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Research Article

Floating aquatic plants- A challenge for operation of irrigation canals in Punjab Pakistan and way forward

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Abstract
The problem of entry of unwanted floating matter (aquatic plants) has been persisting for many years and is increasing gradually in Indus River Basin Irrigation System (IBIS). It is causing hindrance in smooth flow of water in irrigation network starting from the barrages to the main canal, branch canals, distributaries, minor canals, and water courses. Under this study Pakpattan Canal has been selected for detailed survey and sampling of floating material. Results of the study have diagnosed that aquatic plants as the "water hyacinth". Survey of Sulemanki Headworks and Pakpattan Canal indicated that aquatic plants grow in abundance at upstream of Sulemanki Headworks in the form of contiguous colonies. The plants are also growing in different patches along the berm of Pakpattan Canal. These aquatic plants appear to have some entry from Ravi River through Balloki Sulemanki Link Canal as these also exist in the form of scattered colonies along the sides of Ravi River upstream Balloki Headworks. Keeping in view the ecosystem for controlling the water hyacinth, chemical control method is least recommended as it may deteriorate the water quality. Mechanical methods may be used as a short-term strategy but it may be costly. The runoff control method is a good tool for its minimal proliferation. Biological control may produce classical results with the least adverse effects. Chinese Grass Carp fish may be used in off-season (stagnant waters) where water hyacinths (aquatic plants) are in a huge quantity forming colonies. Overall, an integrated management strategy may be adopted to mitigate the problem of un-wanted floating plants to ensure smooth flow in water channels.

Keywords: *Aquatic plants, water hyacinth, Pakpattan Canal, grass carp, Punjab, Pakistan.*

1. Introduction
Agriculture in Pakistan mainly relies on irrigation water. However, growth of aquatic vegetation in irrigation channels reduces the efficiency of irrigation network (Brinkhoff, *et al*., 2018). Excessive growth of vegetation, specifically in earthen irrigation channels, reduces the flow rates and inhibits a timely delivery of water to agricultural fields (Dugdale, *et al*., 2013). These aquatic plants cause weed problems and may be grouped into four categories; algae, floating weeds, emersed weeds (foliage above water) and submersed weeds (majority of foliage below water) and can be grouped into three types which are submerged, floating and emergent (Kascomarine.com).

These plants are most obvious in terrestrial environment and can inhabit many types of aquatic conditions. These exist in abundance in warm, swampy areas and form a natural part of the aquatic ecosystem used by many different animals either as food or as a hiding place (Block & Rhoads, 2011). Many people find aquatic plants interesting and attractive. However, as with any naturally occurring organisms, they may interfere with people activities either by their over-abundance or merely by their presence. When this occurs, the plants are considered "weeds" and some control is desired. Sometimes these plants when accumulated in abundance, may cause contamination water with heavy metal and then these heavy metals/pollutants leach down to groundwater. heavy metals in groundwater cause severe threats to human health (Zakir-Hassan, Baumgartner, Allan, Punthakey, & Rasheed, 2025).

Microscopic plants (algae) form the base of the aquatic food chain. Larger algae and plants provide habitat and shelter for fish, waterfowl and other wildlife; and all plants produce oxygen as they photosynthesize during daylight hours. In view of such benefits, growth of some aquatic plants to a certain extent is, therefore, desirable in a water body. However, excessive growth of aquatic plants can cause detrimental effects on the water body, its inhabitants and its users. The aquatic plants enter into the canals, form the shape of colonies and cause hindrance in the flow of irrigation channels (Redding & Midlen, 1991).

Aquatic plants management is necessary in canals to keep water flowing from failing which would clog down the systems very quickly. Management of both native and invasive plants in canal system is integral to water control because aquatic plants greatly affect the water–handling capacity of the water control system (Systema & Parker, 2011). These plants have also contributed to the loss of water through excessive evapotranspiration. Experts say that water loss due to evapotranspiration can be as much as 1.8 times than that of evaporation from the same surface but free from plants (Jensen & Allen, 2016). This has great implication particularly where water is already scarce. Literature shows that the flow of water in the Nile (Africa) would be reduced by up to one-tenth due to increased losses in Lake Victoria from water hyacinth. Water hyacinth is also considered to be one of the most invasive species among aquatic plants (Yaghoubi, et al., 2020). The management of aquatic plants can be done using a variety of techniques including chemical, physical, biological and environmental manipulation (Lancar & Krake, 2002). Decisions on the use of aquatic plants management techniques for aquatic vegetation are not based entirely on economy and efficacy; there are many inexpensive and effective ways to remove aquatic plants from canals.

Indus Basin Irrigation System (IBIS) is one of the largest contagious irrigation networks in the world. A major part of IBIS falls in the Punjab province. Punjab Irrigation Department (PID) is mainly responsible for providing water for irrigated agriculture, involving components but the department has also infrastructure for drainage, flood protection, diversion of river water through barrages and link canals, small dams, and planation (PID, 2017). For irrigation purposes almost all the water is diverted from rivers to canals by barrage structures and headworks built across the river Indus and its four main tributary rivers; Jhelum, Chenab, Ravi and Sutlej. There are 14 barrages (including Mailsi Siphon Structure under the river Sutlej). These structures have a capacity of diverting about 120,000 Cusecs. Major features of Punjab Irrigation network is shown in Figure 1 (PID, 217; Zakir-Hassan, 2017). Canal irrigation network in Punjab is one of the largest networks in the works which runs under gravity. Water flows from mountains to sea after passing through dams, barrages, link/main canals, distributaries, minors, water courses (Zakir-Hassan et al., 2023).

Headworks/Barrages	13
Main Canals	24
Length of Main Canals and Branches	3993 Miles
Length of Distributaries and Minors	19191 Miles
Length of Inter River Link Canals	528 Miles
Off-take capacity of Main Canals	1.2 Lac Cs
Off-take Capacity of Link Canals	1.1 Lac Cs
Total Outlets	58000
GCA	23.35 m.a
CCA	20.78 m.a

Figure 1: Major feature of Punjab Irrigation System

Growth of such aquatic plants cause hindrance in flow and a significant of public exchequer are spent on removal of such weeds to ensure the smooth flow of water in the channels. Sometimes, breaches of channels also take place due to this hindrance.

Irrigation water flows from Rivers/Barrages to main or link canals then it reaches the agricultural fields through a network of distributaries, minors, and water courses. Aquatic plants cause interruption in flow in almost all components of irrigation system; mostly such problem is extensive near the upstream of barrages and along the berms of the main canals. Some glimpses of efforts of field formation of PID to mitigate this threat in field are shown in Figure 2.

Current study has been carried out encapsulates the following activities/scope.

- Field survey of Pakpattan Canal for observing problems caused by floating matter (aquatic plants) and its growth along berms of the channel.
- Identification of aquatic plants existing in the Pakpattan Canal.
- Remedial measures for controlling excessive entry of this unwanted floating matter (aquatic plants) in irrigation canals

Figure 2: Some field pics of removal of aquatic plants from the irrigation channels in Punjab Pakistan

2. Materials and Methods

Study Area-Selected canal

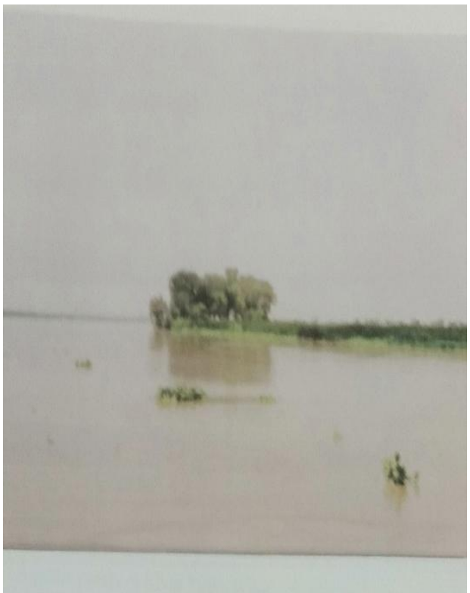
Pakpattan Canal has been selected for this research which off-takes from Sulemanki Headworks in East-South of Punjab Pakistan. It is a perennial channel which is a part of Sahiwal Irrigation Zone. Pakpattan Canal off-takes from right side of Sulemanki Barrage and is intercepted by Sindhnai-Mailsi Link (SML) canal. The reach between Sulemanki Barrage and SML is called Pakpattan Canal Upper while the reach beyond SML is called Pakpattan Canal Lower. Pakpattan Canal Upper is 173.13 Km long and is designed to 186.721 m^3/sec (PID, 2017). The problem of entry of unwanted floating matter (aquatic plants) had existed for many years and is increasing gradually over the time. The study was carried out for proper investigation of the issue of excessive entry of these unwanted floating plants in Pakpattan Canal Upper and their growth along berms of the channel. After identification, remedial measures for controlling them were also suggested to improve the situation.

Filed Surveys and Observations

Detailed field surveys of the study sites were conducted. The growth of aquatic plants was observed at a stretch of eye view on both sides of Sutlej Pond Figure 3. Aquatic plants are grown in abundance at a sketch of 15x2 Km^2 upstream of Sulemanki Headworks in a reach of about 15 Km forming vast colonies with rapidly increasing growth trends. A complete survey of the pond between B.S link and Sulemanki Headworks was carried out. It was seen that aquatic plants had made their colonies along both sides of the river pond flourishing rapidly. It was noticed that from the right side of Sutlej River, heaps of plants enter into the Pakpattan Canal. Large and bulky plants could not pass through the gate of Pakpattan canal from Sulemanki Headworks, only small plants were seen passing through the gate and floating in the canal (Figs 3). The situation at the upstream side of the canal head has been depicted in Fig. 3. Survey of Pakpattan Canal was carried out from Sulemanki Headworks RD 0+000 to RD 152+000. Some plants got entangled with the piers of the bridges of the canal and also with the mile gauges which were installed at every 5000 ft (Fig 3). Other plants continued floating in the canal. Floating plants were seen in the channel at the top of water surface level. The plant growth on the berms of canal was observed from RD 67+000 to RD 125+000 in the shape of small patches. From RD 125+000 to RD 148+000, the plant growth on berms was found in large patches and after RD 148+000, continuously long formation of the plants on berms was also noticed. The problematic canal area remained under observation from June to November 2007. Up to October 2007, entry of unwanted plants remained as usual which started diminishing during November.

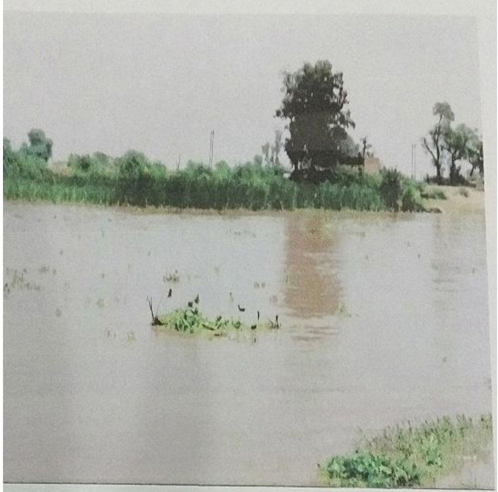
Aquatic plants existing on both sides of Pakpattan canal were manually plucked at RD 152+000 during September 2007. It was observed that growth of plants did not take place within the next two months. Later on, an area of 10' x 10' at RD 164+000 was manually cleaned during October and no plant growth was observed for one month. At the end of November, plants started to dry due to cold weather. The overall situation observed so far has revealed that the real problem lies outside the Pakpattan canal, i. e., the source from where these plants travel in the pond of Sutlej River during monsoon season. The growth increases in the stagnant water areas. Outfall of BS Link and Balloki Headworks were also visited. It was observed that aquatic plants also enter through BS link from upstream of Balloki Headworks from Ravi River and later on reach and colonize in the River Sutlej Pond. It was noticed that these plants also exist vastly in the form of scattered colonies along the sides of Ravi River upstream Balloki Headworks (Fig. 3).

: Aquatic plants in River Sutlej Pond

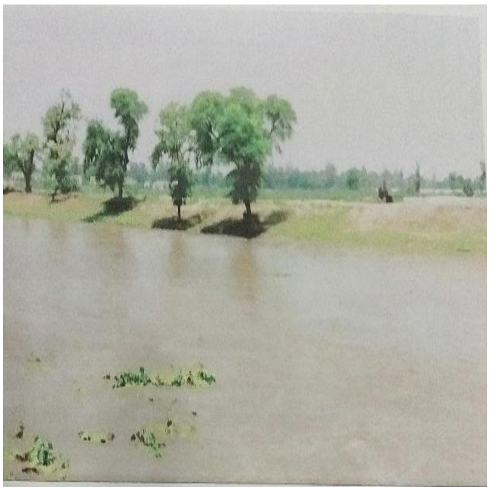


Aquatic plants in River Sutlej Pond

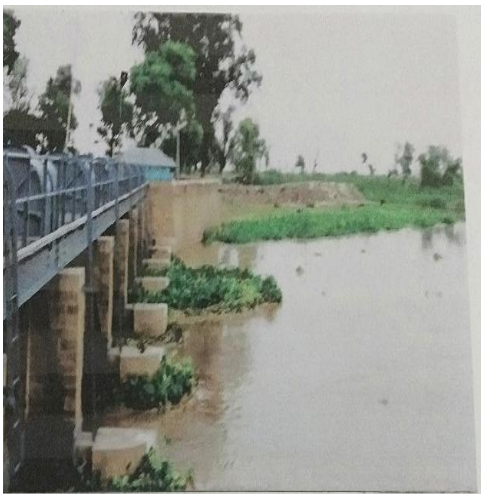
: Aquatic plants in River Sutlej Pond



Aquatic plants floating on the water surface level of Pakpattan Canal



Aquatic plants floating on the water surface level of Pakpattan Canal



: Aquatic plants floating around the piers of Head of Pakpattan Canal after coming from River Sutlej Pond

Aquatic plants hanging around the piers of bridge of Pakpattan Canal

: Aquatic plants hanging around the piers of bridge of Pakpattan Canal

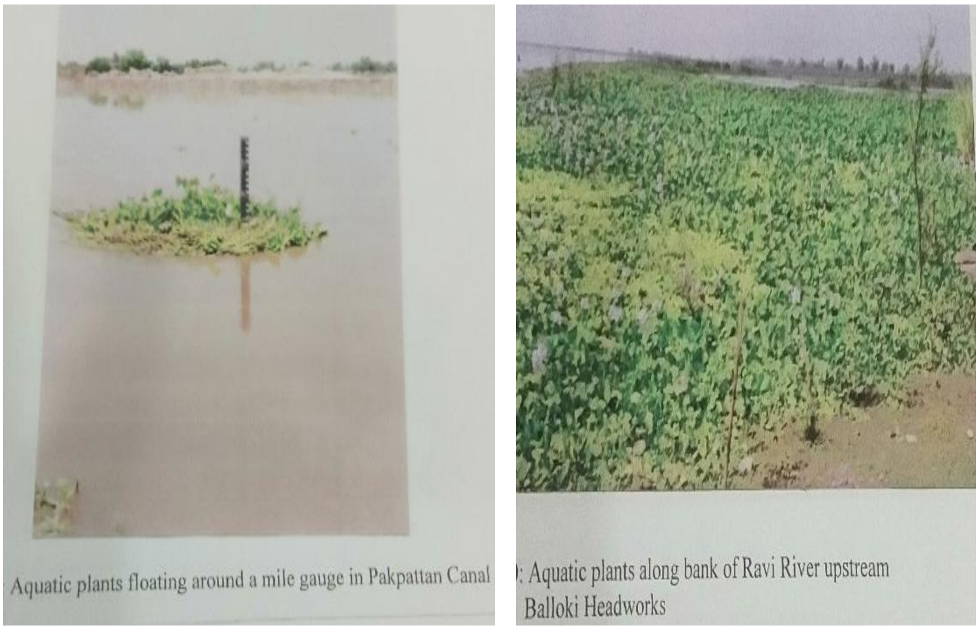


Figure 3: Pictorial views of floating materials at different locations

Sample collection of aquatic plants

Samples of aquatic plants were collected. These samples of plants were sent to Botany Department, Punjab University, Lahore for identification and suggestions for remedial measures in controlling the growth and flow of aquatic plants.

3. Results and Discussion

Identification of unwanted floating matter

The plant species were identified and technically described duly supported by ready references, by the Botany Department of Punjab University, Lahore as shown in Box 1.

Box- 1

Eichhornia crassipes *(Mart.) Solms*

English Name	:	Water Hyacinth
Urdu Name	:	Gul-e-Bakaoli
Place of Origin	:	Brazil
Habitat	:	Native to tropical South America
Kingdom	:	Plantae
Division	:	Magnoliophyta
Class	:	Liliopsida
Orders	:	Liliales
Family	:	Pontederiaceae

Free-floating perennial aquatic plants can be anchored in mud with broad, thick and glossy ovate leaves. Water Hyacinths may rise to approx. 1 meter in height. The leaves are 10-20 cm across supported above the water surface by long, spongy and bulbous stalks. The feathery, freely hanging roots are purplish black. An erect stalk supports a single spike of 8-15 conspicuously attractive flowers mostly lavender to pinkish in color with six petals. It flowering time is from April-November. When not in bloom, Water Hyacinth may be mistaken for frog's-bit (*Limnobium spongia*).

One of the fastest growing plants known as "water hyacinth" reproduces primarily by way of runners or stolen, eventually forming daughter plants which form on rhizomes and produce dense plant beds. These may also reproduce via seeds and vegetative propagation. The single plant can produce as many as 5000 seeds. The common water hyacinth (Eichhornia crassipes) is a vigorous grower known to double its population in two weeks. A healthy acre of floating water hyacinth can weigh up to 200 tons. Individual plants can break off mats and can be dispersed by wind and water currents. The seed can also be eaten and transported by waterfowl. It grows in mats up to 2 meters thick which can reduce light and oxygen entry, change water chemistry, affect flora and fauna and cause significant loss due to evaporation. It is now also considered as a serious threat to biodiversity.

Water hyacinth (*Eicchornia Crassipes)* is one of the most prominent freshwater plants found throughout the tropical and sub-tropical areas. The plant occurs in nutrient rich aquatic environments such as lakes, reservoirs and freshwater streams. The beauty of its flower led to the plant's introduction into other tropical countries as a decorative plant and finally its conversion into a weed as a consequence of high level of nutrients in the urban, industrial and municipal wastewater. Pollutants from urban, industrial and agricultural activities provide essential nutrients for the growth of this aquatic macrophyte. International experience shows that the plant's reproductive capacity, adaptability, nutritional requirements and resistance to adverse environments makes it impossible to eradicate and difficult to effective control. Experts now demand a call at the government level to seek a permanent solution by cracking whip on perpetual polluters of the water bodies. There is dire need to find ways and means for reducing pollution which enriches Ravi River near Lahore with nutrients and create a conducive environment for the weed.

Possible Solutions

A variety of methods have been tried to curb the growth of weeds. Herbicides are used most often because these provide an immediate action tool, although being costly and prone to create toxic effects if not applied according to the manufacturers' instructions. However, in severe infestations, high coverage techniques are needed such as herbicides and mechanical control to reduce the infestation. There should be sustainable management of water hyacinth and the establishment of a maintenance control program would ensure the reduction of the infestation levels.

A detailed discussion with panel of researchers keeping in view ecosystem for controlling the water hyacinth (aquatic plants) converged to the four main mechanisms used for preventing the spread of or eradication of water hyacinth. These included biological, chemical, physical/mechanical and surface run-off control techniques. The suitability of these measures was also discussed with the researchers.

A) Biological control of water hyacinth

Biological control is based on the use of host specific natural enemies to reduce the population density of pests. Several insects and fungi have been identified as control agents for water hyacinth. Biological control of water hyacinth is said to be environmentally compassionate as the control agents tend to be self-regulating. The biological control of water hyacinth began in the 1960s and produced the classical control strategy that involved the importation of natural enemies from the point of origin of the weed. One major drawback is that biological control requires time for the assessment of their impact. It can take several years for the insect population to reach a population density sufficient to tackle the weed production. However, once established, populations remain present and, in this way, the long-term cost in weed management is less than other control measures and also less harmful to the environment (Lancar & Krake, 2002). Research into the use of biological agents for water hyacinth control includes:

i) Arthropods (variety of Weevils and Moths)
ii) Pathogens (Fungi etc.)
iii) Herbivorous animals (like fish etc.)

i) Arthropods

In the case of arthropods, only a few insects have been found to reduce the growth of water hyacinth significantly. Of these, only the following species have been considered worthy of introduction to the other countries:

- The mite Orthogalumna terebrantis Wallwork;
- The moths Acigona infusella Walker and Sameodes albiguttalis (Warren);
- The miridae Eccritotarsus catarinensis Carvalho;
- The weevils Neochetina eichhorniae Warner and Neochetina bruchi Hustache.

The last two species are the agents that have provided the best results when used within an integral control program. However, its impact has been variable. The efficacy of those arthropods was not achieved at the desired level of control because of the following factors:

- Injudicious herbicide application.
- In the case of *Semodes albiguttalis*, requirements of young and actively growing plants for its establishment.
- In the case of *Neochetina spp*, plant quality might influence the abundance of Neochetina; weevil populations increase slowly and therefore weevil density is too low for control. In addition, these insects have relatively long life cycles (66-75 days for *N. bruchi* and 96-120 for *N. eicchorniae*). Population build-up is slow, compared with rapid plant-growth rates.
- In the case of *Eccritotarsus catarinensis* and *Orthogalumna terebrantis*, this insect has been released in far fewer countries; and little impact on plant growth has been observed.
- High incidence of disease on insects.

Despite the difficulties connected with insect establishment, Water Hyacinth remains a candidate for successful biological control. However, following considerations must be kept in view while adopting such measures:

- Surveying possible insect disease before and after release;
- Ascertaining its reproductive capacity;
- Continuing insect release;
- Releasing new insects-ecotypes;
- Understanding factors affecting insect population growths that regulate and maintain populations at realistic sizes.

ii) Pathogens (Fungi etc.)

a) **Use of Bioherbicides**: Because of the reproductive capacity and fast growth of water hyacinth, it has been necessary to use a set of biocontrol agents to increase the biotic stress in order to reduce population resurgence. Among the natural enemies of water hyacinth, plant pathogens can be useful because, as bioherbicides in an integrated weed control program are often host-specific (no risk to crops, native plants or animals), easy to propagate and disseminate and self-maintaining; thus, reducing the need for repeated applications. However, as is the case for other biopesticides, microbial herbicides are inactivated in the environment by exposure to temperature, low humidity and ultraviolet radiation. In fact, the main problem of biopesticides is their large-scale production in a formulation that allows for a successful application in the field.

b) **Use of Pathogenic Fungi:** Among plant pathogens, fungi are the most important natural plant pathogens. Many fungal pathogens have been cited in the literature as potential biocontrol agents for water hyacinth. Among them are *Cercospora piaropi* (=*C. rodmanii*), *Acremonium zonatum*, *Alternaria eichhorniae*, *Myrothecium roridum*, *Rhizoctonia solani* and *Uredo eichhorniae*. *A. eichhorniae* and *C. piaropi,* have been studied for their biology, biocontrol potential, host specificity formulation and have been tested in experimental conditions by various scientists. Results indicate that damage produced by fungus is enhanced when used in combination with insects.

However, no commercial bioherbicide for water hyacinth is available. Biological control reduces weed vigor, combined with environmental conditions, phenology of the plant and integrated use of other management options. The sole use of a biocontrol agent does not in itself ensure the success of the control. The biocontrol of Water Hyacinth should form part of an integral control program that includes timely, programmed technical visits to evaluate progress. In a severe infestation, a wide integrated approach (chemical and /or mechanical control) may be needed. Once the infestation has been brought down to a manageable size, the biocontrol agents should be released in safe areas.

iii) Aquatic animals (such as fish)

Opuszynski (1992) and Opuszynski & Shireman (1995) classify the herbivorous fish as those in which food contributes >50% plant material by weight or volume, at least some period of its life. Opuszynski and Shireman (1995) mentioned that 24 families of fish contain fresh water herbivorous representatives. In total, 37 species are listed as feeding on macrophytes and two on "plant species". Twenty of the macrophyte-feeding species belong to the family *Cyprinidae and* eight to the family *Cichlidae*. Among these, Grass Carp is the only fish used on large scale for optimal aquatic weed control.

The Grass Carp (*Ctenopharyngodon idella*) has been subject to wide interest due to its potential for biological control of aquatic macrophytes. Its ability to consume large quantities of aquatic plants is well documented (Kilgen et al, 1971).
The Grass Carp is one of the largest members of the minnow family commonly reaching weights in excess of 32 Kg. It has been introduced into 50 countries worldwide due to uncanny ability to control a wide variety of aquatic Plant species. In pond experiment carried out in Alabama, Grass Carp successively reduced the water hyacinth plant size by eating the roots. Water hyacinth was eliminated within 30 days after the fish were stocked at 16 per 0.04-hectare pond (Kilgen, 1978).

B) Chemical control

Application of herbicides for controlling water hyacinth has been carried out for many years (Yaghoubi*, et al*., 2020). There are three most commonly used aquatic herbicides:

i) 2,4-D (2,4-dichlorophenoxy)
ii) Diquat (6,7-dihydrodipyrido l[1,2a:2'1'-c] pyrazinediumion)
iii) Glyphosate

It has been found in literature that there is a good success rate when dealing with small infestation but less success with larger areas. The main concern when using herbicides is the environmental and health related effects especially where people collect water for drinking and washing (Lancar & Krake, 2002).

For the use of herbicides, an approval from Plant Protection Agencies is necessary, and must be applied strictly by trained technicians. The formulation of 2,4-D includes granular ester for use on submerged weeds and liquid dimethylamine for emergence such as Water Hyacinth.

2,4-D is a systematic herbicide which readily translocated from foliage to roots. It inhibits cell division of new tissue and stimulates cell division resulting in growth inhibition, necrosis of apical growth and eventually total cell disruption and plant death. Control is carried out approximately two weeks later.

The diquat formulations, for aquatic macrophyte weeds use, are liquid bromide salts. Diquat is rapidly absorbed by foliage (1-2 hours) causing a rapid inactivation of cells and cellular functions through release of oxidants (Systema & Parker, 2011).

Glyphosate is a non-selective systemic herbicide, readily absorbed by leaves and throughout the plant. All plants can be eliminated after three weeks. Glyphosate has a low toxicity and rapid decomposition in water (Systema & Parker, 2011). Herbicide applications are usually less expensive than mechanical control but may have to be repeated on an annual basis owing to the fact that once plants are removed, light penetration increases, favoring the germination of water Hyacinth seeds and therefore new water Hyacinth reinfestation. In addition, human and ecosystem health have to be considered when aquatic herbicides are applied to water supplies, particularly drinking water. In this way, the main problem is the use of a wetting agent and a penetrant necessary to increase the effectiveness of herbicides.

C) Mechanical/Physical Control

Mechanical removal of water hyacinth is seen as the best short-term solution to the proliferation of aquatic plants. Mechanical harvesters can also remove the plants and prevent regrowth. Physical control, using mechanical movers, dredgers or manual extraction methods is used widely but is costly and cannot deal with large infestation. Such methods are suitable for relatively small areas. Mechanical control by using a chopper or a shredder is not recommended because fragmentation may accelerate the spread of plants and consequently aggravate the problem.

Hand pulling is not recommended as this weed becomes a habitat for dangerous reptiles. Various studies show that weed has increased the population of snakes. It not only poses health risk but transportation of harvested weed is also costly and labor intensive.

D) Surface Run-off Control

Besides the above mentioned three mainstream forms of control, another method dwelling upon reduction of nutrients into the surface water bodies is also suggested (Harley, et al, 1997). Although strictly speaking, this is a primarily preventive method, yet it can be argued that reduction in nutrients in the water body will result in a reduction in the proliferation of water hyacinth. In recent decades, there has been a significant increase in the level of nutrients dumped into Ravi River from industrial and municipal/domestic sources as well as from land where fertilizers are used or where clearance has caused an increased in the surface run-off. It seems that the systematic use of successive vetiver hedges along the river, besides improving bank protection, has also helped in retaining nutrients, pollutants and sediments from the run-off to flow in the water.

4. Conclusion and recommendations

After thorough survey of the problematic canal and its upstream sides done by the research team of the IRI, the plant had been identified as Water Hyacinth (*Eichhornia crassipes* (Mart.) Solms). Amongst various methods tried to curb the weed, chemical control is the least recommended due to its detrimental impacts on environmental and human health. Mechanical/physical control has been ascertained to be a useful tool as a short-term strategy, particularly before the sexual reproductive phase of the plant. Mechanical harvesters can also remove the plants and prevent regrowth, but mechanical method is labor-oriented and may be expensive. “Run-off Control Method” another technique used for minimizing the nutrients into the surface water bodies also results in reduction in the proliferation of water hyacinth. The biological control of water hyacinth is found to be environmentally benign and produces the classical control strategy. It can, however, take some longer time to reach a population density sufficient to tackle weed production. Further, use of Chinese Grass Carp acting as a herbivorous fish can also be advantageous especially in off-seasons/stagnant waters. Based on the work done by the IRI personnel on this issue, it can be concluded that an integrated weed management strategy coupled with best management practices may be tested, at a small area to start with, in order to minimize the spread of water hyacinth. It has been suggested that, at the present, Chinese Grass Carp may be used in off-season (stagnant waters) in the pond area upstream of Sulemanki Headworks where Water Hyacinths (aquatic plants) are in a huge quantity forming bellas. Water Hyacinth is a favorite plant for the Grass Carp acting as a herbivorous fish and also an earning product. As regards the plants along banks of Pakpattan Canal, these may be plucked/eradicated by using mechanical means. The experience gained in this way may be replicated in other similar areas over time.

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Data availability Statement:

All the relevant data has been made part of the paper; however further detail can be obtained from the corresponding author.

Conflict of Interest:

The authors declare that there is no conflict of interest.

Note: the views expressed in the paper are of the author's own; and do not reflect the responsibility of any organization/department.

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