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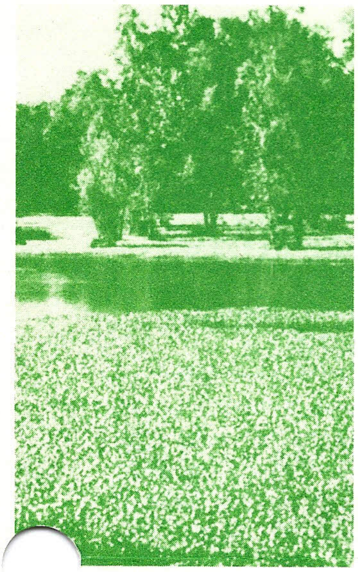

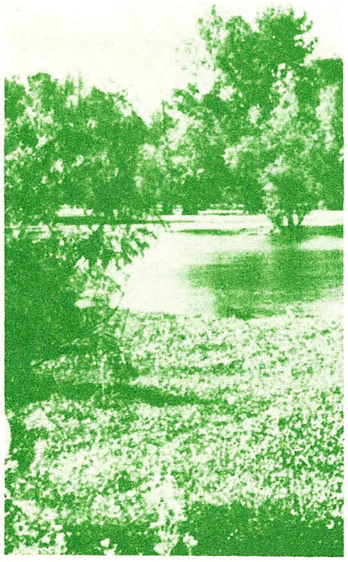

ENVIRONMENTAL LABORATORY

AQUATIC PLANT CONTROL RESEARCH PROGRAM

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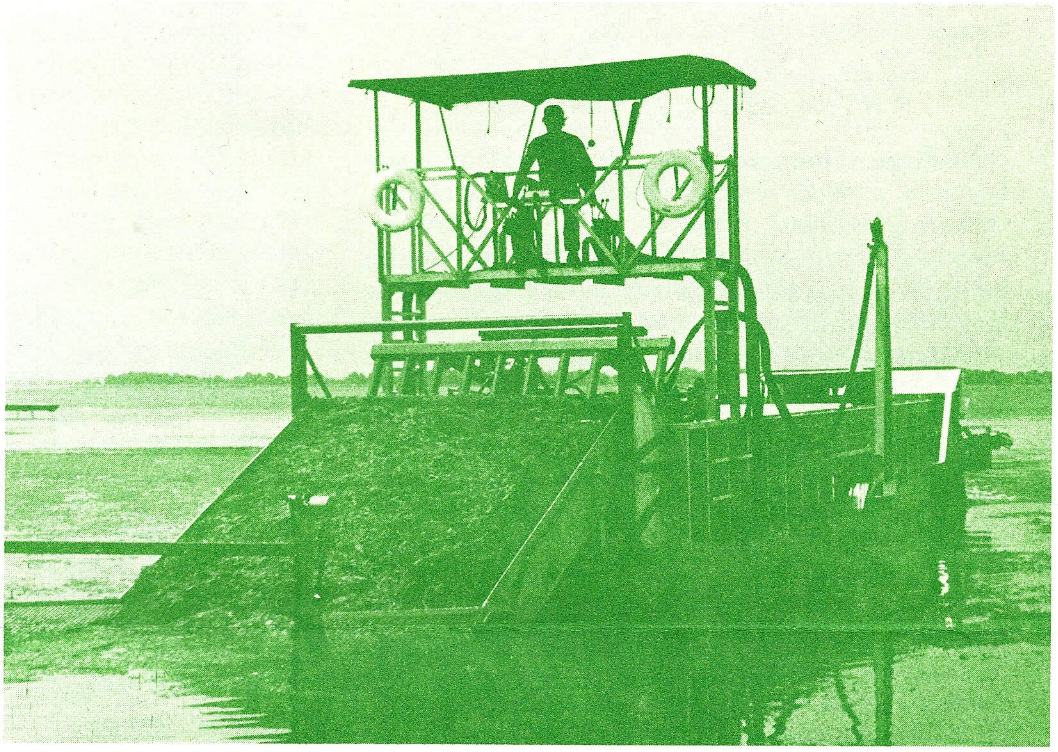

SIMULATING MECHANICAL CONTROL OPERATIONS

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SYNOPSIS — The computer program HARVEST simulates mechanical harvesting of aquatic plants and can be used in estimating costs and planning control operations. In addition to estimating the time and cost of using a specific system, the model can identify the most cost effective of a number of harvesting systems, as well as the most cost-effective way to use a particular system. Two application examples are given.

Mechanical methods for controlling nuisance aquatic plants are addressed in one of the research areas of the Aquatic Plant Control Research Program (APCRP). The purpose of the work is to develop technology for more effective and less expensive use of mechanical control methods.

One of the difficulties facing those who plan to use mechanical control techniques is the lack of guidance on how to estimate cost and how to plan an operation. The questions facing an aquatic plant manager in this situation include:

- How long will the job take with a specific harvesting system and how much will it cost?
- What is the most cost-effective harvesting system to use?

- What is the most cost-effective way to use a particular system?

A computer model was developed that can simulate mechanical harvesting operations using any specific mechanical system operated in any realistic environment. The model, called HARVEST, has been tested and used experimentally for a number of years. The tests and experimental use showed that the model's simulations are realistic and that the model would be a good operations-planning tool.

WHY A COMPUTER MODEL?

Mechanical harvesting of nuisance aquatic plants typically involves a number of stepwise or simultaneous operations. First, the harvester cuts submersed plants at a predetermined depth and gathers them onboard, usually with a moving conveyor belt reaching below the water's surface. Floating plants are simply gathered onboard. The cutting/gathering operation continues until the storage capacity of the harvester is reached; the harvested plants are then transported to a shore takeout point. If the harvester is serviced by one or more transporter units (barges specifically designed to haul harvested plant material), the harvester off-loads onto a transporter, which takes the material to the shore takeout point while the harvester continues working. If no transporter is available, the harvester must transport the plant material to the takeout point. At the takeout point, the harvested material is off-loaded to a shore conveyor. The transporter (or harvester) then returns to the harvesting site. The shore takeout point may be the final disposal site for the harvested material or the material may be hauled to another disposal site.

The overall productivity of a harvesting system (tons or acres harvested per hour) is determined by the interaction of all the processes involved in the operation. With any given set of harvesting conditions (environmental and operational conditions and mechanical performance parameters), the system productivity will be limited by the slowest step in the process. For example, if harvesting is conducted a long distance from the shore takeout point or if the transporter is extremely slow, then the overall system productivity is limited by the transport step. Or if plant density is relatively sparse in the harvesting area, then the harvester's material-collection rate (and overall system production) will be limited by the forward speed of the harvester and the width of the harvester's cutting bar.

Since mechanical harvesting requires one or more pieces of very costly machinery, the overall expense tends to be high. It is critical that cost of mechanical operations be accurately estimated and that the planned operations be conducted in the most cost-effective manner possible. This requires a means of estimating costs and determining how individual steps in the operation affect the overall performance.

Rule-of-thumb estimates, which do not take into account important interactions between plant density, takeout point location, and mechanical performance parameters, may result in large errors in cost estimation. To keep track of all these simultaneous operations manually and attempt to predict harvesting system performance or how a change in one of the steps would affect system performance would be a monumental task. This is, however, a very easy task for a computer. HARVEST simulates each important step in a mechanical control operation and estimates the total time and cost required for a mechanical system to complete a specific harvesting operation.

HOW HARVEST WORKS

HARVEST takes all important environmental, operational, and mechanical characteristics into account to simulate an operation. Table 1 contains the list of inputs for the model. Equipment parameters determine the speed at which plants are

TABLE 1. INPUTS REQUIRED BY HARVEST

Equipment Parameters:
- Cutter width, ft
- Harvester -
  - maximum throughput, tons/hr
  - maximum working speed, ft/min
  - turning time, min
- Transporter -
  - onloading time, min
  - capacity, tons
  - speed loaded, ft/min
  - speed empty, ft/min
- Docking and setup time at takeout point, min
- Truck -
  - speed empty, mph
  - speed loaded, mph
  - unloading time, min

Environmental Parameters:
- Plant density grid array or mean site density, tons/acre
- Water depth, ft
- Water current speed, mph

Operational Parameters:
- Dimensions of harvest site, ft
- Distance from harvest site to shore takeout point, ft
- Distance from shore takeout point to final disposal site, ft
- Hourly rental cost for each piece of equipment used, $/hr

removed from the water, delivered to the shore takeout point, and deposited at a disposal site. Plant density determines the rate of movement of the harvester through the site and the number of loads that must be transported to shore. Harvesting site geometry, distance between harvest site and shore takeout point, and distance between shore takeout point and upland disposal area determine the amount of time that must be spent transporting harvested plant material.

The equipment characteristics and the environmental database are used by the model to determine the speed, based on plant density, at which the harvester can make a full-depth/full-width pass through the first swath to be harvested. If plant density is too great for a full-depth/full-width pass (i.e., the harvester cannot travel at a minimum acceptable speed), the swath width is reduced until an acceptable speed is achieved. If plant density is too great to achieve an acceptable speed at any swath width, then combinations of reduced depth and reduced width are employed. This procedure is continued on a swath-by-swath basis until the site has been completely harvested. After initial harvesting, cleanup operations are simulated if desired. Harvester-transport interactions are simulated throughout the operation, and transport arrivals at the harvester and at the shore takeout point are predicted.

If the material is to be hauled to a remote disposal site, a trucking routine is used. This routine uses the arrival times of the transporters at the shore takeout point to calculate the optimum number of trucks, of three different sizes, needed to avoid delay of the harvesting operations; i.e., the transporter will not have to wait for a truck.

Cost for an operation is estimated from total operational time by applying hourly rental rates for each piece of equipment with operator.

Outputs for the model are listed in Table 2. The most useful outputs, from an operational point of view, are the total time and cost required to conduct the harvesting operation and the time and cost broken out by function (harvesting, transporting, and trucking).

EXAMPLES OF USE

The following examples demonstrate how HARVEST may be used to plan an effective control operation or to study the effects of operational variables on overall system productivity.

TABLE 2. OUTPUTS FROM HARVEST

Swath by Swath:
- Material harvested, tons
- Harvester speed, ft/min
- Time required to harvest, min
- Distance to off-loading point, ft

Time Summary:
- Harvester -
  - harvesting, min
  - waiting, min
  - cleaning up, min
  - doing other functions, min
- Transporter -
  - hauling material

Mass Summary:
- Tons harvested
- Number of harvester loads
- Number of truck loads

Rate and Efficiency Summary:
- Tons harvested/hr
- Acres harvested/hr
- Harvester use effectiveness

Trucking:
- Number of trucks, by truck size, required to avoid delays in operation

Cost Summary:
- Total cost to harvest site, $
- Cost of trucking by truck size, $

Example 1

How does an aquatic plant manager select the most cost-effective mix of equipment for a specific harvesting situation?

For a 35-acre harvesting site that is 420 ft from the shore takeout point, three mixes of equipment are simulated.

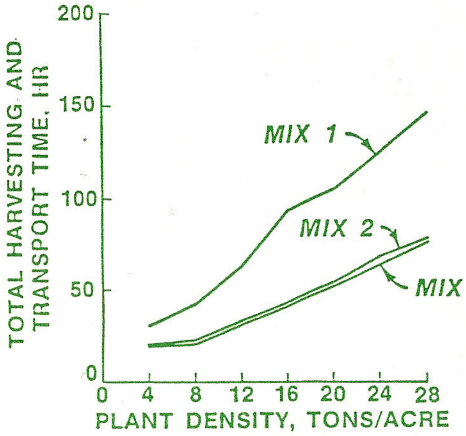
Mix 1 - harvester and shore conveyor

Mix 2 - harvester, 1 transporter, and shore conveyor

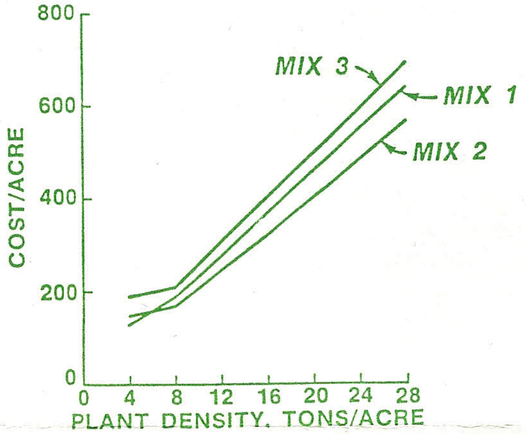
Mix 3 - harvester, 2 transporters, and shore conveyor

The harvester, transporter (if used), and shore conveyor are identical for each mix; no trucking is included. Operations were simulated over a range of plant densities, and output of total operational time and cost per acre was specified. (Figure 1).

The least time consuming is Mix 3, although the time using Mix 2 is virtually the same. This indicates that the extra transporter unit in Mix 3 cannot



a. Total time



b. Cost per acre

Figure 1. Example of effect of mix of equipment on time and cost of operation

be efficiently utilized for the short barging distance. Mix 1 is, of course, the most time consuming because it has no separate transporter and the harvester cannot be used as a harvester while it is transporting.

The most cost-effective mix is Mix 2 with Mix 3 the least cost-effective. This shows that the expense of the extra transport in Mix 3 does not reduce the harvesting time enough to justify the cost. Mix 1 shows an intermediate level of cost effectiveness.

Example 2

How could an operations manager determine how equipment changes or modifications would affect overall production rates?

A harvesting operation using a harvester, a transporter, and a shore conveyor, is being conducted in dense plant growth (36 tons/acre) 4000 ft from the nearest shore takeout point. The harvester spends a large amount of time waiting for the transporter. The operations manager wants to determine how increased transporter speed would affect overall system performance.

The operation is simulated over a range of transport speeds. Figure 2 shows that increased transport speeds up to 11 mph will increase overall system production rate (tons harvested per hour). Beyond 11 mph, no further improvement occurs since transport speed is no longer the limiting factor.

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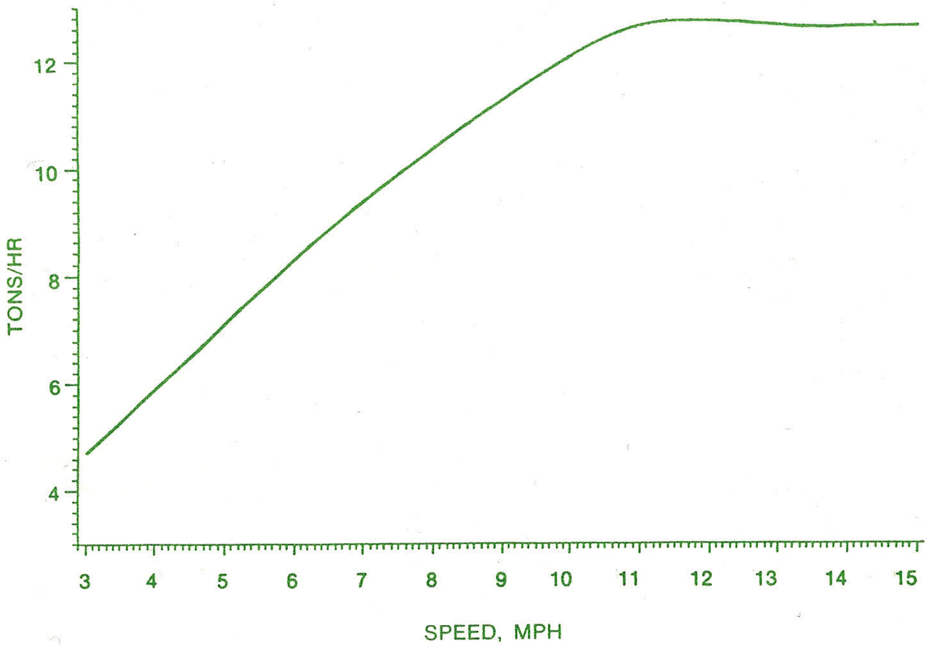

Figure 2. Example of effect of transporter speed on overall production rate

EVALUATION OF HERBICIDE/ADJUVANT MIXTURES IN FLOWING WATER

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Ecosystem Research and Simulation Division, EL

INTRODUCTION

The invasion of nuisance submersed aquatic plants into rivers, streams, and canals has prompted interest in techniques for managing these plants in flowing water. One approach is to use chemical herbicides and herbicide/adjuvant mixtures. Adjuvants are designed to hold herbicides on the surface of leaves and stems, thus enhancing herbicide uptake into plant tissues. Examples of adjuvants are surfactants, wetting agents, oils, stickers, spreaders, thickening agents, and emulsifiers.

For a herbicide to be effective, some minimum concentration of that herbicide must be maintained near the target plant, either in the sediment or in the water column, for some minimum contact time. Contact time presents a problem in flowing water because the water column is continuously moving and herbicides released into the water at one point are transported downstream. Herbicide/adjuvant mixtures have been used effectively for controlling submersed plants in still-water; however, only limited data are available on their use in flowing water. A primary concern is the length of time adjuvants can hold herbicides in the vicinity of the target plant in flowing water.

This study is designed to determine which herbicide/adjuvant mixtures show potential in controlling submersed weeds in typical stream flow velocities and to compare the control achieved by these mixtures with results using conventional herbicide formulations. The submersed species Eurasian watermilfoil (*Myriophyllum spicatum* L.) and mixtures of the herbicide 2,4-D with various adjuvants were included in the initial studies. Eurasian watermilfoil was used as the target plant because it is rapidly spreading throughout flowing water systems in the West and in the Pacific Northwest. The herbicide 2,4-D was selected because of its proven efficacy on Eurasian watermilfoil. Adjuvants used in the initial phases of the study include the inverting oils/emulsions Asgrow 403, Bivert, and I'vod and the polymers Polycontrol and Nalquatic.

* Dr. Getsinger, a member of the faculty of Clemson University, is working as a Plant Physiologist on an Intergovernmental Personnel Act agreement between the university and the Environmental Laboratory, Waterways Experiment Station.

APPROACH

Herbicide/adjuvant experiments were conducted in a modified hydraulic flume. A schematic of the flume system is shown in Figure 1. A 30-m section of the flume channel was divided lengthwise into two equal areas (0.8-m wide × 0.9-m deep) to accommodate duplicate experiments (Figure 2). Individual plant shoots, collected in the field, were cut into 60- to 70-cm lengths and planted in shallow polyethlene basins (23-cm wide × 32-cm long × 10-cm deep) filled with a sand/mud mixture. These basins were arranged along the bottom of the flume (27 basins per channel) to produce two plant stands, 3 m long, consisting of over 1600 shoots each. The plant stands approximate field densities. Greenhouse roof panels (90-percent transmittance) cover the plants and supplemental lighting is available, if needed.

Herbicide/adjuvant formulations were applied directly to the plant stands with techniques similar to those used in the field. Water samples were

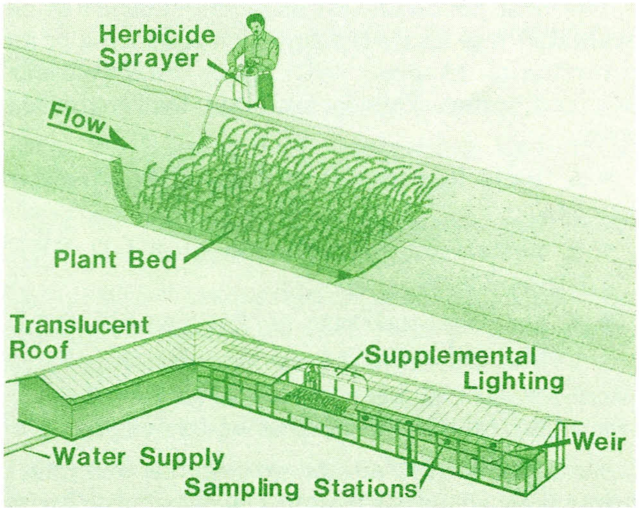

Figure 1. Flume system set up to evaluate the effectiveness of herbicide/adjuvant mixtures in controlling aquatic plants growing in flowing water

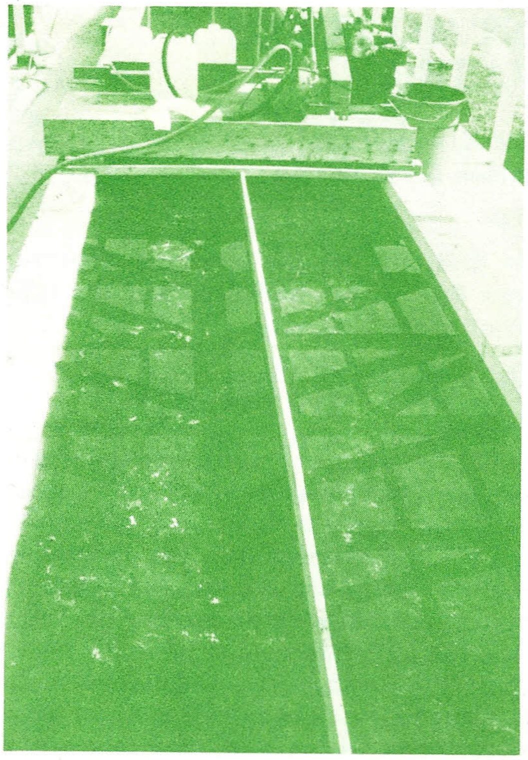

Figure 2. Flume channel divided into two equal areas

collected 5 m downstream from the plant stands by automatic samplers and were analyzed for herbicide residues. Experiments were run at velocities ranging from 3 to 30 cm/sec.

PRELIMINARY STUDIES

The first herbicide/adjuvant formulation to be evaluated was an invert emulsion consisting of an inverting oil (Asgrow 403), 2,4-D DMA (Weedar 64), and water. This formulation was compared with:

- A liquid formulation of 2,4-D DMA (Weedar 64).
- A pelletized formulation of 2,4-D BEE (Aqua-Kleen).
- A noninvert mixture of Asgrow 403, 2,4-D DMA, and water.

All formulations were prepared to give a 2,4-D treatment rate of 45 kg acid equivalent/ha.

Both the invert emulsion and the noninvert mixture consisted of a ratio of 7 parts water to 1 part inverting oil and were prepared using a Minnesota Wanner (MW) Invert Pump Pak designed for aquatic spraying. The principal components of this system included a Briggs & Stratton 11-hp engine, a Wanner 10-gpm positive displacement piston pump, and a MW mechanical inverter.

The quality of an invert is related to a number of mechanical and environmental factors. Selecting appropriate metering orifices for water, herbicide, and inverting oil; maintaining adequate pressure; and eliminating fitting and line air leaks are critical for blending a good invert when using the MW Invert Pump Pak. Trace chemicals in the water used in blending an invert emulsion may also affect the quality of the invert. A deficiency in any one of these factors can result in a poor invert.

When prepared correctly, an invert emulsion consists of water surrounded by oil and has a mayonnaise-like consistency. The herbicide is dissolved within the water phase of the emulsion. Inverts have the appearance of snow flakes when sprayed under the surface of the water and flakes of invert stick to leaves and stems of submersed plants. (Figure 3).

A poor invert mixture (noninvert) has a thin milky consistency (Figure 4), in contrast to the thick consistency of a desirable invert. Field applicators have implied that some confusion still exists concerning the consistency of a desirable invert emulsion. With that in mind, the invert emulsion and the noninvert mixture used in these preliminary studies were prepared with identical water sources, herbicides, and calibrated equipment so that operator error, or inexperience, became the limiting factor in making a desirable invert emulsion.

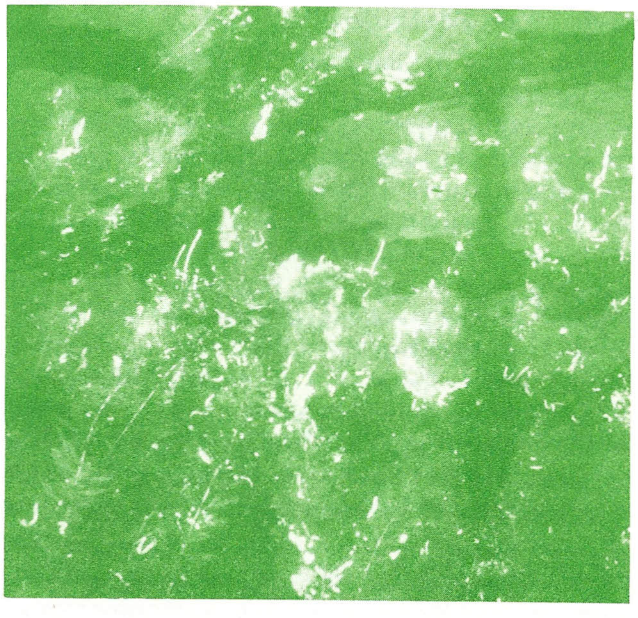

Figure 3. Flakes of invert emulsion clinging to submersed plants

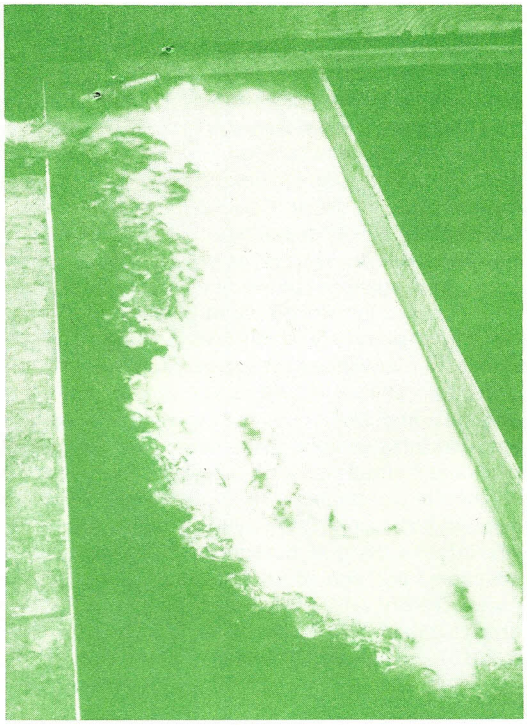

Figure 4. Milky consistency of a noninvert mixture

The invert emulsion and the noninvert mixture were ejected from the Pump Pak into a 19-ℓ plastic bucket. The formulations were transferred to a 7.6-ℓ pressurized pot and sprayed below the surface onto the plant beds at 20 psi using a hand-held wand with a flat-fan nozzle. The liquid 2,4-D DMA formulation was also applied on the plants using the pressurized-pot system. The pelletized 2,4-D BEE was broadcast over the surface of the plant beds by hand.

Stream velocity was set at 3 cm/sec (0.1 ft/sec) with a water depth of 76 cm. Each formulation was applied on duplicate plant beds. Mid-depth water samples were collected 5 m downstream from each plant bed at 2-min intervals for 60 min after treatment. Samples were composited to represent 12-min periods and analyzed for 2,4-D residue.

RESULTS

Water samples collected 5 m upstream from each plant bed during experimental runs showed no herbicide contamination.

Herbicide residue data (Figure 5) demonstrated that the noninvert mixture and the liquid 2,4-D DMA formulation released 2,4-D into the water in a similar fashion. Both formulations released a large pulse of herbicide during the first 12 min, with herbicide residues below detection after 48 min. In contrast, the invert emulsion and the pelletized 2,4-D BEE formulation showed slower herbicide release rates, but herbicide residues dropped below detection 60 min after treatment.

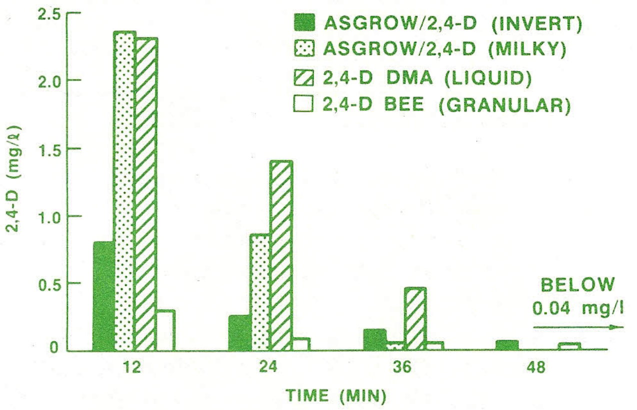

Figure 5. Effect of time on 2,4-D residues monitored 5 m downstream of plant beds

These preliminary data suggest that, when used in flowing water, a noninvert mixture of 2,4-D/Asgrow 403 has no advantage over a liquid 2,4-D DMA formulation and that a good invert mixture of 2,4-D/Asgrow 403 may not have an advantage over a pelletized 2,4-D BEE formulation.

FUTURE STUDIES

During FY 1984, the effectiveness of 2,4-D/adjuvant mixtures (Asgrow 403, I'vod, Bivert, Polycontrol, and Nalquatic) on Eurasian watermilfoil is being evaluated in the flume at various flow velocities. The 2,4-D residues are being determined at 12-min. intervals for 3 hr posttreatment. This monitoring program will demonstrate how flow velocity and time affect the behavior of 2,4-D/adjuvant mixtures.

In FY 1985, a different herbicide (e.g., endothall or diquat) will be mixed with the adjuvants used in the 2,4-D studies. Following evaluation of herbicide-release patterns in flowing water, comparison with 2,4-D release profiles will be used to develop guidance for using the best adjuvants. Recommended herbicide/adjuvant mixtures will be field tested prior to publication of field guidance.

SIMULATING MECHANICAL CONTROL

(Continued from page 4)

HARDWARE REQUIREMENTS

HARVEST, written in FORTRAN IV, needs only about 25K of memory to execute. The program can easily be placed on any personal computer that has enough memory to accommodate FORTRAN software. The program could be run in BASIC language (which requires less memory to load). Interactive graphics software will be added during this fiscal year so that the output from the model can be displayed directly on a color graphics monitor attached to a personal computer.

DOCUMENTATION/USER MANUAL

A technical report and a user manual for the HARVEST model will be published this fiscal year.

This bulletin is published in accordance with Army Regulation 310-2. It has been prepared and distributed as one of the information dissemination functions of the Environmental Laboratory of the Waterways Experiment Station. It is principally intended to be a forum whereby information pertaining to and resulting from the Corps of Engineers' nationwide Aquatic Plant Control Research Program (APCRP) can be rapidly and widely disseminated to Corps District and Division offices as well as other Federal agencies, State agencies, universities, research institutes, corporations, and individuals. Contributions are solicited and will be considered for publication so long as they are relevant to the management of aquatic plants as set forth in the objectives of the APCRP, which are, in general, to provide tools and techniques for the control of problem aquatic plant infestations in the Nation's waterways. These management methods must be effective, economical, and environmentally compatible. This bulletin will be issued on an irregular basis as dictated by the quantity and importance of information to be disseminated. Communications are welcomed and should be addressed to the Environmental Laboratory, ATTN: J. L. Decell, U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss. 39180, or call 601-634-3494.

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