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Evaluation of herbicides to control alligator weed (*Alternanthera philoxeroides*) in mid hills of Himachal Pradesh

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Abstract

An open pot experiment was conducted during *Kharif* 2020 and 2021 at Research Farm of Department of Agronomy, College of Agriculture CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, H.P. to evaluate herbicides for the control of *Alternanthera philoxeroides*. The experiment was laid out in completely randomized design with three replications and consisted of ten herbicide treatments *viz*. glyphosate 1000 g/ha, paraquat 1000 g/ha, 2,4-D Na salt 1250 g/ha, 2,4-D ethyl ester 1000 g/ha, metsulfuron methyl 4 g/ha, carfentrazone 25 g/ha, glufosinate ammonium 500 g/ha, bispyribac Na 20 g/ha, flumioxazin 200 g/ha, diuron 500 g/ha and one weedy check (control). All the herbicide treatments resulted in significantly better control of *Alternanthera* compared to control (weedy check). Glyphosate 1000 g/ha remaining at par with metsulfuron methyl 4 g/ha provided lowest shoot count at all stages of observation during both years. This was followed by application of 2,4 D ethyl ester 1000 g/ha and carfentrazone 25 g/ha which except for initial stage of observation gave results statistically similar to glyphosate 1000 g/ha and metsulfuron methyl 4 g/ha from 25 to 55 days after spray. The lowest weed dry matter (g/m^2) and therefore highest weed control efficiency was recorded with application of glyphosate 1000 g/ha, metsulfuron methyl 4 g/ha and 2,4 D ethyl ester 1000 g/ha at 55 days after spray.

Key words: Alligator weed, herbicides, pot studies

Biotic invasion has gradually become as one of the top five causes for loss of global biodiversity and factors such as tourism and globalization are further accelerating the situation. Invasive species are those which proliferate, spread and persist in a new range to the detriment of environment or pre-existing native ecosystem (Mack 2000). These species invade natural ecosystems and can cause substantial modifications to indigenous biodiversity and ecosystem function (Williams and West 2000). *Alternanthera philoxeroides* (Martius) Griseb is one such invasive weed established in various parts of the world including many Indian states such as Himachal Pradesh which needs management addressal on priority.

A. philoxeroides, commonly known as 'Alligator weed', belonging to Amaranthaceae family, is a stoloniferous, perennial, herbaceous plant that can grow in littoral, aquatic and even terrestrial sites. Alligator weed is a native of South America, however with time it has spread to and invaded aquatic and terrestrial environments in over 30 countries across Asia, Europe, North America, South America and Oceania (EPPO 2016). It is a potentially devastating weed and has the capability to destroy natural systems, agriculture and recreational areas. In terrestrial situations, it steadily increases its biomass, displaces other species and contaminates agricultural lands (Spencer and Coulson 1976). In China, *A. philoxeroides* has been reported to reduce the stability of plant community and with time permanently displace the native species (Guo and Wang 2009).

The use of various control methods for management of introduced invasive species is

increasing due to the growing awareness that biological invasions have large economic and environmental costs. Among the different management methods, use of physical and biological methods sometimes creates disturbances and also infestation over a large area is difficult to control through such approaches because of invasive nature of these weeds (Sainty *et al*. 1998). Thus, various introduced invasive plants are effectively managed using herbicides. Though a few herbicides like 2,4-D, glyphosate, metsulfuron-methyl, dichlobenil and triclopyr etc. have been used to control these weeds in countries like USA, Australia and Brazil. Hitherto, limited attempts have been made to evaluate herbicides against *A. philoxeroides* in Indian sub-continent. Thus, the present investigation was undertaken to evaluate some herbicides for the control of alligator weed (*A. philoxeroides*).

Materials and Methods

An open pot experiment was conducted during *Kharif* 2020 and 2021 at Palampur (32° 6' N latitude, 76° 3' E longitude and 1280 m altitude). *Alternanthera* plants were grown in the month of March in pots of 25 cm diameter each containing potting mixture prepared by mixing FYM, soil and sand in equal ratio. Pots were arranged in a completely randomized manner under natural conditions. Eight shoots of weeds were grown in every pot.

Eleven weed control treatments consisting of glyphosate 1000 g/ha, paraquat 1000 g/ha, 2,4-D Na salt 1250 g/ha, 2,4-D ethyl ester 1000 g/ha, metsulfuron methyl 4 g/ha, carfentrazone 25 g/ha, glufosinate ammonium 500 g/ha, bispyribac Na 20 g/ha, flumioxazin 200 g/ha, diuron 500 g/ha and weedy check (control) were tested against the weed growth by spraying herbicides using a hand sprayer, once the weeds had established and reached appropriate growth stage. The count of viable shoots of *Alternanthera* was taken after 15, 25, 35 and 55 days after spray. The remaining shoots after 55 days of spray were collected from the pots and dry weight was recorded after oven drying at 72° C till constant weight was obtained. The data on weed count and weed dry weight were subjected to square root transformation.

Weed control efficiency of different treatments was worked out based on weed dry weight as per formula given by Mishra and Tosh (1979).

$$\text{Weed control efficiency (\%)} = \frac{\text{DWC} - \text{DWT}}{\text{DWC}} \times 100$$

Where,

DWC = weed dry weight (g/m^2) in control plot and

DWT = weed dry weight (g/m^2) in treated plot

Results and Discussion

Shoots per pot

All herbicide treatments resulted in significantly better control of *Alternanthera* than control (weedy check) except for diuron 500 g/ha and flumioxazin 200 g/ha at 15 days after spray (Table 1). Within a week after treatment, plants exhibited symptoms such as wilting, stem deformation etc., with a subsequent decline in the number of viable shoots of alligator weed.

At 15 days after spray all the shoots were killed with application of glyphosate 1000 g/ha; however it behaved statistically at par with paraquat 1000 g/ha and metsulfuron methyl 4 g/ha during both the years of study. Such response was also reported by Langeland (1986) wherein glyphosate application gave 90 to 100% weed control at 28 days after application.

At later stages of 25, 35 and 55 days after spray, treatment of *Alternanthera* with glyphosate 1000 g/ha, metsulfuron methyl 4 g/ha and 2,4-D ethyl ester 1000 g/ha gave significantly higher control, with no regrowth of *Alternanthera* shoots. Similar results were also documented by Pradhan and Sushilkumar (2019) where glyphosate being at par with 2,4-D was found superior in controlling alligator weed at 25 days after herbicide application.

Carfentrazone 25 g/ha also gave effective control of this weed, though it behaved statistically at par with glyphosate 1000 g/ha, metsulfuron methyl 4 g/ha and 2,4-D ethyl ester 1000 g/ha from 25 to 55 days after spray during both years. However, this is in contrast with the findings of Richardson *et al*. (2008) as they observed limited control of alligator weed with use of carfentrazone upto 8 weeks after treatment.

Application of paraquat 1000 g/ha provided good control of the weed during initial days of observation, however 4 weeks after treatment, regrowth of the shoots was recorded. This is in accordance with the results reported by Pradhan and Sushilkumar (2019),

Table 1. Effect of different treatments on number of *A. philoxeroides* shoots per pot

Treatment	Rate (g/ha)	Days after spray							
		15		25		35		55	
		2020	2021	2020	2021	2020	2021	2020	2021
Glyphosate	1000	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Paraquat	1000	0.88	0.88	1.05	0.88	1.77	1.58	1.87	1.95
		(0.33)	(0.33)	(0.67)	(0.33)	(2.67)	(2.00)	(3.00)	(3.33)
2,4-D Na salt	1250	1.56	1.46	0.71	0.88	0.88	0.71	1.05	1.05
		(2.00)	(1.67)	(0.00)	(0.33)	(0.33)	(0.00)	(0.67)	(0.67)
2,4-D ethyl Ester	1000	1.29	1.17	0.71	0.71	0.71	0.71	0.71	0.71
		(1.33)	(1.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00
Metsulfuron methyl	4	1.05	0.88	0.71	0.71	0.71	0.71	0.71	0.71
		(0.67)	(0.33)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Carfentrazone	25	1.56	1.46	0.71	0.71	0.88	0.71	0.88	0.71
		(2.00)	(1.67)	(0.00)	(0.00)	(0.33)	(0.00)	(0.33)	(0.00)
Glufosinate	500	1.66	1.46	0.88	1.05	1.05	1.17	1.05	1.17
ammonium		(2.33)	(1.67)	(0.33)	(0.67)	(0.67)	(1.00)	(0.67)	(1.00)
Bispyribac Na	20	2.04	2.12	1.22	1.34	1.05	1.22	1.22	1.46
		(3.67)	(4.00)	(1.00)	(1.33)	(0.67)	(1.00)	(1.00)	(1.67)
Flumioxazin	200	2.48	2.41	1.34	1.46	1.17	1.05	1.34	1.22
		(5.67)	(5.33)	(1.33)	(1.67)	(1.00)	(0.67)	(1.33)	(1.00)
Diuron	500	2.61	2.55	1.46	1.58	1.34	1.44	1.34	1.56
		(6.33)	(6.00)	(1.67)	(2.00)	(1.33)	(1.67)	(1.33)	(2.00)
Weedy check		2.92	2.92	2.92	2.92	2.97	2.92	2.97	2.97
		(8.00)	(8.00)	(8.00)	(8.00)	(8.33)	(8.00)	(8.33)	(8.33)
SE(m±)		0.16	0.12	0.09	0.10	0.14	0.11	0.10	0.12
LSD (P=0.05)		0.48	0.37	0.26	0.30	0.41	0.33	0.31	0.35

Values in parentheses are the means of original values; Data transformed to square root transformation ($\sqrt{x+0.5}$)

where the leaves of alligator weed treated with paraquat began to regain their colour after a week after spray.

Glufosinate ammonium 500 g/ha, bispyribac Na 20 g/ha, flumioxazin 200 g/ha and diuron 500 g/ha failed to achieve complete mortality of shoots at any stage of observation during both the years. They were also not as effective in reducing the weed growth as compared to other herbicides except at 25 and 35 days after spray (2020) for glufosinate ammonium 500 g/ha and 35 days after spray (2020) for bispyribac Na 20 g/ha. These results are in accordance with Alfas *et al*. (2021), Kelly *et al*. (2006) and Chauhan and Abugho (2012) who reported limited weed control with application of diuron, flumioxazin and bispyribac Na, respectively.

Dry weight and weed control efficiency

The effect of different herbicides on dry weight of

A. philoxeroides at 55 days after spray and the weed control efficiency is presented in the Table 2. The response of *Alternanthera* to herbicide application in terms of plant biomass is in accordance with the number of viable shoots at 55 days after spray (Table 1).

Glyphosate 1000 g/ha, metsulfuron methyl 4 g/ha and 2,4 D ethyl ester 1000 g/ha resulted in the lower dry weight of *A. philoxeroides* since no regrowth of weeds was observed even at 55 days after spray. However, carfentrazone 25 g/ha application also behaved statistically similar with these treatments during both the years of experiment. The highest dry weight was recorded from weedy check (control), during both the years, as in accordance with the highest shoot number per pot (Table 1).

At 55 days after spray the highest weed control efficiency (100%) was obtained with use of glyphosate 1000 g/ha, metsulfuron methyl 4 g/ha and 2,4-D ethyl ester 1000 g/ha in both the years of experiment. These results are validated by Sushilkumar *et al*. (2008) who also reported that glyphosate, 2,4- D and metsulfuron-methyl caused almost 100 per cent superficial killing of alligator weed.

Carfentrazone 25 g/ha, glufosinate ammonium 500 g/ha, 2,4-D Na salt 1250 g/ha and bispyribac Na 20 g/ha also gave good control of *Alternanthera* with more than 90% weed control efficiency. However, among the herbicide treatments, paraquat 1000 g/ha resulted in the lowest efficiency in controlling the weed growth. Similar limited weed control with paraquat application have also been reported by Chauhan *et al*. (2022).This could be attributed to the fact that paraquat only has a temporary effect on control of perennial weeds (Martin and Gaudard 1997).

Conclusion

From the present study it can be concluded that *A. philoxeroides* can be effectively controlled with the application of glyphosate 1000 g/ha, metsulfuron methyl 4 g/ha and 2,4 D ethyl ester 1000 g/ha upto 8 weeks after treatment. Thus, these herbicides can further be tested for managing the population of this invasive weed in field conditions.

Conflict of interest: The authors have no conflict of interest in this publication.

Table 2. Effect of different treatments on dry weight and weed control efficiency of *A. philoxeroides* at 55 DAS

Treatment	Rate (g/ha)	Dry weight (g/m^2)		Weed control efficiency (%)	
		2020	2021	2020	2021
Glyphosate	1000	0.71(0.00)	0.71(0.00)	100.0	100.0
Paraquat	1000	3.07(8.94)	2.90(7.93)	66.8	75.3
2,4-D Na salt	1250	1.47(1.94)	1.38(1.62)	92.9	94.8
2,4-D ethyl Ester	1000	0.71(0.00)	0.71(0.00)	100.0	100.0
Metsulfuron methyl	4	0.71(0.00)	0.71(0.00)	100.0	100.0
Carfentrazone	25	1.07(0.90)	1.04(0.80)	96.6	97.4
Glufosinate ammonium	500	1.45(1.87)	1.38(1.62)	93.2	94.8
Bispyribac Na	20	1.79(2.71)	1.75(2.58)	90.0	92.0
Flumioxazin	200	2.02(3.69)	1.91(3.24)	86.5	89.8
Diuron	500	2.03(3.73)	1.97(3.51)	86.1	89.0
Weedy check		5.24(26.95)	5.71(32.08)	-	-
SE(m±)		0.22	0.20		
LSD(P=0.05)		0.64	0.60		

Values in parentheses are the means of original values; Data transformed to square root transformation $(\sqrt{x+0.5})$

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