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Allelopathic Effects of Aqueous Extracts of *Alternanthera philoxeroides* (Mart.) Griseb on the Growth of *Eichhornia crassipes* (Mart.) Solms

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Abstract

Alternanthera philoxeroides (Mart.) Griseb (Alligator weed) and *Eichhornia crassipes* (Mart) Solms (Water hyacinth) are invasive species worldwide, generally affect native aquatic ecosystem. *E. crassipes* (water hyacinth) is found to be more aggressive invader than *A. philoxeroides.* To safeguard aquatic flora, fauna and to reduce invasive weeds it is suggested to use allelochemicals than chemicals. Investigations indicated that allelopathy potential of *A. philoxeroides* play an important role in suppressing water hyacinth at higher concentration. A study was conducted in year 2020-21 at AICRP-weed management, UAS, Bangalore, to investigate the allelopathic effect of aqueous extracts of *A. philoxeroides* plant parts on the growth *E. crassipes*. The results indicated that the spraying of allelochemicals present in the *A. philoxeroides* at lower concentration at the initial days after spray showed stimulatory effect likely due to the growth promoting effects of the nutrients present in the extracts. At higher concentration the allelo chemicals in different concentration in different plant part of *A. philoxeroides* had varying inhibitory effect on growth of water hyacinth. The inhibitory effect ranged from 2.09 to 78.13 per cent due to presence of allelochemicals in the form of phenolic compounds at different concentrations in different plant parts. The findings elucidate that there is mechanism of the biological invasion of *E. crassipes* by *A.philoxeroides*.

Keywords : Allelochemicals, *A. philoxeroides*, *E. crassipes,* Inhibitory effect, Stimulatory effect, Phenolic compound

Allelopathy in aquatic ecosystems plays an important role in establishing the composition of aquatic life (Gross, 2003), the competition between different aquatic plants vary because of their differential allelopathic potential (Abbas *et al*., 2014).

Biological invasion refers to the invasion of new environments by alien species from their original habitats through natural or artificial processes and resultant damage to the native ecosystem. Biological invasions can severely affect indigenous biological diversity, natural resources and even global ecosystem balance, as the invasive species are often more competitive than the native species. Invasive species exert negative impacts on environmental, economic, and social systems worldwide (Saccaggi *et al.,* 2016).

Alternanthera philoxeroides (Mart.) Griseb a perennial invasive aquatic plant, can rapidly outcompete indigenous species and occupy their aquatic or terrestrial niche to become the dominant species. Previous studies on *A. philoxeroides* have focused mainly on its biological characteristics and its apparent reviews and various studies have proved that phytochemicals released by *A. philoxeroides* aquatic weed known to have significant inhibitory influence on germination effect on field crops on mustard, rice and lettuce (Dhanapal & Ganeshaiah, 2000; Khanh *et al.*, 2007 and Mehmood *et al.,* 2014) respectively,

In recent years, aquatic weeds spread very rapidly and have reached alarming proportions in aquatic

ecosystems (Aloo, 2013). Allelopathy in aquatic ecosystems plays an important role. They also influence the competition between different aquatic plants because of their differential allelopathic potential (Abbas, 2015). One such illustration is *Eichhornia crassipes* (water hyacinth) and Alligator weed.

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms a perennial aquatic herb which belongs to the family Pontederiaceae, is a native of tropical America. It has been classified as one of the worst aquatic weeds in the world (Holm *et al.,* 1991). It is a floating perennial aquatic plant that most often colonizes fresh water aquatic habitats where water velocity is low. Water hyacinth is one of the fastest growing macrophytes in the world and it can profoundly change the ecosystems that it invades. The large, dense monoculture formed by this species covers lakes and rivers, blocking waterways and interfering with the water transport of agriculture products, tourism activities, water power and irrigation of agricultural fields. Dense mats of water hyacinth can lower dissolved oxygen levels in water bodies leading to reduction of aquatic fish production (Fu *et al.,* 2017).

The allelopathic potential of *A. philoxeroides* in its successful invasion of new area has been reported by Dhanapal & Ganeshaiah, 2000 and Mehmood *et al.,* 2014. It is hypothesized that *A. philoxeroides* may hamper the growth by releasing the water soluble allelochemicals. The objective of the study was to assess the phytotoxicity of *A. philoxeroides* on *E. crassipes.* With this background an experiment was conducted to study the competitive interaction between two invasive weeds: water hyacinth and *A. philoxeroides* with a progress that allelopathy concept could be used as a promising ecofriendly tool for managing water hyacinth.

Material and Methods

The experiment was taken up in the greenhouse experimental plots of department of Crop physiology in University of Agricultural Sciences, GKVK, Bengaluru during the year 2021. The station is located at an altitude of 924 m above mean sea level. The annual rainfall ranges from 528 mm to 1374.4 mm with the mean of 915.8 mm. The mean annual maximum temperature during 2021 was 27.4°C against 26.4°C of the normal.

To study the allelopathy effect of *A. philoxeroides on* growth and development of *E. crassipes,* pot experiment was conducted under greenhouse condition. Round shaped plastic pots with 51 cm diameter and height 27.2 cm filled with 38 lit. of water was used to conduct the experiment. The treatment encompasses different plant parts *viz.,* stem, leaf, root and whole plant aqueous extracts at different concentration at 5, 10, 20, 40 and 80 g L^{-1} (Table 1) including control. In collaboration with AICRP on Weed Management, UAS, GKVK, Bengaluru the experiment was designed in complete randomized design (CRD) comprising twenty-one treatments in three replications. The experimental data were statistically analysed using the methods described by Panes and Sukhatme (1978) after subjecting difference to analysis of variance. Least significant difference was worked out at 0.01 per cent probability level.

Plant Material Collection and Culture

Water Hyacinth : Water hyacinth plants were collected from Hebbal lake, Bengaluru. Plants of similar shape with long rhizome segment each having a bulb with at least one stolon were selected and washed several times using tap water. The 5 plant samples selected were placed in the pots where temperature in between 25-30°C. The experiment was conducted under greenhouse condition and total volume of water in each pot was kept constant by adding water to compensate for water loss through plant evapotranspiration. Water level in the pot was maintained by refilling them once in every 15 days, after recording the observations

Preparation of Extracts : Fresh plants of *A. philoxeroides* were collected from a Hebbal lake at Bengaluru. The plant samples were washed thoroughly three to four times with running tap water then finally with sterile water followed by shade drying at room temperature for 20 - 30 days and

The Mysore Journal of Agricultural Sciences

TABLE 1

Effect of *Alternanthera philoxeroides* on fresh weight (g) of *Eichhornea crassipes*

Treatments	Before spray	DAS		
		15	30	45
T_1 : Control	167.00	177.33	201.33	234.33
T_2 : Root extract @ 5 g L^{-1}	84.00	100.67	86.00	66.00
T_3 : Root extract @ 10 g L^{-1}	112.67	107.33	116.67	63.33
T_4 : Root extract @ 20 g L^{-1}	132.67	124.67	82.67	52.00
T_5 : Root extract @ 40 g L^{-1}	102.00	118.67	93.33	56.67
T_6 : Root extract @ 80 g L^{-1}	145.67	143.00	87.33	42.33
T_7 : Stem extract @ 5 g L^{-1}	126.33	120.67	108.67	64.33
T_8 : Stem extract @ 10 g L^{-1}	137.33	128.00	97.00	56.00
T_9 : Stem extract @ 20 g L^{-1}	113.67	110.00	94.00	60.67
T_{10} : Stem extract @ 40 g L^{-1}	122.67	118.00	109.33	55.33
T_{11} : Stem extract @ 80 g L^{-1}	120.00	131.33	93.67	34.33
T_{12} : Leaf extract @ 5 g L^{-1}	89.33	90.00	117.33	79.33
T_{13} : Leaf extract @ 10 g L^{-1}	140.67	105.00	85.00	57.67
T_{14} : Leaf extract @ 20 g L^{-1}	147.33	145.33	134.67	81.33
T_{15} : Leaf extract @ 40 g L^{-1}	109.67	111.67	105.67	55.33
T_{16} : Leaf extract @ 80 g L^{-1}	122.00	140.67	88.33	39.00
T_{17} : Whole plant extract @ 5 g L^{-1}	132.67	131.00	116.00	107.33
T_{18} : Whole plant extract @ 10 g L^{-1}	93.33	128.00	128.67	70.67
T_{19} : Whole plant extract @ 20 g L^{-1}	102.00	167.67	115.00	57.00
T_{20} : Whole plant extract @ 40 g L^{-1}	116.33	127.00	116.67	48.33
T_{21} : Whole plant extract @ 80 g L^{-1}	160.00	124.67	83.67	35.00
SE (M) ±	9.63	8.63	7.15	4.52
C.D. @ 5 %	36.75	32.93	27.27	17.25

powdered by using an electric blender and stored in airtight container. *A. philoxeroides* aliquots diluted with water of 5, 10, 20, 40, and 80 g L^{-1} are prepared was mixed with de-ionized water (1 L). The turbid solutions were placed on a shaker (250 rpm, 25ºC) for 24 h and the extracts were filtered by vacuum through qualitative filter paper using a Buchner funnel and stored at 4ºC until being used in the pot culture experiment. The observation taken are fresh weight (g/plant), stem length (cm), root length (cm), number of leaves and number of branches are taken in the interval of 15, 30 and 45 days after spray.

Results and Discussion

A. philoxeroides and water hyacinth is regarded as an execrable weed that is widely distributed in aquatic world. Earlier studies (Dhanpal & Ganeshaiah, 2000 and Kamala Bai *et al.,* 2021) revealed that allelopathy was recognized as one of the most important factors responsible for the successful interference by alien species (Huang *et al.,* 2017).

In the present study, the extracts of each plant part of *A. philoxeroides* had distinct effect on the stem length (cm), number of branches, number of leaves and fresh weight (g/plant) of water hyacinth (Table 1, 2 and fig 1 to 3). In the present study it was found that extracts of the different plant parts *viz.,* stem, leaf, root and whole plant part of *A. Philoxeroides* at higher concentration was responsible for invasion of water hyacinth.

The extracts concentration *A. philoxeroides* of stem at 5 to 20 g L^{-1} appeared to promote the growth of stem length (cm) of water hyacinth. Root extraction at 5 g L^{-1} had stimulatory effect on fresh weight, root length, stem length and number of leaves the concentration at 10 to 40 g L^{-1}. The leaf extracts at 80 g L^{-1} had stimulator effect on water hyacinth. Whole plant extracts at 10 to 40 g L^{-1} had growth promoting effect on fresh weight, root length and number of leaves. The stimulatory effect was prominent till 15 days after spray (DAS). The extracts of all the plant part of *philoxeroides* at higher concentration after 15 DAS had inhibitory effect on water hyacinth.

TABLE 2

Effect of *Alternanthera philoxeroides* on stem length (cm) of *Eichhornea crassipes*

Treatments	Before spray	DAS (Days after spray)		
		15	30	45
T_1 : Control	17.47	18.20	24.97	25.33
T_2 : Root extract @ 5 g L-1	17.03	17.27	17.30	14.57
T_3 : Root extract @ 10 g L-1	18.17	16.97	17.97	15.70
T_4 : Root extract @ 20 g L-1	20.17	18.40	18.13	13.73
T_5 : Root extract @ 40 g L-1	16.63	17.03	16.40	13.10
T_6 : Root extract @ 80 g L-1	17.13	17.43	15.50	12.13
T_7 : Stem extract @ 5 g L-1	16.07	17.03	17.77	15.60
T_8 : Stem extract @ 10 g L-1	15.43	17.60	14.67	13.77
T_9 : Stem extract @ 20 g L-1	17.37	18.73	16.10	14.17
T_{10} : Stem extract @ 40 g L-1	16.47	18.00	17.77	12.90
T_{11} : Stem extract @ 80 g L-1	17.80	17.43	15.87	11.73
T_{12} : Leaf extract @ 5 g L-1	18.07	17.90	15.90	13.53
T_{13} : Leaf extract @ 10 g L-1	20.20	18.33	16.60	13.83
T_{14} : Leaf extract @ 20 g L-1	20.53	21.70	16.47	13.80
T_{15} : Leaf extract @ 40 g L-1	22.97	20.17	16.67	14.53
T_{16} : Leaf extract @ 80 g L-1	19.83	20.23	15.63	12.00
T_{17} : Whole plant extract @ 5 g L-1	20.17	20.73	16.73	14.37
T_{18} : Whole plant extract @ 10 g L-1	19.26	20.77	17.67	12.00
T_{19} : Whole plant extract @ 20 g L-1	17.36	19.37	16.30	12.53
T_{20} : Whole plant extract @ 40 g L-1	20.5	20.00	17.30	14.20
T_{21} : Whole plant extract @ 80 g L-1	21.26	18.87	14.07	10.27
SE (M) ±	0.97	0.93	0.80	0.43
C.D. @ 5 %	3.71	3.56	3.04	1.66

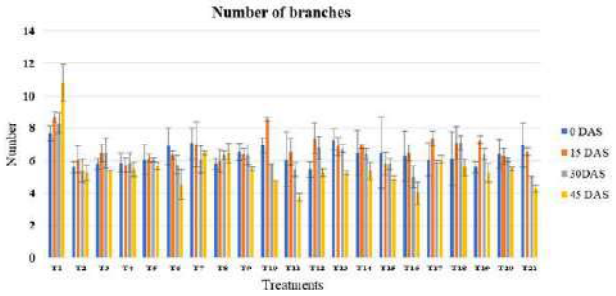

Fig. 1 : Effect of *Alternanthera philoxeroides* on number of branches of *Eichhornea crassipes*

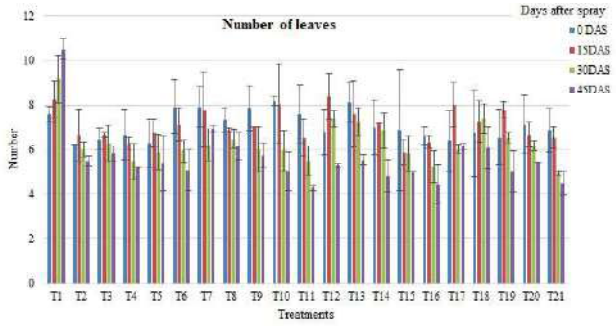

Fig. 2 : Effect of *Alternanthera philoxeroides* on number of leaves of *Eichhornea crassipes*

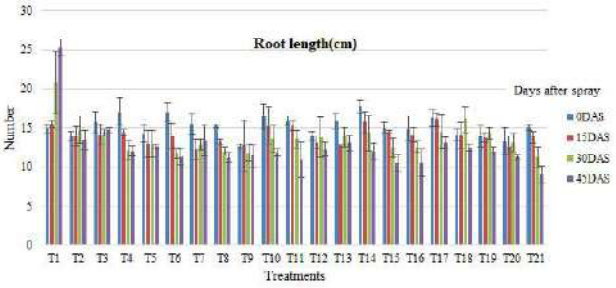

Fig. 3 : Effect of *Alternanthera philoxeroides* on root length (cm) of *Eichhornea crassipes*

In the study, low concentration of *A. philoxeroides* plant part extracts at initial days after spray promoted the growth of water hyacinth, possible due to the growth promoting effects of the nutrients present in the extracts counteracting any damage of the water hyacinth.

Data shows that suppressive affect was more severe at higher concentration of all the plant part extracts (Table 3). The per cent inhibition of root extracts varied from 3.59 to 70.9 per cent, stem (2.09 to 71.39%), Leaves (3.66 to 68.03%) and whole plant (4.17 to 78.13%), under increasing concentration of plant part extracts, the growth of water hyacinth was inhibited as its capacity for photosynthesis and

The Mysore Journal of Agricultural Sciences

TABLE 3

Influence of aqueous extracts of *Alternanthera philoxeroides* on growth of *Eichhornea crassipes*

Treatments	Growth change (%)				
	Fresh weight	Stem length	Root length	Number of leaves	Number of branches
T_1 : Control	40.32	45.04	68.75	38.60	40.87
T_2 : Root extract @ 5 g L^{-1}	-21.43	-14.48	-3.59	-11.83	-5.95
T_3 : Root extract @ 10 g L^{-1}	-43.79	-13.58	-6.57	-10.31	-6.90
T_4 : Root extract @ 20 g L^{-1}	-60.80	-31.90	-29.61	-22.00	-6.82
T_5 : Root extract @ 40 g L^{-1}	-44.44	-21.24	-11.45	-13.83	-6.59
T_6 : Root extract @ 80 g L^{-1}	-70.94	-29.18	-33.46	-36.13	-33.98
T_7 : Stem extract @ 5 g L^{-1}	-49.08	-2.90	-13.79	-12.61	-8.49
T_8 : Stem extract @ 10 g L^{-1}	-59.22	-10.80	-26.54	-16.36	11.49
T_9 : Stem extract @ 20 g L^{-1}	-46.63	-18.43	-10.00	-27.12	-16.33
T_{10} : Stem extract @ 40 g L^{-1}	-54.89	-21.66	-28.19	-39.02	-30.77
T_{11} : Stem extract @ 80 g L^{-1}	-71.39	-34.08	-31.16	-43.86	-38.46
T_{12} : Leaf extract @ 5 g L^{-1}	-11.19	-25.09	-12.65	-22.55	-3.66
T_{13} : Leaf extract @ 10 g L^{-1}	-59.00	-31.52	-17.47	-31.97	-27.52
T_{14} : Leaf extract @ 20 g L^{-1}	-44.80	-32.79	-32.39	-31.43	-16.49
T_{15} : Leaf extract @ 40 g L^{-1}	-49.54	-36.72	-30.07	-27.18	-23.71
T_{16} : Leaf extract @ 80 g L^{-1}	-68.03	-39.50	-28.99	-33.33	-36.17
T_{17} : Whole plant extract @ 5 g L^{-1}	-19.10	-28.76	-18.93	-4.17	0.00
T_{18} : Whole plant extract @ 10 g L^{-1}	-24.29	-37.72	-11.14	-9.90	-8.70
T_{19} : Whole plant extract @ 20 g L^{-1}	-44.12	-27.83	-13.43	-23.47	-5.95
T_{20} : Whole plant extract @ 40 g L^{-1}	-58.45	-30.73	-15.58	-24.30	-14.58
T_{21} : Whole plant extract @ 80 g L^{-1}	-78.13	-51.72	-40.13	35.00	-38.46

*(-) indicates percent inhibitory on growth of *Eichhornea crassipes* at 45 days after spray

the accumulation of nutrients are affected. These inhibitory indices on growth was significantly higher compared to control. Similar study conducted by Ahamd *et al. (*2008) indicated strong inhibitory effect of *A. philoxeroides* extracts on germination and seedling growth of parthenium. Huang *et al.* (2017) reported *A. philoxeroides* plant part *extracts* had suppressive and inhibition effect on growth of *Zoysia matrella*.

The inhibition effect of *A. philoxeroides* on water hyacinth may be due to presence of water soluble phenolics namely 4 hydroxy-3-methoxy-benzoic acid and m-coumaric acid these allelochemicals in *A. philoxeroides* would have played an important role in inhibiting the growth of water hyacinth, the studies are in line of Mehmood *et al.* (2014).

The study showed that different plant part had differential suppressive effect on the growth of water hyacinth. The differential inhibitory effect of different plant parts of *A. philoxeroides* plant was noted due to presence of different allelochemicals in different concentration as supported by Kadioglue *et al.* (2005) and Tanveer *et al.* (2008 & 2010). These findings partly explain the mechanism of biological invasion of water hyacinth by *A. philoxeroides* and also provide information that may aid in the alleviation of the allelopathic effect of *A. philoxeroides* in the field. Dongroe and

Singh (2007) noted that allelopathic effects of *A. philoxeroides* weed residues increased by increasing their concentration. Previous literature and the earlier studies revealed *A. philoxeroides* extracts showed deleterious effect on growth and development of rice by releasing water soluble phenolic acids (Batish *et al.,* 2009). Kamala Bai *et al.* (2021) reported that leachates of *A. philoxeroides* had significant inhibition effect over water hyacinth growth.

The allelopathic effects of extracts of each plant part of *A. philoxeroides* on the growth and development of water hyacinth ranged overall as growth stimulatory effect at lower concentration and inhibitory effect at higher concentration. The strength of the allelopathic effects of different plant parts of *A. philoxeroides* on water hyacinth was high in whole plant part and followed by the order of whole plant, leaves, root and stem. These findings partly explain the mechanism of biological invasion of water hyacinth by *A.philoxeroides* and also provide information that may aid in the alleviation of the allelopathic effect of *A.philoxeroides* in the field.

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