INFLUENCE OF HERBICIDE SPRAY DROP CHARACTERISTICS ON PLANT RESPONSE

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CHAPTER I

INTRODUCTION

Crop production in the United States has increased rapidly in the last two decades. The increase in production has primarily been a result of advancements in technology. Herbicides, a product of this advanced technology, have played an important role in achieving this crop production increase. Properly applied herbicides have resulted in the removal of weeds which compete with crops for plant nutrients, water, and light.

Although herbicides have generally been used successfully, failures in herbicide weed control have occurred. Many of these failures may be attributed to improper application procedures. Herbicide drift has also complicated the problems with herbicide applications. Conventional nozzles emit a wide range of drop sizes ranging from very small or minute drops to very large drops. The small drops are easily airborne and can then be a hazard to adjacent susceptible crops. Using equipment which produces only large or particular drop sizes should reduce this hazard.

Herbicide carrier volume applications with ground equipment have generally ranged from 188 to 376 liters per hectare (L/ha). Reducing the carrier volume would have the results of allowing the spraying of a larger acreage with the same size sprayer tank and in a savings in both time and the amount of total carrier volume required.

This study was concerned with the effects of herbicide spray drop sizes, herbicide concentrations and carrier volumes on plant response. The objectives of the research were:

(1) Evaluate in the field the influence of different combinations of herbicide spray drop sizes and carrier volumes on plant response,

(2) Determine the influence of various drop sizes and carrier volumes on coverage and drop deposition rate,

(3) Study the influence of various drop volumes and herbicide concentrations on foliar absorption by particular plant species, and

(4) Evaluate herbicide loss under particular environmental conditions.

CHAPTER II

REVIEW OF LITERATURE

Drop Size and Carrier Volume

Drop Size

In studying the influence of herbicide spray drop size on plant response, various methods have been used to produce drops of various sizes. Early researchers conducted studies using conventional nozzles and mass median drop diameters (dia) as a measure of drop size.

Riepma (35) conducted studies with translocated herbicides and a mass median drop dia of 150 and 200 micron (u). He found no significant difference in the control of *Paspalum conjugatum*, *Imperata cylindrica* and *Axonopus compressus*. Studies by Ankler and Morgan (1) indicated that the terminal growth of bean (*Phaseolus vulgaris* L.) decreased as the operating pressure of three conventional nozzles was increased from 1.4 to 5.6 kilogram per square centimeter (Kg/cm^2). Due to the large range in drop sizes produced by conventional nozzles, the effect of drop sizes was difficult to evaluate. The mass median dia does not indicate the range in drop size. It is defined as the drop size at which 50% of the volume consists of drops which are smaller and 50% of the volume consists of drops which are larger than the mass median dia.

More recent research has been conducted with a spinning disc apparatus which produces more uniform drop sizes than conventional nozzles.

Studies by Behrens et al. (7) with mesquite seedlings indicated that 2,4,5-T (all chemical herbicide names are listed in Table I) applied as 200 u drops at 37.4 L/ha was more effective than the 400, 600, or 800 u drops. They also reported that at a constant volume as the drop deposition rate increased from 72 to 575 drops/6.45 cm^2, there was a significant increase in herbicidal effectiveness. However, later Behrens (6) reported that except for minor variation, drop size and spray volume had no influence on response of mesquite and cotton seedlings. He also reported that drop deposition rate was more important than drop size. Application effectiveness decreased when less than 72 drops/ 6.45 cm^2 were deposited on mesquite seedlings regardless of drop size.

Ennis and Williamson (17) indicated that smaller drops of 2,4-D applied at 1.3 milliliters (ml) per square meter ($/m^2$) caused greater retardation of kidney bean plant growth than larger drops. Studies by Way (41) with lettuce and sub-lethal doses of MCPA indicated that smaller drops (100 u) were more effective than larger drops (500 u). Hurtt et al. (27) indicated a five fold increase in activity as drop size of 2,4-D and 2,4,5-T decreased from 500 to 125 u. Black Valentine beans were used as indicator plants. Studies by Douglas (15) indicated optimum herbicidal efficiency of diquat and paraquat was achieved with a 400-500 u drop using broadbean (*Vicia faba* L.) as an indicator plant. Buehring et al. (13) also reported that a 473 u drop with paraquat was more effective than a 300 or 710 u drop.

Various other methods have been used to produce various drop sizes. Studies by Hurtt et al. (27), using a micro-syringe, showed that the 0.1 microliter (ul) drop volume of 2,4-D and 2,4,5-T was more effective on bean plants than the 0.2 ul or 0.4 ul drop volumes. Mullison (33) used

TABLE I

COMMON AND CHEMICAL NAMES OF HERBICIDES

Common Names	Chemical Names
alachlor	2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide
amitrole	3-amino-s-triazole
atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine
butylate	S-ethyl diisobutylthiocarbamate
chloramben	3-amino-2,5-dichlorobenzoic acid
chlorpropham	isopropyl m-chlorocarbanilate
dalapon	2,2-dichloropropionic acid
dinoseb	2-sec-butyl-4,6-dinitrophenol
diquat	6,7-dihydrodipyrido[1,2-a:2',1'-c]pyrazinedi= ium ion
diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea
fenuron	1,1-dimethyl-3-phenylurea
fluometuron	1,1-dimethyl-3-(a,a,a-trifluoro-m-tolyl)urea
linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea
MCPA	[(4-chloro-o-tolyl)oxy]acetic acid
monuron	3-(p-chlorophenyl)-1,1-dimethylurea
MSMA	monosodium methanearsonate
naptalam	N-1-naphthylphthalamic acid
neburon	1-butyl-3(3,4-dichlorophenyl)-1-methylurea
nitralin	4-(methylsulfonyl)-2,6-dinitro-N,N-dipropylaniline
norea	3-(hexahydro-4,7-methanoidan-5-yl)-1,1-dimethylurea
paraquat	1,1'-dimethyl-4,4'bipyridinium ion
propachlor	2-chloro-N-isopropylacetanilide
pyrazon	5-amino-4-chloro-2-phenyl-3(2H)-pyridazinone

TABLE I (Continued)

Common Names	Chemical Names
TCA	trichloroacetic acid
trifluralin	a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine
2,4-D	(2,4-dichlorophenoxy)acetic acid
2,4,5-T	(2,4,5-trichlorophenoxy)acetic acid
vernolate	S-propyl dipropylthiocarbamate

a micrometer syringe to apply various drop volumes of 2,4-D to bean plants. He found no difference in response between small (0.002 ml) and large drops (0.006 ml). Bengtsson (8) used an air injection nozzle to produce drops of various sizes and found that the formative effects on flax were greater with small drops (92 u) of MCPA than larger (560 u) drops. Small drops (92 u) of dinoseb caused more injury to peas, Chenopodium album, Chyrsanthemum segetum and Stellaria media than large drops (560 u).

Smith (39) used a De Vilbiss paint sprayer at different pressures to produce different drop sizes. He reported that sprays of phenoxy herbicides of relatively large drop sizes [250-561 u average (av) dia] were more effective than those of smaller drop sizes (30 u av dia). The difference in effectiveness was attributed to a higher percentage of spray interception when the large drops were applied. However, studies by Ennis and Williamson (17) indicated that smaller drops [0.2-1.6 millimeter (mm) dia card stains] were more effective than the large drops (2.9-7.2 mm dia). Ennis et al. (17) explained the difference in results from Smith (39) was due to difference in air pressure and spray volume. Smith, in his work, used higher pressures than Ennis et al. and near saturation volume. Ennis and Williamson (17) also conducted drop size studies using a glass drop sizer to produce drops of various sizes. They reported that small drops (less than 0.1 mm dia) of 2,4,5-T, 2,4-D and chlorpropham were more inhibitory than larger drops (greater than 0.3 mm dia) on seed yield of flax, soybean, sugar beet, and wheat.

Buehring et al. (13) reported that the effect of drop size varied with the herbicide. No difference in activity due to drop size was observed with MSMA and amitrole. The phytotoxicity of diuron and fluometuron increased as the drop size decreased from 1200 to 473 u. Herbicide rates were able to mask the effect of drop size.

Studies were conducted by Fisher et al. (18, 19, 20) using 2,4,5-T and six types of airplane spray equipment to produce drops ranging from very fine (100 u) to coarse drops (550 u). They reported that medium coarse to coarse drops were equally as effective as the fine drops in the control of mesquite.

Carrier Volume

Postemergence, preemergence and soil incorporation applications have been used in the study of herbicide carrier volume influence on weed control. Postemergence studies conducted by Molberg (32) indicated that increasing the spray volume of 2,4-D amine and ester, and MCPA from 23.4 to 140 L/ha resulted in a decrease in both the degree of injury and delay of flax maturation. Borodina et al. (11) also reported that 2,4-D activity was enhanced as the spray volume decreased from 100 to 50 L/ha. Buchholtz (12), Hellquist (24) and Sexsmith (38) all reported increased injury to canning peas resulted when spray volume was reduced.

Wilson et al. (43) indicated that broadleaved weed control increased as the spray volume of atrazine and linuron decreased from 376 to 188 L/ha. Studies by Ennis and Hollingsworth (16) indicated that chlorpropham and dinoseb applied at 140 and 188 L/ha was as effective in weed control as 376 L/ha. However, weed control at 70 L/ha was inferior. McWhorter et al. (31) found that diuron applied at 188 L/ha to crabgrass was more effective than 376, 752 or 1128 L/ha. However, the rate of diuron was able to mask the effect of carrier volume.

On the contrary, studies by Riepma (35) indicated no difference in grass control with carrier volumes of translocated herbicides ranging from 234 to 935 L/ha. Applications of mixtures of amitrole and dalapon in volumes ranging from 376 to 935 L/ha resulted in no difference in the control of Axonopus compressus and Paspalum conjugatum (34). Studies by Stamper et al. (40) indicated that dalapon applied at 5.6 Kg/ha was most effective on johnsongrass kill when applied at 140 L/ha. However, he reported that there was not enough differences in 47, 94, or 140 L/ha to justify cost of applications of higher carrier volumes. Horowitz (26) reported that paraquat (0.24 Kg/L) applied to established oats at 2 L in 100 L/ha was comparable in activity to 3 L applied in 400 L/ha.

The influence of carrier volumes with preemergence applications has also been studied. Baker (2, 3) in a three-year study with various spray volumes (47, 94, 188 L/ha) of cotton herbicides, found no difference in weed control due to carrier volume with diuron, fluometuron and norea. Bovey and Burnside (10) compared herbicides applied by aerial and ground equipment at 47 and 188 L/ha, respectively. They found few differences with respect to weed control and crop yield. However, where differences occurred, the 47 L/ha aerial application was more effective than the 188 L/ha ground application.

Bode and Gebhardt (9, 22) evaluated three low volume applicators for preemergence application of trifluralin and chloramben in soybeans and corn. They reported the spinning disc which produced larger drops than the air nozzle consistently gave poor control of both weeds and grasses at 9.35 L/ha. However, at 23.5 and 47 L/ha, the spinning disc nozzle gave the best broadleaved weed control. The air nozzle with volumes of 9.35 and 47 L/ha gave the best grass control. In another report (22) they stated that herbicides could be applied at volumes down to and including 47 L/ha without major changes in equipment or herbicide performance. At lower volumes (47 to 23.5 L/ha) care must be observed in selection of tanks, valves, strainers and lines for sprayer.

Barzee et al. (4) conducted field studies with 11 herbicides applied preemergence at low volume (9.35 to 37.4 L/ha) and conventional volume (187 L/ha). They reported that chloramben, atrazine, alachlor, linuron, napthalam plus chlorpropham, nitralin and propachlor were equally effective in controlling grasses or broadleaf plants when applied at conventional and low volumes. Pyrazon plus TCA was less effective when applied at low volume on broadleaf weeds than when applied at the conventional volume.

A three-year study conducted by Baker (3) with nitralin and trifluralin incorporated in the soil indicated no difference in weed control at 47 and 188 L/ha in 1966 and 1967. However, in 1968, the 188 L/ha volume was more effective with both nitralin and trifluralin. Santelmann et al. (37) reported that trifluralin was more effective when applied at 47 or more L/ha. Nitralin was equally effective at carrier volumes, ranging from 9.35 to 188 L/ha. However, Garner et al. (21) found that trifluralin and fluometuron were equally effective in controlling weeds at 18.7, 56 and 262 L/ha. Barzee et al. (4) also reported that trifluralin as a soil incorporated treatment was usually equally effective in controlling grass and broadleaf plants at 14 and 188 L/ha. They reported, however, that butylate and vernolate were more effective when applied at 188 L/ha than 9.35 L/ha.

Past research on herbicide spray drop size and carrier volume, generally, has been conducted either with several drop sizes and one carrier volume rate or several carrier volume rates with a conventional nozzle. Plant response has been used as a measurement of drop size effectiveness. No research has been reported on interpretation of this response in terms of greater foliar absorption or higher herbicide concentration per leaf area covered with larger spray drops. This research was conducted to evaluate herbicide spray drop size and carrier volume combination effects on plant response. Comparisons of the various herbicide spray drop sizes with a conventional nozzle were also made to determine whether a particular drop size was equally or more effective than a conventional nozzle. Laboratory studies were also conducted to describe plant response to drop sizes in terms of greater foliar absorption or higher herbicide concentration per leaf area covered with larger spray drops.

CHAPTER III

MATERIALS AND METHODS

Drop Size and Carrier Volume Studies

Field experiments were conducted as postemergence applications on the Oklahoma State University Agronomy farm at Stillwater or Perkins, Oklahoma, in 1970 and 1971. The influence of drop size and carrier volumes with various herbicides in the control of tumble pigweed (*Amaranthus albus* L., var. *albus*), Palmer's pigweed (*Amaranthus Palmeri* S. Watts.), smooth pigweed (*Amaranthus hybridus* L.) crabgrass [*Digitaria sanguinalis* (L.) Scop.] and red sprangletop [*Leptochloa filiformis* (Lam.) Beauv.] were studied. Individual experiments were conducted with paraquat or fluometuron plus MSMA applied at two rates with four different nozzle sizes and four carrier volumes.

Single jet orifices were used with a magnetostrictive device to produce drops of uniform size. The single jet nozzle orifices used were 200, 400 and 600 u. These orifices produced sprays in which drop dia sizes averaged 401, 699 and 860 u respectively. The standard deviations for the respective drop sizes were ± 27 u, ± 41 u and ± 44 u (36). A conventional nozzle (Spraying System SS8001) was also included in the experiments as a standard for comparison. The drop size range was not established for this nozzle. However, the mass median drop dia as indicated by the nozzle manufacturer was 375 u at 1.76 Kg/cm^2.

The spray equipment consisted of a portable generator, high voltage power supply, oscillator, amplifier, mixing tank and 1.52 meter (m) spray boom mounted on a Hagie high clearance chassis. Boom height and nozzle spacing varied with the nozzle size. Nozzle spacings for the 200, 400 and 600 u single jet nozzle orifices was 6.35, 19.0 and 19.0 centimeter (cm), respectively. Boom height for 200, 400 and 600 u orifices were 0.96, 1.1 and 1.1 m, respectively. The conventional nozzle had a spacing of 0.51 m and height of 0.6 m.

The single jet streams were directed through insulated aluminum tubing (1.9 cm dia) which were electrically charged to obtain drop dispersion and pattern uniformity, and to prevent drop coalescence. Tubing length for the 200 u was 8.9 and 12.4 cm for the 400 and 600 u orifices. Voltage of 2.0, 3.75 and 5.0 kilovolts was applied to the aluminum tubing with the 200, 400 and 600 u orifices, respectively. Operating boom pressure for the single jet orifices and the conventional nozzle was 1.05 and 1.76 Kg/cm^2, respectively.

The angle of the nozzles also varied with the single jet orifices sizes used. The 200 u orifices were angled such that the spray stream was directed to the rear at a 45° angle below the horizontal position. The 400 and 600 u orifices were angled such that the spray stream was directed to the rear at 30° angle below the horizontal position. The spray stream of the conventional nozzle was positioned perpendicular to the soil surface.

Experiments were conducted as a factorial arranged in a randomized block design with four replications. Applications of fluometuron plus MSMA were made at 1.1 + 2.2 and 1.7 + 3.3 Kg/ha of active ingredient with four different sized nozzles and four carrier volumes (47, 94, 188 and 281 L/ha). Paraquat plus a non-ionic surfactant [alkyl phenoxy polyethoxy (HDD, 0.5% by volume)] was applied at 0.28 and 0.67 Kg/ha with the above nozzle sizes and water carrier volumes. A preemergence experiment with alachlor was also conducted in 1971 but failed due to dry weather following herbicide application. The ground speed of the sprayer was varied to achieve the desired carrier volume per acre. Due to mechanical failure at the time of application, the 600 u orifice treatments at 47 L/ha were omitted in some of the experiments.

Pigweed and grass height at the time of treatment ranged from 1.3 to 6.5 cm and 2.5 to 5.0 cm, respectively. The grasses and pigweeds were evaluated separately 7, 14 and 21 days after treatment. A rating scale of 0 = no weed control or kill ranging up to 10 = complete weed control or kill was used. The ratings were converted to percent control by multiplying the rating by a factor of 10. Statistical analysis was conducted at the 95% confidence level. Duncan's multiple range tests were conducted at the 5% level.

A percent card coverage analysis was conducted for each nozzle size and carrier volume at the Agricultural Engineering Laboratory. A fluorescent dye plus a surfactant (HDD 0.5% by volume) water solution was applied with each drop size and carrier volume to four replications of 152 x 5 cm white smooth absorbent cardboard with the plot sprayer previously described.

Three 5 cm squares were selected at random from each replication and photographed with a magnification power of two by ultraviolet photography using P/N 55 Polaroid film. The negatives of the photographs were magnified 10 or 20 fold with a Wilder Comparator and tracings of the spots (spray drop images) in three 1.0 cm squares selected at random on the negatives were made on Dietzgen 161 M tracing paper. The spots on the tracing paper were cut and weighed with an analytical balance. The total weight of the 1.0 cm square area was also determined. The ratio of spot weight to the total area weight was calculated and converted to percentage card coverage. Statistical analysis was conducted at the 95% confidence level.

Percentage drop deposition rate analysis was conducted on the 152 x 5 cm white smooth cardboard which had been sprayed with the various drop sizes and carrier volume combinations. Using a 0.64 cm grid, the number of 0.64 cm intersections (where lines crossed) of a 2.54 cm square section which were covered with fluorescent spray dye were counted. Ten samples taken at random per treatment replication were counted. The percent of the 0.64 cm intersections which were covered with spray particles were calculated based on a total of 25 0.64 cm intersections per 6.45 cm^2. Statistical analysis was conducted at the 95% confidence level.

Herbicide Loss

Glass Slide Surface

Growth chamber experiments were conducted to determine the loss of fluometuron from glass microscopic slides (2 x 3 cm) under various environmental conditions. Experiments with continuous darkness were conducted at 27 and 32 centigrade (C). Experiments were also conducted with continuous light at 16, 27 and 32 C. The light intensity of 32,000 lux was provided by fluorescent and incandescent light sources. The chamber had no method for relative humidity regulation. However, the relative humidity was determined with each experiment 12, 24, 36 and 48 hours (hrs) after placement of glass slides in the chamber with a psychrometer. The experiments were conducted as a randomized block design with 12 replications.

Four 0.25 ul drop volumes of 120 parts per million (ppm) trifluoromethyl ^{14}C labeled fluometuron (specific activity of 2.39 millicurrie/millimole) water solution were applied to individual microscopic slides. A stationary 1.0 ul syringe was used in the application of the herbicide solution. The desired amount of solution was metered from the syringe. The glass slide was placed on a laboratory jack, and then gradually raised until the slide surface came in contact with the drop adhering to the tip of the syringe. The slide was then lowered with the process being repeated until the desired number of drops had been applied.

Immediately after treatment, the slides were placed in the growth chamber. Glass slides were removed from the growth chamber various intervals (2.5, 5.0, 12.0, 24.0, 36.0 and 48 hrs) after treatment and washed in 15 ml of counting solution.

The counting solution consisted of 5 parts xylene, 5 parts para-dioxane and 3 parts ethanol in which 80 grams (g)/L of napthalene was dissolved plus 5 g/L of PPO. The samples were counted in a Beckman liquid scintillation counter. The ^{14}C unaccounted for was considered loss. The percentage loss at various intervals after treatment were calculated based on the ^{14}C-fluometuron initially applied.

Commercial Formulation vs ^{14}C-Fluometuron Loss

A comparison study of ^{14}C-fluometuron and commercial formulation loss from glass slide surfaces was conducted. The experiment was conducted as a factorial arranged in a randomized block design with three replications and two sub-samples per replication. Four 10 ul drop volumes of 90 ppm fluometuron (labeled ^{14}C and commercial formulation) water solution were placed on individual glass slides. A stationary 10 ul syringe was used in the application of the herbicide solution as previously described.

Immediately after treatment the glass slides were placed in the growth chamber with 32 C and continuous light. The light sources were incandescent and fluorescent lamps with an intensity of 32,000 lux. Slides of both treatments were sampled at various intervals (5, 12, 24 hrs) after treatments. The ^{14}C treated slides were washed with 15 ml of counting solution and counted in a Beckman liquid scintillation counter. The commercial formulation treated slides were washed in 10 ml of pentane (spectrophotometric analysis grade). The samples were quantitated with a Beckman BD spectrophotometer at 238 millimicron wavelength. A standard curve was developed for the commercial formulation and the sample quantities were extrapolated from the curve.

The amount of both herbicide formulations unaccounted for at various intervals after treatment was considered loss. The percentage loss was calculated based on the initial applications.

Foliar Absorption Studies

Experiments were conducted to evaluate the influence of various factors on foliar absorption of ^{14}C-fluometuron. Species used in the studies were annual morningglory [Ipomeoa purpurea (L.) Roth.], Palmer's pigweed and velvet leaf (Abutilon theophrasti Medic.). The seeds of the various species were germinated for 4, 7 and 5 days, respectively, in a germinator at 32 C. Seeds of morningglory and velvet leaf were germinated in perlite. A mixture of sand and perlite (1:2 ratio by volume) was used in the germination of pigweed. Seedlings of each species were transplanted to jars containing 300 ml of an aerated complete Hoaglands (25) nutrient solution in a growth chamber. Environmental conditions were: light intensity of 32,000 lux, 14 hrs day length, 32 C day temperature and 27 C night temperature.

The first true leaf of each plant was treated when the mid-rib length ranged from 3 to 4 cm. Application of the herbicide solution was made with a 1.0 ul stationary syringe. The desired amount of solution was metered from the syringe. Then the plant, with the leaf supported horizontally, was gradually raised with a laboratory jack until the leaf surface came in contact with the drop adhering to the tip of the syringe. The plant was then lowered and the process was repeated until the desired amount of solution had been applied to the leaf. The drops were applied only to the intra-veinal leaf areas.

Immediately after treatment the plants were placed in the growth chamber with continuous darkness and 32 C. At various intervals after treatment, the treated leaf was excised and placed in a 20 ml vial containing 10 ml water plus a non-ionic surfactant (X-77, 0.5% by volume) solution. The vial was then shaken by hand for one minute. The leaf was removed, allowed to drain and ground in 10 ml of 95% ethanol with a tissue homogenizer. Aliquat samples of leaf wash (1 ml) and leaf tissue (2 ml) were placed in 15 ml of counting solution. The samples were counted in a Beckman liquid scintillation counter. The ^{14}C found in the leaf tissue was considered absorbed and was converted to a percentage based on the initial application. The following experiments were conducted in this manner unless otherwise stated.

Autoradiography

Translocation of foliar applied ^{14}C-fluometuron by annual morningglory, velvet leaf and Palmer's pigweed was studied. The first true leaves of 10 plants of each species were treated with a 10 ul drop of 720 ppm ^{14}C-fluometuron water solution plus X-77 (0.5% by volume).

Forty-eight hrs after treatment the plants were removed from the nutrient solution and the roots were allowed to drain. Five plants of each species were mounted on individual white glossy cardboard sheets (18 x 23 cm) using white glue. The plant mounts were then covered with a sheet of plastic wrap. In the dark room, plant mounts were placed in Kodak Ready Pack No Screen X-ray film packets with the plant facing the film. Film packets were sealed with masking tape and placed in a plant press. Individual film packets were placed between alternating layers of foam rubber (2.5 cm thick) and 1.3 cm thick plywood sheets. The plant press was fastened tightly together with two cotton web belts and placed in a freezer at -5 C. An exposure time of 30 days was used after which the film was developed in a dark room.

The treated leaf of the five remaining plants was excised and placed in a 20 ml vial containing 10 ml of 95% ethanol and shaken by hand for one minute. The leaf was removed, allowed to drain and then ground in 10 ml of 95% ethanol with a tissue homogenizer. The remaining plant parts of the treated plant were also ground in 10 ml of 95% ethanol. One ml aliquats of leaf tissue and other plant part tissue samples were placed in 15 ml of counting solution and counted in a Beckman scintillation counter. The ^{14}C found in the various plant parts were determined and expressed as a percentage of the initial application.

Washing Solvents

The influence of drop volume and various washing solvents on the amount of ^{14}C-fluometuron found in leaf tissue at various intervals after treatment were studied. The experiment was conducted twice as a factorial arranged in a randomized block design with three washing solvents, two drop volumes and two replications. Each plant was considered a replication. Drop volume treatments were 0.25 and 1.0 ul.

A total volume of 2.0 ul of a 90 ppm of ^{14}C-fluometuron solution plus X-77 (0.5% by volume) water solution was applied to the first true leaf of annual morningglory. Ethanol (95%), benzene and water plus X-77 (0.5% by volume) were used as washing solvents.

Various intervals (3, 6, 12, 24 and 48 hrs) after treatment the treated plant leaves were removed from the growth chamber and washed in 10 ml of ethanol (95%), benzene or water plus X-77 (0.5% by volume). Aliquat samples of ground leaf tissue (2.0 ml) and leaf wash (1.0 ml) were placed in 15 ml of counting solution and counted in a Beckman liquid scintillation counter. The percent of ^{14}C found in the leaf tissue and leaf wash (removed by washing) for the various treatment combinations were calculated based on the ^{14}C initially applied.

Drop Volume

Foliar absorption of various drop volumes by morningglory, Palmer's pigweed and velvet leaf were studied. The experiments were conducted twice as a randomized block design with three drop volumes and three replications. A total of 4.0 ul of 90 ppm ^{14}C-fluometuron plus X-77

(0.5% by volume) water solution was applied to the first true leaf of each plant as 0.25, 1.0 or 2.0 ul drop volumes. The 2.0 ul drop volume was achieved by applying two 1.0 ul drops successively on the same leaf area.

Morningglory treated leaves were excised 0.75, 1.5, 3.0, 6.0 and 12.0 hrs after treatment whereas velvet leaf and pigweed treated leaves were excised 0.75, 1.5, 3.0, 6.0, 12.0 and 24.0 hrs after treatment. The ^{14}C found in the leaf tissue and the leaf wash samples at the various time intervals were expressed as a percentage based on the ^{14}C-fluometuron initially applied. Statistical analysis was conducted at the 95% confidence level.

Herbicide Concentration

Studies were conducted on the effect of herbicide concentration on foliar absorption by annual morningglory, Palmer's pigweed and velvet leaf. The experiments were conducted twice as a factorial arranged in a randomized block design with three herbicide concentrations (45, 135 and 405 ppm) and three replications.

Four 1.0 ul drop volumes of various concentrations of ^{14}C-fluometuron plus X-77 (0.5% by volume) water solution were applied to the first true leaf of each weed species. The percentage of ^{14}C (based on the initial application) found in the leaf wash and leaf tissue were determined for each herbicide concentration treatment and intervals (0.75, 1.5, 3.0, 6.0, 12.0 and 24 hrs) after treatment. Statistical analysis was conducted at the 95% confidence level.

Uniform Concentration per Unit Area

The effect of various drop volumes on foliar absorption with uniform herbicide concentration per unit leaf area was studied. Weed species studied were: annual morningglory and Palmer's pigweed.

The leaf area covered by the various drop volumes (0.25, 1.0 and 2.0 ul) treatments was determined before the experiments were conducted. The first true leaf of three plants of each weed species was treated with three 0.25, 1.0 and 2.0 ul drops of a chartreuse fluorescent dye + X-77 (0.5% by volume) water solution. When the liquid had evaporated from the leaf, the leaf was excised and photographed in a dark room using ultraviolet photography and a magnification power of seven.

Negatives of the photographs were enlarged tenfold with a Wilder Comparator and the drop images were traced using Dietzgen 161 M tracing paper. The drops on the tracing paper were cut and weighed on an analytical balance. The area covered by each drop volume was calculated based on the paper weight per unit area.

The ratios of area covered by four 0.25 ul and two 1.0 ul drops to one 2.0 ul drop were calculated. The herbicide concentration was adjusted according to this ratio for a uniform concentration per unit area covered by the various drop volumes. A herbicide concentration of 90 ppm of ^{14}C-fluometuron + X-77 (0.5% by volume) water solution was used as a standard with the 2.0 ul drop volume.

Absorption experiments were conducted twice as a factorial arranged in a randomized block design with three drop volumes and three replications. A total of 4.0 ul of herbicide solution was applied to the first true leaf of each plant either as 0.25, 1.0 or 2.0 ul drop volumes. The percentages of ^{14}C (based on initial application) found in the leaf wash and leaf tissue were determined for each drop volume various intervals (0.75, 1.5, 3.0, 6.0, 12.0 and 24.0 hrs) after treatment. Statistical analysis was conducted at the 95% confidence level.

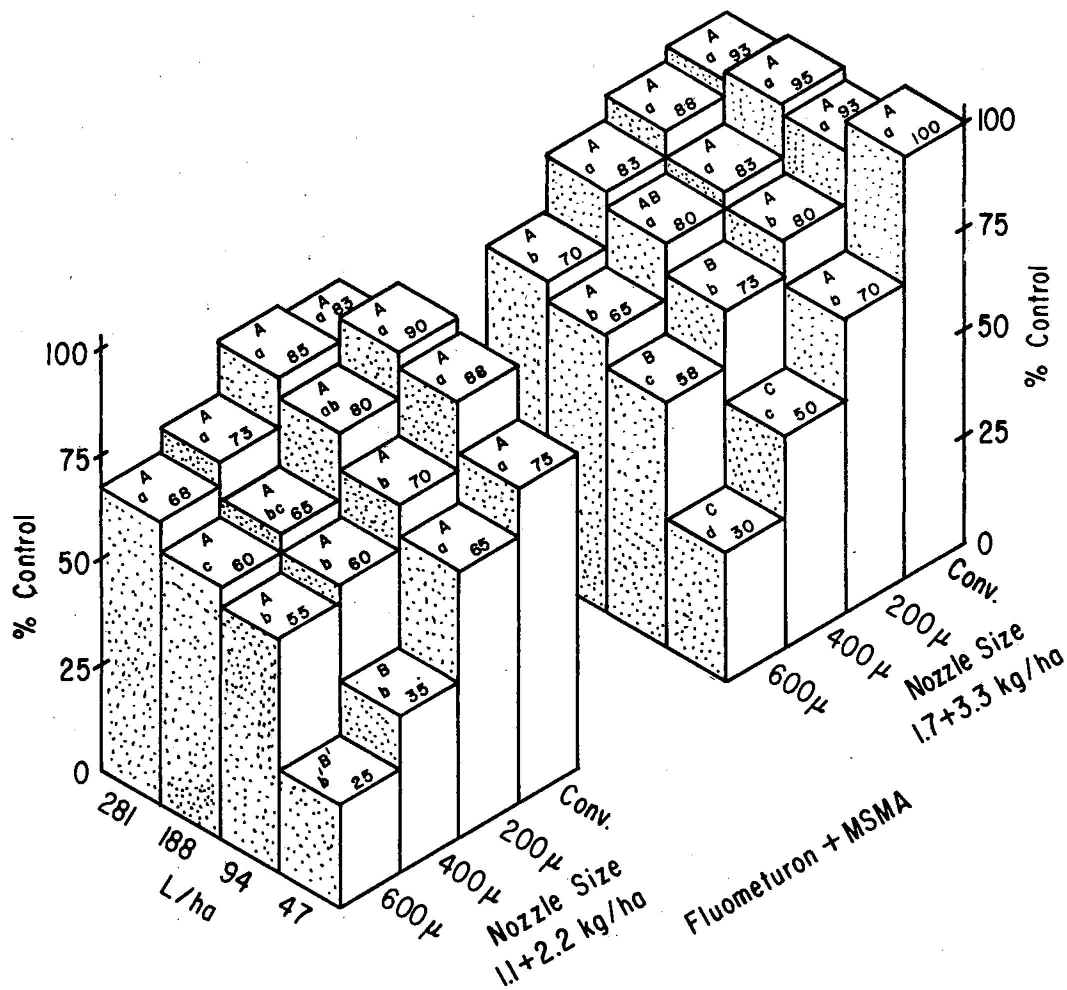
CHAPTER IV

RESULTS AND DISCUSSION

Drop Size and Carrier Volume Studies

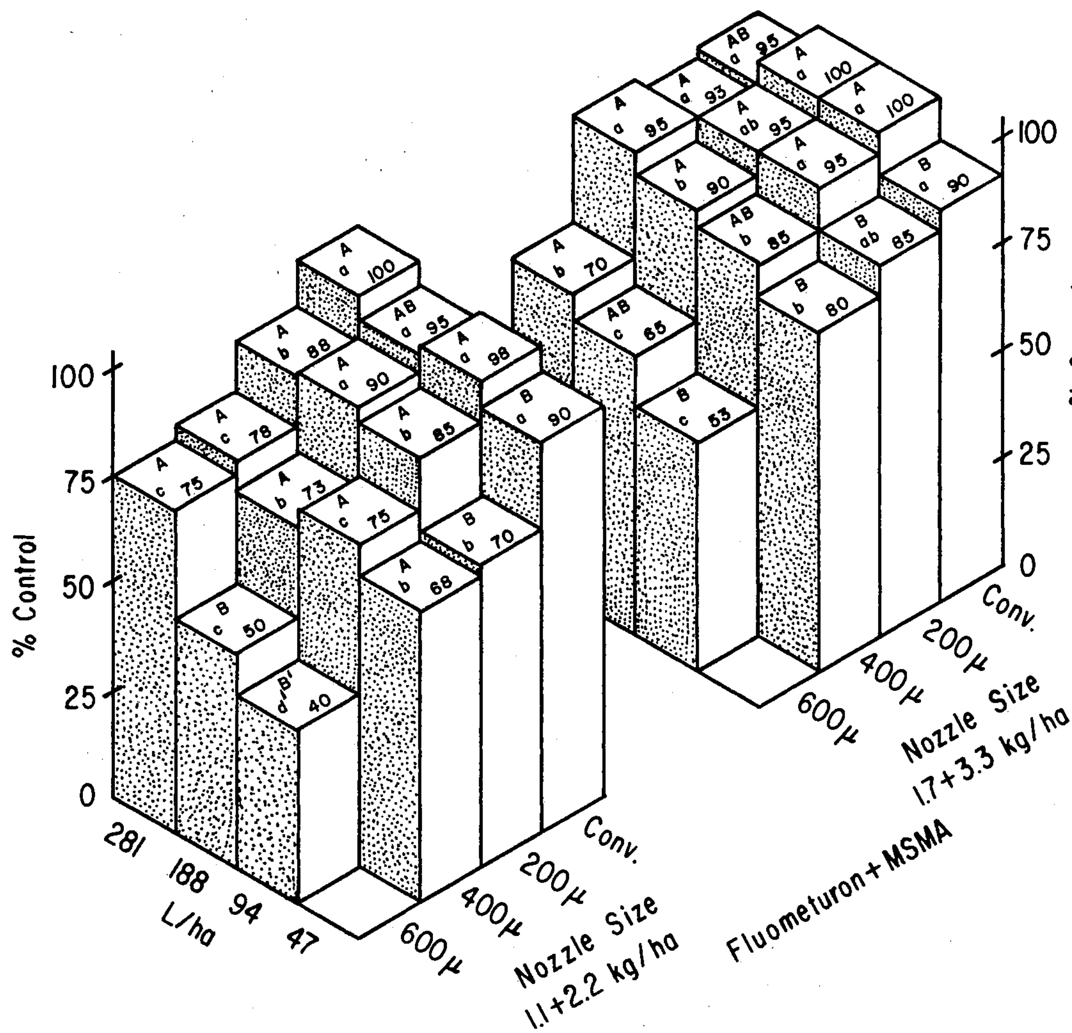
Field studies were conducted during the summers of 1970 and 1971 to determine the effect of herbicide spray drop size and carrier volume on the control of pigweeds, crabgrass and red sprangletop. The dominant grass in the 1970 fluometuron plus MSMA experiments was red sprangletop. In the 1971 experiment the dominant grass was crabgrass. Due to insufficient grass in the 1971 paraquat experiment, grass evalutions were not made. The 47 L/ha 600 u nozzle treatments were omitted from some of the 1970 and 1971 experiments due to mechanical failure of the sprayer. Therefore, the factorial analysis of these data was conducted with the 94, 188 and 281 L/ha.

Statistical analysis of the fluometuron plus MSMA experiments in 1970 and 1971 (Figures 1-4) indicated a significant difference in control due to nozzle size, carrier volume, herbicide rate and weed species. Both 1970 and 1971 pigweed data indicated an interaction with nozzle size and carrier volume. In general, control of pigweed increased with increasing spray volume and herbicide rate. Excluding the conventional nozzle, as the drop size increased and carrier volume decreased, pigweed control decreased. However, with the conventional nozzle, which produced a wide range of drop sizes, there was no difference in control



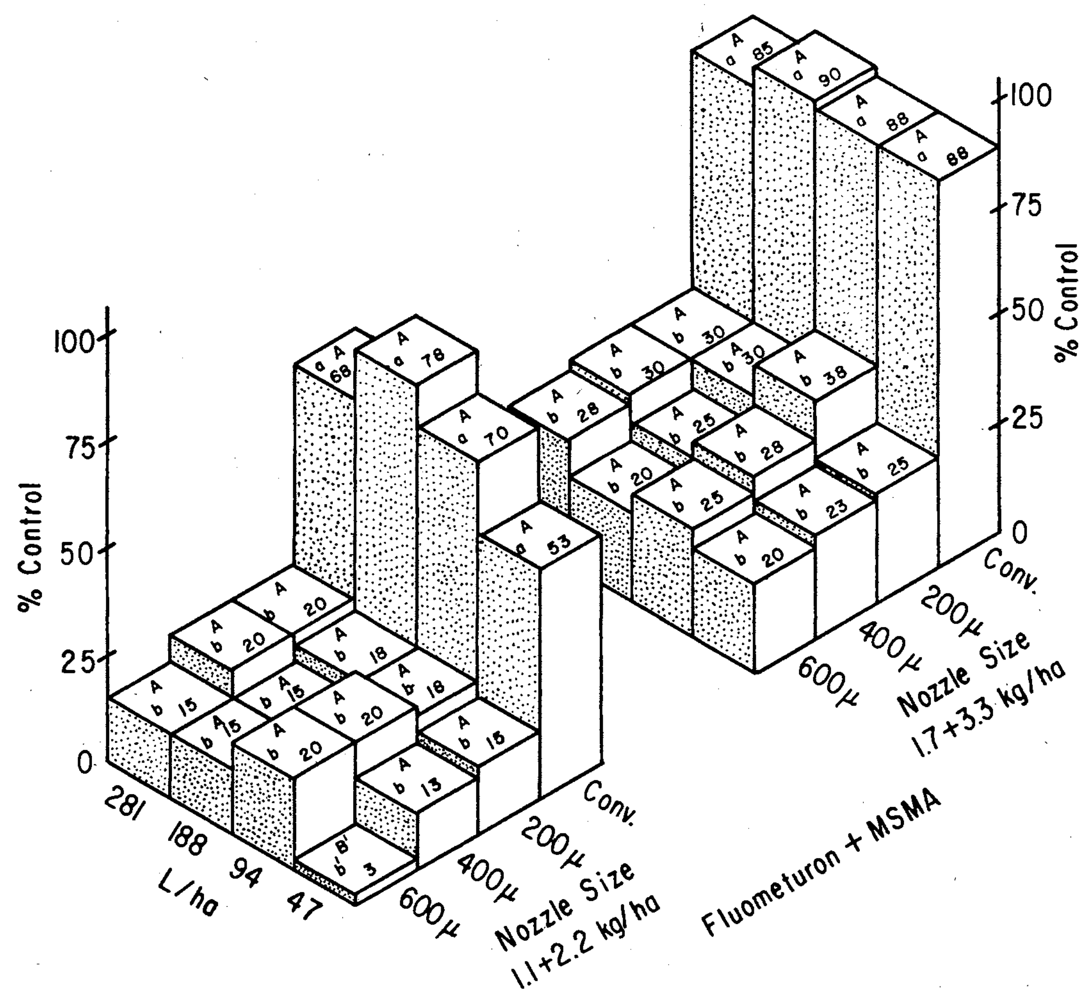
[1]The same capital letters for a given nozzle size and the same small letters for a given L/ha are not significantly different.

Figure 1. Influence of Fluometuron Plus MSMA Rate, Nozzle Size and Carrier Volume on Control of Pigweed in 1970, 21 Days After Treatment



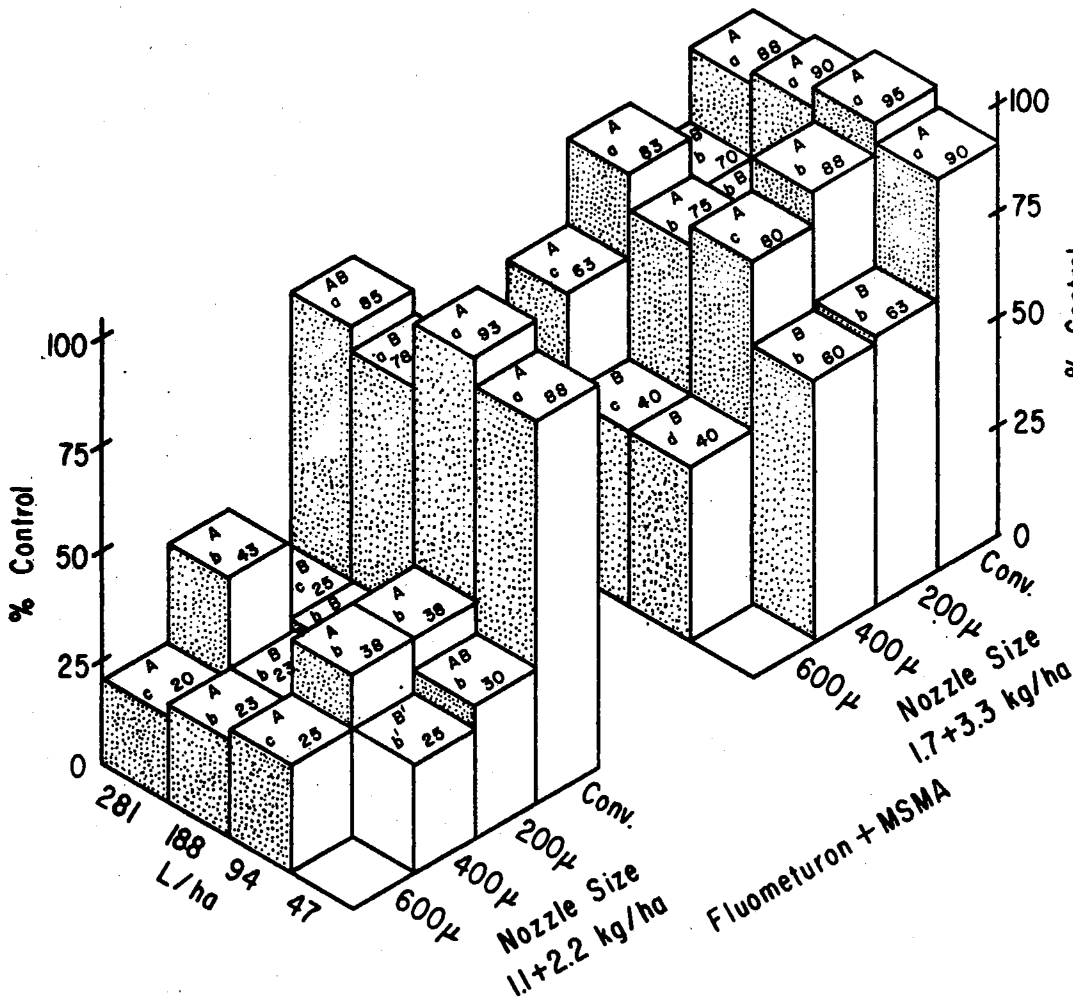
[1]The same capital letters for a given nozzle size and the same small letters for a given L/ha are not significantly different.

Figure 2. Influence of Fluometuron Plus MSMA Rate, Nozzle Size and Carrier Volume on Control of Pigweed in 1971, 21 Days After Treatment



[1]The same capital letters for a given nozzle size and the same small letters for a given L/ha are not significantly different.

Figure 3. Influence of Fluometuron Plus MSMA Rate, Nozzle Size and Carrier Volume on Control of Grasses in 1970, 21 Days After Treatment



[1]The same capital letters for a given nozzle size and the same small letters for a given L/ha are not significantly different.

Figure 4. Influence of Fluometuron Plus MSMA Rate, Nozzle Size and Carrier Volume on Control of Grasses in 1971, 21 Days After Treatment

due to carrier volume. The 47 L/ha carrier volume was equally as effective as the 94, 188 or 281 L/ha spray volume.

The effect of drop size tended to be masked with an increase in herbicide rate and carrier volume. Differences in pigweed control at 47 L/ha occurred, in descending order of control, between the conventional, 200 and 400 u nozzles in 1970 (Figure 1) at both herbicide rates. However, in 1971 (Figure 2) at the high herbicide rate, there was no difference in control between the conventional 281 L/ha and 200 u at 47 L/ha. The 281 L/ha carrier volume with the higher herbicide rate in 1970 (Figure 1) and 1971 (Figure 2) resulted in no difference in pigweed control between the conventional, 200 and 400 u nozzles. The 600 u nozzle was less effective than the other nozzles at 281 L/ha. These results indicated that exclusive of the conventional nozzle the smaller drops were more effective as carrier volume decreased.

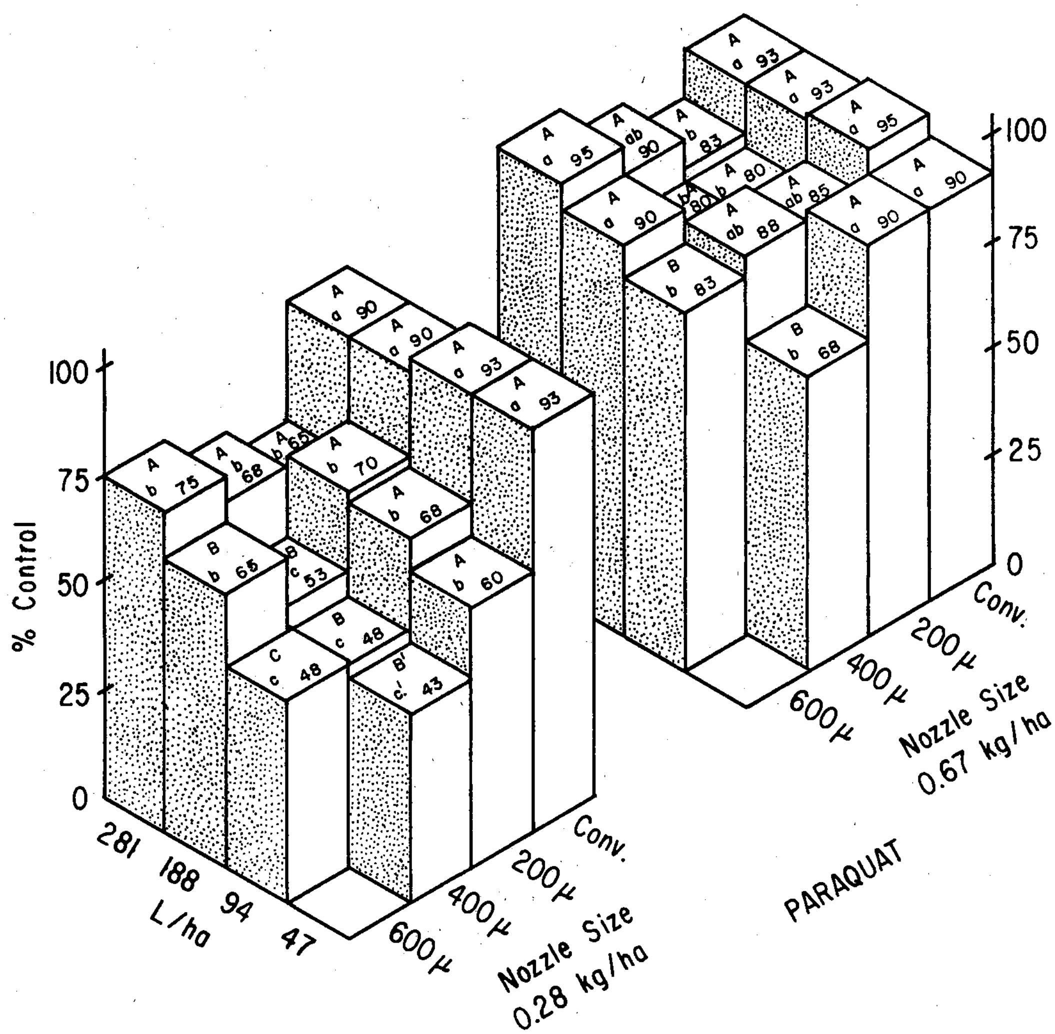
Grass response to fluometuron with MSMA varied greatly from 1970 (Figure 3) to 1971 (Figure 4) experiments particularly at the high herbicide rate. The difference in response may possibly be attributed to the difference in grass species and soil moisture. Visual estimates indicated that red sprangletop was the dominant grass species in the 1970 experiment. In 1971, crabgrass was the dominant grass species. The 1970 experiment was irrigated 5 days prior, 7 and 14 days after treatment with 4.3 to 5.0 cm of water. The 1971 experiment was not irrigated. Soil moisture at the time of treatment was good and fair in 1970 and 1971, respectively. In 1971 the only rainfall after treatment was 5.0 cm which occurred 8 days after treatment.

The 1970 data (Figure 3) indicated differences in grass control due to nozzle size. There was no interaction of nozzle size with carrier volumes. The conventional nozzle was the most effective treatment with no difference in grass control due to carrier volume. The 200, 400 and 600 u nozzles were less effective at all carrier volumes and herbicide rates with no difference in response between these three nozzle sizes. The conventional nozzle, which was the most effective treatment, produced a large number of small drops and possibly resulted in better wetting of the grass and herbicide distribution. Red sprangletop and crabgrass also are slightly more resistant to fluometuron than pigweed.

Statistical analysis of 1971 data indicated differences in grass control due to herbicide rate, nozzle size and carrier volume. An interaction of nozzle size with carrier volume also occurred. With the exception of the high herbicide rate and 281 L/ha, the conventional nozzle resulted in better grass control than the other nozzle sizes at both herbicide rates and all carrier volumes.

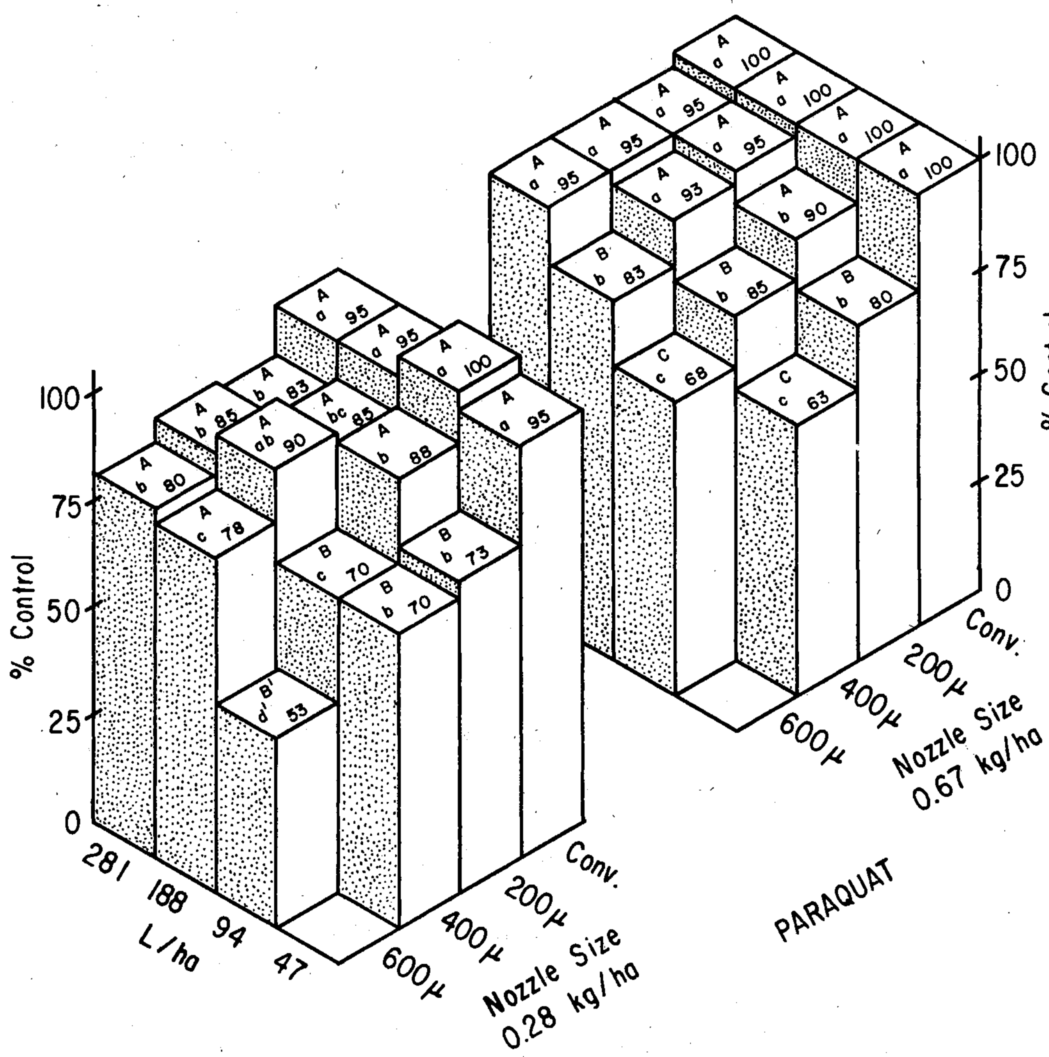
Grass control results in 1971 (Figure 4) at the high herbicide rate were somewhat similar to the pigweed (Figures 1, 2) results in that generally as nozzle size increased and carrier volume decreased, grass control decreased. However, with the 200 u nozzle, grass control was better at 94 L/ha than 47, 188 or 281 L/ha. Grass control with the 400 u nozzle treatments were better at 94 L/ha or greater carrier volume. The 600 u nozzle gave the best response at 281 L/ha.

The 1970 (Figure 5) and 1971 (Figure 6) pigweed response to paraquat drop size and carrier volume experiments were similar to those of the fluometuron plus MSMA experiments. The responses for both years also were similar in that an increase in carrier volume generally resulted in increased pigweed control. However, the conventional nozzle,



[1]The same capital letters for a given nozzle size and the same small letters for a given L/ha are not significantly different.

Figure 5. Influence of Paraquat Rate, Nozzle Size and Carrier Volume on Control of Pigweed in 1970,[1] 21 Days After Treatment



[1]The same capital letters for a given nozzle size and the same small letters for a given L/ha are not significantly different.

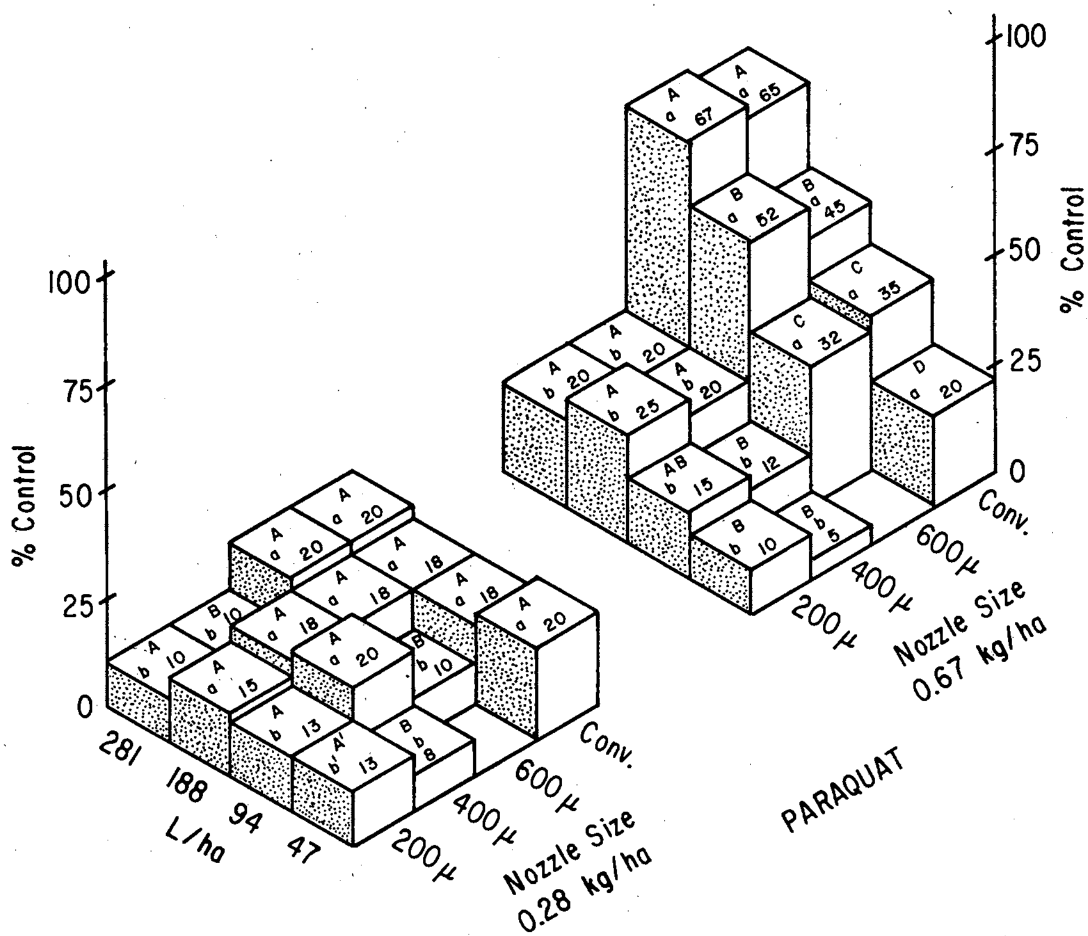
Figure 6. Influence of Paraquat Rate, Nozzle Size and Carrier Volume on Control of Pigweed in 1971, 21 Days After Treatment

both years, was equally effective at all carrier volumes and herbicide rates. The conventional nozzle at the low herbicide rate and carrier volumes gave better pigweed control than the other three nozzle sizes. The higher herbicide rate and carrier volumes tended to mask the effect of drop size.

Statistical analysis of the 1970 and 1971 data indicated differences in pigweed control due to nozzle size, carrier volume and herbicide rate. There was also an interaction of nozzle sizes with carrier volumes. In 1970 (Figure 5) and 1971 (Figure 6) with the low herbicide rate, the conventional nozzle was more effective than the other three nozzle sizes at all carrier volumes. The 200 u nozzle in 1970 was more effective than the 400 or 600 u nozzles at 94 L/ha or less. In 1971, with the low herbicide rate, the 200 u nozzle was more effective than the 400 or 600 u nozzle only at 94 L/ha.

In general, the high herbicide rate reduced the effects of increasing spray volume and drop size on pigweed control. In 1970 the 600, 400 u and conventional nozzles were equally effective at 281 L/ha and the high herbicide rate. The 200 u nozzle was less effective than the other nozzles at 281 L/ha. However, at 47 L/ha the 200 u nozzle and the conventional nozzle were equally effective and were superior to the 400 u nozzle. In 1971 at the high herbicide rate and 281 L/ha there was no difference due nozzle size.

The grass response in the paraquat drop size and carrier volume experiments (Figure 7) were quite different from the pigweed (Figures 5, 6) response and fluometuron plus MSMA grass (Figures 3, 4) response. Unfortunately, the 1971 experiment contained insufficient crabgrass for proper evaluation. The statistical analysis of the 1970 data (Figure 7)



[1]The same capital letters for a given nozzle size and the same small letters for a given L/ha are not significantly different.

Figure 7. Influence of Paraquat Rate, Nozzle Size and Carrier Volume on Control of Grasses in 1970, 21 Days After Treatment

indicated differences in grass control due to nozzle size, carrier volume and herbicide rate. There was a significant interaction of nozzle sizes and carrier volumes.

With the low herbicide rate, poor grass control was obtained from all treatment combinations. However, with the higher herbicide rate, the conventional and the 600 u nozzle were equally and more effective at 94, 188 and 281 L/ha than the 200 and 400 u nozzles. In general, with the high herbicide rate, grass control increased with increased carrier volume. The conventional and 600 u nozzle were more effective at 281 L/ha. These data indicate that for grass control with paraquat higher herbicide rates and volumes are necessary. Since the results are from one year's data, it is difficult to make a thorough interpretation of the data.

The field studies indicated that carrier volume, drop size and herbicide rate may affect plant response to herbicide applications. In general (excluding the conventional nozzle) as carrier volume decreased and drop size increased, pigweed control decreased. However, increased herbicide rate and carrier volume masked the effects of drop size. The smaller drops at low carrier volumes were more effective on pigweed. These results agree with those who have reported that smaller drops were more effective than larger spray drops (8, 13, 17, 27, 41).

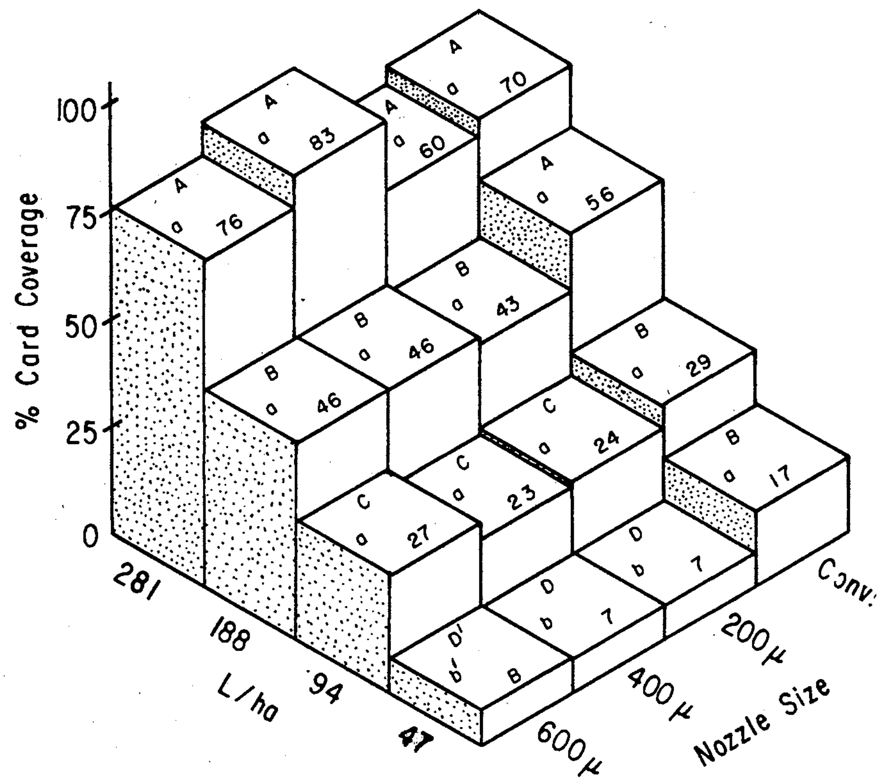
The results, however, do not completely agree with Behrens (6) who reported that drop size and carrier volumes of 2,4,5-T had no significant effects on mesquite and cotton seedlings. He also reported that drop spacing was the most important factor. The 72 drops/6.45 cm^2 which he suggested as necessary for optimum herbicide effectiveness is equivalent to 38 L/ha with a 400 u drop (6). Our data suggested that more than 72 drops are necessary for a 400 u drop (200 u nozzle) to be most effective if paraquat or fluometuron plus MSMA are used as the herbicides. However, the card coverage analysis (Figure 8) and drop deposition rate (Figure 9) analysis suggested that plant response to herbicide applications may be due to foliage coverage and drop spacing which are functions of drop size and carrier volume.

The results of paraquat experiments with pigweed are in agreement with Douglas (15) and our earlier research (13) which indicated that paraquat was most effective with drop sizes in the range of 400 to 500 u. However, carrier volume and herbicide rate were able to mask the effect of drop size.

The grass response in these experiments differed greatly from that of pigweed response. In the paraquat experiment, grass response indicated that the large drop (600 u nozzle) was more effective than the smaller drop. Grass control was greatest at the high herbicide rate and carrier volume.

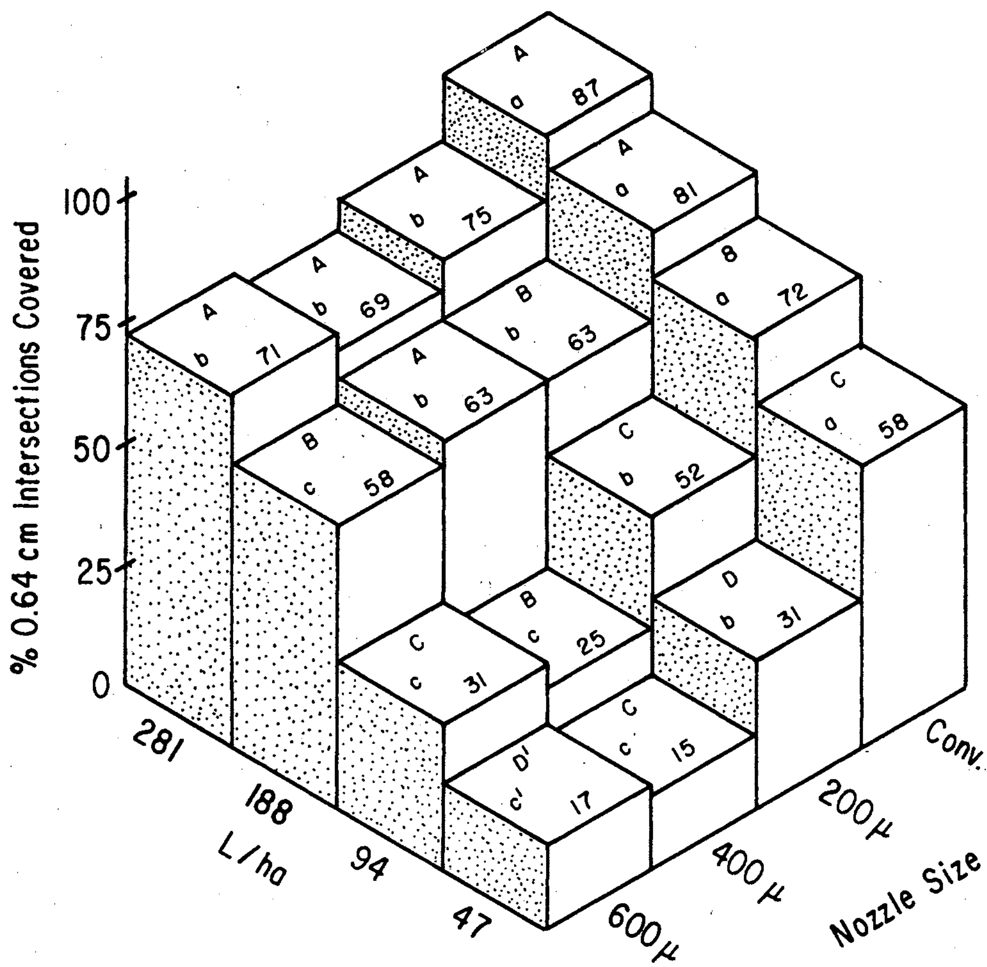
The 1970 fluometuron plus MSMA experiment on grass response indicated no effect due to drop size and carrier volume. However, in 1971 the grass response was somewhat similar to pigweed response. The difference in 1970 and 1971 responses may possibly have been due to species and soil moisture. The dominant species in 1970 was red sprangletop while in 1971 crabgrass was the dominant species. The 1970 experiment had better soil moisture than 1971 at the time of treatment. However, both received irrigation or rainfall 7 to 8 days after treatment.

In general, with other than conventional nozzles, the higher carrier volumes were more effective. Considering the conventional nozzle, carrier volume had no effect on weed control except with paraquat on



[1]The same capital letters for a given nozzle size and the same small letters for a given L/ha are not significantly different.

Figure 8. Influence of Nozzle Size and Carrier Volume on Percentage of Card Area Covered by Spray Drops



[1]The same capital letters for a given nozzle size and the same small letters for a given L/ha are not significantly different.

Figure 9. Influence of Nozzle Size and Carrier Volume on Percentage of 0.64 cm Intersections of Cards Covered by Spray Drops

grass control. The 281 L/ha carrier volume was more effective than the lower volumes.

Most reported research on postemergence weed control with non-phenoxy herbicides has been conducted with 140 L/ha or greater volumes. Most of these reports (31, 34, 40, 43) indicated that the lower L/ha was equal to or more effective than higher carrier volumes. However, Ennis and Hollingsworth (16) reported that dinoseb and chlorpropham applied at 70 L/ha were inferior in weed control in comparison to 140 or 188 L/ha. These results differ from most of our field results but the difference may be due to different weed species, herbicides or size of conventional nozzle. With phenoxy herbicides most research reports (11, 12, 24, 32) indicated that lower spray volume caused more plant injury than higher spray volume.

Card coverage analysis was used to get a relative idea of the coverage that occurred with the various nozzle sizes and carrier volume combinations. Statistical analysis indicated differences in card coverage (Figure 8) due to carrier volume and nozzle size. However, no interaction occurred with nozzle size and carrier volume.

In general, card coverage increased with increasing carrier volume. Theoretically, one would expect that as the nozzle size decreased, an increase in card coverage would occur for a given volume. However, the data indicated no difference in card coverage due to nozzle size at 94, 188 or 281 L/ha. The results may be due to drop size spread factors and larger drops breaking into several smaller drops on impact thus masking the expected effect of drop size on coverage. The conventional nozzle had a greater card coverage than the other three nozzle sizes at 47 L/ha. Card coverage with the conventional nozzle at 188 and 281 L/ha was greater than at the 47 and 94 L/ha. With the 200, 400 and 600 u nozzles there were differences in card coverage between the 47, 94, 188 and 281 L/ha.

There was a significant difference in the number of 0.64 cm intersections (where lines crossed) covered due to nozzle size and carrier volume. There was also an interaction with nozzle size and carrier volume. In general, as the carrier volume increased, the percentage of 0.64 cm intersections covered by spray drops increased (Figure 9). The conventional nozzle had a greater drop deposition rate than the other three nozzle sizes at all carrier volumes. This indicated that the conventional nozzle produced a greater number of spray drops for the same volume as compared to the other three nozzle sizes. The 200 u nozzle had a greater drop deposition rate than the 400 and 600 u nozzles at 47 and 94 L/ha. However, at 281 L/ha there was no difference in drop deposition between these three nozzle sizes.

A difference in drop deposition rate occurred between 47, 94 and 188 L/ha carrier volume with each nozzle size. There was no difference in drop deposition between 188 and 281 L/ha with the 400 u and conventional nozzles.

Herbicide Loss

Glass Slide Surface

The various environmental conditions (Figure 10) resulted in differences in ^{14}C-fluometuron loss from glass slide surfaces at various time intervals. Greater herbicide loss occurred with time in all experiments. However, the higher temperatures showed higher rates of loss

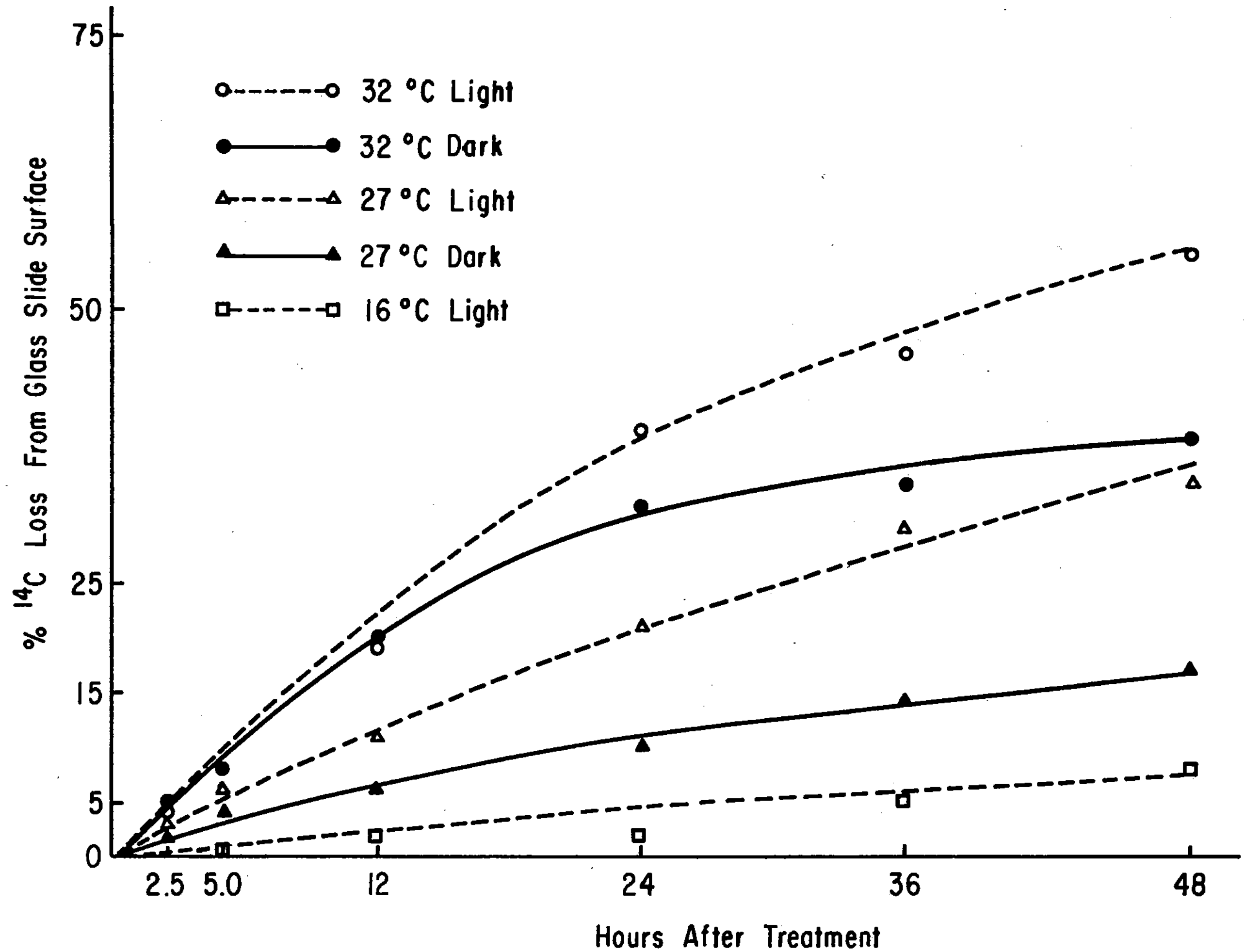


Figure 10. Influence of Environmental Conditions on ^{14}C-Fluometuron Loss From Glass Slide Surfaces

in the light. The 32 C light experiment had a loss of 55% in comparison to an 8% loss for the 16 C light experiment 48 hrs after treatment.

The average relative humidity for the 16, 27 and 32 C experiments (12, 24, 36 and 48 hrs after treatment) were 59, 44 and 33%, respectively. The relative humidity in the chamber did not vary more than ± 3% during the course of each experiment. The differences in loss between experimental temperatures on continuous dark cycles could be attributed to the differences in relative humidity. The higher atmospheric vapor pressure would be expected to result in more herbicide volatilization.

There was no difference in relative humidity between the dark and light experiments at the same temperature. However, there was a much greater loss of herbicide in the light than in the dark. The 32 C dark experiment had a loss of 38% in comparison to 55% loss in the light 48 hrs after treatment. The 27 C dark experiment resulted in an 18% loss in comparison to 33% loss in the light.

A possible cause for the difference in loss due to light is that light caused degradation of ^{14}C-fluometuron to a more volatile ^{14}C compound. The glass surface also may have been at a higher temperature than the surrounding air due to absorption of some of the wave lengths of light. No research has been reported on fluometuron photodecomposition, but research has been reported on photodecomposition of other substituted urea herbicides (28, 29, 30, 42). Reports indicated that diuron, neburon, monuron and fenuron photodecomposed with sunlight or ultraviolet light. However, under field conditions the photodecomposition may be much slower than on a glass surface. The soil is porous and herbicide may be adsorbed by the soil particle sufficiently to reduce photodecomposition.

Commercial Formulation vs ^{14}C-Fluometuron Loss

There was a difference in herbicide loss due to time but no difference due to formulation (Table II). In general, herbicide loss increased with time. The results suggest that the loss of ^{14}C herbicide is similar to that of the commercial formulation. No attempt was made to analyze for degradative products of the ^{14}C or commercial formulation.

TABLE II

PERCENTAGE LOSS OF ^{14}C AND COMMERCIAL FLUOMETURON FROM GLASS SLIDES AT VARIOUS INTERVALS AFTER TREATMENT

Time (Hours)	% Loss ^{14}C	% Loss Commercial
0	0	0
5	23	23
12	37	44
24	63	58

The herbicide loss in this experiment was greater than the previous experiment (Figure 10) at the same environmental conditions. This difference in loss may possibly be due to a greater surface area covered by the four 10 ul drops in comparison to four 0.25 ul drops.

Foliar Absorption Studies

Autoradiography

The autoradiography of the various species indicated no translocation and only slight movement of the ^{14}C-fluometuron in the treated leaf. Pigweed showed more movement in the treated leaf than velvet leaf or morningglory. The entire treated pigweed leaf contained sufficient ^{14}C herbicide to develop an autoradiograph of the entire leaf. Morningglory and velvet leaf autoradiographs indicated only slight movement from the point of application.

The plant part analysis in Table III indicated that more ^{14}C-fluometuron was absorbed by morningglory, a semi-resistant species, than pigweed, a susceptible species. Velvet leaf absorbed less than the other species. Differences in absorption may be due to leaf surface characteristics. Velvet leaf has a very dense pubescent leaf surface as compared to the relatively smooth leaves of pigweed and morningglory. The type of wax and cuticle thickness may also affect absorption. The percentage of ^{14}C-fluometuron translocated from the treated leaf ranged from 0.3% for pigweed to 1.1% for morningglory. The results of these experiments agree with others who have reported that substituted urea herbicides did not translocate when applied as foliar applications (5, 14, 23).

The percent of herbicide unaccounted for was 21, 18 and 25% for morningglory, pigweed and velvet leaf, respectively. This loss may be attributed to volatilization and possibly metabolism by the plants.

TABLE III

DISTRIBUTION OF FOLIAR APPLIED ^{14}C-FLUOMETURON BY VARIOUS SPECIES

Species	% in Treated Lf. Tissue	% in Lf. Wash	% Translocated
A. Morningglory	72.0	5.9	1.1
P. Pigweed	57.0	25.0	0.3
Velvet Leaf	42.0	33.0	0.5

Washing Solvents

The amount of ^{14}C-fluometuron found in the leaf wash and tissue was significantly influenced by the solvent used to wash the treated leaves (Figure 11). The more polar solvents removed less fluometuron from the treated leaf. Since the leaf cuticle consists of lipids and waxes which are nonpolar, the more nonpolar solvent would dissolve and remove more of the herbicide contained in the cuticle layer. The exact influence, however, of nonpolar solvents on cuticle and other plant membranes has not been fully resolved.

Water is a polar solvent which does not dissolve leaf cuticle waxes and lipids. Therefore, only the ^{14}C-fluometuron not bound to the leaf cuticle should be removed by washing. Ethanol, a less polar solvent than water, removed more fluometuron from the leaf than water. Benzene, a nonpolar solvent, removed more herbicide from the leaf than ethanol or water. There was a difference in the amount of ^{14}C-fluometuron in the leaf wash and leaf tissue between each solvent at each time interval

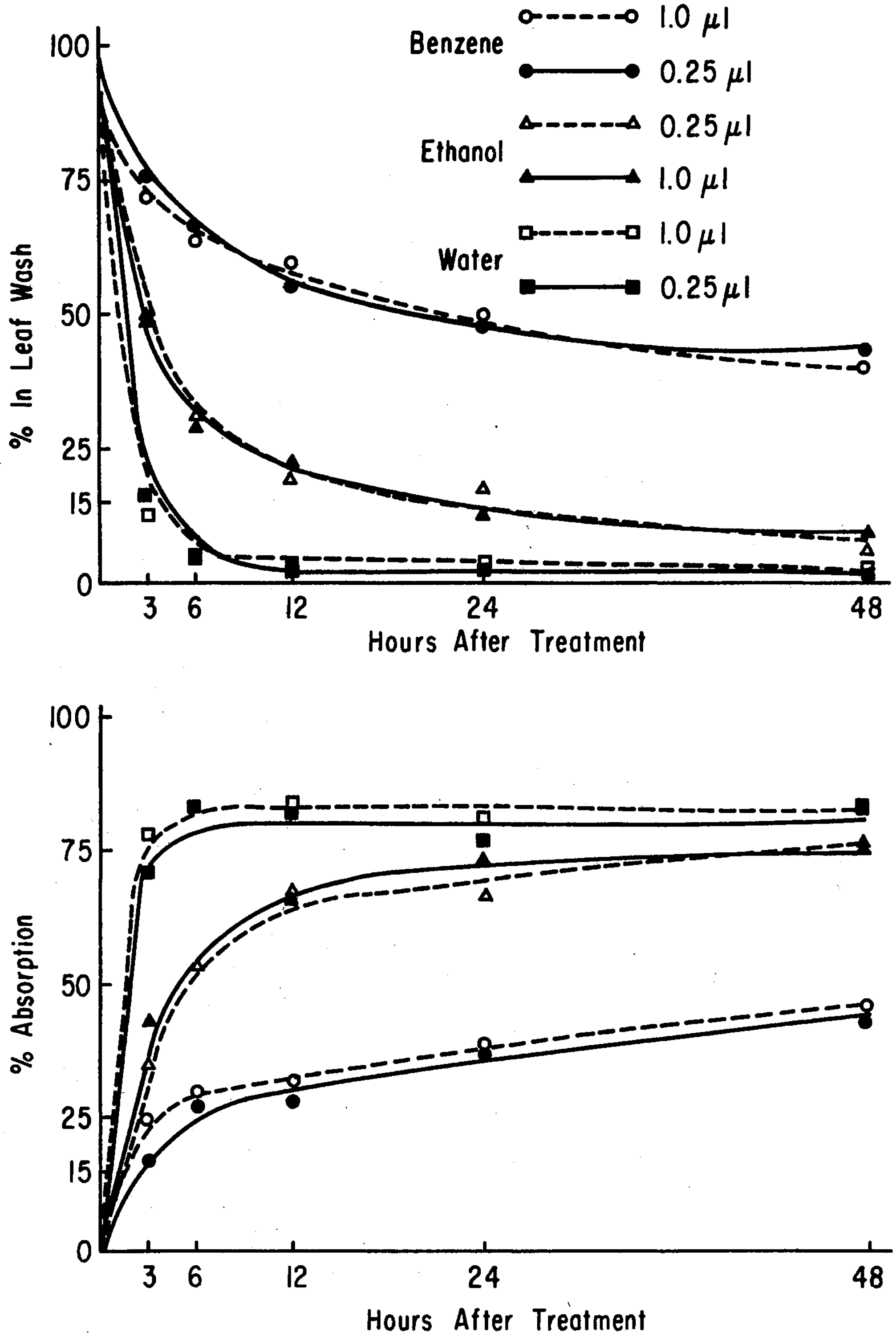


Figure 11. Influence of Drop Volume and Washing Solvents on Percentage of ^{14}C-Fluometuron, Initially Applied, in Leaf Wash and Absorption by Morningglory at Various Time Intervals After Treatment

after treatment except 48 hrs where there was no difference between ethanol and water. In general, as the amount of ^{14}C in leaf tissue increased the amount in the leaf wash decreased.

Treated leaves washed with water reached a maximum concentration of ^{14}C-fluometuron in the leaf tissue six hrs after treatment while ^{14}C-fluometuron in the leaf tissue washed with ethanol and benzene was still increasing 48 hrs after treatment. Drop volume had no effect on ^{14}C found in the leaf wash or tissue. The results of this study indicated that the solvent used to wash treated leaves may definitely affect the amount of herbicide found in the leaf tissue.

Drop Volume

The absorption by various species of four ul of a ^{14}C-fluometuron water solution applied as 0.25, 1.0 and 2.0 ul drop volume was studied. No difference in foliar absorption due to drop volume was found with velvet leaf and morningglory. With pigweed, however, there was a difference in herbicide absorption due to drop volume.

Morningglory (Figure 12) had a very rapid rate of absorption, attaining 90% three hrs after treatment. The rate of reduction of ^{14}C-fluometuron in the leaf wash was very rapid reaching a low of 1 to 3% 12 hrs after treatment. In comparison to morningglory, velvet leaf (Figure 13) had a much slower rate of foliar absorption, reaching only a high of 65% six hrs after treatment. The rate of fluometuron reduction in the leaf wash was also much slower than morningglory. The percent of ^{14}C-fluometuron in the leaf wash 24 hrs after treatment ranged from 4 to 8%.

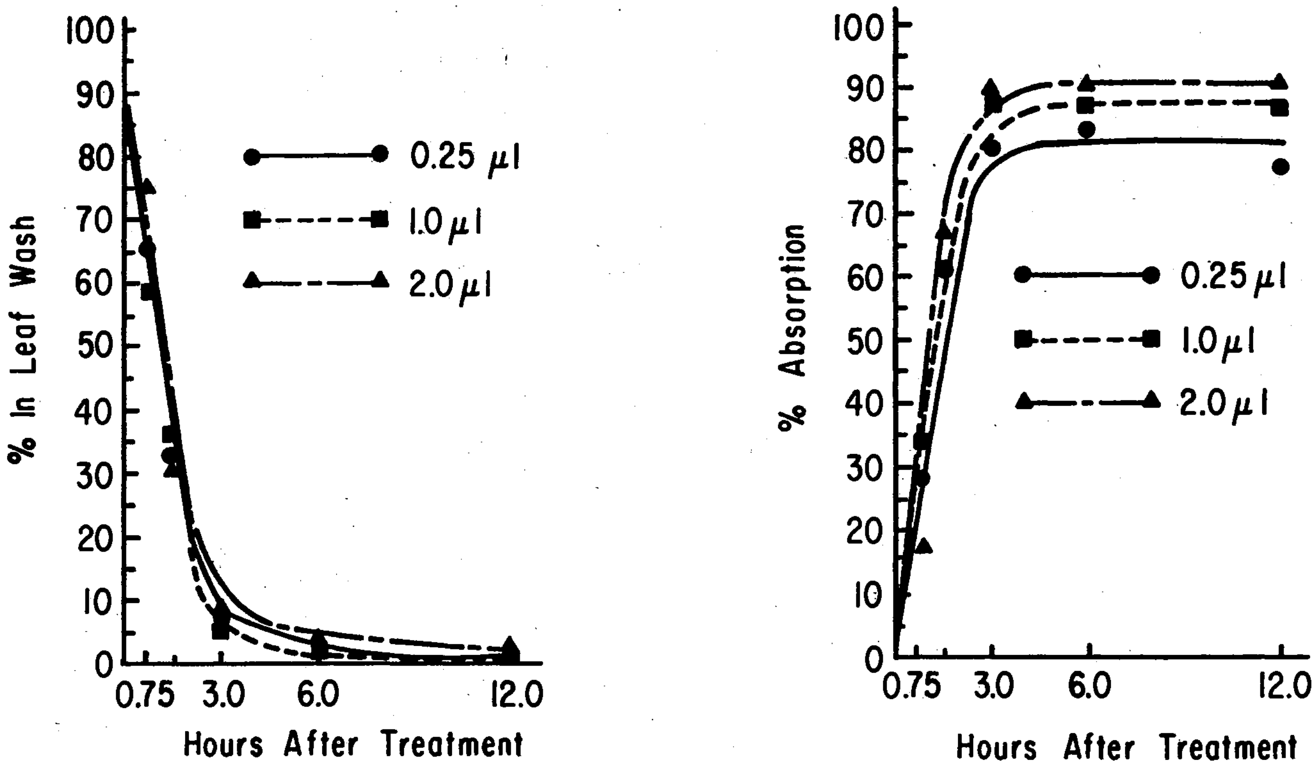


Figure 12. Influence of Various Drop Volumes on Percentage of ^{14}C-Fluometuron, Initially Applied, in Leaf Wash and Absorption by Morningglory at Various Time Intervals After Treatment

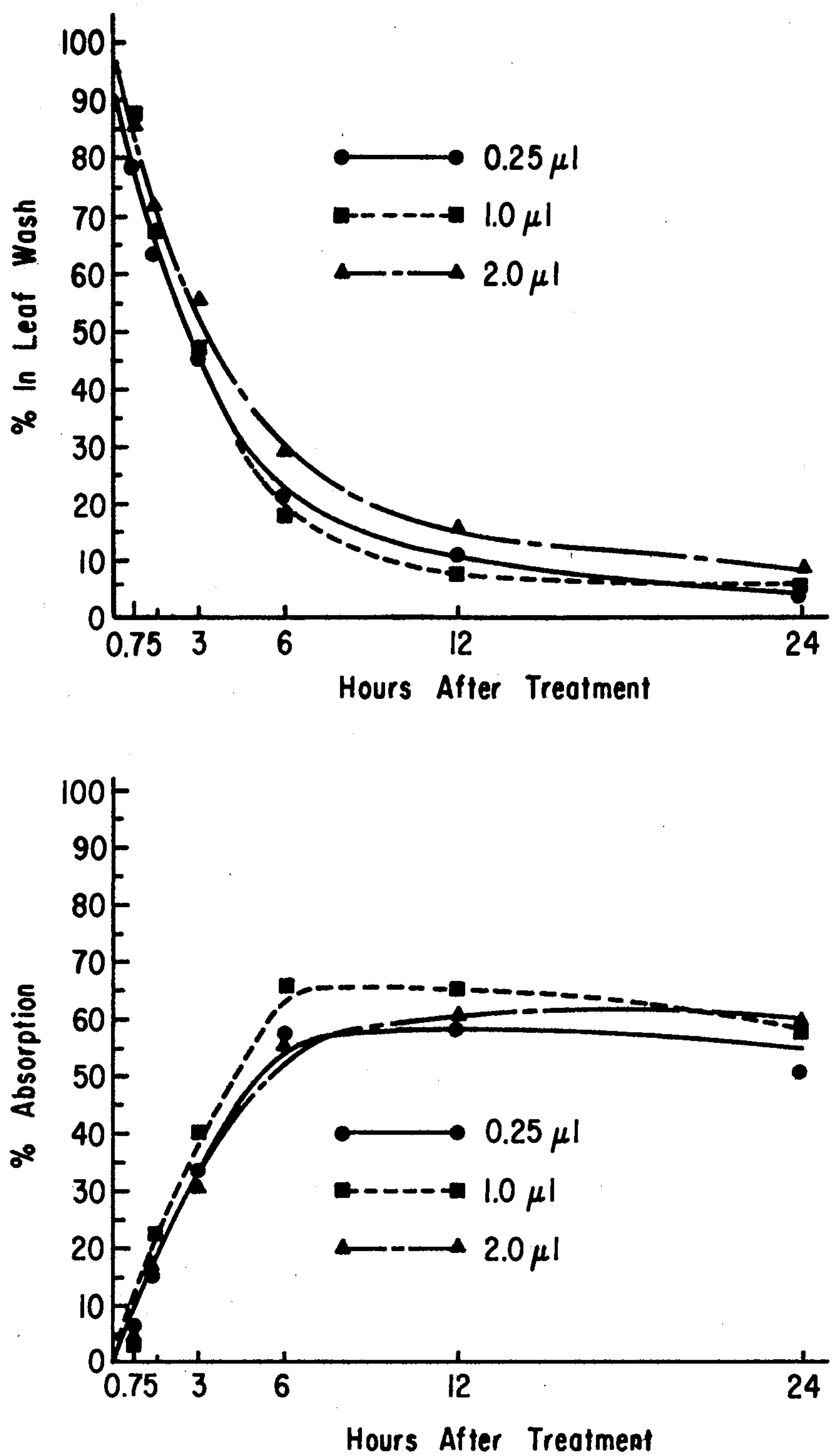


Figure 13. Influence of Various Drop Volumes on Percentage of ^{14}C-Fluometuron, Initially Applied, in Leaf Wash and Absorption by Velvet Leaf at Various Time Intervals After Treatment

Pigweed foliar absorption (Figure 14) rate was somewhat similar to morningglory but reached a high of only 68% six hrs after treatment. There was more ^{14}C-fluometuron found in the leaf tissue with the 0.25 ul drop volume than the 1.0 or 2.0 ul drop volumes up to three hrs after treatment. Six hours after treatment the leaf tissue treated with 0.25 and 1.0 ul drop volumes contained more of herbicide than the 2.0 ul drop volume. The leaf wash of the 0.25 ul drop volume treatment also contained less herbicide than the 1.0 or 2.0 ul drop volume 0.75, 1.5 and 3.0 hrs after treatment. It is of interest to note, however, that 24 hrs after treatment there was no difference in the percentage ^{14}C found in the treated leaf tissue or the leaf wash due to drop volume.

If greater phytotoxicity is associated with greater absorption then these results would agree with Mullison (33) who reported no difference in response of 2,4,5-T between 2.0 ul and 6.0 ul drop volumes. However, the results are not in complete agreement with Hurtt et al. (27) who reported that the 0.1 ul drop volume of 2,4-D and 2.4,5-T was more effective on bean plants than the 0.2 ul or 0.4 ul drop volumes. These differences in results may be attributed to differences in measurement of response, plant species or herbicide. It is possible for smaller drop volumes to be more effective than larger drop volumes with no differences in percent absorption since smaller drops may have a greater distribution rate per unit area than larger drops. Differences due to herbicide structure interacting with drop volume may possibly be another explanation. Buehring et al. (13) found that drop size effects varied with the herbicide.

In these experiments a large difference in absorption between species was observed. Order of absorption in descending order was

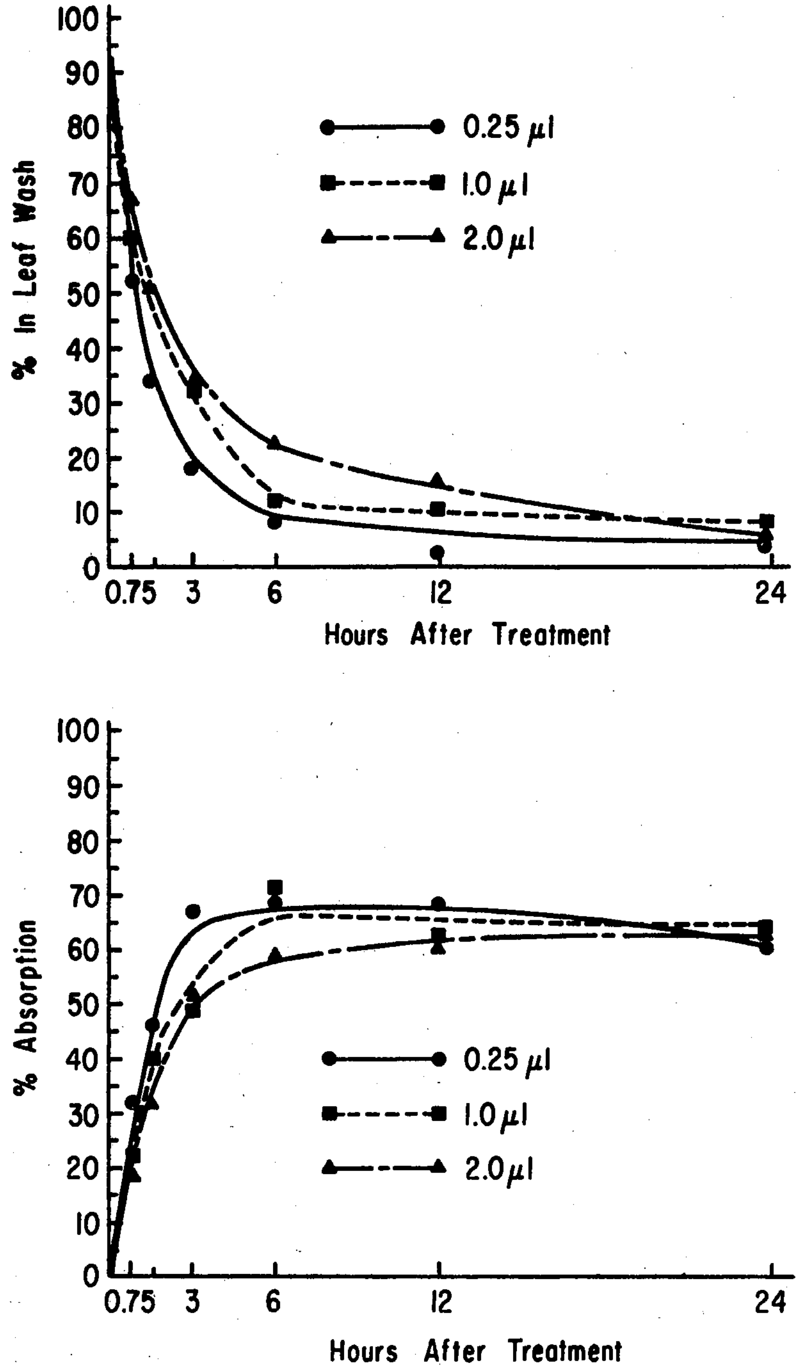


Figure 14. Influence of Various Drop Volumes on Percentage of ^{14}C-Fluometuron, Initially Applied, in Leaf Wash and Absorption by Pigweed at Various Time Intervals After Treatment

morningglory, pigweed and velvet leaf. The average ^{14}C-fluometuron loss at the termination of the experiments were 33, 36 and 13% for pigweed, velvet leaf and morningglory, respectively. There was no difference in the percent loss due to drop volume. The loss is attributed to volatilization from leaf surface and possibly metabolism by the plant.

Herbicide Concentration

The influence of herbicide concentrations (45, 135, 405 ppm), applied as a 1.0 ul drop volume, on foliar absorption was studied. There was a difference in foliar absorption by the various species due to herbicide concentration and time, but there was no interaction with time and concentration. Generally, with the exception of velvet leaf, as the herbicide concentration increased the percentage (initial application basis) of absorption decreased.

Morningglory (Figure 15) showed a rapid increase of ^{14}C-fluometuron in the leaf tissue, reaching a high of 85% three hrs after treatment. The ^{14}C-fluometuron in the leaf wash showed a rapid decline, reaching a low of 2 to 4% 24 hrs after treatment. The higher concentrations had more total herbicide in the leaf tissue than lower concentrations at all time periods. However, on a percentage of initial application basis, the 45 and 135 ppm treatments had more herbicide in the leaf tissue and less in the leaf wash than the 405 ppm treatment 1.5, 3.0, 6.0 and 12.0 hrs after treatment. Twenty-four hours after treatment, there was no difference in the percent herbicide in the leaf tissue or leaf wash.

The percentage absorption (Figure 16) in pigweed was similar to morningglory, but only reached a high of 78% 12 hrs after treatment. The rate of decline in the amount of herbicide in leaf wash was slower

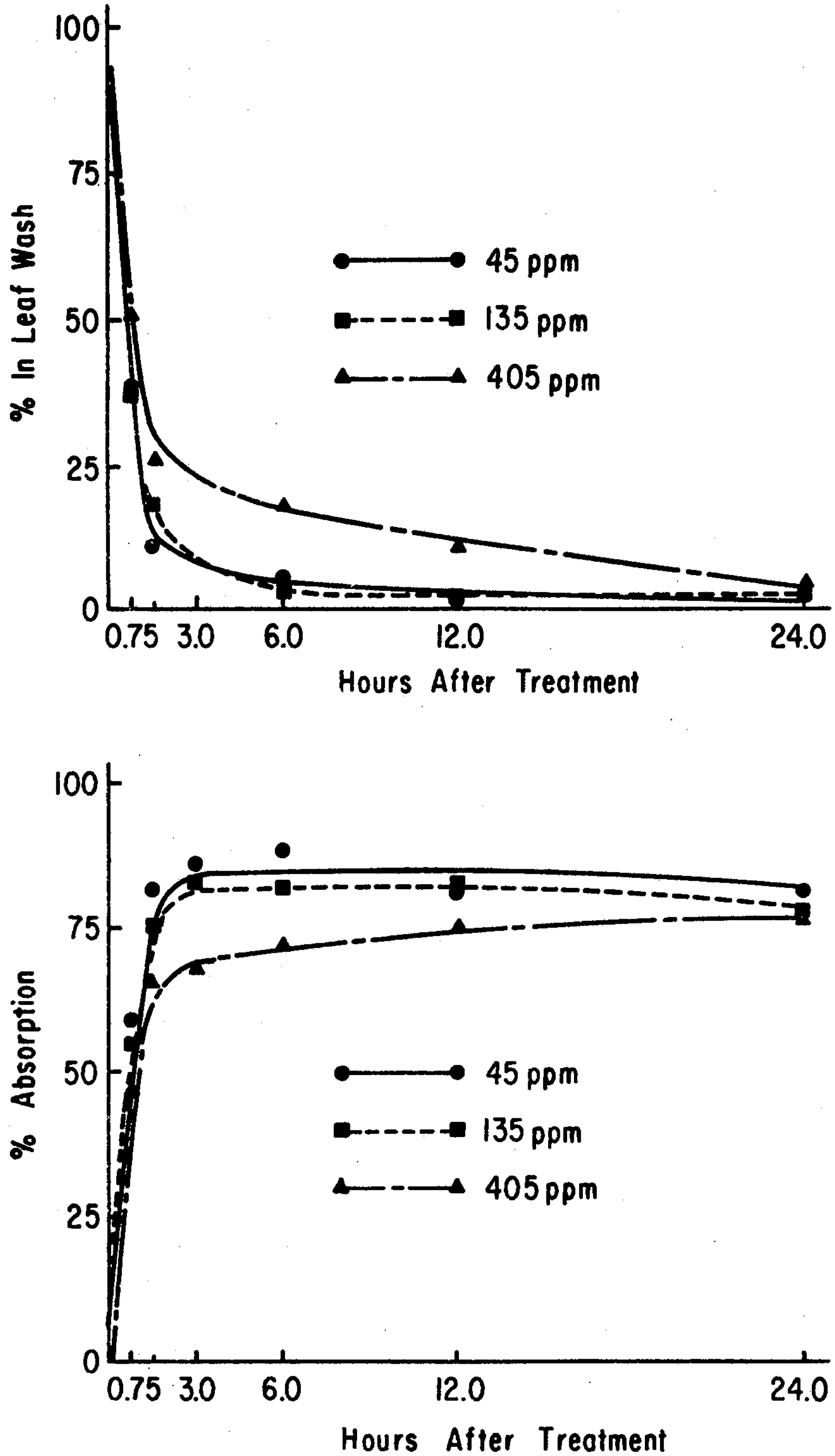


Figure 15. Influence of Herbicide Concentration on Percentage of ^{14}C-Fluometuron, Initially Applied, in Leaf Wash and Absorption by Morningglory at Various Time Intervals After Treatment

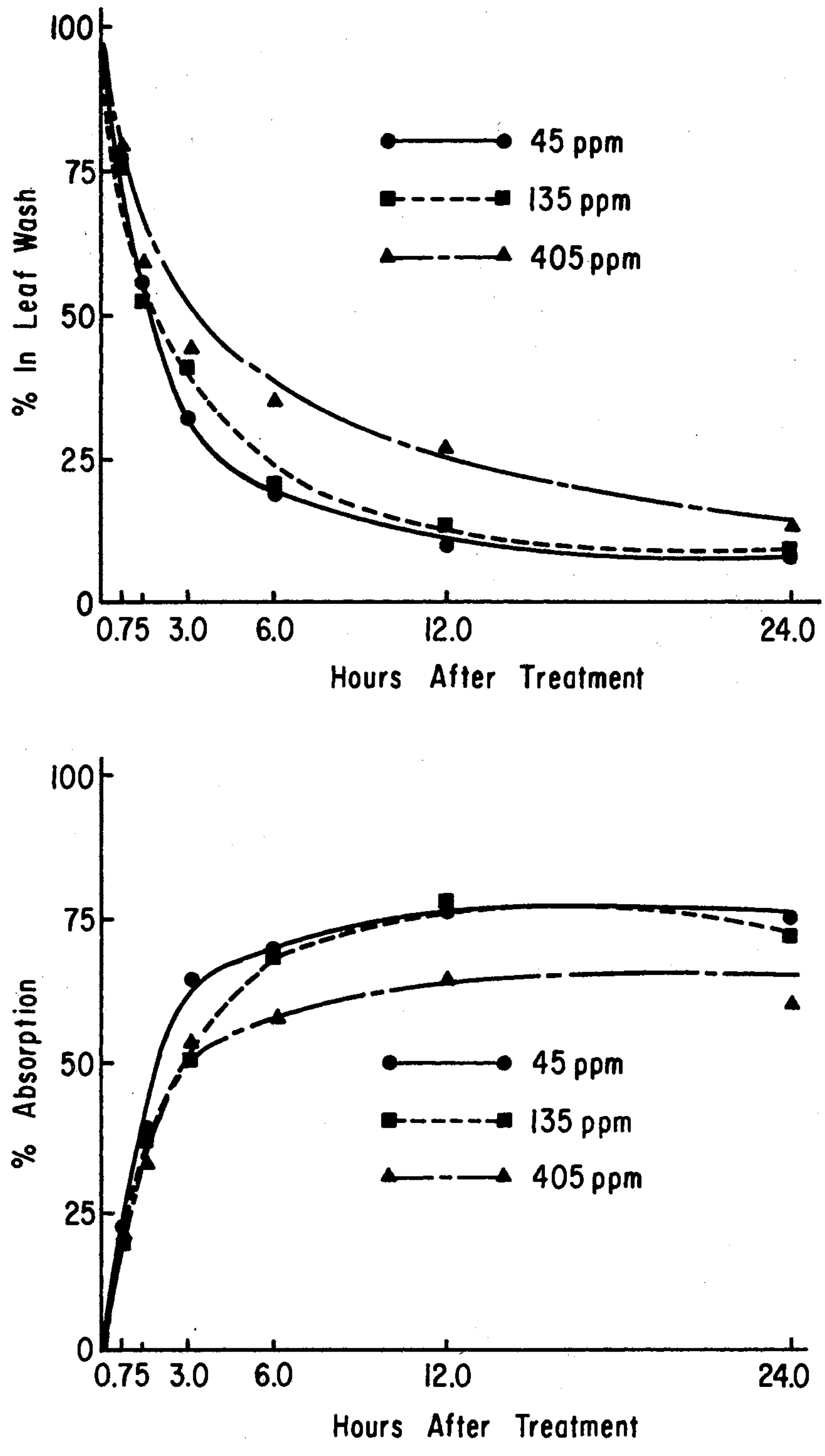


Figure 16. Influence of Herbicide Concentration on Percentage of ^{14}C-Fluometuron, Initially Applied, in Leaf Wash and Absorption by Pigweed at Various Time Intervals After Treatment

than in morningglory, reaching a low of 8 to 13% 24 hrs after treatment. As the herbicide concentration increased, more herbicide was found in the leaf tissue at all time periods. But on a percentage of the amount initially applied, the 45 ppm and 135 ppm treatments had a higher percentage of ^{14}C-fluometuron in the leaf tissue and less in the leaf wash than the 405 ppm treatment 6, 12, and 24 hrs after treatment. Three hours after treatment the 45 ppm treatment had a higher percentage of herbicide in the leaf tissue than the two other treatments.

Velvet leaf (Figure 17) had a much slower rate of absorption than morningglory reaching a high of 62% 12 hrs after treatment. The 135 ppm treatment had the lowest percentage rate of absorption. This is difficult to explain since increasing the concentration generally tends to slow the percentage rate of absorption. The experiment was repeated with similar results.

The 45 ppm concentration showed a greater percentage of ^{14}C-fluometuron in the leaf tissue than the 135 or 405 ppm at 3, 6, 12 and 24 hrs after treatment. The 45 ppm treatment resulted in less herbicide in the leaf wash than the 135 or 405 ppm treatments 6, 12, and 24 hrs after treatment.

The average percent of ^{14}C-fluometuron unaccounted at the termination of the experiments were 18, 22 and 20% for morningglory, pigweed and velvet leaf, respectively. There was no difference in loss due to herbicide concentration. The loss is attributed to volatilization from the leaf surface and possible plant metabolism.

Uniform Concentration per Unit Area

The leaf area covered by various drop volumes indicated that at a

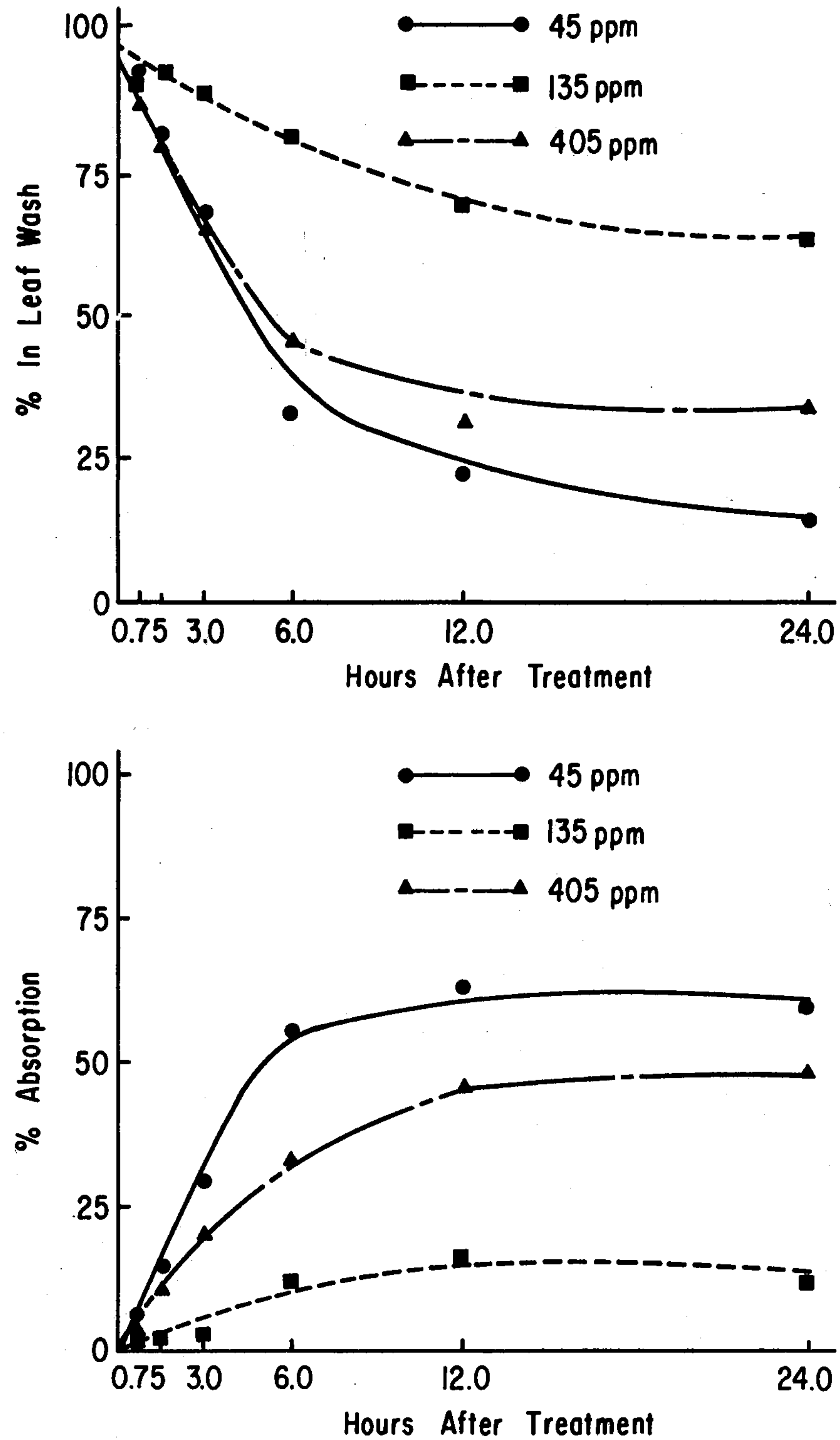


Figure 17. Influence of Herbicide Concentration on Percentage of ^{14}C-Fluometuron, Initially Applied, in Leaf Wash and Absorption by Velvet Leaf at Various Time Intervals After Treatment

given volume, as drop volume increased the leaf area covered decreased (Table IV). There were only minor differences in leaf coverage between morningglory and pigweed for the same drop size.

TABLE IV

LEAF AREA (mm^2) COVERED BY VARIOUS DROP VOLUMES WITH A TOTAL VOLUME OF 4 ul

Species	Drop Volume (ul)		
	0.25	1.0	2.0
A. Morningglory	10.72	8.10	6.18
P. Pigweed	10.96	7.18	5.69

The absorption studies with morningglory (Figure 18) indicated a difference in percentage (basis of initial application) absorption due to drop volume only at 0.75 hr. The 2.0 ul drop volume resulted in a greater percentage of herbicide in the leaf tissue and less in leaf wash than the 0.25 and 1.0 ul drop volumes. However, at the other time intervals there was no difference in the percent of herbicide found in the leaf tissue or leaf wash due to drop volume. The percentage of herbicide applied that was found in the leaf tissue reached a high of 89% three hrs after treatment. The herbicide in the leaf wash decreased rapidly, reaching a low of 2 to 3% six hrs after treatment.

Pigweed absorption was slower than morningglory (Figure 19). The 0.25 ul drop had a greater percentage of herbicide in the leaf tissue

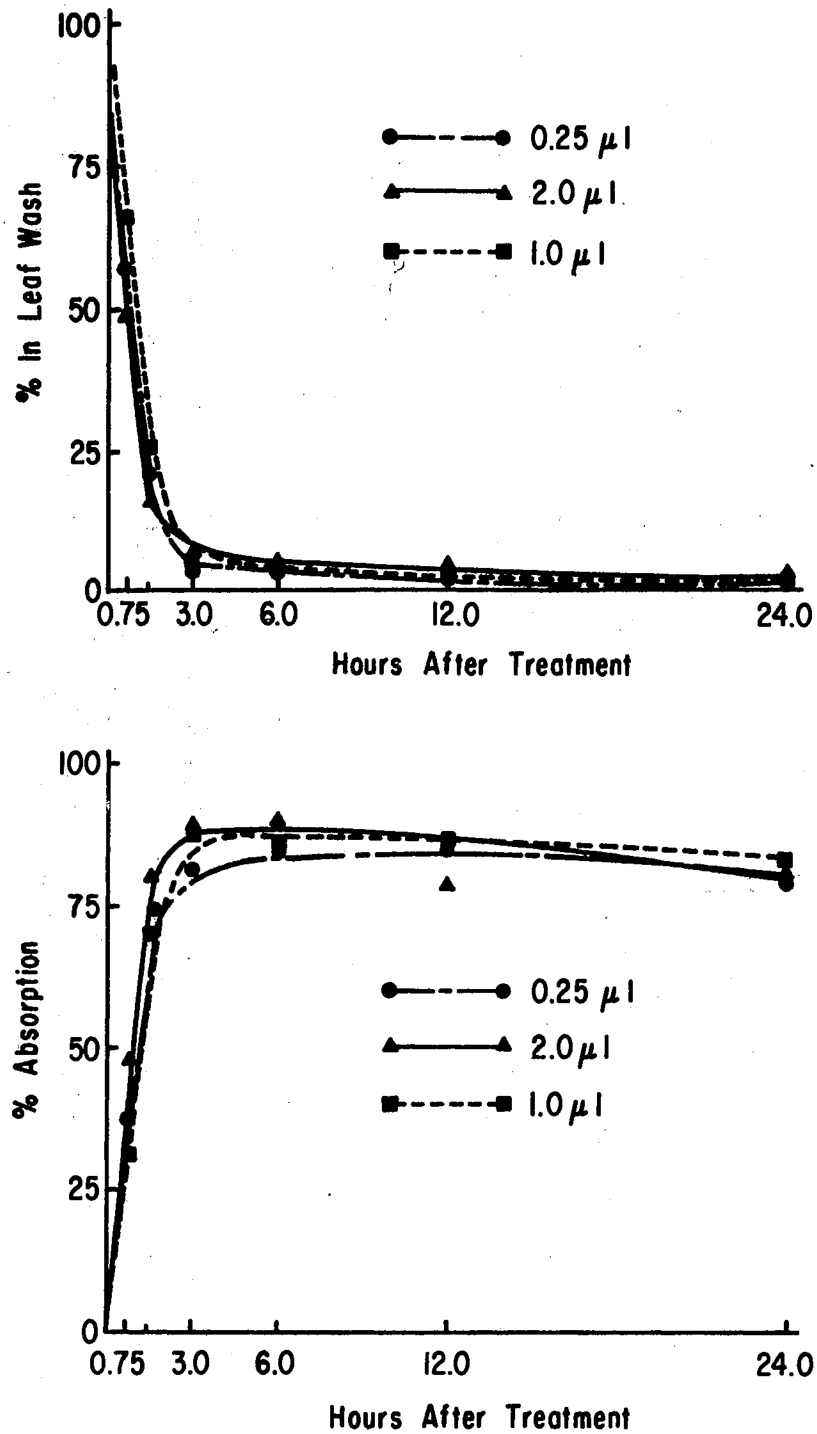


Figure 18. Influence of Various Drop Volumes of ^{14}C-Fluometuron, Applied As a Uniform Concentration per Leaf Area, on ^{14}C in the Leaf Wash and Absorption by Morningglory at Various Time Intervals After Treatment

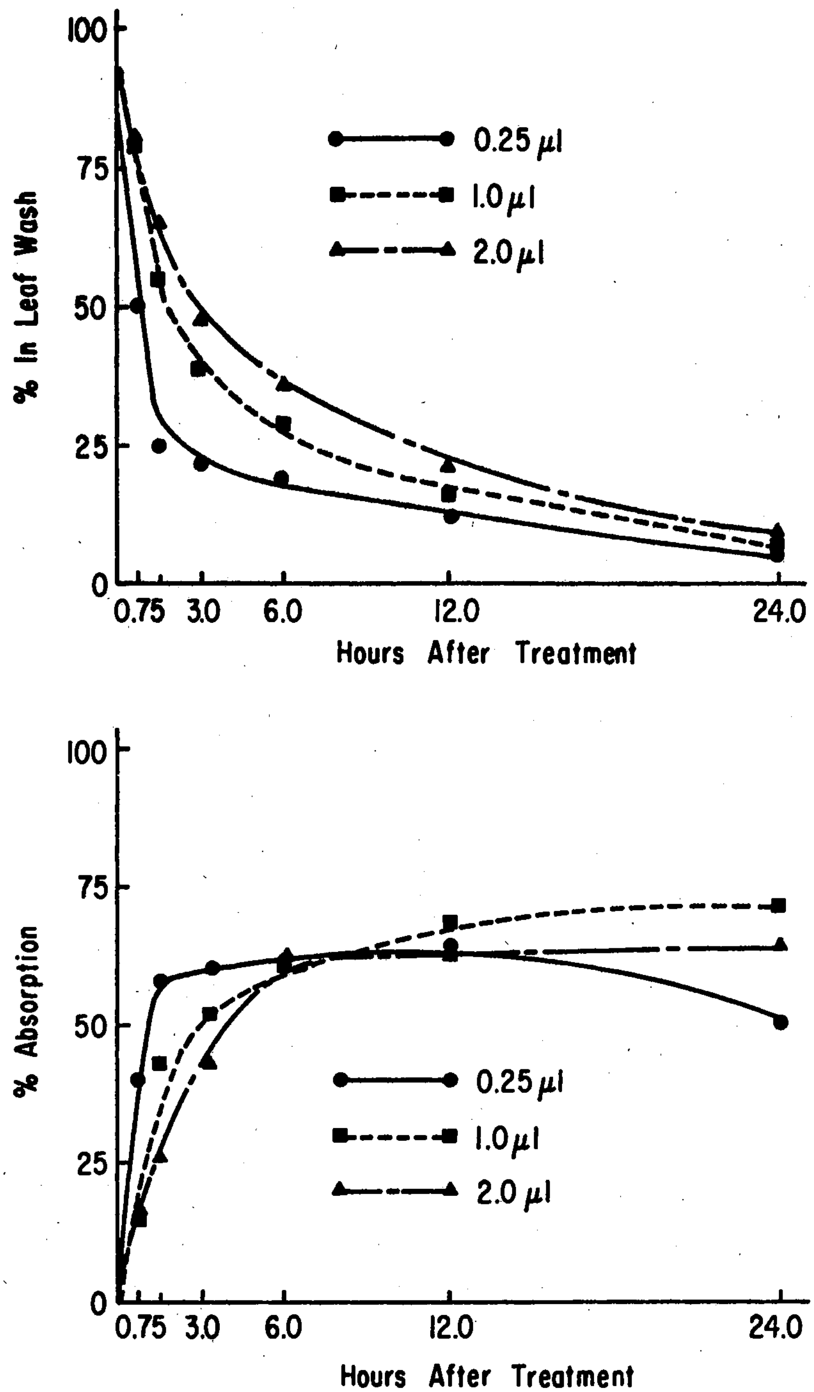


Figure 19. Influence of Various Drop Volumes of ^{14}C-Fluometuron, Applied As a Uniform Concentration per Leaf Area, ^{14}C in the Leaf Wash and Absorption by Pigweed at Various Time Intervals After Treatment

than the 1.0 and 2.0 ul drops 0.75, 1.5 and 3.0 hrs after treatment. Three hrs after treatment there was more herbicide in the leaf tissue with the 0.25 and 1.0 ul drops than the 2.0 ul drop. Six and 12 hrs after treatment there was no difference in absorption due to drop volume. However, 24 hours after treatment there was a greater percentage of herbicide in leaf tissue with the 1.0 and 2.0 ul drops than the 0.25 ul drop. In comparison to the 6 and 12 hr intervals the 0.25 ul drop showed a decrease in the percent of herbicide found in the leaf tissue. This decrease may possibly be due to evaporation and metabolism by the plant.

The herbicide found in the leaf wash decreased more gradually with pigweed than morningglory. However, the percent in the leaf wash reached a low of 5 to 9% 24 hrs after treatment. The 0.25 ul drop showed less herbicide in the leaf wash than the 1.0 and 2.0 ul drops 0.75, 1.5, 3.0 and 6.0 hrs after treatment.

The herbicide unaccounted 24 hrs after treatment for pigweed was 45, 21 and 26% for the 0.25, 1.0 and 2.0 ul drops. The herbicide unaccounted 24 hrs after treatment for morningglory was 20, 15 and 19% for 0.25, 1.0 and 2.0 ul drops, respectively. This loss is attributed to volatilization and possibly metabolism by the plants.

These data, in general, suggest that smaller drops for the same total volume will cover greater leaf area than larger drop volumes. Initially drop volume (with uniform herbicide concentration per leaf drop area) may affect absorption. However, later time intervals suggested no difference due to drop volume.

The results of this research indicate that plant species and herbicide rates all interact with spray drop sizes and carrier volumes in providing weed control. Grasses responded differently than broadleaf. The grass responses also varied greatly from one year to the next in the fluometuron plus MSMA experiments. Some of the variation in response may be attributed to differences in plant species population composition and soil moisture.

The response of grasses to paraquat drop size and carrier volume differed greatly from the fluometuron plus MSMA. The 600 u nozzle at the high herbicide rate was more effective than the 400 or 200 u nozzles at all carrier volumes. The conventional nozzle and the 600 u nozzle were equally effective at 281 L/ha. All nozzle sizes were ineffective at the low herbicide rate with all carrier volumes. The paraquat experiment was the only experiment in which the conventional nozzle was affected by carrier volume. The conventional nozzle was most effective at the higher carrier volume. This suggests that for grass control paraquat should be applied at higher carrier volumes. Since the high herbicide rate in the experiment only gave fair grass control, further increase in herbicide rate may mask the effect of carrier volume. Paraquat experiments with grasses need to be conducted with a wider range of herbicide rates and carrier volumes.

In general, pigweed response with both herbicide experiments were similar. Excluding the conventional nozzle, the smaller spray drops were more effective than the larger drops, especially at the lower carrier volumes. However, high carrier volumes and herbicide rates were able to mask the effect of drop sizes. The card coverage analysis indicated no difference in coverage between the three single jet nozzle sizes at a given L/ha. However, the drop deposition rate analysis indicated that the 200 u nozzle had a greater number of drops per 0.64 cm intersections than the 400 or 600 u nozzles at 47 and 94 L/ha. These data suggest that drop spacing is an important factor and becomes critical as the drop size increases and carrier volume decreases. The drop volume laboratory studies suggest that the difference in pigweed response due to drop size in the field studies was not due to greater absorption of herbicide with the smaller drops, but rather a better herbicide spray drop distribution on the plant leaf surfaces.

Although the card coverage indicated no differences due to drop size, one cannot conclude that this is true when interpreted to leaf surfaces. Leaf surfaces differ greatly from that of the card surface. The card surface was very absorbent as compared to the leaf surfaces which generally are not very absorbent. One would, however, expect it to give a relative idea of coverage. Better methods must be developed for determining leaf surface coverage by herbicide spray drops.

Considering the conventional nozzle, it was more effective than the other three nozzle sizes, especially at the lower carrier volumes and herbicide rates. The drop deposition rate analysis data also indicated that the conventional nozzle had a greater drop deposition rate than the three other nozzles at all carrier volumes. This suggests that conventional nozzle produces more numerous drops for the same volume as compared to the three other nozzle sizes. Therefore, drop distribution does not become a critical factor with the conventional nozzle as it does with the other three nozzle sizes at lower carrier volumes.

Additional drop size and carrier volume studies are necessary to determine what is occurring from the time the spray drop is emitted from the nozzle until after impact occurs on the leaf surfaces. The larger drops may be breaking into several drops upon impact. Certain size drops may also glance off the leaf surface upon impact. Research with other herbicides is also necessary.

Since many herbicides are applied preemergence or preplant, further work is needed to determine the influence of spray drop size and carrier volume when herbicides are applied as preemergence or preplant treatments. It would appear that spray drop size and carrier volume would be less critical with preemergence or preplant than with postemergence applications.

Herbicide loss from glass surface studies under particular environmental conditions indicated that higher temperatures and light both caused more herbicide loss. However, additional studies are necessary to determine if this loss actually occurs under field conditions. Studies on the influence of humidity and light on degradation and loss are also necessary.

Herbicide drop volume studies indicated no difference in absorption due to drop volume, but did indicate a large difference in species absorption. This suggests that difference in absorption may possibly be due to leaf surface characteristics. Methods need to be developed for characterizing leaf surfaces and cuticle layers of plant species. This would possibly help to explain why plant species may respond differently to herbicide treatments. There is also a need for methods for determining how much herbicide actually penetrates the cuticular layer.

CHAPTER V

SUMMARY

Field and laboratory studies were conducted to gain a better understanding of the influence of herbicide spray drops and carrier volume on plant response.

Field studies indicated that plant response to herbicide applications may be influenced by carrier volume, spray drop size and herbicide rate. Pigweed and grasses, in general, responded differently. Pigweed was more susceptible to the herbicide treatments than grasses.

Pigweed response in these experiments generally indicated that, excluding the conventional nozzle, the smaller drops were more effective at lower carrier volumes. However, higher herbicide rates and carrier volumes could mask the effects of drop size.

Grass response in these experiments differed greatly from pigweed. In the paraquat experiment grass response indicated that the large drop (600 u nozzle) was more effective than the smaller drop. The 1970 fluometuron plus MSMA experiment indicated no difference in grass response due to spray drop size and carrier volume. However, in 1971, the grass response was somewhat similar to pigweed response. The difference in 1970 and 1971 responses may be due to a difference in grass species. The dominant species in 1970 was red sprangletop and in 1971 crabgrass was the dominant species.

In all of the experiments, carrier volume did not have any effect on plant response with the conventional nozzle except with grass treated with paraquat. In this experiment the 281 L/ha volume was more effective than the lower volumes.

The card coverage and drop deposition rate analysis suggests that plant response to herbicide applications may be due to coverage and drop spacing. These are both functions of drop size and carrier volume. The conventional nozzle which was more effective than the other three nozzle sizes at the lower herbicide rates and 47 L/ha also had greater card coverage and drop deposition rate than the other nozzles at 47 L/ha.

The loss of fluometuron from glass slides was affected by light and temperatures. The lower temperatures had a higher relative humidity and had less herbicide loss. The amount of ^{14}C-fluometuron found in treated leaf tissue after washing was greatly affected by the solvent used for washing. The ascending order for removing greater amounts of ^{14}C-fluometuron from treated leaves by washing for various time intervals after treatment were water, ethanol and benzene. Autoradiography experiments with pigweed, morningglory and velvet leaf indicated no translocation of ^{14}C-fluometuron from the treated leaf.

Drop volume studies with morningglory, pigweed and velvet leaf indicated no difference in the amount of herbicide found in the leaf tissue, at the termination of the experiments, due to drop volume. This would suggest that smaller drops may be more effective due to their greater number and closer spacing and not to greater absorption by the plant. The absorption rates varied widely among the three species. The ascending order of absorption was velvet leaf, pigweed and morningglory.

Herbicide concentration had a significant effect on foliar absorption. With pigweed and morningglory the high concentration treatment

(405 ppm) had a lower percentage of absorption than the 135 or 45 ppm. However, with morningglory there was no difference due to herbicide concentration 24 hrs after treatment. With velvet leaf the 135 ppm treatment had the lowest percentage foliar absorption.

The studies of uniform herbicide concentrations per unit leaf area covered by various drop volume indicated that the smaller drop volume covered greater leaf area, per four ul total volume applied, than larger drop volumes. The absorption studies indicated that six or more hrs after treatment there was no difference in the percentage of fluometuron in the leaf tissue due to drop volume when the herbicide concentration per unit leaf area covered by the various drop volumes was constant.

Based on this research the conventional nozzle which was more effective than the other three nozzle sizes at low carrier volumes, could be used at lower carrier volumes (47 L/ha) in postemergence applications of paraquat for pigweed control and fluometuron plus MSMA for pigweed and grass control. Paraquat for grass control should be applied at 281 L/ha or more. The other three nozzle sizes which produced drops of uniform sizes generally were more effective at the high carrier volumes and therefore could possibly be used equally as effective as the conventional nozzle at higher carrier volumes with certain weed species. However, further research is necessary.

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