He must also be looking at combinations to be released at timed intervals in order to provide the needed broad spectrum weed control.

LIQUID FORMULATIONS

Liquid formulations have established minimum specifications. They must have good emulsifier systems to aid in the diffusion of the herbicide throughout the total water body. Adequate shelf life is also important, they must retain their efficiency when carried over into the next year's spray season. The formulation should wet well, having compatability with a range of surfactants. Finally, just as in terrestrial weed control work, the effective easy to apply liquid formulation must control drift and volatility when used in areas of sensitive crops or ornamentals.

EQUIPMENT FLEXIBILITY

The well formulated aquatic herbicide, whether liquid or granular, must be adequate for aerial, ground or mistblower application. For liquids, this means sprayability from 5 to 200 gallons per acre and with granular materials, uniform distribution at water level and at 50 to 60 feet above the water.

VII. ECONOMICAL IN COST

Within reason cost must be a limiting factor. In discussing formulations Dr. A. S. Crafts makes this statement: "Formulations are designed first to improve performance, and secondly to make for convenience in handling and application." When a manufacturer is forced to put out a cheap formulation to meet a price situation, that is exactly what is delivered. The extra efforts that go into quality formulations have to be left out. Weed control is what is being bought, not the cheapest chemical, and performance rather than price must eventually be considered the primary criterion of a good herbicide.

AMCHEM'S PROGRAM IN AQUATICS

Amchem has a past history of successful solutions for terrestrial weed control problems. This backlog of experience is being carried over into aquatic weed control. The knowledge and experience is shown in the development of improved formulations such as the original low volatile esters of 2,4-D and other phenoxy compounds. It is also expressed in the use of emulsifiable acids and invert formulations designed to control drift and volatility. At times formulation alone did not completely answer the problem and special equipment such as the centrifugal sprayer and granular applicator were developed to obtain maximum utilization of improved formulations.

The backbone of any herbicide development operation is a good screening program which can produce new compounds and improve old ones. Amchem has been able to utilize past knowledge gained from terrestrial screening in developing its aquatic program. At present we have a very effective 2.4-D formulation labelled for the control of several submerged and emerged weeds. We have an amitrole or amitrole-T for controlling cattails, phragmites, and water hyacinths, and we have just recently been given permission to label fenac as a soil-applied herbicide for hard-to-kill submersed weeds such as the Potamogeton species.

We have not resolved all aquatic weed problems, but we will continue to offer products which are as good as or better than any others available, and equipment for spraying or spreading them efficiently so their full potential can be realized.

Program Your Aquatic Weed Control Needs

By

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The title of this talk is PROGRAM YOUR AQUATIC WEED CONTROL NEEDS. What does it mean to program? Do we realize what the word program can imply? Webster defines program as a "plan of future procedures." An apt definition but one which does not completely describe all of the side effects of programming. Another definition listed for program is "a doctrine, theory or system whose validity can be tested only in practical application." This, perhaps, is even a better definition for us working in weed control. Basically, however, the word programming means "what are we trying to accomplish" and "how can we go about with the task at hand." One way to do this is to list what the problems might be in regard to the type of aquatic weed "problem" you have. "Problem" would include not only the species that are present, but which species you would like to have present, or perhaps what is the purpose of the weed control program, be it drainage ditch, irrigation canal, farm pond, water fowl refuge or what have you. Other points that need to be listed; what are the ramifications of your control program, is spray drift a problem, is it a water shed area, how about fish population, is the area used for swimming, irrigation or what else? One factor that must be considered is that you obviously cannot use a different material for each species present. Therefore, you must use a material which has a broad enough spectrum so that the primary weed populations will be removed. Perhaps the next year, then, the material will have to be changed to pick up the resistant weeds that were not killed by the first year's application. Another factor which may be important is ecology. After you spray one weed population, what changes can be expected in the population? And, of course, last but not least, are the economics involved. Of course, they are always important but sometimes these are relatively important, sometimes they are relatively unimportant when looking at the total program. In short, programming your aquatic weed control needs actually becomes very complicated when all factors of control are considered.

Let us examine some of these factors in detail so that we can arrive at principles where these factors might be taken into consideration in programming our control needs. Perhaps the most obvious place to start is which weeds do we have to control or which weeds are our problem. It is not necessary to go into any discussion on identification of the various aquatic weeds since these have been discussed in some detail before the society on several occasions. One point, however, that must be considered is the considerable variation in the time when the aquatic weeds are most susceptible to chemical treatment. For some species like the Arrow-arum *(Peltandra spp.)* the most susceptible period is during the flowering stage. For other plants such as the rose mallows, hibiscus species and cattails (*Typha spp.*) the time of greatest susceptibility is during the late flowering and the early stages of seed production. Giantcutgrass can be killed most easily during the period of maximum runner growth, which usually extends about a month after the initial flowering period. With the phragmites the most susceptible period is at the time of flowering or pollination, two to three weeks after the plant tassels. Cattails are most easily killed when in the late flowering or early fruiting stage. In the south the tropical cattail often flowers about two months after the narrow leaf cattail. For this reason multiple treatments sometimes have been required to control both species. Farther north, however, the period between flowering of the two species is much shorter. In Maryland, for example, tropical cattail flowers about one month after narrow leaf cattail and one treatment has given satisfactory control of both species. The best time for treatment of needlerush occurs during the flowering stage and lasts for three to four weeks. Regardless of all this, however, spraying can and should be done over a wide range of growth periods since satisfactory results can be obtained and frequently less chemical is required because of the smaller size of the plants. Whether the plant sites are flooded or non-flooded can also play an important role in determining effective control from a herbicide.

Aquatic plant control is also complicated by the need to consider the role of plants in different situations. Weeds are described as plants being out of place. Thus, plants that are undesirable in one location may be beneficial in another. To the waterfowl manager a weed is a plant that does not provide enough food or cover to justify the space it occupies. For example, buttonbush is responsible for 70% or more of the coppice growth which is a problem in the marshes and swamps of the lower Mississippi valley area. Yet in Maryland, Virginia and the Carolinas buttonbush contributes to valuable waterfowl habitat. Phragmites also can have a place in waterfowl management. The root growth will protect a marsh during storms. Also, the phragmites furnishes excellent cover for both the hunter and the hunted. For example, in past years it has helped to make the Thousand Acre Marsh in Delaware one of the best duck shooting areas along the Atlantic Coast. But solid stands are undesirable since landing areas are not available.

Since water is intimately associated with aquatic weed control many problems are unique to the water weed control field. Aquatic plants differ in physiology and habitat so significantly from terrestrial plants that one cannot confidently apply to aquatic plant control the information gained from experience solely with terrestrial plants. Water quality may be an extremely important factor. For example, work done by The Dow Chemical Company shows the effect of pH on coontail as shown in Table I. Similar results were also obtained with potamogeton and alligatorweed. Table II shows the effect of calcium as well as the effect of pH. Notice that the presence of calcium in the water, particularly at a pH of 7 or above, improved kill of coontail. Water temperature may not influence the reaction of a chemical to a significant degree but the aquatic weeds may be in their most active growth at higher temperatures and thus would be more susceptible.

Contamination of water by herbicidal chemicals is of prime importance. Naturally, all due caution should be exercised when using herbicides. It is necessary to use those materials which are relatively non-toxic to humans and fish as well as possible desirable plant species along the edges of the aquatic area. It is thus very important to control spray drift; spray drift in this instance being that physical drift, which through high pressure spray equipment or otherwise negligent use of spray equipment, in which particles of the spray material move onto desirable areas such as vegetables, citrus trees, home lawns, gardens, etc. Some of these problems can be avoided by using well trained and well equipped spray crews. Spray crews should be instructed or shown how to exercise care in proper chemical application. Materials should be used which have a non-volatile nature. It is important to use low pressure to provide largest sized droplets that are compatible with the type of application and control necessary. The end use of the water should be considered. That is, whether the water is used for swimming, irrigation, drinking, fishing; whether it is a water shed area, and some attention must be paid to this when selecting herbicides for weed control use.

Practical considerations must also be included in your choice of weed control materials. You obviously cannot use a different weed control material for each species you may find along a ditch bank or canal. You must, therefore, use a material which will control the primary species involved. This may require over a period of time that two or more herbicides be used if eradication is desired. It may even be desirable to make combinations of herbicides so that all the species are properly controlled. In this regard attention must be paid to the ecology, that is, the changing population after a herbicide application. In the case of waterfowl refuges, where certain plants are desirable, this can be made to work for you. Table III shows the effect of two chemicals on the ecology of two plots before and after chemical application. Note that before application the plant composition is approximately the same, yet after application, the plant composition is radically different.

A farm pond presents a somewhat different situation in aquatic weed control since you have a substantially stable water environment as contrasted to a ditch or canal. This means that chemicals applied to the water remain in contact for a long period of time. This has advantages in that it tends to make the chemical more effective in weed control but has a disadvantage in that it continues the water pollution problem for a long period of time unless after a period of weed control the pond can be flushed with fresh water. Ponds have an additional advantage in that construction of pond edges that drop off quite rapidly and fertilization which shades the aquatic weed serves as a reasonable means of weed control without chemicals. However, once weeds get into a pond, then chemicals must be used to eliminate them. Weeds may get into the pond from seeding upstream or birds scattering seeds or a number of other ways. Water weeds often grow in water stored for irrigation. They clog outlet and inlet pipes, spray nozzles and irrigation structures. They also harbor mosquitoes and interfere with fishing. Many irrigation reservoirs are shallow and have flat bottoms and are subject to frequent draw-down and refilling. In this case neither deep edges nor fertilization control weeds in such impoundments because of the fluctuating water levels. In deeper reservoirs or those in which draw-downs are infrequent, fertilization and deep edges may be practical. However, in irrigation ponds extreme care must be taken so that waters which have been contaminated with chemicals are not used for irrigating sensitive crops. Lakes have similar problems and normally not being equipped with deep edges and not being practical in most cases to fertilize, the problems are considerably magnified.

Let's discuss some of the chemicals that are available for aquatic weed control taking into account some of the principles and problems we have discussed above. I'm sure all of you have seen recommendations put out by Bob Blackburn and Lyle Weldon from Ft. Lauderdale. One of the chemicals you will notice mentioned in almost all of the aquatic weed problems is silvex. Kuron is The Dow Chemical Company trademark for its formulation of silvex as the propylene glycol butyl ether ester. This is not a new material. It has been tested since the early fifties for aquatic weed control. Early tests indicated that the Kuron herbicide at 5 qts/acre foot would control many of the troublesome submerged aquatic weeds in the United States. Experimental tests in 1957 and 1958 in several sections of the country evaluated the effectiveness of this concentration on several aquatic weeds. Commercial applications in 1958 and subsequent years contributed additional performance information. Kuron controls all of the weeds shown in Table IV.

Several methods of application can be used. Emergent species are controlled by using Kuron at 1 gal./100 gal. of spray solution applied to the emerged foliage as a thorough wetting spray. Application for the control of submerged aquatic weeds is generally made by diluting Kuron at 1 gal. in 10 to 40 gal. of water and directing this solution on or into the water. Proportioning pumps are also often used to mix Kuron with lake water and pump it to the boom which would distribute the solution over a wide swath. Uniform distribution appears to be desirable to allow a lethal concentration of Kuron to come into immediate contact with all the vegetative growth. Injections of undiluted formulations of Kuron have been used on a limited basis with varying results.

Kuron weed killer is not completely safe to fish. Experimental treatments to plots in several ponds have caused some fish injury in shallow areas where high concentrations occurred. Commercial applications at concentrations of 5 qts./acre foot have given some fish kill in a limited number of treatments. There has been no fish injury in over 99% of the treatments applied. Rapid incorporation of the spray solution, particularly those associated with rates in excess of 5 qts./acre foot should be avoided where fish kill cannot be tolerated. Pierce in New Jersey found that applications of Kuron had no influence on oxygen content in treated plots. Aquatic weeds treated with Kuron normally decompose slowly. In most situations ten to twenty days are required for decomposition. This slow decomposition apparently does not lower the oxygen content of the water. This is a problem with some aquatic herbicides which give a rapid kill of weeds. Pierce also reported that treatments with Kuron showed no effect on the population of benthic organisms. Applications of Kuron temporarily decreased populations of some plankton but within two weeks after treatment the populations were equal to untreated areas. The plankton studied consisted of fifty species. There was no deleterious effect on large aquatic vertebrates such as frogs and turtles in treated areas. Prolific algae growth is often a problem soon after treating aquatic weeds with some aquatic herbicides. Algae growth does not normally occur until three to four weeks after treatment with Kuron. The delay in appearance of algae apparently is associated with the slow kill of the aquatic weeds and thus the delay in release of nutrients into the water from decaying vegetation. Kuron is also low in toxicity and presents a low degree of hazard in handling and use. The Kuron herbicide was fed to groups of various animal species and the following LD50's were found. These are shown in Table V. From these data it may be concluded that there should be no problem from ingestion incidental to the handling and use of this product. Of course, no herbicide should be left where children or livestock have access to it. Cattle, sheep, swine, ducks and chickens have consumed water containing Kuron herbicide at 50 ppm over a four week period with no adverse effects as determined by water consumption, body weight gains and growth observations including gestation and parturition in sheep. These data indicate that foliage or water treated with Kuron herbicide as recommended should not present a hazard from ingestion. Skin irritation tests conducted upon rabbits have indicated that Kuron herbicide and its dilutions are slightly irritating upon repeated prolonged contact. In these studies there was no evidence of absorption through the skin in acutely toxic amounts. The observation of reasonable care and personal cleanliness practices should be adequate to avoid skin difficulties. Kuron herbicide when diluted to 1% with water or 1 gal. per 100 gal. caused no primary irritation or allergenic responses when applied to the skin of fifty human volunteers using a repeated insult technique. In addition, the product was patch tested on a second group of fifty human subjects at concentrations up to 50% without cutaneous reaction. Even when applied undiluted to the skin for two hours it caused no skin response. Thus it may be concluded with a high degree of assurance that when used as directed, this product should cause no skin irritation or skin sensitization responses.

Kuron may remain in water for three to four months after treatment where no dilution occurs. Accordingly it is suggested that water treated with Kuron should not be used for spray purposes or for irrigation.

Thus Kuron appears to present a possible solution to a wide variety of aquatic weed problems. It has a wide spectrum of activity on both submerged and emerged weeds, is relatively low in toxicity to fish and other aquatic animals and it has been exhaustively tested throughout the years. The scientists at Ft. Lauderdale and other places around the United States have had Kuron in test in the laboratory and in the field. The Corps of Engineers has put out a large scale field test for the control of alligatorweed. Since Kuron does have a wide spectrum of activity it is very useful where mixed stands of aquatic weeds occur. For example, in areas where alligatorweed and water hyacinth are intermingled, Kuron offers a solution for control of both species. Many chemicals such as 2,4-D and others will control water hyacinth but will not appreciably affect the alligatorweed. Kuron offers economic and efficient control of both.

For the control of aquatic and ditch bank grasses a material generally recommended is dalapon or the Dow trademarked product Dowpon or Radapon. This material, like Kuron, has been extensively field tested in a wide variety of locations and species. It is particularly useful in drainage ditches since grass and cattails can seriously reduce the flow of water. Cattails are particularly troublesome. They interfere with the proper utilization and maintenance of drainage and irrigation canals by reducing the velocity and volume of flow, and by causing deposition of silt and debris. Safety can also be an important consideration. In weed clogged drainage ditches water is held for a longer period of time after storms, increasing the chance that small children may tumble in and drown. In reservoirs, farm ponds, marshes and lake margins cattails waste large quantities of water, crowd out plants which provide food for wildlife and often interfere with fishing, boating and other uses of these bodies of water. An excellent bulletin on this has been issued by the U. S. Department of Agriculture, July 1963, entitled "Studies on the Control of Common Cattail in Drainage Channels and Ditches." These studies indicated that Dowpon herbicide was extremely effective in controlling cattail. Additional work has been reported in Michigan, Oregon and other states which shows the effectiveness of Dowpon in controlling cattails. Ted Ball of the U. S. Fish and Wildlife Service reported the results applying Dowpon by aircraft in the southeast. In this test Dowpon was applied to control cattail, maidencane and giantcutgrass. All showed good response. In addition, Dowpon is non-toxic to fish and wildlife species as well as domestic animals.

Brush control can also be important in certain cases of aquatic weeds, particularly in ponds and ditch banks. Brush control has been done by 2,4-D, 2,4,5-T or combinations of both. All of you are familiar with these results. Recently The Dow Chemical Company has discovered a new brush control material trademarked Tordon. Although this material is not yet in the marketing stage for aquatic weed control, excellen brus control results have been obtained on utility rights-of-way. The material is also currently under test throughout the United States with aquatic weed workers.

In summary—remember that aquatic weed control is perhaps more complicated and has more ramifications than terrestrial weed control. Be sure to take into consideration all the problems and possibilities of problems in controlling aquatic weeds by chemicals. The chemical companies are aware of your complicated problems and are constantly striving in research and development to offer better solutions to those problems. It is up to each of you to be aware not only of the problems of aquatic weed control but also the latest solutions to these problems.

TABLE I

Effect of pH of Water on Silvex Effectiveness

pH	Silvex ppm	Kill rating
5.0	0	0
7.0	0	0
9.0	0	0
5.0	3.5	10
7.0	3.5	8
9.0	3.5	3

TABLE II

Effect of Ca and pH on Response of Coontail to Silvex at 2.5 ppm

Ca ppm	pH	Kill rating
0	5	10
0	7	7
0	9	2
250	5	10
250	7	9
250	9	8
500	5	10
500	7	9
500	9	8

TABLE III

Plant Composition as Affected by Chemical Treatment

	Plot 1		Plot 2	
	Before	After	Before	After
Cordgrass	96%	1%	95%	20%
Hibiscus	3%		3%	70%
Dock	1%	98%	2%	
Cyperus	Trace	1%	Trace	2%
Smartweed			Trace	5%

TABLE IV

Aquatic Weeds Controlled by Kuron at 1.25, 2.5 and 5 Qts./acre foot.

1.25 quarts/acre foot or less (0.5 ppm)	
White water lily	(*Nymphaea spp.*)
Pickerelweed	(*Pontederia cordata L.*)
2.5 quarts/acre foot or less (1.0 ppm)	
Yellow water lily	(*Nuphar spp.*)
Mud plantain	(*Heteranthera spp.*)
Water milfoil	(*Myriophyllum heterophyllum*)
5 quarts/acre foot or less (2 ppm)	
Bladderwort	(*Utricularia spp.*)
Watershield	(*Brasenia schreberi*)
Coontail	(*Ceratophyllum demersum*)
Fanwort	(*Cabomba caroliniana*)
Waterweed	(*Anacharis canadensis*)
Variable pondweed	(*Potamogeton diversifolius*) (*Potamogeton amplifolius*)
Naiad	(*Najas flexilis*)
Spike rush	(*Eleocharis spp.*)
Tapegrass	(*Vallisneria americana*)
Waterstarwort	(*Callitriche spp.*)
Soft rush	(*Juncus effusus*)
Bulrush	(*Scirpus americanus*)
Burreed	(*Sparganium spp.*)

TABLE V

LD_{50} Values

Animal Species	mg/kg
Rat	1070
Guinea pig	850
Rabbit	850
Mouse	2140
Chicks	2000

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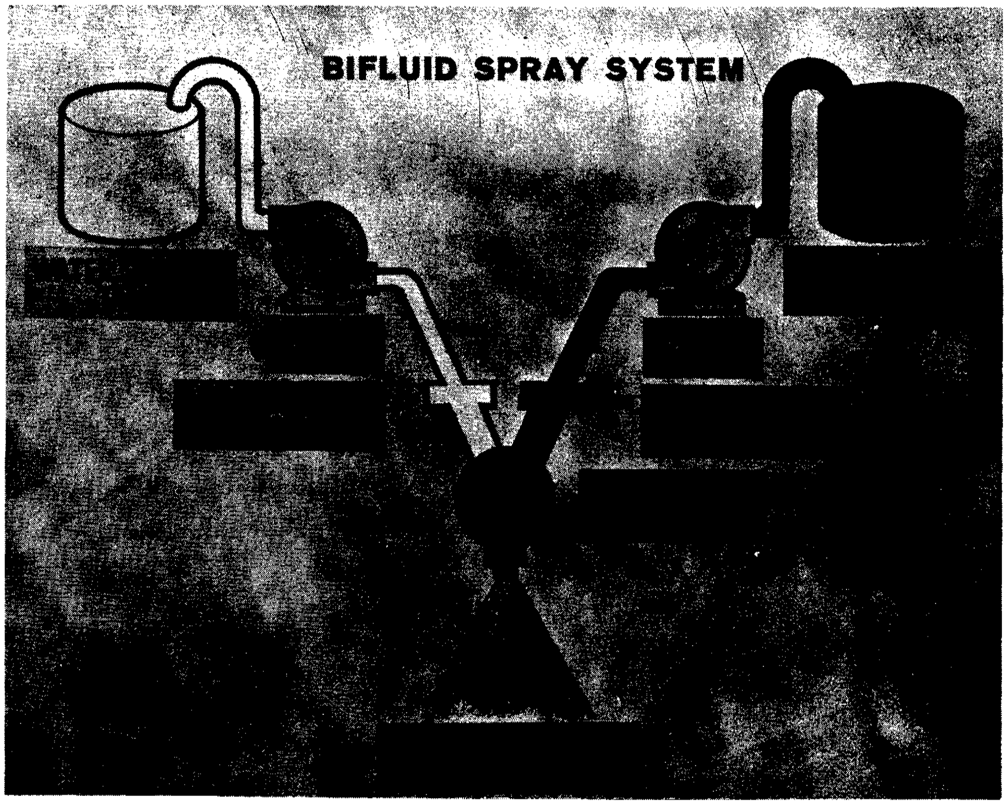
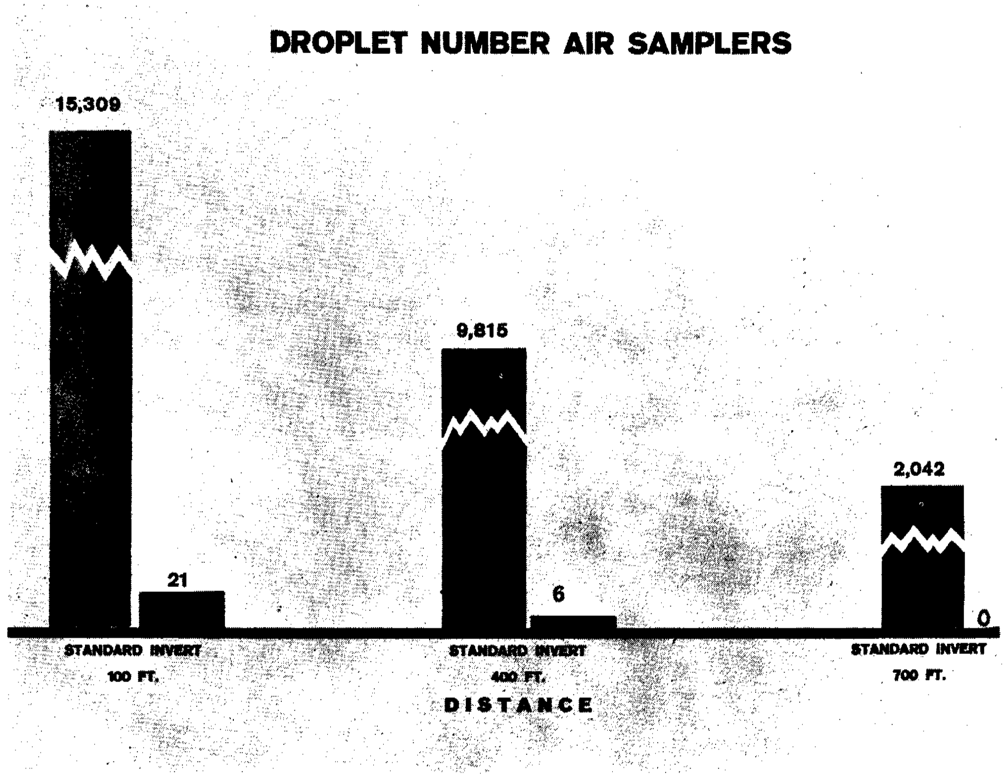
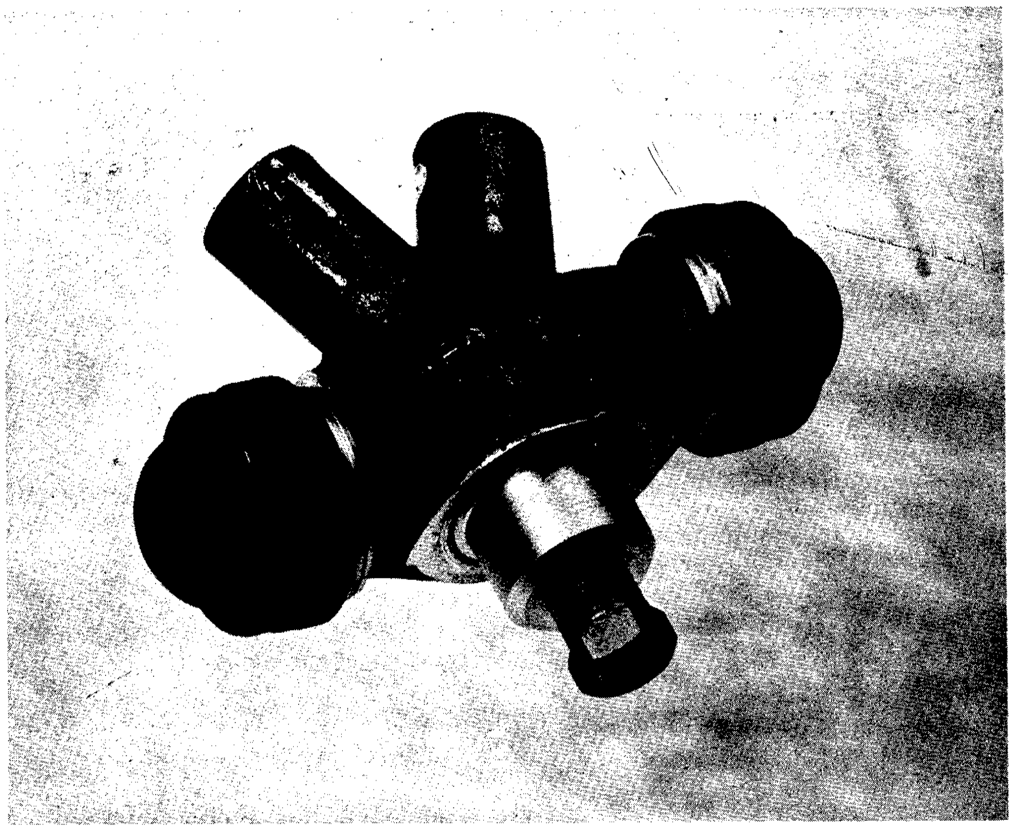


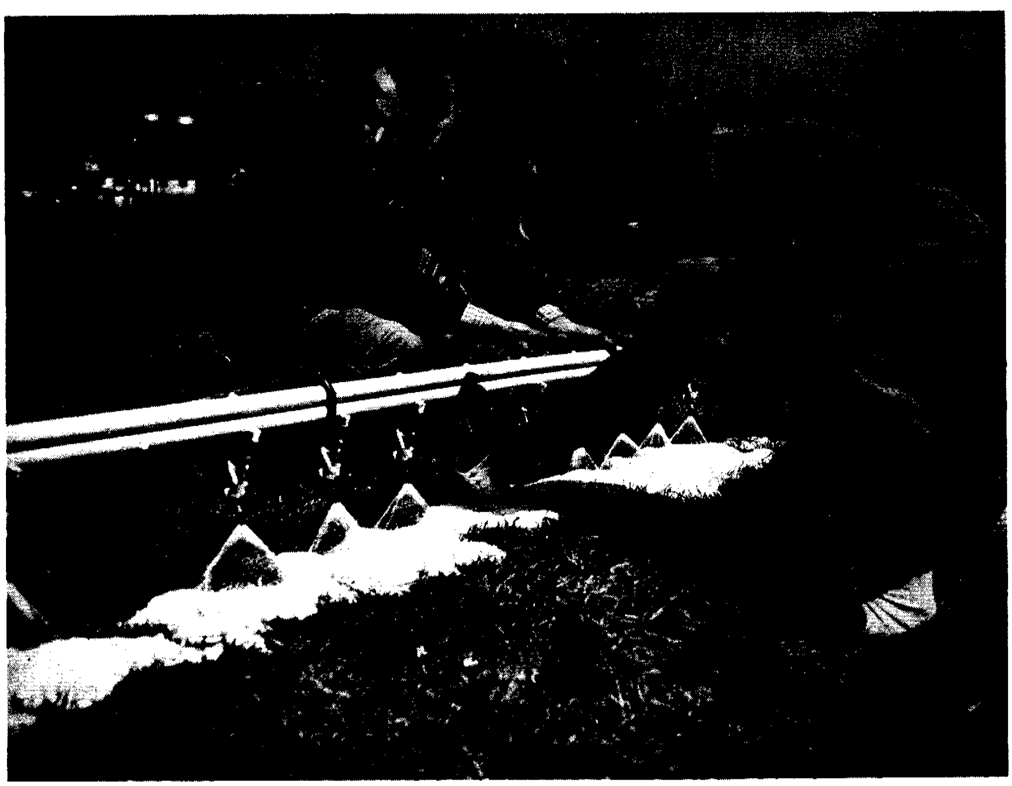
Schematic drawing shows how Hercules bifluid system (Rhap-Trol) operates. An invert mixture — water in oil, instead of oil in water — produces a thick mayonnaise-like spray consisting of larger drops minimizing drift. Note that oil and water phases do not meet until they reach the nozzle mixing chamber at the nozzle.



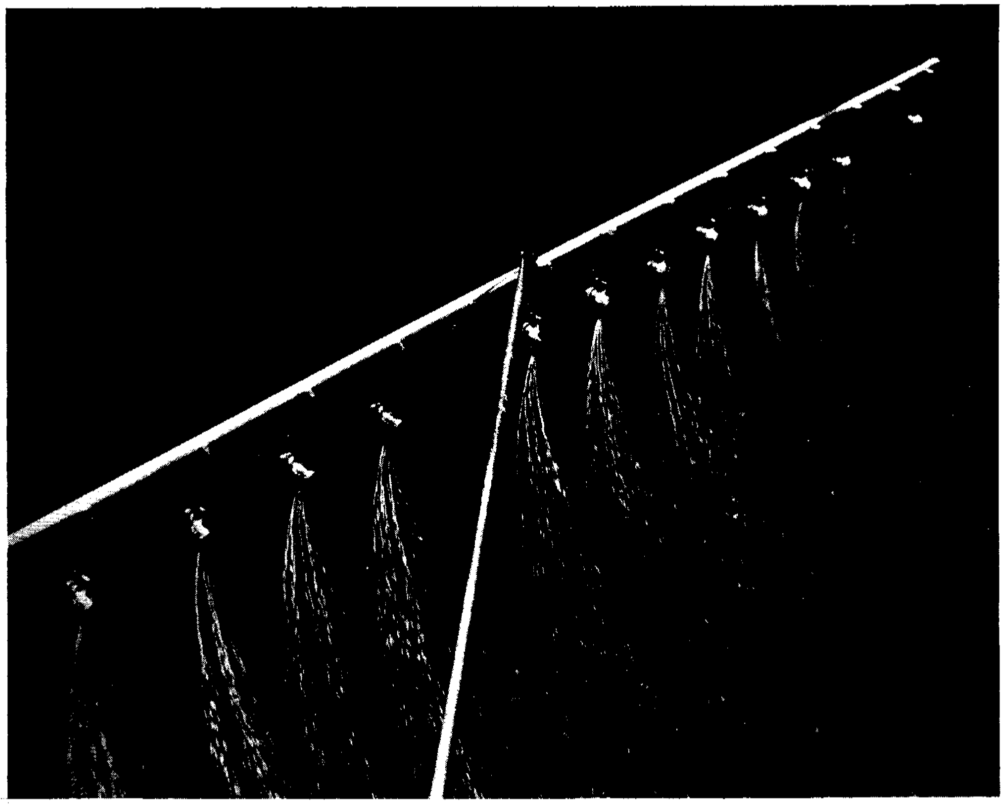
Comparison of number of droplets from standard and invert spray system at measured distances from target point. At 100 feet, standard system shows 15,309 droplets compared to 1 for invert system. At 400 feet, the impres difference continues.



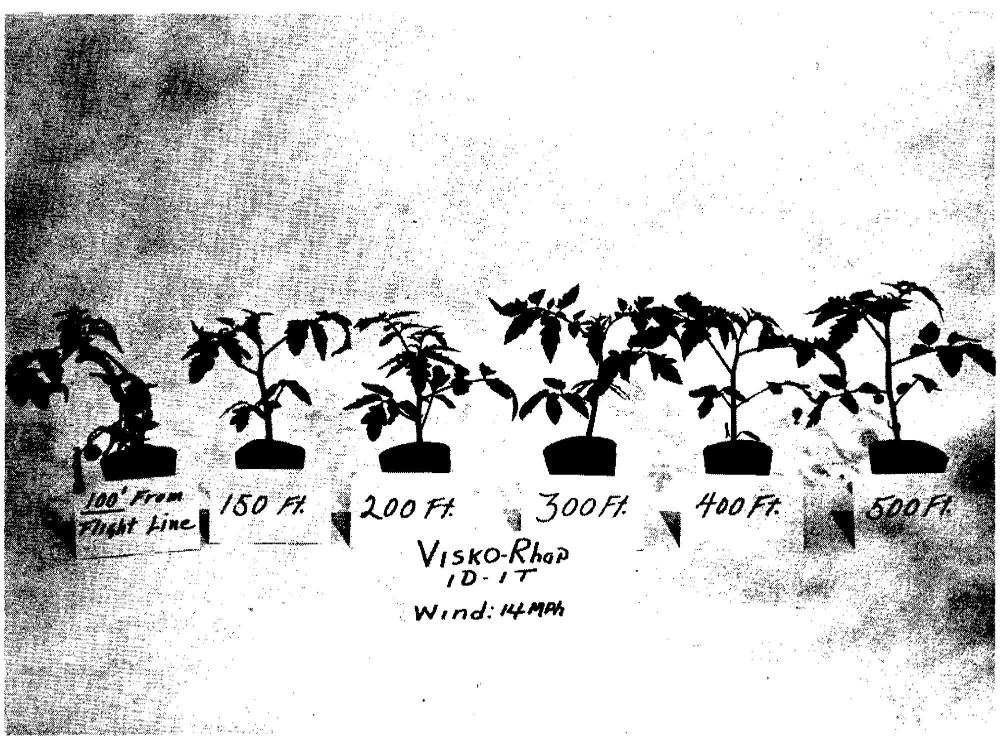
A close view of the nozzle of the Hercules Rhap-Trol bifluid system. The oil phase and the pater phase of the emulsion are separate . . . each coming through an independent system until they are mixed in the chamber in the nozzle.



A boom spraying the Hercules Rhap-Trol system of bifluid herbicide application lays down a thick, creamy emulsion that "builds up" on the ground. In flight the emulsion produces large, uniformly sized drops that drop straight and minimize drift. An invert emulsion is a water in oil emulsion as contrasted to an oil in water.



Large droplets from Hercules bifluid system (Rhap-Trol) fall from helicopter in flight. Because invert emulsions of water in oil produce large uniformly sized droplets, drift is minimized.



Samples of tomato plants taken at different locations away from flight line of helicopter spraying Rhap-Trol low lrift formulation of phenoxyl herbicide. Hercules bifluid system of applying invert emulsion was used and only minimal damage noted at 100 feet; almost none thereafter.