EVALUATION OF CURRENT PESTICIDES APPLIED SYSTEMS AND DEVELOPING A PROPER IMPLEMENT TO SUIT MOST OF AGRICULTURAL CROPS

BY

AHMED ALI IBRAHEM MOHAMED

A thesis submitted in partial fulfillment of

the requirement for the degree

of

Doctor of Philosophy of Science

in

Agricultural Science

(Agricultural Mechanization)

Department of Agricultural Mechanization

Faculty of Agriculture

Ain-Shams University

1994

Approval sheet

EVALUATION OF CURRENT PESTICIDES APPLIED SYSTEMS AND DEVELOPING A PROPER IMPLEMENT TO SUIT MOST OF AGRICULTURAL CROPS

by

AHMED ALI IBRAHIM MOHAMED

B.Sc. Agricultural Engineering Dept.,
Faculty of Agriculture, Alexandria University, June 1977.
M.Sc. Agricultural Mechanization Dept.,
Faculty of Agriculture, El Menofia University, October 1987.

Approved by:

1- Prof. Dr. SALAH EL-DEEN ABD EL-MAKSOD ....

Head of Agri. Eng. Dept.,

Faculty of Agriculture-El-Zagazik University.

2- Prof. Dr. ZIDAN HINDY ABD EL-HAMID ....

Prof. of Pesticides, Plant Protection Dept.,

and Vice Dean for Graduate Affairs.

Faculty of Agriculture-Ain Shams University.

3- Prof. Dr. MOHAMED NABIL EL-AWADY..............................

Head of Agricultural Mechanization Dept.,

Faculty of Agriculture-Ain Shams University.

(Supervisor)

Date of examination: 8/6/1994

بسم الله الرحمن الرحيم

EVALUATION OF CURRENT PESTICIDES APPLIED SYSTEMS AND DEVELOPING A PROPER IMPLEMENT TO SUIT MOST OF AGRICULTURAL CROPS

BY

AHMED ALI IBRAHIM MOHAMED

B.Sc. Agricultural Engineering Dept.,
Faculty of Agriculture, Alexandria University, June 1977.
M.Sc. Agricultural Mechanization Dept.,
Faculty of Agriculture, El Menofia University, October 1987.

Under the supervision of:-

Prof. Dr. M. N. EL AWADY Head of Agric. Mech. Dept., Fac. of Agric. Ain Shams Univ.

Abstract:-

Twelve hydraulic nozzles used on nozzle-boom sprayer were evaluated by measuring flow rate, spray patterns, droplet sizes, and spray deposits. Deposition is quantified by position on artificial cotton canopy (upper, middle, or lower region) and by upper vs. lower leaf surface. Different combinations of TJ60-11004VS and TXVS-12 nozzles. were used to modify the nozzle-boom sprayer.

A "Spray-System Effectiveness" number (SSE) is devised in this research to Judge the spray deposit characteristics among the tested nozzles. SSE is a function of spray deposits efficiency, spray-distribution uniformity, and intensity ratio within the whole plant.

Results obtained show that the twin orifice, and the TX hollow cone, nozzles produced the most uniform droplet size distributions and had a coefficient of variation of 7 % or less for a simulated boom pattern at 276 kPa. Also, it was found that the spray deposits and penetration on upper and lower leaf surfaces on artificial cotton plant increased after modifying the nozzle-boom sprayer.

Keywords: spray droplet size, spray deposition, flow rate, drop sizes, application uniformity, nozzle-boom sprayer, artificial cotton canopy, spray-system effectiveness.

ACKNOWLEDGMENTS

By the name of Allah (God) the most merciful the most gracious.

Grace is due to God for God is the provider of life and knowledge. I would like to express my deepest gratitude and appreciation to my major professor Dr. Mohamed Nabil El Awady for his close and sincere supervision, fruitful guidance and suggestion, valuable advice, and his generous effort that enabled me to undertake this work.

I would also like to express my gratitude to Dr. William E. Steinke and professor Norman B. Akesson for their supervision, help, and guidance as my advisors throughout my entire stay at the University of California, Davis, U.S.A..

I would like to acknowledge my gratitude to the government of EGYPT and U.S.A. for financial support during my stay in U.S.A. Also, I thank the Department of Biological and Agricultural Engineering, at the University of California, Davis, U.S.A. for help and cooperation.

Special thanks to professor Dr. Ahmed Faried El Sahrigy the director of Agricultural Engineering Research Institute for his sustaining encouragement and supporting my research.

The greatest respect and thanks are also extended to staff members of both Agricultural Engineering Research Institute and Research & Testing Station of Tractor & Agricultural Mechanization for their encouragement.

Finally, I would like to express sincere gratitude and appreciation to my wife for her patience and faithfulness. I would like to let my kids know that they are a blessing from Allah and it is because of them that life is worth living.

Ahmed A. A. Mohamed

CONTENTS

1. Introduction 1

2. Literature Review 4

2.1 The atomization Process 5

2.2 Hydraulic Sprayer..6

2.3 Spray Droplet-Size Spectra 9

2.4 Factors affecting the droplet size in hydraulic atomization....................4

2.5 Spray deposition and penetration into plant canopies............................23

2.6 Evaluation of current pesticide application techniques 30

3. Materials and Methods 40

3.1 Measurement of flow rate 44

3.2 Measurement of pattern distribution 44

3.3 Measurement of droplet sizes 47

3.4 Measurement of spray deposit within the plant canopy 50

3.4.1 Artificial cotton plant 50

3.4.2 Experimental apparatus and procedure 50

3.4.3 Spray deposit calculations 55

3.4.4 Spray deposit intensity rat o 56

3.4.5 Spray deposit efficiency 56

3.4.6 Spray deposit uniformity 57

3.4.7 Spray system effectiveness 57

3.5 Developed nozzle-boom sprayer 61

4. Results and Discussion 68

4.1 Spray flow-rate measurements 69

4.2 Spray pattern measurements 71

4.3 Spray droplet-sizes spectra measurements 74

4.4 Spray deposition measurements 83

4.4.1 Spray deposit, intensity ratio, and efficiency 83

4.4.2 Spray system effectiveness 91

4.5 Development of nozzle-boom sprayer 98

4.5.1 Effect of nozzle position on the spray deposits 98

4.5.2 Practical combination 105

5. Conclusion 118

6. Summary 122

7. References 128

8. Appendices 137

9. Arabic summary and abestract 194

1. Introduction

Use of pesticides is a major concern among both farmers and the general puplic. The farmers and growers turn to the application of pesticides and herbicides to fight pests and weeds since they either feed on agricultural crops or act as vectors of disease and cause major losses of the yield and quality. Control of pests can only be achieved if pesticides are properly applied at the correct rate, at the right time, and on the target. Precise application techniques are more important now than when pesticides were first introduced, because of narrow margins of selectivity and more public concern about precise application of chemical pesticides.

Chemical application has been done using a wide range of equipment, varying from simple hand-held devices to sophisticated sprayers mounted on self-propelled ground or aerial vehicles. Liquid spraying, by itself, includes many different types of equipment designed to accommodate many modes of liquid spray chemical application. This variability is dictated by the type of crop to be sprayed such as orchard, vineyards, row crops, field crops or green house crop. Liquid-soluble chemical sprayers have several features in common.

Hydraulic atomizers (pressure atomizing nozzles) are commonly used in applying agricultural chemicals to crops. These are sprayers where hydraulic pressure is created by the direct action of the pump on the liquid to be applied. The pressure forces the liquid through the nozzle, which not only meters the liquid but also breaks the liquid into droplets, and disperses the droplets in the spray pattern desired. Regardless of the size or function of the sprayers, the nozzle is the primary link between the chemical and proper application to the target. According to Novak and Cavaletto (1988), proper application of pesticides involves applying at the proper application of active chemical rate and applying a uniform distribution pattern.

Most of Egypt's exports are agricultural products (nearly 80%) and most of these are raw materials . Cotton alone represents 60% of the exports, both as fiber and manufactured material (Salama, 1983). Whenever Egyptian agriculture is mentioned, one immediately thinks of Egyptian cotton that has dominated agricultural production for the last 100 years. Egypt is known for long-staple cotton of extremely high quality. Cotton in Egypt is attacked by various insect pests during the different stages of its development. The most important insect pests are: thrips, aphids, cotton leafworm, corn earworm, nematodes, and white flies. These insect pests cause losses in yield and quality, either by feeding on the crop, or indirectly as vectors of disease. Therefore, pest control through chemical spraying is highly needed in Egypt to reduce the annual losses in crops caused particularly by pests. Nozzle-boom sprayers are commonly used to apply pesticides in Egypt. Therefore, boom and nozzle arrangements are focused upon in this study in order to improve its performance.

The objectives of this research are to:

A) Evaluate different types of hydraulic nozzles used on nozzle-boom sprayer for their ability to deposit the pesticides through the plant. Four parameters were measured during the evaluation:

1- Flow rates of the selected nozzles at selected pressures;

2- Pattern under selected operating parameters;

3-Droplet size distribution produced by these nozzles; and

4- Pesticide deposition on the lower and upper surfaces within the plant canopy at the top, middle, and bottom of the plant.

Results expected from the evaluation give selection parameters to recommend the appropriate type of nozzle for nozzle-boom sprayer.

Literature

2.1 The atomization process :

The atomizer, or nozzle, is the primary link between the chemical and proper application to the target. According to Matthews (1992) a large range of hydraulic nozzles have been designed in which liquid under pressure is forced through a small opening or orifice so that there is sufficient velocity energy to spread out the liquid, usually in a thin sheet that becomes unstable due to interaction with the air and disintegrates into droplets of different sizes.

According to Palti and Ausher (1986) spraying may be defined as dispersal of a liquid, after its break-up into individual droplets, by an atomizing device such as a nozzle.

Awady (1977), Azime et al. (1985), and McWhorter and Gebhardt (1988) reported that the atomizer has three functions: to meter or regulate liquid flow rate; to form and control droplet size; and to disperse and distribute the droplets in a specific pattern.

Atomization is the process of breaking-up bulk liquid into small droplets. Examples of common devices used to achieve atomization are pressure, gas-atomizing nozzles, and spinning disks. According to Nakano and Tien (1970), the atomization process is considered to consist of two stages: primary and secondary. In the primary stage, the liquid mass is broken as a result of capillary force. Primary atomization depends on the device as well as the operating conditions. In the secondary stage, the disintegrated drops are split further into small droplets by the dynamic effect of a surrounding medium. No further atomization occurs after this stage, and atomization process is said to be completed.

According to Mugele (1960), the atomization process is completed when all the drops so formed are less than the maximum stable size.

2.2 Hydraulic sprayers:

According to Smith and Wilkes (1976), hydraulic sprayers are commonly used for pesticides and plant protection applications in which the spray pressure as an energy sources is built up by the direct action of the pump on the liquid spray material. The pressure forces the liquid through the nozzle, which breaks the spray into droplets and dispenses them in the spray pattern desired. Also, sufficient energy is imparted to the spray droplets to carry them from the nozzle to the surface to be treated.

They also reported that the other essential parts of the hydraulic sprayer are: pump, tank containing an agitator, combined pressure regulator and unload or relief valve, pressure gauge, strainer and screens, control valves, piping and fittings, distribution system, and power source.

Awady (1978) reviewed empirical studies and presented theories of spray atomization from agricultural nozzles. The research focused on the prediction of resulting droplet size from a given pressure and flow situation. Two theories were developed: (1) droplets separate under viscous shear whenever surface tension is strong, (2) droplets separate under surface tension whenever viscous resistance is high.

Masters (1991), Lefebvre (1989) and McWhorter and Gebhardt (1988) stated that the pressure atomizer is used to covert the pressure energy in the liquid

Masters (1991), Lefebvre (1989), and McWhorter and Gebhardt (1988) stated that the pressure atomizer is used to covert the pressure energy in the liquid bulk into kinetic energy in the form of thin sheet of liquid at high velocity. The sheets break up due to the influence of the liquid physical properties and by the frictional effects with the medium into which the liquid sheet is discharged. Generally the medium is air. Reating with the air, the sheet rapidly becomes unstable and disintegrates into droplets of different sizes (see Fig. 2.1).

Elba et al. (1984) and McWharter and Gebhardt (1988) mentioned that the liquid in a hydraulic spray nozzle is broken into droplets by collapse of unstable sheets or jets, or by the shearing action of air. There are several forces acting on the surface of a thin liquid sheet as it emerges from an atomizer: the surface tension forces which tend to draw the liquid back to its original position and the aerodynamic drag which tend to pull the liquid outward. If the aerodynamic forces exceed the surface tension forces, unstable waves result and propagate with exponentially increasing amplitude until the liquid sheet detaches in the form of a ribbon. Surface tension then causes this ribbon to contract into a ligament of liquid. This ligament subsequently disintegrates into drops.

According to Master (1991), there is a maximum sheet length for a given pressure. An increase in pressure reduces the sheet length. an increase in viscosity acts to lengthen the sheet, whereas an increase in surface tension increases sheet length Increase in sheet velocity and increased turbulence caused by frictional effects with the air medium act to reduce sheet length. Reduced frictional effects from spraying into a medium at sub-atmospheric pressure result in elongation of sheet length.

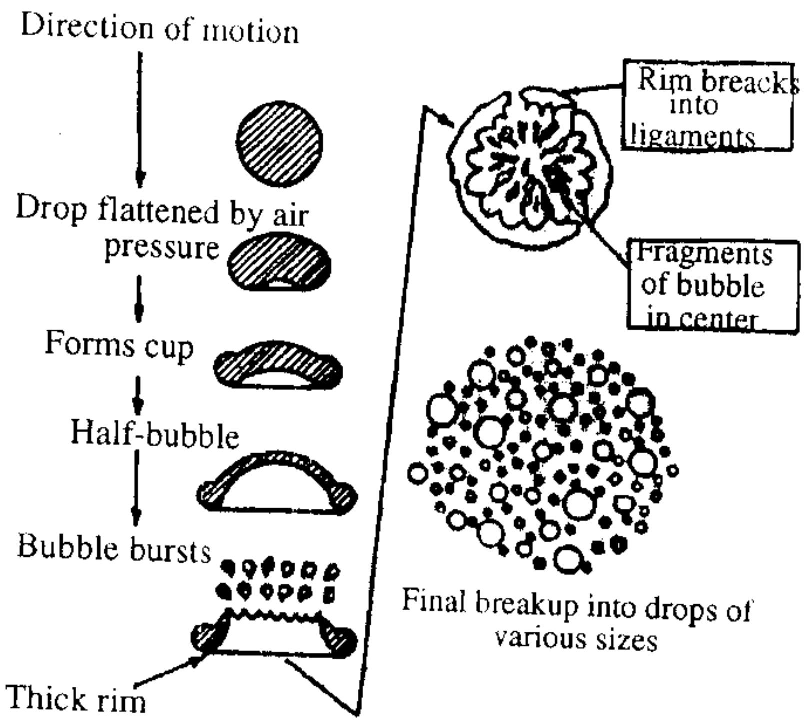

Fig. 2.1 Breakup of a spherical drop by interaction with ambient air (lefebfre, A.H. 1989).

Bache (1985) speculated that the main concept behind any sprayer system is to use a highly turbulent and forceful air jet to increase the ability of the spray to penetrate deeply within the plant canopy and to improve the uniformity and efficiency of spray application.

2.3 Spray droplet size spectra:

Atomizers used for applying liquid pesticide atomize the liquid not into droplets of identical size but into a range of droplet sizes. The atomization of spray volume (liquid) into various droplet sizes creates a droplet size distribution, or droplet size spectrum. The standard measurement for the droplet size is its diameter, expressed in micrometers, or microns* (μm). According to Awady (1977), Kepner et al. (1978), Goering and Smith (1978), Patel (1981), Arnold (1983), Masters (1991), McWhorter and Gebhardt (1988), and Matthews (1992) the most widely used parameters of droplet size are the volume median-diameter (VMD) or the mass diameter (MMD), and number median-diameter (NMD) or count median diameter (CMD). The volume median-diameter (VMD) divides the droplets into two portions by volume, so that one half of the volume is contained within droplets whose diameter is smaller than a droplet whose diameter is the VMD, and the other half of the volume is contained of droplets whose diameter is larger (see Fig. 2.2). Sometimes the term mass median-diameter MMD is used in place of the VMD, when mass, as a function of the liquid density, is used instead of volume as a measure. Number median diameter is defined as a droplet of diameter such that one half of the total number of droplets have a diameter smaller than this value and the other half of the total number of droplets have a diameter larger than this value.

---

* 1 mm = 1000μm