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Duster-low-volume sprayer comparison in applying insecticides to snap beans

Hugo E. Perez

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I am submitting herewith a thesis written by Hugo E. Perez entitled "Duster-low-volume sprayer comparison in applying insecticides to snap beans." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Biosystems Engineering.

Bobby L. Bledsoe, Major Professor

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Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

February 15, 1972

To the Graduate Council:

I am submitting herewith a thesis written by Hugo E. Perez entitled "Duster-Low-Volume Sprayer Comparison in Applying Insecticides to Snap Beans." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Mechanization.

B. L. Bledsoe
Major Professor

We have read this thesis and
recommend its acceptance:

John J. McDow

Lester J. Thompson

Edward E. Burgess

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

DUSTER-LOW-VOLUME SPRAYER COMPARISON IN APPLYING INSECTICIDES TO SNAP BEANS

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Hugo E. Perez
March 1972

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ABSTRACT

The objective of this study was to compare the effectiveness of two makes of low-volume sprayer and one make of duster in applying insecticides for controlling cabbage loopers on snap beans. With the low-volume machines, five gallons of mix per acre was used; with the conventional duster 25 pounds of mix per acre was used.

A fluorescent particle technique was used to determine the insecticide particle deposition on the foliage. Machine performance was evaluated by count of deposited particles.

The low-volume sprayers were more efficient in applying insecticide material to plant leaves than the duster. Between low-volume sprayers there was no significant difference. It was found that the insecticide deposition achieved with the low-volume sprayers was almost 250 percent greater than that of the duster. The low-volume Span Spray unit produced the highest deposition mean (122.12 FP/mm^2) and the lowest insecticide drift. Second was the John Blue sprayer (120.52 FP/mm^2) and last in rank was the duster (49.82 FP/mm^2). Also, application dates (replications), blocks, rows, and leaf sides effects were significant. The third replication had higher particle counts than the second and the second had higher counts than the first. The difference indicates an accumulative effect of the insecticide on the crop with succeeding replications. Row 7 particle counts were higher than those of Row 8 for all the machines. The top of the leaf was found to receive more insecticide material than the bottom for all the machines and at two different heights on the plant.

Loopers apparently were controlled by both Sevin and Thuricide HP, although looper infestation, even on the check plots, was too low for conclusive control prediction. There was poor control of Mexican bean beetles, with Sevin providing better control of these beetles than Thuricide HP. There was a better control of flea beetles by both Sevin and Thuricide HP treatments. Again, Sevin proved superior.

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CHAPTER I

INTRODUCTION

Dusters have been widely used to apply insecticides to snap bean plants grown on the Cumberland Plateau of Tennessee. Insecticides are applied to prevent insects from damaging plants and causing reduced yields and low quality of beans produced. Control of the cabbage looper (*Trichoplusia ni*, Hübner) is especially desired since presence of these larvae on harvested pods renders the crop unmarketable. Processors will not accept beans on which loopers are detected.

The effectiveness of chemical insect control depends on the agent to be controlled, the chemical applied, and the machinery used for application. The problem is to apply the necessary quantity of toxic materials at the desired points with a minimum of waste. Since dusters have been reported to be inefficient insecticide applicator machines (3, 6, 7, 17, and 22), a search for more efficient machines is warranted.

Low volume sprayers offer the advantage of requiring less insecticide mix to control insects for a given area of plants and perhaps could be used for more efficient control of loopers on snap beans. To evaluate this possibility the Departments of Agricultural Engineering, Agricultural Biology, and Horticulture organized a comprehensive research program.

One phase of this program was to evaluate and compare the effectiveness of two makes of low-volume sprayer and one make of duster in controlling cabbage loopers on snap beans. This research was performed at the Cumberland Plateau Experiment Station at Crossville, Tennessee.

CHAPTER II

REVIEW OF LITERATURE

Previous studies report findings in the following areas:

1. Efficiency of sprayers and dusters
2. Insecticide drift
3. Techniques to measure spray deposits

Efficiency of Sprayers and Dusters

Much work has been done to increase the efficiency of machines used in applying chemicals to control diseases and insects. Dusters have received much attention because of the low efficiency of application of materials to the crop.

Frank Irons (22), in 1943, made a study of commercial dusters and found the following problems: (a) unreliable feed rate control--the feed rate was affected by both depth of dust in the hopper and changing dust condition resulting from agitation and vibration; (b) wide variations in dust distribution--the variations were measured in most duster models used.

A. H. Glaves (17) also studied the performance of several representative multiple-outlet dusters in 1947. He found varied responses of different dusts to the action of ordinary feed mechanisms, and they were due to various combinations of such physical characteristics as particle size, particle shape, and volume weight. He also reported that head of dust above the dust port, change in fluidity of the air and dust mixture in the hopper, and lack of positive control of the dust port opening were factors causing irregularities in dust delivery.

Bowen *et al*. (3) and Brittain *et al*. (5) pointed out that dust recovery was about 10 to 20 percent with conventional field dusting, where dust recovery refers to the percentage of dust discharged by the duster that actually deposits on the plant. To increase the deposition efficiency Bowen and his co-workers applied electrostatic charging which combines electrostatic and dynamic forces resulting in a considerable increase in dust recovery and improved distribution. They also said that particles less than 10 microns in diameter are very difficult to precipitate with dynamic forces alone, but electrostatic forces will precipitate them. Brittain and Carlton (6) reported that the pubescent surfaces of bean and tomato leaves were more favorable for dust deposition than the lettuce leaf. This study also showed a significantly higher deposit on the lower surfaces of the leaves than on the upper when both surfaces were exposed directly to the dust stream. They said that this may have been due to protruding veins. It was also found that while the deposit of the finer dust increased with an increasing air velocity, the deposit of the coarser dust actually decreased with an increased air speed. Another result was the increase in the percent of dust deposited as the leaf approached a position parallel to the air-dust stream rather than perpendicular to it.

S. F. Potts (29), in 1946, pointed out the effect of particle size of insecticides on its application, distribution, and deposit. He reported that a field of resistance surrounds all objects, including plants and insects, and repels most individual dust particles of small size, as well as droplets smaller than approximately 30 microns in diameter. He also said that if the particles are small, the deposit on insects and plants consisted almost entirely of agglomerates. Finally, he reported that fine atomization is necessary to obtain adequate distribution with low gallonage, but droplets must be large enough to deposit on foliage and insects. He concluded that for ground application most of the spray should be in droplets 30 to 80 microns in diameter.

Chester M. Himel (20) reported in 1969 that the optimum size for insecticide spray droplets is one of the most important and one of the most elusive of all the factors which affect the efficiency of insecticide sprays. He said that spray efficiency is related to optimum droplet size, but that no commercial sprayer can produce optimum efficiency since sprays emitted are all nonhomogeneous in droplet size. He concluded that the optimum size for insecticide spray droplets is in the range of 20 microns in diameter.

F. A. Brooks (7) reported in 1947 the problems due to the practice of dusting tomato vines with calcium arsenate where the total off-tract waste of insecticide was generally 50 to 60 percent when applied by airplane. He said that drift control becomes virtually impossible for particles smaller than 10 microns diameter and that dispersion is greater in turbulent air. He concluded from his study that the use of very fine particles is a mistake and that dusting machines would be most efficient if designed to get high dynamic catch within the foliage by forced turbulence.

Orve K. Hedden (21) studied in 1961 the spray drop sizes and size distribution in pesticide sprays. He reported that the practical coverage and deposit obtained was produced by the impact of the spray pattern on the sprayed surface. He found a wide variation in drop sizes in all patterns sampled and said that the greatest number of drops collected were of very small sizes (under 100 microns) but these drops contained relatively little of the total volume of spray produced. Large drops (over 300 microns) contained the greatest portion of the spray volume.

Wesley E. Yates (41) investigated the spray pattern and evaluated deposits from agricultural aircraft. He reported that spray deposits can vary as much as ±50 percent from the average application rate. Bode et al. (2) also studied in 1968 the spray deposit patterns and droplet sizes obtained from nozzles used for low-volume application. They used fan spray, cone spray, and pneumatic atomizing nozzles with each type operated at three speeds and each speed used at three pressures. Their results indicated that the spray patterns from the fan spray and cone spray nozzles were more uniform when operating at 40 psi than at 25 or 30 psi. Pressure did not significantly affect the deposit patterns of the air nozzle. Also, they concluded that speeds of 3, 4, and 5 m.p.h. did not significantly affect the spray patterns of any of the nozzles tested. Finally, they concluded that the droplet-size distribution did not vary significantly across the spray swath or with a change in speed for any of the nozzles tested.

Harrel et al. (18), in 1965, and Casselman et al. (8), in 1966, evaluated the electrostatic charging of chemical dusts on sweet corn and on celery, Irish potatoes, snap beans, and cabbage respectively. Harrel and his co-workers concluded that the cloud containing the charged particles tended to hover near the plants and settle faster than those without charged particles. They also said that greater efficiency could be obtained with the charged particles, which would result in more economy in quantities of insecticide used and in more uniform plant coverage resulting in better insect control. Casselman and his co-workers found that deposition of charged dusts was highly significantly greater than uncharged dusts on both upper and under-leaf surfaces. They also concluded that deposition on the underside of the leaf increased in about the same proportion as that on the upper leaf surface as a result of charging.

R. J. Courshee (9) proffered in 1957 some opinions about small volume sprayers based on his experience with spraying machinery for fruit trees. He said that for spray greater than 40 microns and at wind speeds greater than 10 m.p.h., the impactation is nearly 100 percent and is appreciable even for smaller drop sizes. He said that low impactation efficiencies are not a major cause of drift even for the finest sprays used in practice on fruit trees.

L. N. Staniland (38) made a research in 1960 to evaluate the efficiency of a wide range of spraying machines on a number of crops using the fluorescent tracer techniques. The results showed great variation; they threw light on many of the factors responsible for poor coverage and indicated ways of bringing about greater efficiency. He concluded that poor application is playing a very full part in the variable results being obtained by growers. The tests showed that it is essential for any form of automatic spraying to be carried out from two directions. Trace techniques also showed that spraying up the rows provides only one-sided cover of the plants and that the value of angled nozzles to permit side spraying is evident. The tracing of strongly directional air-blast sprays, particularly those of high velocity, has shown that masking is a common feature and can arise from intervening parts of the same or another plant which may be some distance away. Even raised veins on the undersurface of a leaf can give rise to shaded areas on their lee sides. Air-blast spraying is also responsible for much packing together of foliage and this leads to excessive shielding from spray cover. It was pointed out that machines employing high velocity air have given poorer undersurface leaf cover than those with air blasts of lower velocity. He summed up by saying that the most efficient of the machines tested have been those employing the larger volumes of air at the lower velocities within the confines of the crop, those producing droplets of moderate size, and those applying not less than 50 gal./acre.

King *et al.* (26) studied the efficiency of equipment for the application of pesticides to citrus trees in Florida. They used the leaf print method to measure distribution of spray materials from different sprayers and attachments. Spray coverage comparisons were made from samples of 35 leaves picked from the inside and outside top portions and from the skirt of three or more trees for each sprayer. Prints were rated separately for distribution of spray leaves.

A rating of 0 (very poor) to 3 (very good) was made by comparing each leaf print with a set of standard leaf prints. Data showed that there was little difference in the distribution of spray deposited on the upper and lower surface of leaves.

Insecticide Drift

O. C. French and A. S. Crafts (15) studied in 1936 the characteristics of spray nozzles for vegetable and weed spraying. They found that pressures higher than 75 p.s.i., especially with the small orifice sizes, produce a drifting mist that is objectionable where poisons are being applied.

R. J. Courshee made in 1959 two studies (10, 11), about spray drift. First, he studied the small drop component of sprays related to spray drift, and he concluded that the drops which drift are those corresponding to stains smaller than approximately 250 microns diameter (stain diameters are twice the drop diameter). He found that 3 to 3.6 percent of the spray volume is smaller than this size. From his second research, "the occurrence of drift," he reported that both theory and measurements showed that, at a given wind speed, drift can best be reduced by keeping the nozzles low, by using flat rather than cone nozzles, and by avoiding small drops in the spray. He said that the latter was achieved most readily with low pressure on ground sprayers and by a combination of low pressure and modifications of the spray liquid when using aerial sprays.

Courshee and Ireson (12) continued in 1961 the investigations on spray drift. They studied the range of projection of small drops. Drops of water of a known size were projected horizontally at various initial speeds through the air, and the distances which they traveled horizontally before coming to rest were measured. It was shown that the maximum range attainable with drops of conventional sizes was of the order of 1 m.

Yates *et al*. (43) reported in 1966 the results of their research about drift residues from aerial applications. For the evaluation of drift data, they considered four basic factors related to the quantity of drift residue: (a) distance downwind, (b) type of aircraft and operating conditions, (c) meteorological conditions, and (d) particle-size distribution and its evaporation characteristics. They determined the effect of each of these factors on drift characteristics, using a summation technique to predict the pesticide residues. They concluded that this procedure can be utilized to estimate the pesticide residue that would accumulate as far as one half mile downwind from the border of the treated area.

C. R. Kaupke and W. E. Yates (25) also studied the drift characteristics of agricultural sprays by modifying viscosity with invert solutions. They used the tracer and field techniques described by Yates et al. (42) to measure spray drift. They found that ground applications of the invert sprays appear to be promising for reducing drift.

L. O. Roth and J. G. Porterfield (31) reported the effects of liquid atomization for drift control. They found that jet stream atomization offers considerable promise as a practical means of reducing the drift potential of sprays. They ran several field tests to determine the drop distribution pattern and drift produced. A fluorescent material was added to the water and the jet stream was charged electrostatically. They found that the charged drops showed a better dispersion and less drift than the noncharged drops.

In 1970, Frost and Ware (16) studied pesticide drift from aerial and ground applications. They used an airplane, a high clearance ground sprayer, and a tractor-drawn mist blower and concluded that:

1. Drift residues from aerial applications one fourth to one half mile downwind can be reduced by as much as 80 percent when changing to high clearance sprayer application.

2. The pesticide drift from the mist blower is but slightly greater than the aerial applications.

3. With wind velocities under 5 m.p.h., wind and inversion temperature had little influence on drift from high clearance sprayer application, and

4. In ground application, nozzle size has a definite influence on drift downwind.

Techniques to Measure Spray Deposits

To test the performance of sprayers and dusters in the field, a number of techniques have been used.

Brittain *et al*. (5) used in 1955 the titrimetric analysis method for the quantitative evaluation of insecticidal deposits on plant leaves. This method was limited to insecticides containing copper which could be washed from the plant leaves and dissolved in the wash solution for analysis.

The polarography technique was used in 1955 by Ban and Carleton (1) for the same purpose. They reported this method to be faster and at least as accurate as other methods used. This method could be applied to organic or inorganic materials provided that a suitable solvent and a good supporting electrolyte were found for each one, and provided that the substances measured were electroreducible or electro-oxidizable. This technique was also described by Brazze (4) in 1963. He cited the application of polarography to determine several pesticide deposits such as copper sulfate, malathion, etc.

The activation analysis technique has also been used to measure quantities of spray material deposited on leaves--by Norby and Steemberg (28) and by Wilkes and Brusse (40). The latter defines the activation analysis like a method of making a chemical analysis through the use of atomic energy. The process involves the irradiation of a material by nuclear particles and measuring the radioactive isotopes with a gamma ray spectrometer. This technique was reported to be fast and highly sensitive.

Sanders (32) studied in 1953 the equipment and procedures for the measurement of deposits of aerially applied materials. Dusts and sprays were collected on pans representing 1/20,000 of an acre. The dye treated dusts or sprays collected were combined with 500 c.c. of water and the relative dye concentration was measured by a photometric instrument. The application rate was determined by comparing the instrument reading with a previously developed calibration curve from known concentrations.

Isler, D. A. (23) reported in 1963 the different methods for evaluating coverage and drop size in forest spraying. He said that one of the early methods used was the glass plate method in which plates were laid out in a line at right angle to the proposed line of airplane flight. He cited other methods such as colorimetric or dye tracer methods that were used for quantitative measurements of aerially sprayed deposits. Disadvantages of these techniques include the considerable time and personnel required to handle the sampling procedures and complete the calculations. Finally, he reported the fluorescent tracer technique which offers an excellent opportunity to simplify and improve distribution assessments.

Fluorescent materials have been used to determine drift (31, 42, 43) and deposit of insecticides (2, 13, 14, 19, 27, 35, 36, 37, 38, and 41). Liljedahl and Strait (27) developed and tested a fluorescent method to evaluate spray deposits in an accurate and quick way. Spray containing fluorescent material was collected on a paper strip which was passed under a scanning chamber. There the strip was illuminated with ultraviolet light and the fluorescence measured with a photocell. The photocell current was amplified and recorded on a strip-chart recorder which graphically indicated the distribution of spray as collected on the paper. Himel (19) reported in 1969 the fluorescent particle (FP) spray droplet tracer method. He said that this method makes it possible to identify pesticide spray droplets by size and by number directly on insects, foliage, and other solid substrates. In addition, the FP method makes data available on the transport, distribution, and impingement of pesticide sprays. He said that this method is based on the uniform suspension of a known number of solid, insoluble, micron-size, fluorescent (Zn-Cd sulfide) particles in a known volume of nonvolatile pesticide liquid. Himel pointed out that the experimental importance of the fluorescent particle spray tracer system is that it uses the actual insect and its foliage environment as the test substrate so the data obtained are directly pertinent to the insect problem being studied.

Staniland (37) also used fluorescent materials for the study of spray and dust deposits. He listed several fluorescent materials that can be used with sprayers or dusters and also cited the following applications of fluorescent tracers: 1. Use of tracers in soil. 2. Use of tracers in spraying investigations. 3. Use of tracers in relation to spraying hazards, and 4. Use of tracers in experimental work on insecticides. He concluded that fluorescent materials are suitable for incorporation with spray fluids, dusts, and, to some extent, in insecticidal smokes and heat generators of insecticides.

Insecticidal deposits have also been evaluated by the leaf print method (26) and by the flame spectrophotometric technique (41). Similar techniques, such as the sprayograph technique (30, 34), index cards (39), dyes (21), and ink (33) have been used to study and evaluate other characteristics of spraying machines.

CHAPTER III

MATERIALS AND METHODS

Two low-volume sprayers, one manufactured by John Blue (Model S-707) and one manufactured by Span Spray (Model SS-35) and a conventional duster (Gustafson Model C) were used in this experiment. Two types of insecticides were used to compare the efficiency of the sprayers with that of the duster and to determine which insecticide had better control on cabbage loopers.

From August 21 to September 13, three insecticide applications were made with the machines (Figures 1, 2, and 3). Attempts were made to apply the treatments of each replication in one day, but additional time was required for the first two replications because of machine failures and weather conditions. The first two replications required a period of two and three days, respectively. The first replication was begun 35 days after the planting date. Replications two and three were begun 10 days and 20 days, respectively, subsequent to the start of replication one.

Description of the Machines

Duster. A 4-row Model C Gustafson duster (Figure 1) was used in this experiment. It was mounted on a

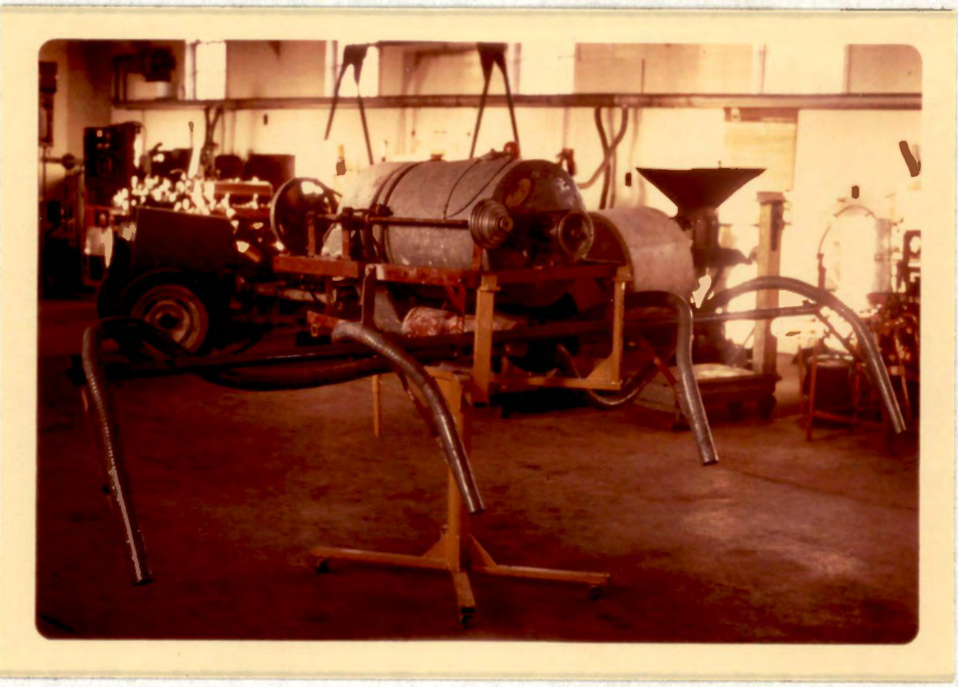


Figure 1. The conventional duster.

Figure 2. The low-volume John Blue sprayer.

Figure 3. The low-volume Span Spray unit.

Massey-Ferguson tractor (Model MF-165). This duster had an insecticide holding drum which revolved while in operation to maintain an even mixture of the material to be applied. In addition to the revolving drum, the dusting system was composed of three subsystems. The first subsystem was the feeder unit which had a metering coil and a feeder shaft pulley. The coil determined the volume of poison dispensed per revolution of the shaft, and the shaft speed determined the rate of applying material. The second subsystem was the blower unit which received the dust from the feeder unit and blew it to the four distributors. The main part of this unit was the 4-blade impeller. The third subsystem was the dust distributors which delivered the dust to the crop.

The following are specifications of the Model C duster:

Capacity	3.25 cubic feet (18" diameter, 22" long)
Feed System	1 1/2" auger and feeder barrel
Output	5 to 50 pounds per acre
Air Velocity	100 M.P.H. at 500 R.P.M.-P.T.O. speed
Air Volume	750 cubic feet per minute at 500 R.P.M.-P.T.O. speed.

John Blue sprayer. An S-707 Model (motor driven) John Blue sprayer (Figure 2) was one of the low-volume sprayers used in this experiment. It was mounted on an International Harvester tractor (Model IH-414). This sprayer had a 12 H.P.

Wisconsin air-cooled engine which drove the blower fan and the pump of the spraying system. Insecticide material was pumped through the nozzles into a powerful stream of air created by the blower fan. A 20-gallon tank was available with this sprayer; but because of the small amount of mixture to be applied and the even distribution required for the fluorescent material in the liquid carrier, a 5-gallon milk can was used in substitution for the other tank. This sprayer was designed to operate most efficiently at 2600 R.P.M. and with a liquid pressure of from 20 to 50 pounds per square inch.

Span Spray sprayer. A two-fan, low-volume, Span Spray machine (Model SS-35) was the other sprayer used in this experiment (Figure 3, page 20). It was mounted on an International Harvester tractor (Model IH-444). This tractor-P.T.O.-driven-sprayer had two main systems: (1) a hydraulic system, powered by the tractor P.T.O., which drove the two fans, and (2) the spraying system which delivered insecticide material through a nozzle placed in the center of each fan. The Span Spray machine, utilizing the hydraulically-powered propeller units, dispersed the insecticide material through 40-mesh stainless steel cages at the hubs of the propellers which turned at about 3500 R.P.M. A 100-gallon tank was available with this sprayer; but because of the same considerations referred to with the John Blue sprayer, a 5-gallon milk can was used in substitution.

Machine Calibration

The field tests in this study were performed according to the specifications listed in Tables I, II, and III. The machines were calibrated and adjusted to cover only the four rows to be treated.

Insecticides

Two insecticides, Thuricide-HP and Sevin (10 percent active ingredient for the dust and 4 pounds active ingredient per gallon for liquid), were used with each of the machines to determine which machine-insecticide combination had better control on cabbage loopers. Both insecticides were used in the liquid form for the sprayers and in the dust form for the duster.

Thuricide-HP. This is a bacterial type insecticide which has *Bacillus thuringienesis* (Berliner) as the active ingredient. This active ingredient affects the worm's stomach producing a gut paralysis. The dust form had a concentration of 90 Million International Units per pound and it is recommended for use at a rate of 20 to 60 pounds per acre of commercial material for cabbage loopers. It was used at 25 pounds per acre in this experiment. The liquid form is

TABLE I

DUSTER CALIBRATION DATA

Component or Condition	Specification
Application rate	25 pounds per acre* (lbs/acre)
Machine discharge rate	2.00 pounds per minute (lbs/min)
Swath width	4 rows (12.7 feet)
Forward speed	3.1 miles per hour (MPH)
Tractor set	Third gear - low range 1700 R.P.M. on the engine
Distributor height	17 inches above ground
Distributor angle	15° backward

*The insecticides were recommended for use at 25 lbs/acre (Thuricide HP) and 20 lbs/acre (Sevin), but because of practical considerations in the calibration of the duster only one application rate was used.

TABLE II

SPAN SPRAY CALIBRATION DATA

Component or Condition	Specification
Application rate	5 gallons per acre (GPA)
Machine discharge rate	0.32 gallons per minute per fan $\left(\frac{\text{GPM}}{\text{Fan}}\right)$
Swath width	4 rows (12.7 feet)
Forward speed	5 miles per hour (M.P.H.)
Liquid pressure	30 pounds per square inch (PSI)
Orifice plate number	4916-55 which delivers 0.33 GPM at 30 p.s.i. (TeeJet)
Nozzle height	36 inches above ground
Nozzle separation	39 inches
Tractor set	Fourth gear - low range 540 R.P.M. on the engine

TABLE III

JOHN BLUE CALIBRATION DATA

Component or Condition	Specification
Application rate	5 gallons per acre (GPA)
Machine discharge rate	0.32 gallons per minute per nozzle $\left(\frac{\text{GPM}}{\text{Nozzle}}\right)$
Swath width	4 rows (12.7 feet)
Forward speed	5 miles per hour (MPH)
Liquid pressure	25 pounds per square inch (PSI)
Flat spray tip number	8004 which delivers .32 GPM at 25 p.s.i. (TeeJet)
Nozzle height	29 inches above ground
Sprayer head angle	25° backward
Tractor set	Second gear - high range 1500 R.P.M. on the engine
Sprayer engine speed	2600 R.P.M.

recommended for use in a mixture using from one to two quarts active ingredient per acre for cabbage loopers. Here, it was used at one quart per acre.

Sevin. This is a carbamate type insecticide which acts by contact but which has slight systemic properties also. The formulations used for this experiment were: dust at 10 percent concentration and liquid at four pounds active ingredient per gallon. Sevin was recommended for use at two pounds active ingredient per acre in both dust and liquid forms. Sevin dust was used at 25 pounds per acre (for practical calibration considerations) in this experiment. Liquid form was used at half gallon active ingredient per acre. The liquid form (Sevin-Mol) had molasses in it for the purpose of attracting insects.

Fluorescent Particle Technique

The fluorescent particle (FP) method was developed by Himel (19) in 1969. This method made it possible to identify pesticide deposition by counting the number of fluorescent particles directly on the leaves of the crop. The FP method was based on the uniform suspension of a known number (2 x 10^{10} FP per gram) of solid, insoluble, micron-size (2.5 μ), fluorescent (Zn-Cd sulfide) particles in a known volume of pesticide liquid or amount of insecticide dust. Arlacel 83 was used as a suspension and dispersion aid for the FP's. Commercial dioctyl phthalate (DOP), which is an excellent solvent for pesticides, was used to stabilize the suspension of the fluorescent particles. For these tests, insecticide mixtures were prepared in 5-gallon cans for 5 G.P.A. mixture applications. The following method was used: (1) Preparation of the FP concentrate: 189 grams of FP's (concentration recommended: 2×10^8 FP per mililiter) were mixed with 378 grams of Arlacel 83 and 400 ml of DOP. The well-stirred mixture (800 ml) was allowed to stand overnight or longer and was then transported to the field. (2) Each of the insecticides was mixed for a volume of 5 gallons less the FP concentrate volume. Then, the FP concentrate was stirred again and added to the insecticide solution in agitation so an even distribution and suspension of the fluorescent particles was obtained. The agitation system continued functioning while treatment application was made. A new FP concentrate and new insecticide mix were used for each replication.

For the insecticide dusts, a concentration of four ounces of FP's per acre was used. These FP's were mixed with each of the dusts using the revolving action of the duster drum for at least one hour before the treatments so an even mixture was obtained.

Ratio of insecticide active ingredient to fluorescent particles in both dust and liquid form was the same (10:1).

The leaf samples were collected soon after each treatment and examined in a dark room under ultraviolet (U.V.) light. Figures 4 and 5 show the fluorescent particles on the top and bottom of a treated leaf. These fluorescent particles were counted by two operators using a square milimeter or a half square milimeter reticle on a 20 power microscope. The most concentrated area of FP's on the top and bottom of each leaf was selected by each operator in counting the FP's. An average of these two countings was computed and used to analyze the results.

Experimental Design

Snap beans were planted according to a predetermined statistical plan, a randomized complete block design, in which 14 38-inch rows, 50 feet in length, constituted the experimental unit. Labeling the machines that were compared A1 (Duster), A2 (Span Spray), and A3 (John Blue), and the two insecticides used B1 (Thuricide-HP) and B2 (Sevin), six treatments resulted from their combinations. These six treatments plus a check plot constituted a block which was replicated four times for a total of 28 experimental units.

Three insecticide applications were made, the first during the period August 21 and 23; the second during the period September 1, 2, and 3; and the third on September 13.

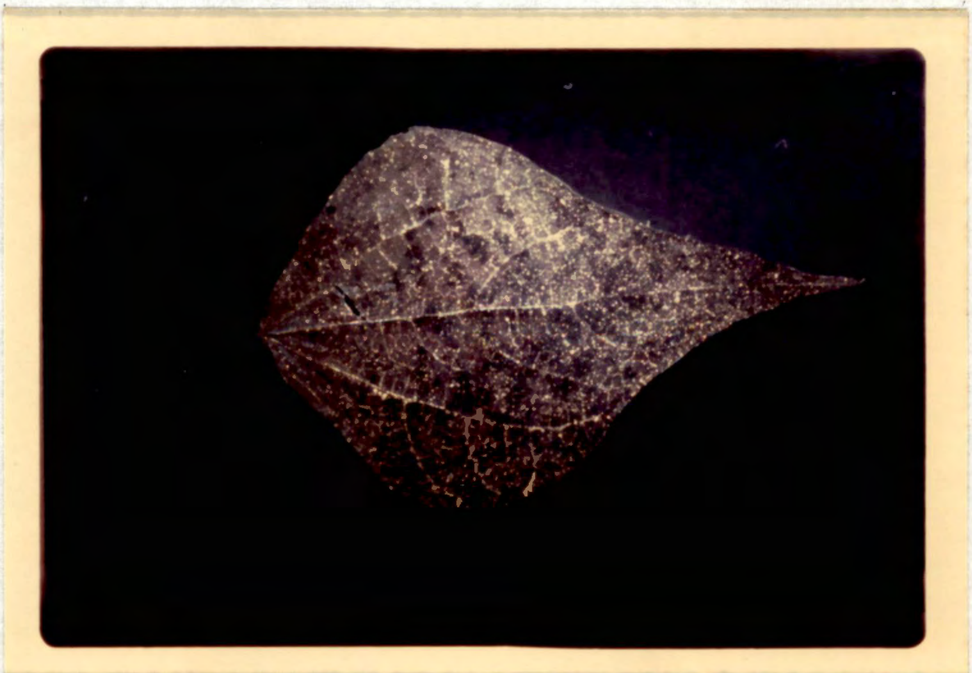


Figure 4. FP's on top of the leaf.

Figure 5. FP's on bottom of the leaf.

Rows were oriented in an east-west direction and were sprayed in the same direction. Data obtained from these applications were: First, count of insecticide particle deposition (FP's) on plant leaves which were taken from two heights, 6 inches above the ground and top of the plant. Leaf samples were taken from six plants in each plot on each of rows 1, 4, 7, 8, 11, and 14. Rows 6, 7, 8, and 9 were sprayed in each plot, but rows 7 and 8 were the ones used to determine the machine performance. Rows 1, 4, 11, and 14 were used to determine drift caused by the machines. The insecticide particle count was done at two locations on top and bottom of each leaf by means of the U.V. light and microscope with magnifying power of 20X. The other information collected was insect count from representative treated area of plots. The insect counts were made on a 10 ft. length of the two center rows (7 and 8) of each plot. The sweep method was used to collect the insects. This method consisted in sweeping the 10 ft. row length with a net six times, counting the insects collected, and keeping record of them.

Machinery Management

The use of a 5-gallon milk can on each of the low volume sprayers facilitated enormously the application of the two insecticides. After one of the insecticides was applied, the insecticide containers were exchanged on the sprayer so that minimum downtime occurred in this operation. Before the insecticide transfer was made on the machine, the spraying system was washed with soapy water and then rinsed with clean water to clean the complete spraying system and therefore avoid any effect of the previous solution on the new one. The same was done for the other sprayer. Both milk cans were adapted to the spraying system of each of the low-volume sprayers by additional plumbing.

For the duster, more downtime was required to change the insecticide in the drum. This drum had to be dismounted from the duster, the insecticide taken out, and then the drum blown out with compressed air to provide a clean drum for the other insecticide dust.

The calibration of the machines was checked before each replication.

CHAPTER IV

RESULTS AND DISCUSSION

Three sets of data were obtained from the insecticide applications: (1) insecticide particle deposition, (2) insect control, and (3) drift of the deposited material.

For the fluorescent particle data, a nested analysis of variance model was used to obtain the maximum information from this study. All of the collected data was analyzed to determine the effect of replications, blocks, machinery, insecticides, rows, heights of the plant and leaf sides on particle deposition. Also, this model provided information about the interaction of all of these factors. A similar factorial analysis was run for the insect count data to determine the insecticide effects on insect control.

An IBM 360/65 digital computer was used to perform the analysis of variance for the machine performance and for the insect control counts. Duncan's Multiple Range tests were also performed for those factors (single and two-way interactions) which were significant in the analysis of variance.

In the FP count analysis of variance (Table IV), the different effects were tested by error terms consisting of the following interactions:

TABLE IV

ANALYSIS OF VARIANCE FOR THE FP COUNTS

Source	DF	Mean Square	F Value	Prob. > F
Replication	2	474335.523	244.30877	0.0001
Block	3	23381.854	12.04294	0.0068
Error 1	6	1941.541		
Machinery	2	327282.887	19.06218	0.0002
Error 2	16	17169.224		
Insecticide	1	12385.835	1.52349	0.2272
Error 3	24	8129.922		
Row	1	27625.210	5.19514	0.0255
Error 4	48	5317.514		
Height	1	15118.752	3.24294	0.0713
Mach*Hgt	2	23649.783	5.07283	0.0082
Error 5	96	4662.049		
Side	1	304290.141	139.39650	0.0001
Mach*Side	2	9879.224	4.52571	0.0120
Insc*Side	1	13659.766	6.25759	0.0127
Hgt*Side	1	5011.460	2.29577	0.1273
Error 6	192	2182.911		
Others	176	2897.916		
Corrected Total	575	7359.923		

Error 1: Replication * Block

Error 2: Sum of Replication * Machinery and Replication * Block * Machinery.

Error 3: Replication * Insecticide plus all the interactions of Error terms 1 and 2 with Insecticide.

Error 4: Replication * Row plus all the interactions of Error terms 1, 2, and 3 with Row.

Error 5: Replication * Height plus all the interactions of Error terms 1, 2, 3, and 4 with Height.

Error 6: Replication * Side plus all the interactions of Error terms 1, 2, 3, 4, and 5 with Side.

In the analysis of variance for the insect count data, the treatment effect (machinery + insecticide) could not be broken down into its components to determine the insecticide effect alone because of the unbalanced data array gotten from this study. The criteria assumed to analyze the insecticide effect was that machinery did not have any effect on the insect control. Insect counts were made for the following insects: loopers, flea beetles, Mexican bean beetles, and others. Statistical analyses were run only for flea beetles and Mexican bean beetles because of the low population observed for the others. Insect population graphs were prepared for the first three insects mentioned above to indicate the relative population of each insect and the insecticide control of them.

Insecticide Particle Deposition

The low-volume sprayers were significantly higher in performance than the duster at the .01 and .05 levels of significance (Table IV, page 35), but there was no significant difference between the low-volume sprayers (Table V). The low-volume Span Spray unit was found to be the machine with the best performance, having a deposition mean of 122.12 fluorescent particles per square milimeter. Second was the low-volume John Blue sprayer with a deposition mean of 120.52 fluorescent particles per square milimeter. Last in rank was the duster with a deposition mean of 49.82 fluorescent particles per square milimeter. As can be seen, the insecticide particle deposition achieved with the low-volume sprayers was almost two and one half times greater than the one achieved with the duster.

The replication effect was also significant for both .01 and .05 levels of significance. The Duncan's Multiple Range test for this factor (Table V) indicated that the counts made on the third replication were greater than those of the second, and the second replication counts were greater than

TABLE V

DUNCAN'S MULTIPLE RANGE TESTS FOR THE FP COUNTS, SINGLE EFFECTS

Effects			Mean
Replication			
Third		+	143.91
Second		+	103.51
First		+	45.05
Block			
I		+	113.85
IV	+	+	101.22
II			88.72
III	+		86.15
Machinery			
Span Spray		+	122.12
John Blue		+	120.52
Duster		+	49.82
Row No.			
Seven		+	104.41
Eight		+	90.56
Side			
Top		+	120.47
Bottom		+	74.50

those of the first. This difference indicates an accumulative effect of the insecticide on the crop with succeeding replications. The block factor was also highly significant. Blocks I and II received about the same amount of insecticide and so did blocks II, III, and IV; but block I received a greater deposition than blocks II and III (Table V). Factors like plant density, foliage differences due to different fertilization levels in the soil, or presence of protruded veins (Figure 6) could have contributed to this difference between blocks. Another significative factor at the .05 level of significance was the row factor. Row number seven received more insecticide deposition than row number eight from each of the machines, but the interaction of machines and rows was not significant. Misalignment of the machines from the center rows due to some freedom on the tractor linkage or difficulties found in steering the equipment through the center rows may have been reasons for this difference. Finally, the last significant main effect was that of leaf sides, which was highly significant. Data indicated that the top of the leaf received a better deposition of insecticide material than the bottom for each of the three machines. This fact can be discussed more clearly with reference to the machinery and leaf side interaction which was significant at the .05 probability level. The Duncan's Multiple Range test for this interaction (Table VI) indicated that the low-volume sprayers deposited a

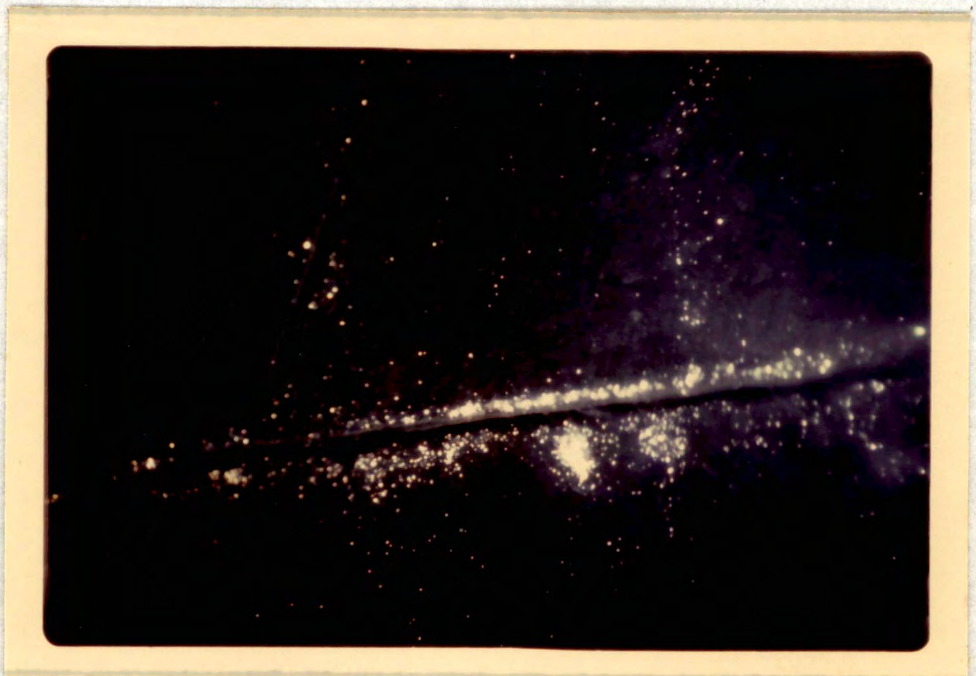


Figure 6. Protruded veins effect.

TABLE VI

DUNCAN'S MULTIPLE RANGE TESTS FOR THE FP COUNTS, TWO-WAY EFFECTS

Mach*Hgt

No.			Mean	Effects: Mach	Effects: Hgt
1		+	137.73	2	2
2	+	|	126.78	3	2
3	|	+	114.26	3	1
4	+		106.51	2	1
5		+	56.32	1	1
6		+	43.32	1	2

Mach*Side

No.		Mean	Mach	Side
1	+	152.89	2	1
2	+	142.07	3	1
3	+	98.97	3	2
4	+	91.35	2	2
5	+	66.46	1	1
6	+	33.19	1	2

Insc*Side

No.		Mean	Insc	Side
1	+	129.98	1	1
2	+	110.97	2	1
3	+	74.74	2	2
4	+	74.27	1	2

Code:
Mach 1: Duster
Mach 2: Span Spray Sprayer
Mach 3: John Blue Sprayer
Hgt 1: 6" above the ground
Hgt 2: Top of the plant

Side 1: Top of the leaf
Side 2: Bottom of the leaf
Insc 1: Thuricide-HP
Insc 2: Sevin

greater amount of insecticide material at the top of the leaf than at the bottom, and there was no difference between these machines with respect to this deposition rate differential. The duster also deposited better at the top of the leaf, but there was less difference between depositions on top and bottom with this machine.

The insecticide main effect and that of plant height at which the leaves were taken, were not significant, but the machinery and height and insecticide and side interactions were significant (Table IV, page 35). The machinery and height interaction (Table VI) showed that the low-volume Span Spray unit sprayed better at the top of the plant than at six inches above the ground and that the low-volume John Blue sprayer and the duster applied insecticide uniformly throughout different heights of the plant. This difference may have resulted from the more direct air stream of the John Blue unit and duster which achieved a good penetration of air-insecticide mix into the plant. The low-volume Span Spray unit had an air pattern which covered a wider area and may have produced a packing together of foliage. This action possibly led to a lower deposit of insecticide in the lower portion of the plant. Generally, the low-volume sprayers produced a greater deposit of insecticide at either of the two locations on the plant than the duster.

The insecticide and leaf side interaction showed that Thuricide HP had a better adherence at the top of the leaf than Sevin but both insecticides had better adherence at the top of the leaf than at the bottom.

Figure 7 shows the height and leaf side interaction. Although this interaction was not significant, the means show that the top of the leaf received more insecticide material than the bottom for both heights at which the leaf samples were taken.

Insect Control

Figure 8 shows means of the three main insect populations collected throughout the three replications. Looper population was too low for statistical analysis of control gained by treatments; however, it appeared they were more effectively controlled by Sevin. Greater populations of the other two insects are indicated for those treatments containing Thuricide-HP than Sevin.

The analysis of variance for the flea beetle insects showed that there was significant difference for replications and treatments at the .05 and .01 levels of significance, respectively (Table VII). The Duncan's Multiple Range test for the replication effect (Table VIII) indicated that there was control of the flea beetles throughout the experiment, but the same test for the treatment effect did not show

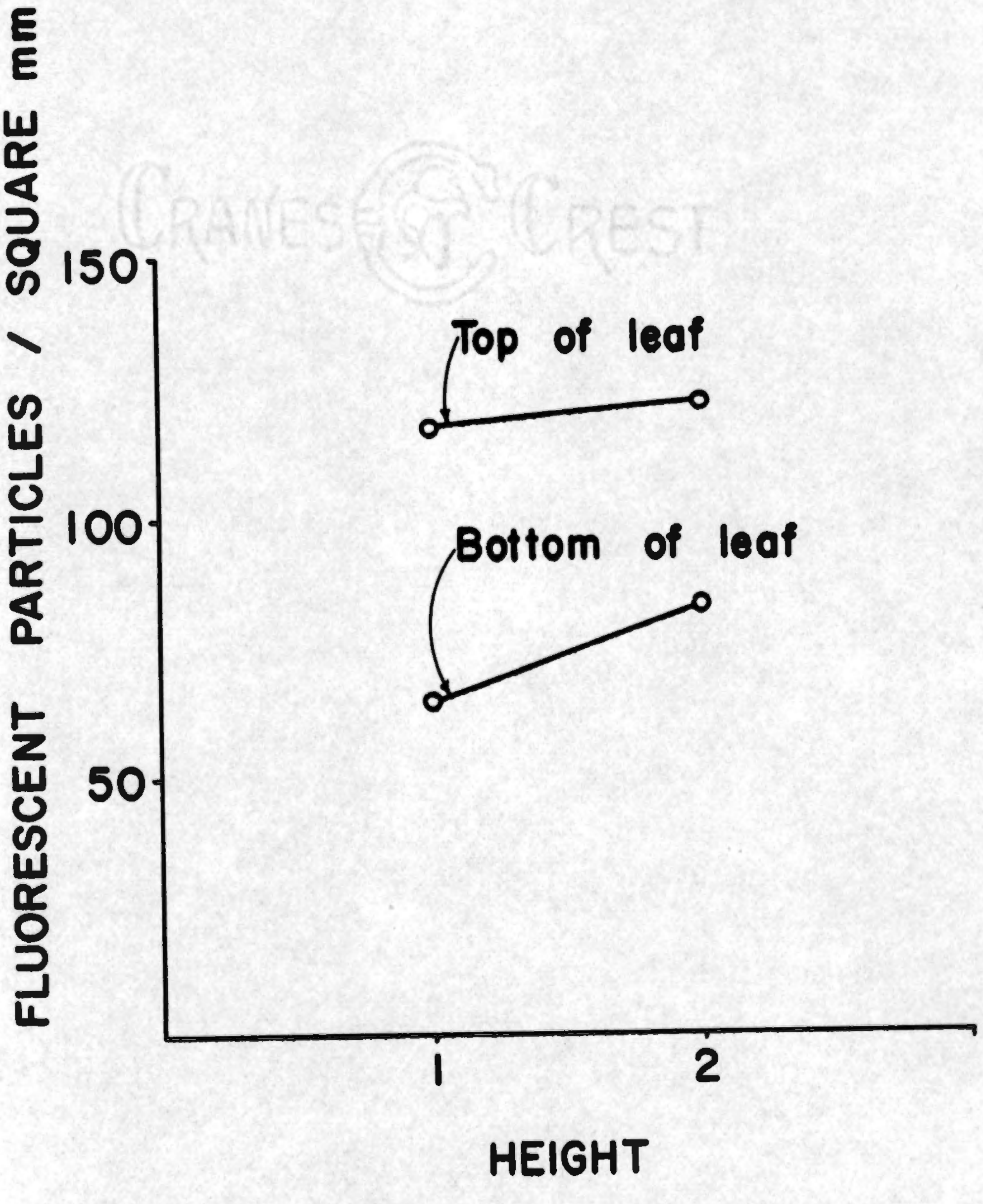


Figure 7. Height and side interaction.

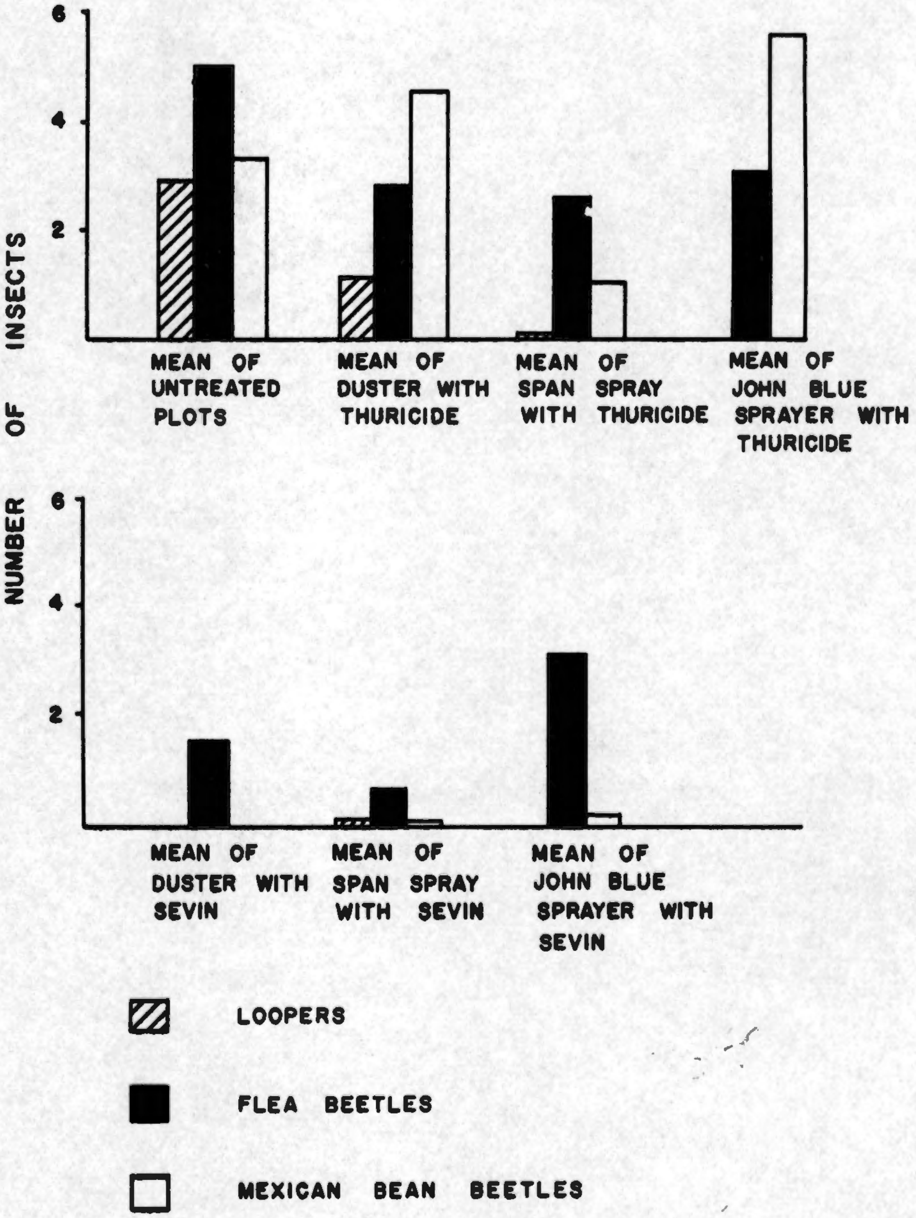


Figure 8. Insect populations.

TABLE VII

ANALYSIS OF VARIANCE FOR FLEA BEETLE COUNTS

Source	D.F.	Mean Square	F Value	Prob. > F
Replications	2	6.446	4.484	0.0129
Treatments	6	5.055	3.516	0.0032
Others	22	2.372		
Residual	137	1.438		
Corrected Total	167	1.751		

TABLE VIII

DUNCAN'S MULTIPLE RANGE TESTS FOR FLEA BEETLES

Effects			Mean
<u>Replication</u>			
First		+	1.25000
Third		+	0.78571
Second		+	0.58929
<u>Treatment</u>			
Check		+	1.66667
John Blue with Sevin	+	|	1.04167
John Blue with Thuricide	|	+	1.00000
Duster with Thuricide	|	+	0.91667
Span Spray with Thuricide	|	|	0.79167
Duster with Sevin	+	|	0.50000
Span Spray with Sevin		+	0.20833

clearly which insecticide had better control on these insects. By count, a higher control with Sevin was observed.

The Mexican bean beetle analysis of variance (Table IX) showed that replications and treatments were significant, both at .01 level of probability. The Duncan's Multiple Range test for these effects (Table X) showed that for replication effect, the third replication had more Mexican bean beetles than the first two replications. This fact indicates poor control on them. For the treatment effect, treatments containing Sevin were much more effective in control than the ones containing Thuricide HP.

Drift Caused by the Machines

Insecticide drift produced by each of the machines is shown in Figures 9, 10, and 11 for the first, second, and third replications, respectively. Particle counts on leaves from nontreated rows indicate the drift for each machine and each insecticide used in the research. Figure 9 shows that the duster and the low-volume John Blue sprayer produced a higher drift than the low-volume Span Spray unit. It also shows that the FP counts for the duster and John Blue sprayer drift were sometimes higher than those counts for the treated rows. During this replication, wind blew toward west-southwest at 7 M.P.H. (Table XIII in the Appendix) for the A1B1 and A3B2 treatments, which could lead to the slightly higher drift

TABLE IX

ANALYSIS OF VARIANCE FOR MEXICAN BEAN BEETLE COUNTS

Source	D.F.	Mean Square	F. Value	Prob. > F
Replications	2	33.881	13.170	0.0001
Treatment	6	14.784	5.747	0.0001
Others	22	6.010		
Residual	137	2.573		
Corrected Total	167	3.839		

TABLE X

DUNCAN'S MULTIPLE RANGE TESTS FOR MEXICAN BEAN BEETLES

Effects			Mean
Replication			
Third		+	1.57143
Second		+	0.46429
First		+	0.07143
Treatment			
John Blue with Thuricide		+	1.87500
Duster with Thuricide		|	1.50000
Check	+	+	1.12500
Span Spray with Thuricide	+	+	0.33333
John Blue with Sevin		|	0.08333
Duster with Sevin		|	0.0
Span Spray with Sevin		+	0.0

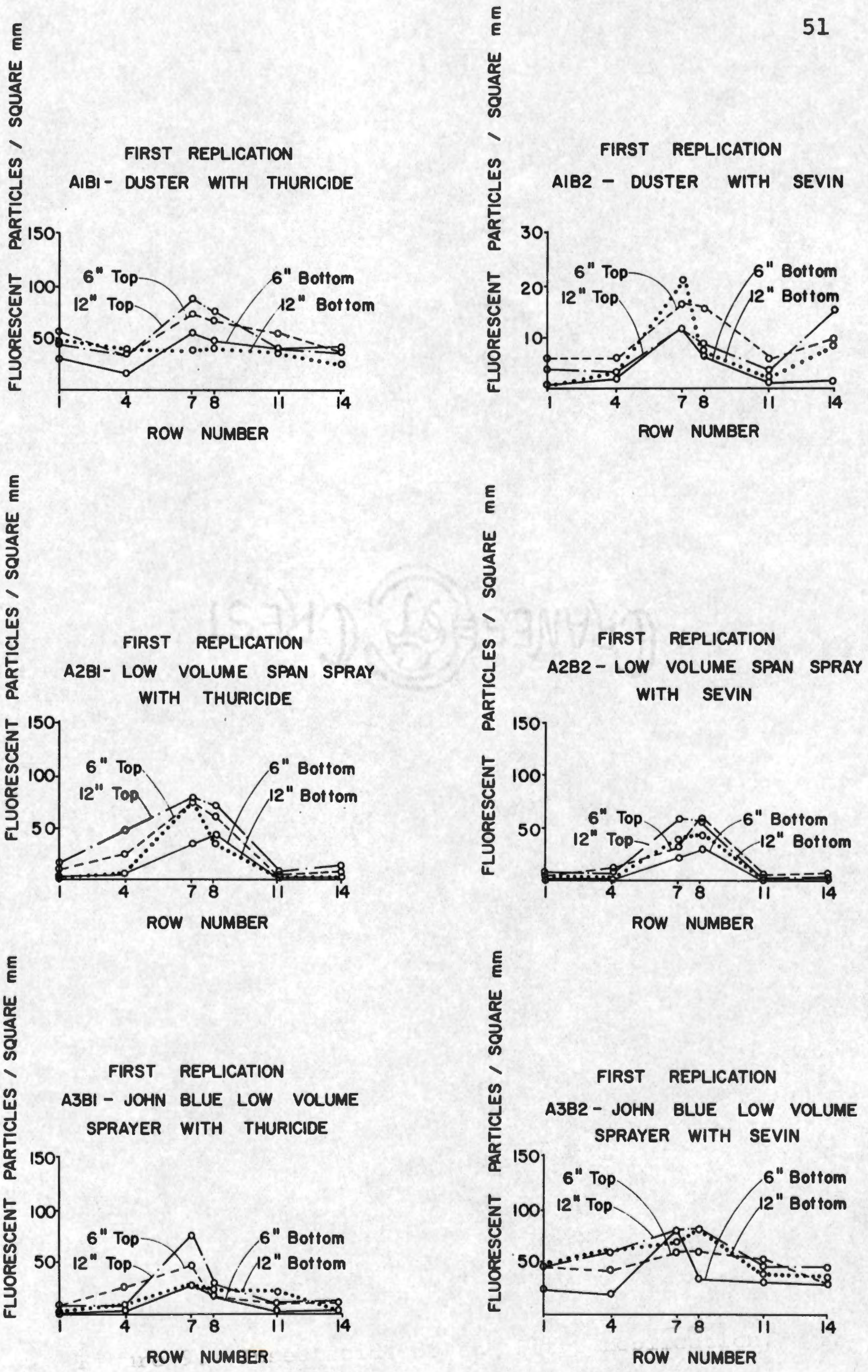


Figure 9. Insecticide drift--first replication.

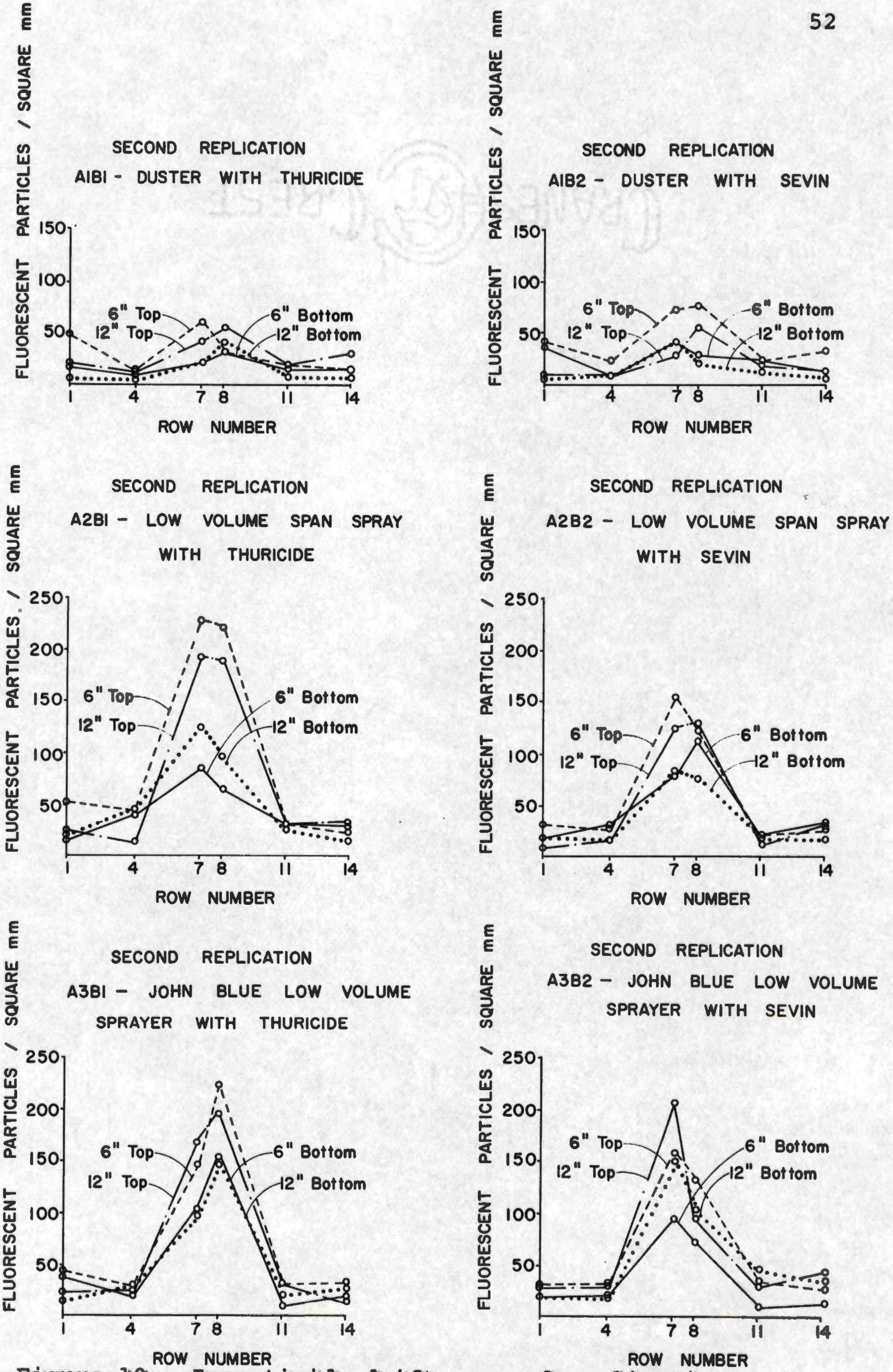
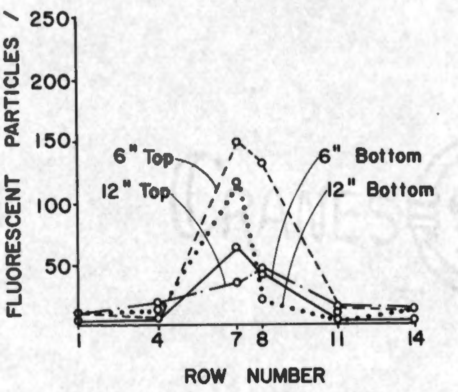
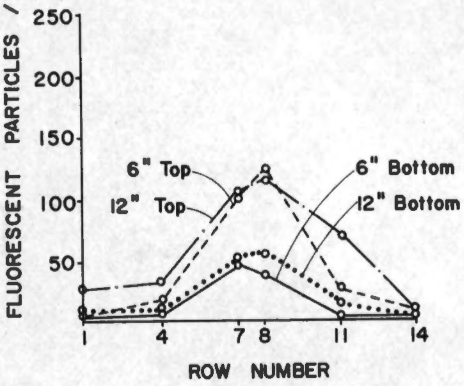


Figure 10. Insecticide drift--second replication.

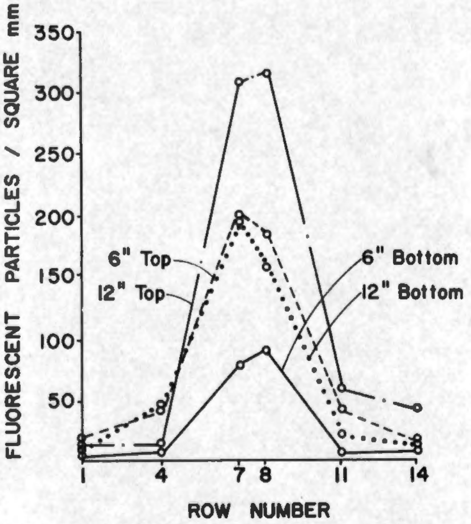
THIRD REPLICATION
A1B1 - DUSTER WITH THURICIDE



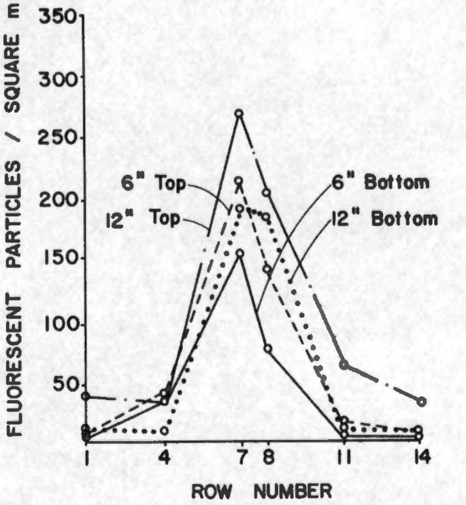
THIRD REPLICATION
A1B2 - DUSTER WITH SEVIN



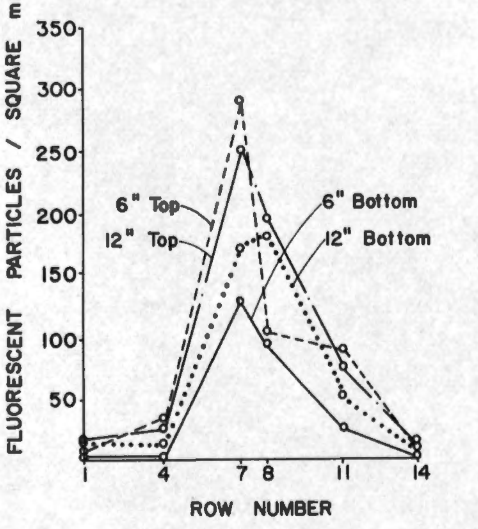
THIRD REPLICATION
A2B1 - LOW VOLUME SPAN SPRAY
WITH THURICIDE



THIRD REPLICATION
A2B2 - LOW VOLUME SPAN SPRAY
WITH SEVIN



THIRD REPLICATION
A3B1 - JOHN BLUE LOW VOLUME
SPRAYER WITH THURICIDE



THIRD REPLICATION
A3B2 - JOHN BLUE LOW VOLUME
SPRAYER WITH SEVIN

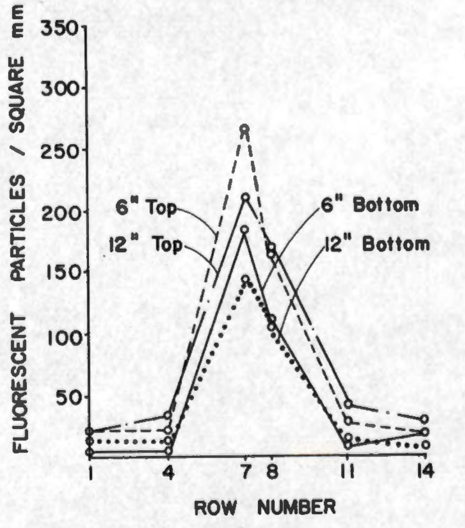


Figure 11. Insecticide drift--third replication.

counts on the southern rows (1 and 4) of these treatments. For the other treatments of this replication, wind blew toward north-northwest at 6 M.P.H. which could explain the higher drift counts for the northern rows (11 and 14) of the treatment A1B2 in particular.

Figure 10 shows higher FP counts for the drift and machine performance determinations (treated rows) which indicates an accumulative effect of the insecticides for the second replication over the first. This figure also shows that the duster produced a higher relative drift than the low-volume sprayers if a comparison is made for each machine of the ratio of particle counts on unsprayed to sprayed rows. During this second replication, wind blew from the north at 7 M.P.H. for all the treatments. Higher drift counts, in general, were observed for the southern rows, especially for the duster treatments.

Figure 11 shows that the low-volume sprayers produced a slightly higher drift than the duster and that the drift counts were lower than the ones for the second replication. Rains occurred before this replication, especially on September 3 (.32 in.), which could have washed away the material accumulated during the first two replications and therefore caused lower drift counts to be observed. Wind blew from the west at 10-12 M.P.H. in the direction of the plant rows during this replication which may account for the low drift observed for this replication.

Figure 12. Insecticide drift caused by the duster.

Figure 12 shows clearly the drift produced by the duster during each of the treatments, but this effect seems not to be recorded in the counts for drift determination. Perhaps the particles of insecticide in this cloud drifted over nearby areas and settled on plants outside that area used for data collection.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objective of this research was to evaluate the effectiveness of two makes of low-volume sprayer and one make of duster in applying two types of insecticide for controlling cabbage loopers on snap beans. To accomplish this objective a low-volume Span Spray unit, a low-volume John Blue sprayer, and a conventional duster were used. Field tests were performed using the fluorescent particle technique to assess the machine performance. Insect population counts were made to evaluate the insecticide control. These tests were performed during August and September, 1971, at the Cumberland Plateau Experiment Station at Crossville, Tennessee.

The following conclusions were drawn from the treatment data means evaluated at the .01 and .05 levels of significance via Duncan's Multiple Range tests:

Machine Performance

1. The low-volume sprayers were more efficient than the duster. Number of particles of insecticide deposited on plant leaves by the sprayers were about two and one half times greater than the number deposited by the duster. No significant difference was detected between the low-volume sprayers.

2. The John Blue sprayer and the Gustafson duster deposited particles uniformly throughout the plant, but the Span Spray machine deposited more particles at the top of the plant than on the foliage at lower levels.

3. The top of the leaf received more insecticide material than the bottom from each of the machines and at any height of the plant considered in this study.

4. The low-volume Span Spray unit apparently produced the least drift, although statistical evidence to document this observation was not obtained.

Insect Control

1. The treatments containing Thuricide HP did not control the insect populations other than that of loopers.

2. The treatments containing Sevin showed good control on Mexican bean beetles but not on flea beetles. Sevin controlled loopers.

Suggestions for Further Studies in this Area

Studies are recommended with this type of machinery for the determination of air pattern velocity and air volume influence on the machine performance. Also, determination of drift to nearby areas of the research place is recommended.

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APPENDIX

TABLE XI

FLUORESCENT PARTICLE COUNTS PER SQUARE M.M.

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
				First Replication--Row No. 1						
A1B1										
6	100	54	31	28	48	36	11	20	53	29
12	47	53	40	33	53	41	41	51	43	47
A1B2										
6	10	7	2	3	1	3	0	1	6	1
12	8	2	3	3	1	2	1	1	4	1
A2B1										
6	5	14	5	17	2	2	2	1	10	2
12	21	6	13	17	1	2	1	2	14	1
A2B2										
6	20	1	5	1	1	1	1	0	7	1
12	20	2	2	16	6	1	3	1	10	3
A3B1										
6	4	2	18	10	1	1	3	0	9	1
12	6	2	2	22	1	2	2	1	8	2

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
A3B2										
6	42	43	40	46	23	26	15	29	43	23
12	63	53	20	37	37	56	19	57	43	42
Check										
6	1	2	2	3	1	0	1	1	2	1
12	1	3	18	1	1	2	1	1	6	1
First Replication--Row No. 4										
A1B1										
6	45	33	27	19	36	21	11	12	31	20
12	46	25	27	27	61	29	31	20	31	35
A1B2										
6	13	3	4	4	1	2	2	4	6	2
12	4	2	2	4	1	1	4	5	3	3
A2B1										
6	30	18	9	29	6	1	5	2	22	4
12	58	39	14	71	6	2	2	4	46	4
A2B2										
6	46	1	1	9	1	3	1	1	14	2
12	11	11	8	10	7	2	1	1	10	3

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
A3B1										
6	4	2	2	88	6	1	1	1	24	3
12	5	2	8	14	1	3	1	21	7	7
A3B2										
6	79	33	18	22	43	13	8	16	38	20
12	92	37	43	58	128	34	41	26	58	57
Check										
6	1	3	3	3	0	1	1	2	3	1
12	3	2	4	3	1	1	1	3	3	2
First Replication--Row No. 7										
A1B1										
6	63	47	71	104	45	43	43	81	71	53
12	156	38	42	109	33	30	46	31	86	35
A1B2										
6	12	17	22	16	7	13	8	19	17	12
12	21	17	13	17	18	9	18	42	17	22
A2B1										
6	81	35	109	53	19	22	38	47	70	32
12	83	83	71	59	71	39	102	68	74	70

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
A2B2										
6	36	35	30	33	12	52	22	11	34	24
12	73	68	80	29	54	57	12	24	63	38
A3B1										
6	47	35	53	42	26	28	9	42	44	26
12	96	39	101	52	11	44	22	28	72	26
A3B2										
6	56	55	31	89	76	83	118	38	58	79
12	127	62	42	90	79	99	66	26	80	68
Check										
6	2	2	1	6	0	2	0	1	3	1
12	1	4	8	7	2	1	1	0	5	1
First Replication--Row No. 8										
A1B1										
6	71	66	39	77	26	52	34	72	63	46
12	145	51	29	56	59	20	26	37	70	36
A1B2										
6	7	10	25	21	5	11	6	7	16	7
12	8	11	11	4	3	5	20	5	9	8

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
A2B1										
6	77	62	77	28	20	19	96	31	61	42
12	63	114	19	70	51	23	53	18	67	36
A2B2										
6	24	98	50	81	63	15	28	27	63	33
12	79	76	45	46	54	25	56	24	62	40
A3B1										
6	17	3	14	33	11	1	5	54	17	18
12	24	13	16	55	68	2	8	5	27	21
A3B2										
6	57	98	28	41	50	76	9	10	56	36
12	262	9	34	19	278	16	21	10	83	81
Check										
6	1	4	1	4	2	3	0	2	3	2
12	9	3	0	8	11	2	3	2	5	5
First Replication--Row No. 11										
A1B1										
6	79	81	32	14	27	41	60	24	52	38
12	46	25	70	12	53	32	42	13	38	35

TABLE XI (continued)

Treatment Height (in.)	Average Count									
	Top				Bottom				Mean Count	
	Blocks				Blocks					
	I	II	III	IV	I	II	III	IV	Top	Bottom
A1B2										
6	10	3	6	4	1	1	0	1	6	1
12	2	10	1	2	3	1	1	1	4	2
A2B1										
6	5	4	3	4	1	1	2	2	4	2
12	8	2	10	4	2	2	1	3	6	2
A2B2										
6	12	1	12	2	1	1	2	0	7	1
12	8	2	4	2	3	1	2	1	4	2
A3B1										
6	3	14	7	3	11	2	1	1	7	4
12	11	3	3	16	68	2	3	3	8	19
A3B2										
6	60	78	29	36	39	61	23	10	51	33
12	59	28	30	62	30	41	31	50	45	38
Check										
6	3	2	2	2	1	3	1	1	2	2
12	2	3	2	3	0	3	0	2	3	1

TABLE XI (continued)

Treatment	Average Count									
	Top				Bottom					
	Blocks				Blocks				Mean Count	
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
First Replication--Row No. 14										
A1B1										
6	36	24	33	42	43	23	19	13	34	25
12	35	40	36	25	38	51	39	27	34	39
A1B2										
6	6	9	16	7	2	1	1	2	10	2
12	13	17	31	4	28	2	4	3	16	9
A2B1										
6	2	10	2	14	1	2	0	3	7	2
12	20	14	2	10	1	1	1	4	12	2
A2B2										
6	2	2	6	5	1	1	2	3	4	2
12	3	1	6	2	2	2	2	1	3	2
A3B1										
6	11	5	6	19	2	1	3	2	10	2
12	2	5	7	26	5	2	3	2	10	3
A3B2										
6	37	29	14	30	39	15	25	30	28	27
12	22	72	22	57	49	43	23	14	43	32
Check										
6	2	4	2	6	12	1	1	5	4	5
12	1	4	2	19	6	5	2	3	7	4

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
Second Replication--Row No. 1										
A1B1										
6	11	11	143	32	29	16	17	6	49	17
18	36	18	12	14	11	5	4	8	20	7
A1B2										
6	25	98	14	8	19	91	5	13	36	32
18	22	8	18	4	12	7	16	5	13	10
A2B1										
6	93	71	30	14	34	23	6	5	52	15
18	39	9	34	12	35	20	20	7	24	21
A2B2										
6	51	25	30	19	14	36	17	5	31	18
18	10	7	16	12	46	6	8	11	11	18
A3B1										
6	111	14	17	39	142	7	7	3	45	40
18	45	30	15	9	54	10	4	4	25	18
A3B2										
6	41	40	31	13	48	11	6	15	31	20
18	47	22	35	4	19	46	15	5	27	21
Check										
6	16	79	35	4	44	21	32	3	34	25
18	17	15	9	8	7	7	19	4	12	9

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	83	89	III	IV	Top	Bottom
Second Replication--Row No. 4										
A1B1										
6	13	17	18	17	12	5	13	10	16	10
18	9	7	23	13	11	5	9	6	13	8
A1B2										
6	68	8	9	8	12	23	4	9	23	12
18	15	17	17	8	24	10	9	8	14	13
A2B1										
6	66	80	17	21	30	83	27	7	46	37
18	23	15	7	7	46	73	6	35	13	40
A2B2										
6	56	17	13	22	36	25	6	52	27	30
18	11	29	8	20	12	20	4	25	17	15
A3B1										
6	69	34	13	11	57	24	4	7	32	23
18	63	22	12	12	91	11	9	7	27	30
A3B2										
6	100	8	14	15	49	12	13	9	34	21
18	54	33	24	16	35	11	23	5	32	19
Check										
6	19	15	28	26	12	11	26	20	22	17
18	14	19	12	71	8	14	8	11	29	10

TABLE XI (continued)

Treatment Height (in.)	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
	I	II	III	IV	I	II	III	IV	Top	Bottom
Second Replication--Row No. 7										
A1B1										
6	59	23	14	149	17	23	15	34	61	22
18	74	12	19	66	40	15	10	28	43	23
A1B2										
6	151	60	41	41	33	68	31	11	73	38
18	22	37	13	41	64	33	6	39	28	36
A2B1										
6	311	210	96	293	119	139	20	67	228	86
18	229	267	136	125	213	155	62	74	189	126
A2B2										
6	84	260	114	150	112	40	97	58	152	77
18	139	112	106	137	91	97	61	77	124	82
A3B1										
6	55	41	334	142	29	62	113	228	143	108
18	115	164	163	222	37	61	141	159	166	100
A3B2										
6	181	186	95	179	99	103	22	157	160	95
18	230	203	103	286	145	96	161	199	206	150
Check										
6	12	10	9	8	15	11	7	5	10	10
18	10	6	15	14	12	4	13	7	11	9

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
	Second Replication--Row No. 8									
A1B1										
6	40	20	13	59	17	34	17	64	33	33
18	12	68	18	124	41	49	14	50	56	39
A1B2										
6	162	38	55	49	40	13	35	27	76	29
18	123	64	16	19	37	32	10	7	56	22
A2B1										
6	316	153	217	192	90	69	70	30	220	65
18	170	129	268	166	175	68	60	80	183	96
A2B2										
6	82	87	255	64	134	90	114	119	122	114
18	99	61	181	168	74	64	82	80	127	75
A3B1										
6	296	167	212	216	245	119	180	61	223	152
18	245	214	143	178	220	161	79	108	195	142
A3B2										
6	153	33	133	203	47	19	30	99	131	74
18	197	19	146	20	152	23	53	178	96	102
Check										
6	43	15	8	12	45	8	12	10	20	19
18	23	9	8	12	21	6	8	3	13	10

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
	Second Replication--Row No. 11									
A1B1										
6	23	23	12	23	10	28	19	14	20	18
18	17	22	26	19	6	7	6	11	21	8
A1B2										
6	37	10	25	8	75	8	4	7	20	24
18	28	25	13	16	23	17	7	8	21	14
A2B1										
6	22	66	22	12	19	93	8	7	31	32
18	55	33	38	6	37	54	5	7	33	26
A2B2										
6	39	16	5	10	17	28	26	8	18	20
18	24	14	8	14	6	47	21	11	15	21
A3B1										
6	53	9	12	10	21	11	6	6	21	11
18	65	31	12	16	30	9	5	35	31	20
A3B2										
6	22	8	35	56	7	15	8	20	30	13
18	27	41	63	13	79	14	79	16	36	47
Check										
6	35	6	12	13	28	11	15	5	17	15
18	52	30	25	18	24	7	8	14	31	13

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
	Second Replication--Row No. 14									
A1B1										
6	31	8	9	17	25	5	13	14	16	14
18	37	41	12	27	8	7	12	7	29	9
A1B2										
6	25	15	67	25	8	7	30	10	33	14
18	13	12	19	16	13	6	4	11	15	9
A2B1										
6	22	53	12	9	31	57	11	4	24	26
18	53	43	11	12	21	39	4	9	30	18
A2B2										
6	19	49	36	8	41	74	8	7	28	33
18	49	29	31	10	61	7	4	17	30	22
A3B1										
6	73	25	7	29	47	5	20	3	34	19
18	15	20	16	16	39	12	36	17	17	26
A3B2										
6	31	36	5	40	30	11	6	16	28	16
18	56	98	17	17	128	4	4	6	47	36
Check										
6	12	9	39	11	6	22	12	7	18	12
18	14	9	8	19	11	19	11	3	13	11

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
	Third Replication--Row No. 1									
A1B1										
6	7	5	5	16	2	6	2	2	8	3
18	14	4	10	4	25	3	5	3	8	9
A1B2										
6	7	2	4	5	4	5	3	6	5	5
18	8	13	63	9	2	5	18	8	26	8
A2B1										
6	28	6	14	31	5	4	2	6	20	4
18	8	8	17	34	14	20	3	18	17	14
A2B2										
6	12	6	3	7	3	12	2	3	7	5
18	46	53	12	48	18	10	6	11	40	11
A3B1										
6	10	7	5	14	3	8	3	4	9	5
18	40	7	6	14	3	6	41	10	17	15
A3B2										
6	21	40	15	6	7	4	4	6	21	5
18	6	47	5	31	6	24	20	3	22	13
Check										
6	8	6	3	11	4	1	11	3	7	5
18	31	18	3	44	4	4	5	3	24	4

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
Third Replication--Row No. 4										
A1B1										
6	9	6	4	4	4	5	5	1	6	4
18	53	5	2	10	8	4	14	13	18	10
A1B2										
6	24	29	12	7	16	9	2	2	18	7
18	9	74	35	12	7	6	27	3	33	11
A2B1										
6	66	21	7	62	9	16	1	2	39	7
18	15	29	3	8	157	15	3	4	14	45
A2B2										
6	107	31	17	7	11	6	27	3	41	37
18	41	64	18	29	41	6	2	1	38	13
A3B1										
6	15	78	4	48	5	7	1	5	36	5
18	4	14	3	87	1	40	8	5	27	13
A3B2										
6	37	20	4	21	2	7	2	4	21	4
18	76	20	14	16	5	37	9	4	32	14
Check										
6	21	6	3	8	6	4	3	5	10	5
18	18	6	4	14	3	15	3	7	11	7

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
Third Replication--Row. No. 7										
A1B1										
6	194	94	70	236	46	71	30	109	149	64
18	26	43	54	12	16	21	25	5	34	17
A1B2										
6	152	37	126	92	78	12	69	33	102	48
18	29	146	138	121	20	14	116	55	109	51
A2B1										
6	274	279	197	52	156	57	82	23	201	80
18	328	352	263	296	146	171	173	307	310	199
A2B2										
6	295	122	279	158	205	118	131	161	214	154
18	316	212	236	316	121	231	213	196	270	190
A3B1										
6	236	386	186	345	189	82	107	141	288	130
18	324	310	177	205	215	198	162	106	254	170
A3B2										
6	199	352	241	272	205	220	158	160	266	186
18	286	212	183	161	188	117	175	95	211	144
Check										
6	32	7	5	8	2	2	1	3	13	2
18	30	16	5	12	2	7	1	11	16	5

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
Third Replication--Row No. 8										
A1B1										
6	133	41	92	278	39	32	20	67	136	40
18	19	18	26	123	18	22	36	17	47	23
A1B2										
6	61	229	82	131	16	83	19	42	126	40
18	42	58	145	234	23	12	108	84	120	57
A2B1										
6	242	133	68	279	89	71	108	101	181	92
18	250	315	468	222	104	193	203	129	314	157
A2B2										
6	181	148	79	139	135	72	58	50	137	79
18	222	241	149	222	214	220	119	179	209	183
A3B1										
6	322	83	13	16	347	8	15	10	109	95
18	274	151	135	234	173	273	56	205	199	177
A3B2										
6	182	38	194	237	217	201	11	22	163	113
18	167	35	147	322	41	55	72	272	168	110
Check										
6	8	14	8	5	5	4	1	4	9	4
18	39	23	7	14	6	3	2	6	21	4

TABLE XI (continued)

Treatment	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
Height (in.)	I	II	III	IV	I	II	III	IV	Top	Bottom
Third Replication--Row. No. 11										
A1B1										
6	12	8	14	8	2	5	6	2	11	4
18	5	35	6	5	3	5	7	1	13	4
A1B2										
6	17	10	83	6	6	3	2	6	29	4
18	44	42	190	4	32	8	22	3	70	16
A2B1										
6	58	63	45	7	12	5	6	6	43	7
18	75	89	42	41	33	5	35	13	62	22
A2B2										
6	12	4	15	3	20	6	3	2	10	8
18	83	45	88	44	12	29	8	22	65	18
A3B1										
6	315	4	38	4	93	5	3	8	90	27
18	223	44	31	8	202	5	2	2	77	53
A3B2										
6	25	8	66	10	12	9	2	11	27	9
18	65	16	30	47	8	7	19	12	40	12
Check										
6	29	3	3	8	2	3	3	10	11	5
18	48	10	7	8	2	3	2	6	18	3

TABLE XI (continued)

Treatment Height (in.)	Average Count								Mean Count	
	Top				Bottom					
	Blocks				Blocks					
	I	II	III	IV	I	II	III	IV	Top	Bottom
	Third Replication--Row No. 14									
A1B1										
6	5	22	3	4	7	2	2	1	9	3
18	7	14	6	4	7	10	21	3	8	10
A1B2										
6	24	11	6	6	5	3	1	6	12	4
18	11	13	17	6	4	3	1	5	12	4
A2B1										
6	17	14	5	27	6	19	3	2	16	8
18	83	83	3	10	10	28	4	6	45	12
A2B2										
6	4	7	10	14	2	7	4	2	9	4
18	44	6	17	67	4	14	8	2	34	7
A3B1										
6	14	11	8	2	3	4	6	2	9	4
18	33	5	8	4	6	20	2	2	13	8
A3B2										
6	57	8	5	15	40	8	15	8	21	18
18	16	79	10	15	12	15	3	8	30	10
Check										
6	14	7	4	9	1	3	4	6	9	4
18	17	6	4	9	4	3	3	3	9	3

TABLE XII

INSECT COUNT AVERAGE

Treatment	Row 7 Replication No.	Row 8 Replication No.	Count, Average for Four Blocks		
			Loopers	Flea Beetles	Mexican Bean Beetles
A1B1	1		0.00	1.75	0.00
	2		1.00	0.25	1.50
	3		0.25	0.50	0.75
	Total		1.25	2.50	2.25
		1	0.00	2.00	0.00
		2	0.75	0.50	1.50
		3	0.25	0.50	5.25
		Total	1.00	3.00	6.75
A1B2	1		0.00	1.00	0.00
	2		0.00	1.25	0.00
	3		0.00	0.00	0.00
	Total		0.00	2.25	0.00
		1	0.00	0.75	0.00
		2	0.00	0.00	0.00
		3	0.00	0.00	0.00
		Total	0.00	0.75	0.00
A2B1	1		0.00	2.00	0.00
	2		0.00	1.25	0.50
	3		0.00	0.00	1.00
	Total		0.00	3.25	1.50

TABLE XII (continued)

Treatment	Row 7 Replication No.	Row 8 Replication No.	Count, Average for Four Blocks		
			Loopers	Flea Beetles	Mexican Bean Beetles
		1	0.00	0.75	0.00
		2	0.00	0.75	0.25
		3	0.25	0.50	0.25
		Total	0.25	2.00	0.50
A2B2	1		0.00	0.00	0.00
	2		0.00	0.50	0.00
	3		0.25	0.00	0.25
	Total		0.25	0.50	0.25
		1	0.00	0.75	0.00
		2	0.00	0.00	0.00
		3	0.00	0.00	0.00
		Total	0.00	0.75	0.00
A3B1	1		0.00	1.25	0.25
	2		0.00	1.00	0.25
	3		0.00	0.75	4.50
	Total		0.00	3.00	5.00
		1	0.00	1.75	0.00
		2	0.00	0.75	0.75
		3	0.00	0.75	5.25
		Total	0.00	3.25	6.00
A3B2	1		0.00	0.50	0.00
	2		0.00	0.00	0.00
	3		0.00	0.75	0.00
	Total		0.00	1.25	0.00

TABLE XII (continued)

Treatment	Row 7 Replication No.	Row 8 Replication No.	Count, Average for Four Blocks		
			Loopers	Flea Beetles	Mexican Bean Beetles
		1	0.00	3.25	0.25
		2	0.00	0.25	0.00
		3	0.00	1.50	0.25
		Total	0.00	5.00	0.50
Check	1		0.00	1.50	0.25
	2		2.00	0.50	0.75
	3		0.75	2.50	2.25
	Total		2.75	4.50	3.25
		1	0.00	0.75	0.00
		2	1.25	1.50	1.00
		3	1.75	3.25	2.50
		Total	3.00	5.50	3.50

TABLE XIII

WEATHER DURING SPRAYING ACCORDING TO DATE

Date	Wind Direction	Wind Speed (MPH)	Rain (in.)
August 21	Toward West-Southwest	7	.23
August 23	Toward North-Northwest	6	.04
September 1	Toward South	7	Trace
September 2	Toward South	7	.02
September 3	Toward South	7-8	.32
September 13	Toward West	10-12	Trace

VITA

Hugo E. Perez was born in Betijoque, Trujillo, Venezuela, on April 3, 1943. He was educated in the public school system of Cabimas and was graduated from Hermagoras Chavez High School in 1961. He received an Agronomic Engineer degree from Universidad del Zulia at Maracaibo, Venezuela, in 1966. In January of 1967 he joined the staff of this university to teach agricultural machinery with the rank of Instructor. In 1969 he gained the rank of Assistant Professor. In September of 1970 he entered the graduate School of The University of Tennessee to obtain his M.S. in Agricultural Mechanization. In March of 1972, he expects to receive his Master of Science degree.

He is married to the former M. D. Zulima Gonzalez Vargas of Venezuela.