Research Paper

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Invasive Alien Weeds of Water Hyacinth (*Eichhornia Crassipes*) in Tamil Nadu Irrigation System and the Impact of Herbicidal Control on Aquatic Environment

Agriculture

KEYWORDS : Fish mortality, Herbicides, Irrigability, Water hyacinth, Water quality, Histology

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ABSTRACT

In India almost 80 percent of the lakes are already infested with this weed. Even in Tamil nadu, very big tanks like, Chembarabakkam tank, Dusi-Mamandur tank, Kaveripakkam tank, Tamiraparani tanks and Veeranam tank etc., are also affected by this weed. The Veeranum Lake, it has been connected through 27 distributary channels form the major irrigation source that covers a large proportion of the rice tract of the state with a command area of 18,000 ha. Recent survey on the infestation of aquatic weeds in these channels indicated that many of these channels were infested heavily with water hyacinth. A research programme supported by Ministry of Water Resources, Government of India was taken up to study the impact of herbicides on the control of water hyacinth, to optimize their doses and time of application and to study their impact on aquatic environment, through a series of green house and watershed studies. Among the different herbicides tried viz., 2, 4-D Na salt, glyphosate and paraquat, glyphosate proved more efficient with higher magnitude of plant height reduction, weed mortality (cent percent) and reduction in bio-mass. The doses of 1.5 kg ha-1, 2.5 kg ha-1and 1.5 kg ha-1 were found to be optimum for glyphosate, 2, 4-D Na salt and paraquat, respectively. Different seasons did not vary in influencing the impact of herbicides on the weed. Glyphosate also caused least fish mortality of 23.30 per cent after 32 days. Different organs like gills, brain, liver and kidney of the fishes were studied for histopathology and the observations showed tissue distractions in glyphosate treated fish. In the watersheds also, glyphosate proved more efficient and safe on water quality in terms of pH, EC, DO, COD and mineral content, of treated water. The glyphosate treated water was also found to be safe for irrigating crops with 87, 58 and 62 per cent germination of paddy, cotton and ladysfinger.

INTRODUCTION

The free-floating aquatic weed water hyacinth *Eichhornia crassipes* [Mart.] Solms-laubach is considered to be the world's worst aquatic weed. In India almost 80 % of the 39000 tanks are already infested with this weed. Even very big lake such as Chembarabakkam, Dusi-Mamandur, Kaveripakkam, Tamiraparani and Veeranam Lake Etc., are also affected by this weed (Deivasigamani, 2013). The lake Veeranum in Tamilnadu, a constituent southern state of India and its distributaries form the major irrigation source that covers a large proportion of the rice tract of the state with a command area of 18,000 ha connected through 27 distributary channels, and recent days have been heavily infested with water hyacinth (Kathiresan, 2012). It is believed to occupy over 0.2m ha of water surface in India (Murugesan *et al.,* 2005). Excessive infestations of the weed deleteriously affect water traffic, fishing potential, infrastructure for pumping, hydro electricity generation, water use and biodiversity, other damages include water loss due to evapotranspiration which is 1.02 to 9.8 times higher than evaporation from an open surface (Singh and Gill, 1996). *E. crassipes* also affects the water quality by reducing water temperature, pH, bicarbonate, content, DO and increasing BOD, free carbonate and nutrient level that ultimately makes water unfit for livestock and human use (Deivasigamani and Kathiresan, 2013). Based on the above facts, several mechanical, chemical and biological methods have been used to control this alien weed. Frequent mechanical removal of this weed is highly expensive, laborious and time consuming process. Biological control require a minimum of several years, usually 3 to 5 years, for insect population to increase to density that could bring down the weed stand to a substantial decline (Harley *et al.,*1996; Kathiresan, 2000). Chemical control using weed killers such as 2, 4-D Na salt, glyphosate and paraquat seems to be effective and fast acting.

MATERIALS AND METHODS

The studies were conducted at the Department of Agronomy, Faculty of Agriculture, Annamalai University during 2010-11, to screen different herbicides for managing water hyacinth and to trace their impact on non-target flora and fauna. These studies comprised a series of green house, pond experiments and laboratory studies. Screening of different herbicides was taken up in cement pots of dimension 2' x 2.5' x 2' with water filled up to three fourth of the pot's height, holding five water hyacinth plants. Graded doses *viz.* 1.25, 1.5 and 1.75 kg ha^{-1} of 2, 4-D Na salt, 2, 2.5 and 3 kg ha^{-1} of glyphosate and 1.25, 1.5 and 1.75 kg ha^{-1} of paraquat were compared. These herbicides were sprayed using a spray fluid of 500 *l* ha^{-1} of water, using knapsack sprayer fitted with flood jet deflector nozzle and 12 *lb* $inch^{-2}$ of pressure. After standardizing the dose, different time of application *viz.* month of May, August and November were also compared. Based on the results of these green house experiments, a pond experiment was conducted. A farm pond located in the university premises of dimension 70 m x 10 m with a water depth of 1.5 m was divided into four compartments using polyethene sheets stretched and nailed at the ends and middle to bamboo poles. Each compartment was accommodating water hyacinth subjected to treatments *viz.* untreated control, 2, 4-D Na salt 1.5 kg ha^{-1}, glyphosate 2.5 kg ha^{-1} and paraquat 1.5 kg ha^{-1}. All the green house and pond experiments were laid out in RBD (Randomized Block Design) with four replications and observed for reduction in plant height, biomass, reduction in chlorophyll content and mortality percentage. The studies on non-target flora and fauna comprised laboratory studies for comparing the effect of treated water obtained from the pond studies on seed germination percentage of paddy, cotton and ladysfinger. Further, the fishes *viz.* Common carp, Mrigal and Rohu were compared for their response to treatment with 2, 4-D Na salt 1.5 kg ha^{-1}, glyphosate 2.5 kg ha^{-1}, paraquat 1.5 kg ha^{-1} and untreated control in the presence of water hyacinth, in cement pots as tried for screening herbicides. The tissues of gills, brain, liver and kidneys from the fishes in these treatments were fixed in neutral buffered formalin 10% dehydrated in ascending grades of ethanol, embedded in soft paraffin, sectioned at 5 nm thickness and stained with Hematoxylin and Eosin (H&E) for comparison. The water quality in terms of pH, EC, dissolved oxygen and chemical oxygen demand, were observed at 15 days interval. Mortality percentage of the weed, was calculated using following formula,The fish mortality

$$\left[\text{Mortality of } E.crassipes\ (\%) = \frac{\text{No.of plant died tank}^{-1}}{\text{Total No.of plant stocked tank}^{-1}} \text{X100}\right]$$

was calculated on 32 DAS using the formula.

$$\text{Mortality of fishes } (\%) = \frac{\text{No.of fishes died tank}^{-1}}{\text{Total No.of fishes stocked tank}^{-1}} \text{X100}$$

The experimental data were statistically analyzed using the

methods described by Panes and Sukhatme (1978). After subjecting the data to analysis of variance, least significant difference was worked out a 0.05 per cent probability level. The data on percentage values were transformed by angular transformation before analysis.

RESULTS AND DISCUSSION

Pot culture experiments

Herbicide effect on weeds

Among the different doses tried, the highest doses *viz*. 1.75 kg ha^{-1} of 2, 4-D Na salt, 3.0 kg ha^{-1} of glyphosate and 1.75 kg ha^{-1} of paraquat recorded the least plant height and biomass on 50 DAS and highest mortality of the weed on 35 DAS and highest reduction in chlorophyll content on 28 DAS (Table 1).

Among the different seasons compared for application of these herbicides *viz*., May, August and November, no significant difference was observed the biomass and mortality percent of weed. Based on the observations it could be inferred that these herbicides can be sprayed during any part of the year, regardless of the seasonal variation (Table 2).

Among the herbicides tested, glyphosate was observed to be more efficient in suppressing the growth of the weed plant by virtue of reducing plant height, biomass and mortality percentage. This is because of the efficient absorption and translocation to all the parts of the plant in addition to the effective interruption of biosynthesis of essential amino acids through EPSP synthase activity. Though 2, 4-D Na salt also happens to be a translocated herbicide, the comparatively less efficiency performance is due to comparatively slower process of interruption of protein synthetic mechanism and the ability of water hyacinth to regenerative compensatory growth from vegetative propagules from runners and smaller plant lets. Paraquat, though very effective in tissue disruption by virtue of free radical and superoxide activity and inhibition of photosystem-I, with the activity being mainly contact and restricted to plant parts of exposure, failed to compare with glyphosate (Kannan and Kathiresan, 2002).

Pond experiment

Among the herbicides tested, glyphosate showed highest reduction in biomass with a biomass of 5.0g $plant^{-1}$ at 50 DAS which was followed by paraquat and 2, 4-D Na salt. Untreated control showed the highest biomass of 162.40g. The glyphosate application caused highest mortality percentage of 87.80 at 21 DAS. However all the herbicides exerted 100 per cent mortality on 35 DAS (Figure 1).

Effect of treated water on crops and fishes

Considering the impact of herbicide treated water on the germination of crops also, glyphosate appeared to be safe, recording germination percentages comparable with untreated control, while that of paraquat and 2, 4-D Na salt treated water were slightly inhibitory, recording significantly lesser germination percentages. Similarly, all the fishes *viz*., Common carp, Mrigal and Rohu suffered mortality when subjected to treatment with weed and herbicidal spray. But glyphosate proved comparatively safe, with significantly lesser fish mortality. The treatment with weeds without any herbicidal treatment was also lethal to fishes, recording fish mortality of 27.30 per cent, which is significantly higher than treating the weed with glyphosate (that has shown significantly lesser fish mortality of 26.57 per cent). Similar results were obtained by Kannan and Kathiresan (2002) and Varshney *et al.* (2008). Fishes in water free from water hyacinth as well as any herbicide treatment alone showed no mortality percentage (Table 3).

Herbicides effect on water quality

Chemical Oxygen Demand (COD), the amount of oxygen required to oxidise all oxidisable substrate present in the water is used as a typical measure of contamination. In all herbicide treated system, COD was significantly higher over control and this shows the presence of oxidisable organic matter by virtue of dying and decaying plant (Table 4). The 2, 4-D Na salt application caused highest COD of 38 and 59 ppm at 15 and 30 DAS followed by paraquat and glyphosate. The dissolved oxygen, an estimate of oxygen as dissolved in water implies its supportive ability to organism living in aquatic environment like fishes. The dissolved oxygen (DO) of untreated water was 7.82 and 7.20 ppm on 15 and 30 DAS, respectively. The DO content was declining significantly in all treatments of which 2, 4-D Na salt recorded the lowest of 6.89 and 5.02 ppm on 15 and 30 days after spray, respectively. This decline in dissolved oxygen was in agreement with a previous study by Kannan and Kathiresan (2002). The pH and electrical conductivity were also affected by the treatments. Glyphosate was observed to be safe, regarding the impact considering all these water quality characters.

Effect on histopathology study of fish organs

All the herbicides imparted tissue destruction in all the different types of organs compared. Regarding the gills, congestion of blood vessels in the primary lamellae and hyperplasia of branchial arch were some of the injuries suffered. Liver suffered vacuolization, focal necrosis and common lesion with different herbicides. Increased granular layer and swelling of pyramidal cells in the brain, degeneration in tubular epithelium and expanded renal tubules of the kidney are also observed with herbicide treatments (Figure 2, 3, 4 & 5). Similar results were obtained by Kathiresan and Ramah (2000); Bharat *et al.* (2011) and Reza *et al.* (2011).

Conclusion

Herbicides like 2, 4-D Na salt, glyphosate and paraquat offer rapid and efficient control of water hyacinth and their weed control efficiency is unaltered by the differing seasons. The treated water is safe for crops. The water quality remain altered in terms of DO and COD, where as no significant difference was observed in other characters. Fishes were shown to suffer mortality and tissue damage by the herbicides. Among the herbicides tested, glyphosate caused the mild congestions on gills, brain, liver and kidney tissues. It was confirmed by histopathology of the organs examined. Fish mortality also found to be least with the mortality percentage of 23.0, 16.0 and 20.0 on common carp, mrigal and rohu at 32DAS, respectively.

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Table. 1 Effect of different doses of herbicides sprayed on plant height (cm), biomass (g), morality percentage and chlorophyll content of *E. crassipes*

Treatments	Plant height (cm) 50 DAS	Biomass (g) 50 DAS	Mortality (%) 35 DAS	Reduction in chlorophyll content (%) 28 DAS
2, 4-D Na salt				
Control (Unsprayed check)	43.50	283.51	0.01 (0.00)	0.00
2, 4-D Na salt @ 1.25 kg ha^{-1}	4.0	16.31	60.0 (75.10)	94.22
2, 4-D Na salt @ 1.50 kg ha^{-1}	3.2	14.30	76.1 (94.25)	94.73
2, 4-D Na salt @ 1.75 kg ha^{-1}	3.0	13.41	77.0 (95.00)	96.44
S.E$_D$ CD(p=0.05)	0.10 0.20	0.89 0.90	0.37 0.75	
Glyphosate				
Control (Unsprayed check)	43.50	283.51	0.01 (0.00)	0.00
Glyphosate@ 2.0 kg ha^{-1}	3.5	25.91	51.3 (61.0)	95.40
Glyphosate@ 2.50 kg ha^{-1}	2.2	23.87	76.2 (95.0)	95.61
Glyphosate@ 3.0 kg ha^{-1}	1.0	19.93	90.0 (100.0)	97.48
S.E$_D$ CD(p=0.05)	0.60 1.20	0.95 1.90	0.57 1.15	
Paraquat				
Control (Unsprayed check)	43.50	283.51	0.01 (0.00)	0.00
Paraquat @1.25kg ha^{-1}	3.8	20.10	54.8 (66.85)	94.98
Paraquat @1.50kg ha^{-1}	2.5	19.50	72.9 (90.25)	95.00
Paraquat @1.75kg ha^{-1}	1.5	15.70	74.1 (92.50)	95.56
S.E$_D$ CD(p=0.05)	0.50 1.00	1.90 3.80	0.60 1.20	

(Figures in parenthesis are original values)

Table. 2 Effect of time of application of selected herbicides on biomass (g) and mortality percentage (%) of *E. crassipes*

Treatment	Biomass (g)			Mortality (%)		
	Control (Unsprayed check)	2, 4-D Na salt @ 1.50 kg ha^{-1}	Glyphosate @ 2.50 kg ha^{-1}	Control (Unsprayed check)	2, 4-D Na salt @ 1.50 kg ha^{-1}	Glyphosate @ 2.50 kg ha^{-1}
Months	50DAS	50DAS	50DAS	35 DAS	35 DAS	35 DAS
MAY	281.56	12.75	8.21	0.01 (0.00)	75.60(93.80)	90.00(100.00)
AUGUST	282.41	10.21	6.27	0.01(0.00)	71.56(90.0)	90.00(100.00)
NOVEMBER	282.40	9.70	5.00	0.01(0.00)	75.20(93.50)	90.00(100.000
S.E$_D$ CD(p=0.05)	NS NS	NS NS	NS NS	NS NS	NS NS	NS NS

(*NS-Non-Significant)

Table. 3 Effect of herbicide treated water on germination percentage of crops and fish mortality percentage on 32 DAS

Treatments	Germination percentage			Mortality percentage of fish		
	Paddy (7 days) Irrigation after 24 hours	Cotton (7 days) Irrigation after 24 hours	Ladysfinger (7 days) Irrigation after 24 hours	Common carp	Mrigal	Rohu
Control (Unsprayed check)	95.00	65.00	70.00	-	-	-
2, 4-D Na salt @ 1.50 kg ha^{-1}	90.00	59.00	62.00	(46.00) 42.70	(33.33) 35.26	(25.00) 30.00
Glyphosate @ 2.50 kg ha^{-1}	93.00	63.00	67.00	(23.30) 28.86	(16.60) 24.05	(20.00) 26.57
Paraquat @1.50kg ha^{-1}	90.00	57.00	63.00	(42.00) 40.39	(50.66) 46.73	(25.00) 30.00
Fish alone	-	-	-	(0.00) 0.01	(0.00) 0.01	(0.00) 0.01

Control (Unsprayed check with E. crassipes + fish)	-	-	-	(14.50) 22.38	(50.00) 45.0	(21.70) 27.30
$S.E_D$	1.00	1.00	1.00	3.16	2.62	0.36
CD (p=0.05)	2.00	2.00	2.00	6.32	5.25	0.73

Figures in parenthesis are original values before angular transformation

Table.4 Effect of different herbicide spray on physicochemical parameters of water

Treatments	pH		COD (ppm)		Conductivity (milli mhos)		DO (mg/lit)	
	15 DAS	30 DAS	15 DAS	30 DAS	15 DAS	30 DAS	15 DAS	30 DAS
Control unsprayed check	7.01	6.94	32	43	11.5	11.1	7.82	7.20
2,4-D Na Salt@ 1.5 kg ha^{-1}	7.06	6.90	38	59	11.7	11.0	6.89	5.60
Glyphosate@ 2.5 kg ha^{-1}	7.12	6.89	36	49	11.9	10.9	7.02	6.32
Paraquat @.1.5 kg ha^{-1}	7.0	6.93	36	53	11.0	10.6	6.95	6.20
$S.E_D$	NS	NS	1.00	3.0	NS	NS	0.15	0.17
CD (P=0.05)	NS	NS	2.00	6.0	NS	NS	0.19	0.22

NS – Non Significant, COD: Chemical Oxygen Demand, DO: Dissolved oxygen

Figure 1. Effect of different Herbicide sprayed on biomass (g) and mortality percentage of E. crazies at pond experiment

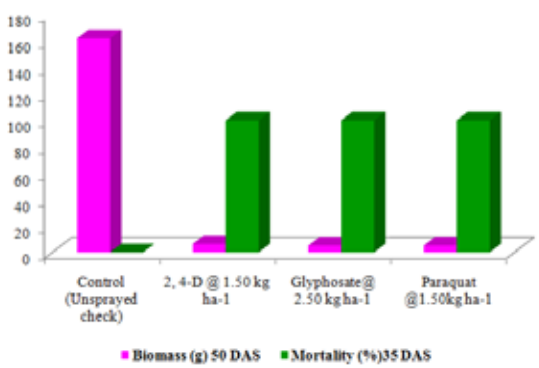
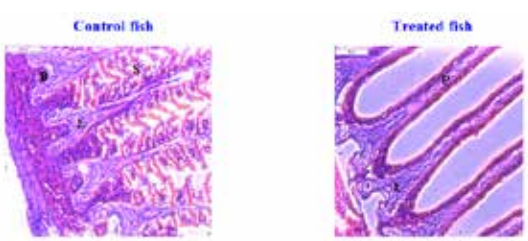
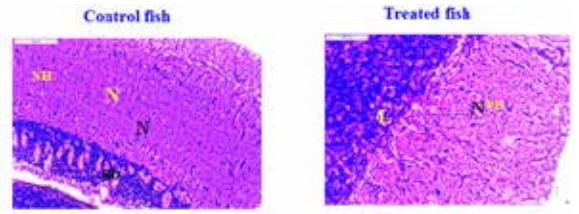


Figure 2. GILLS



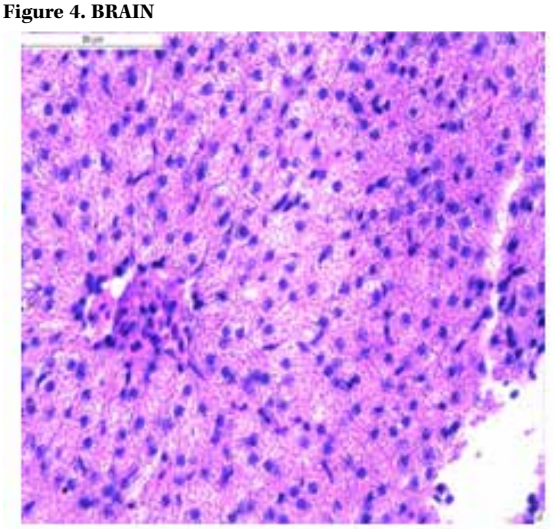
B-Basement membrane, E-Epithelium layer S-Secondary lamellae, P-Primary lamellae

Figure 3. LIVER



NH-Normal hepatocytes, BD- bile duct, N-nucleus, L-Leukocytes,
VH-vacuolization hepatocytes

Figure 4. BRAIN



N- Neuroglial cells

Figure 5. KIDNEY