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Research Paper

Herbicidal control of water hyacinth (*Eichhornia crassipes*) and its impact on aquatic environment

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ABSTRACT

A research programme was taken up to study the impact of herbicides on the control of water hyacinth [*Eichhornia crassipes* (Mart.) Solms-laubach], optimize dose and time of application, and to trace the impact on aquatic environment through a series of greenhouse and pond studies. The study was undertaken at Veeranum Lake which has a command area of 18,000 ha connected through 27 distributary channels, and infested heavily with water hyacinth. Among the different herbicides tried, viz. glyphosate, 2,4-D Na salt and paraquat, glyphosate proved more efficient with higher magnitude of plant height reduction, weed mortality and reduction in biomass compared with 2,4-D and paraquat. The optimum dose of glyphosate, 2,4-D Na salt and paraquat was 2.5 kg/ha, 1.5 kg/ha and 1.5 kg/ha respectively. Different seasons did not influence the efficacy of herbicides. Glyphosate caused least fish mortality of 23.3% after 32 days. Different organs like gills, brain, liver and kidney of the fishes were studied, for histology and the observations showed tissue distractions in herbicides- treated fish. Glyphosate also proved more efficient and safe on water quality in terms of pH, electrical conductivity, dissolved oxygen, chemical oxygen demand and mineral content of treated water. The glyphosate-treated water was found safe for irrigating crops with 87, 58 and 62% germination of rice, cotton and okra respectively.

Key words **:** Fish mortality, Herbicides, Histopathology, Irrigability, Water hyacinth, Water quality

Water hyacinth is considered to be the world's worst aquatic weed. The weed is believed to occupy over 0.2 m 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 1.02–9.8 times higher than evaporation from an open surface (Singh and Gill, 1996). Water hyacinth also affects the water quality by reducing water temperature, pH, bicarbonate content, dissolved oxygen and increasing biochemical oxygen demand, free carbonate and nutrient level that ultimately makes water unfit for livestock and human use (Deivasigamani and Kathiresan, 2013). Several mechanical, chemical and biological methods have been used to control this invasive alien weed. Frequent mechanical removal of this weed is highly expensive, laborious and time-consuming process. Biological control requires a minimum of 3–5 years for insect population to bring down the weed stand to a substantial decline (Harley *et al.,* 1996; Kathiresan, 2000). Chemical control using weed killers such as glyphosate, paraquat and 2,4-D Na salt seems to be effective and fast acting. Hence present study was undertaken at Veeranum Lake in Tamil Nadu having a command area of 18,000 ha connected through 27 distributary channels which are heavily infested with water hyacinth.

MATERIALS AND METHODS

The studies were conducted at the Department of Agronomy, Faculty of Agriculture, Annamalai University during 2010–13, to screen different herbicides for managing water hyacinth and evaluate its impact on non-target flora and fauna. These experiment comprised a series of greenhouse, pond trials and laboratory studies. Screening of different herbicides was taken up in cement pots of dimension 60 cm × 75 cm × 60 cm with water filled-up to three-fourths of the pot's height, each holding 6 water hyacinth plants. Graded doses, viz. 1.25, 1.5 and 1.75 kg/ha of 2,4-D Na salt, 2.0, 2.5 and 3 kg/ha of glyphosate, and 1.25, 1.5 and 1.75 kg/ha of paraquat were applied. These herbicides were sprayed using a spray fluid of 500 l/ha of water, using knapsack sprayer fitted with flood jet

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deflector nozzle and 12 lb/Inch^2 of pressure. After standardizing the dose, different time of application, viz. months of May, August and November, were also compared.

Based on the results of these greenhouse experiments, a pond trial was conducted. A farm pond located in the university premises (11° 24' N and 79° 41' E, 5.79 m from mean sea-level) of dimension 70 m × 10 m with a water depth of 1.5 m was divided into 4 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, glyphosate 2.5 kg/ha and paraquat 1.5 kg/ha.

All the greenhouse and pond trials were laid out in a randomized block design with 4 replications. Observations were recorded on plant height, biomass, chlorophyll content, and mortality percentage. Data on biomass reduction and mortality percentage are presented in this paper. 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 of rice, cotton and okra. Further, the fishes, viz. common carp, mrigal and rohu, were compared for their response to water treated with 2,4-D Na salt 1.5 kg/ha, glyphosate 2.5 kg/ha, paraquat 1.5 kg/ha 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 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, electrical conductivity, dissolved oxygen and chemical oxygen demand was measured at 15 days interval. Mortality of the weed was calculated using following formula:

$$\text{Mortality (\%)} = \frac{\text{No. of plants died/tank}}{\text{Total no. of plants stocked/tank}} \times 100$$

Fish mortality was calculated as follows:

$$\text{Mortality (\%)} = \frac{\text{No. of fishes died/tank}}{\text{Total no. of fishes stocked/tank}} \times 100$$

The experimental data were statistically analyzed following analysis of variance and least significant difference was worked out at 5% probability level.

RESULTS AND DISCUSSION

Pot culture trial

Effect of herbicides on weeds: Among the different doses tried, the highest dose of 1.75 kg/ha of 2,4-D Na salt, 3.0 kg/ha of glyphosate and 1.75 kg/ha of paraquat recorded the least biomass of water hyacinth at 50 days after sowing (DAS) and highest mortality at 35 DAS (Table 1).

Table 1. Effect of different doses of herbicides sprayed on biomass and morality of water hyacinth

Treatment	Biomass at 50 DAS (g/plant)	Mortality at 35 DAS (%)
2,4-D Na salt		
Control (unsprayed check)	283.5	0.01 (0.0)
2,4-D Na salt @ 1.25 kg/ha	16.3	60.0 (75.1)
2,4-D Na salt @ 1.50 kg/ha	14.3	76.1 (94.2)
2,4-D Na salt @ 1.75 kg/ha	13.4	77.0 (95.0)
SEm±	0.80	0.37
CD (P=0.05)	0.90	0.75
Glyphosate		
Control (unsprayed check)	283.5	0.01 (0.0)
Glyphosate @ 2.0 kg/ha	25.9	51.3 (61.0)
Glyphosate @ 2.50 kg/ha	23.8	76.2 (95.0)
Glyphosate @ 3.0 kg/ha	19.9	90.0 (100.0)
SEm±	0.95	0.57
CD (P=0.05)	1.90	1.15
Paraquat		
Control (unsprayed check)	283.5	0.01 (0.0)
Paraquat @1.25 kg/ha	20.1	54.8 (66.8)
Paraquat @1.50 kg/ha	19.5	72.9 (90.2)
Paraquat @1.75 kg/ha	15.7	74.1 (92.5)
SEm±	1.90	0.60
CD (P=0.05)	3.80	1.20

DAS, Days after sowing
Figures in parentheses are original values and those outside are angular transformations

Among the different seasons compared for application of these herbicides, no significant difference was observed among the months of application viz. May, August, November (Table 2). Based on the observations, it could be inferred that these herbicides can be sprayed during any part of the year, regardless of the season.

Among the herbicides tested, glyphosate was observed to be more efficient in suppressing the growth of water hyacinth by decreasing biomass and increasing mortality percentage. This was 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 (Waelder and Schmidt, 2000). Though 2,4-D Na salt is also a translocated herbicide, the lesser efficiency was probably due to comparatively slower process of interruption of protein synthetic mechanism and the ability of water hyacinth for a regenerative compensatory growth from vegetative propagules of runners and smaller plantlets. Paraquat is 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, but gave poor control compared with glyphosate (Kannan and Kathiresan, 2002). However, even at medium doses, all the 3 herbicides resulted in comparable control at later dates, and these were chosen for the pond experiment.

Pond trial

Among the herbicides tested, glyphosate (2.5 kg/ha) showed the highest reduction in biomass at 50 DAS, which was followed by paraquat and 2,4-D Na salt. Untreated control showed the highest biomass. Glyphosate application caused highest mortality at 21 DAS. However, all the herbicides exerted 100% mortality on 35 DAS (Fig. 1).

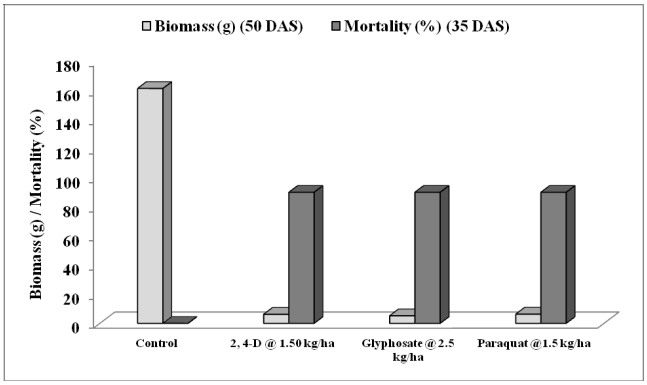

Fig. 1. Effect of different herbicides on biomass and mortality of water hyacinth in pond experiment

Effect of treated water on crops and fishes: Considering the impact of herbicide-treated water on the germination of crops, glyphosate appeared to be safe, recording germination percentages comparable with untreated control. However, paraquat and 2,4-D Na salt treated water showed significantly lesser germination. Similarly, all the fishes, viz. common carp, mrigal and rohu, suffered mortality when subjected to treatment with herbicidal spray. Glyphosate proved comparatively safe, with significantly less fish mortality. The treatment with weeds alone without any herbicide was also lethal to mrigal fish, recording fish mortality of 50.0%, which is significantly higher than treating the weed with glyphosate (that has shown significantly lesser fish mortality of 16.6%). Similar results were obtained by Kannan and Kathiresan (2002). This was due to decline in water quality imparted by the presence of water hyacinth. Fishes in water free from water hyacinth as well as any herbicide showed no mortality (Table 3).

Table 2. Effect of time of application of herbicides on biomass and mortality of water hyacinth

Month	Biomass at 50 DAS (g)			Mortality at 35 DAS (%)		
	Control	2,4-D Na salt @ 1.50 kg/ha	Glyphosate @ 2.50 kg/ha	Control	2,4-D Na salt @ 1.50 kg/ha	Glyphosate @ 2.50 kg/ha
May	281.5	12.75	8.21	0.01 (0.0)	75.6 (93.8)	90.0 (100.0)
August	282.4	10.21	6.27	0.01 (0.0)	71.5 (90.0)	90.0 (100.0)
November	282.4	9.70	5.00	0.01 (0.0)	75.2 (93.5)	90.0 (100.0)
SEm±	0.42	0.25	0.97	0.00	0.20	0.00
CD (P=0.05)	0.84	0.51	1.95	0.00	0.40	0.00

DAS, Days after sowing
Figures in parentheses are original values, and those outside are angular transformations

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

Treatment	Germination at 7 days (%)			Fish mortality at 32 DAS (%)		
	Rice	Cotton	*Okra*	Common carp	Mrigal	Rohu
Control	95.0	65.0	70.0	-	-	-
2,4-D Na salt @ 1.50 kg/ha	90.0	59.0	62.0	(46.0) 42.7	(33.3) 35.2	(25.0) 30.0
Glyphosate @ 2.50 kg/ha	93.0	63.0	67.0	(23.3) 28.8	(16.6) 24.0	(20.0) 26.5
Paraquat @1.50 kg/ha	90.0	57.0	63.0	(42.0) 40.3	(50.6) 46.7	(25.0) 30.0
Fish alone	-	-	-	(0.0) 0.01	(0.0) 0.01	(0.0) 0.01
Control	-	-	-	(14.5) 22.3	(50.0) 45.0	(21.7) 27.3
SEm±	1.0	1.0	1.0	3.16	2.62	0.36
CD (P=0.05)	2.0	2.0	2.0	6.32	5.25	0.73

DAS, Days after sowing
Figures in parentheses are original values, and those outside are angular transformations

Table 4. Effect of different herbicide spray on physico-chemical parameters of water

Treatment	*p*H		COD (ppm)		EC (dS/m)		DO (mg/lit)	
	15 DAS	30 DAS	15 DAS	30 DAS	15 DAS	30 DAS	15 DAS	30 DAS
Control	7.01	6.94	32	43	11.5	11.1	7.82	7.20
2,4-D Na salt @ 1.5 kg/ha	7.06	6.90	38	59	11.7	11.0	6.89	5.60
Glyphosate @ 2.5 kg/ha	7.12	6.89	36	49	11.9	10.9	7.02	6.32
Paraquat @ 1.5 kg/ha	7.0	6.93	36	53	11.0	10.6	6.95	6.20
SEm±	0.03	0.02	1.00	3.00	0.01	0.01	0.03	0.30
CD (P=0.05)	0.05	0.04	2.00	6.00	0.02	0.03	0.07	0.60

DAS, Days after sowing
COD, Chemical oxygen demand; DO, dissolved oxygen; EC, electrical conductivity

Effect on water quality: In all herbicide-treated systems, chemical oxygen demand was significantly higher than the control, indicating the presence of oxidisable organic matter by virtue of dying and decaying plant (Table 4). Application of 2,4-D Na salt caused the highest chemical oxygen demand of 38 and 59 ppm at 15 and 30 DAS followed by paraquat and glyphosate. Dissolved oxygen of untreated water was 7.82 and 7.20 ppm at 15 and 30 DAS, respectively. The dissolved oxygen content declined significantly in all treatments, of which 2,4-D Na salt recorded the lowest of 6.89 and 5.02 ppm at 15 and 30 days after spray respectively. This decline in dissolved oxygen was in agreement with Kannan and Kathiresan (2002). The pH and electrical conductivity were also affected by the treatments. Glyphosate was observed to be safe, as it showed little adverse impact on water quality parameters.

Effect on histopathology of fish organs: All the herbicides showed tissue destruction in different organs of fish. 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 were also observed with herbicidal treatments. Similar results were obtained by Kathiresan and Ramah (2000), Patnaik *et al*. (2011) and Reza Sayrafi *et al.* (2011).

It was concluded that herbicides like 2,4-D Na salt, glyphosate and paraquat offered rapid and efficient control of water hyacinth, and their efficiency was unaltered by the differing seasons. The water quality remained altered in terms of dissolved oxygen and chemical oxygen demand, and other characters. Fishes showed mortality and tissue damage by the herbicide. As no herbicide is registered for use in a waterbodies in India, it is essential to frame policies that would enable cautious use of safe herbicides for controlling water hyacinth in aquatic systems depending on the nature of water utility.

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