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Developments in Aquatic Weed Control Research in India Relating to Fisheries

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ABSTRACT

Aquaculture in India is a more recent technology as compared to agriculture. Even in agriculture the developments in scientific farming are still being assimilated by the farmers. While priorities are to obtain high yields of fish, the goals of sufficient fish and breeds of fish to meet the farmers needs will only be achieved as the benefits of weed control are realized. Even so, it is possible to achieve some low-cost, feasible, and economic returns with the application of the few developments that have been made in aquatic weed control.

Key words: Ammonia, control-release, grass carp, mechanical control, biological control.

INTRODUCTION

The extent of aquatic weed problems in India can be realized from the fact that waterhyacinth [*Eichhornia crassipes* (Mart.) Solms] alone accounts for about 0.5 million ha. The area infested with other aquatic weeds, is estimated to be an additional 320,000 ha, which represents a potential annual loss of fish crops of 160,000 metric tons a year, conservatively worth a billion dollars. These estimates were made several years (2) ago and the current figures may be even more staggering.

Recently, another serious weed (*Salvinia molesta* D. S. Mitchell) has been spreading very rapidly in the southern part of the country and is now considered the second major national weed problem following waterhyacinth. Among submersed weeds, *Hydrilla verticillata* L. F. Royle is the most important, difficult to control, and ecologically more subversive and insiduous. Under this category of weeds other members like *Ceratophyllum, Najas, Vallisneria, Nechamandra, Potamogeton* also commonly occur.

Persistent algal blooms, particularly *Microcystis, Anabaena* and other blue-green algae, seriously affect fish culture in ponds and become even more problematic in intensive culture programs with high stocking densities of fish with accompanying high inputs of feeding and fertilizer. Dinoflagellate blooms such as *Peridinium* cause allergic skin problems to fishermen and other users of water.

Aquatic weed problems as serious as the above are caused by emergent species such as *Nymphaea, Nymphoides, Trapa, Limnophila, Myriophyllum, Cyperus, Panicum, Brachiaria,* and *Leptochloa.* We have also recognized a new weed, *Ipomea carnea,* an invader from land to water which may well become a serious threat in other parts of the world as well.

Against the major challenges mentioned above, and in the light of diversified uses of water areas by the people, primary consideration has been given to developing inexpensive, economical, and safe methods for management of aquatic weed problems.

MANUAL CONTROL

The practice of aquatic weed removal by manual

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labour as traditionally practiced is not adequate to keep them under control. A carefully integrated approach had to be developed to bring about a change of thinking among those concerned. Since weeds in any farming system represent a waste of energy and nutrients, the quantum of profit in farming depends upon tapping these energy and nutrient resources by a proper channelization. It has been demonstrated in comparable situations that fish production without any additional inputs (fertilizers and feeds) is not enhanced by removal of weeds by manual means as in the case of other methods like chemical or biological control. The yield of fish in ponds where waterhyacinths were removed by manual methods was about 1000 kg/ha per yr, while production was nearly doubled by chemical control with 2,4-D[2]. This increased fish production resulted from more effective control and release of detritus and nutrients into the pond under the chemical method.

Among the Indian major carps, the growth of Catla (5), a surface feeder which also consumes decaying plant matter, was particularly found to be satisfactory, and also the bottom feeder common carp (3) also responded very well in the chemically treated ponds. The fish could rapidly attain market size (1 kg) in the chemical control ponds, but did so much more slowly in manually cleared ponds. In a large 500-ha waterhyacinth infested lake, management, by employing labour to remove the weeds, failed to provide satisfactory control and the fish production was as low as 100 to 200 kg/ha/year.

The difficulty of standardization in manual labour operations resulted in varied costs for comparing this method from one area to another. Differences were found due to various weeds, biomass, and efficiency of workers in terms of work output measured as the quantity of weeds removed per man hour and the number of operations required to control the weed in a year. While waterhyacinth required 360 to 900 hours per ha for densities of about 20 to 30 kg per sq m, the figures for *Pistia* or *Salvinia* with less biomass (1.5 to 16.0 kg per sq m) also varied from 134 to 965 man hours per ha (4).

MECHANICAL CONTROL

Compared to the equipment available in other countries, India still has relatively simple devices and equipment for mechanical control of aquatic weeds. Mechanical control suffers basically from the same disadvantage in aquaculture as manual removal; it depletes nutrients from the fishery system. Also the heavy equipment is unsuitable for many of our situations because of lack of sufficient structural facilities like roads and embankments, thus making it difficult to transport equipment in certain areas. The operational costs in terms of fuel consumption, man power requirements, and maintenance are uneconomical.

The average fish farmer manages the aquatic weeds in his ponds with hand scythes, hooks, and draglines. Public agencies like State Fishery Departments occasionally use power operated winches, Hockney weed cutters and rakes. The Central Institute of Fishery Technology recently developed a mechanical harvester combining a rake and power winch mounted on a barge and obtained satisfactory results for removal of submersed weeds such as *Hydrilla, Najas* and the emergent weeds *Nymphea* and *Nelumbo*.

CHEMICAL CONTROL

The basic advantage of herbicides in aquaculture systems is that the biomass, which has trapped and stored out of the productive cycle large quantities of energy and nutrients, is broken down *in situ* and all the essential ingredients of productivity flow back into the system to help increase fish yields. The efficacy of the herbicidal action is more reliable and measurable than other control methods and, if properly applied, needs no further attention. Hence, the cost effect ratio is likely to be more favourable than with non-lasting methods.

The Indian "Green revolution" in agriculture helped to make available several fertilizers and pesticides, though some of the others like the chelated copper compounds, diquat (Regalone), endothall, glyphosate, etc. are still not available. Except for copper, the other herbicides might be difficult to use in our waters due to the precautionary measures prescribed on them. Our highly alkaline waters, and the use of copper sulphate which is the only copper herbicide we have at present, results in difficult problems of precipitation as copper carbonate.

Our recent efforts therefore were directed to select and use only the inexpensive and safe herbicides commercially available, and try to standardize the doses and techniques of application. The economical limits of application including the cost of the chemical and application to give at least 90% initial control were taken into consideration. Also, the fertilizer value of weeds and expected increase in fish yields were accepted as recoveries in the cost of weed control.

The most widely used and effective chemical against a large number of aquatic weeds is 2,4-D. In the evaluation of a biocide, the dose is usually determined on the basis of body weight. The differences in plant size, weight, and density of infestations were considered by categorizing the waterhyacinth infestations into small, medium and large plant categories on the basis of their weights and morphological characters such as leaf area, petiole, and root length. The smaller plants were usually less than 100 g in weight, the medium size 100 to 500 g and the large plants above 500 g. Doses of 2,4-D required by the individual plants studied in laboratory experiments varied from 10 mg/kg

[2]See table one for list of common and chemical names of herbicides mentioned in the text.

TABLE 1. LIST OF COMMON AND CHEMICAL NAMES OF HERBICIDES MENTIONED IN TEXT.

Common name	Chemical name
2,4-D	(2, 4-dichlorophenoxy) acetic acid
diquat	6,7-dihydrodipyrido[1,2- :2′ ,1′-c] pyrazinediium ion
endothall	7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid
glyphosate	N-(phosphonomethyl)glycine
diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea
simazine	2-chloro-4,6-bis(ethylamino)-s-triazine
paraquat	1,1′-dimethyl-4,4′-bipyridinium ion

plant weight for the small, 20 mg/kg for the medium and 30 mg/kg for the large plants to give a desired 90% level of control. Under actual field conditions, these doses proved very effective for the three categories at the rate of 1 to 2 kg/ha for the small category, up to 10 to 12 kg ai/ha for the large category, and the treatments remained within the set economic limits. The technique of application was also varied for each of the categories by increasing the spray volume from 400 to 1000 liters per ha. The spray gun is connected by long polythene tubing to the sprayer in the boat or on the shore. Although this may seem to be slow to cover large areas, it can provide work in rural areas for unemployed youth and others. A pilot project in a large weed infested waterhyacinth lake (500 ha) proved quite successful in this regard.

The slow decomposition process of the chemically treated weed mass (over 2 to 3 months) does not cause any harmful oxygen depletion or fish kills. The process is hastened if there are intermittent showers and also by disturbing with boats. Isolated left over or regenerating plants are picked up by hand, while large patches have to be treated with herbicides again. The maintenance operations have been essentially sucessful and resulted in control of other weeds such as *Lemna, Spirodela* and *Pistia,* which often developed after the waterhyacinth was controlled. In some cases, dominant submersed or emergent weed populations grew. Each of these had to be tackled specifically. Duckweeds provided a useful source for feeding grass carp (*Ctenopharyngodon idella* Val.) wherever needed, while others like *Pistia* were treated appropriately (either chemical or manual removal).

Ammonia. In our attempts to find indigenously available, harmless chemicals for the control of major submersed weed problems, a breakthrough in 1960 found that ammonia, a highly phytotoxic compound with natural elements was an effective aquatic herbicide. Ammonia needed surprisingly short contact time of a few minutes to a few hours for achieving control of many submersed aquatic plants. At concentrations of 10 ppm and above, it seems to act by destroying the photosynthetic mechanisms of the plant. The efficacy of the non-ionized molecular form (NH_3) was enhanced by high water pH where the proportion of molecular NH_3 was greater. Conversely, low pH with free carbon dioxide or any acidic conditions of water could largely nullify phytotoxic effects. As a simple natural chemical, ammonia easily enters the productive life processes of the ecosystem as nitrogenous fertilizer (NH_4+) and thus is utilized in aquaculture. It can be applied in the water body straight from the storage cylinder under its own pressure to kill and clear submersed infestations. Also, lighter than water, ammonia concentrated at the surface photosynthetic layers of the plants and is gradually carried into bottom layers by the dead sinking mass and through diffusion. The toxicity of ammonia to fish and other animal life in waters is an advantage in clearing old weed infested ponds from predators, unwanted fish, mollusk, crabs and other harmful organisms prior to pond fertilization and re-stocking. In other situations, ammonia is utilized as a fish poison, toxicant for undesirable biota, and a fertilizer. Sectional treatments in large ponds helped fish to move to safe zones where they could be transferred to other ponds. The toxicity of ammonia lasted for 3 to 4 weeks after which the ponds were ready for stocking. As a foliar spray of an aqueous solution (1 to 2%) with a wetting agent, ammonia quickly killed *Pistia* and *Salvinia.* Algal blooms of *Peridinium* could be quickly cleared by treating with about 4 ppm N ammonia, produced by reacting slaked lime with ammonium sulphate.

Though ammonia has been found to be very effective and valuable in fishery management, it has still not been possible to achieve wider use of the same in our country due to problems of obtaining suitable storage cylinders and purchase of the material at ex-factory price from the fertilizer factories. Bulk carriers are not available and the heavy duty cylinders are difficult to move. The retail outlets which buy bulk quantities of ammonia from fertilizer factories and other businesses, (refrigeration), charge high prices. These are not serious problems in developed countries where ammonia is already being widely used as a fertilizer in agriculture. The possibility of eutrophication due to excessive use of nitrogenous fertilizers may have to be considered in the light of higher positive benefits of the use of water for irrigating agricultural fields or other pasture lands. Besides this, most other herbicides are constantly under scrutiny for long range toxicological effects which may not be the case with the use of ammonia.

Among other herbicides which we have successfully tried under field condition, Paraquat (Gramoxone) was very effective against *Pistia* at only 0.2 kg/ha and *Salvinia* at a higher rate of 1 kg/ha.

Granules. The application of herbicides as foliar sprays for aquatic weeds usually entails wastages, loss of material, insufficient absorption, contact with non-targetted areas, and reinfestation from subterranean parts of the plants. The development of granular formulations and other means of better placement of herbicides for greater uptake by plants and/or slow release of active material for longer periods of time, has been of interest in India. However, commercial formulations of these are expensive and not readily available. Consequently, we have made successful trials with locally available materials and simple formulation techniques. Formulations of 2,4-D, prepared with sand and starch as binding material and broadcast over the water surface showed a fine deposition of sand granules over the leaves, particularly in the broad-leaf plants such as *Ottelia.* Absorption through leaves and roots from the bottom soil easily uprooted the plants which float on the water and can be picked up or removed by dragging a net. Even better results were obtained by using brick pellets soaked in herbicide solution and scattered over the water where they sank to the bottom and facilitated herbicide uptake by plant roots. The formulations contained 1 to 2% of the active ingredient of the herbicide to achieve better coverage of the treated area. The brick pellets, having been baked in kilns, absorb herbicides very well and did not cause any microbial action on the active material. In rural areas this simple technique of pellet making proved to be a definite advantage. A number of submersed weeds including *Ottelia, Nechamandra, Hydrilla, Najas,* and emergent weeds (*Nymphaea* and *Nymphoides*) could be effectively treated and controlled at 5 to 10 kg 2,4-D/ha by repeated applications. The persistence of 2,4-D in the hydrosoil lasted about 2 to 3 weeks as determined by germinating bean bioassy.

Algal blooms of *Microcystis* in fish ponds have been much more difficult to control due to their high biomass. Any sudden destruction of them was accompanied by oxygen depletion and distress or mortality of fish. Copper sulphate (0.25 to 0.5 ppm) could be used in neutral or alkaline waters only, while simazine (though effective at 0.3 to 0.5 ppm) became commercially non-available in the last few years. More recently, diuron was tested at 0.1 to 0.3 ppm, and found that when applied in developing stages of the bloom or after dilution of the blooms by rains, the risk of adversely affecting the fish was less. The use of diuron which is also effective against blanketing filamentous algae and some of the submersed weeds on a wider scale may be possible after residue problems and long range effects on biota are better understood.

The quick control of *Peridinium* achieved by using only 4 ppm N of ammonia was remarkable. Free ammonia was produced by reacting slaked lime with ammonium sulphate in solution which made the technique of application easier. Rapid development of zooplankters (rotifers) after the clearance of the bloom within a week was particularly encouraging. Although quicklime (CaO Mol. wt. 56) reacts with more than twice its own weight of ammonium sulfate $(NH_4)\ SO_4$ (Mol. wt. 132), in actual practice about equal amounts were used to make up for the below-par quality of the commercial lime.

BIOLOGICAL CONTROL

The use of Chinese grass carp for biological control of several aquatic weeds, particularly submersed weeds, have been a continuing program since its introduction into India in the early 1960's and successful induced breeding of the same achieved in 1964 and 1965. The Exotic Fish Culture Section, in cooperation with the Pond Culture Section of the Inland Fisheries Institute, have been engaged in assessing the potential of this fish, not only for weed control, but also for its cultural qualities which have been found to be highly compatible with our own indigenous carps and a valuable asset in the composite culture of both.

While the fingerlings of grass carp utilized and controlled *Lemna, Spirodela, Wolffia* and *Azolla* efficiently, they were unable to control the larger rooted weeds, and also they had to be introduced only in predator-free waters. In small bodies of water grass carp of 60 to 2640 g in weight were needed to give satisfactory control of both duckweeds and submersed weeds at the rate of 250 to 5000 fish/ha (1). In large tanks (ponds) of 2.8 ha, 219 grass carp, 1.2 kg in weight controlled *Ceratophyllum,* the total biomass of weeds estimated over 112 tons. The order of preference of weeds taken by grass carp was *Hydrilla, Najas, Ceratophyllum, Ottelia, Nechamandra* and *Vallisneria.* Among the emergent weeds *Trapa, Myriophyllum, Limnophila,* and leaves of *Monochoria* and *Ipomoea* are also preferred by the fish.

There remains great interest in India for biological control agents for aquatic weeds and also for utilization of certain aquatic species. Although many ponds are cleared by manual labor, the use of inexpensive herbicides and grass carp appears to be more effective, particularly where fish production is a consideration.

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