Lecture 2

Nursery, Rearing and Growout Ponds: Preparation and Management

Different types of Ponds:

- *Nursery ponds:* Ponds where spawn are reared to fry stage. In carps it takes about 15-20 days to grow spawn to fry size
- *Rearing ponds:* These are ponds where fry are grown to fingerling size. In carps it takes about 2-3 months to rear fry to fingerlings size.
- *Grow-out ponds:* In these ponds fingerlings are stocked and grown to harvestable size. Carps grow from fingerlings to marketable size in about 10-12 months.

Intervention strategies to enhance pond production of fish can be broadly classified as pre-stocking management stocking and post-stocking management

Pre-stockingManagement

- The ponds need to be prepared such that the pond environment provides optimum condition for growth of the fish.
- The pond environment should be free from predators, aquatic weeds, weed fish; it should have optimum water quality parameters and sufficient natural food should be available in semi- intensive culture systems.
- The steps involved in pre-stocking and post-stocking management are similar in the nursery, rearing and grow-out ponds.
- An additional step in the pre-stocking management in nursery ponds is the eradication of aquatic insects which predate on spawn and fry.

The pre-stocking pond management of drainable ponds, which can be dried, is as follows.

1. Draining and drying
2. Ploughing
3. Liming
4. Filling with water and

5. Fertilization

Perennial un-drainable water bodies require the following additional pre-stocking management measures.

1. Control of aquatic weeds
2. Eradication of weed fish and predatory fish and animals. (Mostly done in Nursery Pond)

Pre-stocking pond management of drainable ponds

1. ***Drying:***

This is considered as the initial step of pond preparation before culture begins.The pond should be dried for 7-8 days. The importance of drying is mentioned below

- Oxidation of organic matter
- Degassing of toxic gases such as ammonia and hydrogen sulphide
- It kills pathogenic micro organisms
- Kills predatory and weed fish
- Kills unwanted aquatic plants

2.Ploughing

The ponds should be ploughed using wooden ploughs or power tillers or tractors. Ploughing helps in Mixing up of soil which helps in oxidation of organic matter, Proper degassing of soil from toxic gases Mineralization of nutrients.

3.Liming

Pond bottom is important for productivity since process of mineralization of organic matter and release of nutrients to the overlying water takes place. Liming helps in improving the quality of the pond soil, thus enhancing productivity.

A range of liming materials are used such as

- Agricultural lime or calcite ($CaCO3$)
- Dolomite [$CaMg(CO3)$]
- Calcium hydroxide/slaked line $Ca(OH)2$
- Calcium oxide/quicklime - CaO

The dose of a particular variety of lime depends on its effectiveness and soil pH. Generally 200-500 kg/ha of line is used for application to pond soil

Note: Quick lime is preferred for applying to soil and calcite agricultural lime for application to water after stocking of the ponds

Liming helps in

- Correcting soil pH
- Mineralization of organic matter
- Release of soil sound phosphorous to water
- Disinfection of the pond bottom

4. **Control of Aquatic Weeds:**

Has been discussed in details in the next section

5. **Eradication of Predatory and Weed fish**

Predatory fish severely affect survival of fish primarily in nursery and rearing ponds. Weed fish compete with stocked fish for food, space and oxygen and result in reduction in production of desirable fish. Common predatory fish are murrels (Snakeheads), Catfishes such as Wallago attu, Clarias batrachus, Heteropneustis fossilis, Ompak sp. Etc., Weed fish include Puntius, Barbas Danio, Aplocheilus, Anabas etc., Most predatory and weed fish breed prior to the onset of carp breeding. They infest the ponds before carp fry and fingerlings are stocked. Hence their eradication prior to stocking of carps is necessary

Control

Dewatering followed by sun drying is most effective way to control weed and predatory fish. In ponds which cannot be dewatered, piscicides are used.

A suitable piscicides should have the following characteristics:

- Effective at low dose
- Not injurious to people and animals
- Doesn't make fish unsuitable for human consumption
- Gets detoxified quickly
- Easily available and economical

Types of piscicides

Following are the three types of piscicides that can be used to eradicate weed fish and predatory fish

- Plant origin
- Chemicals
- Pesticides (Chlorinate hydro carbons and organophosphates)

Piscicides of plant origin

A. Derris root powder

- Rotenone is the active ingredient
- It is a contact poison
- Lethal to other organisms also such as zooplankton, Benthos and insects

- Dosage is 4-20 ppm (mg/l)
- The powder is mixed thoroughly with water and sprayed all over the pond
- It is effective only on sunny days when the temperature is above 25^0C
- It is less effective in cold waters.

B. Mahua oilcake

- The active ingredient is saponin
- It causes lysis of the RBC and kills fish, frogs, snakes and turtles
- Dosage is 250 ppm
- The cake is soaked in water for 2-3 hrs and applied all over the pond.
- Detoxification takes about 25 days
- The toxicity can be reduced to 10 days through aeration and application of oxidizing agents.

The other less widely use fish toxicants of plant origin are

- Tea seed cake – 60 ppm
- Tamarind seed husk – 50-100 ppm

6 . Stocking

- Nursery, rearing and stocking ponds are stocked with spawn, fry and fingerlings respectively. They need to be acclimatized in ponds before stocking to prevent abrupt changes in water quality which will stress them resulting in poorer survival. Generally mono-culture is followed in nursery and rearing ponds, while poly-culture of carps in followed in grow-out ponds. When rearing space is limited polyculture is also followed in the rearing ponds. Grow-out culture of carnivores is done under monoculture. The stocking densities followed vary according to the level of management that can be under taken. For example when carp spawn are stocked in earthen nursery ponds, a stocking density of 300 to 500 numbers per m^2 of pond area, while, stocking densities of 1000 to 2000 numbers per m^2 followed when they are stocked in cement tanks where, higher level of management is followed.

Rearing ponds are stocked with carp fry @ 20 to 30 numbers per square meter in rearing ponds while carp grow out ponds are stocked @ 5000-1000 numbers per hectare when polyculture is followed.

Stocking has to be done in cool hours, early morning is better, but they can be stocked in evenings or nights. One disadvantage of stocking early in the morning in fertilized ponds is that if plankton bloom is heavy, dissolved oxygen could be less in the early morning. The disadvantage if stocking in the evenings is that the temperature of the water may be high resulting in stress to the stocked fish. These aspects should be taken care of while stocking ponds with spawn, fry or fingerlings.

7. Supplementary feeding

When fish are stocked at high stocking densities, the natural food produced through fertilization and manuring may not be sufficient to sustain high growth in shorter period of time. Hence, the stock has to be fed with supplementary feeds. Commonly, supplementary feeds such as mixture of rice bran or wheat brawn mixed with oil cakes such as groundnut cake or mustard cake or cotton seed cake and other cakes are used in a ratio of 1:1. In order to improve the quality of feed to get better growth and production, extra ingredients such as fish meal, soya flour, vitamin and mineral mixtures could be added to the feeds. The feed mixture is generally mixed with appropriate quantity of water and made in dough which is then shaped into a form of ball or cake is either broadcast into the ponds or kept in feeding trays at several places in the pond.

Feeding rates vary according to the size of the fish. Spawn are fed at a rate of 8-10% of the biomass, while fry when stocked in rearing ponds up to fingerlings stage are generally fed @ 6-8% of the standing crop. In grow-out ponds the fish are fed initially at a rate of 5% which is gradually decreased to 2-3% biomass till harvest. Periodic sampling of the stock is necessary to estimate the biomass and adjust feeding rates.

8. Supplementary fertilization

Ponds are fertilized prior to stocking fish with manures and fertilizers, when they are applied as a basal dose. Due to overfeeding by fish on the plankton and other natural fish food organisms, the plankton biomass may get depleted. In order to maintain the crop of fish food organisms, supplementary feed post-stocking may be required. When the water starts to lose its plankton turbidity, amounts less than basal dose of fertilizers need to be applied to ponds and fortnightly intervals. For example in carp rearing and grow-out ponds are manured with cow dung as a basal dose of 3-4 tons/ha. The ponds are subsequently fertilized with cow dung at a dose of 0.5 tons/ha at fortnightly intervals. However, supplementary fertilization should be followed with caution since application of excess of fertilizers and manures may lead to poor water quality of the pond, or undesirable blue green algae such as Microcystis may develop which apart from being toxic, will not form food for the fish

9. Water quality management

Good growth and production of fish not only depends on availability of good quality feed, but also and the quality of the water in which they live. Physico-chemical properties of the water should be within the range of tolerance of the species being cultured. Normally water quality will not be an issue with lower stocking densities and lower yields (extensive and lower level of semi-intensive culture). However, when higher stocking densities are followed, water quality tends to deteriorate, particularly when the stock grows and biomass increase

The most important water quality parameters are the dissolved oxygen. Oxygen dissolves from the atmosphere and also produced by photosynthesis phytoplankton and higher macrophytes which produce liberate oxygen during the day but consume oxygen during night. The levels of DO in culture systems should be above 5 mg/L. When oxygen tends to fall below this level, which usually occurs during night, aeration of the ponds becomes necessary. Various types of aerators are commercially available, which may be expensive. A simple way to aerate is to circulate the pond water such that bottom water comes to the surface and surface water goes to the bottom. This can be done using a pump whose intake (foot valve) is lowered into the pond and water is pumped such that the water splashes back into the same pond. Aeration may also become necessary during cloudy weather since lack of sunlight prevents photo-synthetic production of oxygen by the algae and higher plants.

Accumulation of metabolites and decayed matter will also result in poor water quality in ponds. Ammonia may get accumulated which is toxic to fish. In order to maintain water quality, water exchange may be required to be carried out. The frequency and amount of water to be replaced with freshwater depends on the quality of the water. This requires experience as well as analysis of the water quality.

Aquatic Weeds and Their Management for Fisheries

What is a weed?

Weeds are plants which grow out of their place, interfere with the utilization of natural resources, prolific, persistent, resistant, competitive, harmful and even poisonous in nature and can grow under adverse climatic conditions. Some times economical plants may also grow out their proper places which are termed as rouge and not weeds e.g. presence of mustard plats in wheat fields, plants of durum wheat variety growing in aestivum variety etc. The process of removing (uprooting) these plants is called rouging.

What are aquatic weeds?

Aquatic plants are essential parts of natural aquatic systems and form the basis of a water body's health and productivity. Invariably aquatic plants become over abundant or unsightly and require control. Aquatic weeds are those unabated plants which grow and complete their life cycle in water and cause harm to aquatic environment directly and to related eco-environment relatively

Aquatic plants are essential parts of natural aquatic systems and form the basis of a water body's health and productivity. On the other side, when aquatic plants become over abundant it requires control. Water is one of most important natural resource and in fact basis of all life forms on this planet. Therefore, appropriate O_2 management of water from source to its utilization is necessary to sustain the normal function of life. It is an important part of the natural resource management. The presence of excessive aquatic vegetation influences the management of water in natural waterways; man made canals and reservoirs which amount to millions of kilometres of such water bodies. They pose serious threat to fish and fisheries. They compete with fish for water, nutrients, light, niche and oxygen and thus reduce the yields. Fish worth millions of rupees are lost every year at the hand of weed menace. Considering the losses caused by aquatic weeds, their management is of utmost importance to improve the availability of water from the source to its end users. This does not only improve availability but also the conveyance efficiency. Growth of aquatic weeds interferes with the storage and delivery systems of irrigation water, maintenance of canals, drains, barrages, lakes, ponds etc. These systems often get choked with the weeds and cause environmental pollution. On low lying areas, adjoining irrigation and drainage channels, soil salinity and alkalinity problems do arise.

Different types of aquatic weeds

Proper identification of aquatic weeds is of primary importance for their control. They are classified according to various habitats which form their eco-environment and become conducive for their growth, reproduction and dissemination. Aquatic weeds can be divided into two botanical groups; algae and flowering plants.

Algae are usually very simple in structure with no apparent leaves or stems. However, some (for example, Chara) can resemble flowering plants. For effective chemical control, it is essential that you distinguish between algae and flowering plants. Aquatic flowering weeds are broadly divided into three groups:

a. Emergent weeds – shore & marginal

b. Floating weeds - Free floating, rooted floating
c. Submerged weeds – Rooted and non-rooted

Algae

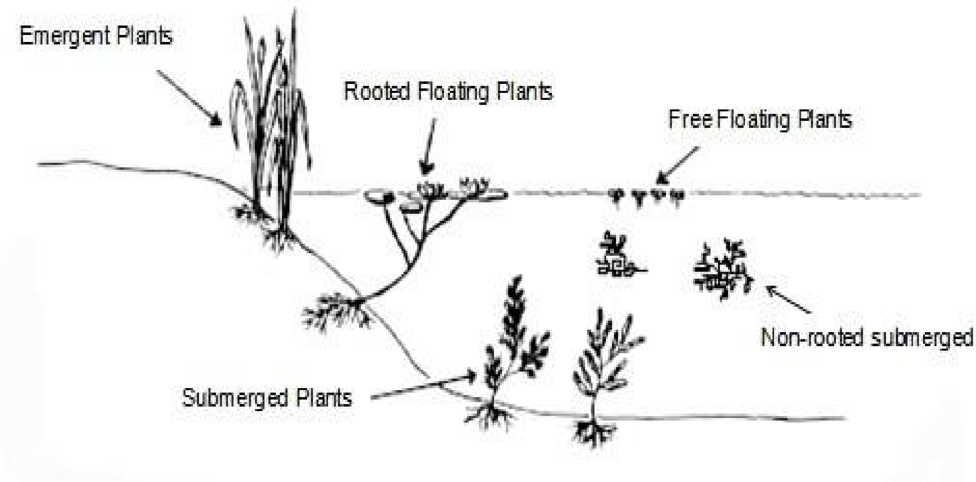
Microscopic algae are planktonic and their rapid proliferation results in to algal blooms, in which they form scums and/or color the water green or yellow-green. Sometimes they cause red, black, or oily streaks in the water called "blooms". Examples of this group are Microcystis and Anabaena. Blooms usually occur where abundant nutrients are reaching the water. They should be treated with chemicals before they cause a noticeable color but a sudden die-off of these algae can cause fish kills. Filamentous algae also known as moss form floating, mat-like growths which usually begin around the edges and bottom of ponds in the early spring. Most prominent filamentous algae in ponds are Spirogyra, Nitella and Pithophora. Often, repeated chemical treatments during the summer season are necessary for effective control. Chara or stonewort usually grows in very hard water and is often calcified and brittle. The plant is rooted, and leaves are arranged along the stem in whorls. It grows completely underwater and has a musky smell. Chara can be difficult to control once it has become established and has a heavy coating of calcium carbonate. Use contact herbicides when the plants are still young and not heavily calcified. Although this plant resembles some flowering plants, it is an alga.

Flowering Plants

Flowering plants can be grouped into three broad categories according to where they are found in a body of water.

Emergent weeds (shore or marginal)

These weeds grow in shallow waters and situations existing near the water bodies where water recedes and rises with the seasons or regular releases from a large water body or reservoir. Most of such situation is of permanent in nature where minimum and maximum water levels are consistent. Such situations includes banks of canals, rivers, periphery of water bodies which are mostly in earthen dams, and partly in masonry dams, drainage ditches and water ponds near villages. These weeds may be called semi-aquatic but more appropriately referred to as emergent aquatic weeds. These grow on the margins or on the shore line of the water body and are also called marginal weeds. They are mostly rooted in water logged soils, e.g. Typha, Nymphaea, Trapa, Otellia, Phragmites etc.



Examples of the emergent weeds

Botanical Name	Common Name	Family
Typha latifolia	Cattail common	Typhaceae
Typha angustata	Cattail narrow leaved	Typhaceae
Typha orientalis	Cattail	Typhaceae
Phragmites communis	Common reed	Poaceae
Commelina benghalensis	Watergrass	Commelinaceae
Alisma plantago	Water cattail	Alismataceae
Cyperus difformis	Umbrella plant	Cyperaceae
Ipomea carnea	Besharam	Convolvulaceae
Ipomea aquatica	Floating morning glory	Convolvulaceae

Trapa bispinosa	Water chestnut	Trapaceae
Hydrocotyle umbrella	Water pennywort	Hydrocolylaceae
Jussiaea repens	Water primrose	Onagraceae
Ludwigia parviflora	Water purslane	Onagraceae

Floating weeds

These are plant which grow and complete their life cycle in water. In case of drying of water bodies most of them give their seeds and other vegetative reproductive organs in base ground lands. These weeds are observed in the surface of the large, deep and shallow depths of water bodies; deep continuous flowing canals; continuously flowing rivers, large ponds tanks etc. Some of the weeds in this ecosystem freely float and move long distances, while some of them do float on the water surface but anchor down to soil at the bottom of the water body. These weed species make loss of water through evapo-transpiration in addition to impediment caused in flow of water. Therefore, these weeds can be classified in two sub groups viz. a) Free floating and b) Rooted floating weeds. Examples of common weeds under each sub group are given below:

Free floating weeds

Botanical Name	Common Name	Family
Eichhornia crassipes	Water hyacinth	Pontederiaceae
Salvinia auriculata	Water fern	Salviniaceae
S. molesta	Water fern	Salviniaceae
S. natans	Water fern	Salviniaceae
Pistia stratiotes	Water lettuce	Araceae
Lemna minor	Duck weed	Lemnaceae
Spirodela polyrhiza	Giant duck weed	Lemnaceae
Azolla imbricate	Water velvet	Salviniaceae
A. pinnata	Water velvet	Salviniaceae
Polygonum	Water smart weed	Polygoneaceae

amphibium

Rooted floating weeds

Botanical Name	Common Name	Family
Sagittaria guayanensis HBK	Arrowhead	Alismataceae
Ipomea hederacea	Nilkal	Convolvulaceae
Nelumbo nucifera	Lotus	

Submerged weeds

Weeds species belonging to this group germinate/sprout, grow and reproduce beneath the water surface. Their roots and reproductive organs remain in the soil at the bottom of the water body. These weeds damage the maximum, because they are not visible on the surface and impede the flow water varying upon the degree of their intensity and growth. Most of these weeds are found in shallow and medium deep water bodies, continuous flowing canals and drainage ditches. Submerged weeds may be further categorized as (a) Rooted and (b). Non- rooted or floating-submerged weeds.

Rooted and non-rooted submerged weeds: Submerged weeds which are completely submerged within water and rooted in the bottom soil e.g. Hydrilla, Najas etc.

Non-rooted free floating submerged weeds e.g. Ceratophyllum.

Usefulness (Economic importance) of Aquatic weeds:

Economic importance is a new concept which has originated due to heavy costs entailed on the control of aquatics by manual, mechanical and chemical methods. Aquatic plants, when in limited quantity, are useful and necessary for the ecology of the pond. They form natural food for many species of fishes; they provide shade and shelter and oxygenate water. They reduce turbidity and provide spawning beds. The utilization of aquatic weed, in fact, an indirect method of their control and it should be given serious consideration. In parts of tropics and subtropics, summer vegetation is limited on land, but it is abundant in water

Usefulness of Aquatic weeds can be categorized as:

Aquatic Weeds as compost, soil conditioners and green manure

Several aquatic plants can form valuable source of nutrient-rich compost. But, thus far, water hyacinth alone has been exploited. The compost made from water hyacinth is superior to town compost and farm yard manure. The fresh water hyacinth plants contains about 3.5% organic matter, 0.04% N, 0.06% P_2O_5 and 0.02% K_2O and on dry weight basis 1.5% N, 0.15% P which are equivalent to 1250 Kg/ha N and 125 Kg/ha P . Besides composting fresh aquatic weed can be used as green manure. AzolIa and some blue green algae viz. Anabaena, Nostoc, Rivularia are known to fix atmospheric nitrogen and can be utilized for increasing nitrogen level of fish ponds. In the USA, energy-intensive, complete drying and grinding of aquatic weeds are practiced to prepare organic soil conditioners.

Weeds as feed for Animal, bird or fish

The leafy parts of the aquatic plants such as duck weed, water hyacinth and some submerged weeds contain, 25-35% protein on dry matter basis, which is exceptionally high. Certain fresh water algae such as Chlorella pyrenoides synthesis has considerable amounts of protein. Some submerged aquatic weeds, such as Hydrilla and Mariophyllum are particularly rich in carotenes and Xanthophyils. These valuable pigments are being added to poultry rations in many countries. In China, pig farmers boil chopped water hyacinth with vegetable wastes, rice bran, copra cake and salt to make a suitable feed. In Malayasia, the fresh water hyacinth is cooked with copra meal as feed for pigs, ducks and fish. Aquatic weeds are used as feed by pigs.

Feed for farm birds: Ducks, geese, swans and other water fowl feed on vegetation, controlling, weeds on the banks of water ways and often clearing aquatic weeds and algae from small lakes, ponds and canals. Dried duck weeds (30-50 gm) can be added to the daily poultry ration for their weight increase.

Feed for fish: There are number of herbivorous fishes which directly consume aquatic weeds. The growth performance, food conversion ratio and protein efficiency ratio along with nutritional qualities of weeds what are incorporated in pelleted feeds in fish was reported. The grass carp is efficient in this Endeavour This fish relishes most submerged and some floating weeds. A gain of one kilograms body weight for 50kg of grazed hydrilla has been recorded. Tilapias also reported to eat several weeds and grow to a marketable size, up to 2.7kg. It was observed that incorporation of the aquatic weed, N. cristatum in the diet of L. rohita substituted the conventional feed ingredients.

Aquatic weeds as food crops

Aquatic plants can provide three types of food, foliage for use as green vegetable, grain or seed that provide protein, starch, oil and fleshy swollen roots that provide carbohydrates. Some common aquatic plants and their parts are consumed by human

- *Ipomea aqutica*- Young leaves and stem.
- *Nelumbo nucifera*- flowers, leaves, rhizome.
- Euryaleferox- seeds.
- Trapa- fruit.
- Colcoasia- petiole, rhizome and tubers.

Aquatic weeds as a source of energy

For Present energy crisis, all efforts are being made to find out the unconventional sources of energy from Water hyacinth and Salvania. Water hyacinth is used as a source of methane-rich biogas. The high moisture content of aquatic weeds is helpful in maintaining anaerobic condition and bacterial decomposition to produce methane. Each Kg of water hyacinth on dry weight basis yielded about 370 L of biogas with 69% of methane.

Waste water treatment

Many aquatic plants are able to scavenge inorganic and some organic compounds from water e.g. Water hyacinth, which is found to be very efficient in this regard. *Ceratophyllum demersum, Hydrilla verticillata*, Phragmites, Scripus, Myriophyllum, Elodea spp., *Spirodella polyrhiza* and *Lemna minor* are common pollution demolioshing aquatic, plants . The industrial and domestic effluents containing heavy metals like mercury, iron, manganese, Zinc, aluminum, cadmium, nickel, silver, cobalt, copper, lead, sodium, chromium etc. phenols, phenolic derivatives and pesticide residues are removed to certain extent by water hyacinth, Lemna and Myriophyllum and hence improves its quality. Potamogeton and Elodea were very effective in removing asbestos fibres from drinking water.

For pulp, paper and fibre

The common reed Phragmites communist is extensively used in Romania, for making printing cheaper, cellophanes, card board and various synthetic fibres. The aquatic plants like Typha (Cattails) and Cyperus are the sources of pulp for paper and fibre although these are cultivated as fibre crop

For Mushroom cultivation

Substrate made from water hyacinth plants has high biological efficiency (8-9%) for mushroom cultivation. Due to high cost of wheat straw, mushroom farming can be made economical by using water hyacinth for preparing substrate.

Production of methane gas

In goober gas plants crow dung can be substituted by water hyacinth plants (biomass) and methane gas, produced through anaerobic digestion can be used as food for cooking. Consistently warm daily temperature, 32 to 36^0C as found in tropics, greatly enhances the rate of gas production. The slurry can be used directly or after sun drying as organic manure.

Fish poisons:

Few weeds are also used for fish poisons. The bulb of *Chlorogelum pomeridinum* is used for fish poison. Leaves of turkey mullein is also used as fish poison.

Other uses of Aquatic weeds

Rough and tough marginal weeds can be used for making huts, thatching roofs, traditional fishing rafts, fishing rods, musical instruments, writing pens and floats. They can be used for making screens and mats. Water hyacinth is very helpful in reclaiming alkaline soils.

Effects of aquatic weeds on ecosystems and aquaculture

(a). Aquatic weeds create situation which are ideal for mosquito growth:

The mosquitoes are sheltered and protected from their predators by aquatic weeds roots and leafy growth and are responsible for the spread of malaria, yellow fever, river blindness and encephalitis.

(b). Aquatic weeds also affect quality of water:

Aquatic weeds are responsible for lowering quantity as well as quality of water. These weeds cause taste and odor problems and also increases biological oxygen demand because of organic loading (Gopal and Sharma, 1979).

(c). Increase the organic matter content of water:

Aquatic weeds increase the organic matter content of water, which may of affects the strength of the concrete structures when used as curing and mixing water. It is due to organics matter that combined with cement to reduce bond strength and may cause large amount of air entailed concrete.

(d). Hindrance for water flow

Aquatic weeds impede the free flow of water which may contribute to increase seepage and may cause rises in water tables in the adjoin areas. This may lead to water logging. This may also create saline or alkaline condition in the soil and also give rise to many other land weeds. Aquatic weeds reduce flow water in canal, drainage and ditches etc. Floating weeds retardnt coefficient (n) of water in canal to over twice than the clean water flowing in that canal. Submerged weeds can raise it almost 20 folds. It has been reported that water hyacinth raise the ‘n’ value of a channel from 0.024 to 0.55 i.e. about 2 folds. Najas spp. raise from 0.04 to 0.68 i.e. approximately 16 folds (Varshney and Singh,1976).

(e). Water clogging

Aquatic weeds propagate at a tremendous rate. Eichhornia needs a special mention in this category. A pair of these plants can multiply up to four thousand times in one season.

(a). These are water wasters

Evapotranspiration losses of water through mats of weeds are much more than from open water surface. Consumption of water by aquatic weeds is much higher because of their high water needs (Walia, 2003).

(b). Pose pollution and health problem

Decaying masses of aquatic weeds pollute drinking water. Decomposing weeds omit offensive odor. Moreover, decomposing of certain blue-green algae can prove toxic to life of water. Similarly, allelochemicals released by certain aquatic weeds can prove harmful to the fish (Lancer and Krake, 2002).

(c). Hinder navigation:

Aquatic weeds obstruct netting operations. They bind around the propellers of boats and stop their working. Water hyacinth can stop the movement of even ship.

(d). Increase sedimentations

Aquatic weeds particularly emerged ones growing in seasonal drain not only add a lot of organic matter after completion of life cycle but are also responsible for sedimentation of loose clay or sand particles from flowing water or air. Due to growth of aquatic weeds, the depth of pond, drain, rivers etc. goes on decreasing every year resulting in over flow of water.

(e). Reduce the aesthetic value:

Charm of boating, swimming, bathing and other recreations in water is lost due to infestation of water bodies' with weeds.

(f). Effect on Fish production

Fish production is greatly affected by the presence of aquatic weeds (Wiley et al., 1984). Isolated weed beds may be tolerated, providing shelter and shade for fish, but when the growth become thick and cover entire water body, it can lethal for fish growth. Fish may suffocate from a lack of oxygen and may cause death. When floating and submerged aquatic weeds become extremely dense, many fish species are unable to exist in such environment and vanish. For example, fish's production in Harike Lake in Punjab is decreasing and is a matter of concern to all. As they cause oxygen depletion, and accumulation of Carbondioxide, gases like hydrogen sulphide and methane are formed; these gases are harmful to the fishes. Algal blooms choke the gills of the fishes and spoil the water on rotting. They effect fish production by-

- Limiting the space for many culturable fishes
- Competing with phytoplankton and absorbing nutrients. (iii). Causing imbalance in dissolved oxygen concentration.
- Causing siltation.
- Hampering netting operations of harbouring unwanted predatory fishes, molluscs etc.

Management of Aquatic weeds

Management of aquatic weeds consists of two approaches

1. Preventive approaches
2. Control of existing infestation

Broadly, these methods can be grouped under four groups: -

(1) Physical or Mechanical methods
(2) Cultural and physiological methods
(3) Biological methods
(4) Chemical methods

Preventive Approaches

Quarantines are legislative tools that may be used to mitigate the effect of weeds. Quarantine is defined as the restriction imposed by duly constituted authorities whereby the production, movement or existence of plants, plant products, animals, animal products, any other article or material or the normal activity of persons is brought under regulation in order that introduction or spread of a pest may be prevented or restricted. If a pest has already been introduced and established in a small area, quarantine is necessary so that it may be controlled or eradicated or dissemination stopped in newer areas, thereby reducing the losses that would otherwise occur through damage done by pest. Preventive weed programs usually require community action through enactment and enforcement of appropriate laws and regulations. In India, irrigation canals appear to be a potential source for spreading water hyacinth.

Proper design and construction of ponds is an important factor in preventive control of weeds. Shallow water at the margins provides an ideal habitat for immersed weeds, such as cattails. These weeds can spread then to deeper water. Banks should be sloped steeply so that in shallow region water is at least 2' to 3' deep. Proper design and construction of ditches and channels makes weed control easier in the future. If the banks are leveled and smoothed, hard-to- reach places will be eliminated. Lining canals will help to alleviate water weed problems, too. When prevention and eradication fail to give desired results under aquatic environment, the only alternative left is to keep aquatic weeds under manageable limits so that water use efficiency with respect of water storage in reservoirs and transportation through canals is not reduced.

Control Methods

Controlling weeds in an aquatic environment is greatly complicated because of lack of ownership of water bodies. Most of these are places of public interest. Often frequent approvals are needed from public health Dept., water surveyor, fish and other wildlife agencies before weed control works may be carried out. In many developing and under developed countries there is no control on water use. In many Asian countries a water body can be used for a number of purposes including bathing, drinking, stock watering and irrigation.

(a). Physical or mechanical control methods

Mechanical control of aquatic weeds primarily consists of removing the weeds of any group physically from the water body. It may also involve any physical power which may directly or indirectly inhibit the growth and development of aquatic weeds. This could be done manually by hand, using hand tools or machine power. It may also consist of altering the environment or creating conditions/situations which may inhibit or do not permit growth and development of weeds.

(i). Manual Cleaning

Manual cleaning is the oldest, cheapest method of aquatic weeds control. In areas sparsely infested, weeds can be removed by hand. In this method, human labour is employed with or without the aid of simple implements. Generally, this method is applied to emergent weeds eg. Typha spp., Phragmites spp., Justicia spp. (Willow), where men cut the vegetative growth with heavy knives and hooks. In shallow water the propagules, rhizomes and other underground reproductive organs can be removed. The emergent and marginal weeds are removed by pulling them with hand or can be kept under check by cutting their floating leaves repeatedly. This could also be applied to the removal of floating weeds likewater hyacinth which can either be hand picked or removed by wire, coir or nylon nets. This method requires constant vigil because of temporary effect.

(ii). Cutting

This method consists of physically cutting the biomass over and under the water with the help of heavy knives, or mechanical weed cutters. In the case of Typha, it has been observed that if plants are cut under the water and remain submerged for more than a week to 10 days, control is possible. This may also hold good for Phragmites, spp. Also mechanical cutting of water hyacinth, Chara spp, Filamentous algae, Potamogeton spp. will give temporary relief from weed infestations. A mechanical weed cutter is used to cut floating and submersed weed at 1-1.5 m depth in water reservoirs. It consists of sharp cutter bar and operates from a boat. The harvested weeds are collected and water is squeezed from them to hasten dehydration and desiccation.

Water weed cutters and harvesters: In high discharge canals and very large water bodies weed cutters/harvesters are used to control rooted submerged weeds.

Under water cutters: These are normally attached to a motorboat. The equipment consists of sharp and strong cutter bars with heavy reciprocating blades, sliding against a fixed blade.

Harvesters: Machine that cut and picks up the weeds from water body and convey these to shore simultaneously.

Chaining:

Chaining consists of a heavy iron drag chain attached between two tractors, which is dragged down a densely weed infested ditch or medium canal. The chains tear the rooted weeds and loosen them from the bottom. This method has been found effective where there is dominance of emergent and submersed weeds. The practice of chaining should be followed when new shoots of weed are around 30-50cm above water level. Dragging the chain up and down the stream may be effective in dislodging most of the weeds. For effective weed control the practice should be repeated at frequent intervals if found successful. One of the limitations of this method is that ditches need to have uniform width, accessible from both the sides with tractors and free from trees and other such obstructions. The debris thus collected at the end should be removed to avoid reinfestation by plant propagules further downstream.

Netting: Scattered floating weeds can be skimmed out of small water bodies using nets usually made of 3 mesh coir ropes.

(b). Eco-physiological alterations

(i) Drying or water level manipulations

This method is a simple and effective way of controlling submerged weeds. Most of the aquatic weeds respond quickly to changes in water level. Control is achieved by either dehydration of the vegetation or by exposure to high temperatures. In tanks, fish ponds and canals emptying the water periodically to kill the weeds susceptible to desiccation is practiced. Drying or water level manipulation is generally practiced in flowing water system like irrigation canals, drainage ditches. In some cases where facilities exists, in tanks and ponds. During the process the water is removed and the base of the tanks, canals etc. are made dry by exposing the land to sun & air. This totally changes the eco-environment, which is very adverse to the eco-environment required for growth and development of submerged weeds. Frequent drying and wetting for several days may control the growth of roots and propagules in the bottom soil. This method is not effective for control of emergent weeds.

b) Light

Light is an essential component of the photosynthetic process, which is necessary for the growth and development of aquatic plants, especially submersed aquatic weeds. Growth of submerged aquatic plants in small tanks and ponds can be checked by reducing light penetration. Use of fiber glass screen is popular in some countries. Coloring chemicals have also been tried for intercepting solar radiation reaching the water. Planting of trees on the banks of canals may create shade to reduce light intensity hence checking the weed growth. However care should be taken that trees or their appendages do not impede water flow. Light intensity can also be checked by adding dyes to the water. This type of control is more effective in static water such as ponds or tanks where dye remain suspended for a longer time. Ponds that are adequately fertilized develop millions of tiny plants which give the water a cloudy appearance. If this water is nearly 75 cm deep, submerged aquatic weeds have almost no chance to grow. This is due primarily to shading the submerged plants.

Biological Control of Weeds

Biological management of aquatic weeds is a broad term for the exploitation of living organisms or their products to reduce or prevent the growth and reproduction of weeds. The organisms that are used for biological control are diverse e.g. insects, pathogens, nematodes, parasitic and competing plants. Biological control involves the deliberate use of organisms such as insects or fungi to control weeds. Biological control is more complex than chemical control because it requires (a) long term planning (b) multiple tactics and (c) manipulation of cropping system to interact with the environment.

Chemical control of Aquatic Weeds

Aquatic weeds can be controlled effectively by use of herbicides. The time and method of herbicide application varies with the type of weed flora and the habitat in which the weeds are to be controlled. Control of aquatic weeds by herbicides is generally easier, quick and usually cheaper, when compared to mechanical methods. The use of herbicides has the disadvantage of being in water as residue and more especially in areas where there is no control on water use. Not all herbicides can be used for weed control in aquatic environment.

A herbicide should have certain specifications for its use in different types of aquatic environments

It should have high degree of phytotoxicity to kill weeds fast.

The chemical should degrade or dissipate from water immediately after the action on weeds.

Technology should be available for their use in static or flow water systems.

It should be environmentally safe for humans, fish and other aquatic fauna.

Controlling Algae by algaecide

Copper sulfate specifically known as Copper sulfate pentahydrate is one of the most common and largely used chemicals for control of algal growth in aquatic system all over the world. It was first used in 1904. It controlled water bloom at 0.1 ppm, common sown algae at 1.0 ppm and Chara sp. at 5 ppm. Pithophera spp. are difficult to control. It is one of the cheapest chemicals available and that is why it is used so widely as an algaecide. It does not degrade in water hence, repeated applications may accumulate to toxic levels in the substrate of the water body. The safe limits are 2.3 – 12.0 ppm Cu in human drinking water and 100 ppm in animal drinking water.

Chelated copper: Copper that is held in an organic complex is known as chelated copper. Chelated copper formulations do not readily precipitate in high alkalinity waters or hard waters but stay in solution and remain active longer than copper sulfate. Chelated copper is less corrosive to application equipment than copper sulfate. Because it is more soluble, chelated copper is generally used at slightly lower rates than copper sulfate. Chelated copper formulations are slightly less toxic to fish than copper sulfate. However, in waters with low alkalinity (≤ 20 ppm), or in water with an alkalinity of ≤ 50 ppm that contains trout, using chelated copper is extremely risky, particularly during the summer. Some of the chelated copper compounds work on higher plants (e.g. Hydrilla, Najas spp. etc.). Some other chemicals have been proposed and used for algal control such as sodium arsenite, potassium permanganate, bleaching powder. Some scientists have proposed heavy application of nitrogenous fertilizers to irrigation water. Chelates of Cu are used in hard water to avoid in-activation. It also reduces Cu toxicity to fish culture. In alkaline water having >100ppm $CaCO_3$, Cu gets precipitated as oxychloride to insoluble forms. In turbid water Cu gets adsorbed to suspended fine pentacles. Copper chloride is a Cu based algaecide made for use in irrigation water and stored recreational water. It is less harmful to fish and other crustaceans. It is less corrosive to sprayers. Copper sulphate should be applied to water which has a pH of approximately 6. However, in alkaline water (pH > 7) the successful application of Copper Sulphate is carried out with a pre dosage of sulfuric acid which reduces pH of the water.

2,4-D, Glyphosate, Diquat, Paraquat are used to control the emergment and floating weeds.

2,4-D is a translocated herbicide used for control of broad leaved weeds and sedges. Glyphosate is a post emergent, non selective herbicide. Glyphosate is effective in controlling grassy, broad-leaved weeds & sedges. It is equally effective on annual & perennial weeds. Therefore, Glyphosate is classified as a broad spectrum herbicide. Diquat and Paraquat are contact, non selective herbicides and are very effective for control of floating and submerged aquatic weeds and algae. However, the use of Diquat and Paraquat is not permitted in fisheries.

Glyphosate (Roundup®)

Glyphosate translocates from the treated foliage to underground storage organs such as rhizomes. It is most effective when applied during a perennial weed's flowering or fruiting stage @ 1.5-4 Kg/ha. If rainfall occurs within 6 hours of application, the effectiveness of glyphosate will be reduced. It may take 7 to 10 days or more to observe the symptoms and may take 30 days or more for complete destruction.

2,4-D, glyphosate etc. are not effective against submerged weeds. Till today there is not a single herbicide registered in India which can give effective control against submerged weeds.