Review: Egyptian Experience in Controlling Aquatic Weeds

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Abstract: Aquatic plants are considered nuisances when excessive growth interferes with desired water uses, including human health. The establishment of Aswan High Dam in the southern part of the River Nile in Egypt has many side effects. The aquatic macrophyte vegetation is growing so rapidly and densely that it represents an acute problem. The problems created by the hydrophytes are many such as, constituting a health hazard by providing mosquitoes larvae with an ideal breeding place, causing oxygen depletion, interfering with navigation, obstructing drainage and flow of water in irrigation canals, decreasing phytoplankton production, polluting water supplies, increasing sedimentation by trapping silt particles and causing loss of water through evapotranspiration and decrease the hydraulic efficiency of open channels infested by aquatic weeds. There are four main methods used to control aquatic weeds, in addition integrated weed control: manual methods; mechanical method; physical method; biological method and Integrated weed control. The objective of this paper is to present the Egyptian Experience that was gained through researches in order to be implemented in the field of control aquatic weed by using biological method (grass carp).

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1- Introduction

In Egypt, some of the problems arising from the construction of Aswan High Dam (AHD) involve the waterway environment as a result of the consequent regulated flows. Constructing AHD across the Nile at Aswan is obviously has some effect on the aquatic macrophyte. It provided routes for some aquatic weed species to the system where they had been previously absent, or they caused permanent elimination for some of them within Lake Nasser, Aswan reservoir, Nile River and waterways (canals and drains) (Kotb *et al.,* 2002; Salwa, 2013; Tarek and Salwa 2013).

Aquaticweedsarethoseunabatedplantswhichgrow andcompletetheirlifecycleinwaterandcause harm to aquatic environment directly and to related eco-environment relatively. Water is one of most important natural resource and in fact basis of all life forms on this planet. Therefore, appropriate management of water from source to its utilization is necessary to sustain the normal function of life. It is one important part of natural resource management. The presence of excessive aquatic vegetation influences the management of water in natural waterways, man-made canals and reservoirs which amounts to millions of kilometers/ square kilometers of such water bodies around the world(Lidia and Kevin, 2002).

Aquatic plants are considered nuisances when excessive growth interferes with desired water uses, including human health. Aquatic plant problems have increased in the last two centuries, in line with increases in industrialization, travel and communications, agricultural productivity (including the agricultural "green" revolution), the growth of the human population and changes in consumption patterns. Increased travel has expanded the opportunities for transmission of aquatic plants from their home ranges to new environments. Factors such as population growth and changing consumption have led to changes in land and water use, which have increased pressure on endemic aquatic plants and provided suitable habitats for introduced species. Aquatic plant problems are usually a symptom of broad land and water use changes and poor water management. Aquatic plant management should therefore be based on preventing or minimizing the side effects of developments that disturb aquatic environments. (Richard and Rafik, 2005).

The purpose of this paper is to review the research on aquatic weed management which has been carried out in Egypt, and identify key research needs for the future.

2- Aquatic Weeds Problems

Aquatic weeds often reduce the effectiveness of water bodies for fish production. Aquatic weeds can assimilate large quantities of nutrients from the water reducing their availability for planktonicalgae. They may also cause reduction in oxygen levels and present gaseous exchange with water resultinginad verse fish production. Although excessive weed growth may provide protective cover in water for small fish growth it may also interfere with fish harvesting. Dense growth of aquatic weeds may provide ideal habitat forth development of mosquitoes causing malaria. These weeds may also serve as vectors for disease causing organisms and can greatly reduce the aesthetic value of water bodies from recreational point of view. Aquatic weeds have been found to severely reduce the flow capacity of irrigation canals thereby reducing the availability of water to the farmer's field. Aquatic weeds may also damage pumps and turbines in super thermal power stations and hydroelectric power stations influencing electric production and increasing the cost of maintenance of power stations. Many aquatic plants are desirables since they may play temporarily beneficial role in reducing agricultural, domestic and industrial pollution. Many aquatic weeds may play a useful role of providing continuous supply of phytoplankton and help fish production (ICID, 2002).

Aquatic weeds (emergent, floating and submerged) interfere with the static and flow water system. They cause tremendous loss of water from water bodies like lakes and dams through evapotranspiration. In flowing water system, aquatic weeds impede the flow of water in irrigation canals and drainage channels thereby increasing evaporation damage structures in canals and dams, clog gates, siphons, valves, bridge piers, pump etc. Impediment in flow of water may result in localized floods in neighboring areas. Floating and deep rooted submerged weeds interfere with navigation. Water hyacinth and Alligator weed grow profusely and create dense mats which prevent the movement of boats and at times even large ships (Lidia and Kevin, 2002; Tarek and Salwa, 2009).

3- Aquatic plant Type

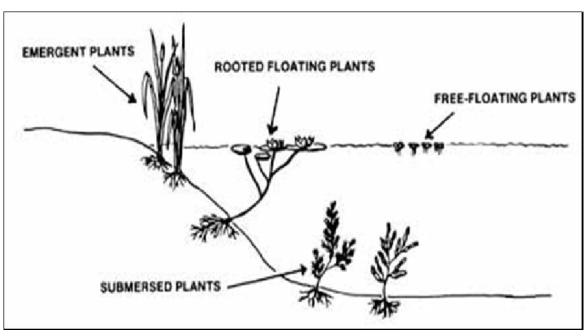

Figure (1): The categories of aquatic plants

Aquatic plants are grouped into four broad categories (figure 1) based on where they grow:

1. Submersed plants
2. Free-floating plants
3. Rooted floating plants
4. Emergent plants (also called shoreline or marginal plants)

4- Open Channel Challenges

Open channels are still the major conveyers to deliver water to agriculture all and sin Egypt where 33,000 km length of canals supplies irrigation water to the cultivated lands. The main task and responsibility of the irrigation engineers is to operate these channel sat the highest possible efficiency. However, the presence of aquatic weeds in irrigation channels causes many problems such as water velocity reduction, water level rising, preventing water from reaching canals' ends, decrease water flow, in-efficient water distribution, etc (Abdeen, 2008).

Several researchers have investigated the hydraulic efficiency of open channels infested by aquatic weeds. The research community in this field divides the studies according to the type of weeds (or their simulators) and their impact on the roughness as rigid or flexible roughness studies (El Samman *et al.,* 2003; Abdin and Abdeen, 2007; and Abdeen, 2008;). All literature review for the investigation of the hydraulic efficiency of open channels that are infested by aquatic weeds recorded the impacts of submerged aquatic weeds on the hydraulic performance of the Egyptian open channels within the irrigation and drainage networks in field and by using physical model and mathematical model.

Also field studies were carried out on 21 Egyptian channels infested by all types of weeds to determine their effect on the hydraulic efficiency. Results obtained (Khattab and El Gharably 1990) showed that the hydraulic efficiency was reduced to 39% and 50% in channels where the water surface is 100% and 70% covered with floating (*Eichhorniacrassipes*) weeds respectively. In case of submerged weeds the hydraulic efficiency was reduced to 61% and 78% in channels where the plants occupied 20 and 10% of the water cross section respectively. Emergent weeds not much effect on the channels efficiency since they grow usually at the top zone of the side slopes where velocities are too low. Two channels were considered the study where the efficiency was reduced to 86% and 82 % where the emergent weeds occupied 6 and 10% of water cross section respectively. Aquatic weeds also create stagnant conditions in water causing a suitable medium for the deposition of large amounts of organic matter and accumulating sediment, this will lead to a short cycles for channel maintenance(Khattab and El Gharably 1990).

Therefore, considering the losses caused, it is essential to keep aquatic weeds under control in water bodies, flow water systems, ponds and tanks so that these systems can be utilize to best of their efficiency.

5- Methods of Controlling Weeds in Egypt

There are numerous methods to control aquatic weeds. These methods have been developed over a number of years through research and development and by trial and error. There are three main methods used to control aquatic weeds, In addition integrated weed method as follows:

- Manual methods
- Mechanical method
- Physical method
- Biological method
- Integrated weed control

There are many various aspects of each method can be explained in the next part:

3-1 Manual Weed Control

This method was practiced in Egyptian canals and drains of bed width and water depth less than 4 m and 1.5 m respectively (khattab and El-Gharably, 1984). Since 1985, the use of this method is decreasing and being replaced gradually by mechanical control (Khattan and El-Gharably, 1986). In 1995, a new project was started to clean and maintain small Egyptian canals (bed width less than 2m) by using developed manual tools. The results of applying this project in Upper Egypt and Delta were suitable to be applied in a large scale. One of the main advantages of this method is to clean the canal without any damage on the cross section (Tarek and Salwa, 2006). But there are other advantages as follow:

- The weeds are cut at the root or removed with the root.
- The canal slopes are maintained in a good state or even strengthened by a short plant cover.
- With regular weeding a high production (length of canal cleaned per hour) can be realized.
- The work is less heavy. This also allows laborers to work more effectively throughout the day.
- The contact with the water and thus the risk of workers contracting Bilharzia and other water related health hazards is reduced.

The disadvantages of using manual control may be slow, inefficient in huge infestation, and labors may be poorly trained to do an adequate job and sometimes fail to remove enough target weeds.

3-2 Mechanical Weed Control

Mechanical control methods involve the complete or partial removal of plants by mechanical means, including: harvesting, mowing and chaining. Mechanical control methods can also be used to expedite manual harvesting activities, including hand harvesting, raking, and cut stump control, with the use of motor-driven machinery (Haller 2009; Lembi 2009). These management techniques for plants rarely result in localized eradication of the species, but rather, reduce target plant abundance to non-nuisance levels. A range of machinery for managing and controlling aquatic vegetation is in use today for specific plant types (floating, submersed and emergent vegetation) and for operation in specific aquatic habitats (open channels and shorelines). The equipment used in mechanical weed control for different aquatic weed types can be summarized as follows:

- **Floating Equipment**

a. Weed mowing boats are used in canals with bed width 5-10 m.

b. Harvesters are used in wide canals, branches and the river Nile.

- **Earth Equipment (used from the embankments**:

a. Hydraulic excavator with attachments (mowing or cutting equipment) such as;

- Shallow draft bucket
- Weed mowing bucket

b. Flail mower and rotary cutter (used to remove ditch bank weeds).

c. Weed rake (used to remove submerged and floating weeds).

d. Chaining (used in channels to conduct non selective control of submersed and emergent weed.

In fact, the equipment used for channel maintenance was usually the excavation bucket. This reflected the main task: excavation, but some weed removal could also take place with the excavation buckets. Generally, the excavation buckets were mounted on draglines for wide channels and on hydraulic excavators for smaller channels (Smout *et al.* (1997)).

Excavators can be expensive and can be used for either large scale or small scale operations. Excavators remove water hyacinth directly from the water and either deposits it in stockpiles above the shore line or directly into a dump truck. Excavation buckets are not fit for removing aquatic weeds only and the destructive work continued to lead to frequent collapsing of canal embankments. Submerged weeds can only be removed by excavating down to root depth; otherwise the bucket slips over the plants, bending the stems without removing the weeds. Pulling out vegetation by means of the teeth often attached to the excavation buckets leaves ugly holes in slopes and embankments causing collapses (Smout *et al.*, 1997).

So, excavation should be minimized to prevent excessive reshaping of the channels prism. It is preferable to excavate only while de-silting or using mowing buckets. And using excavators to pick up and remove large built up accumulations of floating water hyacinth upstream irrigation structures is necessary.

So, the use of mowing buckets instead of dredging buckets for mechanical weed control which can remove all aquatic weeds in the water as well as bank weeds in one continuous working movement. The Egyptian Public Authority for Drainage Projects (EPADP) in close cooperation with Consulting

Services for the Maintenance of Drainage Projects (MDP-II) to implement a project from 2004 till 2008 (MDP-II,2008). The project use of mowing buckets for cutting of weeds in the wet section and on side slopes of the open drains. The results of the use of mowing buckets have been suitable to apply on large scale. The mowing buckets proved to be effective for cutting and removing both floating and rooted weeds from the open drains and from the side slopes of the open drains. Observations in the field clearly show that only plant materials are removed from the open drains and no soil removed. The project recommends the use the mowing buckets for the removal of all aquatic weeds (floating and emergent) from the wet section and side slopes of the drains (MDP-II,2008).

3-3 Physical method

Physical control is the removal or containment of water hyacinth using mechanical methods such as machinery, containment booms or fences and manual removal. Choosing which method or combination of methods to use will depend on the size of the infestation, resources available and the use of the waterway (Van Oosterhout 2006).

Physical removal of water hyacinth is quite an expensive and laborious task; however, it does provide a few advantages over other control methods, including:

- There are no with holding periods and the water can be used immediately following control. This can be suitable for water bodies that are used for irrigation or stock and human consumption purposes.
- Immediate eradication of small infestations where small man-made water bodies can be made inactive by filling in the site(for example a small dam).
- Reduced long-term monitoring costs when the seed bank is removed from a water bodies banks.
- Removal is immediate, opening up space available for boat Ingo recreational activities or immediate improvement in water quality or habit at value.
- There are no issues with diminished water quality as it minimizes the amount of dead plant material left in the water to decompose.
- The removal of nutrients to reduce growth rates for re-infestation.

All control activities undertaken must have a long- term monitoring, maintenance and follow-up control plan in place, to restrict seed bank buildup and reduce the risk of reinvasion.

Physical barriers such as floating booms and containment fences can be used in conjunction with all types of control measures and can be used to:

- Contain an infestation to one area, to help minimize the cost and time required for physical removal,
- Separate are as that require different treatments that used as in-stream wetland.
- Reduce the risk of further invasion downstream, where it could have potential long-term environmental impacts,
- Allow staged removal,
- And encircle and drag water hyacinth to an excavator with weed bucket for removal.

In Egypt, Channel Maintenance Research Institute (CMRI), has a long experience on the controlling of aquatic weeds and overcome the problems of weeds upstream hydraulic structures, lifting pump stations and power stations, such as designing barriers upstream hydropower station of new Esna Barrages (Sherif *et al.,* 2004), new Naga Hamady barrages and El Alamain drink water station by (Hosam *et al.,*2004), upstream Marazik bridge, and upstream El-Nasr lift station number 1 on El-Nasr canal (Emam *et al.,*2013).

3-4Biological Weed Control

3-4-1 aquatic weed control using grass carp

Mechanical control is costly and requires accessibility to the waterways, and chemical herbicides are often so toxic that the water cannot be used subsequently for fish culture or human consumption or other uses. Fish can play a potential role in this aspect since they are active, feed voraciously and will produce a valuable by-product in the form of protein. The species which has been most widely used in this regard is the grass carp, *Ctenopharyngodonidella*, although there are other species with potential in this regard.

Originally a native of China's river systems the grass carp has been introduced throughout the world. One of the reasons for its wide dispersal has been its effectiveness as a biological control agent in the control of nuisance aquatic weeds (Schramm and Jirka, 1986; FFI, 1989). Biological weed control with the Chinese grass carp was introduced in Egypt by the GCP during 1979 – 1982 on an experimental scale. The attractiveness of this biological weed control increased since chemical aquatic weed control was banned 1991.

3-5 Experimental of grass carp in Egypt

A biological weed control initiative started in 1975 under the Channel Maintenance Project (1975-1978). This initiative was followed by launching a Weed Control Research Programme for the period from 1976 to 1979 to study the various means of controlling aquatic weeds, including consideration of conventional and biological methods with special attention to their ecological impacts. One of these experimental methods was the use of grass carp or white Amur (a fish from the catchment area of the river Amur and some other rivers in Eastern China)

(Ilaco, 1985). The Grass Carp Project for the period from 1979 to 1985 studied, therefore, the breeding, raising and management of grass carp. The bilateral Dutch-Egyptian cooperation in the field of biological weed control continued until 2004 including a variety of parallel activities aimed at studying different biological control methods, development, organization and evaluation of various biological weed control methods (FAO, 2007).

As the application of chemical weed control was completely banned by the Egyptian Government in 1991 due to its health hazards, weed control was mainly done by biological means. The biological control, through the use of grass carp, required organizational structures and physical facilities for the production of fish and its implementation in the field. Both were lacking in Egypt. Therefore, it was proposed to continue the experiments with grass carp on a larger scale and to breed the required fish in Egypt itself. The experiments were carried out as part of the Weed Control Project Phase II (1978) and the Grass Carp Project (1979-1982). Both projects were financed, in-part, by the Government of The Netherlands under the responsibility of the Ilaco and another firm, acting as consultant (FAO, 2007).

Weed control experiments with grass carp took place in the surroundings of Ismailia and Cairo and led to the conclusion that weeds in Egypt can be effectively controlled with the help of grass carp in a large number of canals and drains. When the experiments showed positive indications, a larger hatchery was constructed along the Nile near El-Kanater. This hatchery, called the Delta Breeding Station (DBS), was constructed within the framework of the Delta Breeding Station Phase I project. The station became operational in the spring of 1982. Technical assistance was provided for training and management during the first two operational years of the station. Attention was also given to the application of grass carp in the field. Although weed control as such proceeded well, organizational difficulties and technical issues remained. Therefore, the project was extended for two more years (FAO, 2007).

During the FWMPs (1994 – 1996) further experiments were implemented and the effectiveness to control submerged weeds was tested; also effective conditions under which grass carp can be introduced into the canal system were investigated. Similar experiments were carried out in 20 canals and drains in Ismaelayia, Giza and the Delta Barrage area. Results have shown that, for instance, applying biological weed control, rather than mechanical weed control, reduces the costs of maintenance by about 70%. Based on these years of experiments, it was concluded that biological weed control by grass carp is an effective method, although it does not control the ditch bank weeds and water hyacinths. Also sometimes high infestations, with submerged weeds or with water grass in the beginning of the season, cannot be controlled effectively; in these cases pre-cleaning is needed (by means of mechanical weed control). With grass carp no rapid effects can be expected, since every plant, that has not been consumed yet, continues to grow. With grass carp, weed control progresses relatively slowly, but weed vegetation remains at a low level for the whole season, this in contrast to other weed control methods (mechanical and manual). In conclusion a combination of mechanical, biological and manual weed control was thought to render the best results as none of the methods under review can adequately cover all maintenance needs in the Egyptian canal system. With this in mind, in 1991 the MWRI adopted a policy to introduce biological weed control with grass carp in the wider canals (bed-width >6 m), which are operated under continuous flow. This decision was also based on the fact that this method has less negative environmental side effects compared to other weed control methods, it is relatively cheap and it is a source of protein (equivalent to a maximum of 500 kg/ha/yr) (Kotb *et al.,* 2002).

3-4 Implemented Biological weed control

Two breeding stations belong to the MPWWR; one experimental breeding station in the Delta (Delta Breeding Station; DBS) producing some 400.000 fingerlings of 10 grams and one other in Upper Egypt (Aswan Breeding Station; ABS) with a production of some 5-6 million 10 gram fingerlings to cover Aswan district. Also, in Egypt 11 hatcheries are in operation belong to the Ministry of Agriculture (6 in Lower and 5in Upper Egypt). The total annual production is about 38.5 million fingerlings of 10 gram and 1.25 million grass carp of 40-60 gram (CMRI, 2008).

From year 2000 up to now about 2,700 km (equivalent to 13% of all irrigation canals with a bed-width > 2 m, where biological weed control can be applicable) are under biological weed control.

3-5 Case studies for applying biological weed control

The channel maintenance research institute (CMRI) involves itself with setting rules and criteria for biological weed control application, evaluates, since 1998, on a yearly basis, the application of biological weed control nationwide and acts as a trouble shooter to solve technical problems at regional level.

3-5-1 Evaluate Biological weed control in canals

There are various parameters to evaluate the effectiveness of biological weed control method. Generally, only short term effects are evaluated and rated either "good" (few plants) or "poor" (high density of weeds still present).

Tarek and Salwa (2006) were selected twenty two Egyptian canals distributed on six Irrigation Districts to evaluate the effect of applied biological control method (using grass carp) to control aquatic weeds. These districts are distributed along upper (Assuit and Qena), middle (Fayoum), and Delta (Ismailya, Monoufya, and Dakahlya) of Egypt. From the result of the available data, it can be shown that the Qena and Assuit Districts applied the procedure of applying stoking density of Grass carp by estimating the total water surface area of canal. Therefore an acceptable result was obtained to control weeds. While in Fayoum District, it depends on estimating of the infested water surface area of canals. However in the Monoufya and Dakahlya District in some years reduced the number of grass carp by estimating the infested area, so a problem of aquatic weeds was observed. Ismailya District had weeds problem when the stocking density of grass carp (100kg/hectare) depend on the estimated of infested area and when the infested area equal to total surface area, acceptable result was obtained. It was concluded that the low stocking rates of grass carp reduced the efficiency of weeds control. The suggested stocking density of grass carp was depended on experimental study and reduce this density was not recommended. Finally, the infested surface area is not needed to estimate the stocking density of grass carp. However, it may be important to estimate the cost for mechanical control, which is used to clean the selected canals before using grass carp. These may make confusion in estimating the number of grass carp. Also, biological weed control encourages three problems: escape of fish from the stocked sections, Bayluscide injections by the Ministry of Public Health for bilharzias control, illegal fishing. The recommended rules to apply biological control method by Grass carp must be applied to increase the efficiency of using grass carp to control aquatic weeds.

Salwa *et al.,* 2009 were selected twenty one Irrigation Districts to evaluate the effect of applied biological control method (using grass carp) to control aquatic weeds. These districts are distributed along upper, middle, and Delta of Egypt. The infested percentage of each canal was evaluated before and after application as shown in table (1).

From the twenty one public irrigation directorates as shown in table (1), the decrease in infestation in some directorate is considered weak. But it maintained the stability of aquatic weeds, which were not up. Also, the research show that the estimation number of grass carp, which was stoked into the canals, was suitable to control weeds in most canals. Different size of grass carp was used to consume all types of submerged weed in some canals. This result means that the increasing grass carp density is essential to obtain an acceptable result in controlling submersed weeds.

3-5-2 Evaluate Biological weed control in Aswan Reservoir

In Egypt, some of the problems arising from the construction of High Dam (HD) involve the waterway environment as a result of the consequent regulated flows. Before constructing (HD), Aswan Reservoir (AR) showed a pronounced annual change in the water level. However, after constructing HD, the water level regime is followed in fixed pattern every day, in order to release sufficient amount of water to generate the hydroelectric power and to satisfy domestic, agricultural and industrial needs. The water in the reservoir is usually stored overnight and released during the day resulting in water level fluctuation ranging between 2 and 3 meters. For several years, this reservoir (the reach between Aswan Reservoir and High Dam) has been suffering from aquatic weed infestation, mainly the submerged one, *Ceratophyllumdemersum*, which is a predominant species. This type of aquatic weed constrained water use by blocking water intakes in front of operating pumps of hydroelectric Aswan Power Stations (1) and (2).

The mechanical control of aquatic weed cannot be applied in the reach between High Dam and Aswan Reservoir due to difficult topography of the region to take down the equipment. For controlling the submerged weed in the reservoir, herbivorous grass carp fingerlings were applied annually from year 1999 to year 2012.

As a result, the total percentage of the aquatic weed infestations along the whole reservoir sharply decreased from 0.5 % in year 1998 to 0.07 % in year 2007 (figure 2) and then increased to 0.26 % in year 2011 (Salwa and Tarek, 2013; Salwa, 2013). The increase of aquatic weed infestation in year 2010 due to lack of continue evaluation of aquatic weed infestation to determine the density of grass carp required (CMRI, 2011). Therefore it is recommended to use grass carp for controlling aquatic weed biologically annually with evaluation the percentage of aquatic weed and the stocked fish.

3-6 Integrated weed control

The integrated weed control method is the combining of two or more of the standard weed control methods into a planned system, or integrated method, to achieve more efficient and effective control of weeds. The various weed control methods must support and complement one another to be integrated.

Table (1): Infestation of Egyptian canals by different types of submersed weed before and after applying biological weed control during 2007/2008.

No.	District Name	Canal Name	Type of submersed weed	Infested Percentage (%)	
				Before application	After application
1	East Qena	EL-Kalabia	*Myriophylumspicatum. Ceratophyllumdemersum*	20-50	15-30
2	West Qena	Asfon	*Myriophylumspicatum. Ceratophyllumdemersum*	15-40	3-20
3	Sohag	Naga hamady El-Sharkeyia	*Myriophylumspicatum. Ceratophyllumdemersum*	5-13	5-10
4	Assuit	Irad EL-Mahraq	*Myriophylumspicatum*	5-20	3-7
		El Basuony	*Myriophylumspicatum Ceratophyllumdemersum PotamogetonCrispusl Potamogetonnodosuspoir*	5-20	7-25
		EL-Sheik Awny	*Myriophylumspicatum*	10-20	8-12
		AbouGabal	*Myriophylumspicatum. Ceratophyllumdemersum*	7-20	10-15
		EL-Gargawia	*Myriophylumspicatum. Ceratophyllumdemersum*	30-40	12-18
		EL-Waldia	*Myriophylumspicatum*	5-20	5-10
		EL-Mana	*Myriophylumspicatum. Ceratophyllumdemersum*	20-35	7-10
		EL-Sant	*Myriophylumspicatum. Ceratophyllumdemersum*	20-25	10-13
		Bany Magd	*Myriophylumspicatum. Ceratophyllumdemersum*	5-10	5-8
		EL-Qusia	*Myriophylumspicatum. Ceratophyllumdemersum*	10-15	8-10
		Naga Hamady El-Sharkeyia	*Myriophylumspicatum. Ceratophyllumdemersum*	5-35	5-20
		Naga Hamady El-Gharbia	*Myriophylumspicatum. Ceratophyllumdemersum*	10-25	7-12

Continue table (1): Infestation of Egyptian canals by different types of submersed weed before and after applying biological weed control during 2007/2008.

No.	District Name	Canal Name	Type of submersed weed	Infested Percentage (%)	
				Before application	After application
5	West EL-Menia	Manshat EL-Dahab	*Myriophylumspicatum. Ceratophyllumdemersum Potamogetonnodosuspoir*	15-55	15-35
		SarayaBasha	*Myriophylumspicatum. Ceratophyllumdemersum NajasarmataLindb*	10-40	10-25
		Bany E bad	*Myriophylumspicatum. Ceratophyllumdemersum*	10-15	10-12
		Mantot	*Myriophylumspicatum. Ceratophyllumdemersum*	7-45	5-25
		Masarathagag	*Myriophylumspicatum.*	5-10	5-7
6	Bany Sawif	EL-Soltany	*Ceratophyllumdemersum NajasarmataLindb*	10-15	8-17
		Bahr yossif	*Ceratophyllumdemersum Najasarmata Lindb*	5-8	4-6
		EL-Ibrahimia	*Ceratophyllumdemersum NajasarmataLindb*	8-12	8-10
		EL-Giza	*Ceratophyllumdemersum NajasarmataLindb*	10-20	10-15

7	EL-Fauim	Tanhala	*Ceratophyllumdemersum*	12-15	10-12
		Soliman Desoky		5-8	5-7
		Wahby		3-5	2-3
		EL-Roda	*Potamogeton Crispusl*	15-20	15-20
		Hogman	*Potamogeton Crispusl*	10-15	10-15
		EL-Serb	*Potamogeton Crispusl*	5-10	5-8
		Snoras EL-Omom	*Potamogetonnodosuspoir*	10-15	8-10
		EL-Zawia	*Myriophylumspicatum.*	5-10	7-10
		Qaron	*Myriophylumspicatum.*	50-60	40-45
		Emtdad Qaron	*Myriophylumspicatum.* *Potamogetonnodosuspoir*	40-50	30-35
		EL-bashawat	*Myriophylumspicatum.* *Potamogetonnodosuspoir* *Potamogeton Crispusl*	50-70	40-55
		EL-Gargaba	*Myriophylumspicatum.*	20-30	15-20
		Snoro EL-Gadid	*Potamogetonnodosuspoir*	5-7	5-7
8	Ismailia and West Sinia	Suez	*Myriophylum Spicatum.*	8-15	6-13
		Port said	*Myriophylum Spicatum.* *Potamogetonnodosuspoir*	10-25	10-20
		EL-Manaif	*Myriophylum Spicatum.* *Potamogetonnodosuspoir*	5-15	5-12

Continue table (1): Infestation of Egyptian canals by different types of submersed weed before and after applying biological weed control during 2007/2008.

No.	**District Name**	**Canal Name**	**Type of submersed weed**	**Infested Percentage (%)**	
				Before application	**After application**
9	EL-Salhia	Ismailia	*Myriophylum Spicatum.* *Potamogetonnodosuspoir*	5-10	5-8
		EL-Shabab	*Myriophylum Spicatum.*	5-7	3-5
		EL-Malak	*Myriophylum Spicatum.* *Potamogetonnodosuspoir*	30-40	15-25
		EL-Salhia	*Myriophylum Spicatum*	8-10	5-7
		EL-hesinia	*Myriophylum Spicatum*	10-50	10-30
		EL-Tolmbat	*Myriophylum Spicatum*	5-7	3-5
		EL-Saidia	*Myriophylum Spicatum*	10-20	5-10
10	East EL Sharkia	Bahr Moes	*Myriophylum Spicatum*	8-10	5-8
		Bahr Abo EL-Akdar	*Myriophylum Spicatum*	5-10	5-7
		Bahr Fakos	*Myriophylum Spicatum*	3-5	2-5
		EL-samana EL-Gedida	*Myriophylum Spicatum*	10-20	7-15
		EL-Wadi EL-Sharky	*Myriophylum Spicatum*	3-10	3-7
11	West EL-Sharkia	Bahr Mores	*Myriophylum Spicatum*	7-15	7-12
		Km 24-Km36	*Myriophylum Spicatum*	5-15	5-10
		Km 36-Km48	*Myriophylum Spicatum*	5-8	3-6
		Km 48-Km56	*Myriophylum Spicatum*	5-10	4-8
		Km 56-Km67.8	*Myriophylum Spicatum*		
12	EL-Kalubia	EL-Bassosia	*Myriophylum Spicatum*	4-15	5-12
		EL-Sharkawia	*Myriophylum Spicatum*	5-15	5-14
		Ismailia	*Myriophylum Spicatum*	5-8	4-6
		EL-Rayah EL-Twfiky	*Myriophylum Spicatum*	5-10	5-8
13	EL-Monofia	EL-Bagoria	*Myriophylum Spicatum.* *Ceratophyllumdemersum.*	5-25	5-20
		EL-Neanaeia	*Myriophylum Spicatum.* *Ceratophyllumdemersum.*	5-20	7-12
		EL-Sersawia	*Myriophylum Spicatum.* *Ceratophyllumdemersum.*	2-10	2-10
		Shoab Shenowan	*Myriophylum Spicatum.* *Ceratophyllumdemersum.*	2-35	2-15

14	South Dakahilia	El Bohia			
		Km 0 to Km8	*Myriophylum Spicatum*	10-15	7-10
		Km 8 to Km 16	*Myriophylum Spicatum*	8-10	5-8
		Km 16 to Km 29	*Myriophylum Spicatum*	8-12	5-10
		Km 29 to Km 39	*Myriophylum Spicatum*	12-15	8-10

Continue table (1): Infestation of Egyptian canals by different types of submersed weed before and after applying biological weed control during 2007/2008.

No.	District Name	Canal Name	Type of submersed weed	Infested Percentage (%)	
				Before application	**After application**
15	EL-Garbia	Meat yazeed	*Myriophylum Spicatum. Potamogetonnodosuspoir.*	3-7	4-6
		EL-Kased	*Myriophylum Spicatum*	7-10	6-8
		Bahr Shebeen	*Myriophylum Spicatum*	3-7	5-7
		EL-Malah	*Myriophylum Spicatum. Potamogetonnodosuspoir.*	7-50	10-30
		EL-sahel	*Myriophylum Spicatum. Potamogetonnodosuspoir.*	5-50	7-35
		Dalil EL-Kased	*Myriophylum Spicatum. Potamogetonnodosuspoir.*	5-10	4-7
		Kanattanta EL-Melahia	*Myriophylum Spicatum. Potamogetonnodosuspoir.*	5-50	10-30
16	West kafr EL-sheik	EL-kased	*Myriophylum Spicatum*	20-40	7-20
		Royena		5-10	5-6
		Bahr Nashart		3-10	3-7
		EL-kadabe		10-15	8-12
		EL-Manifa		40-50	10-35
		Bahr EL-seidy		5-10	2-7
		EL-Rashedia		4-10	3-5
17	Zefta	Bahr shebeen	*Myriophylum Spicatum*	5-30	5-12
		Dalel EL-Atf		25-45	15-20
		Meet Bara		2-5	2-5
		EL-Rayah EL-Abasy		3-5	5-7
18	EL-Nobaria	EL-Nobaria	*Myriophylum Spicatum. Potamogetonnodosuspoir.*	10-20	10-15
		EL-Hager	*Myriophylum Spicatum. Potamogetonnodosuspoir.*	30-40	25-30
		Ferhash	*Myriophylum Spicatum. Potamogetonnodosuspoir.*	25-35	20-30
19	Behera	EL-Mahmodia	*Myriophylum Spicatum*	5-45	5-10
		EL-Kanobia		5-10	5-7
		Sahel Morkos		5-8	5-8
		EL-Kenawia		5-8	3-5
20	West Behira	EL-Kandk EL-sharky	*Myriophylum Spicatum*	7-20	7-13
		Sahel Morkos	*Myriophylum Spicatum*	5-12	3-8
		Dalel EL-entelak canal	*Myriophylum Spicatum*	15-40	10-25
		Fara 6 EL-Tahrer	*Myriophylum Spicatum Najasarmata Lindb f.*	30-50	20-35
		Dalel EL-Tahady Canal	*Myriophylum Spicatum*	10-15	8-12

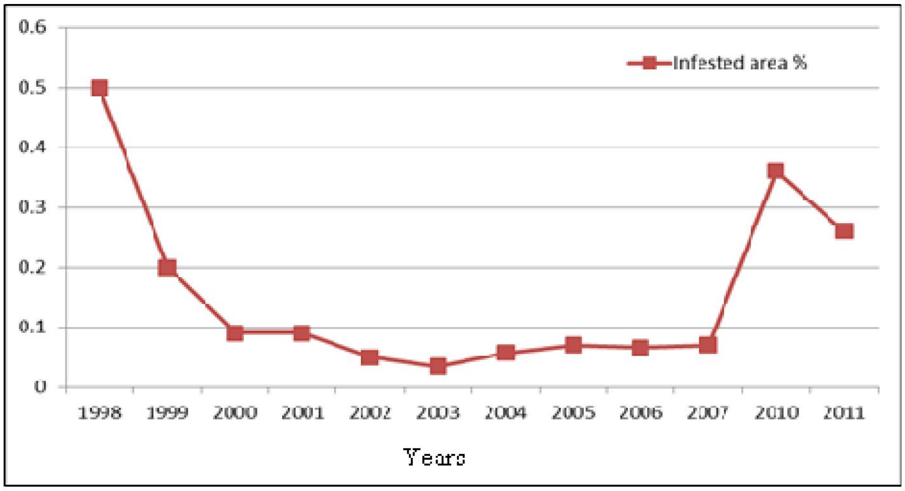

Figure (2): Percentage of infesting submerged weeds (%) during different years

4- Criteria for selection of maintenance methods

1. Type of weeds to be controlled
   - weed habit
   - general control or targeted at certain species
2. Resources required
   - labor
   - equipment
   - maintenance facilities
   - fuel and spare parts
   - operator skills
   - biological agents
3. Access to channels
   - service roads, on one banks, for foot/ tracked/wheeled machine
4. Operational requirements
   - draining of channel before maintenance
   - time restrictions on maintenance activities
5. Environmental impacts
   - Water quality
   - operators' health
   - public health
   - short /long term impacts
6. Period of effectiveness of control method
7. Estimated output /productivity of control method
8. Compatibility of control method with other maintenance activities
9. Costs
   - Capital/recurrent
   - Life cycle/equivalent annual costs
   - Foreign /local currency
   - Finance available

5- Benefits of weed control

There are numerous benefits that are derived from an effective weed control programme. These are as follows:

- Reduction in quantity of water used.
- Increased agricultural production due to quantity of water delivered and reliability of delivery.
- Less cost of maintenance of irrigation system due to absence of weeds.
- Reduced threat to human health.
- Remove non-indigenous plants and restore a diverse community of desirable native plant species.
- The best method to control aquatic plants is prevention.

6- Conclusion and recommendation

Growth of aquatic weeds in waterways causes many serious problems. These weeds should be managed and controlled to a minimum acceptable level depending on the available yearly data about surveying, monitoring, and classification of the different types of aquatic weeds infesting the waterways. It can be concluded that the following:-

- It is possible to use manual weed control method in channels with maximum bed width of 2 m, and this method employs labor and consequently contributes in solving the existing unemployment problem.
- It is being found necessary to control aquatic weeds in Egypt. At present, mechanical removal is the most popular control method, but this provides only temporary relief and is expensive. Other control methods, such as manual control, physical control and biological control, have generally been neglected because of public opinion. We should select an effective management system which makes minimal environmental impact by reducing the unwanted effects.
- The mechanical weed control, using the mowing buckets is an efficient method, as it prevents any further expansion and deepening of the water channels resulting from the use of the traditional excavation buckets.

- Biological weed control method is effective in water channels with bed width of more than 2 m, which are deep enough to allow for continuous water flow and considered as one of the most environmentally sound methods, as it provides the inhabitation with the necessary protein.
- Grass carp have to be stocked with density not less than 100 kg/ha for average grass weight ranged from 10 to 20 gm. to obtain the acceptable result.
- In order to remove the aquatic weeds, the mowing system is given higher priority to excavating methods in Egypt, and the contracts should include the use of such a system.
- Increasing the number of grass carp breeding stations to cover all the district requirements.
- In order to implement integrated weed control methods, monthly and yearly plans should be formulated, in addition to data base system.
- Accordingly, aquatic weed management systems must be developed which are socially and environmentally acceptable. In addition, freshwater systems are now being viewed as a public amenity and recreational area which should be in harmony with the environment. It should be noted that no single method will guarantee the success of aquatic weed management. The combined use of several appropriate methods, including utilization of weeds as are source, is often the best way of protecting the quality of the environment.

In opinion of the authors, more basic research, to give us a better understanding of the biological, ecological, physiological and economical aspects of aquatic weeds, is needed for developing more effective ways of managing aquatic weeds.

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