacing of 15 cm x 15 cm to represent spacing of the hills of the standing crop. Then a colour spray with black ink was given. All the four types of nozzles were tested. The paper roll near the nozzle has got some run off. Because the spray liquid coming out of the nozzle tip has got no time and distance for development when the paper roll was very close to the nozzle. The experiments were repeated for different pressures and at different walking speeds. DSD nozzle was found to be better from a large number of trials, and it could give a uniform spray pattern upto a maximum distance of 60 cm from the tip of nozzle.

3.3.3. Third stage testing

After selecting the most suitable nozzle as DSD nozzle and the spacing of the down pipes as 60 cm, the fabrication of the sprayer was done. 18 mm GI pipe was used as the boom carrier. Four sets of DSD nozzles were connected to four down pipes, and they were connected to a hand compression sprayer by flexible hose. Plate -IV shows the general set up of the prototype model. This model was tested in the Agrl. Engg. Workshop, Mannuthy with paper rolls as mentioned in para 3.3.2. It was found that even though an initial pressure of 4 Kg/cm^2 was developed, the pressure dropped rapidly and sufficient atomization could not be achieved. This was because the air pressure came down very quickly since four sets of

Plate III. Simulated field testing of nozzle

Plate IV. General set up of a prototype model

DSD nozzle were attached to one hand compression sprayer.

Then the boom was modified using two hand compression sprayers by connecting two sets of DSD nozzle to one sprayer tank each. At this stage, two hand compression sprayers were connected to the boom, one at each end. This modified model is shown in Plate - V. The testing was repeated with different pressures and paper rolls. It was found to be satisfactory and a uniform spray pattern was obtained. However the pressure was not sufficient for the complete discharge of liquid in the sprayer; so it was pressurised once again.

From the above tests, DSD nozzle was found better than other nozzles. The size of the DSD nozzle was very small compared to the triple action nozzle, so it could be moved freely under the plant canopy. Moreover it had two nozzles on each side so complete coverage could be achieved with minimum number of down pipes. This type of nozzle can be tilted or directed to any angular position. It was also found that it gave fine spray pattern at moderate pressures than the flat-fan nozzles.

3.4 Main experimental programme

From the design criteria and preliminary studies a prototype model was developed. This prototype model was then tested in actual field conditions.

3.4.1. Initial field testing

The prototype fabricated was tested firstly at Regional Agricultural Research Station, Pattambi, in April 1987. The testing was conducted in a transplanted paddy field. The crop had just completed its flowering stage. A view of the field operation is shown in Plate -VI. The boom was tested after the flowering stage because BPH infestation mainly occur at this stage, and the plant reach its maximum growth at this stage.

During the test, the following difficulties were observed:

(i) tilting of the boom backwards from vertical position due to the leaf hindrance on the nozzle.

(ii) pressure in the tank drops very quickly.

(iii) it was difficult to keep the boom at constant perpendicular height from the field surface.

3.4.2 Modifications incorporated

In order to overcome these difficulties following modifications were made in the boom:

1. A shoe shaped nozzle cover was designed and made with MS Sheet. It is shown in Plate -VII. This arrangement helped the combing-off operation in the thickly populated crop. This also reduced the tilting of the boom to some extent.

2. The boom carrier was modified by extending the length of boom in the perpendicular direction as shown in Fig. 9. This helped the operator to hold the downpipes in the vertical position.

Plate V. Simulated field testing of boom

Plate VI. Initial testing of the boom

By operating the pump lever of the hydraulic energy knapsack sprayer, constant spraying pressure can be maintained. A canvas belt was also provided for carrying the boom on the shoulder of the operator. This arrangement helped the operator to keep the boom at a particular height from the field surface, and gave more operational comfort.

3.4.3. Second stage field testing

Second stage field testing was carried out to locate the spray height and coverage. This was to study the effectiveness of spray. Black ink was mixed with water for spray which would stain the plant stem and bottom leaves. Since there were a large number of droplets it was very difficult to measure with naked eye. Counting the number of droplets under a microscope was also difficult, because the plants gets withered and the droplets could not be identified.

In order to overcome this difficulty glass pieces having the size of 25 cm length and 2.5 cm width were taken. Magnesium ribbon was burned in atmospheric air, and the magnesium oxide fumes coming were allowed to fall on one side of the glass plate. The glass plate is to be waved during coating to obtain a uniform coating of magnesium oxide.

The coated glass plates were tied in pairs with their coated sides facing in opposite directions. This were then arranged in vertical position randomly in plant hill rows so as to catch the spray running from opposite directions, in a transplanted paddy crop which was at the flowering stage. The arrangement is shown in Plate -VIII. The impact of the sprayed droplets of water forms micro-craters on the coating.

Initial and final pressures on the gauge fixed on the boom, and also the speed of travel was noted. The number of craters formed were counted with the help of a microscope. The experiment was repeated at different pressures. The results obtained are tabulated in Table - 6.

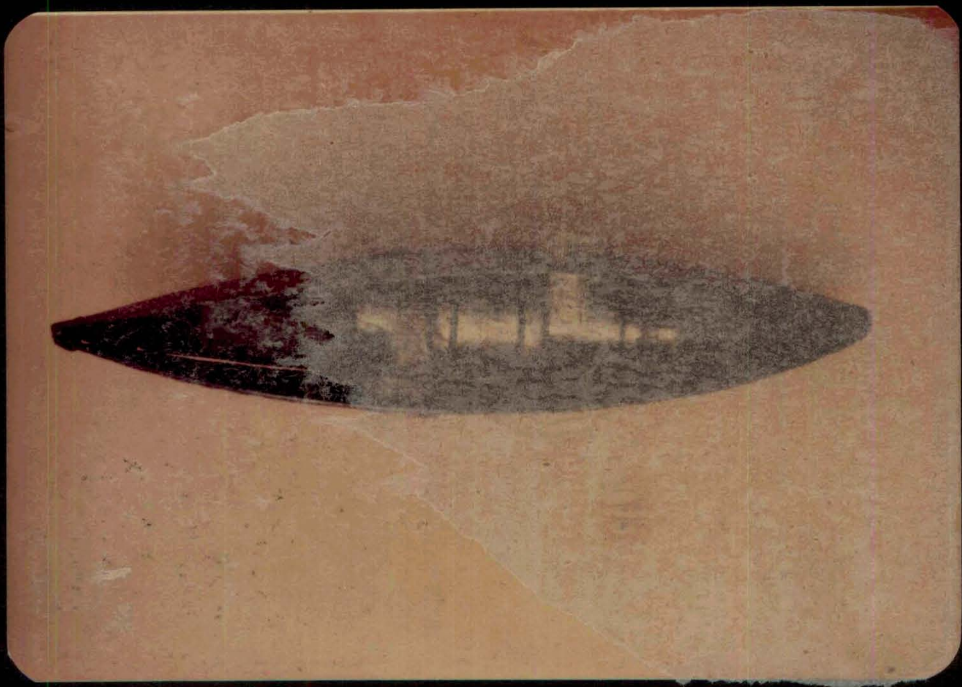
The boom was also tested at the Instructional Farm, Tavanur. The testing was done in the transplanted paddy which was near the flowering stage. A uniform spray coverage was obtained at heights of about 5 to 25 cm. Only visual observations were made in this test.

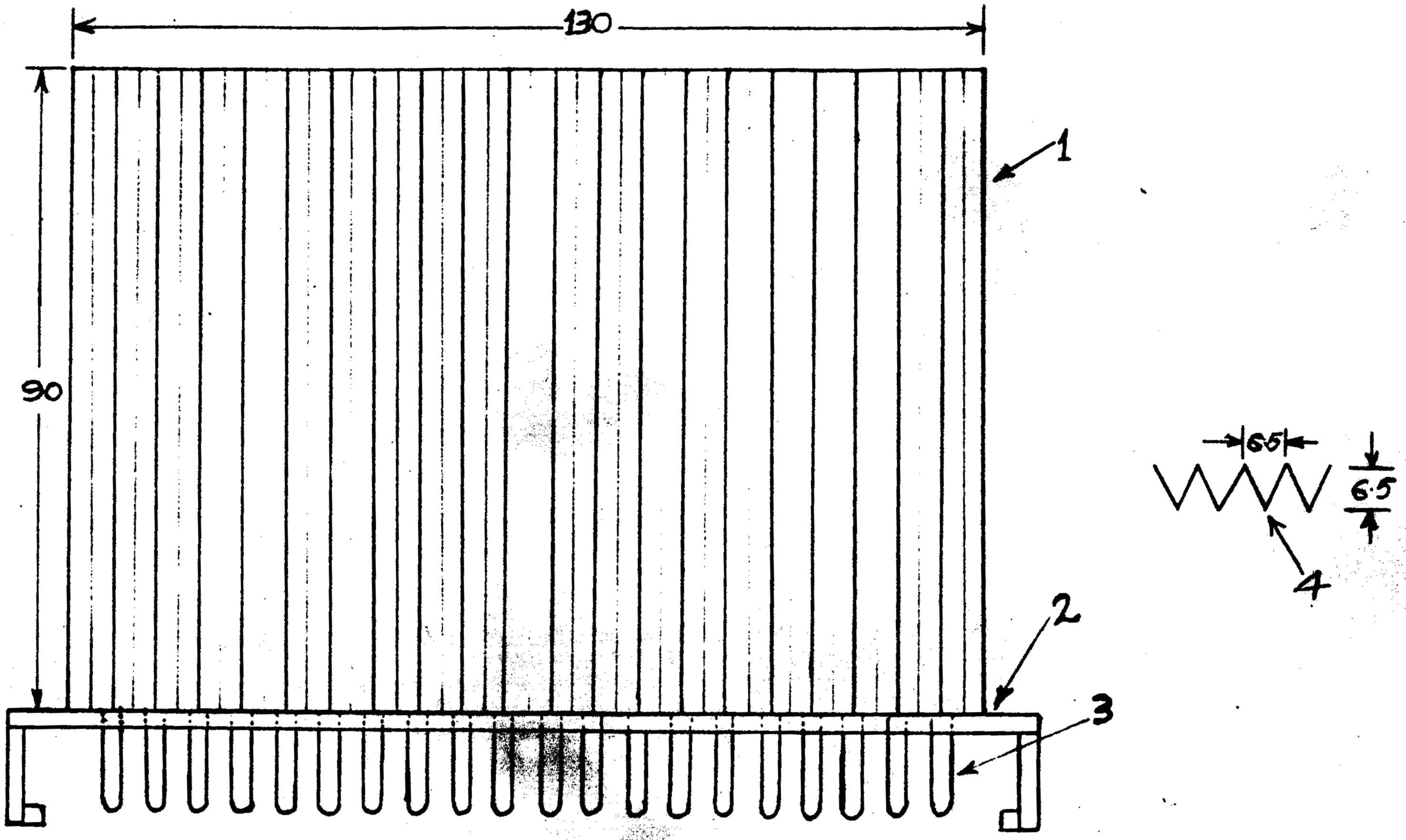
3.5. Final laboratory test

Final laboratory test was conducted at the Farm Machinery Laboratory, Tavanur. In this, spray intensity distribution was tested with a patternator in a closed room to avoid the air drift. A patternator was made with 24 gauge GI sheet. This comprised 20 "V" shaped channels (Fig. 10) each of 6.5 cm width and 6.5 cm depth. The total length of patternator was 130 cm and width being 90 cm. Test tubes were kept close to the end of each of the channels, so that the spray fluid falling in each channel could be collected in the test tubes

Plate VII. **Double Swivel Dure Nozzle in shoe shaped cover**

Plate VIII. **Arrangement of magnesium oxide coated glass plate in paddy field**





1. triangular sectioned G.I.sheet , 2. test tube stand ,
3.test tube , 4.cross section of G.I. sheet.

SCALE 1:10

ALL DIMENSIONS IN CM.

FIG: 10 – PATTERNATOR MODEL.

provided. The quantity of fluid collected in test tubes were measured with a measuring cylinder. In this testing, two types of spray patterns were studied.

In the first test patternator was placed vertically with adequate support. The nozzle was kept perpendicular at a height of 20 cm from the top of the test tube at a distance of 30 cm from the patternator. Water was sprayed for a time interval of one minute, keeping the spraying pressure at 2.0 kg/cm^2. The quantity of liquid collected in the test tube was measured. The experiment was then repeated for distances from 40 to 80 cms. The results are tabulated in Table - 7. A spray intensity curve was also drawn shown in Fig. 11.

In the second test, the patternator was kept inclined at an angle of 5.5° to horizontal, the test tube stand was kept under it in such a way that the liquid falling in the channels was collected in the test tube below it (Mathews, 1979). The boom was kept above the patternator in such a way that the nozzle height from the centre of the patternator was 25 cm. The experimental set up is shown in Plate - IX. The liquid was sprayed for one minute, keeping the pressure constant. The liquid fell in in each channel was collected in the test tubes below it. The quantity of liquid collected in the test tube was measured. This is also shown in Plate - X. The experiment was repeated by varying the pressure. The results are presented in Table - 8. The spray intensity curve is drawn and shown in the Fig. 12a, 12 b, and 12 c.

Plate IX. Experimental set up to determine the flow pattern

Plate X. Evaluation of the flow pattern

3.6. Observations and measurements

During the study the following observations were made;

(i) Discharge rate, measured in lpm

(ii) Coverage, measured in number of droplets per unit area

(iii) Flow pattern

The discharge rate and the coverage were recorded during the experiments and are presented in Table - 6 and 5. The flow pattern was taken during the final laboratory test and is given in the Table - 7 and 8.

It was also decided to observe the efficacy of the applicator, but it could not taken, because severe BPH attack was not reported from any where during the period of study.

Results and Discussion

RESULTS AND DISCUSSION

The results of the laboratory studies as well as the field tests of the applicator for BPH control are discussed in this chapter.

4.1 Laboratory tests

Selection of the nozzle, determination of the effective width per nozzle and the preliminary testing of the applicator were conducted in the laboratory.

4.1.1 Nozzle testing

The results of the laboratory tests conducted with the hand compression sprayer fitted with solid cone, hollow cone, flat-fan and DSD nozzles for finding out the uniformity and spray pattern when the direction of the spray was perpendicular to the paper (Plate -II) are given in the Table - 4. From this test, it was observed that the spray pattern was more uniform for the DSD nozzles. The nozzles were tested at a uniform pressure of 4 kg/cm^2. In the case of DSD nozzles it could be swiveled to 180° in vertical plane and their size was small compared to other type of nozzles. Moreover, by fixing it at the end of the downpipe the two nozzles could be directed to opposite sides. This arrangement get better coverage with lesser number of downpipes.

Table - 4. Spray characteristics of the nozzles

Nozzle moved parrllel to the full paper

Trial - I. Triple action (hollow cone) nozzle pressure = 4kg/cm^2

Sl. No.	Nozzle height from bottom cm.	No.of droplets per unit area (cm^2) for distances from paper			
		[illegible]	60cm	70cm	80cm
1	2	3	4	5	6
1	4	56, 52, 32, 30, 38, 33, 26	52,47,39,14, 15,24,10	31,25,15,11,12,10, 4	8, 5, 2, 5, 4, 4, 4
2	8	34, 36, 35, 25, 28, 25, 32	42,37,31, 8, 8,14,10	29, 6,10, 4, 3, 6,11	5, 5, 0, 3, 9, 6, 2
3	12	44, 47, 34, 32, 37, 31, 34	14,22,15,13, 9,18,22	68,55,30,51,34,33,36	41,21,30,24,20,18,15
4	14	20, 14, 16, 18, 17, 10, 10	18,15,16,17, 26,15, 7	8,14,12, 9,11, 9,14	14, 5, 3, 1, 2, 7, 7
5	18	39, 31, 33, 35, 36, 34, 28	10, 7,11,10, 8, 9, 3	8, 7, 8, 3, 8,10, 6	0, 2, 4, 1, 0, 1, 0

Trial - II. Triple action (solid cone) nozzle

1	4	46, 41, 38, 38, 41, 40, 29	50,47,43,41,36,29, 9	56,51,46,36,23,18, 8	59,56,44,41,38,36,32
2	8	53, 45, 49, 51, 43, 40, 15	36,36,38,34,20,17, 9	30,38,38,36,31,28,16	44,44,41,41,43,30,12
3	12	44, 42, 43, 41, 42, 39, 42	32,36,37,41,35,42,40	46,41,44,41,39,38,27	35,36,33,32,30,28,18
4	14	66, 50, 60, 51, 49, 42, 39	72,63,66,61,61,46,51	42,29,32,27,30,19,12	10,12,21,20,19, 9, 9
5	18	44, 43, 45, 42, 44, 41, 38	35,33,36,36,31,31,33	44,39,34,32,21,21,18	28,40,32,19,20,28,27

Table - 4 (contd.)

Trial - III Flat fan - nozzle

1	2	3	4	5	6
1	4	42,40,38,34,40,36,32	42,37,38,33,28,26,21	44,31,33,31,33,29,22	46,40,41,37,28,27,23
2	8	40,35,37,34,38,30,23	36,26,37,34,24,27,18	48,42,34,38,42,35,31	49,41,33,31,24,21,20
3	12	50,49,46,43,36,34,30	48,46,42,38,40,31,38	51,48,33,40,42,34,30	36,37,32,29,26,19,21
4	14	61,46,52,52,44,54,40	30,45,25,34,49,36,42	33,31,32,33,35,33,31	21,16,25,32,25,19,18
5	18	43,44,41,37,42,45,36	31,24,37,29,31,28,32	25,26,23,34,33,23,29	17,17,12, 5, 9, 3, 2

Trial - IV Double swivel nozzle

1	4	42,36,30,21, 8, 5, 0	39,35,33,31,24, 9, 4	38,36,32,29,24,10, 2	25,21,26,21,13, 5, 3
2	8	42,39,25,22,12, 2, 1	43,41,36,34,32,24,14	29,26,28,13 7, 3, 1	27,24,14, 4, 2, 1, 0
3	12	42,36,30,27,26,24,17	26,28,32,30,23,19, 6	21,20,28,30,26,20,18	28,33,23,17,14,12,13
4	14	34,35,40,26,25,12, 7	25,22,30,25,16,15,15	15,14,20,18,14,12,11	8, 6, 4, 9, 5, 6, 2
5	18	31,29,26,28,25,24,21	25,30,29,25,17,13, 7	21,16,13,14,15,12,13	9, 2, 3, 5, 9, 5, 3

4.1.2 Row coverage of the nozzle

The spacing of the nozzles or downpipes were determined on the basis of the results obtained in this test. The paper roll near the nozzle got run off and a uniform spray pattern was observed upto a maximum distance of 60 cm from the nozzle. Visual observations only were taken in this aspect. The spacing of the downpipes was taken as 60 cm from these results.

4.1.3 Preliminary testing of applicator

A single pneumatic knap-sack sprayer was connected to four DSD nozzles. It was found that the pressure decreased from 4 kg/cm^2 to zero in two minutes due to the high rate of fluid discharge through more number of nozzles. When this test was repeated with two pneumatic knap-sack sprayers, each one connected to two DSD nozzles, almost constant pressure could be maintaned and a better discharge and spray pattern were observed.

4.2 Field test

Field test was conducted with the prototype model of the boom for the preliminary observation of its field performance. It was found that tilting of the boom from vertical position was a problem, due to leaf hindrance. A shoe shaped nozzle cover was designed and fitted with the nozzle (Plate - VII), which reduced the problem to a greater extent. A canvas shoulder belt was also provided to the boom so that the weight of the boom was transferred from hand to shoulder of the operator. This arrangement also helped to keep the nozzle at a constant height from the field surface.

Testing of the boom, to find out its discharge and coverage, was conducted using magnesium oxide coated glass plates. It was observed from the results that a discharge of 1250 ml in 55 sec was got when the pressure range was 3-2 kg/cm^2. The number of droplets per sq. cm area for distances 5, 10, 15 and 20 cm from bottom was around 15, 16, 17, 14 as in Table - 5. It was observed that, in order to spray one hectare of field infested with BPH, 450 litres of spray fluid was necessary, this is in agreement with the recommended value. It could be sprayed in a total time of about 80 hours by two persons. The results are presented in Table - 6, and Appendix - I. It was found from the trials that as the length of plot increases the time taken to spray one ha decreases. This is because greater time was taken at the end of row for curving.

4.3 Final laboratory test

Patternator testing was the final laboratory test to determine the spray intensity distribution. In this test, the nozzle axis was kept perpendicular to the vertical

Table - 5 Coverage characteristics of the boom

Sl. No.	Pressure kg/cm^2 Initial	Final	Number of drop lets per cm^2 Distance from bottom (cm) 5	10.	15	20
1 - a	3.0	2.0	15	16	17	14
1 - b	"	"	18	20	21	19
2 - a	"	"	11	12	9	8
2 - b	"	"	20	23	25	19
3 - a	3.25	2.0	16	18	20	15
3 - b	"	"	18	21	20	16
4 - a	"	"	20	22	20	18
4 - b	"	"	17	16	19	15
5 - a	3.5	1.5	20	23	22	18
5 - b	"	"	21	25	23	18
6 - a	"	"	16	19	21	17
6 - b	"	"	20	23	21	18
7 - a	4.0	1.5	25	26	28	20
7 - b	"	"	26	28	24	21
8 - a	"	"	21	20	18	16
8 - b	"	"	28	30	32	15

a and b represents two sides of the pair of magnesium coated glass plates.

Table - 6 Discharge characteristics of the boom

Sl.No.	Pressure (kg/cm^2)				Discharge (ml)					Time (Sec)	Distance travelled (m)
	Initial		Final		1	2	3	4	Total		
	Left	Right	Left	Right							
1	3.0	3.0	2.0	2.0	320	305	300	315	1250	55	11.6
2	3.25	3.25	2.0	2.0	332	310	307	325	1274	55	11.6
3	3.5	3.5	1.5	1.5	660	640	625	680	2605	90	25.6
4	4.0	4.0	1.5	1.5	690	682	675	685	2732	90	25.6

patternator. Because in the field the target (plant stem) was always perpendicular to the nozzle. The results are given in Table - 7. From the results it is observed that the total discharge per nozzle increased with the spacing between nozzle and patternator reaching a maximum value of 256.5 ml/min at 60 cm spacing and then decreased. This may be due to:

(i) When the nozzle is closer to the patternator the droplets reflects back from the patternator and are not collected.

(ii) When the nozzle distance increases the droplet velocity in that direction decreases, so the rebounding decreases.

(iii) When the nozzle distance from the patternator was further increased, the spray cone size increases, and a portion of the cone was not reaching the patternator, due to the lower height of the nozzle, hence the discharge decreases.

Figure 11 shows the graphical representation of the spray pattern when the nozzle was kept perpendicular to the vertical patternator.

When the nozzle plane was parallel to the patternator, which is at 5.5° to horizontal as in Plate - IX, a uniform spray pattern was obtained in this test and the results are shown in Table - 8. This spray pattern is represented in Fig. 12 a, 12 b and 12 c.

Table - 7 Spray pattern characteristics of DSD nozzle
(Patternator plane perpendicular to spray)

Test tube No.	Discharge in ml/min. Distance between patternator and nozzle at pressure 2 kg/cm^2					
	30 cm	40 cm	50 cm	60 cm	70 cm	80 cm
1.						
2.						
3.						
4.			0.5	0.5	0.5	
5.	0.5	0.5	1.0	2.0	1.0	0.5
6.	1.5	1.0	7.0	7.5	2.0	1.0
7.	6.5	3.0	12.0	18.5	6.5	3.0
8.	26.5	12.5	14.5	21.5	11.0	8.5
9.	49.5	25.5	32.5	24.5	19.0	12.5
10.	56.5	33.5	36.0	28.0	20.5	12.5
11.	30.5	55.5	53.0	42.5	31.5	21.5
12.	3.0	31.5	33.5	44.5	33.0	23.5
13.	1.0	7.5	13.5	42.0	29.5	27.0
14.		1.0	2.5	18.0	16.5	26.5
15.		0.5	1.0	5.0	5.5	17.0
16.			0.5	1.5	1.5	7.0
17.				0.5	0.5	2.0
18.						0.5
19.						
20.						
Total	175.5	172.0	207.5	256.5	178.5	163.0

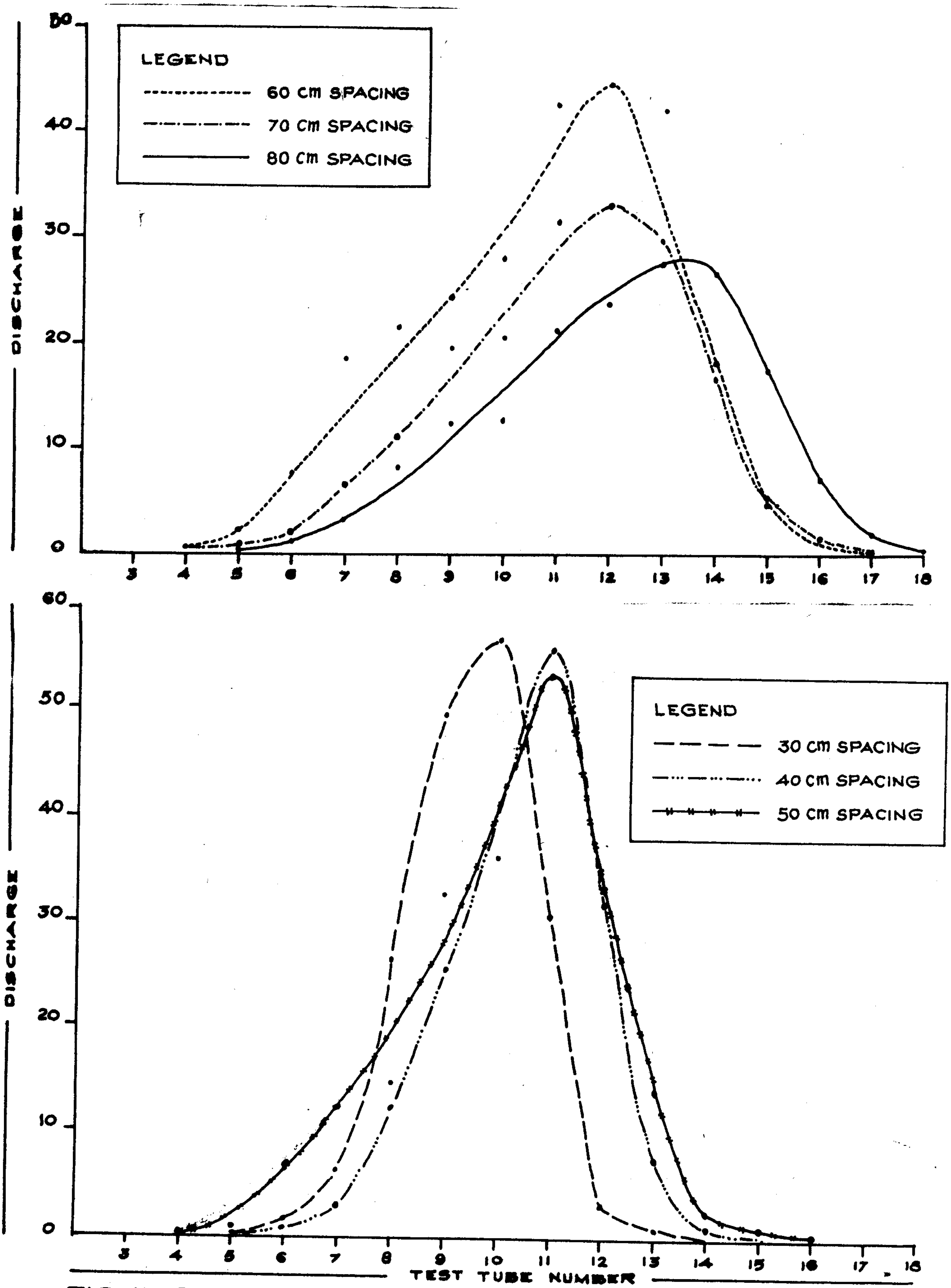


FIG. 11. SPRAY PATTERN.

Table - 8. Spray pattern characteristics of boom
(Patternator plane parallel to spray)

Test tube No.	Discharge ml/min Pressure kg/cm^2		
	3	2.5	2
(1)	(2)	(3)	(4)
1	20.0	19.4	18.6
2	22.6	22.0	21.4
3	28.5	26.6	25.2
4	29.2	27.0	25.0
5	30.0	29.0	27.4
6	38.0	34.2	31.2
7	26.8	25.2	24.4
8	26.8	25.4	24.6
9	28.5	26.5	25.6
10	22.6	21.2	20.6
11	26.8	25.2	24.6
12	36.2	34.4	33.2
13	36.0	34.8	32.8
14	40.0	36.2	33.8
15	46.0	42.4	38.5
16	42.2	39.2	36.4
17	35.2	33.6	31.2
18	28.0	26.2	24.8
19	28.6	26.0	24.6
20	19.4	18.6	17.8

Table - 8 (contd.)

(1)	(2)	(3)	(4)
21	30.0	27.4	25.8
22	33.2	30.2	28.4
23	32.0	29.6	27.2
24	37.2	34.6	32.2
25	40.0	36.2	33.4
26	29.4	27.2	25.0
27	26.6	24.8	23.2
28	26.6	24.6	23.4
29	23.0	21.6	23.2
30	22.6	20.4	19.6
31	20.0	19.6	18.6
32	16.6	15.4	14.6
33	21.2	20.2	19.8
34	30.6	28.2	26.4
35	16.0	15.0	14.5
36	16.2	15.2	14.6
37	16.6	15.4	14.4
38	17.2	16.4	15.6
39	16.4	15.4	14.6
40	20.6	19.2	18.4
Total	1051.8	1030.7	973.2

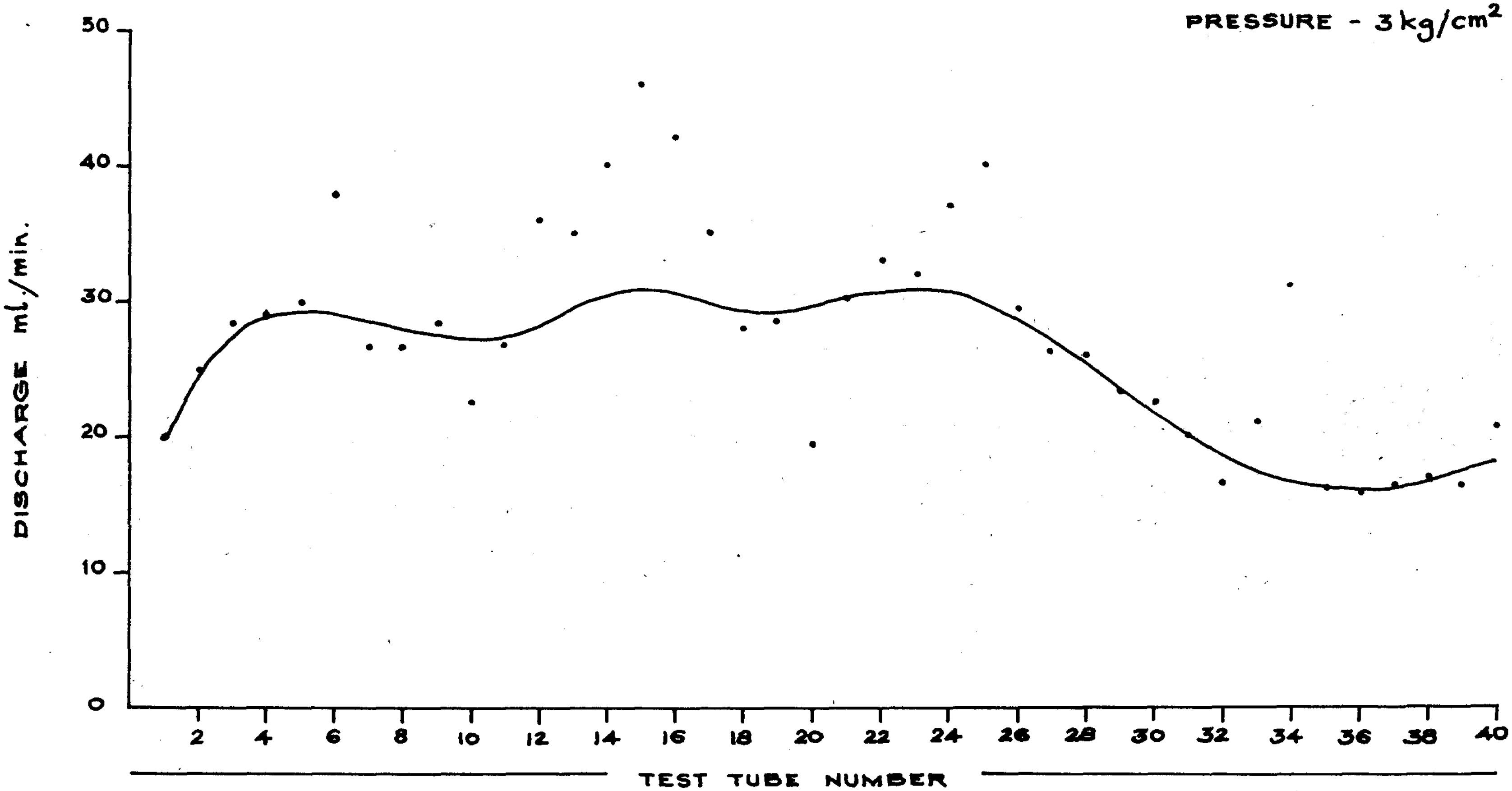


FIG. 12.a. SPRAY INTENSITY CURVE.

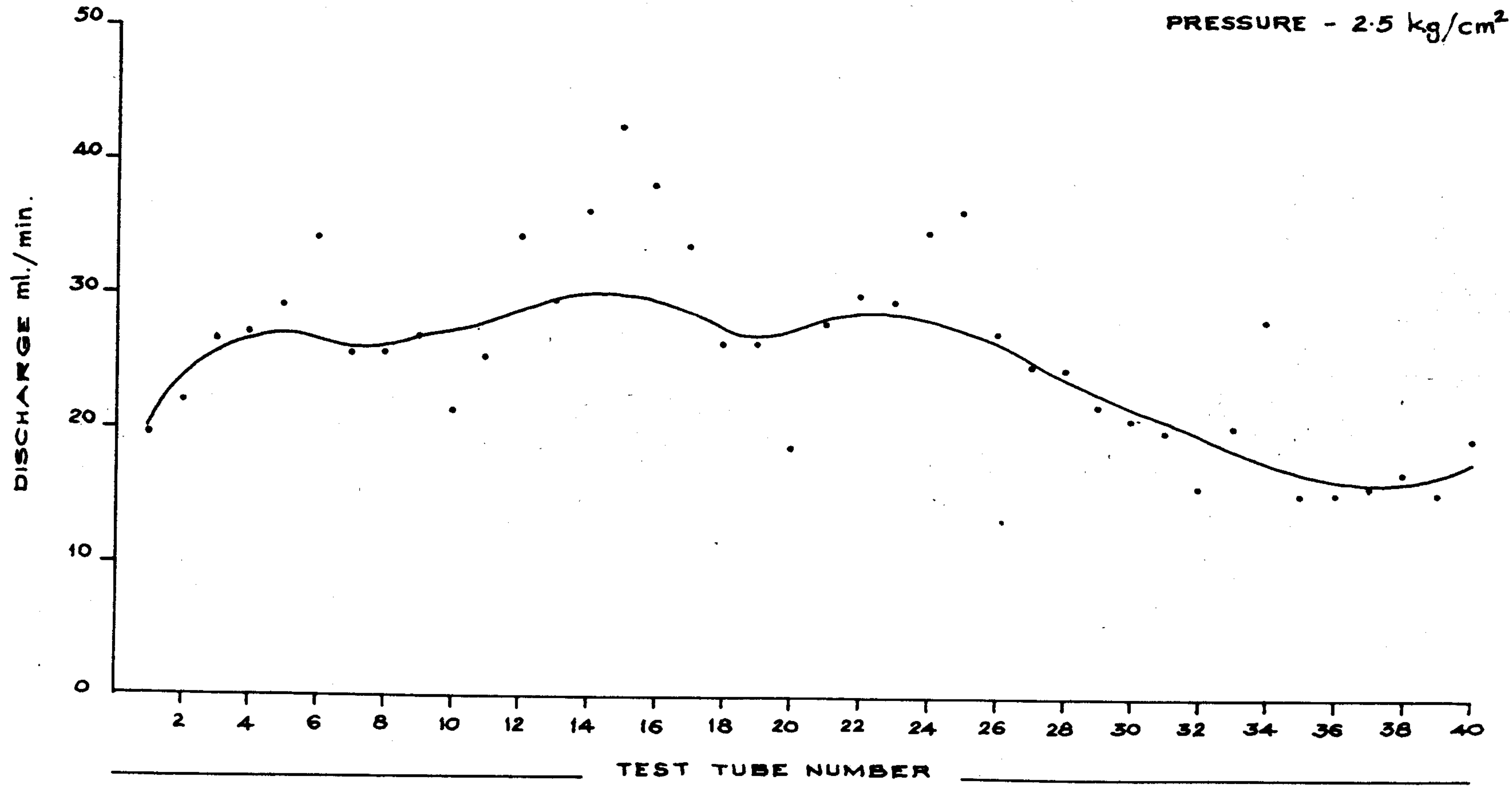


FIG. 12.b. SPRAY INTENSITY CURVE.

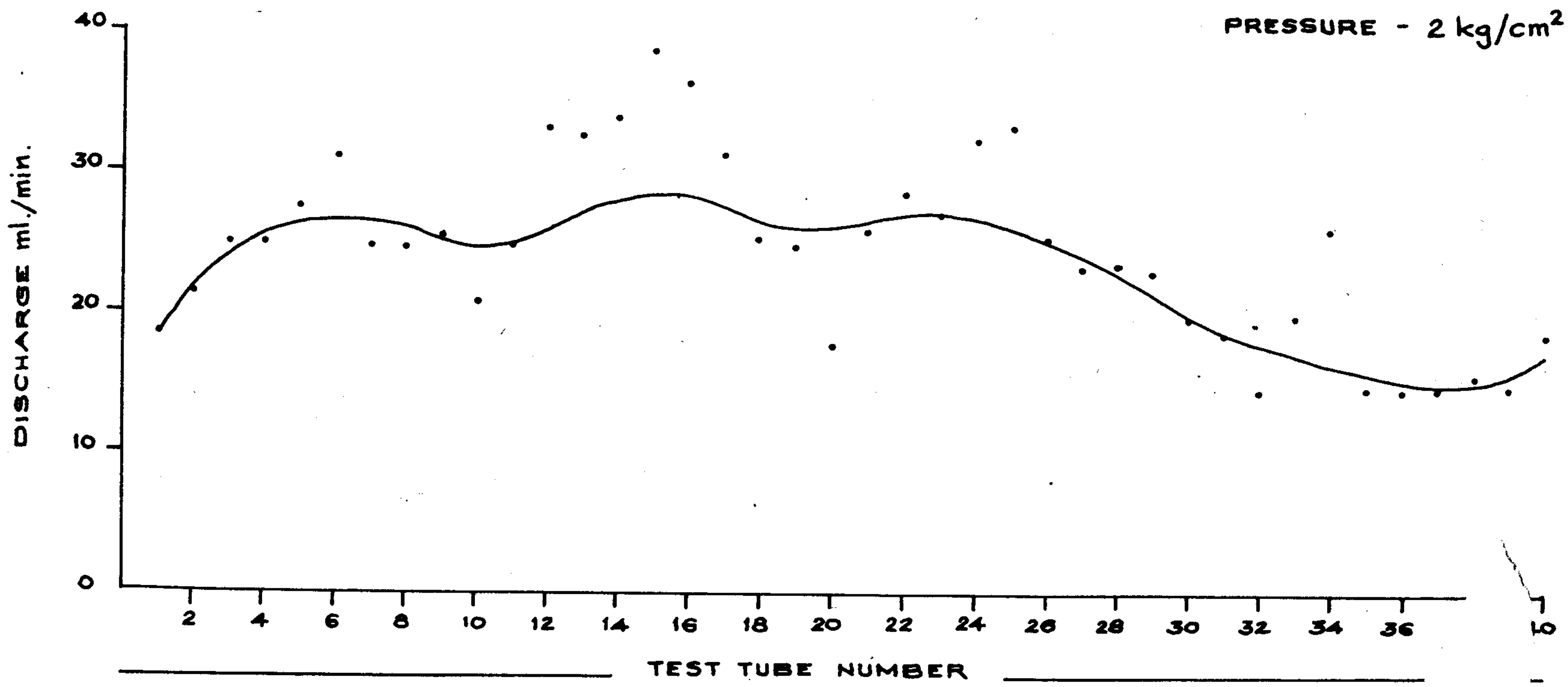


FIG. 12.C. SPRAY INTENSITY CURVE.

The results from the laboratory as well as the field tests showed that, the sprayer boom could be used as an applicator against BPH and also for the canopy spraying after reducing the length of down-pipes. If this boom is to be used for canopy spraying the spacing of the down-pipes can be increased from 60 to 80 cm. This applicator has got the following advantages over the ordinary foliar applicator:

(i) The spray fluid is delivered around the plant base and thus the BPH population can be effectively suppressed.

(ii) For BPH control it is not necessary to spray the entire foliage, since the pest populations are confined to plant stems. This contrivance enables to restrict the applicator to plant bases, and thus saving the total quantity of the insecticide.

(iii) Since the entire foliage was not sprayed with toxicants, it is possible to spare the parasites and predators of BPH which occur on the foliage. It is thus possible to conserve and augment bio-control agents which may aid in keeping down the pest population.

4.4 cost analysis

The total operating cost of the applicator is worked out on the basis of the assumptions and calculations given in Appendix II. It is worked out on the assumption that the BPH problem most commonly occur during the mundakan and punja seasons.

The assumptions taken are:

1.	Hours of wear out	=	1500
2.	Number of working hours per year, H	=	300
3.	Life of the applicator, L	=	5 years
4.	Salvage value, S	=	10%
5.	Walking speed	=	1 kmph
6.	Spraying hours per day	=	5.5
7.	Tank capacity of hydraulic knapsack sprayer	=	16 lit.
8.	Mixing and refilling time	=	5 min/tank

From Appendix I the total time for spraying one hectare of BPH infested paddy field is 8.0 hours. And from Appendix II the expected cost for spraying was Rs.154.40 excluding the cost of insecticide.

Summary

SUMMARY

An investigation on design and development of an insecticide applicator for the control of Brown Planthopper was carried out for spraying the plant base effectively. The main emphasis of the study was to spray the insecticide at the zone of infestation without much injury to plant and with a higher speed of spraying, with minimum drudgery to the operator. For easy combing of the boom in the paddy field, a shoe shaped nozzle cover was developed, which experienced less obstruction from the interlocked paddy leaves.

The optimum position of the nozzle for effective control of BPH was 12 cm from the field surface. The details of the complete BPH applicator boom is shown in Fig. 9. The design aspects and results obtained from field evaluation are enlisted below:

(i) Four sets of DSD nozzles were attached to the downpipes for directing the spray to the plant base up to a height of 20 cm from the field surface.

(ii) The boom developed, had a total weight of 10.5kg and its width of coverage is 2.40 m.

(iii) The discharge of the boom was found to be around 1300 ml/min.

(iv) The field tests revealed that around 450 litres of chemical could be sprayed in one hectare of rice in an average time of 8.0 hrs.

(v) The total cost of the boom was Rs.980/-, the cost of the complete applicator including the cost of two sprayer was Rs.1,850/-.

(vi) Economic analysis revealed that the operating cost of the applicator per hour is Rs.19.30, excluding the cost of insecticide used.

Following are some of the works suggested for further investigations:

1. Modification of boom to reduce the weight.
2. Modification of the system to use motorised knapsack sprayer.
3. Reduction in length of boom, so that a single person can operate the boom.

References

REFERENCES

Abraham, C.C. and Nair, M.R.G. 1975. The brown planthopper outbreak in Kerala, India. *Rice Entomol. Newsl.* 2 : 36

Asahina, S. and Tsuruoka, Y. 1968. Records of the insect which visited a weather ship located at the ocean weather Station Tango on the Pacific.II. *Kontyu* *36* (2) : 190-202

Bindra, O.S. and Harcharan Singh, 1977. *Pesticide application equipments.* Oxford and IBH publishing Co., New Delhi, 2nd Ed.pp. 6-66, 261-279.

*Dyck, V.A. etal.1975. *Ecology of the brown planthopper in tropics.* IRRI, Los Banos, Phillippines, pp. 61-64, 68-69, 71-75.

Dyck, V.A. and Thomas, B. 1979. The brown planthopper problems. *Brown planthopper, threat to rice production in Asia.* IRRI., Los Banos, Phillippines, pp. 3-13.

Gopalan, M. 1974. Brown planthopper and grassy stunt epidemic in Kerala. *Rice Pathol. Newsl.* 1 (74) : 17

Heinrichs, E.A. 1979. Chemical control of Brown planthopper. *Brown planthopper, threat to rice production in Asia.* IRRI., Los Banos, Phillippines. pp. 145-165.

*Heong, K.L. 1975. Occurence and chemical control of rice planthoppers in Malaysia. *Rice Entomol. Newsl.* 3: 31-32

Hisano, K. 1964. Occurrence and injury of White-backed and brown planthopper and control measures (in Japanese). *Agric. Horticulture* 39 : 141-146.

Kalode, M.B. and Khrishna, T.S. 1979. Varietal resistance to brown planthopper in India. *Brown planthopper threat to rice production in Asia.* IRRI., Los Banos, phillippines, pp. 181-199.

*Kisimoto, R. 1976. Bionomics, forcasting of outbreaks and injury caused by the rice brown planthopper. *Paper presented at the Int. Sym. on the Rice brown planthopper. Asian and Pacific Council, Food and Fertilizer Technology Center,* October 1976. Tokyo Japan 16 p.

*Koya, V.K.M. 1974. Brown planthopper the destructive pest. *Kurukshetra.* *22* (19) : 13

Kulshreshtha, J.P. 1974. Brown planthoppers in Kerala. India. Rice Entomol. Newsl. 1:3-4

*Kulshreshtha, J.P., Anjaneyulu, A. and Padmanabhan, S.Y., 1974. The disastrous brown planthopper attack in Kerala. Indian Fmg. 24 (9) : 5-7

Mathews, G.A. 1979. Pesticide application methods. Longman, London, pp. [illegible], [illegible], [illegible], 1[illegible]-143.

Menon, A.G.G. 1986. Kerala Agricultural University package of practices [illegible]. Directorate of Extension Mannuthy. 8th Ed.pp. [illegible], 31.

Miles, P.W. 1972. The Saliva of Hemiptera. Advances Insect Physiology. 9. 183-255

Mochida, O. 1970. Long-distance movement of Nilaparvata lugens (Stal). Rev. Entomol. 1 : 95-109

Mochida, O. and Dyck, V.A. 1976. General bionomics of the brown planthopper, Nilaparvata lugens, Pap. presented at Int. Rice Res. Conference, April 1976. IRRI Los Banos, Philippines. pp.[illegible]

Muhammed, C.P. 1979. Design, development and testing of a transplanting mechanism for conventional paddy seedlings. M. Tech. Thesis. Punjab Agricultural University, Ludhiana. pp. 1-4.

Nalinakumari, T. and Mammen, K.V. 1975. Biology of the brown planthopper, Nilaparvata lugens Agric. Res. J. Kerala. 13 (1) : [illegible]

Pathak, M.D. (1971). Resistance to leafhoppers and plant-hoppers in rice varieties. Proceedings of a symposium on rice insects. Tropical Agric. Res.5 : 179-200.

*Suenaga, H. and Nomura, K. 1970. Host. Oryza Sativa (rice); Organism: Nilaparvata lugens (brown planthopper) FAO Manual on evaluation and prevention of losses by pests disease and weeds. p.52.

*

* Originals not seen.

Appendices

APPENDIX - I

Calculation for determining the quantity of mixture and time needed for spraying one hectare.

<u>Trial No. I</u>

Distance travelled in 55 sec	= 11.6 m (from Table - 5)
Discharge in 55 sec	= 1250 ml(")
Width of boom	= 2.4 m
Area of strip covered by 1.250 lit of mixture	= 11.6 x 2.4
	= $27.84 m^2$
Quantity needed for one hectare	= $\frac{1.25}{27.84} \times 10{,}000$
	= 448 lit/ha

(This is in agreement with the recommended quantity)

Time taken for spraying $27.84 m^2$ area	= 55 sec
Time taken for spraying one hectare	= $\frac{55}{60 \times 60} \times \frac{10000}{27.84}$
	= 5.5 hours
Number of tanks of mixture per ha	= $\frac{448}{15}$ = 28
Number of filling	= 14
Time for one filling	= 5 min

Total filling time	$= 14 \times 5 = 70$ min
Turning time at headlands	= 1 min/turn.
Number of turning per hectare	$= \frac{10000}{27.84} - 1 = 358$
Turning time	$= 358 \times 1 = 358$ min = 6 hr
Total time	$= 5.5 + 1.16 + 6 = 12.66$ hr
Field efficiency	$= \frac{5.5}{12.66} \times 100 = \underline{\underline{43.44\%}}$

<u>Trial No.II</u>

Distance travelled in 55 sec	= 11.6 m (from table - 5)
Discharge in 55 sec	= 1274 ml = 1.274 lit
Area of strip covered by 1.274 lit of mixture	$= 11.6 \times 2.4 = 27.84\ m^2$
Quantity of mixture needed for one hectare	$= \frac{1.274}{27.84} \times 10000 = \underline{\underline{457.6}}$ lit

(This is in agreement with the recommended quantity)

Time take for spraying $27.84 m^2$ area	= 55 sec
Time taken for spraying one hectare	$= \frac{55}{60 \times 60} \times \frac{10000}{27.84} = \underline{\underline{5.5}}$ hr
Number of tanks mixture needed per ha	$= \frac{457.6}{16} = 28.6$
Number of filling	= 15
Number of turning per hectare	$= \frac{10000}{27.84} - 1 = 358$
Turning time	= 358 min = $\underline{6\ \text{hr}}$
Total time	$= 5.5 + 1.25 + 6 = \underline{12.75}$ hr
Field efficiency	$= \frac{5.5}{12.75} \times 100 = \underline{\underline{43.13\%}}$

Trial No.III

Distance travelled in 90 sec = 25.6 m

Discharge in 90 sec = 2605 ml = 2.605 lit

Area of strip covered by 2.605 lit. of mixture = 25.6 x 2.4 = 61.44m^2

Quantityof mixture needed for one hectare = $\frac{2.605}{61.44}$ x 10000 = 424 lit

(This is in agreement with the recommended quantity)

Time needed for spraying one hectare = $\frac{90}{2.605} \times \frac{10000}{60 \times 60}$ = 4.07

Number of tanks mixture needed per ha = $\frac{424}{16}$ = 26.5

Number of filling = $\frac{26.5}{2}$ = 14

Filling time = 70 min

Number of turning per hectare = $\frac{10000}{61.44}$ - 1 = 162

Turning time = 162 min = 2.7 hr

Total time = 4.07 + 1.16 + 2.7 = 7.93 hr

Field efficiency = $\frac{4.07}{7.93}$ x 100 = 51.32%

Trial No.IV

Distance travelled in 90 sec = 25.6 m

Discharge in 90 sec = 2732 ml = 2.732 lit

Area of strip covered by 2.732 lit. of mixture = 25.6 x 2.4 = 61.44m^2

Quantity of mixture needed for one hectare $= \frac{2.732}{61.44} \times 10000 = 444.66$ lit

(This is in agreement with the recommended quantity)

Timeneeded for spraying one ha $= \frac{90 \times 10000}{2.732 \; 60 \times 60} = 4.07$ hr

Number of tanks mixture needed per ha $= \frac{444.66}{16} = 27.8 = 28$

Number of filling required = 14

Total filling time = 70 min = 1.16 hr

Number of turning per hectare $= \frac{10000}{61.44} - 1 = 162$

Turning time = 162 x 1 = 162 min = 2.7

Total time = 4.07 + 1.16 + 2.7 = 7.93 hr

Field efficiency $= \frac{4.07}{7.93} \times 100 = 51.32\%$

APPENDIX – II

Calculation of operating cost of BPH applicator.

I. Assumptions:

1. Hours of wearout = 1500
2. Number of working hours per year, H = 300 hour
3. Life of the applicator, L = 5 years
4. Salvage value, S = 10% of initial cost
5. Rate of interest, i = 18% of investment
6. Repair maintenance and storage cost = 5% of initial cost
7. Wages for semi-skilled, man labour = Rs.35 per day
8. Wages for un-skilled women labour = Rs.25 per day
9. Number of working hours/day = 5.5
10. Minimum number of semi-skilled man labour = Two
11. Minimum number of un-skilled women labour for bringing water and mixing = One

2. Investments

Table - 9

Cost of components of prototype BPH applicator as on April,1988

Sl.No.	Item	Quantity	Total cost Rs.
1	Hydraulic every knap-sack sprayer - 16 lit. capacity (without spray-lance and cut off device)	2 No.	870/-
2	Flexible hose	7 m.	55/-
3	Pressure regulator cum-Trigger cut-off valve	2 Nos.	260/-
4	Bourden pressure gauge	2 Nos.	70/-
5	Wing nut with nipple	10 Nos.	75/-
6	Hose clip	20 Nos.	30/-
7	Spray lance	4 Nos.	100/-
8	Double Swivel Duro nozzle	4 Nos.	140/-
9	18 mm G I Pipe	3 m.	60/-
10	Canvas belt	2 Nos.	20/-
11	Fabrication charge of brass 'Tee' joint	2 Nos.	50/-
12	Fabrication charge of M.S.Shield	4 Nos.	80/-
13	Overhead charge for Fabrication work	-	40/-
	Total (C)	-	1850/-

3. Calculations

1 Depreciation $= \frac{0.9C}{} = \frac{0.9 \times 1850}{5 \times 300}$ = Rs.1.11/hr

2 Interest on capital investment $= \frac{C+S}{2} \times \frac{i}{H \times 100} = \frac{1850+185}{2} \times \frac{18}{300 \times 100}$

= 0.61/hr.

3 Repair, maintenance and storage cost $= \frac{C}{H}\frac{5}{100} = \frac{1850}{300} \times \frac{5}{100}$ = Rs.0.31/hr

4 Labour charges

i) Semi-skilled man labours $= \frac{70}{5.5}$ = Rs.12.73/hr

ii) Unskilled women labours $= \frac{25}{5.5}$ = Rs. 4.55/hr

5 Operating cost (sum of items 1 to 4) = 1.11+0.61+0.31+12.73+4.55

= Rs.19.31/hr

Total operating cost of BPH applicator = Rs.19.31/hr

DESIGNING AND DEVELOPMENT OF AN INSECTICIDE APPLICATOR FOR THE CONTROL OF BROWN PLANT HOPPER

By

V. R. RAMACHANDRAN

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of
the requirement for the degree

Master of Science in Agricultural Engineering

Faculty of Agricultural Engineering
Kerala Agricultural University

Department of Farm Power Machinery and Energy
Kelappaji College of Agricultural Engineering and Technology
Tavanur - Malappuram

1988

ABSTRACT

The brown planthopper *Nilaparvata lugens stal*. is a dangerous pest which causes, quick and serious damage to rice in South East Asia. In India a serious damage occurred in Kerala during 1973-76, and the estimated loss in this was 12 cores of rupees.

An investigation on the design and development of an insecticide applicator for the control of BPH, by spraying specifically the plant base, at a height of about 15-20cm from the field surface, was carried out.

The applicator developed consisted of two hydraulic energy knap-sack sprayers each of 16 lit. capacity, a boom carrier having a length of 2.4 m made of 18 mm GI pipe, flexible hose a pair of cut-off devices, 4 down pipes each carrying a set of nozzles and shoe shaped nozzle cover. The nozzle used in this study was DSD nozzle, which was giving more uniform spray pattern and which could be used with minimum number of down pipes. The shoe shaped nozzle cover reduced the tilting of the boom and enabled easy movement in the field.

The boom had a total weight of 10.5 kg and swath width 2.4 m. The discharge of the boom was 1300 ml/min,

at a pressure of 2 kg/cm^2. From the field tests it was observed that around 450 litres of fluid was sprayed in 8.0 hours of time covering an area of one hectare. The total cost of the complete applicator was Rs.1850/- including the cost of two knap-sack sprayers. The economic analysis revealed that, the operating cost of the applicator per hour was 19.30 rupees, excluding the cost of insecticide.