百週年學術研討會專刊

臺灣省農業試驗所特刊第52號

# 自動化施藥技術研討會專刊

中華民國八十四年四月二十五日至二十七日　台中・霧峰

行政院農業委員會　支助

臺灣省農業試驗所
國立中興大學農機系　主辦

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自動化施藥技術研討會

# 目　　錄


杜所長金池致詞…… i

黃校長東熊致詞…… ii

何副廳長偉眞致詞…… iii

【自動化施藥技術研討會】議程…… iv

【自動化施藥技術研討會】參加人員名錄…… vi

Recent trend of research and development of pest control machine in Japan ……
…… Koichi Tosaki 1

水稻施藥機械的研究……邱銀珍、
游俊明、吳文政、何新奇、施淸田、鄭榮瑞、葉仲基、盛中德、王明茂 12

廣域鼓風式施藥技術的研究……盧子淵 19

Test of plant protection equipment in Germany and European standardization ……
…… Heinz Ganzelmeier 26

Present state of the art of plant protection equipment and recent developments in Germany ……
…… Heinz Ganzelmeier 27

Current state of pesticide application technology in the U.S.A. …… H. Erdal Ozkan 28

間歇式施藥技術的研究…… 盛中德 38

微電腦式藥量控制技術的研發…… 王康男 43

氣輔式施藥機械之研究…… 黃禮棟 47

高架式施藥機械…… 梁連勝 蔡致榮 周廷弘 53

設施內自動化施藥技術的研究……何榮祥 陳令錫 龍國維 田雲生 58

果園管路自動化噴藥控制系統示範推廣……洪明治 欒家敏 64

靜電式噴灑農藥技術的研究…… 欒家敏 71

綜合討論結論 …… 74

中心議題：

1.自動化施藥機械發展的方向

2.施藥機械作業性能標準及檢定方法之建立

# 杜所長金池致詞

各位長官、各位貴賓、各位先進、各位女士、各位先生，大家好：

本人謹代表台灣省農業試驗所全體員工由衷的歡迎各位貴賓、各位女士、各位先生的蒞臨指導，共同就本省以往作物病蟲害防治作業機械技術之開發與應用成果，及所遭遇的問題，研討未來農作物病蟲害防治機械技術的研究發展方向與目標表示萬分的感謝。誠如大家所瞭解，台灣地處亞熱帶，周年高溫多濕是作物病蟲害最容易滋生的自然環境；為防止病蟲害對作物的為害，無論在作物保護技術上，或相關的作業機械方面，過去我們的確盡了最大的努力，也共同為本省農業締造了輝煌的成就。本次研討會，要藉重各位先進的智慧，詳加探討和規劃，整合、應用機械科技和現代生物技術，建立低污染的綜合防治體系，以改變我們過去以藥劑為重心的防治作業模式。在此我要特別感謝的是這次研討會，承蒙農委會以及農林廳的長官在經費或精神上的支持，中興大學與本所同仁的籌劃，在籌備期間所有籌備委員的精心設計，使本研討會能夠順利舉辦，本人謹在此向所有長官、所有為研討會盡心盡力的先進、同仁表示衷心的感謝，最後我敬祝研討會成功，讓我們共同為建設明日富麗的台灣農村而努力，敬祝各位貴賓、各位先進身體健康事事如意。謝謝！

# 黃校長東熊致詞

主席、各位貴賓、各位女士與先生：

今天很高興能來此參加由農試所與本校共同舉辦的自動化施藥技術研討會，雖然我本身是學法律對農業並不是非常的了解，但中興大學在農學上的成就一直是本校引以爲傲的。針對這個研討會的主題雖然我無法也無資格以專家的立場發表意見，但研討會的舉辦對我而言仍具有下列重大的意義：

首先要恭喜農業試驗所一百週年所慶，這是一件大事。臺灣的農業在過去與現在之所以能有如此輝煌的成就，農業試驗所的貢獻功不可沒；雖然隨著工商業的發達，農業在整體經濟的份量越來越輕，但農業在人類生活的重要性卻與日俱增。「留給後世子孫一片淨土」不只是一句口號而已，而是越來越多人共同的要求，在未來如何去實踐它，我深信農業必然是扮演積極且關鍵的角色。因此我相信未來貴所所務必將蒸蒸日上，更爲昌榮。

雖然農業不是我的本行，但對此次研討會的主題我仍願提供一些外行人的意見供各位參考。這次研討會的主題爲：自動化施藥技術，與農藥的使用有關。今天不只是我，國人普遍地對農業生產中農藥的使用心存畏懼，這可由每次只要有農藥殘毒的新聞，產品即滯銷得到證明，而在生鮮市場中清潔農產品的受歡迎是另一明證；消費者討厭農藥、害怕農藥，我相信農民也不會喜歡用農藥，而目前之所以使用農藥必然有其無法避免的原因，這些不是我所能了解的，在此我懇切的期望此次研討會能將如何利用自動化技術減少農藥的使用列爲重點之一，而由研討會所安排的內容來看確實也包括了這點。此外自動化技術的應用依我個人的淺見必然是越來越方便、越來越有效率，因此如果施藥技術完全充分自動化，是否將來農民使用農藥會因自動化的發展而更頻繁？在此我希望自動化施藥技術的發展應著重在越來越有效率，能更經濟有效的施用農藥。

這次之研討會所安排的內容非常的精彩且豐富，且自世界各地分別邀請了最頂尖的相關人士前來參加，我相信籌備的人必花了不少的心力，而參加的人不但可藉此次研討會了解國內的研究方向與成果，同時經由與會外賓的介紹，將對歐、美、日等國在自動化施藥技術上的現況與發展有一番新的體認，意義非凡。最後我謹代表中興大學敬祝此次研討會成功，農業試驗所所務昌榮，各位來賓身體健康萬事如意。

# 何副廳長偉眞致詞

各位貴賓、各位學者專家、各位女士先生大家早：

今天很榮幸有此一機會前來參加農試所爲配合成立100週年所舉辦之『自動化施藥技術研討會』。各位都知道台灣地理位置屬於亞熱帶地區，氣候高溫多濕，農作物栽培過程中，病蟲害極易滋生蔓延，因此施藥(病蟲害防治作業)爲不可避免之作業。惟近來由於農民大多數均不願從事與農藥相關之田間工作，致施藥作業勞力嚴重缺乏，工資猛漲，佔生產成本比率逐年升高，再加上環保意識抬頭，有關環境藥物污染，生態遭農藥的破壞等問題，使得施藥作業更雪上加霜。所以個人認爲極有必要藉此機會深入探討相關的合理施藥技術，開發或引進適當技術，並加强教育與推廣工作，提升農民的用藥技術與品質，達到抑制農藥濫用，從中求得環境保護與農業發展需求兩者的平衡點，建立適時、適量、適地(或部位)、省工(機械化或自動化)的病蟲害防治作業模式。最後希望大家能夠透過此一研討會，檢討過去，策勵將來，有助於台灣未來農業的發展。並祝研討會圓滿成功，大家身體健康、身心愉快、工作順利。

# 「自動化施藥技術研討會」會議議程

**84年4月25日（星期二）**

0830-0900 報到

0900-0920 開幕典禮

主席致詞

長官致詞

貴賓致詞

0920-1000 團體照相/休息

**第一節 主持人：古德業**

| | | |
|---|---|---|
| 1000-1200 | 戶崎紘一 | 日本自動化施藥機械技術介紹與展望 |
| 1200-1300 | 午餐 | |

**第二節 主持人：欒家敏**

| | | |
|---|---|---|
| 1300-1330 | 邱銀珍 | 水稻施藥機械的研究 |
| 1330-1400 | 盧子淵 | 廣域鼓風式施藥技術的研究 |
| 1400-1430 | 休息 | |
| 1430-1630 | H. Ganzelmeier | 自動化施藥機械的測試與檢測技術介紹與發展 |

**84年4月26日（星期三）**

**第三節 主持人：葉仲基**

| | | |
|---|---|---|
| 0820-1020 | Erdal Ozkan | 自動化施藥機械技術與展望 |
| 1020-1050 | 休息 | |
| 1050-1120 | 盛中德 | 間歇式施藥技術的研究 |
| 1120-1150 | 王康男 | 微電腦式藥量控制技術的發展 |
| 1150-1300 | 午餐 | |

**第四節 主持人：王康男**

| | | |
|---|---|---|
| 1300-1330 | 黃禮棟 | 氣輔式施藥技術的研究 |
| 1330-1400 | 梁連勝 | 高架式施藥機械的研究 |
| 1400-1430 | 休息 | |
| 1430-1630 | 戶崎紘一 | 日本施藥機械藥量控制之自動化技術介紹與展望 |

84年4月27日（星期四）

### 第五節 主持人：李廣武

| | | |
|---|---|---|
| 0820-1020 | H. Ganzelmeier | 施藥機械性能自動化檢測技術 |
| 1020-1050 | 休息 | |
| 1050-1120 | 何榮祥 | 設施內自動化施藥技術的研究 |
| 1120-1150 | 洪明治 | 管路自動化施藥技術的研究與發展 |
| 1150-1300 | 午餐 | |

### 第六節 主持人：盛中德

| | | |
|---|---|---|
| 1300-1330 | 欒家敏 | 靜電式施藥技術的研究 |
| 1330-1530 | Erdal Ozkan | 自動化施藥機械藥量控制技術介紹與發展 |
| 1530-1600 | 休息 | |

### 綜合討論
### 主持人：鄭隨和、柳台生、盛中德、杜金池

| | | |
|---|---|---|
| 1600-1630 | 中心議題 | 1.自動化施藥機械發展的方向 |
| | | 2.施藥機械作業性能標準及檢定方法之建立 |

# 參加人員名錄

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勝美行
許茂雄
代耕中心等
黃水連　陳正珍　梁德盛　蔡阿輝

# RECENT TREND OF RESEARCH AND DEVELOPMENT OF PEST CONTROL MACHINE IN JAPAN

Koichi Tosaki
Chief Researcher
Bio-Oriented Technology Research
Advancement Institution ( BRAIN )

## INTRODUCTION

Steady crop production, increase of the yield, and improvement of the quality, largely depend on the improvement of cultivation techniques and so on, as well as that of agricultural chemicals application techniques.

These application techniques improve as agricultural chemicals, pest control machines and application methods improvement and development, since the above three are closely related with each other.

Requirements for the pest control machine cause high efficiency, labor saving and work load reduction, as well as sufficient effects by most effective application with minimum quantity of agricultural chemical applied target.

The development of techniques to avoid exposure to agricultural chemicals for safety of the workers during application and that of techniques to minimize drift of agricultural chemicals for the environmental preservation are also important.

This paper shows recent trend or situation of research and development of pest control machine in Japan.

### 1. Power sprayer

Reciprocating pumps for the power sprayer are used as a main part of pest control machines such as portable type power sprayer, traveling type sprayer or air blast sprayer, all of which spray liquid chemicals. Each basic structures of pump are similar, but the weight has due to adoption of aluminum die-cast and ceramic has come to use for the plunger, suction valves, discharge valve or pressure regulator and so on, allowing high pressure, high speed revolution and improving the durability of the pump. This allows use of smaller size diameter spray hoses while keeping the pressure of the nozzle even when using a long hose and making handling a hose much easier.

Also there are pumps which are designed to simplify maintenance. For example, those are designed to avoid uneven abrasion of the V-packing with the self aligning mechanism, those are equipped with the non lubrication mechanism to the V-packing, or those have spring loaded semiautomatic fastening mechanism mounted for the fixing portion of the V-packing.

For hose reels used in the portable power sprayer, automatic hose reels or self-arrangement hose reels has been developed, thereby reducing the number of workers and the work load on the workers, or enhancing the efficiency of the operations.

The levee nozzle has a valve attached which closes automatically at the time of pressure drop. The valve operates to prevent the agricultural chemicals dropping times when the pressure regulator lever is shifted to the side of the pressurization or when the liquid chemical tank is emptied and the pressure at the nozzle pipe become lower than normal pressure.

Generally, power sprayer are used with hose reel, spraying hose and nozzles. Some models of the commercialized power sprayer have radio controller to reel the hose, start and stop the engine, or adjusted the throttle, thereby has attained substantial load saving.

## 2. Pest control machines for paddy fields

(1) Knapsack type power applicator

The knapsack type power applicator is a small and high-efficient pest control machine, especially, if it is used a boom type blow head with swath 20-40 m wide, it allows the area of 10a to be finished working in a few minutes. This is also used to apply powder, granular, or liquid formulation by changing or adjusting part of the machine. In addition, it is used to apply granular fertilizer as well as agricultural chemicals, resulting in wide spread on the market.

For knapsack type power applicators, enhancement of performance, research and development have been performed recently for more light weight and easier handling, in order to reduce work load on operators.

Just as the name shows, the knapsack type power applicator is carried on man's back while working, so it is difficult to know residual chemicals quantity in the tank, causing lack or over application. To prevent this, some applicators have the liquid-crystal indicator on the blow pipe at hand and silicon photo transistors to detect the residual chemical quantity in the tank, allowing you to know residual quantity during application.

Also, there are some applicators of the same type that are designed to prevent static electricity using the blow head and earth chain made of material with high conductivity, and that are designed to improve vibration resistance and air per meability by reforming the back plate.

Materials of conventional knapsack type power applicators were light alloys such as aluminum alloy or magnesium alloy, which are inferior in corrosion resistance, very often causing the inside corrosion even with sufficient surface treatment because of too much permeability of chemicals. To prevent this, plastic material has been used in recent years, thereby the corrosion resistance has been improved and the weight become more light.

Plastic materials have been used for chemical tank, fuel tank, and blow pipe. Recently, plastic parts are increasing except the parts such as blower and engine. Moreover, considering the heat resistance , stiffness or other features, polyester, Teflon, acotal, polycarbonate and nylon, etc. have been widely used.

Therefore, plastic is considered to be used more widely in terms of its features in the future.

(2)Riding type vehicle with applicator in paddy fields

As spray for paddy, the application method which adopts a power sprayer with a levee nozzle, has acquired a widely spread conventionally. However, this method provides only the swath width of less than 20 m, which is insufficient for large plots, and has caused difficulty in ensuring the number of workers to hold spray hose.

Aerial application by manned helicopters or knapsack type power applicators is high efficiency, but they have caused a pollution problem in the regional environment due to drift as mixed areas of houses and farms expands.

In this background, techniques of the vehicle for the paddy fields has been developed recently.

A riding type vehicle in paddy field mainly used is a traveling device of the riding type rice transplanter, which can reduce production costs, attain more labor saving and can enhance the availability of the machines. Also, techniques to allow multiple works have been studied and developed.

While the method of band fertilizing for simultaneous work with rice planting intended for labor saving has been become popular, a rice planter with pest control machine and band fertilizer has been developed recently. The rear mounted pest control machine can apply granule herbicide in proportion to planting speed.

Granule discharged from the tank, is adjusted by metering device and it is drooped on the impeller which is rotating at high speed. Finally it is spread and applied.

Since fluid type herbicide has been developed and spread , dropping applicators set up on the riding type rice transplanter have been developed as well.

For multipurpose use or improvement availability of rice transplanter, researches have been performed on seeding and application of granule chemicals or granule fertilizer by the knapsack type power applicator mounted on the riding type rice transplanter whose transplanting device is remove.

Also, low volume sprayer which the pump is driven by ground speed PTO of the rice transplanter, has been developed and its availability is recognized.

In all the above cases, the rice transplanters are utilized. Based on the accumulated research on vehicle for crop tending work in paddy field, BRAIN has been making a joint research and development with manufacturers on the vehicles.

The purpose of this development is to develop multipurpose vehicle and working machine which carry out transplanting or crop tending work (agricultural chemical application and fertilization etc.), with high accuracy and efficiency.

In March, 1995, a vehicle itself, rice transplanter and low volume boom sprayer have been developed, and also they are scheduled to be put on the market around this fall of 1995. Also, we are carrying on study make a practical use of a granule applicator for herbicide, fertilizer and so on in next spring.

The vehicle has been developed based on a riding type rice transplanter, and has the following features:

1）It has a standardized quick hitch, allowing a simple attaching or removing of various working machines.

2）It has two PTO shaft (one is ground speed PTO shaft and the other one is live PTO shaft), allowing various works.

3）Tread of front and rear wheel are same（120 cm）,in order to reduce damage of paddy.

4）It is equipped with wheels suited for rice transplanting or crop tending work, allowing a good traffic ability and less damage of paddy.

5）Its minimum ground clearance is about 10 cm higher than that of ordinary rice planter, allowing less damage of paddy.

Low volume boom sprayer has the following features:

1）Application rate of this sprayer （swath width of 7.5 m）is 25L/10a（dilution is 300 times）. Traffic ability and stability of the vehicle have been improved because the tank become smaller and the body become more light than ordinary sprayer.

2）It drives the spraying pump by ground speed PTO shafts, allowing more constant and accurate application in proportion to application speed.

3）It has the air-assist system therefor deposit efficiency on paddy has improved and drift has been reduced.

Rice transplanting by the vehicle is almost the same accuracy and efficiency as the ordinary riding type rice transplanter. Application speed is about 0.6-0.8m/sec and its work performance is about 1 ha/h.

There is small damage while working but one example of test results show that decrease rate of yield is estimated at 1-2% after 4-5 times works.

(3）Unmanned helicopters

Chemical application by manned helicopters tend to be harder, as the area where it is impossible to perform has been expanding due to more mixed area of farm and habitation in recent years. In this background, unmanned helicopters have been developed, designed to supplementary apply for paddy fields where application by manned helicopters is difficult and to be utilized for the upland fields or orchards where manned helicopters are hard to use due to small acreage and complicated cropping.

The fundamental design of unmanned helicopters is as follows:

1）Maximum weight of equipment should be 100 kg or less.

2）The loading capacity of agricultural chemicals should be 10 kg, and payload for the machine shall be 20 kg or more.

3）The flying speed, application height, and effective swath width shall be allow for approximately 10-20 km/h, 2-5 m, and 5 m respectively.

4）It shall be operated mainly manually for radio control, and it should be easy operation.

5）The accuracy of the radio control shall be expected in accessible distance of 100 m at least.

As a result that the test was performed on its effect on paddy rice, its practical use has been considered, and " guidelines for utilization techniques of unmanned helicopters " was established in April, 1990.

As unmanned helicopters have been spread recently, much effort have made to increase applicable agricultural chemicals and train a lot of excellent operators.

In addition, its practical use on the following has been considered: pest control of wheat, soybean, lotus root, fruit trees and direct seeding.

## 3. Applicator for upland field: boom sprayer

Most of the traveling systems of the boom sprayer are conventionally of tractor-mount type, but recently self-propelled type boom sprayer with high volume liquid tank has been marketed, and also those with simple cabin or cabin have air conditioner, has been put on the market in order to improve working conditions or exposure of agricultural chemicals for workers.

Generally, the boom is mounted as the part of the machine, but some self-propelled type, boom sprayers have the front mounted boom, allowing work while watching the splaying condition, with easier adjustment of application height.

The swath width of many boom sprayer is usually more or less than 10 m, but recently those with swath width of 25 m has been marketed as the weight has been reduced due to adoption of the boom made of aluminum. Many of the booms with such wide swath width allows the swath width to be adjusted by the telescopic boom, thereby improving the work efficiency or preventing overlap application.

Also, in large scale vegetable production areas, one side application type boom sprayers with swath width of about 15 m have increased with increase of big size tractors in recent years. There are fixed and reversible one side application type boom sprayers. Some of the former sprayers have the liquid chemical tank offset considering stability of the machine.

These one side application type boom sprayers allow the number of paths in the upland field to be half decreased, thereby improving utilization and work efficiency of upland field.

During application, the application height varies depending on height of crops and unevenness inclination of upland field. Also under some conditions of upland fields, the application speed varies with slippage of wheels, etc., causing non uniformity of application due to inconstant application rate. To prevent this, the devices which use photo elutric sensors or ultrasonic sensors to detect the distance from boom to crop and adjust the boom to keep constant application height automatically have been developed, or the study in which the application rate can be controlled automatically in proportion to application speed have been made.

## 4. Pest control machines for greenhouse

Recently, production of vegetables, flowers, or fruits has been getting more dependent on greenhouse cultivation, especially that of tomato, cucumber, strawberry, and melon grown in greenhouses is more than that in open fields. These greenhouses have some faults to damage by disease and insects pest due to its closed condition and high temperature and humidity. Therefore, chemical application is generally more necessary to keep steady yield or quality than that for open fields. For pest control in greenhouses, the application method which application rate of diluted liquid chemicals is high, has been widely used conventionally. However, this method causes a trouble in handling hoses, high work load and exposure to agricultural chemicals on workers under the condition of high temperature or humidity.

To solve these problems, various unmanned application methods which workers need not stay longer in a green house, have been utilized. Especially, automatic sprayers with ridge sensing systems have been widely used in recent years. Also much attention is paid to the study about method of electrostatic application utilized for the cold foggier.

(1)Automatic sprayer with ridge sensing system

The automatic sprayer with ridge sensing system is constructed of traveling devices which mounts a hose reel nozzles. The traveling devices driven by motors whose power source is battery, and that can travel by the front wheels with a one -way clutch mounted on the axle.

For application, it adopts an automatic reciprocating application method in which it travels along the ridge intervals, and when getting to end of the ridge, the switch of the sprayer touches the pre-installed stake and starts traveling back ward while reeling the hose automatically proportionally to the traveling speed, until it returns back to the starting point. The liquid chemical is applied by power sprayer and liquid chemical tank where is located on the outside of greenhouse.

Four kinds of methods on guided traveling systems have been developed. One is the method which L-shaped steel is put between the ridges guides the machine to travel to according to the guide mounted on the wheel at the right side of forward, one is the machine travels along the side of a ridge by the guide wheel, one is using electromagnetic guide cables, and other is that to detect the ridge to guide the machine to travel by the photoelectric sensors mounted at front, rear, right and left sides of the machine.

As good points, it is capable to apply without human by using power sprayer at hand, and also use any applicable agricultural chemicals inside a greenhouse.

Moreover it is able to use not only for greenhouse cultivation but also for open field cultivation.

(2) Electrostatic application with cold foggier

In electrostatic application method, agricultural chemicals are applied to be attached to crops by using the electric power generated when fine particles of agricultural chemicals given high voltage static electricity and crops given the opposite electric charge.

This method has the same features as follows. Reduction agricultural chemicals can be possible because of its high effect on application of agricultural chemicals. The deposit on even back side of leaves can be higher than the conventional method. It is good for environment because of its less scatteration agricultural chemicals.

On the other hand, it has some problems as following. It needs high voltage equipment. Careful attention should be paid to insulation. After agricultural chemicals are used to apply because it is possible to only low and ultra-low volume application.

The equipment considered to use for a practical use of it, consists of a liquid chemical tank, blow head (two-fluid nozzle), a voltage generator, an electrode, and a compressor to send air to the nozzle.

For the electrode charged on applied particles, annular electrode by inductive electrification method is adopted.

## 5. Sprayer for fruit trees

In fruit culture, chemical application is necessary for pest control. More than ten applications per year are performed, though it depends on the kinds of trees. Chemical application was mechanized for fruit culture on relatively earlier time and in cultivation of deciduous trees like apples, the reduction of labor has been accomplished due to adopt of air blast sprayers.

On the other hand, the decline in both quantity and quality of labor force is caused by increase people of advanced age for farm work. To solve this problem, the reduction of labor and a safety and comfortable working condition should be used.

Form this point of view, study for full-automating sprayers(unman)for fruit trees has progressed, and in fact some of them have already been commercialized.

(1)Radio control sprayer

The radio control sprayer is constructed of an automatic hose reel, blower and blow head on a traveling unit. Liquid chemicals are sent to sprayer by power sprayer from liquid chemical tank where are located outside of the field as in the automatic traveling type sprayers.

It is employed one side application type which is able to apply agricultural chemicals to one side row in forward travel, and after the direction of the blow head is shifted at the end of the tree row, it sprays agricultural chemicals to other side row in backward travel while the hose is reeled.

The traveling unit employs a crawler which allows forward and backward traveling, stoppage, open/close of spray cock, and turning the blow head, by radio control. A switch is mounted at the front bumper of the machine, and if the bumper touches a stake pre-installed at the end of the tree row, the traveling of the machine and its application can stopped.

This is mainly used for chemical application of dwarf apple, and also it has been attempted for citrus trees.

(2) Citrus sprayer

Because of that citrus is generally grown on slant areas and it is densely planted in Japan, it is difficult to use machines.

At present, the spraying by using a power sprayer with a long hose is widely performed, but since it is a very hard work, a development of a sprayer is needed to reduce the labor and rise the efficiency.

In some cases, sprinklers or air blast sprayers are utilized . However one row of trees should be cut away to make enough space for using air blast sprayer. As result, it is caused a problem of decrease in yield per area, and another problem of safety due to easily fall of the sprayer on the slant area. The citrus sprayers have come to use practically as following.

(1) Citrus sprayer with twirling nozzle pipes for small type vehicle

As stated above, it is difficult to use a sprayer in citrus orchards, but it can be possible to use a machine by changing the shape of the machine and dwarfing of it. So a low height vehicle which has a traveling part with the crawler was developed to avert falling on the slant area and narrow the contacting portion with the trunks.

At the same time airless sprayer which travels spraying agricultural chemicals with twirling multiple nozzle pipes was developed practically in 1992.

This machine is capable to spray agricultural chemicals with twirling nozzle pipes in order to improve the application effect without blower. Also it has the another advantages as follows.

The required power can be reduced little due to no use of a blower.

It is possible to dwarf the body of the machine.

It makes noise lower.

It causes less drift of agricultural chemicals.

As the comparison between an air blast sprayer and a citrus sprayer though an air blast sprayer is little but better than a citrus sprayer in the ability of application, a citrus sprayer is no less than manned application ability.

Recently the study about radio control for vehicles is carried out

(2) Pipe guiding type sprayer

There is a lot of trouble to install air blast sprayers due to its way of cultivation in Japan. Especially labor saving is also one of them. To solve these problems, small pipe guiding type unmanned sprayers have been developed.

This sprayer has a liquid chemical tank with capacity of 300 L and it works along about 3-4 cm wide guiding pipes which are placed on the earth without driver. The traveling part employs 3 wheels. The front wheels are constructed of dual wheel and auxiliary guiding wheel which sandwich the guiding pipe while traveling. For guiding pipes, the polyethylene is usually used on effectively in installation or functions. However, another materials can be available with the same diameters. And in the case of the moving or an orchard where no pipes can be used as a walking type machine with man. For transmission, a hydrostatic transmission system is adopted to select the working speed depending on the conditions of the fields.

The spraying system employs airless spray method with twirling nozzle pipes. Each 5-nozzle pipes on both side of the machine. Though it is available for about 2.5 m high, the number of nozzles can be increased and the angle of them can be adjusted, depending on the height of trees. And infra-red ray type sensor detects trunks, and opens/closes the vales of the sprayer on the right and left side automatically.

Moreover, it allows working in the safety and pleasant environment because start or stoppage of the machine or open/close operation of the spray valves can be performed wireless by radio control from far distance.

In addition, the traveling clutch is released and the machine is stopped automatically in any case as following. When the amount of agricultural chemicals is reduced less than the specified. When the machine deviates from the guiding pipe. When the machine contacts any objects.

This has similar advantage with citrus sprayer. Its efficiency is more than twice manual spraying. Moreover, it is possible to reduce the application rate due to its uniform application.

This is planed to be put on the market after this fall.

(3) Microcomputer controlled unmanned air blast sprayer

Since the spraying direction for fruit trees is upward there is problem of exposure to agricultural chemicals on the operator during application. This requires that the operator must wear protective clothing, thereby causing hard work during the hot seasons. It is possible to work with a cabin mounted on the air blast sprayer to avoid exposure to agricultural chemicals on the operator, but if space between tree branches and the top of the cabin is too small it can't be use.

For application in orchards, substantial labor saving has been allowed by using the air blast sprayers, and further if the unmanned sprayer is developed, exposure of operators to agricultural chemicals will be avoided and the working condition will be improved

Then, BRAIN developed a unmanned sprayer in 1933. which have already been put on the market by some manufacturers.

There are various types of unmanned operation system, and the machine developed employs a microcomputer controlled method in which the traveling operation can be performed depending on the deviation of the forward travel while right and left sensors sense the magnetic field incurred by supplying electric current to the cables which are installed along the work course in the orchard.

The cable can be installed along the work course on the earth or from the surface to up to 30 cm deeper for common fruit trees such as apples, and can be installed in the air, 150-200 cm high from the earth for trellis fruit trees such as pears or grapes. Two loops whose range are about 1000 m each can be installed.

The transmission frequency sending signals to the cables is 1.5 kHz, and Ni-Cd battery is used as the power source, and once the battery charged, it allows a continuous 8 hours of operation.

Start-up of sprayer is performed by the assisting radio control system (maximum accessible distance of radio wave: 150m) at the area far from the unmanned sprayer in order to avoid exposure to agricultural chemicals on the operator. In addition, the assisting radio control system can be done as follows. Start/stop of the machine, operate and stop the blower, and stop the spraying.

In unmanned operation the following functions are operated.

1) Overall application is performed among the tree rows during unmanned spraying, but the application is stopped at unnecessary part specially outward of tree rows while turning automatically.

2) Both traveling and spraying automatically as soon as the liquid chemicals is emptied in the

tank.

3) All the operation are stopped at the time of completion of work. When the drivels operation is released, it can be used as the manned air blast sprayer.

In full- atomization, it should be given the most priority to safety.

From this point of view, this machine is equipped with the following safety systems.

1) Automatic suspension system to stop the traveling and spraying when detecting obstacles.

2) Automatic suspension system to stop the operation of the machine when contracting obstacles.

3) Manual suspension system to stop the operation of the machine when in an emergency.

4) Automatic suspension system to stop the traveling and spraying when control of the auxiliary radio control is disabled.

5) Automatic suspension system to stop the operation when deviating from the microcomputer cable and breakage of wires occurs.

By using this sprayer, the following can attained

1)Possibility to avoid exposure to agricultural chemicals, noise and danger for operators.

2)Possibility to improve labor saving and efficiency in work because the operator can be performed another work like prescription of agricultural chemicals during unmanned application.

3)Possibility to improve labor saving and good timing application because under some conditions one operator can operate multiple sprayers.

## Future View

It is said that the mechanization of paddy production has been completed, but as large-scaled management or compartment advances, the current system is insufficient, accordingly, more labor saving, more efficient, and more precise mechanization are coming necessary.

In terms of high productivity, low cost and labor saving, sufficient working methods and mechanized techniques should be improved, corresponding to the expansion of machine-dependent areas, huge compartment of paddy fields. organic utilization of machines. And increase in working period.

To cope with lack of workers or to reduce the working load, transition from walking agriculture to riding agriculture must be obviously advanced.

Not only labor saving and amenity but also high efficiency and high precision for riding agriculture, are considered to advance further.

The series work of administration in paddy field by vehicles is expected much, since they can contribute to the labor saving and high precision-acquisition and so on. Especially, low volume application techniques are important for the work in paddy field required portability of the machines.

In terms of the environmental preservation type agriculture promotion in recent years, low volume application techniques are more important. It is necessary to contribute to control the occurrence of carbon dioxide. In conventional application methods, since the machine would be large to put large quantity of liquid chemicals, the high rate power was necessary to operate machine. Thereby it was caused that increasing the consumption of fossil fuel and increasing the occurrence of carbon dioxide.

Recently much social attention has been paid to non chemical cultivation or low volume chemical cultivation in Japan. Accordingly, there are less poisonous chemicals to avoid the agricultural chemicals residue and to prevent environment pollution. This new types of agricultural chemicals for that purpose are being developed.

It seems that development of resistant variety or biotic pesticide for pest control will be advanced the advancement in biotechnology. On the other hand, there will be no change in necessity of application by spraying pesticide (agricultural chemicals) in the future.

From now on improvement of safety for both consumers and workers must be done. And it is also necessary to reduce the amount of agricultural chemicals in agricultural management, therefor, it is important to perform on suitable period of application and restrain both over-application and drift of agricultural chemicals.

And it seems that it will be more necessary to develop an application machine and techniques be able to apply lowest amount of agricultural chemicals for highest efficiency.

In order to achieve the above purposes such as high accuracy, high efficiency of the pest control machine, labor saving, and safety, it is important to adopt sensing techniques like crop information sensors or controlling techniques and soon. It can be said that since the working conditions in case of agricultural production are not so same in industrial fields, it is difficult to use high technology practically. However, a technology, has advanced steadily, so full-automation and intellectualization of sprayers will be progressed further, and will be more utilized more in the area of agricultural production.

# 水稻施藥機械的研究

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## 摘　　要

爲解決水稻施藥人工不足和減輕施藥操作人員的勞累，並提高施藥安全性，八十一年元月從日本引進丸山牌BSA-01自走型承載式四輪傳動高壓施藥機貳組分送桃園場及台南場嘉義分場，進行各項性能測試工作及田間實際施藥作業。經初步測試得知當噴嘴藥液壓力固定在20kg/cm2，26個直徑1.3厘米之噴嘴每分鐘噴藥量爲33公升。該機施藥臂寬度爲8公尺，配合二檔前進時，平均每小時可施藥1.2公頃。該機之操作簡單，可減輕農友施藥時之辛苦，且經調查得知該機在紋枯病、褐飛蝨之防治上比傳統式施藥效果爲佳，可減低藥劑之使用量，進而增加農友之淨收入。

【關鍵字】水稻、施藥機

## 一、前　　言

目前農友水稻施藥方式不外以人工背負微粒動力噴藥機，或以自走式搬運車搭載混合藥液桶、高壓施藥泵浦及軟管，從事水稻田施藥防治作業，所費工時較多且工作也甚勞累。鑑於提昇水稻施藥走向自動化趨勢，自日本引進丸山牌 BSA 400-01 型自走型承載式四輪傳動水稻高壓施藥機貳組，在桃園區農業改良場及台南區農業改良場嘉義分場轄區內，從事試驗探討所引進之丸山牌 BSA 400-01 型自走型承載式四輪傳動水稻高壓施藥機之作業性能，並配合示範農戶之合作推廣介紹水稻高壓施藥機。同時爲解決水稻施藥受困於人工短缺所造成之問題，擬以81年度所引進之日本製丸山牌 BSA 400-01 型桿式施藥機爲國產之藍本，配合本省農地之要求，並在台灣大學、中興大學農機系之整體性規劃協助下，進行國產水稻施藥機之製造開發。希望能藉著水稻施藥機之製造開發，落實水稻自走式施藥機在國內生產之技術，並讓國內代耕中心能擁有價廉物美、性能完好之施藥機，同時配合代耕中心之作業方式，達到降低稻米生產成本、增加農民收益及減輕工作負擔之目標。

## 二、試驗設備與方法

1. 以所引進之日本製丸山牌 BSA400-01 型自走型承載式四輪傳動水稻高壓施藥機在桃園場及嘉義

分場進行水稻高壓施藥機靜態性能試驗。

2. 試驗田區分爲水稻高壓施藥機區、傳統式施藥區及對照區。
3. 爲區分水稻施藥機施藥效果，同時搭配搬運車搭載混合藥液桶之傳統式施藥及對照區之試驗。
4. 配合水稻、植物病蟲害專業人員，分別於桃園區農業改良場及嘉義分場轄區內，進行田間施藥。並從水稻、植物病蟲害及農業機械各方面分析試驗所得結果及使用效率。
5. 調查目前水稻施藥常用方式、所遭遇之問題及每公頃施藥所需工時。
6. 評估並比較傳統式施藥與引進之水稻高壓施藥機作業性能之差異，及對病蟲害防治效果差異及產量差別比較。
7. 本計畫從八十一年一期作起至八十二年一期作在桃園縣新屋、新竹新埔、雲林斗六、嘉義大林、鹿草等地從事施藥試驗及示範介紹給農友。
8. 配合合作意願高之鉅業車體公司，以其現有從事製造施藥機之能力及設備，參考自日本引進之丸山牌 BSA 400-01 型桿式施藥機進行製造開發工作，使國內廠商能在短期間內生產水稻自走式施藥機。
9. 爲配合本省田區作業便利，將噴桿寬度由8 公尺改爲10公尺，藥液桶改爲500 公升。

# 三、結果與討論

1. 面積 VS 作業時間

本水稻施藥機施藥時如同駕駛曳引機般方便輕鬆，由於該機配有26個直徑 1.3 厘米陶片噴嘴，分佈在左、中、右三節之噴桿上如表一，爲便便利田間操作，三節噴藥桿可由駕駛台上之開關個別控制，由於配合強勁迴旋氣流之單孔噴嘴之使用，施藥時使用20kg/cm²之壓力較傳統式施藥使用35kg/cm²之壓力爲小，使用較小之壓力並不會減低病蟲害防治效果，相對的可以減低動力之需求，並且水稻施藥機施藥時間較傳統式施藥方式可節省一半之時間及可減少二或三個作業人員如表二、三。

表一、日製丸山牌BSA400-01型水稻施藥機格規：

尺寸部份：

全　　長：3030厘米
全　　高：1750厘米
全　　寬：1750厘米
輪　　距：1400、1500厘米
最低離地高：650厘米
空 車 重 量：600公斤

動力部份：

引擎類別：汽油氣冷式四衝程
排　氣　量：323CC
引擎馬力：8.2 PS(最大)

驅動部份：

檔　別：前進三檔、後退一檔
轉　向：四輪轉向
驅　動：四輪傳動

施藥部份：

泵　　浦：MS 5002 S 型電磁控制式
泵浦流量：41.5公升/分鐘
泵浦壓力：20 kg-f/m（最大35）
噴嘴格規：直徑1.3厘米單孔陶片
噴嘴數目：26個
施藥寬度：8　公尺
藥桶容量：400公升

表二：使用水稻施藥機施藥方式面積 V S 作業時間

| 地　點 | 鹿草 | 鹿草 | 鹿草 | 新屋 | 新埔 |
|---|---|---|---|---|---|
| 作業面積 | 0.375 | 0.375 | 0.399 | 0.245 | 0.345 |
| 使用時間 | 12’ | 12’ | 11’28" | 7’30" | 10’50" |
| 用藥水量 | 375 | 340 | 400 | 240 | 345 |

備註：使用壓力：20 kg/cm²
操作人員：1 人
平均用水：885.8 公升/公頃
平均時間：11’20"　/0.4 公頃

表三：傳統式施藥方式面積 V S 作業時間

| 地　點 | 鹿草 | 鹿草 | 鹿草 | 新屋 | 新埔 |
|---|---|---|---|---|---|
| 作業面積 | 0.188 | 0.188 | 0.217 | 0.2 | 0.176 |
| 使用時間 | 13’ | 13’ | 19’15" | 17’15" | 11"01" |
| 用藥水量 | 105 | 118 | 167 | 150 | 130 |

備註：使用壓力：35 kg/cm²
操作人員：3-4 人
平均用水：670 公升/公頃
平均時間：21’40" /0.4 公頃

2. 利用水稻施藥機械與傳統式施藥稻田產量之比較

使用水稻施藥機病蟲害防治時，依台灣省政府農林廳編印之植物保護手冊所介紹之稀釋比例用藥即可。由於本機採用可造成强勁迴旋氣流之單孔陶片噴嘴，其强勁迴旋氣流可確實滲入水稻欉基部，比傳統式人工手持噴藥桿左右揮動施藥更能有效防治病蟲害之發生。平均每公頃每期作可增加產量6.3～13.9% 如表四。

表四、水稻施藥機械與傳統式施藥產量之比較　單位：公斤/公頃

| 地　　點 | 鹿草 | 鹿草 | 大林 | 斗六 | 新屋 | 新埔 |
|---|---|---|---|---|---|---|
| 水稻施藥機 | 5467 * | 7120 ** | 6760 | 8720 | 6210 | 6750 |
| 傳統式施藥 | 4800 * | 6660 ** | 6360 | 8000 | 5678 | 6104 |
| 無施藥(CK) | 4667 * | 6460 ** | —— | —— | —— | —— |
| 指　　數 | 113.9 | 106.9 | 106.3 | 109 | 109.4 | 109.9 |

備註：(1) * 表台梗八號品種
(2)**表台梗二號品種
(3)其餘爲台農六十七號品種
(4)作業日期：八十一年一期作至八十二年一期作
(5)指數=(水稻施藥機/ 傳統式施藥)×100

3. 水稻施藥機田間操作造成之水稻損失

由於水稻施藥機田間操作時必須在水稻田中行走，常因行走時操作不當或枕地兩邊轉向時車輪壓傷水稻株而造成減產。經過兩年之試驗結果得知、每公頃每期作平均損失 640.8 元如表五。

表五、水稻噴藥機操作損失（單位：公斤/公頃）

| 地　點 | 損失金額 |
|---|---|
| 鹿　草 | 520 |
| 大　林 | 908 |
| 斗　六 | 462 |
| 新　屋 | 608 |
| 新　埔 | 706 |
| 平　均 | 640.8 |

備註：(1)損失金額：以一般市價15元/公斤計算
(2)作業日期：81年1期作至82年1期作

4. 病蟲害防治效果差異比較如下：

81年 1期作：

因一期作紋枯病無重大病蟲害發生，稻施藥機及傳統式噴藥機防治效並無顯住差異。

81年 2期作：

水稻施藥機在紋枯病，褐飛蝨之防治效果上比傳統施藥方式較佳，產量也因病蟲害穫得防治而較傳統式施藥爲多。

5. 作業成本統計

水稻施藥機之作業成本包括固定成本及操作成本，固定成本包含折舊，利息等費用，操作成本爲燃料，潤滑油，維護及工資等。平均每公頃施藥需要作業成本 601元(不包含農藥費如表六)，而傳統式施藥每次則約需 2,000元。

表 六、水稻施藥機作業成本統計　　　單位：元

| 項　目 | 單　位 | 數　量 | 說　明 |
|---|---|---|---|
| 購入金額 | 元/台 | 460, 000 | |
| 殘　值 | 元/台 | 46, 000 | 購入金額10%計算 |
| 每　年<br>作業面積 | 公頃 | 240 | 一次施藥防治以40公頃，每一期作施藥3次計<br>(40公頃/次×3次/期×2期/年＝240公頃/年) |
| 使用年限 | 年 | 7 | |
| 折 舊 費 | 元/公頃 | 246. 4 | (460, 000－46, 000)元／(240公頃/年)×(7年) |
| 投資利息 | 元/公頃 | 68. 6 | 0. 065×[(460, 000＋46, 000)元/2]/240公頃 |
| 維 護 費 | 元/公頃 | 191. 6 | 年維護費以購入金額10%估計　460, 000元×10%÷240公頃 |
| 油 料 費 | 元/公頃 | 38 | 16. 5元/公升×3公升/公頃＋潤滑油脂費(燃料費×15%) |
| 人 工 資 | 元/公頃 | 125 | 男工(1500元/天／ 8時/天)×0. 66小時/公頃)，以一小時施藥 1. 5 公頃計算 |
| 合　計 | 元/公頃 | 601 | |

備註：本表比較只針對機械及人工田間施藥之差別，並不包含農藥費用之比較。

6.水稻施藥機之國產化

(1)國產水稻桿式高壓施藥機在克服油壓傳動車軸之取得、行走鐵輪之自製及大藥桶之開模製造等作業困難後，完成組裝並於83年6月中旬將雛型機運交桃園場，進行靜態與動態之測試，以了解雛型機之優缺點。

(2)83年11月完成修改之雛型機運回桃園區農業改良場，再經動靜態測試，發現雛型機尚有一些缺點，經與鉅業公司聯絡，決定作局部修正。

(3)84年2月底完成車樑骨架及前後油壓傳動軸之更新，重新調整藥桶、引擎等裝設之位置，與皮帶輪更新。3月初將雛型機運回桃園場，準備再進行田間測試。

# 四、結　　論

自走型四輪傳動水稻高壓施藥機，施藥管施藥寬度爲八公尺，並裝配强勁迴旋氣流之單孔噴嘴二十六個，霧化效果良好，由於强勁迴旋氣流可使霧化之藥液滲入水稻欉基部及附著於葉背，比傳統式人工手持噴藥桿左右揮動施藥更能有效地防治病蟲害之發生；且噴藥管分爲左、中、右三段，可隨意分段調整開關，更適合水稻田噴藥作業。現行傳統式施藥，每組作業人力（不包含農藥成本）每公頃每次約2000元；從水稻施藥機作業成本統計分析，可得知每公頃每次作業成本約須601元，每期作施藥三次，可節省部份成本支出；就單位收穫量來比較，使用本機，比採用傳統式施藥，對紋枯病，褐飛蝨之防治效果較佳，而使產量增加。因此，使用自走型四輪傳動水稻高壓施藥機，測試結果可得以下之結論：

1. 防治病蟲害效果較佳。
2. 縮短施藥工時,減輕農友工作之辛苦。
3. 可減低藥劑之使用量,並減輕對環境之污染。
4. 可節省施藥部份成本支出。
5. 增加6.3～13.9% 之產量。

總而言之，使用水稻高壓施藥機可增加農友之淨收入。由於本機屬專用型，小面積之農友使用時較不經濟，故本機如能搭配代耕中心之作業方式，相信能減輕農友施藥之辛苦，且能減低藥劑之使用，減輕環境污染，進而增加農友之收益。因此，水稻施藥機値得大力推廣並介紹給農友使用。

國產水稻施藥機，希望透過不同作業條件之水稻田，進行測試及修改，修改後再測試，使本機能符合田間施藥作業所需之各項要求爲目標。

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# 廣域鼓風式施藥技術的研究

盧　子　淵

台南區農業改良場

## 摘　　要

為配合水稻大面積集團栽培之病蟲害防治作業環境需要，本場在農委會計畫支助下由日本引進丸山牌廣域鼓風式自動噴霧車VSA-1100型。此型噴藥機械是利用風扇產生强力氣流以攜帶藥霧微粒到達施藥目標，因此會產生藥液飄移的問題，在施藥作業時應特別注意風速及風向，在實際作業時並可根據單位面積的施藥量需要及施噴距離，調整噴藥壓力與行走速度以提高噴藥工作效率。

【關鍵詞】噴霧機、鼓風式

## 一、前　　言

水稻是本省最主要糧食作物，迄民國八十二年止，每期作栽培面積仍達二十萬公頃左右，其栽培生產過程均已機械化作業，而病蟲害防治作業目前主要使用農地搬運車搭載動力噴霧機配合管線來施行噴藥作業，因環保意識的覺醒及農村勞動人口短缺與老化，使得稻田噴藥作業已面臨嚴重的困境，因此，噴藥自動化的需求也日趨迫切。鼓風式噴霧機從1940年起在美國大量應用於果園，也有專供行列作物施噴之型式，但仍以果樹居多。鼓風噴霧機乃利用空氣流以攜帶微粒到達施藥地區，因此，會產生藥液飄移的問題，在作業時應特別注意風速。而在日本則將鼓風式噴霧機大型化後，改用於稻田噴藥作業，並已商品化推廣給農民使用。為配合稻作大面積集團栽培環境病蟲害防治作業之需，由日本引進此型噴藥機械，以提高噴藥工作效率，解決農民噴藥之困境，期能有效降低稻作生產成本，增加農民收益。

## 二、實驗裝置與方法

㈠實驗裝置

1.日製丸山牌廣域鼓風式VSA-1100 型自動噴霧車 。

2.風速計、風向計、動力泵及水試紙。

3.電腦影像分析系統。

㈡試驗方法

1.廣域鼓風式自動噴霧車性能試驗

⑴在不同距離各放置一張水試紙(76㎜ x 26㎜)，然後以出風口不同角度模擬噴藥作業順風噴

水，利用水試紙變色面積百分率探討單位面積落水量的均勻度及出風口角度與霧粒飄移的關係。

⑵使用動力泵以不同噴霧壓力測定單組噴嘴噴霧量，每次噴水90秒，噴嘴下方使用軟管包圍導入水桶後測水量，每種壓力測三次。

⑶以出風口不同角度原地逆風噴水30秒，量取潮濕地面之距離，探討逆風噴藥之可行性。

2.水稻病蟲害調查方法：

⑴於噴藥前1天及噴藥後10天調查，每一小區調查30欉水稻。

⑵紋枯病罹病等級係參考國際稻米研究所(IRRI)所訂之等級。

3.水稻病蟲害統計：

⑴罹病莖率=罹病莖數/總莖數×100

⑵發病欉百分率(%)，即每小區欉水稻中發生紋枯病之欉數。

⑶發病欉之平均罹病等級，將各發病欉之罹病等級相加求和，再以發病欉數除之。平均罹病等級大小均在1至9之間，小數點求至第二位。

⑷褐飛蝨總數，每30欉水稻之褐飛蝨蟲數相加求和。

4.廣域鼓風式自動噴霧車水稻田間噴藥試驗。

5.廣域鼓風式自動噴霧車多用途化作業。

# 三、結果與討論

㈠機械規格

<table>
<tr><td colspan="2">型　式</td><td>自走式</td></tr>
<tr><td rowspan="3">機體規格</td><td>全長 (mm)</td><td>6760</td></tr>
<tr><td>全幅 (mm)</td><td>1880</td></tr>
<tr><td>全高 (mm)</td><td>3320</td></tr>
<tr><td colspan="2">重量 (kg)</td><td>4200</td></tr>
<tr><td rowspan="4">作業用引擎</td><td>型式</td><td>水冷4行程6汽缸渦流噴射柴油引擎</td></tr>
<tr><td>總排氣量 (cc)</td><td>5654</td></tr>
<tr><td>定格出力 (ps/rpm)</td><td>145/2700</td></tr>
<tr><td>最大扭力 (kgf/rpm)</td><td>46/1600</td></tr>
</table>

| | | |
|---|---|---|
| 噴霧用泵 | 形　　式 | 往復活塞式 |
| | 常用回轉數 (rpm) | 650 |
| | 常用吐出壓力(kgf/cm) | 15 ～ 20 |
| | 吐　出　量(l/min) | 216 |
| 給水泵 | 形　　式 | 迴轉式 |
| | 吐　出　量(l/min) | 240 ～ 250 |
| 送風機 | 形　　式 | 後置靜翼軸流式 |
| | 回轉速度 (rpm) | 0 ～ 1750(無段變速) |
| | 風　　量 ($m^3$/min) | 0 ～ 1890 |
| 噴嘴 | 種　　類 | 圓形噴嘴＋田埂噴嘴 |
| | 個　　數 | 0.3$\phi$x122個+<br>盲口×6個+阿波羅田埂3-20型 |
| | 噴　霧　量(L/min) | 188 (20 kgf/$cm^2$時) |
| 出風口 | 旋回角度 | 200° |
| | 上下角度 | +25° ～ -10° |
| 藥液箱容量(l) | | 1100 |
| 攪 拌 方 式 | | 機械攪拌(螺旋漿) |

㈡噴藥作業唯有在確知施藥量之下，才能確保預期之防治效果，因此每個噴嘴實際噴霧量之測定極爲重要，自動噴霧車噴嘴噴霧量之測定結果如表一，在實際作業時可根據單位面積的施藥量及施噴距離，調整噴藥壓力與行走速度。經試驗得知依照散佈長度對0.1公頃的散佈量之適當的壓力及行走速度如表二。

表一　噴嘴噴霧量測定

| 噴嘴 | 壓力 kgf/cm² | 噴霧量 cc/90sec | | | 平 均 cc | 標準差 cc |
|---|---|---|---|---|---|---|
| 單噴頭 | 15 | 1960 | 2060 | 1980 | 2000 | 43 |
| | 20 | 2610 | 2610 | 2720 | 2647 | 52 |
| | 25 | 2720 | 2620 | 2780 | 2707 | 66 |
| 雙噴頭 | 15 | 3480 | 3450 | 3490 | 3473 | 17 |
| | 20 | 3690 | 3690 | 3680 | 3687 | 5 |
| | 25 | 4470 | 4530 | 4460 | 4487 | 31 |

表二　依照散佈長度對0.1公頃的散佈量之適當的壓力及行走速度

| 散佈長度 (m) | 散佈量 (l/10a) | 噴霧壓力 ($kg/cm^2$) | 行走速度 (km/min) | 0.1公頃地散佈需要時間(秒) |
|---|---|---|---|---|
| 100 | 100 | 20 | 1.0 | 36.0 |
| | 80 | 20 | 1.3 | 27.7 |
| | 60 | 20 | 1.6 | 22.5 |
| 80 | 100 | 20 | 1.3 | 34.6 |
| | 80 | 20 | 1.6 | 28.1 |
| | 60 | 20 | 2.0 | 22.5 |
| 60 | 100 | 20 | 2.0 | 36.0 |
| | 80 | 20 | 2.5 | 28.8 |
| | 60 | 20 | 3.3 | 21.8 |

＊實際作業的時候，上述數據會因外界環境及操作者純熟度的影響而有些許的差異，由上表的散佈幅、散佈量，可推算噴霧壓力及行走速度。

㈢1. 由不同距離之水試紙變色面積百分率(表三)得知，出風口角度太大則藥液飄移現象嚴重，反之角度太小則施噴近處有藥液過量之虞，因此順風噴藥狀況下若考慮單位面積落水量的均勻度及藥液飄移，則出風口角度以0°～+10°間較理想。

表三、 水試紙變色面積百分率（噴霧壓力20kgf/cm$^2$，順風噴霧）

| 出風口角度 | 風速 (m/sec) | 作業速度 (m/sec) | 距離 (公尺) 0 | 20 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -10° | 3.58～3.96 | 0.38 | 100%* | 79% | 75% | 38% | 20% | 17% | 10% | 6% | 2% | 3% |
| 0° | 3.93～4.68 | 0.51 | 100%* | 100%* | 90% | 84% | 55% | 63% | 28% | 12% | 6% | 2% |
| 10° | 2.87～3.83 | 0.42 | 81% | 80% | 83% | 88% | 80% | 88% | 70% | 59% | 27% | 20% |
| 20° | 3.15～3.63 | 0.42 | 12% | 74% | 77% | 70% | 42% | 48% | 31% | 33% | 33% | 31% |

* 水試紙表面如被水浸過，無法辨視出霧粒形狀

㈢出風口仰角視風速大小作適當調整，可減低藥液飄移現象，使藥液集中在所要施噴的對象，由田間試驗得知下表作爲噴藥時之參考。

| 風速(M/SEC) | 出風口角度 |
|---|---|
| 0 ～1.5 | 10° |
| 1.5 ～3.0 | 8° |
| 3.0 ～4.0 | 6° |

㈣廣域鼓風式自動噴霧車作業注意事項

1.太陽剛出來時，地面的溫度變暖，氣流上昇，散佈作業效果會降低。

2.逆風向散佈時，施藥散佈距離會減少許多，且爲保護作業者之安全建議不可逆風向噴藥。

3.風速在 4 M/sec以上情形下，作業要停止。因風速高時，藥液更易被風擴散，所以藥液會飛散到散佈目標區外。

4.藥液的補給若以補給車作業，可節省更多的工時，但會增加補給車的操作者。

5.噴藥防治作業，需適時、適量、適藥才能得到最佳的防治效果。

㈤自動噴霧車與人工動力噴藥作業比較

1.使用自動噴藥車作噴藥工作可較使用動力噴藥節省工時 9/10以上，並且不增加操作人員。

表三 自動噴霧車與人工動力噴藥作業效率比較

| | 作業員(人) | 作業時間(分鐘/公頃) |
|---|---|---|
| 人工動力噴藥 | 3～4 | 62.6～88.7 |
| 自動噴霧車 | 2 | 6.0～6.5 |

2.廣域鼓風式自動噴霧車與人工動力噴藥作業調查，結果如表五～表八。

表五　廣域鼓風式自動噴霧車噴藥作業記錄

| | |
|---|---|
| 作業速度 | 1.09km/hr(0.303 m/sec) |
| 藥液量 | 900L |
| 作業面積 | 0.952ha |
| 噴藥作業時間 | 6分25秒 |
| 作業環境 | 順風噴藥 |
| 風　速 | 0.85m/sec |
| 出風口角度 | I 10° II 8° III 6° |

表六　噴藥車作業時不同距離之水試紙變色面積百分率

| 距離 | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100公尺 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 94.3% | 94.9 | 82.6 | 87.2 | 99.1 | 98.2% | 97.8 | 64.8 | 52.9 | 41.0 | 11.5% |
| II | 63.7% | 86.7 | 79.2 | 79.4 | 90.6 | 70.8% | 66.4 | 65.7 | 43.7 | 11.0 | 2.5% |
| III | 61.1% | 78.3 | 75.1 | 96.1 | 66.9 | 72.3% | 76.0 | 49.1 | 13.5 | 2.2 | 0.3% |

表七　二化螟被害莖率調查

| | 施　藥　前(83.4.6) | | | 施　藥　後(83.4.15) | | |
|---|---|---|---|---|---|---|
| | I | II | III | I | II | III |
| 25m | 1.9% | 0.7% | 4.7% | 2.6% | 1.7% | 4.9% |
| 50m | 1.2% | 1.2% | 0.5% | 2.4% | 4.8% | 0.3% |
| 75m | 3.0% | 2.6% | 2.4% | 3.9% | 1.0% | 1.2% |
| 100m | 6.7% | 1.5% | 1.2% | 1.5% | 0.8% | 1.9% |
| 人工噴藥 | 4.1% | | | 4.3% | | |
| 無施藥 | 1.7% | | | 4.0% | | |

表八　紋枯病被害度調查

| | 施　藥　前(83.4.6) | | | 施　藥　後(83.4.15) | | |
|---|---|---|---|---|---|---|
| | I | II | III | I | II | III |
| 25m | 0% | 0% | 0% | 0% | 0% | 0% |
| 50m | 0% | 0% | 0 | 0% | 0% | 0.6% |
| 75m | 0% | 0% | 0 | 0% | 5.0% | 1.5% |
| 100m | 0% | 1.6% | 0 | 2.4% | 18.3%* | 8.5%* |
| 人工噴藥 | 0% | | | 0% | | |
| 無施藥 | 0% | | | 2.8% | | |

* 田區位於下風處水稻最易感染紋枯病

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# Test of plant protection equipment in Germany and European standardization

Heinz Ganzelmeier

Introduce Biological Research Center for Agriculture and Forest (BBA).

History and test plant protection equipment.

* test procedure with approval for new sprayers
  - test offer is voluntary
  - structure
  - requirements
  - technical test methods by the BBA
  - field tests by the office of plant protection services approval, test report.
* procedure of declaration for new sprayers
  - procedure is obligatory and given by law
  - structure
  - requirements, features published in BBA-Guidelines
  - tradable sprayers have to fulfill legal requirements
  - tradable sprayers are published
  - technical tests
  - test facilities and test methods.
* check of sprayers already in use
  - experience of 30 years in voluntary check
  - obligatory check of field sprayers
  - voluntary check of air-assisted sprayers
  - recognition, test equipment
  - requirements/features
  - statistics of checked sprayers/defects
* European regulation for plant protection products (PPP) and plant protection equipment-standardization.
  - registration of PPP in Europe
  - standardization in safety for human beings and environment
  - cooperation of European partners in joint projects.

# Present state of the art of plant protection equipment and recent developments in Germany

Heinz Ganzelmeier

* present state of the art
    - sprayers already in use in arable crops, vine, orchards and hops
    - good agricultural practice
    - exposure of user and protection measures
    - electronic control systems
    - quality of distribution
    - drift
    - soil contamination
    - cleaning of sprayer / waste disposal
* Recent developments of field sprayers
    - general trends
    - nozzles
    - cropfilter
    - shield sprayers
    - air assistance
    - injection systems
    - patch spraying
    - defect spraying
* Recent developments of air-assisted sprayers in high growing crops
    - sprayer with axial, radial, crossflow fan
    - recycling sprayer
    - sensor controlled nozzles
* Recent developments of sprayers in glass houses

# CURRENT STATE OF PESTICIDE APPLICATION TECHNOLOGY IN THE U.S.A.

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## ABSTRACT

Although application methods and equipment have improved, chemical application is still an inefficient operation. Often only a small portion of the spray chemical actually reaches the target and contributes to the desired biological effect. There have not been many major changes in the design of application equipment for several years. Some of the recent pesticide application research programs and technological developments in the U.S.A. are discussed in this paper.

## INTRODUCTION

The use of synthetic organic pesticides in the U.S.A began in the 1940's. Total amount of farm pesticide use has tripled between 1950 and 1985. The total amount of pesticide active ingredients applied on farms increased 174 percent between 1964 and 1982 while total area under cultivation remained nearly constant. Herbicide use was predominant and increased from 95 million kg of active ingredient in 1971 to a peak of 206 million kg in 1982 (USDA, 1984). In 1985, approximately 95% of the corn and soybean fields was treated with herbicides, compared to about 40 percent in 1970. As a percent of total pesticide amount applied, herbicides rose from 33% in 1966 to 90% in 1986 (USDA, 1970; 1986). During that time insecticide use declined while fungicide use stayed relatively the same. Total pesticide use has declined from more than 227 million kg of active ingredient in 1982 to about 195 million kg in 1987. The greatest volume of pesticides is applied on field crops. About 90 percent of all herbicides and insecticides are applied on four crops; corn, cotton, soybeans and wheat (USDA, 1986). In 1986, corn alone accounted for 55% of all herbicides and 44% of all insecticides used on field crops. Nearly half the total amount of pesticides was used in corn production. Soybeans received about 25% of all herbicides, and cotton about 25% of all insecticides. Fungicides now account for less than 10% of all pesticides applied in agriculture.

The success of pesticide applications depends on the accuracy of placement on the target. Most herbicides used on row crops are applied by sprayers powered by tractors. About two-thirds of all insecticides and fungicides are applied aerially. Citrus orchards may be aerially treated 10 to 20 times per season with insecticides, fungicides and protectant oils. Helicopters are often used because the turbulence from the main rotor tends to push the pesticides down toward the crop. Fixed-wing aircraft are more commonly used in field crops such as wheat and cotton. Although the current chemiapplication methods and equipment have improved the application accuracy considerably, chemical application is still an inefficient application. Often only a small portion of the spray chemical actually reaches the target and contributes to the desired biological effect.

## RESEARCH THRUST AREAS

The main focus of the chemical application research in the U.S.A. has been to develop and adopt application techniques to increase the percentage of the chemical deposited on the target, and to protect the environment from contamination by pesticides. Some of the major research areas in pesticide application technology in the last decade include in-line injection of pesticides, spray drift, shielded booms, the management and disposal of pesticide wastes, subsurface placement of pesticides, techniques for measuring spray deposits on targets, spray droplet size analysis, retention of droplets on target surfaces, and new atomizers such as controlled droplet applicators and electrostatic nozzles. Following is a summary of research and educational activities that we are involved in Ohio, and brief discussion of some other studies conducted elsewhere in the U.S.A.

### Ohio Studies

#### In-line Pesticide Injection Systems

Safe disposal of unused tank mixtures after spraying is a major problem. Due to many variables, it is almost impossible to make a quantity of pesticide and water that will be exactly enough for the intended treatment. Sprayer operators tend to make a larger tank mixture than needed to insure that there will be plenty of mixture for the treatment. It is common to have unused mixtures of pesticide and water after the pesticide application. Safe disposal of unused tank mixtures creates problems. Some have suggested that the operator dilute the unused mixture and spray it over the treated area. However, such practice could result in excessive pesticide residue on the treated crop. Improper disposal of the unused mixture may contaminate the water supply due to runoff after rainfall and leaching.

It is possible to eliminate unused tank mixtures after spraying if sprayers with in-line pesticide injection systems are used. When in-line pesticide injection systems are used, the only left-over liquids are the water in the water tank and the pest icide in the pesticide tank. The unused pesticide can be kept in the pesticide tank for the next application or drained through a tube into the original pesticide container. Reichard and Ladd (1983) developed and tested a field sprayer that would meter pesticides at the proper rate, regardless of travel speed, and mix the pesticides with water in line to nozzles. The sprayer also included a portable closed system of pesticides from shipping containers to the pesticide tank on the sprayer.

Although it is obvious that the in-line direct injection of pesticides is an effective method of reducing operator exposure and left over chemical mixtures, injection systems have not been widely accepted by applicators. The reasons are: (a) slow response time of the systems after sudden changes in travel speeds, (b) inadequate mixing of some chemicals in the spray line which results in non uniform application, and (c) higher cost and maintenance requirements. To reduce the time lag problem, some researchers have studied direct injection of pesticides into the nozzle body. Although some progress was made in reducing the response time, the complexity and non uniform mixing of chemicals with the carrier remain as the major problems associated with this system. Research in this area will continue to eliminate or reduce these problems.

## Uniform mixing of pesticides in sprayer tanks

Achieving satisfactory results with a sprayer is greatly dependent on the performance of many sprayer components. One component often overlooked is the agitation mechanism. When some pesticides, especially wettable powders, are added to tanks with insufficient agitation, they either tend to float on the surface of the liquid or settle to the bottom of the tank. In either case, the result will be non uniform distribution of pesticides on the target. While some treated areas may not receive enough pesticides, other areas will receive too much. Not enough pesticide causes ineffective pest control, while an overdose increases the cost of production, and may damage the crop.

Unfortunately there has been little investigation of the uniformity of pesticide distribution in sprayer tanks during spray applications. The latest known research was conducted almost three decades ago. The predominant tanks on tractor mounted sprayers then were standard, uniformly shaped 206-liter (55 gallon) oil drums. Sprayer tanks today can hold as much as 4000 liters, and they have a wide range of shapes. In spite of these changes in size and shape, the agitation methods and mechanisms in sprayer tanks have remained basically the same and little is known about what is required to provide uniform mixtures.

A thorough investigation of current agitation systems should lead to the development of better tank mixing systems. Improvements in the mixing technology could: a) result in more efficient use of pesticides, application equipment, and applicator time; b) avoid under application of pesticides which could cause reduced yields and increased production costs because of additional applications that may be necessary; c) eliminate over application which could lead to crop damage, increased production costs and costly litigation's between the farmer and others.

Research is underway to determine variation in the pesticide concentration at several points in the tank during the entire spray application for various agitation systems. Two methods are being developed to determine uniformity of pesticide concentration at various locations in spray tanks. The first method is based on the amount of light transmitted across a gap between two fiber optic probes. A high amount of light transmission indicates low pesticide concentration. The second method consists of drawing small liquid samples simultaneously from different locations in the tank, drying and weighing the residues. The results of this research should determine an effective and agitation system for pesticides difficult to mix with water for various tank sizes.

## Retention of spray droplets on targets

The performance of chemicals is directly related to the retention of droplets on the target. Until recently, research on the impaction and retention of droplets on spray targets has been neglected because of the many variables involved and lack of suitable equipment for the research. We are studying rebound of droplets on the target surface by using high speed photographic techniques which enable us to see actions that could not normally be seen. A high speed 16 mm motion picture camera is used to take 6000 pictures per second. Viewing the film at 24 pictures per second provides time magnification of 250.

Our initial studies show that for some operating conditions a large portion of the spray droplets rebound from the spray target. Among 35 different plant leaves used as a target, 12 were very reflective of spray droplets. The micro structure of the leaf surface greatly influences whether a droplet rebounds or not. Of the variables we have studied so far, adding surfactant to the water is the best way to reduce the rebound of spray droplets from leaves that tend to reflect drops. The optimum type and amount of surfactant is yet to determined. Research will continue to improve the deposition efficiency of spray droplets through a better understanding of the impaction process.

## Application accuracy

The effects of pesticides on the targets are greatly influenced by the method and timing of application and the operation and accuracy of the equipment used. Labels on pesticide containers indicate the proper application rates. However, these rates can be achieved only if sprayers are calibrated. Growing concerns about pesticide contamination of ground water and increasing chemical costs makes accurate application of pesticides even more important than in the past.

We have been conducting traditional extension meetings in counties to each farmers how to calibrate sprayers. Unfortunately most of these classroom oriented programs have not been very effective. A more successful approach has been the calibration clinics which invites audience participation and hands-on practices. At these clinics, the operators were asked what their intended application rates were before sprayers were calibrated. This was compared with the actual rate of application. Regulatory guidelines in the U.S. indicate that the application error should be within 5% of the recommended or desired rate. Of the 80 sprayers tested, only 20% were capable of applying a tank mix within ± 5% of the intended application rate. Of those 64 sprayers showing an unacceptable performance, roughly one-half overapplied the spray mix while the other one-half underapplied. A unique part of these sprayer calibration clinics was the use of a microcomputer program SPRAYCAL (Ozkan, 1987), developed mainly to emphasize the economic aspects of using improperly calibrated sprayers. For an overapplication, SPRAYCAL determines the amount of pesticide wasted and the subsequent cost to the farmer.

## Wear life of agricultural spray nozzles

Calibration clinics conducted in Ohio revealed that more than 1/3 of the sprayers surveyed were overapplying chemicals. The major reason for overapplication was nozzles. No general recommendations exist for how often nozzles should be replaced. Nozzle tips are made from a variety of materials including stainless steel, brass, nylon, plastic and ceramic. All of these materials have different wear characteristics.

We are investigating the effect of nozzle wear on both flow rate and spray pattern. To study the change in flow rate, a mixture of water and an abrasive wear agent (kaolin) is continuously circulated through nozzles. As many as 18 nozzles can be tested simultaneously. In addition to the type of nozzle material, the system will be used to study other factors that affect wear rate such as orifice size and shape, material used in tank mix and operating pressure. After circulating a 150 liter tank mixture that contains 60 grams of Hydrite Flat D (Georgia Kaolin Co.) per liter of water through 3 each of brass, nylon, and stainless steel nozzles delivering 0.75 liter/minute for 40 hours, the increase in flow rate with these nozzles were 28.9%, 11.7 and 10.4% respectively. Although not included in our current wear tests, data from various university and industry research stations indicate that nozzles made from ceramic are most resistant to wear.

Nozzle wear also changes the spray pattern of nozzles. Distortions in the nozzle pattern could lead to non-uniform spray distributions causing streaks with poor pest control and/or an excessive amount of chemicals. We have constructed an automated spray patternator table to investigate the changes in spray pattern of nozzles as a result of wear.

## Subsurface placement of agricultural chemicals

Surface applications often result in inefficient use of agricultural chemicals. When agricultural chemicals are broadcast, they are subject to different types and amounts of losses. In addition, surface applications of pesticides can be hazardous to people, and animals exposed to the pesticides. This risk is often greater in areas such as home lawns, parks, and golf courses where there is considerable chance for human contact with the pesticides applied on the grass surfaces. To reduce this danger, injection systems were developed to place pesticides below soil surface. Current results indicate that fertilizers and pesticides can be successfully injected with little damage to the surface.

## Spray drift evaluation

The problem of spray drift, movement of a pesticide to a site other than the intended site of application, remains a serious problem. Reduced spray drift not only reduces environmental pollution but also improves application efficiency. There have been many research projects conducted to study spray drift. Unfortunately, there are still many unknowns regarding spray drift.

Weather conditions, which the applicator has no control over, play an important role in the creation as well as reduction of drift. Two other factors which influence spray drift are chemical formulations, and application parameters which include selection and proper operation of the spray equipment. The most important application factor influencing drift is the size of droplets produced by spray atomizers. Research has shown that droplets smaller than 150 $\mu$m in diameter have a tendency to drift during many typical spray application conditions. For typical applications with boom type sprayers, droplets of 100 $\mu$m or less drift out of the intended swath and 50 $\mu$m or less diameter droplets, completely evaporate before reaching the target (Bode, 1984). Although the number of small droplets produced by conventional nozzles used with ground sprayers are high, the total volume of spray made up of droplets less than 100 $\mu$m in diameter is relatively small. But, the spray drift should be reduced as much as practical.

Small spray droplets are desirable, especially for insect control in orchards, because they provide better penetration into the canopy and a better coverage. Air blast sprayers which produce a relatively high number of small droplets and also direct the spray upward are commonly used to apply fungicides and insecticides in orchards. Spray drift can be a more serious problem with air blast spraying. Most spray drift research, however, has centered on aircraft or ground operated boom sprayer applications. Few studies of drift from orchard air sprayers have been reported. The first step in developing some strategies to reduce spray drift is to measure the amount of drift occurring under different application parameters. Actual pesticides as well as tracers such as salts, color, and fluorescent dyes have been used by researchers for measuring spray deposits collected on foliage, cards, plastic sheets, paper tape, string, bottles, and other targets.

Fox et al. (1990) conducted a study to measure the deposition pattern of spray material produced by orchard sprayer and to compare several types of spray collectors. They measured ground deposits using 10 × 20 cm plastic sheets. The airborne spray deposits from the sprayer were measured using bottles as well as strings mounted on vertical collection racks 3.0, 4.5 and 15 m away from the sprayer. The mixture, containing tracer, was applied at a rate of 470 L/ha using an air blast orchard sprayer equipped with 6, disk-core type, hollow cone nozzles. Sprayer operating pressure was 900 kPa. The results of this study indicate that most of the spray was collected at 1 m elevation and that deposits steadily decreased as height increased. About 3.5% of the released spray was still air borne at 122 m from the spray line. Spray deposited on the ground between 150 and 300 m was less than 0.1% of the material released.

Field research at several universities have indicated that adding certain adjuvants in the spray solution can reduce the number of drift-prone droplets. In addition, some of these thickening agents reduce the evaporation rate of droplets as much as 30% (Bode, 1981). Reduced pressure at the nozzle also generally causes an increase in the volume median droplet size. The pressure range recommended for conventional hydraulic flat fan nozzles is from about 200 kPa to 350 kPa. Recently, nozzle manufacturers in the U.S. have introduced new nozzles that can be used at pressures as low as 100 kPa. Test results have verified that drift deposits from these nozzles are much lower than those from popular nozzles. Additional research is needed to determine the most efficient application equipment and methods to reduce drift.

## Droplet size characterization and its effect on pest control

Studies conducted recently indicate that spray coverage in terms of number of droplets per unit area is an important factor in achieving maximum phytotoxic effect from a pesticide. All commercially available spray atomizers produce a range of droplet sizes, some ranging from under 10 $\mu$m to over 1000 $\mu$ m. The droplet size range, however, can be altered by changing the viscosity of the pesticide formulation through the addition of some adjuvants to the mixture. Research is underway to determine the effects of pesticide formulations and concentrations; oils; atomizer types, sizes and orientations on size distributions of spray droplets produced by agricultural nozzles.

The requirements for coverage, provided by different sizes of droplets and application rates varies with pesticides. Therefore, in order to improve the efficiency and effectiveness of spray applications for pest control and other uses, information is needed on the effects of various drop sizes and number of drops per unit area. Currently several types of laser equipment are available to determine the droplet sizes generated by nozzles. It is, however, necessary to isolate a given size of droplet from others in order to study the effect of droplet size on biological efficiency achieved from different pesticides. Various devices have been used to produce narrow ranges, or uniform sizes of drops in the past. None have been widely accepted by researchers for different reasons, but usually because these units could not easily produce a wide range of uniform-size drops or vary the number of drops per unit area. Reichard et al (1987) developed a drop generator and associated system to study the effect of drop size and number of drops/unit area on insect control. Another experimental drop generator permits production of uniform-size drops within a range of about 100 to 1800 $\mu$m diameter. The operator can select the number of drops delivered from 1 to 10000 and the frequency of drop production from a single drop when desired to over 10 drops/second.

## Electrostatic Spraying of Pesticides

Gravity and wind are the two major forces affecting deposition of spray droplets produced by conventional nozzles. Small droplets, especially those with a diameter of less than 100 um, reach terminal velocity soon after they are released from a nozzle, and are subject to being swept away from the application site by movement of air currents. This results in increased drift and reduced coverage especially on the undersides of plant leaves. Electrostatic charging of small droplets has been considered as a possible way to increase the deposition efficiency of small droplets.

Although research on electrostatic spraying in industrial applications has been conducted for more than 50 years, the use of charged sprays was not extended to agriculture until early 1970's. Law (1978) designed an experimental electrostatic atomizer and reported excellent insect control when only one-half of the recommended rate of insecticide was applied. Several electrostatic atomizers have been designed and marketed especially in Europe. However, these atomizers have not gained wide acceptance by farmers. Currently there are no mass produced electrostatic atomizers in the U.S. Increased public concern about the environment and the push towards reduced pesticide consumption are likely to provide the impetus to stimulate further investigation of electrostatic spray systems. Some universities in the U.S. have research programs in this area. Most of these programs have been directed towards complementing low volume application systems with the use of electrostatic charging.

## Review of Other Technical Developments

The utilization of electronic sensors, monitors and computer automated controllers in agricultural machines has increased significantly in the last decade. Pesticide application equipment has had many electronic adaptations. The measurement of travel speed, operating pressure, fluid flow rate, area covered, amount of liquid left in the spray tank can now be performed with electronic sensors. Many monitors and controllers are available commercially in the U.S. Most of these systems use a radar sensor to determine the travel speed. Fluid pressure is electronically measured with a pressure transducer, and the fluid flow is measured either with a "paddle wheel" or turbine flow meter. Ayers and Ragowski (1989) have recently evaluated one of the most popular monitors in the U.S. and found satisfactory performance.

Several computer vision and image processing systems are being developed to detect the weed. They are followed by the application of herbicide directly to the weed. Cheshire et al. (1988) developed a technique for detecting the locations of two soil insecticides after their incorporation into soil. The technique involved treatment of the insecticide granules with iodine and a thin coating of lead dust. The granules were detected in soil samples with X-ray computed tomography (CAT scanning). Statistical analysis indicated significant differences between incorporation procedures for dispersion of granules, location of granules, and number of granules detected. Harrowing or rototilling immediately after broadcast insecticide treatments resulted in the shallowest and most variation in distribution of granules.

Recently there is interest in the use of field crop sprayers with some form of wind protection for the nozzles in order to reduce wind drift and improve application efficiency. A Canadian manufacturing firm has designed different types of protective sprayer attachment including complete shrouds over the entire boom, wind shields in front of or behind the nozzles, or small hoods over each nozzle (Rogers and Jackson, 1987 ). Each of these forms of protection, particularly the complete shroud, restricts the operator's ability to visually monitor the nozzles for plugging. Robertson et al. (1988) has developed a detector which measures the airborne sound of the spray and gives warning to the operator if any significant change occur in the initial sound level.

The current methods of handling pesticides poses substantial health risks to applicators. Findings of a study indicate that most of the contamination takes place while transporting, pouring and mixing chemicals. Wesley et al. (1988) designed an enclosed system for mixing and loading both dry and liquid pesticide concentrates without exposing the operator to hazardous materials.

Public concern in the U.S. over disposal of leftover pesticides and pesticide containers is growing continuously. Although in-line injection systems may eliminate the amount of leftover pesticide mixtures in the tank, the problem of container disposal still remains as a potential health hazard. In 1986, about 223 million empty pesticide containers were generated in the U.S., 80 million of them from agriculture (Kepple, 1989). Realizing this problem, pesticide manufacturers have been promoting the use of refillable or recyclable pesticide containers. Most of the major chemical companies now have at least one of such units on the market. These units are usually referred to as mini-bulk or turn-around tank systems. One problem with some of these bulk containers is inadequate metering and not knowing the exact amount of chemical left in the container. Research is being done to investigate the feasibility of adding inexpensive control and monitoring equipment to mini-bulk containers (Howard et al., 1989).

Several are doing research in the U.S. on the fate of agricultural chemicals after their application. The potential movement of pesticides from application site to lakes, streams and ground water resources is a concern of the public, researchers and chemical companies. Management strategies are being developed to provide effective control of surface pesticide transport by reducing the sediment and runoff in which pesticides are carried. One of the most effective ways to reduce the surface water run off is with a crop residue cover on the soil surface. Although some conservation tillage practices require additional herbicide for effective weed control, a common conclusion reached by many scientists is that pesticide losses from fields under conservation tillage systems are generally much less than losses from fields under conventional moldboard plow tillage systems. A recent study by Kenimer et al. (1989) showed this. In addition, they indicated that contour tillage generally yielded lower pesticide losses than up and-down tillage.

## CONCLUSIONS

Although current chemical application methods and equipment have improved application accuracy considerably, chemical application is still an inefficient operation. Often only a small portion of the spray chemical actually reaches the target and contributes to the biological effect. Recent concerns over the contamination of water resources with pesticides has provided a new impetus for scientists to develop methods and equipment to increase the efficiency of pesticide application improvements in pesticide application efficiency will result in less pesticide consumption, less pollution of the environment and reduced energy requirements in the manufacture of pesticides.

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# 間歇式施藥技術的研究

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## 摘　要

在農作物之栽培過程中，病蟲害的發生是無法避免的。早期一直都採用全面覆蓋式來進行噴藥作業，造成過度用藥，破壞生態環境，且嚴重的危害到施藥者的健康。例如目前在國內平地果園作業的動力噴藥車，施藥效果介於5～30％，，絕大部份的農藥都進入了環境成爲污染源，而作物空白區域的施藥量約佔施藥總量的30～50%，視栽培作物的種類和方式而定。因此如何減少作物空白區域的農藥浪費，一直是施藥作業的研究重點之一。雖然在工業界能自動偵測障礙物存在的感測系統已研究多時且有相當成熟的技術。但爲了要滿足田間作業環境的多變化特性，工業上的偵測技術大多均需經過一番修改方能引用於農業上。超音波測距與障礙物偵測已是一項蠻成熟的技術，許多學者在這方面的研究均得到豐碩的成果，它是一種非接觸式且高信賴度的偵測技術。而針對去年度所完成之作物辨識系統，配合改良之市售超音波感測模組，現已將系統之有效辨識距離提升至3m，辨識系統對樹幹及樹葉的辨識率在3m以內可達到100%。而且裝設作物辨識系統後，其覆蓋率非但沒有降低反而增加。因而此辨識系統在藥效方面有顯著的增加。此外，13度的指向角除了可得知此辨識系統之有效辨識範圍外，在獲知株距、平均樹冠半徑、平均空白區域之先決條件下，尙可由其來決定噴藥車作業時應與作物相距之距離，以提高此系統之可信賴度以及節省更多之噴藥量，降低作業成本與減少環境污染。

## 一、前　言

在農作物之栽培過程中，病蟲害的發生是必然的。直至目前爲止，雖有一些生物防治技術與物理性防治技術可資使用，但仍無法完全取代而放棄利用農藥來防治病蟲害。從早期的人工機械式施藥到利用各種動力機具進行噴藥，一直都是採用全面覆蓋式來進行噴藥作業。此種噴藥作業方式常會造成過度用藥的情形發生，亦造成嚴重的環境污染。

目前在平地果園作業的動力噴藥車，施藥效果介於5～30％，絕大部份的農藥都進入了環境成爲污染源，而作物空白區域的施藥量約佔施藥總量的30～50%，視栽培作物的種類和方式而定。由此可見，大部份所施的農藥並未發揮病蟲害防治的效果。仔細研究，原因頗多，缺少有效的藥量管制技術其爲重要的原因。因此如何減少作物空白區域的農藥浪費，一直是施藥作業的研究重點之一。雖然在工業界能自動偵測障礙物存在的感測系統已研究多時且有相當成熟的技術。但爲了要滿足田間作業環境的多變化特性，工業上的偵測技術大多均需經過一番修改方能引用於農業上。目前雖有少部份商品化的間歇性施藥系統，但適用範圍有限，並沒有普遍的被應用，仍舊得採用全面性的噴藥作業方式。全面性施藥的作業方式不僅破壞生態環境，且嚴重的危害到施藥者的健康。目前國民的生活水準日益提高，在農業生產的過程中，爲了保護施藥者、植物和環境以

及在環保意識抬頭、作業成本降低的多重要求下，利用作物辨識系統來進行施藥控制，以達到將作業模式由面噴改爲點噴的要求，已是一件刻不容緩的工作。隨著科技的日益進步，各種更有效率、更敏銳的感測器不斷的問市，其中超音波、紅外線以及影像技術等皆可用以偵測作物。唯影像擷取技術過程複雜、設備昂貴，易受農藥侵害且農藥飄積現象會影響其取像等因素，尚不太適用於施藥場合。紅外線易受外界光源干擾和陰影影響，又易受空氣中塵埃顆粒的影響使其性能產生退化的現象，故有待進一步的探討。超音波測距與障礙物偵測則已是一項蠻成熟的技術，許多學者在這方面的研究均得到豐碩的成果，它是一種非接觸式且高信賴度的偵測技術。

# 二、文獻探討

Giles等(1987)以超音波偵測作物的存在，用做進行間歇性噴藥的依據，其指出，若只使用單一超音波感測，在桃子和蘋果園中用藥量可分別減少10～17%及21～28%，若在三種不同高度分別裝設超音波，則上述兩種果園可減少28～35%及36～52%的用藥量，在農藥飄積現象上也有某種程度的減少。

關於超音波測距應用於導引系統的研究，Munro等人(1990)開發出一套效果不錯的無人自走式超音波導引系統，此系統可偵測角度達60度，距離達5m。Yamashita等人(1991)爲了節省溫室內搬運工作的勞力，其於無人自走式搬運車的一側安裝兩個超音波感測器，利用兩個感測器的距離差並配合編碼器來修正車子，用以導引車子使其以等間距沿著植床壁與植床壁平行的行進。在Tillett (1991)的文獻中說明Bonicelli等人曾利用超音波來導引犁耕用機械人，不過此種導引方式的精確性及可靠度在文獻中並沒有很明確的說明。Tillett並同時介紹了Mcmahon等人利用超音波裝置感測蘋果樹樹幹的位置來導引蘋果收穫機，可量測範圍爲30cm-150cm，誤差爲 4cm，指向角爲22度。Pam Kan-Rice在1991年介紹了由Ken Giles 等人完成的超音波作物偵測噴藥車，其在車頭側面裝設一排超音波感測器，分別指向不同的方向控制不同的噴頭，實驗結果顯示，在種植整齊而果實成熟的果園裡，可節省10%至12%的用藥量。

在1992年Holmberg說明超音波測距應用在機器人自動化及自動導引車輛上有很高的精確度及強健(Robust)的抗干擾能力。Satow等人(1992)則使用超音波由上而下偵測作物以控制噴桿至合適高度，其結論爲，若葉面直徑對高度的比值大於0.05，則超音波可以偵測出正確的高度，另葉片形狀亦爲重要影響因子，如若像小麥類細長形的葉片，就無法準確測得高度了。

Kazuhiko (1993)等人開發Fuzzy控制系統來控制溫室內的農用自律行走式車輛。其在車子的左側裝上兩個超音波感測器，以車輛之行走速度、車輛與目標線的相對位置以及車輛進行方向與目標線的角度等爲主要因子，並利用幾何方法計算出車子偏離目標線的角度；右側則只裝上一個，用以偵測出車子與三種不同模擬田脊間的距離；頻率均爲40KHz。Masayoshi (1993)等人在自律行走車輛的車頭，每間隔10° 即安裝1個頻率爲200KHz的超音波發射接受器，並利用Fuzzy來控制。Mckerrow(1993)於移動式機器人上安裝一圈的超音波感測器，試圖以一演算法來求取代表物體表面的圓弧輪廓線，並利用此輪廓線來繪製一個房間的地圖。

在1994年Figueroa與Mahajan利用Novel的超音波三維定位系統配合傳統的超音波距離測定器來導引和控制自走式車輛。此系統適用於結構性環境(Structured Environment)如：工廠、醫院、辦公室等以及其它對人類有害的環境如核能發電廠等，精確度爲2.54mm。黃(199 4)利用一5×5陣列的超音波感測器，以每隔3度變換感測器陣列的角度，針對不同作物葉片進行各個位置與方向之

測距實驗。在他的實驗中發現超音波感測器測得的距離相當的穩定且與實際距離的差值很小，爲一可靠度極高的測量距離工具。

## 三、實驗方法

本研究即是在動力噴藥車上水平的安裝一組超音波感測器以進行作物的偵測，並將訊號與噴藥系統結合以作爲噴藥與否的依據。目前此辨識系統爲改良市售的超音波感測模組，利用指向角爲13度、頻率爲40KHz的超音波來辨識作物的存在，再配合由兩個最大適用壓力爲7 $kg/cm^2$ 的電磁閥和一個壓力設定爲90psi的洩壓閥所組成的噴藥系統，以決定是否要進行噴藥作業，避免於作物空白區域施藥，以有效的減少環境污染及降低作業成本。由實驗得知，無論針對樹幹或樹葉，在3m以內此辨識系統皆有100%的辨識率，在3.5m時辨識率皆降爲0%。另外在覆蓋率方面亦有顯著的增加。

本辨識系統之超音波模組，原是以交流電來作爲其輸入電源。此交流電壓再經由變壓器降壓、整流器和濾波器的作用而得到12V的直流電壓。由於辨識系統中之電磁閥的激發電壓爲12V的直流電壓，噴藥車上通常也沒有裝設供應交流電源的設備，故需將超音波感測模組電路稍做修改，把交流電輸入直接改爲直流電輸入。因此只要將變壓器去除掉，將電瓶的直流電直接輸入到原是變壓器的輸出端即可。

## 四、結果與討論

⑴針對去年度所完成之作物辨識系統，配合改良之市售超音波感測模組，現已將系統之有效辨識距離提升至3m。

⑵對平均直徑爲15.6cm、平均相距3.44m之樹幹，系統之辨識率在3m以內爲100% ，在3.2m時爲91.25%，在3.3m時爲31.25%，而在3.5m時則已降至0%。

⑶系統對於樹葉之偵測，在平均樹冠半徑爲0.895m，平均株距爲2.28m，平均空白區域約爲0.62m時，系統之辨識率在3m以內皆爲100%，在3.4m時爲12.5%，而相距約3.5m時降爲0%，所得之辨識率與系統對樹幹之辨識率極爲相近。

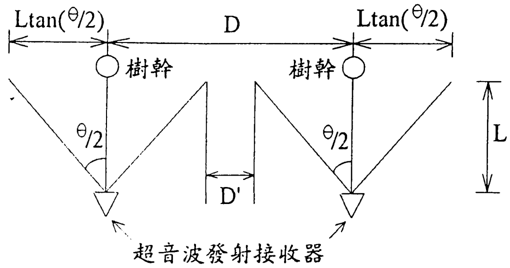
⑷在計算此超音波作物辨識系統之可辨識範圍時，由圖表中可算出此超音波之指向角，且此指向角與利用公式所計算出來之值極爲接近，爲13度。由此指向角除了可得知此辨識系統之有效辨識範圍外，在獲知株距、平均樹冠半徑、平均空白區域之先決條件下，尙可由其來決定噴藥車作業時應與作物相距之距離，以提高此系統之可信賴度以及節省更多之噴藥量，降低作業成本與減少環境污染。

⑸在辨識系統與樹平均相距0.605m，洩壓閥設定壓力爲90psi之覆蓋率實驗中得知，裝設作物辨識系統後，其覆蓋率非但沒有降低反而增加。因而此辨識系統在藥效方面有顯著的增加。

⑹當噴藥車與作物間之距離爲L，株距爲D，超音波指向角爲$\Theta/2$，則此辨識系統之超音波空間辨識比例可由此式求得：

超音波空間辨識比例

$=1-(2L/D)(\tan(\Theta/2))$------------------(1)




圖(一)

由圖一可得知D'=D－2L(tan(Θ/2))，故超音波辨識比例=D'/D而得式(1)。

# 五、結論與建議

⑴此辨識系統僅有一組超音波感測器，水平的安裝於噴藥車上。由實驗執行結果得知具有滿意的效果。由於此辨識系統是以辨識障礙物的有無來決定是否要進行噴藥作業，由各實驗結果，可知只要一組超音波感測器即可得到不錯的結果。不過，爲滿足田間多變化的特性，建議安裝一個以上的感測器以確保作業的穩定性。

⑵若要做到更精確的噴藥作業，此辨識系統之超音波感測器必須具有良好的測距能力，以算出噴藥車與作物間之距離，再根據此距離來控制噴藥壓力，以節省用藥量和提升覆蓋率，增加藥效。因此，超音波感測器的數目和裝設位置有須再加以研究的必要。

⑶由一些文獻中得知，良好的超音波發射和接收室有助於作業靈敏度之提升，增加其指向性並增進有效辨識距離。超音波發射和接收室的開口愈寬，其長度愈長，則其指向性愈好。因此應再進一步研究，以設計出適用於農業環境的發射和接收室。

⑷由於本辨識系統是裝設於噴藥車上，不同於靜置式辨識，故車速與辨識率之相關性應加以深入探討。

⑸應針對不同作物，探討此辨識系統在辨識率、覆蓋率和用藥量之間的變化。

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# 微電腦式藥量控制技術的研發

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【關鍵字】微處理機、控制閥、噴霧

## 一、前　　言

動力噴霧機對作物噴灑藥液時，其對地面作物之施藥量，往往會隨噴霧車行走速度或泵之運轉速度等外在因素之改變而改變，因此容易造成施藥量過多或不足的現象。其結果不但影響施藥效果，更會造成環境之農藥污染問題。因此在各種藥量影響因素變化之下如何進行噴藥之定量控制，以確保施藥效果，並避免環境污染，乃成爲刻不容緩急待解決之課題。因爲此項控制的方式很多，而其中以微電腦爲主控之方式，乃是目前最方便也是最可行的方法 。因此本研究之目的在於研發以微電腦爲主控之動力噴霧機噴藥量控制技術，以解決前述課題。

## 二、實驗裝置與方法

(一)實驗裝置

本實驗裝置如圖一所示，其控制流程方塊圖如圖二所示。本裝置左方之洩壓閥乃是保護管路用，右邊之洩壓閥具有輔助限制回流的作用。系統作業狀態，經泵浦的作動抽取藥槽中的液體之後管路分爲二個分支，其一爲往噴嘴輸送，另一個往微量控制閥端輸送。系統行走速度之快慢由感測輪所感測，泵浦排量由感測其轉速來決定，感測輪與泵浦之轉速訊號傳送給Z-80微處理器，Z-80微處理器計算出所需回流量後傳送控制訊號給控制閥，以決定控制閥的開度，系統中位於控制閥前後兩端之壓力感測器的作用乃是用來檢測回流量是否和所計算出的值相同，若其值不同則Z-80微處理器會傳送控制訊號給控制閥，以修正控制閥的開度。

(二)實驗方法

實驗項目主要包括：

1.量測控制閥開度大小和管路中流體壓力變化情形。

2.量測控制訊號與壓力差、回流量間之關係。

3.量測泵浦排量與其轉速的關係。

4.量測控制閥接受訊號反應間距。

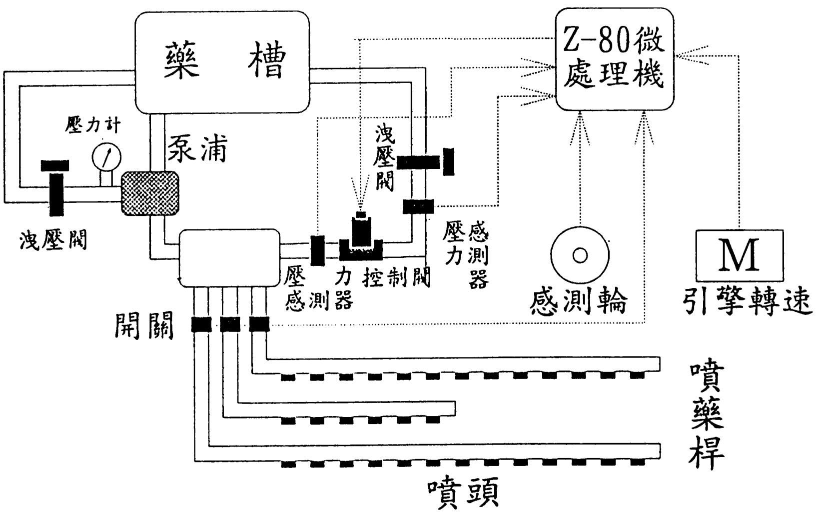
5.利用所測得之實驗結果，及結合感測到的數值進行綜合系統控制實驗，並測試系統的噴霧狀況，比較未經噴量控制之系統和經控制噴量系統之噴量差異。

# 三、結果與討論

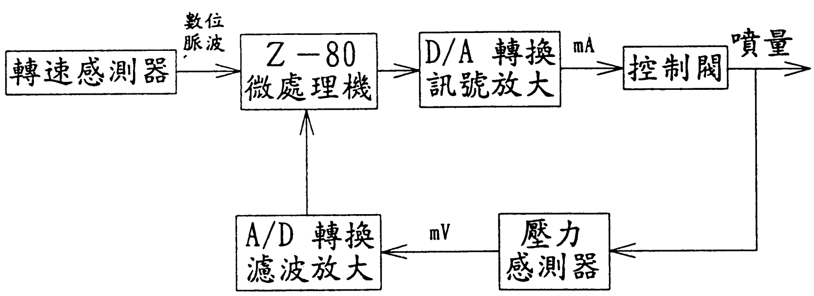
經實驗觀查得控制閥開度和各流量的變化情形如圖三所示，設定系統噴霧狀況爲寬 3.2m 、單位面積所需噴量爲 8 $g/m^2$ 、測試行走400m、所需的理論噴量爲10240g，則控制噴量理論值差與未經控制噴量值差異比較如圖四，控制噴量與理論噴量的比較雖有誤差達14.6%，但就整體而言大部份的誤差值皆小於10%，和未經噴量控制的系統比較，其能達到單位面積定量噴霧的性能遠優於非噴量控制的噴霧機具。

# 四、結　論

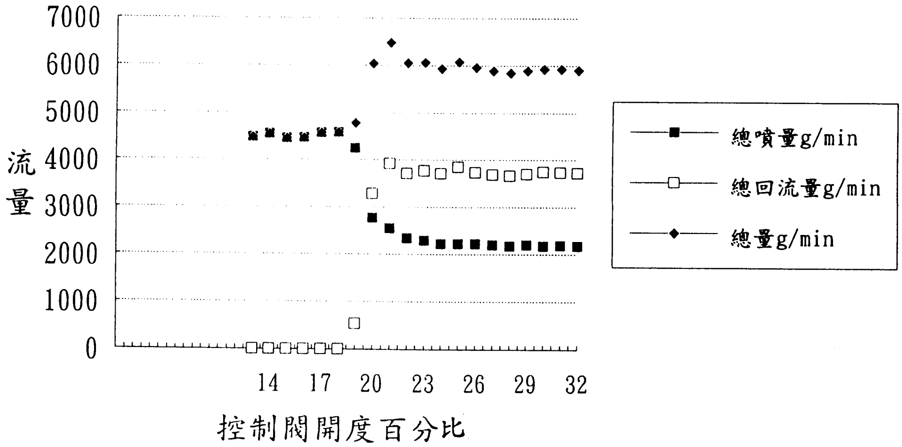
未經噴量控制之噴霧機具行走速度爲12km/hr，則其噴霧量不足率高達46.9%，若行走速度改爲4.4km/hr，則其噴霧量超出達43.4%，比較在相同的作業情況下，依我們所設計出來的作噴霧測試，可以將不足率和超出量控制在10%以下，此顯示本設計之微電腦式施藥量控制系統甚爲有效。



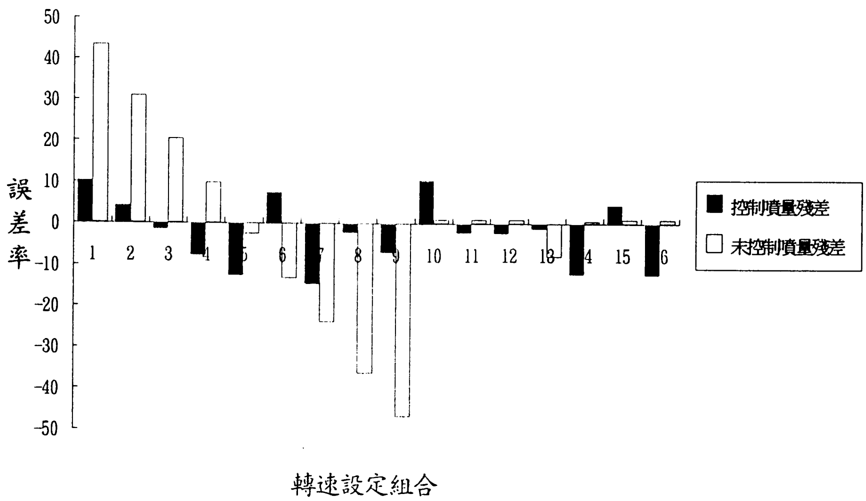

圖一　實驗裝置示意圖




圖二　控制流程方塊圖




圖三　回流壓力設定為10PSI下控制範圍內控制閥開度和各流量變化比較圖




圖四　控制噴量設定值差與未經控制噴量設定值差異比較圖

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# 氣輔式施藥機械之研究

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## 摘　　要

一般傳統噴藥防治病蟲害除了受天氣因素（如風速、氣流）影響之外，在合於作業條件下施藥仍有以下幾個問題必需注意：一為霧粒飄移情形，二為葉背附著效果不佳。前者除了浪費農藥之外，尚有波及臨近作物及人、畜之虞。而後者則使得病蟲害不易根除，繁殖迅速，必須時常噴藥，不但浪費金錢時間而且又造成環境污染，增加社會成本。氣輔式噴藥因有強力氣流的導引，除了大量降低飄移情形外，亦能提高葉背藥液附著度、增强防除效果。且因為有了氣流之輔助，亦提高了適宜施藥作業時間及藥液穿透株欉之能力，可謂病蟲害防治的較佳機具。

【關鍵詞】曳引機、氣體輔助、噴霧器

## 一、前　　言

本省地處亞熱帶，終年高溫多雨，雖適合作物的生長，但也是昆蟲及其它病菌的溫床。農民為確保辛勤耕耘的成果，作物的病蟲害防治實為不可缺少的一環。但是以往噴藥作業偏重於作物之保護與病蟲害之防治，農民已習慣於使用大量之農藥，不但增加農業生產成本，且對生態環境造成極大之衝擊。在將邁入已開發國家行列之今日，農業不僅要提供國民基本之糧食，同時還需兼顧生存環境之永續維護。因此，兼顧環境與農業發展需求之自動化施藥機械與技術，實為當前我國農業發展不可輕忽之重要事項。目前歐美等已開發國家在此一方面之研究，均較國內先進，並且已有可觀而顯著之成果可資應用，如何將彼等開發成功之具體成果，引進供國內使用與參考，並進一步促使該種技術落實於國內，促進我國施用農藥自動化、環保化，進而早日解決國內之施藥問題，實為當務之急。

依據行政院農業委員會農漁牧產業自動化八十一年度人才培育計畫有關研習自動化病蟲害防治技術之出國報告指出，氣輔噴霧可減低施藥量並增加藥液葉背附著效果，建議引進該施藥設備與技術，進行試用與推廣評估，以提升國內噴桿式噴霧之噴藥品質。

## 二、噴霧機功能與規格

### ㈠規格

本試驗所使用之曳引機承載式氣體輔助噴霧器為【Hardi 361-LA-1200-DPA-12-HAB】型，其規格如下：

⑴噴霧器承架使用被覆多元脂之金屬材料，以防護農藥與日曬之侵蝕。具動力傳動軸，且有快速聯結之設計。

⑵1,200公升防撞聚乙稀藥液桶具容量刻畫與螺旋箱蓋。

⑶噴藥系統使用膜片式幫浦，出水量達167L/min，最大壓力可達15bar，具自清式過濾系統且在「吸水處、自我濾清器及噴頭處」有三道過濾器。使用可任意選擇一個噴頭位置「含三組噴頭」之三噴頭承座，可依需要快速旋轉改變使用之噴頭以加快其更換速度，並具防滴漏設計。

⑷作業單元使用電動控制閥，可於定壓下整體或個別開、關各噴桿之噴頭作業，且可於駕駛座內控制壓力調整。

⑸具施藥量自動控制系統，可監測與顯示前進速度、施藥作業、已施藥面積、藥液總施用量、施藥率與差異百分比、噴灑寬度以及作業時間等，並依前進速度自動控制施藥量。

⑹噴桿寬度12米，高度40～220㎝，其舉升、下降、折疊、噴頭、噴氣角度與噴桿傾斜之梯形懸吊系統均可由駕駛室內之油壓直接遙控。其中梯形懸吊系統可使噴桿穩定，噴頭與噴氣氣流間之角度可調整達±30度。

⑺聚乙稀氣囊可使整個噴桿具均勻之空氣速度與分佈，其外翼具彈簧彈跳之安全設計；而輔助空氣之供應使用油壓驅動之軸流風扇，可於0~3000rpm間作無段調整，風速爲0~30m/s，每公尺長度噴桿風量爲0~1500$m^3$/hr。

⑻含獨立之液壓油箱與液壓幫浦，需要23Hp之曳引機PTO功率。

⑼另含清水桶、加藥桶、泡沫標示器、加水器、噴霧槍、壓力錶、400公升前置藥液桶以及聯結曳引機PTO軸之快速接頭零件。

⑽施藥量可調整於40L/ha～1000L/ha間。

## ㈡功能

所謂氣輔噴霧乃使用傳統噴霧系統以製造霧粒，再以風扇及空氣袋製造平穩氣流配合空心錐型噴頭或扇形噴頭使用。當霧粒被導引碰撞向下之氣流時，所需之噴霧型態即於噴桿下方形成，然後氣流即攜帶霧粒將之導入作物叢中。由於霧粒被氣流攜帶較不易被風吹走，因此此種噴霧機械必然可減低飄移作用，且可在比傳統噴頭更少飄移的情形下進行低施藥量之施噴。

## ㈢氣體輔助噴霧之優點有

(1)可充份控制空氣流量以配合作物與施行噴藥之狀況。
(2)由於氣流之導引可增加霧粒穿透株間之效果。
(3)由於氣流之翻攪可提高葉背藥液附著度。
(4)降低對天氣之依賴。
(5)不易受風影響，可提高田間工作效率100～150％。
(6)可減少霧粒飄移50～90％。
(7)較俱有減低施藥量之可能性。

＊HARDI TWIN SYSTEM 之主要機件：

1. 軸流風扇：軸流風扇吹出的空氣速度及體積可無限段調整以得到最佳防治效果。
2. 空氣導槽：噴頭及空氣導槽之夾角可由液壓調整±30°，此方式可在各種作物條件及風速

條件下保持最大穿透植物叢之能力及最多農藥附著度。

3. 膜片式幫浦：本幫浦針對農業上應用之植保化學藥物及液體肥料而發展。且本膜片式幫浦設計成可於無液體情形下操作運轉而不會損壞。藥液幫浦之標準配備爲HARDI 361型，容量爲167公升/分；最大壓力爲15bar（$kg/cm^2$）。
4. 自清式過濾器：爲Hardi Twin system之標準配備，可降低費時的噴頭阻塞及過慮器清洗的問題。
5. 三頭噴頭座：噴頭及座含下列各組件

   膜片阻水閥－－防止未被選用者滴水

   內藏濾網－－易清洗

   旋轉定位式選擇噴頭－－不同工作需要時易於變換
6. EC控制組：控制

   主開關的開或閉（on/off）

   各個分枝噴桿的啓閉

   自動調整噴桿壓力

   上述功能均於駕駛座旁之控制盒設定且是標準配備

## 三、結果與討論

噴霧時，較小的霧粒因可函蓋較大部份的植株表面且較易附著，尤其是在植株的垂直部份，可說是其優點。傳統的方式應用較小霧粒（通常與水量較少相關）可推論出較多的霧粒飄移及有限的穿透植株叢能力。TWIN SYSTEM 是爲較小霧粒噴霧而設計但不會增加上述之危險性。增加霧粒速度亦能提高穿透（penetration）能力。增加霧粒速度在減低水量噴藥時非常重要，因爲此種條件下會產生許多能量較低而又對飄移現象十分敏感的小霧粒。由其試驗結果可知，氣輔氣流顯著地增加粒徑 200 $\mu$m ($10^{-6}$ m) 以下，對自然風速十分敏感的霧粒之速度，氣輔氣流亦相當地提高中等霧粒之速度，而最大霧粒則受氣輔氣流的影響較少。本特點可解釋TWIN SYSTEM在田間施藥時能降低飄移作用之能力。

### 霧粒軌跡（Droplet trajectories）：

當高速的霧粒從噴嘴噴出後，有氣輔與無氣輔之軌跡差異頗大；TWIN SYSTEM控制霧粒軌跡並從各方向翻動植株，植株的頂冠像濾網般收集霧粒，使極少量到達地面。

### 飄移現象測試

許多次試驗結果證實使用TWIN SYSTEM確能較傳統方式有效減低飄移現象。依作物及噴灑技術之不同，飄移現象約降低 50%至 90%之間。

在有氣輔及無氣輔情形下，使用4110-14噴頭以2.0bar壓力在噴頭下方40公分處所測得之霧粒速度，可看出使用氣輔者，直徑200微米以下之霧粒速度較對照者高出許多，亦即對風較不敏感。

在2.0 bar 噴霧壓力及使用4110-14噴頭條件時，傳統噴霧在風速2m/s情形下，於噴頭下方40 cm處測得直徑150微米以下之霧粒幾近於0%，這些微粒被風吹走了。而使用TWIN SYSTEM，在風速2m/s之相同條件時，其測得之微粒數與無風狀態測定時幾乎相同。

以4110-20，4110-12及Lodrift-04等三種噴頭配合氣輔或無氣輔噴灑大麥田做霧粒飄移情形試

驗。結果顯示在均不使用氣輔情形下，4110-12噴頭之飄移量爲4110-20噴頭之2.7倍；且不論使用何種噴頭，仍以配用氣輔噴霧者飄移情形最少，故氣輔噴霧可依農藥條件施藥而仍保持最大工作效率及作物安全。

傳統噴藥法，作業速度在8km/hr以下，受速度影響之飄移情形不顯著，而作業速度在10km/hr以上時，則較明顯。而TWIN SYSTEM則能將飄移維持在較低程度。一般而言，傳統噴藥法在風速達4~5m/s時（在離地2m處量測）即不適宜噴藥作業，故而對防治時效較難以掌握，氣輔式能克服此缺陷。

### 噴藥效果探討

以100L/ha（全劑量）及50L/ha（半劑量）殺草劑噴灑甜菜田做雜草控制試驗，將相同面積內收集之雜草生物量做爲計算效果之指標，不論是全劑量或是半劑量噴灑，均以Twin System控制雜草效果最好，而且使用Twin System噴灑半劑量殺草劑比傳統噴藥法或Lodrift噴頭噴灑全劑量殺草劑效果更佳。

### 作物附著藥液情形

假如整株作物的表面都附著藥液，則防治效果將更加良好。一般施藥時，作物頂端附著情形都不成問題，假如需於密集植株底部提高附著度，傳統噴藥法以增加單位面積用藥量及減低作業速度爲之，此法之缺點則爲大量藥物將噴向地面以及使用較多時間噴藥，尤其當施藥田區與補充水源處相距較遠時費時更多，而氣輔則可提高作物底部及垂直部份之藥液附著情形。

如前所述，吾人可用氣輔原理將部份較小之霧粒導入植株叢中。亦可同時改變植株之垂直部份（莖）與水平部份（葉）藥霧附著比值。一般施藥情形下，植株之垂直部份附著較少量藥霧而水平部份附著較多藥霧；而氣輔則能增加在垂直部份藥霧之附著比。

## 四、結　論

過去十年之間，許多人努力在改良農用殺蟲劑之施用法。特別是下列的四個範圍更受到關注：

1.由應用較低的單位面積劑量（公升/公頃）以改良田間工作速率。

2.於密集作物叢中增加穿透量（penetration）。

3.於標的位置上增加附著度之較佳控制。

4.減低飄移情形。

噴霧器製造公司引用新的噴藥系統以符合上述的一或多個要求。但是有些系統只符合第一個要求，卻犧牲了第四項—即反而增加霧粒飄移。HARDI TWIN SYSTEM符合上述的四項要求而又能保有傳統田區噴藥機器已被公認之優點—即保有容易校正與操縱之優點，且經試驗證明在有風及無風情形下，均能提高葉背部份之藥液附著度，而在有風時此效果更爲顯著。但本省因人口密度高、農田較接近農舍之故沒有生產低倍率高濃度之農藥，因此將降低Twin System原先設計的較低單位面積劑量之優點。

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# 高架式施藥機械

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## 摘　　要

由於HAGIE 280型自動噴霧機具有自動監控之作業功能，對使用者與環境提供了良好之保護效果，在本省具有開發之潛力。使用該機進行作物病蟲防治作業，除可獲致降低農藥中毒、解決僱工困難等無形效益外，並具有提高作業效率與降低作業成本之實質有形效益。本噴霧機作業時受本省農田小區劃之影響，以單一行程30％之淨作業效率確有偏低之趨勢；為有效提高作業效率，應合理改變農田之長寬比，或者改變農民對新施藥技術造成作物損傷之顧忌，以便採用枕地轉彎之作業方式，期能發揮本機之固有作業性能。

【關鍵詞】高架、施藥、機械。

## 一、前　　言

本省農作物之病害防治作業，農民一向偏重藥劑之使用，常在不知不覺中養成過量用藥之習慣，不但徒然增加農業生產成本，且對生態環境造成極大之危害。在世界地球村之觀念逐漸獲得共識與重視之際，農業不再單純為提供人類基本之糧食負責，同時還需在環境保育方面發揮其獨特功能與貢獻，今後農業發展必需兼顧生存環境之永續維護。為發展兼顧環境與農業發展需求之施藥機械與技術，唯有仰賴現代自動化科技之支援。目前歐美等已開發國家在此一方面之研究，均較國內先進，並已有可觀而顯著之成果可資應用，如何將渠等開發成功之具體成果，援引供國內使用與參考，並進一步促使該技術落實於國內，加强具有環保意識之各種作業技術之開發，促進我國農藥施用自動化，進而早日解決國內之施藥問題，實為目前當務之急。再者，由於過去國內對農作物病蟲害防治作業機械與技術之發展，一向偏重於園藝果樹類，對水稻、旱作與蔬菜等則疏於顧及；導致該類作物病蟲害防治作業費用偏高，且遭致僱工困難之瓶頸；職是之故，該三類作物防治用之自動化作業機械亟待開發，以降低生產成本。為了減少作業者在以傳統作業方式進行農作物病蟲害防治時，因疏忽所導致之農藥中毒事例及確保環境不受農藥之過度污染，與適時適量進行農作物病蟲害防治作業，提供適當之作業設施或機具，於民國八十年自美國引進HAGIE 280型高架式自動噴霧機壹套，田間試用觀察結果顯示，以其懸空之大離地面高與自動控制施藥之作業設計特性，可解決本省高、低莖作物之噴藥作業瓶頸，提高作業品質、增進農藥使用之安全。

## 二、試驗設備與方法

㈠試驗設備

1.HAGIE280型高架式自動噴霧機、各型噴頭及配件。

2.飼料用玉米、高粱、花生及蔬菜等作物。

(二)研究方法

1.於田間作業與觀察，分析該機組件對本省作物栽培模式之適用性。

2.適度調整機件組合與修正。

3.調查田間作業經濟效益分析。

# 三、結果與討論

(一)HAGIE280型高架式自動噴霧機之主要配備說明：

本型噴霧機採用六缸、增壓渦輪、106 馬力柴油引擎爲作業動力，其傳動系統應用全油壓二輪或四輪靜液壓傳動；主機架之離地高距爲1680公厘，輪距可由1820MM至3175MM任意調整、軸距2692公厘、不含懸臂之全長爲5486公厘、全高3390公厘與全寬3860公厘。本機所使用之油壓系統爲中位開放、齒輪式，油壓系統壓力爲每平方吋1850磅。噴藥系統包涵1500公升藥液箱二只、油壓機械攪拌及離心自吸式抽水泵、三(五)節噴霧懸臂，以監控器直接控制噴藥作業。農藥原液之控制採直接注入線上混合之作業方式，使用兩只容量56公升之原液桶，兩種不同之農藥可同時使用或單獨使用，其使用量由監控器以預設值隨車速自動調整之。噴霧懸臂由油壓舉升、折疊或作水平位置調整，其標準設計爲三節，本機因應試驗需要改爲五節之設計，展開後之涵蓋寬度爲1830公分，噴頭規格可因作業需要調整更換。本型噴霧機之另一特殊設計爲採用密閉式駕駛室，使用活性炭過濾與空調設備，操作者在作業中無農藥污染之虞。爲減少操作者辨識困難與作業負荷，可增加噴藥標示器、噴頭作業監控裝置等附屬配備，協助操作者確認施藥狀態，減少失誤與重復施藥之機率，適時發現噴頭積堵情形並排除，以提高作業效率。

(二)田間施藥作業：

本機在已實施農地重劃之農場作業時，正常之作業速度爲每小時三公里，避免高速前進作業時，因田面平整變化導致懸臂過度振動，影響作業精度。主控器經依序進行相關校準與調整等使用前準備作業後，進行田間試驗與調查作業。由於本省農家之農田面積與規劃均較狹小，且田區兩頭分別爲給、排水設施，對大型機械作業相當不利，故本機在田間作業時，對枕地之處理可視操作者與現場之條件限制，以枕地迴轉換向或前進施藥倒車返回之單向作業方式來完成。

1.懸臂之作業及噴頭之選用：

本機之懸臂可藉油壓折疊與調整作業之高度或傾斜度，作業時可配合不同型式噴頭之使用，及田區形狀之變化，由操作者適時調整之。作業時懸臂節間之噴頭，其出水分別由制水電磁閥管制，數只噴頭共用一只制水閥，當田區周緣發生畸零現像時或田區中部份無需施藥時，涵蓋該區域之噴頭可經由主控器作選擇性之暫時性關閉，以達成因地制宜之作業效果。

進口之TEEJET噴頭除標準型式外，尙有特殊之附屬裝置，諸如可調整施藥角度者、或多頭並列型者及附加下垂裝置等。配合施藥涵蓋面與懸臂高度之調整，在每平方吋40磅之作業壓力下進行噴施作業，其作業狀況由於與國人習用之噴藥作業迴異，國人對其作業效果存有疑慮，此爲農民有待再教育之處。爲暫時克服農民之傳統習性與疑慮之心理障礙，以國產噴頭取代進口噴頭作業時，經測定發現各噴頭間出水量之個別誤差高達百分之廿五，這一項

事實顯示國產噴頭之規格品質有待商榷與改良；因此，若以國產噴頭代用時，各噴頭應嚴格進行校正作業，以確保施藥量之均勻性與可信度。

2.主監控器及其作業：

主監控器爲本機自動化作業之控制中樞，可分別設定農藥原液混合比，並依據所用之噴頭規格、作業壓力與農藥之單位面積額定使用量，規劃、設定單位積之施藥量，紀錄與顯示單位時間作業面積、累計作業面積及原液桶殘藥量等等功能；同時藉電磁閥之動作，對每節噴霧懸臂之噴頭進行噴霧作業之管制，以因應田區形狀變化之需求。

3.噴霧標示器及其作業：

噴霧涵蓋標示器配置於懸臂之兩外側，以無毒之白色泡沫在作業之同時噴撒在田間或作物頂部，輔助操作者辨識噴藥作業之即時狀況，避免重復施噴浪費資源或造成額外之環境污染。標示器爲選購配備，使用者可依作業需要自行斟酌選購；該器以控制訊號與主控器連接，操作者藉主控器以遙控方式達成開啓與切離之控制作業。

4.噴頭監控器及其作業：

爲將噴頭之作業現況，隨時提供操作者作爲進行檢修噴頭之依據，本機配置之噴頭監控器利用警示訊號，可即時提醒操作者檢修故障之噴頭。當噴頭阻塞時，噴頭監控器之掃瞄光點即停止不動，而以閃動之光點，將故障位置以數位顯示，以指出故障之確切位置以便檢修。

5.在本省栽培飼料玉米與高粱田區之實際作業：

飼料玉米與高粱同屬高莖之旱作物，其生產過程中之病蟲害防治作業，以生長之中後期作業較爲困難；初、中期之噴藥作業，可藉噴霧懸臂位置控制系統調整適當之作業度，至於中、後期噴藥作業時，懸臂系統必需提高以預留足夠之空間，以免傷及作物，同時爲了提高噴藥附著度，在本階段作業用之噴頭必需以下垂連接管與懸臂架連結組合應用，以使噴頭沉懸於作物之冠下，俾農藥附著於相關之葉背，提高作業效果。該連結用下垂管可在國內自行製造，亦可直接自國外購用，該連結管備有各種不同規格，供不同作業時之組合與應用，使用者同時可選購各種噴藥方向可調整之噴頭配合使用，更可發揮本機之作業效果。

6.田間作業效益：

使用本型噴霧機進行作物病蟲害防治作業之效益可分爲有形與無形效益兩種，其中對作業環境之改善、減少環境污染、降低中毒機率確保社會人力資源等均可視爲無形之效益；因利用本型噴霧機作業所節省之作業費用與增加之收益則爲有形之效益。對無形效益而言，因不易查覺，一般較會爲人所忽視，至於有形效益，因利之所在，則爲使用者所矚目與關心。

就有形之效益而論，機械在單位時間內之有效作業面積及其使用成本應爲首要項目；由於本省農田坵塊面積小，規劃時使用小長寬比，對大型機械作業至爲不利，同時由於未規劃、採行合理之栽培區，導致坵塊分散，無形中降低有效作業效率至鉅。以當前之田區規劃與作業方式分析，噴霧機以每小時三公里之理論作業速度進行噴藥作業時，以其18.3公尺噴霧涵蓋面爲全部有效單程作業積計算，每小時之理論作業面積爲5.49公頃，但據田間試驗觀察，實際作業效率與理論值存在著相當大之差異。以本省之田區規劃現況，田區長度以120公尺計算，對玉米之施藥而言，七十公畝之田區需以三個噴藥行程方能完成；若以農路爲迴轉換行用枕地時，需費時24.6分；其中轉彎作業時間爲9.8分鐘，實際噴藥作業時間爲7.6 分鐘，進出田區作業時間爲4.7分鐘，單程退回作業時間爲2.5分鐘；以實際施藥行程時間計算時，得淨

工作效率爲30.9％；若以高粱田之施藥作業而言，以玉米施藥相同之方式進行時，在0.66公頃之田區，計需費時約25.3分；其中轉彎作業時間爲11.3分鐘，實際噴藥作業時間爲7.5分鐘，進出田區作業時間爲3.5分鐘，單程退回作業時間爲3.0分鐘，換算田間淨作業效率得29.6％，兩作物之枕地轉彎時間佔總作業時間之42.3％。因此，若要提高淨作業效率，可分別由擴大田區規劃之長寬比，以減少枕地轉彎次數；或遷就目前之規劃模式，以在兩端枕地轉彎換向進行作業。兩者之間，以擴大長寬比所得之效益較爲顯著，但困難與阻力亦最大。

7.使用成本與經濟分析：

(1)使用成本[2,3]

HAGIE280型高架式自動噴霧機用於一般旱作之病蟲害防治作業，其單位時間內有效作業能量直接影響本機之使用成本；以本省農田規劃現況而論，若採用在田間枕地迴轉之作業方式，以每小時三公里之額定作業速度作業時，每公頃約需卅分鐘之作業時間，與理論作業量相較，作業效率爲40％。以傳統人工之玉米病蟲害防治作業爲例，平均每期作之防治作業爲三次，需24人工小時(每次作業時間分別爲4、8、12小時)，每日以工作六小時計算；每日之噴藥工資爲1600元，折合每公頃之作業工資估算爲6400元，以每公頃6000公斤產量計，合計產值約爲79,000元，則該防治作業費用約佔總產值之8.1％；對高粱之人工病蟲害防治之成本調查指出，每期作同樣實施防治三次，每公頃所費人工亦以24人工小時計算，每公頃需支出工資6400元，每公頃高粱之產量以5000公斤，估計產值爲70,000元，則防治作業費用約佔總產值之9.1％；低莖作物以落花生之栽培爲例，每期作需進行防治作業五次，合計需使用四十工時，折合工支資出爲10,666元，如每公頃落花生總產量以3500公斤估計時，合計產值約爲140,000元，則防治作業費用約佔總產值之7.6％；再以蔬菜每公頃之病蟲害防治成本來分析，每期人工施藥五次，平均80人工小時，每日工作六小時，每公頃折合支出工資21,300元。前述病蟲害防治作業如以HAGIE280型自動噴霧機取代人工作業時，每小時有效作業面積以二公頃計算，本機之作業由操作人員與助手一人合作完成，折合每公頃需使用一人工小時；對前述四類作物而言，每期作每公頃所需作業工時分別爲玉米三人工小時、高粱三人工小時、落花生五人工小時及蔬菜五人工小時，作業速度分別爲人工施藥之8倍、8倍、8倍、及16倍。本型噴藥機每小時需使用燃料十五公升，購置費新台幣2800000元，估計使用十年，每年使用600小時。各項固定費用之計算標準分別爲：折舊費爲購置費之10％、利息則以農機貸款之年息5.5％計算、維護費按則購置費之50％予以估算；變動費用中之所有油料費，以每小時耗用燃料費之1.3倍計算，操作人員及運送供水助手之工資以每日1600元之1.5倍給付，估算每小時之使用成本，合計本型噴霧機每小時之總作業成本爲新台幣1467元，對玉米、高粱、落花生與蔬菜等作物每公頃每期作之施藥作業成本分別爲4400元、4400元、7340元及7340元，與人工作業成本對照時，分別可節省2000元、2000元、3330元及13960元等之有形成本。

(2)對作物損害之調查分析：

以玉米爲例，在長120之田區枕地轉彎作業時，每一轉彎行程受損玉米植株爲210株，以現行75 x 25公分之推廣栽培行株距計算，每公頃之栽培株數爲53,300株，單位面積產量若以6000公斤爲準，則每株產量應爲0.113公斤，則受損植株所減產之玉米應爲23.7公斤，總產值爲312元折合每公頃減產742元，佔總產值之0.94％，應可略去不計；何況，適時之

施藥所產生之保護效益遠比該項損失爲大，無形社會成本之效益尚未計入，本項損失可藉增加田區長寬比予以縮小。其他再生性不佳之作物，作業方式仍可比照玉米之作業以爲之，農民在使用初期或有煩言，但在習慣後對本作業方式應可接受乃無庸置疑。

## 四、檢討與建議

以高架式自動噴霧機取代本省現行之作物病蟲害防治作業方式與機具，除可獲致降低無形之社會成本外，有形之實質經濟效益受田區規劃長寬比之影響，若能加大該長寬比值，減少作業中之轉彎次數，則在每小時三公里之最適額定作業速度下，田間作業效率仍可大幅提高；唯因受限於既有環境，補救之道爲集團栽培，以減少作業時道路移動所浪費之作業時間。對原型機而言，本省現行之栽培行型，由於該機之輪距爲可調式，在使用上並未受到限制；枕地作業時，如採用田間轉彎之作業方式，則可增加作業效率，對作物之損害，因作業時循相同之輪跡前進，故總損失不會每次累加，應可忽略不計。作業時水源補充速度直接影響單位時間之作業能量，因之，在無貯水供應之田間作業狀況下，必需準備專用水車供水。本機作業時使用之壓力爲每平方吋四十磅，約爲每平方公分三公斤，遠低於國人現行使用機型之壓力，故農藥之漂移污染低，應爲不爭之事實，其對環境之保護應值得吾人重視。在應用本機作業時，如欲以國產噴頭取代進口產品，由於國產品品質無法達齊一之規格，故在使用前應按技術資料，進行嚴格校正作業。爲提高葉背之藥液附著度，對高莖作物施藥時，建議採用下垂式連結管裝置可調角度之噴頭，以獲得較佳之作業效果，同時該下垂噴管之設置應每以每行間裝置爲宜，則其作業效果遠超過傳統之平面施噴。爲因應本省小田區作業需要，提高作業效率，應以進口機型之設計，配合本省農場現況，並應用輔助氣流之設計[(1)]，將本型機之設計優點予以國產化，以落實引進新技術之目標。

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# 設施內自動化施藥技術的研究

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## 摘　　要

近年來隨著教育之普及與進步，農民普遍的瞭解到噴藥作業的危險性，尤其在設施中施藥，操作者必須直接面對藥劑之傷害。有鑑於此，本場自民國80年起即進行設施內自走式噴藥裝置之研究，至目前共完成三種型式之噴藥裝置。第一型於民國八十一年完成，用於簡易鍍管塑膠布溫室花卉扦插苗之噴水灌溉作業，噴藥架採用雙鋼索承載，控制系統爲單棟控制，使用時操作者需逐棟操作。第二型用於半永久性鋼架溫室，爲全自動控制系統，操作者僅需於中央控制機房選定欲噴藥之溫室及噴藥模式即可自動完成噴藥作業並可發出警告訊號，通知作業人員離開該區域，並可進行自我偵測以避免誤動作而危及設備安全，各分控箱亦可於現場進行單獨之手動控制。目前應用於玫瑰花之病蟲害防治。第三型噴藥架採用懸吊鍍管承載，其噴頭爲噴水與噴藥兩種並列，噴頭可任意選擇並調整位置，控制系統採三棟溫室共用一個控制箱，操作時需逐一選擇所要進行作業之溫室，目前應用於蔬菜與花卉之育苗與管理。

## 一、前　　言

近年來由於經濟環境快速改善，民眾消費水準提高，對農產品的需求已逐漸著重於質的提昇，生產者爲克服自然環境之障礙，改善其產品品質，紛紛改用設施栽培，尤其是花卉栽培與種苗生產業者最爲普遍，其結構從昂貴的玻璃溫室至隧道簡易設施，種類繁多，但基本上均是爲作物營造適當的生長空間，並隔離病蟲害，但是當病媒一旦進入設施內時，設施亦同樣成爲病媒良好的生長環境，設施內一旦發生病蟲害則蔓延迅速，若未能適時有效防治，後果難以想像。因此病蟲害之管理益形重要，但隨著教育之普及與進步，農民普遍的瞭解到噴藥作業的危險，在一般開放環境中尚可藉由大氣環境之稀釋作用，減低藥劑對人體之危害，但在設施中則必須直接面對藥劑之污染，因此經常面臨無工可雇之困境，自動化噴藥將操作者與藥劑隔離，成爲最有效之解決方式之一。有鑑於此，本場自民國八十年起即進行設施內自走式噴藥裝置研究，於民國八十一年發表第一套簡易設施內噴藥裝置，並繼續研發改進，根據不同之溫室結構與作業項目，共完成三種型式之噴藥裝置供不同之業者使用，並獲致相當之成效。

**設施內自走式自動噴霧裝置之開發：**

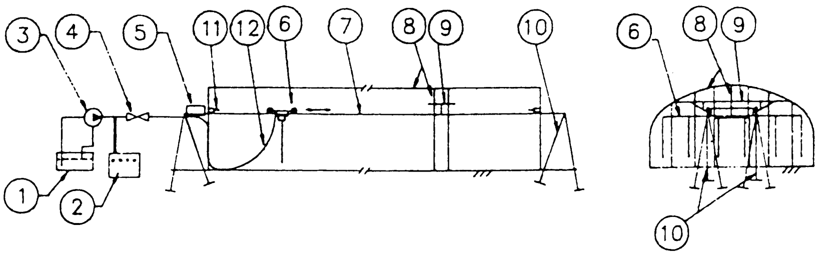
本自動施藥設備概略分類爲硬體組件和控制軟體二大類，包括軌道、噴霧行走架、噴頭、管線組件、行走驅動組件、和裝設在設施之外供給藥液的加壓幫浦、藥桶及自動控制用之信號輸出、入組件，諸如藥液管路壓力開關、液位感知器、極限開關等。控制軟體方面，利用電氣順序控制

的程序規劃，使噴霧裝置能自動依序操作，發揮其功能，而電氣順序控制的自動化程度可採人工半自動操作或全自動定時作業。當在同一田區有多棟連棟溫室，每棟架設一組自動噴霧裝置，其控制規劃可依經營者之作業需求，進行各棟獨立人工個別操作使用，或多棟連線自動控制，其間最大差異是投資成本不同，操作使用便利性亦隨之不同。

目前本場共開發完成三種型式，其主要差別在於噴藥架之懸掛、構造方式與自動化控制程度，噴藥架行走方式均採用定置馬達驅動絞盤，再用細鋼索牽引噴藥架方式。今將三種形式結構分述如下。

## 一、雙鋼索承載型：

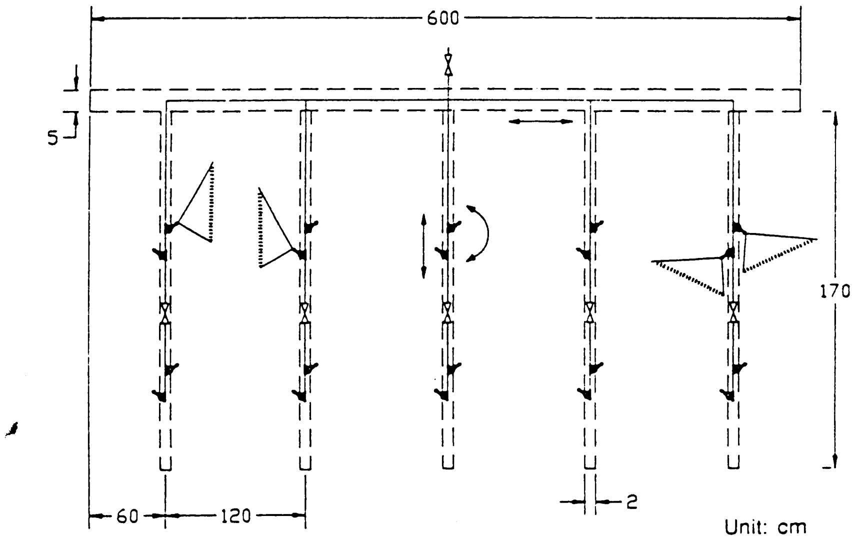
雙鋼索承載型是以國內廣泛應用之簡易鍍鋅鋞管塑膠布溫室爲主要應用對象，構造最簡單，架設容易，每套設備造價約五萬元左右。設備裝設步驟及各部示意如圖一，噴藥系統由鋼索軌道、行走架、噴霧架和電氣控制裝置等下列六大部份組合而成：




| | | | | | |
|---|---|---|---|---|---|
| 1 | Tank | 5 | Driving set | 9 | Support frame |
| 2 | Control panel | 6 | Carrier | 10 | Cement post |
| 3 | Pump | 7 | Ropeway | 11 | Limit switch |
| 4 | Solenoid valve | 8 | Pipe frame | 12 | Liquid hose |

圖一、雙鋼索承載型自動噴藥裝置系統配置圖

1. 鋼索軌道：於設施縱向拉二條直徑8mm鋼索並以水泥樁及地牛支撐拉緊，做爲行走架行走之用，由於鋼索會因自重而下垂，故其間另以鋞管架支持鋼索軌道。
2. 行走架：由四只直徑5cm鐵輪以鋞管連接爲軸架，左右各二輪，行走於二條平行鋼索軌道上，驅動鋼索直徑2.5mm，連接於行走架中心點，牽引行走架行進。
3. 噴霧架：由一支斷面3×5cm，長6m槽狀鋁管水平掛於行走架，槽狀鋁管槽面向下，承裝5支斷面爲2×3cm，長170cm垂直槽狀鋁管。水平及垂直鋁管槽裏放置30組螺絲，以蝶形螺母鎖上，可調節垂直鋁管及噴頭裝設位置以適合不同畦距和植株高度之噴霧作業。噴霧架結構如圖二。
4. 行走驅動組：由一部DC 110V 1/4HP可逆轉馬達經皮帶傳動至絞盤軸上的絞盤，再經絞盤之正逆轉牽動迴繞其上的驅動鋼索達成驅動任務。
5. 電氣控制裝置：由裝置於設施二端的二只限動開關、控制面板上選擇按鈕，構成控制信號輸入部份，經由電氣控制箱之電路研判後再將信號輸出至高壓泵馬達、行走驅動馬達、電磁閥等。
6. 藥液輸送管路：由藥桶、高壓泵、電磁閥、高壓軟管等組成，將藥液送達噴霧架。




圖二、噴霧架構造示意圖

**二、唇槽鋼單軌懸吊型：**

唇槽鋼單軌懸吊型爲本場發展之第二代自動噴霧裝置，主要應用於力霸鋼架型溫室。一般而言力霸鋼架溫室設施結構完善，但其高度與跨距通常都較大，噴藥架加上管路及其他組件整體重量甚重，雙鋼索承載型無法有效承載，故改採唇槽鋼單軌懸吊，以改善雙鋼索承載型噴藥架行走時忽高忽低，以及鋼索平行度不佳時，噴藥架容易出軌之現象。

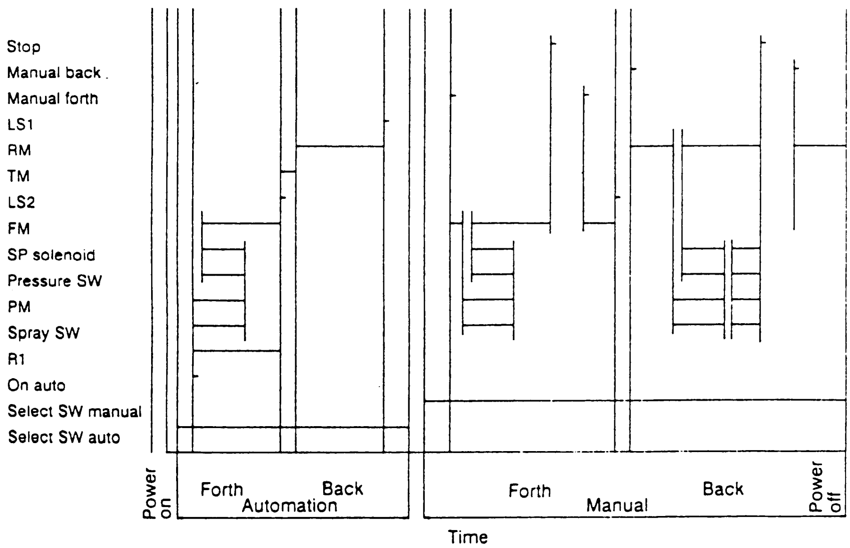
控制系統方面，每棟溫室設置子控箱一個，爲手動控制，另外視需求設置分控箱若干，目前每一分控箱可連接至多6棟溫室，分控箱再連結於中央機房之主控箱，成爲一全自動控制系統，操作者僅需於中央控制機房選定需要進行噴藥之溫室編號，以及噴藥模式即可藉由PLC之控制依序自動完成噴藥作業，作業進行中並可發出警告訊號，以警告現場作業人員離開該區域，噴藥設備並可進行自我偵測，以避免誤動作而危及設備安全，必要時各子控箱亦可於現場進行單獨之手動控制。

**三、鋞管單軌懸吊型：**

鋞管單軌懸吊型爲本場發展之第三代自動噴霧裝置，爲第一代雙鋼索承載型之改良型，主要在改進承載鋼索因自重下垂與鋼索平行度不佳之缺點，同時爲因應國內塑膠布鋞管溫室與植床寬度不一之狀況，並簡化施工程序，以降低設備成本，每一支下懸噴桿改採掛接式構造，施工時可依現場狀況隨時調整，下懸噴桿並具有高度調整功能。噴頭部份採噴水與噴藥用雙噴頭並列，並藉由手動閥門控制噴頭之動作；當本系統用於灌溉時，採用低壓噴霧，噴頭工作壓力爲3～5kg/cm$^2$，此時噴霧用噴頭關閉；當運用於噴藥作業時，藉由手動閥門之切換關閉噴水用噴頭，即可進行噴藥作業。噴藥架與藥液輸送管線均利用滑車掛載於中央鋞管上，此外中央鋞管亦可作爲以下之輕量輸送掛載，以爲溫室內小量搬運之用，使設施架構應用更具有彈性。

## 四、基本電氣控制電路設計：

基本電器控制順序流程圖如圖三，橫座標爲時間，縱座標爲擬採用之電氣元件，由圖中瞭解此一電氣系統須要那些元件，各個元件在何時要啓動，何時要關閉，同時對其他元件會產生何種效應，可據以設計電路和往後電路維護檢修之用。今以自動操作模式說明其功能：啓動電源(Power)後選擇自動操作(Select SW AUTO)及打開噴霧開關(Spray SW)，按下自動啓動按鈕(ON AUTO)，高壓動力噴霧機電源電磁開關(PM)接通便開始運轉，當噴霧壓力到達設定壓力時，壓力開關(Pressure SW ) 接通，噴霧電磁閥(SP Solenoide ) 自動開啓噴霧，前進電磁開關(FM)亦動作開始前進，此時前進且噴霧，若不噴則高壓動力噴霧機電源電磁開關(PM)不動作，動力噴霧機不運轉但噴架仍可繼續前進，當碰到限動開關後停留3秒，以保護驅動馬達，接著後退電磁開關(RM)動作，噴架空車不噴霧返回起點，完成一趟自動單程噴霧作業，另外亦可選擇雙程噴霧作業，也就是噴架在返回原點時繼續進行噴霧。除了自程序外，系統亦保留手動操作。




圖三、電氣控制順序流程圖

## 目前應用概況：

### 一、雙鋼索承載型：

雙鋼索承載型完成於民國81年，設置於彰化縣田中鎮大地農園，溫室爲簡易鍍管塑膠布溫室，噴藥架採用雙鋼索承載，目前共設置五套，主要運用於花卉扦插苗之噴水灌溉作業，平均每棟每日噴水6次，採用單棟控制。使用時操作者需逐棟操作。其溫室面積每棟.03公頃，若採人工噴灑每棟須時15分鐘，但採自走式自動噴灌作業每次1.5分鐘即可完成，約可節省工時10倍。

### 二、唇槽鋼單軌懸吊型：

唇槽鋼單軌懸吊型，應用於后里墩南農場玫瑰花班，爲力霸鋼架式溫室，總面積2.0公頃，溫

室分為A、B兩區，A區面積1.2公頃，設溫室17棟，B區面積0.8公頃，設溫室13棟，共裝設自動噴霧設備30套，主要運用於玫瑰花之噴藥作業。控制系統方面，每棟溫室設置子控箱一個，為手動控制，每五至六棟溫室連結設分控箱一個，分控箱再連結於中央機房之主控箱，成為一全自動控制系統，操作者於中央控制機房選定需要進行噴藥之溫室編號，並選擇單程或雙程之噴藥模式，按鈕起動後即可藉由PLC之控制依序自動完成全部噴藥作業，作業進行中主控箱面板上會同時以燈號顯示當時之作業狀況。

該場於民國83年底完成系統架設，以A區17棟溫室為例，在未導入本系統前，每次噴藥需一組三人進行作業，1.2公頃噴藥須16小時/人，每次噴藥均需抽調大部份人員，致使其它田間管理工作陷於停頓，使用自動噴藥系統後1.5小時/1人可完成棟噴藥作業，效率約為人工噴藥的倍，此外在使用自動噴藥系統時，工人僅需負責配藥及按鈕即可，操作者無需進入溫室之中，工作既安全又輕鬆，工人亦樂於從事噴藥工作，當有病蟲害發生時，更能在發生之初期能立即噴藥及早防治，使病蟲害防治效果更加，用水量上更從公升降至公升，每次噴藥可節省藥量50%。

**三、鍍管單軌懸吊型：**

鍍管單軌懸吊型目前設置於彰化縣員林鎮員林種苗場，其溫室為簡易鍍管塑膠布溫室共裝置套，主要用於蔬菜及花卉育苗之噴水與噴藥作業，自動控制部份採用三棟溫室共用一組控制箱，以節省成本，使用時操作者需先選定目標溫室並設定單程或雙程噴霧。

## 四、結果與討論

近年隨著經濟的快速發展，社會環保意識提高，對於農產品化學藥劑之使用十分敏感，而農業生產者在新一代專業農民加入與新知識、技術的普及下，也逐漸意識到噴藥作業的危險，但位處亞熱帶地區的台灣，高溫高濕的環境，使用藥劑防治病蟲害仍是必要的手段，以往噴藥作業是以確保其作物生產為主，對人及環境缺乏重視，以致經常有因使用農藥而受害者，如今農民意識覺醒，卻又面臨無工可僱之窘境，所以施藥時或以較高之濃度或以多種藥劑混和，以求一次解決，殊不知省工的背面卻又隱含著用藥過量、藥劑間之干涉作用以及抗藥性等等問題，設施中因屬封閉之環境，噴藥對人體危害更為直接，故使用無人化自動噴藥系統，將人與藥劑隔離，以避免受到傷害為最佳選擇。本場發展之三種型式設施自動化噴霧設備，其中雙鋼索承載型施工費用最低，但兩條承載鋼索必需維持平行，以免噴桿架掉落，再者鋼索亦會隨時間逐漸鬆弛，故使用者必需經常調整，以維持鋼索之平行度與鬆緊度。唇槽鋼單軌懸吊型及鍍管單軌懸吊型，因使用鋼軌單軌懸吊，故一經架設完成後即無需經常調整，另外亦無噴桿架掉落之顧慮。

國內設施栽培發展迅速，但個別農民間需求差異甚大，溫室建構業者依個別農戶需求而施工，溫室大小、材質、建構方式並無統一之標準，本場發展之三種型式設施自動化噴霧設備，其自動化程度與構建方式稍有差異，個別農友可根據本身之需求與經費預算進行選擇，以避免過度投資造成浪費，或者因陋就簡而無法達到預期之目標。

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# 果園管路自動化噴藥控制系統示範推廣

洪明治　欒家敏

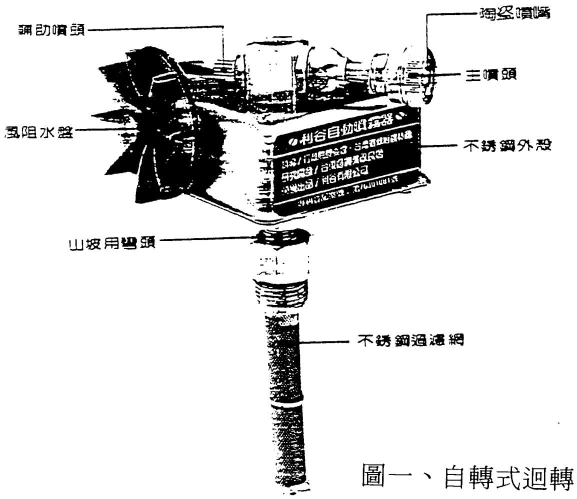
## 摘　　要

台灣地處亞熱帶，高溫多溼，農作物病蟲害繁殖極快，防治工作成為栽培農作物的重要作業，目前農村勞力不足，工資上揚，已使農藥撒佈作業成本大幅提高，臺灣的高接梨、芒果、蓮霧、葡萄與柑橘等水果於生長期間，皆需經噴灑農藥，以保持產品品質，若欲紓解噴藥人工不足，並預防農藥中毒事件發生，果樹管路自動化噴藥為可行之途徑，本場研發完成之自轉式迴轉噴頭，噴藥量少、霧粒小、噴霧有效距離遠、覆蓋率良好且轉速穩定極適用於果園管路自動化噴藥作業，配合配管模式與控制系統之研發，即能使作業更簡化、更安全，施藥更合理，發揮病害防治效果。

本省土地面積有限，果農常利用坡地種植柑橘與梨等經濟果樹，而坡地因受地形地勢限制，其病蟲害防治都以人力為主，加上目前農村人力老化與不足的現象日趨嚴重，坡地果園噴藥作業已面臨無工可僱的窘境，使用管路的自動化噴藥系統可解決這問題。管路自動化噴藥系統中大幅減少農民工作時數與工作負擔，並可改善作物品質，增加作物產量、減少農藥污染等，根據成本評估計算結果，裝設之管路自動化噴藥系統費用可在三至五年內回收，目前管路自動化噴藥設施推廣面積已達1800公頃以上，推廣面積全部集中於台灣西部主要果樹產區，而東部目前具經濟效益之果樹，高接梨及番荔枝也漸漸面臨人工噴藥無工可僱之窘境，果園管路自動化噴藥之利用可解決此困難。

## 一、前　　言

台灣地處亞熱帶，高溫多濕，農作物病蟲害繁殖極快，防治工作成為栽培農作物的重要作業，目前農村勞力不足，工資上揚，已使農藥撒佈作業成本大幅提高，臺灣的高接梨、芒果蓮霧、葡萄與柑橘等水果於生長期間，皆需經常噴灑農藥，以保持產品品質，若欲紓解噴藥人工不足，並預防農藥中毒事件發生，果樹管路自動化噴藥為可行之途徑，本場研發完成之噴頭(圖一)，噴藥量少、霧粒小、噴霧有效距離遠、覆蓋車良好且轉速穩定，極適用於果園管路自動化噴藥作業，若有良好配管模式與控制系統，即能發揮病蟲害防治效果，本研究之目的在規畫及建立果園管路自動化噴藥系統，使作業更簡化、更安全，施藥量更合理，以解決果農施藥及環境污染等問題。

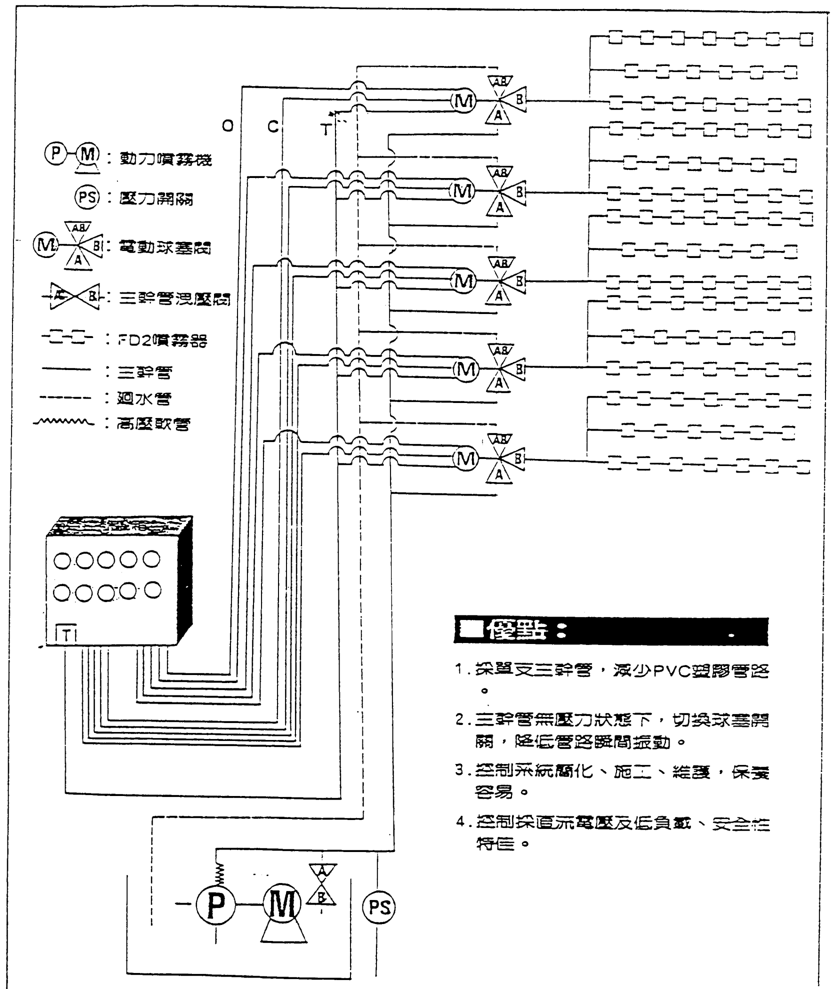



圖一、自轉式迴轉噴頭

| | |
|---|---|
| 重　　量 | 520 (G) |
| 本體尺寸 | 長7.2×寬7.2 ×高8.2(cm) |
| 斜坡調整 | 8°－25° |
| 噴射角度 | 主噴頭－30°～120° 輔助噴頭－180° |
| 散佈範圍 | 360° |
| 使用壓力 | 20kg |
| 噴 霧 量 | 5.5～10 L／分 |
| 噴霧直徑 | 8.5～10米 |
| 配管口徑 | 1／2吋 |
| 迴轉速度 | 20～25(秒／1迴轉) |

## 二、管路自動化噴藥系統

主要設備包括主機系統，控制系統、管路系統，控制室等詳如(圖二)



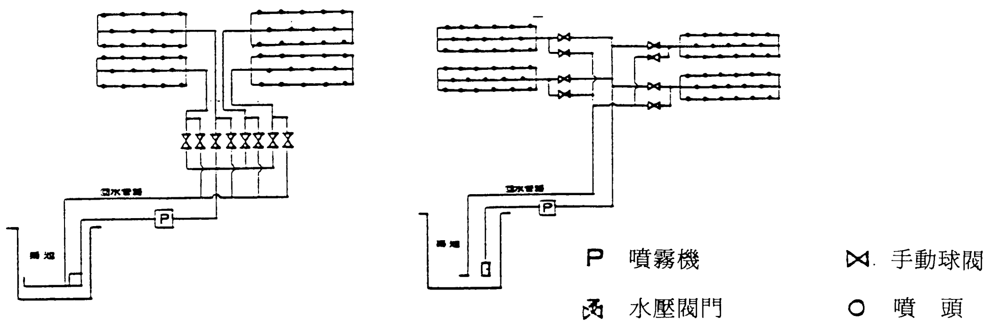

圖二、管路自動化噴藥控制系統配置圖

# 三、果園管路噴藥控制系統管路架設方式

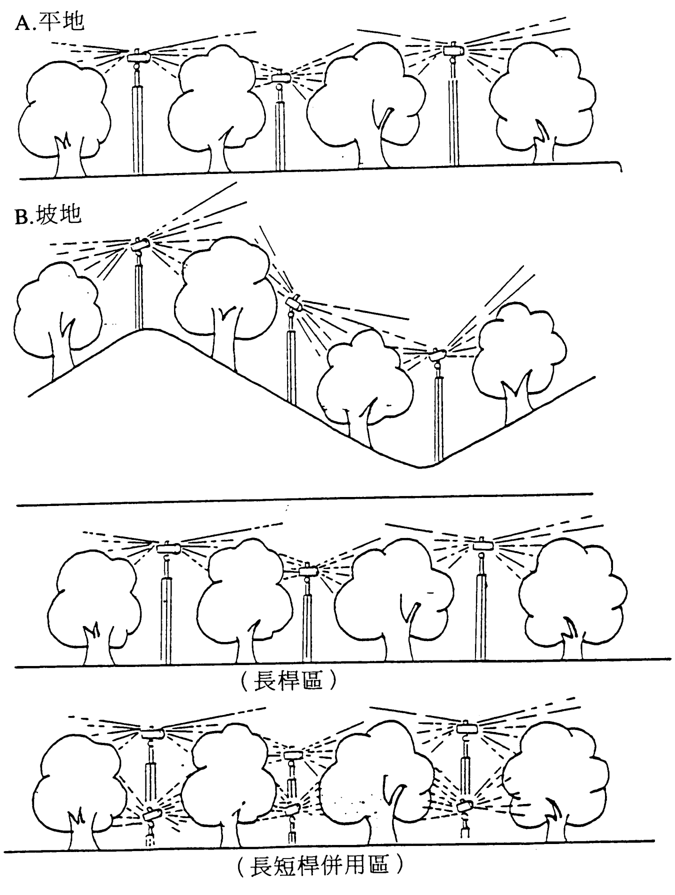
分集中式、散布式兩種(如圖三)。噴頭架設方式分平地、坡地、長桿及長短桿併用式( 如圖四)。

配管說明

集中操作(手動)　　散佈操作（自動）




圖三、果園管路自動控制系統架設方式




圖四、長桿及長短桿噴藥設施圖示

# 四、果園管路噴藥性能之測定

其測定項目計有使用壓力、藥液量、噴頭出水量、噴灑半徑、長桿及長短桿併用區葉表、葉背、果粒附著度測定等其測方法如下：

㈠壓力測定：

在每一測試區取下一只噴頭，裝上壓力錶並啓動高壓泵，以測定噴藥壓力。

㈡噴頭出水量測定：

利用自製之塑膠套袋，套住測定噴頭，經導管將水引入量筒啓動高壓泵一分鐘，以測定每支噴頭每分鐘出水量，以供單位面積噴藥量之參考。

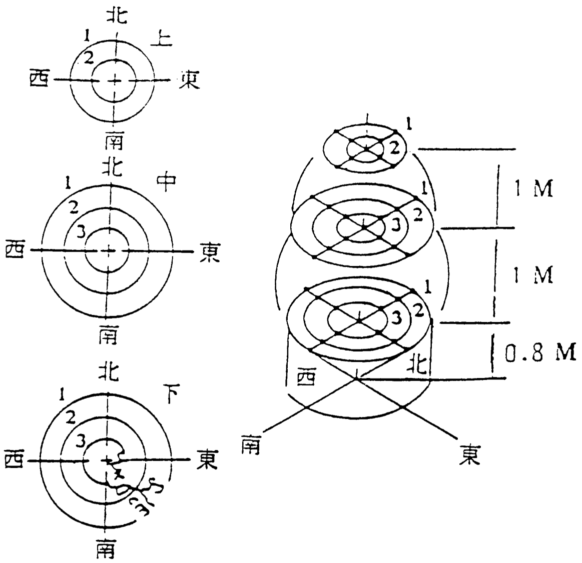
㈢噴灑半徑測定：

將噴頭固定於2公尺高之位置，並將培養皿依照噴頭噴霧方向每隔50公分擺一只，內置水試紙排成一直線，並啓動噴藥泵一分鐘，以測定噴灑半徑。

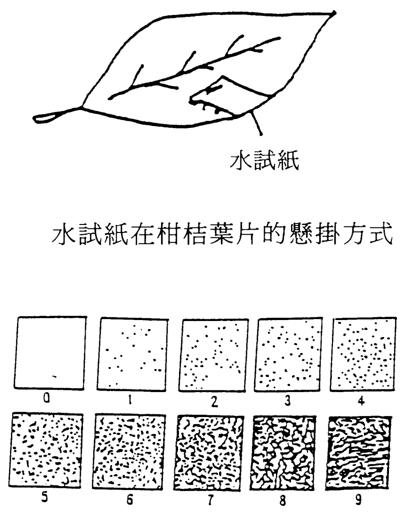
㈣葉表、葉背附著度測定：

將試水紙(76×26公厘)懸掛在柑桔樹之東、西、南、北、上、中、下等各方向之葉片(如圖五所示)，在自然風速1.0m/s以內的環境下，噴藥2～3分鐘(以每公頃4,000L爲依據計算噴藥時間)，並測定各點之葉表、葉背附著度(依圖六附著度評價表標準表評定)。

附著度評點標準參考日本大氏等於1966製作之高速噴霧機(Speed Spayer)標準表及共立用標準附著指數模式圖(1971)製作附著評點標準表如圖六，附著度評點標準表分成0～9共十個階段，依撒布藥液附著在水試紙上之狀態進行評價。

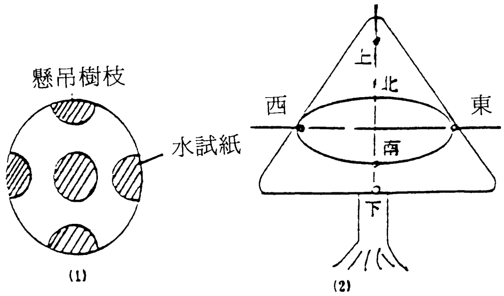



圖五、果樹冠內外懸掛水試紙分佈測定點




圖六、藥液附著度評價標準表

㈤果粒附著度測定其測定方法如圖七所示，利用乒乓球代替柑桔果實，在桌球之東、西、南、北、上、下等球面各貼上1cm$^2$之水試紙，並於果樹之東、西、南、北、上、下等各方向各懸掛吊一只球噴藥2～3分鐘，然後檢視球面水試紙反應，依附著度評價表，評定其等級，填入果實附著度測定表中平均而得之。




註圖(1)每粒桌球貼上1 $cm^2$ 之水試紙六只。

圖(2)每顆柑桔樹懸掛六只乒乓球。依附著度評價表評定果粒附著度。

圖七、果粒附著度測定法

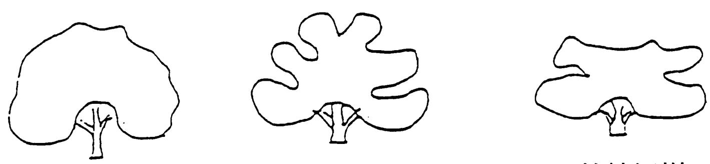
(六)從事管路自動化噴藥與人工噴藥性能調查結果如圖八。

圖八、坡地果園自動化噴藥與人工噴藥

| 公 司 名 稱 | | 管路自動化噴藥 | | 人工高壓高路噴藥 |
|---|---|---|---|---|
| 每公頃架設支數 | | 長 桿 200支 | 長短桿 350支 | |
| 藥液附著度 | 葉 表 | 89% | 92% | 90% |
| | 葉 背 | 51% | 63% | 70% |
| | 果 實 | 60% | 70% | 70% |
| 使用壓力Kg/cm² | | 12～15 | | 25 |
| 噴頭出水量 L/分 | | 7.5 | | 12 |
| 每公頃用藥量 | | 4000 L | | 4000 L |
| 每小區噴藥時間 | | 2 分40秒 | | |
| 每公頃噴藥時間 | | 30分 | | 4天×8＝32小時 |
| 噴 藥 直 徑 | | 9 m | | 10 m |
| 註：藥液附著度，葉表70％、葉背40％、果粒50％以上就能達到防治效果<br>由表得知管路自動噴藥設施其病蟲害效果與人工噴藥相同。 | | | | |

(七)果園管路自動噴藥應注意之事項

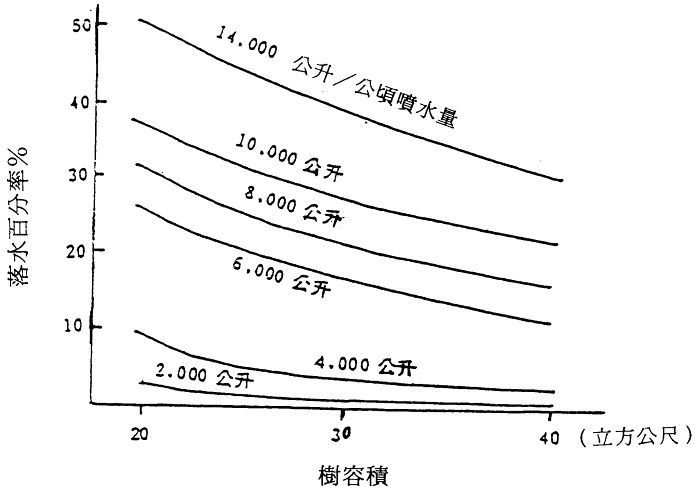
1. 經調查樹形與藥液附著程度有很大關係，管路噴藥密植果園及整枝不徹底的果樹，藥液附著程度很差，爲提高藥液附著量，必需做適當的整枝工作，(如圖九)所示三種樹形附著狀況，樹冠外圍的藥液量沒有差別，但樹冠內部則以粗枝間拔樹型爲較佳。



開心自形　　粗枝間拔樹　　主枝縮短樹

圖九、不同樹型

2. 噴藥量與不同樹容積之樹冠下落水百分率調查(如圖十所示)，在樹容積20至40立方公尺之樹冠下落水量，每公頃噴水量2,000公升時有1.0～2.5％，4,000公升時10％，但8,000 ～10,000公升時，樹容積20立方公尺之樹則有30％，30立方公尺之樹有20～25％，所以噴藥量應據果樹容積選擇適當藥量，以免造成噴藥過量。




圖十、噴藥量與不同樹容積之樹冠下落水百分率

3. 管路噴藥設施(長、短桿併用)經測試結果葉表可達98％葉背為65％，為增加葉背藥液附著量最好能多選擇具有浸透性及較穩定的農藥，則可提高到和人工噴藥略同之防治效果。
4. 管路噴藥時間以選擇無風的上午(以清晨)為最適當，黃昏時因葉面藥液不易乾燥，較易發生藥害。
5. 管路噴藥設施架設應以儘量避免發生噴藥死角外，果樹必須配合適當修剪，以粗枝間拔樹型，藥液附著較均勻。
6. 管路噴藥設施每公頃藥液使用量勿超過4,000公升以上，以免藥液使用過量落入土壤造成環境污染。

## 五、結　　論

台灣土地面積有限，果農常利用坡地種植柑橘與梨等經濟果樹，而坡地因受地形地勢限制，其病蟲害防治都以人力為主，加上目前農村人力老化與不足的現象日趨嚴重，坡地果園噴藥作業已面臨無工可僱的窘境，使用管路的自動化噴藥系統可解決這問題。管路自動化噴藥系統中大幅減少農民工作時數與工作負擔，並可改善作物品質，增加作物產量、減少農藥污染等，根據成本評估計算結果，裝設之管路自動化噴藥系統費用可在三～五年內回收，目前管路自動化噴藥設施推廣面積已達1,600公頃以上，推廣面積全部集中於台灣西部主要果樹產區，而東部目前具經濟效益之果樹，高接梨番荔枝也漸漸面臨人工噴藥無工可僱之窘境，果園管路自動化噴藥之利用可解決此困難。

圖十一、番荔枝果園管路自動化噴藥情形

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# 靜電式噴灑農藥技術的研究

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## 一、前 言

就臺灣高溫多溼的自然環境而言，以農藥防治病蟲害是作物栽培不可缺少的作業項目。施用農藥的過程中，雖然可能造成毒害、污染或其它副作用，但在生物防治技術尙未完全成熟之前，農藥撒佈仍是植物保護最直接有效的利器。台灣地區一年的農藥使用量曾經高達四萬三千五百公噸，使每公頃耕地年平均用量達48.6公斤，就農地大小分配而言，用量偏高。前人研究顯示：傳統的噴藥方式只能使20％的農藥量被有效噴灑到作物上，其它則因飄移或沖刷現象而流失浪費。這些流失的農藥不僅造成財務損失，更是環境污染的重要原因。提高農藥利用效率問題提出兩個解決方案：一為霧粒控制撒佈法(Controlled Droplet Application，CDA)，一為靜電噴灑法(Electrostatic Spraying)。前者係在農藥撒佈作業中，研究出最佳之噴灑壓力、流量及霧粒大小，以求提高農藥溶液對作物植株的附著率。這種方法對不同的作物有不同的噴藥模式，操作者必須經常調整噴藥系統的功能來適應植株條件。後者則是在噴頭部份加裝一組電極板，並通以二千伏特以上之直流高壓電，形成電場，使農藥霧粒穿過電場時被感應而極化成帶靜電的粒子。極化過的農藥霧粒具有較强的趨勢落向地面，使電性中和，此一趨勢即能有效降低農藥霧粒飄散的作用。同時，由於作物植株挺立地面上，與空中的農藥霧粒距離較短，使霧滴對植株形成覆罩(Canopy)及電曲線現象，不僅使植株對極化過的霧粒有較强的吸引力，而且使霧粒易於進入植株葉背及乾燥的底部。在植株表面形成較高的農藥附著度。這種方法操作簡單，噴霧系統需要調整之處不多，只需增加高壓電產生器並使用靜電噴頭即可，是較易實施的方案。

## 二、試驗情形

靜電噴灑系統用於農藥撒佈的情形示於圖 1，直流高壓電源使噴頭前端極板附近形成電場，當農藥霧粒自電極板之間穿過時，即被感應成為攜帶相反電性的霧粒，趨向作物植株。所用的靜電噴頭可分為液壓式噴頭、雙流體噴頭或旋轉式噴頭。雙流體噴頭(圖 2 )具有氣流，使霧粒更微細、易使電極板保持乾燥、且使霧粒在局部區域內不定向飄移，附著情況最為良好，但雙流體噴灑設備的購置成本較高，且需要較大的動力。靜電噴藥設備在國外已商品化生產，但其售價頗高，國內早期曾引進液壓式噴頭及高電壓產生器。前人研究結果顯示：靜電噴灑法不但可增加農藥對植物的附著度，且可使噴藥霧滴的粒徑微細化與均勻化，表 1 所列，即為幾個附著度研究案例。霧滴粒徑變化的研究結果則示於圖 3 與圖 4 。當噴灑壓力為 3 或 4 kg/cm$^2$ 時，此種效果最為明顯；噴灑壓力降壓 2 kg.cm$^2$ 時，由於促使霧滴細粒化的機械功不足，噴灑粒徑較大，靜電的功能便不明顯，當噴灑壓力高至 5 kg/cm$^2$ 時，由於幫浦的機械功率逐步提高，及高壓電路的功率限制，靜電噴灑的細粒化效果即相對減低。

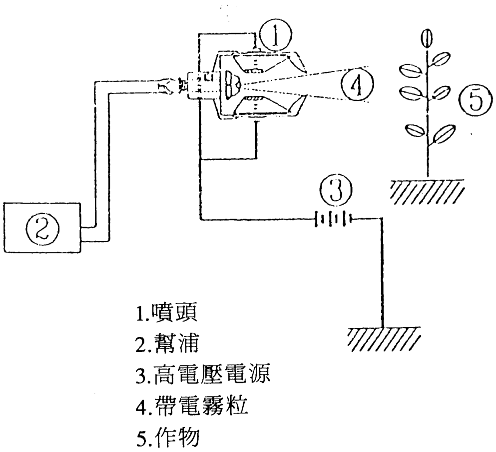


圖 1.　靜電噴灑系統用於農藥撒佈的示意圖

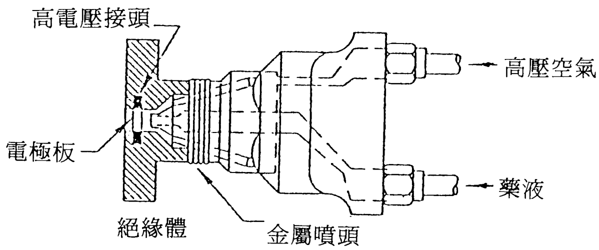


圖 2.　雙流體靜電噴頭

表 1.　幾個靜電噴藥對植物附著度研究案例的結果

| 電壓(KV) | 電流(μA) | 帶電量(cm/kg) | 平均粒徑(μm) | 附著效果* |
|---|---|---|---|---|
| 4.0 | 3.6 | - | - | 3.8倍，葉背 |
| 9.0 | - | 2.0 | - | 1.6至2.8倍 |
| 2.0 | 6.0 | 4.8 | - | 7.0倍(雙流體) |
| 4.0 | 6.6 | 0.61 | 87 | 1.6至3.8，葉背 |

＊備註：附著效果＝靜電噴藥附著度／無靜電噴藥附著度

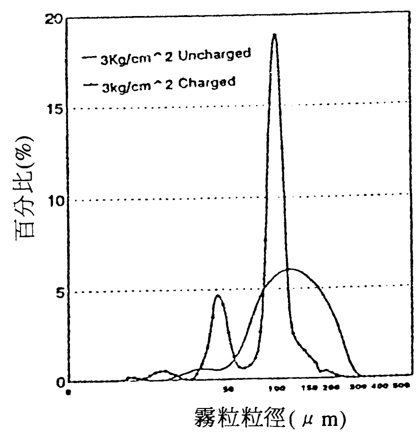


圖 3.　壓力 4 kg/cm² 時，靜電與非靜電噴灑所致霧滴粒徑分配的比較

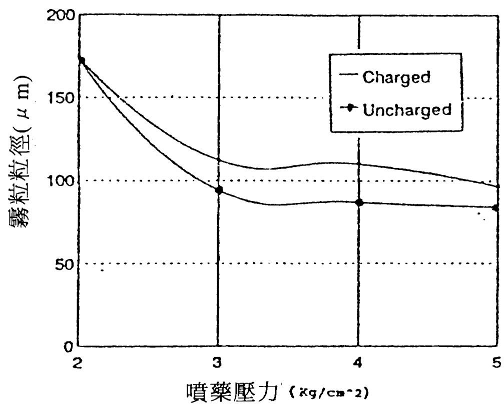


圖 4.　不同噴灑壓力下靜電對霧滴粒徑影響的比較

# 三、結果與討論

國內目前正推行農業自動化政策，許多精緻作物皆置於溫室或棚架設施內種植生產。由於溫室與農業設施內的栽培環境較爲密閉，內部飄移的農藥極易累積，對環境及工作者皆構成危害。既然靜電噴藥技術可提高噴藥效果，相對降低農藥用量，則必有助於減緩農業設施內的藥害危機。國內有關靜電噴藥的研究尙在啓蒙階段，國外的研究則幾乎全偏向於戶外田間的施藥實驗，較少有關溫室或農業設施內靜電噴藥的記錄。將靜電噴藥技術引用於溫室或農業設施內時，可以假設溫室或設施內屬於無風狀態，霧滴只受噴灑裝置本身移動及噴霧所致紊流的擾動而形成少量的飄移外，作業環境的氣流堪稱是靜止的；但帶電的霧滴必然會遭遇到溫室樑柱等定置導體對其飄移方向的誤導。如何克服溫室內定置導體對極化霧滴的吸附效應，避免此類誤導發生，是將靜電噴藥技術引用於溫室或農業設施內成敗的關鍵。表 2 所列即爲塑膠布簡易溫室內的試驗結果，該表數據顯示：靜電霧滴在溫室柱或壁上的附著度乃非靜電霧滴的十倍以上，所以溫室柱壁對靜電霧滴具有明顯的導引吸附作用。探求溫室內的柱壁設施與靜電噴頭之間的適當水平間距的實驗結果示於表 3，當距離增爲60cm時，靜電霧滴在取樣點上的附著度便遽然下降到 6% 以下，而且取樣點愈高，附著度愈低；當距離增爲90cm時附著度更降至 2% 以內。可見柱壁設施對靜電霧滴的導引吸附效果頗受到兩者間距離的限制，距離增大時吸附效果便會急速下降，當距離增至120cm時，附著度便降爲零，亦即完全沒有導引吸附作用存在。因此可以推斷：靜電噴灑時，噴頭若能與鐵柱或塑膠壁等溫室設施結構保持120cm的水平距離，靜電霧滴便不會被這些結構所導引而做錯誤的吸附。

表 2. 溫室柱壁對靜電霧滴具有導引吸附作用的驗證

| 霧滴帶電狀況 | 取樣點靜電霧滴的附著度(%)* | | |
|---|---|---|---|
| | 第一組取樣點 | 第二組取樣點 | 第三組取樣點 |
| 帶　　電 | 42.79 | 29.79 | 33.83 |
| 不　帶　電 | 4.29 | 2.16 | 0.55 |

備註*：取樣點設在溫室鋼柱及塑膠牆壁上。第一組取樣點位於溫室地面與柱或壁相交點向上30cm高處；第二組在60cm高處：第三組在90cm高處。噴頭距離牆壁30cm，高度90cm。

表 3. 靜電霧滴對簡易溫室的柱與壁之附著度

| 噴頭與溫室柱壁的水平距離(cm) | 取樣點靜電霧滴的附著度(%)* | | |
|---|---|---|---|
| | 第一組取樣點 | 第二組取樣點 | 第三組取樣點 |
| 30 | 42.79 | 29.79 | 33.83 |
| 60 | 5.27 | 3.46 | 0.62 |
| 90 | 2.12 | 1.75 | 0.36 |
| 120 | 0.00 | 0.00 | 0.00 |

備註*：取樣點的設置同表二。

# 綜合討論結論

研討主題：⑴自動化施藥機械發展的方向
⑵施藥機械作業性能標準及檢定方法之建立

針對上述兩個中心議題經研討後得到的結論爲：

1.爲改善早期施藥機械作業效率較差、用水量又多之缺點，施藥機械之開發、研究應配合近年來進步之機、電科技，以低容量施藥技術爲發展目標，以解決前述問題，並提高施藥效率；低容量施藥作業所產生之霧粒粒徑較小，飄移較爲嚴重之問題需先克服，且應開發較小型施藥機械以配合低容量施藥作業之需。

2.本省農民使用農藥時因作業習慣經常發生(1)噴藥作業前因無法準確預估農藥需求量，導致準備過量之藥劑，而於作業結束後將殘餘藥劑重復噴施，無形中產生用藥過量。(2)任意傾倒噴藥作業結束後清洗噴藥設備之廢水，造成二次環境污染與公害。爲解決該作業瓶頸，未來施藥機械之研究，應開發農藥與水在線上自動混合之設計，以資解決。

3.爲因應台灣農場規劃與栽培作物種類繁雜等現實環境條件，對噴藥設施於作業時所產生之種種限制，自動施藥機械之開發，宜以具有多元化作業功能之機種爲目標。

4.施藥機械之設計必須與各種作物、栽培技術專長人員密切配合，在不同領域需求間尋找平衡點，相互遷就與合作。

5.建立專業施藥作業人員訓練、講習，及執業許可與證照核發制度，以確立安全之施藥作業體系。

6.農藥霧粒的飄移與作物有關但無法逕予界定，單位面積有下限値飄移量隨距離而異；對平面噴施機械而言，攪拌均勻度及濃度之標準係以基準點之±15%爲準，距離上之差異也是±15%爲準，但鼓風式噴霧機則尙無標準。

自動化施藥技術研討會專刊

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