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Water hyacinth, *Eichhornia crassipes:* A case of successful Biological Control in Lakes Kyoga and Victoria - Uganda

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Abstract

Water hyacinth, Eichhornia crassipes, a world known water -weed was until lately serious a problem in Uganda and indeed the entire East African region. The weed caused serious socio-economic impact on the livelihood of Ugandans. Attempts were made to control the weed through an integrated approach including two biological control weevils, Neochetina bruchi and N. eichhorniae that were integrated in the control effort. Five years after their introduction, the weevils successfully reduced the biomass of the weed to an insignificant problem and life is back to normal in and along the formerly heavily affected lakes, Victoria, Albert and Kyoga. The significance of this operation is discussed

Keywords: Water hyacinth, biological control, Neochetina bruchi, Neochetina eichhorniae, Lake Victoria and Lake Kyoga.

Introduction

Water hyacinth, Eichhornia crassipes (Liliales: Pontederiaceae) is an aquatic weed of South American origin native to the Amazon River basin in Brazil. It has been described as the world's worst aquatic weed because of its negative impact on the livelihood of man. It occurs within the tropical and sub tropical regions of the world that lie between 40°N and 45°S (Holms et al 1977).

Water hyacinth is a difficult weed to control and therefore it is virtually impossible to eradicate. Its recalcitrance is based on the ability to double its biomass within a fortnight under favourable conditions; and to produce seeds that sink and remain viable at the bottom of a water body for more that ten years. The weed is believed to have first appeared in East Africa in the 1930s. In Uganda, the first fringes of the weed were sighted in the Kyoga lakes in 1987 (Twongo, pers. Comm.). It spread to other water bodies including Lakes Victoria, Albert and the Albert Nile River complex. It is believed that the weed invasion of the East African region originated from the highlands of Rwanda via the Kagera river basin.

The rapid spread and colonisation of the water bodies in Uganda appears to be man aided(Ogwang and Molo, 1997).

The detrimental effects of water hyacinth on the socio economic activities of affected countries are documented in literature (Gopalkrishnan and Joy, 1997). In Uganda the greatest impact documented was on reduced industrial power supply, impediments to water transport, reduced fish catches, and increased cost of water purification (National Water and Sewerage Corporation, 1997,cited by Nkuba, 1997).

The design of water hyacinth control strategies ideally depends on the magnitude of the problem that is, area and economic significance of affected water body, cost, efficiency and safety of control options. Ideally, mechanical removers, herbicides and biological control agents should be used in an integrated manner. This article outlines experiences of Uganda in the use of mechanical and biological control methods to contain the water hyacinths in the water bodies in the country.

Material and Methods

The control methods tested included mechanical and biological control options. This started with lauching of and deployment of harvestors at strategic landing sites in 1991 by the Ministry of Agriculture Animal Industry and Fisheries (MAAIF). This was followed by introduction of biological agents. In 1992, the National Task Force on water hyacinth control recommended the importation of two species of weevils, *Neochetina bruchi* and *Neochetina eichhorniae* from the International Institute of Tropical Agriculture (IITA) based in the Republic of Benin – West Africa. In order to ensure that the weevil was not harmful to other crops a survival tests were conducted at Namulonge Agricultural and Animal Production Research Institute (NAARI).The weevil was reared on bananas, rice, onions, and Irish potato. Damage, oviposition and survival counts of adult weevils were recorded. These weevils were multiplied and released in water hyacinth infested parts with initial releases in Lakes Kyoga in 1992 and Victoria 1995 (Table 2 and3.). Other rearing units were established at various points along the shores of lakes Victoria and Kyoga. The rearing facilities were set up following original method developed by the Commonwealth Science and Industrial Research Organisation (CSIRO), Australia. Each rearing facility consists of two metallic containers with 2000 litre capacity enclosed by chain link wires to keep of stray animals and curious local populace. For lake Victoria, the weevil rearing facilities have been set up at Katosi (Mukono), Masese (Jinja), Wakawaka (Bugiri), Lwanika (Iganga), Majanji (Busia), Lake Wamala (Mubende) and Kasensero (at the mouth of river Kagera in Rakai). Along the shores of Lake Kyoga, the rearing facilities are located at Namasale (Lira), Kayeyi (Apach) and Bukungu (Kamuli). Fisheries extension staff and local fishermen from these districts were trained and integrated in the release of the weevils and were instrumental in the fast distribution of the initial weevil population in our water bodies. 3 months after introduction, the impact of the weevil was evident. During weevil impact assessment on the weed, various parameters were collected. At each impact study site, 6 samples were collected from an area enclosed within a $0.25m^2$ wooden quadrant tossed randomly in the weed mats. Data collected from the sample area included plant density (number of mature and young plants (ramets) and biomass (weight of mature plants). Weevil population was similarly estimated from 10 plants by counting feeding scars on the second young leaf of each plant using formula: Number of adult weevils = $0.0336 \times (\text{Average number of feeding scars})^{0.775}$. Additionally, weevil species composition was similarly estimated by collecting adult weevils from sample plants and sorting them out by species and sex using hand lens or more accurately in the laboratory under a dissecting microscope

Results

Use of Mechanical Control

The launching of mechanical removal of the water hyacinths was designed to attain a quick solution to the weed problem. Soon it was realised that this campaign had little or no effect on the colonisation of the water bodies by this weed. Physical removal of the weed failed partly because massive amounts of dense mats were blown ashore from deep-water areas in the lake that was not easily accessible to harvesting machines. The continued build up of water hyacinth mats therefore required other approaches. Uganda government consequently constituted a national task force on water hyacinth control in 1992 under leadership of the Director General of the National Agricultural Research Organisation (NARO). This body, which consisted of Ugandan experts in various scientific fields, was charged with advising the government on the best way to combat the weed. The task force recommended an integrated

Table 1 Life cycle and host specificity of Neochetina eichhorniae and N. bruchi on selected food crops in Uganda.

Test plants	Total feeding scars Per plant	Total eggs laid per plant	Total larvae per plant
Feeding and oviposition of Neochetina bruchi on selected caged test plants			
Bananas	0	0	0
Onions	0	0	0
Rice	0	0	0
Irish potato	0	0	0
Egg plants	0	0	0
Water hyacinth	938	1244	1211

Feeding and oviposition of *N. bruchi* on selected plants tissues in petri dishes			
Bananas	63	0	0
Onions	0	0	0
Rice	0	0	0
Irish potato	0	0	0
Egg plants	0	0	0
Water hyacinth	1838	288	288
Feeding and oviposition of *N. eichhorniae* on selected caged plants			
Bananas	0	0	0
Onions	0	0	0
Rice	0	0	0
Irish potato	0	0	0
Egg plants	0	0	0
	0	0	0
Water hyacinth	544	610	563
Feeding and oviposition of *N. eichhorniae* on selected plant tissues in petri dishes			
Bananas	0	0	0
Onions	0	0	0
Rice	0	0	0
Irish potato	0	0	0
Egg plants	0	0	0
Water hyacinth	544	610	563

approach using mechanical, biological control and pending conclusive tests, a possibility of using herbicides. The use of herbicides was deferred on the recommendation of the National Environmental Management Authority (NEMA).

Use of Biological Control agents as a an option of water hyacinth control in Uganda

Following the introduction of the weevils, tests were undertaken to ensure that the natural enemy of the hyacinths would not destroy food crops. No feeding scars and eggs were observed on banana, onions and rice; and no adult weevil survived on the crops. (Table 1).

After release, weevil population built up in L. Kyoga rapidly to an average of 17.4 weevil / plant while plant density declined by 80% (Tables 2 and 3). *N. eichhorniae* were found to be dominant in tall healthy plants while *N. bruchi* became the dominant species in the stunted plants. This is probably because *N. eichhorniae* takes a longer developmental period than *N. bruchi* hence requires tall healthy plants. Results from Lake Victoria indicate similar observation though the weevil population averaged 25 weevils /plant (Tables 4-6) during monitoring period reported

Table 2 Releases of *N. bruchi* and *N. eichhorniae* in Lake Kyoga (1993 – 1995)

Location	Date of release	Species	Eggs		Adults		
Kyangkole	**August '93**			**N.e***	**-**	**-**	**100**
	September 93	N.e	940		24		
Kambate	"	N.b	1852		-		
Kayago	"	N.b	5500		150		
Lenko	"	N.b	2500		100		
		3000			10		
Dagala	"	N.b	1200		150		
Kachanga	October '93	N.e	1500		-		

Zengebe	February '94	N.b	3100	150
Kyangkole	March '94	N.e	1000	28
		N.b.	2566	80
Kambatane	April '94	N.b	8940	293
		N.e	1770	200
Wansolo	May '94	N.b	2500	200
Kabanyolo pond	"	N.b	2360	100
Kitwe	June '94	N.b	18400	650
Naluboyo	"	N.e	2500	250
Kajansi pond	"	N.b	5000	200
Kayeyi	August '94	N.b	2700	1650
	"	N.e	300	400
Kasambya	November '94	N.b	12500	150
Kigwera	"	N.e	2500	150
Bukungu	January '95	N.b	14250	200
		N.e	750	100
Kasambya	February'95	N.b	11390	100

Table 3 Releases of *N. bruchi* and *N.eichhorniae* in Lake Victoria (1994 - 1997)

Location	Date of release	Species	Eggs	Adults
Kajjansi pond	June 94	*N.bruchi*	-	200
		N.eichhorniae	-	150
Kaatosi	June 96	*N.bruchi*	-	3050
		N.eichhorniae	-	2660
Buluba (Thruston Bay)	December 95	*N.bruchi*	-	2560
Masese	December 96	*N.bruchi*	-	3190
		N.eichhorniae	-	1788
Kabasese	March 97	*N.bruchi*	-	2553
		N.eichhorniae	-	1650
Kachanga	March 97	*N.bruchi*	-	3800
		N.eichhorniae	-	1000

Table. 6. Mean weevil population/ 10 plants in 5 locations in L. Kyoga 1996/97

Location	No. of weevils/plant (1996)	No. of weevils/plant (1997)
Dagala	3.75	8.43
Mayinja	3.15	10.79
Kibuye	8.30	16.79
Kasenyi	9.10	16.80
Kayeyi	5.72	17.84

Table. 7. Mean weevil population/10 plants in 4 locations in L. Victoria 1997/98

Location	No. of weevils/plant (1997)	No. of weevils / plant (1998)
Thruston Bay	21.3	23.71
Lwanika	18.9	25.17
Wakawaka	17.6	21.03
Bugoto	15.8	16.07

Table. 8. Mean number of weevil species/plant in L. Kyoga and L. Victoria 1997/98

Location	Species	
	Neochetina bruchi	***Neochetina eichhorniae***
Dagala (L. Kyoga)	10.31	6.11
Kasenyi (L. Kyoga)	13.21	3.14
Thruston bay (L.Victoria)	15.60	3.77
Lwanika (L.Victoria)	21.31	5.77
Wakawaka (L.Victoria)	17.73	6.23

Table. 9. Biomass of water hyacinth in L. Kyoga and L. Victoria

	Years			
	1995	1996	1997	1998
Location	**Mean kg/plant (fresh weight)**			
(L.Kyoga)				
Kibuye	2.3	1.5	0.8	0.5
Dagala	2.2	1.4	0.7	0.4
(L.Victoria)				
Thruston Bay	2.0	2.1	1.8	0.7
Lwanika	1.8	1.7	1.3	0.9
Wakawaka	2.2	2.0	1.9	1.2
Bugoto	2.8	2.7	2.0	1.6

Discussion

Weevil damage mechanism

Morphological damages by *Neochetina* weevils to water hyacinth that lead to death of the weed have been well presented by Julien et al (1999). Basically, both the adult and larval stages of the weevil cause the damages with combination of other minor but significant factors. The adult weevils feed by scraping the epidermis, leaving numerous wounds on the leaves. These open wounds become avenues for evapo-transpiration and entry points of opportunistic pathogens especially fungi. A combination of both causes wilting and rotting from infection by the opportunistic pathogens. The damaged plants become less vigorous as the ability to photosynthesise is greatly reduced. Adult female weevils lay eggs using ovipositors inserted inside petioles. The eggs then hatch into tiny larvae that burrow through the petioles. This leaf and petiole damage severely weaken the weevil-infested water hyacinth to an extent that root lengths become shorter, plant weight is reduced, plants become water logged and either sink or are crushed by waves.

Results from Lakes Kyoga and Victoria indicate that *Neochetina* weevils cause severe damages that lead to a drastic reduction of water hyacinth biomass. Severe weevil damage reduced water hyacinth leaf area, petiole length, root length and overall plant height and vigour. Observations also showed that heavily infested plants were unable to flower, which resulted into reduced seed production hence a reduction in seed deposition into the lake bed. Similarly, damaged plants became stunted and unable to produce daughter plants. In addition, dry damaged plants either sank or got swept down stream by water current. A combination of these factors resulted in a rapid reduction of the weed hence L. Kyoga and L. Victoria rapidly became clear of the weed.

The apparent rapid reduction of water hyacinth biomass in Uganda by the weevils could be attributed to three factors. Firstly, weather conditions especially the warm all year round temperatures that favour a shorter developmental period of the weevils. Earlier studies confirmed that both weevils' species complete their life cycles within a shorter period in Uganda compared to those in Argentina (Ogwang and Molo, 1997). Secondly, the integration of fishermen in the distribution of the weevils contributed to their rapid spread in lakes. Thirdly, wave actions appear to aid the destruction and sinking of the rotting weed while water gradient helped in the sweeping of the weeds downstream in Lake Kyoga. The heavily damaged plants become light in weight hence easier to remove using mechanical harvesters as demonstrated at the Owen Falls. This is clear evidence of an integrated control of water hyacinth.

The successful control of water hyacinth in Uganda has revamped a vigorous economic activity in the lakes with significant contribution to the overall economy of the country. For example, Uganda currently earns US$ 8,000,000 per month from fish export (Source: Dept of Fisheries-MAAIF, 2001). Fishing has become easier with improved hygiene at landing sites. Similarly, Uganda Electricity Board saves 85 million shillings per month-formerly lost due to clogged turbines while industrial output has improved because of reduced rate of power cuts formerly attributed to the weed.

The apparent 'resurgence' of water hyacinth in Lakes Victoria and Kyoga

Three months after the initial release, impact studies were initiated on L. Kyoga and L. Victoria. Results after 5 years showed that the weed biomass (plant weight and density) were reduced by nearly 80 % in both Lakes Victoria and Kyoga. However, massive mats of water hyacinth were observed being emptied into the western part of Lake Victoria from Rwanda highlands via river Kagera. Weevil rearing and release program were initiated therefore, in Rwanda and Burundi to curb influx of fresh weeds via Kagera river. There is anxiety among the local populace about the previous experience with the weed. However, plantlets of hyacinths have persisted on the fringes of Lake Victoria, arising from seeds deposited from the mats. These plants grow in an atmosphere rich in nutrients but with few or no weevil population.

Biological control of water hyacinth using the two types of weevils, *N. eichhorniae* and *N. bruchi* was the major option used to control water hyacinth in Lake Victoria during the second half of the 1990s. However, when the weed biomass crushed, the weevils, which are solely dependent of water hyacinth for both food and reproduction, crushed in population.

The functioning of the biological control mechanism of the weed or any other pest is dependent on the natural population regulation mechanism. Hence when there was massive biomass of water hyacinth, the weevil population similarly increased rapidly contributing to the reduction of the weed to uneconomically damaging level in 1997 –98. In a situation where there is resurgence, the weevil population builds up slowly and soon catches up with the weed biomass, which crushes once again. This cycle is repeated till an ecological balance between the weevil population and the weed is reached all conditions remaining constant.

Table 10. Mean weevil population density, species composition weed morphometrics at locations in Lake Victoria from October 2000 – January 2001.

Location	*District* (cm)	*No. of weevils* Per plant	*% N.b*	*% N.e*	*Plant wt.* (gm)	*Plant ht*
Port Bell	Kampala	8.34	12.6	87.4	496.5	47.6
Katosi	Mukono	9.79	14.6	85.9	482.3	55.4
Kirinya Bay	Jinja	3.47	16.1	63.9	647.8	53.5
Wanyange	Jinja	2.44	0	100	473.6	34.6

N.b = Neochetina bruchi
N.e = Neochetina eichhorniae

The cyclical phenomenon creates a possibility of weed resurgence. The current weed resurgence is aggravated by the fact that not only is the weed growing in a situation of few or no weevils, but also in a water environment enriched by the decomposing dead water hyacinth from the original crush in biomass. At a rapid pace in weed growth there is need for more releases in phenomenon called 'augmentation' to boost the few weevil population in the water bodies.

Recent surveys in both Lakes Victoria and Kyoga show that the weevil population is far below the minimum threshold of 10 weevils/ plant sufficient to cause a significant damage to the weed (Table 10 and 11).
Surveys carried in Moni, Kigoge and Zengebe in Lake Kyoga showed that most parts of the lake were covered

Table 11. Mean weevil population density, species composition weed morphometrics at locations in Lake Kyoga, january 2001.

Location	*District*	*No. of weevils Plant ht (gm)*	*% N.b Per plant*	*% N.*	*%N.e*	*Plant wt (gm)*
Moni	Nakasongola	1.7	0	100	363.3	33.6
Kikoge	Nakasongola	0	0	0	416.3	43.7
Moni	Nakasongola	1.7	0	100	363.3	33.6
Kikoge	Nakasongola	0	0	0	416.3	43.7
Zengebe	Nakasongola	1.5	0	100	483.7	51.4

N.b = Neochetina bruchi
N.e = Neochetina eichhorniae

with papyrus suds. There were pockets of water hyacinth almost devoid of weevil feeding marks. Weevil population is affected by poor aeration of water hyacinth due to choking and poor water circulation. The weevils require healthy well-aerated root system to complete normal life cycle.

As noted earlier, weevil population is expected to build up as areas of the weed re-invasion centres expand into stationary fringes along the shoreline. There was little evidence of weevil presence in centres of the water 'hyacinth dormancy' as only few and old feeding marks were seen. Similarly, weevils appear not to have established in the riverine systems of Victoria – Nile and River Kagera.

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