Agricultural Sciences, 2020, 11, 617-626
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Comparative Efficacy of Common Broad Leaf Herbicides against an Invasive Weed: *Parthenium hysterophorus* L.

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How to cite this paper: Ali, K., Rehman, A., Khan, K. and Weyl, P. (2020) Comparative Efficacy of Common Broad Leaf Herbicides against an Invasive Weed: Parthenium hysterophorus L. *Agricultural Sciences*, **11**, 617-626.
https://doi.org/10.4236/as.2020.117039

Received: June 25, 2020
Accepted: July 21, 2020
Published: July 24, 2020

Abstract

Parthenium hysterophorus L. (parthenium weed) is an annual weed that grows rapidly in disturbed land. It is considered as one of the most hazardous weeds in Pakistan as it poses serious health problems to livestock as well as severe allergenic reactions in humans. It has invaded the Punjab and Khyber Pakhtunkhwa provinces and also been spreading in other parts of the country where it poses a risk for the grazing lands, roadsides, forests, wet lands, waste lands and of all types of cropped and non-cropped areas in Pakistan. The present studies were carried out to determine the impact of four locally available broad leaf herbicides viz; Stomp 455 CS (pendimethalin), Buctril Super 60 EC (bromoxynil + MCPA), Vantage 48 SL (glyphosate) and Logran Extra 750 WG (triasulfuron + terbutryn) (@ recommended and ½ of recommended dose) against *P. hysterophorus* grown in pots at research field of CABI CWA, Rawalpindi. All herbicides were applied at three growth stages (rosette, bolted and flowering). The observations for the mortality of *P. hysterophorus* were made 2 and 4 weeks after spray. The glyphosate was the most effective and reported 100% mortality of *P. hysterophorus* plants at flowering stage followed by bromoxynil + MCPA (89%), pendimethalin (80%) and triasulfuron + terbutryn (61%) at recommended dose after 4 weeks of spray. All tested herbicides achieved a mortality between 38% - 86% at rosette while 54% - 96% mortality at bolted stage after 4 weeks. Initially, 2 weeks after spray at flowering stage glyphosate caused 53% wilting followed by 49% (bromoxynil + MCPA), 33% (pendimethalin) and 9% (triasulfuron + terbutryn) at their recommended doses. The results indicated that *P. hysterophorus* is the most susceptible to glyphosate and bromoxynil + MCPA, both these herbicides are very promising for the wilting and management of parthenium weed.

Keywords

Parthenium hysterophorus, Annual Weed, Herbicides, Mortality, Wilting

1. Introduction

The exotic plant invasions have become a global threat to agriculture, commercial productivity, conservation of natural resources and human health [1] [2], with alien invasions being categorized as the second largest threat to biodiversity [2] [3]. *Parthenium hysterophorus* L. (Asteraceae) is an annual invasive herb that aggressively colonizes cropped and non-cropped areas. It is native to Southern United States, Mexico, West Indies and South America [4] [5] but has been accidentally introduced into several countries of Africa, Asia, Australia and Pacific Islands, where it has become a serious agricultural and rangeland weed. This invasive weed is ranked as one of the worst weeds currently known [6] [7]. *Parthenium hysterophorus* is capable of producing thousands of small white capitula (flowers), each yielding five seeds on reaching maturity [8]. Due to its high fecundity, a single plant can produce up to 25,000 seeds, while 200,000 viable seeds m^{-1} can be found in abandoned fields [5] [9] [10] [11].

It is thought that *P. hysterophorus* came to India as a contaminate of wheat kernels imported from USA under the Unite States (US) PL-480 scheme, known as "Food for Peace" which was a food assistance programme of the US government [12]. These seeds spread easily in all states of India through air and water because of their minute size and light weight. Since establishment in India, it also spread into neighboring countries including Nepal, Pakistan and Bangladesh. In India, this invasive weed was first noted by Professor Paranjape in 1951 in Poona (Maharashtra) and reported by Rao in 1956 [12]. *P. hysterophorus* arrived in Pakistan in the late 1990s, and since then spread rapidly and now occurs in central and upper Punjab, some parts of North West Frontier Province & Kashmir where it has achieved the status of worst weed in Pakistan [13]. The weed affects the production of crops, animals, human and animal health, and biodiversity. Bajwa and colleagues [14] confirmed that farmers from three different cropping regions of Punjab, Pakistan reported significant impacts of parthenium weed in their cropping area and livestock production, human health and social well-being. In Pakistan, in parthenium weed free treatment up to 81% reduction in grain yield of sorghum has reported by Bajwa and colleagues [15]. According to Nadeem *et al.* [16] the weed also caused a major outbreak of airborne contact dermatitis, where 391 patients reacted positively for *P. hysterophorus* from 511 patients suspected of allergic contact dermatitis at Dermatology Department, Mayo Hospital, Lahore, Pakistan. The losses caused by weeds to agriculture worldwide have been estimated to be about $10 billions annually [10], while in Pakistan the annual losses caused by weeds exceed $1.05 billion [17].

In non-cropped situations, various methods are being used to manage this invasive weed with manual removal being most prevalent in Pakistan. However, manual and mechanical methods for controlling parthenium weed are not effective [18]. Pulling out the weed results in rapid regeneration, followed by quick flowering with thousands of seed being produced and skin allergies are also reported in people removing this weed manually without proper covering [19] [20] [21]. Chemical control in certain circumstances can be an effective and quick method for the management of *P. hysterophorus.* In other parts of the world, chemicals have been shown to effectively control *P. hysterophorus* [22] [23] but in Pakistan little information is available for the chemical control of this weed. The present study aimed to examine the impact of different locally available broad leaf herbicides for the management of *P. hysterophorus*. The results of this study will aid in future management decisions of *P. hysterophorus* in Pakistan.

2. Materials and Methods

Collection of *Parthenium hysterophorus* Seeds

Seedlings of *P. hysterophorus* were collected from the vicinity of Rawalpindi and Islamabad during February 2018 and grown in the experimental field of CABI CWA, Rawalpindi (Lat: 33.644970; Long: 73.083235). After two months, seeds for further studies were collected from this stock population when plants were fully matured and their seeds ripened.

Growing of *Parthenium hysterophorus* plants

Parthenium hysterophorus nurseries were grown one month apart (May, June, July) in order to obtain three different growth stages viz., rosette, bolted and flowering plants. One hundred and eight plastic pots (25 cm diameter) were filled with mixed sandy loam soil and young seedlings were singly transplanted into these pots. After transplanting, the pots were kept in tunnels covered with transparent plastic sheet and irrigated as required on a regular basis.

Toxicity Bioassay

Four locally available broadleaf herbicides Stomp 455 CS (pendimethalin), Buctril Super 60 EC (bromoxynil + MCPA), Vantage 48 SL (glyphosate) and Logran Extra 750 WG (triasulfuron + terbutryn) were purchased from Asia Scientific Store, Rawalpindi. The impact of tested chemicals was studied on three different growth stages (rosette, bolting and flowering) of *P. hysterophorus* using a complete randomized plot with 108 *P. hysterophorus* pots. Each herbicide was tested at recommended (D_1) and half of recommended dose (D_0) including a control treatment. Each treatment was replicated four times and quantity of chemical required for treating each pot was calculated by measuring area covered by a single pot (**Table 1**). The calculated amount of each tested chemical was applied to all potted plants separately except control treatments where similar amount of tap water was applied. All treatments were applied through a simple hand sprayer in morning during a bright sunny day. The trial was carefully

Table 1. Trade name, active ingredient, mode of action and dose rate of the synthetic herbicides used for the experiment.

Trade name	Active Ingredient	Mode of Action	Dose Rate ($kg \cdot ai \cdot h^{-1}$)	
			Recommended Dose (D_1)	½ of Recommended Dose (D_0)
Stomp 455 CS	Pendimethalin	Meristematic inhibitor	1.12	0.56
Buctril Super 60 EC	Bromoxynil + MCPA	Photosystem-II inhibitor	0.80	0.40
Vantage 48 SL	Glyphosate	Non selective, systemic herbicide	4.0	2.0
Logran Extra 750 WG	Triasulfuron + Terbutryn	Acetolactate synthase inhibitor (ALS Inhibitor)	0.30	0.15

observed on regular basis for the appearance of any signs of necrosis or wilting and observations for *P. hysterophorus* mortality was noted based on number of branches wilted after an interval of 2 and 4 weeks after spray.

Mortality was calculated using Abbot's (1925) formula;

$$\text{Mean Mortality}(\%) = \frac{\text{Mo} - \text{Mc}}{100 - \text{Mc}} \times 100$$

Mo = Mortality observed in treatments.

Mc = Mortality observed in control.

Statistical analysis:

Data for mortality of *P. hysterophorus* were subjected to analysis of variance (ANOVA) using Statistica 8.1 software. To determine statistical differences between means the Tukey-HSD post hoc test at the 5% significance level was employed.

3. Results

All the four chemicals tested proved significantly effective (d.f = 3; $f_{cal} = 318.78$; $p < 0.05$) for the wilting of parthenium plants, however, with a variable response to mortality.

Among the four tested herbicides the glyphosate was found to be the most effective against *P. hysterophorus* (**Figure 1**). The effect of herbicides were directly proportional to the time and dose rates, after four weeks of spray with a maximum mortality of 94% with glyphosate followed by bromoxynil + MCPA (86%), pendimethalin (73%) and triasulfuron + terbutryn (51%) at recommended doses (D_1) (**Figure 1**). Initially, 2 weeks after spray the recommended dose of bromoxynil proved slightly more toxic than glyphosate as it induced 48% mortality of the target weed while 46% was observed with glyphosate. However, 4 weeks after spray glyphosate resulted in highest mortality of parthenium plants from all tested herbicides. Triasulfuron + terbutryn showed minor impacts for the control of parthenium weed and proved least effective. The findings also exhibited that D_0 of tested herbicides proved least effective, only glyphosate resulted in slightly higher than 60% wilting of *P. hysterophorus* even after exposure of 4 weeks (**Figure 1**).

The results verified that each herbicide showed a variable response to different growth stages (rosettes, bolting and flowering) of parthenium plants. The recommended dose (D_1) of glyphosate induced 100% mortality of flowering stage, while 96% and 86% mortality was achieved at rosette and bolted stage, respectively, while ½ of recommended doses (D_0) resulted in less than 70% wilting of three growth stages of weed (**Figure 2**). Bromoxynil + MCPA has also proved very effective against parthenium and was second to glyphosate. The recommended dose (D_1) of bromoxynil + MCPA resulted in 94%, 89% and 76% mortality at rosette, flowering and bolted stage after four weeks of spray, respectively (**Figure 3**). While D_0 evidenced 69%, 58% and 44% mortality in flowering, rosette and bolted stages of target weed after same time of herbicidal exposure, respectively (**Figure 3**).

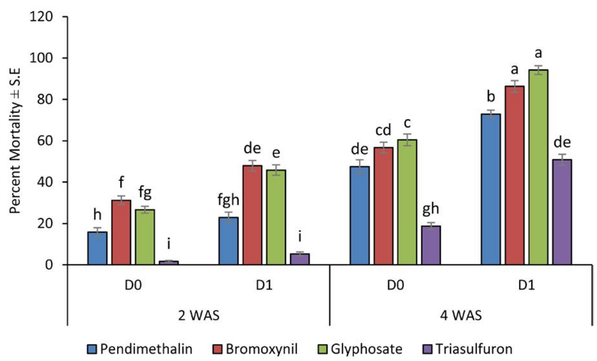

Figure 1. Mortality effects of tested herbicides for *P. hysterophorus* at recommended (D_1) and ½ of recommended doses (D_0) after 2 and 4 weeks after spray (d.f = 3; $f_{cal} = 318.78$; $p < 0.05$).[1]

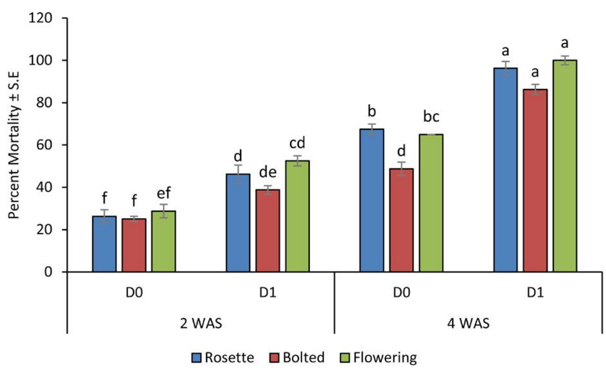

Figure 2. Effect of glyphosate at recommended (D_1) and ½ of recommended doses (D_0) for mortality rate (%) on three different growth stages (rosette, bolted & flowering) of *P. hysterophorus* after 2 and 4 weeks after spray (d.f = 2; $f_{cal} = 18.65$; $p < 0.05$).[2]

[1]Error bars indicate ± SE of the mean values. WAS: weeks after spray.

[2]Error bars indicate ± SE of the mean from four replicates. WAS: weeks after spray.

Other two chemical herbicides (pendimethalin and triasulfuron + terbutryn) proved significantly less toxic (d.f = 3; $f_{cal} = 318.78$; $p < 0.05$) to test weed plants at both concentrations recommended and half (D_1 & D_0) and time intervals (2 & 4 weeks after spray). At early stage (2 weeks after spray) of spray pendimethalin forced almost same mortality in three growth stages of parthenium at D_0 and D_1, but with the increase of exposure time it resulted in 80%, 70% and 69% mortality at D_1 while 58%, 48% and 36% mortality of flowering, bolted and rosette stage at D_0, respectively (**Figure 4**). Triasulfuron + terbutryn proved least effective as compared to all four test herbicides. Initially 2 weeks after spray at D_1 and D_0 of triasulfuron + terbutryn, no mortality was observed in all test growth stages of parthenium, while maximum exposure period (4 weeks after spray) evidenced almost 25% mortality at D_0 while more than 50% mortality at D_1 as it resulted 61%, 54% and 38% mortality in flowering, bolted and rosette stages of parthenium weed (**Figure 5**).

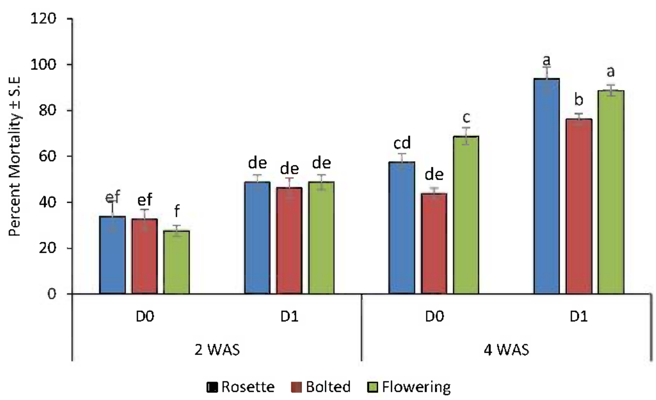

Figure 3. Effect of bromoxynil + MCPA at recommended (D_1) and ½ of recommended doses (D_0) for mortality rate (%) on three different growth stages (rosette, bolted & flowering) of *P. hysterophorus* after 2 and 4 weeks after spray (d.f = 2; $f_{cal} = 6.872$; $p < 0.05$).[3]

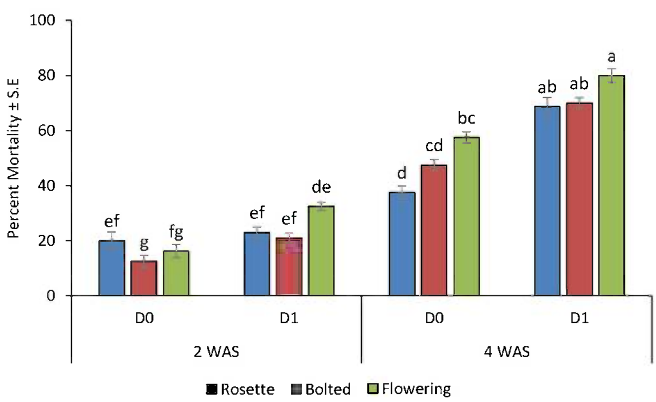

Figure 4. Effect of pendimethalin at recommended (D_1) and ½ of recommended doses (D_0) for mortality rate (%) on three different growth stages (rosette, bolted & flowering) of *P. hysterophorus* after 2 and 4 weeks after spray (d.f = 2; $f_{cal} = 5.165$; $p < 0.05$).[4]

[3]Upright bars indicate ± SE of the mean from four replicates. WAS: weeks after spray.

[4]Error bars indicate ± SE of the mean from four replicates. WAS: weeks after spray.

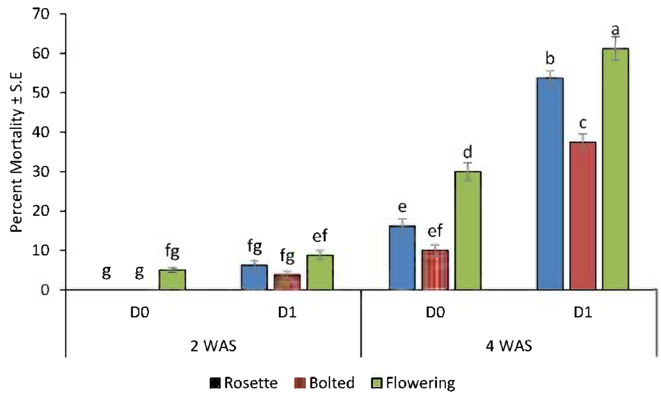

Figure 5. Effect of triasulfuron + terbutryn at recommended (D_1) and ½ of recommended doses (D_0) for mortality rate (%) on three different growth stages (rosette, bolted & flowering) of *P. hysterophorus* after 2 and 4 weeks after spray (d.f = 2; $f_{cal} = 0.31$; $p > 0.05$).[5]

4. Discussion

Comparison of mortality in *P. hysterophorus* weed plants at different growth stages at D_1 and D_0 dose rates of four tested herbicides (pendimethalin, bromoxynil + MCPA, glyphosate and triasulfuron + terbutryn) is an important biological parameter to determine their effectiveness. The outcomes clearly showed that fully grown plants of invasive weed parthenium can effectively be controlled using glyphosate and bromoxynil + MCPA. The other two herbicides used in the experiment did not provide satisfactory results when applied to rosette, bolted and flowering stage. Although their full dose (D_1) shows some mortality but they failed to control the weed up to 50%. Similar results for herbicidal impacts have been reported by Javaid and colleagues [23] and Shabbir [24]. Njoroge [25] proved in Kenya that even low concentrations of glyphosate are very effective against parthenium weed in coffee plantations. Our outcomes are supported by Krishna *et al.* [26] who reported that glyphosate, glufosinate and trifloxysulfuron provided 86% to 95% control of parthenium weed at bolted stage. Earlier studies shows that bromoxynil + MCPA is very effective as post emergence treatment [27] and have also been approved effective against weeds of wheat [28].

Similar observations were noted by Balyan *et al.* [29] and Krishna *et al.* [26] who confirmed that at the rosette stage, glyphosate provided almost 93% control of parthenium weed after three weeks of treatment. Acifluorfen, bentazon, glyphosate, imazaquin, and metribuzin applied post emergence to plants less than 7.5 cm tall controlled 80% parthenium weed [30]. Our observations are in line with Rosale-Robles *et al.* [31] who showed 47% to 82% control of parthenium weed in sorghum field with bromoxynil + MCPA.

Triasulfuron + terbutryn proved least effective in this experiment for the management of *P. hysterophorus*. Singh *et al.* [32] affirmed that 2,4-D, atrazine, metribuzin, triasulfuron + terbutryn, chlorimuron, and glufosinate failed to

[5]Error bars indicate ± SE of the mean from four replicates. WAS: weeks after spray.

control parthenium weed, while glyphosate provided up to 95% control of this noxious weed. Walia *et al.* [33] also stated that herbicides other than glyphosate applied to full grown parthenium plants did not provide satisfactory results for its management. An overall comparison of tested herbicides for the management of parthenium weed showed that maximum control can only be achieved with glyphosate and bromoxynil + MCPA. Moreover, the information on the mortality of different growth stages of parthenium weed will be helpful for devising the strategies for the best time of its management.

5. Conclusion

The recommended dose (D_1) of glyphosate and bromoxynil + MCPA showed promising results for the mortality of parthenium weed after 4 weeks of spray while pendimethalin and triasulfuron + terbutryn provided less control when applied at different growth stages of parthenium. In light of the instant studies, it is recommended that glyphosate as a generalized weedicide (non-selective herbicides: Table 1) is the most effective and can be suggested for non-cropped areas or barren lands, while bromoxynil + MCPA as a specified broad leaf herbicide should be used to manage the parthenium weed in cropped areas.

Acknowledgements

We wish to acknowledge the support of our donors who make action on Invasives possible, in particular UK Aid (DFID) and the Directorate-General for International Cooperation (DGIS, Netherlands). CABI is an international intergovernmental organization, and we gratefully acknowledge the core financial support from our member countries (and lead agencies) including the United Kingdom (Department for International Development), China (Chinese Ministry of Agriculture), Australia (Australian Centre for International Agricultural Research), Canada (Agriculture and Agri-Food Canada), Netherlands (Directorate-General for International Cooperation), and Switzerland (Swiss Agency for Development and Cooperation). See http://www.cabi.org/about-cabi/who-we-work-with/key-donors/ for full details.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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