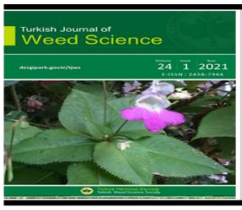

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Araştırma Makalesi/Research Article

Evaluation of the Effect of Different Herbicides for the Control of Parthenium Weed

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ABSTRACT

Parthenium hysterophorus L., is a noxious annual weed rapidly spreading across the cropped and non-cropped and has become a major threat to cropped and noncropped areas. Field experiments were conducted to evaluate the efficacy of different herbicides against parthenium weed at its mixed population of different growth stages in non-cropped area. The experiments were laid out in accordance with RCBD with three repeats of ten treatments. Herbicides used in the experiments were RoundUp 54SL (glyphosate) @ 2.5 l ha^{-1}, Maxtrol 38SC (atrazine) @ 1200 ml ha^{-1}, Sencor 70WP (metribuzin) @ 625 g ha^{-1}, Gesapax combi 80WP (ametryne+atrazine) @ 2.5 kg ha^{-1}, Clean Core 50EC (acetochlor) @ 250 ml ha^{-1}, Gramaxone 20SL (paraquat) @ 1250 ml ha^{-1}, Stomp 330 EC (pendimethalene) @ 2500 g ha^{-1}, Premextra Gold 720 SC (atrazine+s-metolachlor) @ 2000 ml ha^{-1}, and Sodium chloride (common salt) @ 5% solution and untreated control. Statistical analysis of the data showed that different herbicide treatments had significant effect on the mortality of parthenium weed. The post emergence herbicides, glyphosate and ametryne+atrazine at rossete stage provided 97% & 82% and at bolted stage 96% & 60% mortality of parthenium weed at 4 Weeks After Spray (WAS). Among the pre-emergence herbicides pendimathaline and atrazine proved best with 10 & 16 plants m^{-2} respectively and inhibited the regeneration of weeds for a longer period of time. It is recommended that a mixture of glyphosate (non-selective herbicide) in pendimethalne or atrazine at their recommended doses can be used on noncropped areas for effective control of Parthenium weed.

Keywords: herbicides, parthenium, weed control, non-cropped area, biodiversity threat, Gujranwala

INTRODUCTION

Parthenium (*Parthenium heterosphorus* L.) (Asteraceae), an alien invasive species, commonly known as parthenium weed is an annual or short-lived ephemeral herb of neo-tropical origin that now has a cosmopolitan distribution (Javed and Anjum, 2006). This weed is locally known as Gajar booti, chatak chandni and white top, carrot grass or rag grass in English. It is a pan-tropical weed. This weed entered Pakistan through contaminated cereal grain about a decade ago. The recent developments and intensification of world trade systems has strengthened a long-standing trend in the re-distribution of invasive alien species in general and parthenium weed in particular (Khan *et al*., 2012). The vehicle movement and transportation of agriculture products have become the main means by which its seed is spreading rapidly (Shrestha *et al*., 2015). Parthenium plants nestled with its small white flowers, look quite beautiful and are used in flower bouquets and decorations. This practice is contributing to its countrywide seed dispersal involuntarily.

The weed has spread like wild fire throughout the country and is continuously replacing the local flora for the last 15-20 years (Javed and Shabbir, 2006). It occupies fallow lands where ever available to it especially along road sides, green belts, railway tracks and unused grounds, wastelands, degraded areas, rocky crevices, water channels, protected areas and national parks (Shabbir, 2014). This weed has been found in all rangelands, fodder crops, major crops and in vegetable crops as well (Shabbir & Bajwa, 2006) causing severe damage to the agriculture productivity of the country beside increasing cost of production. Because of its adaptability to varying soils and microenvironments and efficient biological activity this weed has a tendency to replace the dominant flora in extensive range of habitats cutting across state boundaries and agro-climatic regions (Shabbir and Bajwa, 2007). Very little or sometimes no other vegetation can be seen in P. hysterophorus dominated areas because wherever it invades, it forms a territory of its own by replacing the indigenous natural flora (Oudhia, 2000). This invasive alien weed has become a cause of threat to local

biodiversity and has reduced plant species richness and changed species composition in grasslands (Shrestha *et al*., 2015). The biological invasion by alien invasive species produces severe, often irreversible impacts on agriculture, recreation, natural resources, human beings and livestock (Shabbir and Bajwa, 2007) as they have caused hundreds of extinctions throughout the world (Anonymous, 2005) resulting in serious economic losses to people and their interests in many countries around the globe (Adkins and Shabbir, 2014). Parthenium weed has strong competitive ability for soil moisture and nutrients and has strong allelopathic effect on neighboring plant species while inhibiting their germination and growth and suppression of the natural vegetation thus posing a strong threat to biodiversity (Adkins & Sowerby, 1996; Oudhia, 2000; Rizvi *et al*., 2000).

Parthenium weed besides causing losses of crops and pastures, degrading the biodiversity of natural plant communities also caused human and animal health hazards (Adkins and Shabbir, 2014). During uprooting, fodder collection or with contact of parthenium leaves to naked hands caused allegic reaction and dermatitis with skin lesion, mouth ulcer with excessive saliva, diarrhea due to irritation of gastro intestine and respiratory problems to susceptible individuals (McFadyen, 1992; Patel, 2011; Shrestha *et al*, 2015). The initial symptoms of allergy are described as itching, redness, swelling and blisters on eyelids, face and neck, which may spread to the elbows and knees (McFayden, 1995). The allergic reactions include hay fever and asthma and can be caused by the dust, debris or volatile fumes from the plant as well as its pollen. Besides this enormous quantity of air born pollens are produced which invade other lands (Lewis *et al*., 1987-88; Seetharamiah *et al*., 1981; Agashe *et al*., 1988).

The cattle and sheep generally do not feed on Parthenium weed because of its unpalatable taste and if do so, it may cause reduction in milk yield, off smell and tainting of milk and mutton, and in severe cases, hemorrhage and rupture of internal tissues which may results in death of animals (Tudor *et al*., 1982; Chippendale, 1994; Patel, 2011).

It has been estimated that weeds are responsible for decreasing annual production of the eight most important food and cash crops by 13.6 per cent, leading to an economic loss of $100 billion around the globe (Anonymous, 2018; Khan *et al*., 2012). In Pakistan, the annual losses in the major crops caused by weeds exceed Rs.130 billion (Hassan & Marwat, 2001). Parthenium weed alone can reduce crop yields by 40 to 97% (Khosla and Sobti, 1981; Nath, 1988) besides having bad impact on agriculture, environment, human and animal health, and biodiversity. Resultantly contributing to social and economic instability, placing restrictions on sustainable development, economic growth, poverty alleviation and threatening food security by increasing cost of production incurred in combating weeds (Singh *et al*., 2004; Tamado & Milberg, 2004; Kohli *et al*., 2006)

Profitable agriculture is based on wise and economic weed management strategies which are possible only after having knowledge of various control measures along with their merits and demerits There are number of options for its control *i.e*., physical, cultural, mechanical, legislative, biological and chemical with different degrees of effectiveness. In physical control weeds are removed by physical or mechanical means, such as mowing, grazing, mulching, soil solarization, flooding, tilling, burning or by hand. The manual removal is most prevalent but manual and mechanical methods for controlling parthenium weed are not much effective. This is because the cutting with machines or manually results in rapid regeneration followed by quick flowering with abundant seed production by this weed (Muniappa *et al*., 1980; Dhawan & Dhawan, 1996). Besides this, manual control method is tedious, time consuming, expensive and may cause allergic reaction to some people. The manual removal or cutting is best before flowering stage provided all the plants are uprooted in an area. Similar is the case of burning with fire but this too is effective on young weeds only that are less than two inches tall but in order to control tougher perennial weeds repeated flaming treatments are required. Burning exposes the soil surface to erosion. In order to minimize the risk of harm to the environment and to those undertaking the activity, caution must be exercised. According to Vogler *et al*. (2006) this method is ineffective and could in fact make the problem worse. In addition this method is not feasible from farmers' point of view as burning requires large quantities of fuel and could destroy other economically important flora and faunathe vicinity (Ray and Gour, 2012). As for as legislative control measure is concerned an effective and co-ordinated prevention of entry of parthenium in new area is the most cost-effective management strategy (Dhileepan, 2009). The vehicles from infested to parthenium-free areas are required to be cleaned or properly washed. It should also be legally mandatory for suppliers of stock, machinery, soil or other agro-products from parthenium infested areas to declare that they are supplying parthenium-free material. For biological control of parthenium nine insect species and two rust species have been used in different parts of the world for over 50 years (Parsons and Cuthbertson, 1992; Dhileepan, 2009; Sushilkumar, 2014; Abdulkerim-Ute and Legesse, 2016; Dhileepan *et al*., 2018). Among the insects *Zygogramma bicolorata* the rust *Puccinia abrupta* showed control of weed to some

extent but none of them qualified as successful bioagent against parthenium (Sushilkumar, 2009).

At present chemical control option in comparison with all other control methods seems to be quick and effective one. A number of herbicides including atrazine, dicamba, 2,4-D, picloram and glyphosate have been found useful to manage this weed overseas (Haseler, 1976) but little information is available from the Punjab, Pakistan where the weed has stablished itself and its infestation is spreading very fast (Shabbir, 2014). Chemical control of parthenium by using herbicides varies with active ingredient of herbicides, does of herbicide applied per unit area, growth stage of weeds and method of application (Etheridge *et al*., 2001). Singh *et al*., (2004) reported that in non-cropped situation 2,4-D, atrazine, atrazine+ 2,4-D, metsulfuron, metribuzin, chlorimuron, and glufosinate failed to control *P.hysterophorus* while glyphosate at higher rates provided more than 90% control after 04 months of treatment. Tamado and Milberg (2004) reported that in grain sorghum for proper control repeated applications of 2, 4-D were necessary whereas Parsons and Cuthbertson (1992) recommended the use of 2, 4-D in combination with atrazine.

Due to recent epidemic spread of parthenium and keeping in view its importance and future threats, under non-cropped conditions field trials were conducted to assess different herbicides and their mixtures against parthenium. The objectives of these experiments were to identify the most susceptible growth stage of parthenium weed to herbicides in non-cropped area and to find out the most suitable, efficient and economic herbicide or a mixture of herbicides for parthenium weed control.

MATERIALS and METHODS

Agro-ecological and Geographic features of Experimental site

The field experiments regarding evaluation of different herbicides for the control of parthenium weed were conducted in District of Gujranwala. It lies at the heart of the Rachna Doab - a strip of land between the rivers Chenab in the north, and Ravi River in the south with hot semi-arid climate. During summer (June to September), the temperature may reaches 36-42 °C (97-108 °F) while in winter (November to February) the temperature can drop to an average of 7 °C (45 °F). On an average annual rainfall is about 500-600 mm with higher concentration in summer (Anonymous, 2020). It is located at 226 meters (744 ft) above sea level on an area of 3,624 km² with 32.100 (N) Lat. and 74.100 (E) Long. with population size of 5.014 M. Majority of the population is concerned directly or indirectly with agriculture and rearing of livestock, sheep and goats. The main source of grazing of these animals are the unattended lands along road side or water channels (Anonymous, 2017). These lands are, therefore a valuable pastures for the herds of poor people in the country.

Treatments and Methodology

Parthenium hysterophorus is usually insensitive not only to thermoperiod but also to photoperiod and its growth rate is greatest on the availability of moisture irrespective of the rainy season. Although the climate of Pakistan is no doubt is quite suitable for Parthenium throughout the year which has made the weed prolific. The experiment regarding chemical control of Parthenium weed were conducted on fallow land along road sides. The soil of experimental site was loamy clay with pH 8.2, organic matter 0.54%, total nitrogen 0.052%, available P 6.76 ppm and available K 257.12 ppm. The experiment was laid out in Randomized Complete Block Design (RCBD) with net plot size of 3 m x 6 m, and each treatment was replicated three times. The herbicides used in the experiment are given in Table 1.

Table 1. Details of herbicides treatments used in the experiments

Treat. No.	Brand names of herbicides	Common names of herbicides	Dose/ha	Distributer
1	Control	-	-	-
2	Round Up 54SL	glyphosate	2500 mL	Monsanto, Pakistan
3	Maxtrol 38SC	atrazine	1200 mL	Tara Group, Pakistan
4	Sencor 70WP	metribuzin	625 g	Bayer crop Sciences, Pakistan
5	Gesapax combi 80WP	ametryne+trazine	2500 mL	Syngenta, Pakistan
6	Clean Core 50EC	acetachlor	250 mL	Tara Group, Pakistan
7	Gramaxone 200SL	paraquat	1250 mL	Syngenta, Pakistan
8	Stomp 330EC	pendimethalene	2500 mL	FMC, United (Pvt.) Limited, Pakistan
9	Primextera Gold 720SC	atrazine+s-metolachlor	2000 mL	Syngenta, Pakistan
10	Common Salt	sodium chloride	5% solution	-

These herbicides and sodium chloride salt were applied against a mixed population of parthenium weed having both the rosette and bolted stages in non-cropped area of Gujranwala District, Punjab, Pakistan during the winter season. Before selection of herbicides their easily availability at the local grain market was kept in mind.

The herbicides were applied at their recommended doses with the help of knapsack sprayer fitted with a T-jet nozzle. The volume of the water used spray was determined by using the standard calibration method on the non-experimental area. Before the application of each herbicide treatment, the knapsack sprayer was washed properly with clean water to avoid any kind of contamination of previously used herbicides. The sprayer shield on the nozzle was also used to avoid herbicide drift between different herbicide treatments. While, spraying the herbicides, all the precautionary measures were observed to avoid any uneven spray (Rehman *et al*., 2017).

Parameters measured

There were a total of ten treatments i.e., eight herbicide, one sodium chloride and an untreated control plot for comparison with herbicide treatments. In control plot no chemical was applied except the spray of simple water. The data regarding population of rosette and bolted stages of parthenium weed was recorded before application of treatments and then 4 and 16 weeks after the application of the treatments (WAT). Plots were monitored for four months after treatment to examine regeneration or regrowth of parthenium weed (Khan *et al*., 2012). The data was recorded with the help of a quadrate of $1m^2$. The area from where the data was recorded was marked with the help of bamboo sticks for onward recording of data. The population of both the rosette and bolted stages was recorded separately before and after application of treatments from that particular marked area. The Parthenium weed control or mortality %age was determined with the help of the following formulae as given by (Misra and Misra, 1997). A higher value indicates the usefulness of herbicide:

$$\text{Mortality (\%)} = \frac{\text{WPBT - WPAT}}{\text{WPBT}} \times 100 \ldots\ldots\ldots \text{(eq-1)}$$

Whereas Weed Control Efficacy (WCE) was determined by the following formula as given by Thakral *et al*., (1988) and Surinder (2016). The higher WCE the better is the herbicide treatment.

$$\text{WCE (\%)} = \frac{\text{WPC - WPT}}{\text{WPC}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots \text{(eq-2)}$$

Where WPBT, WPAT, WPC, WPT, is weed population before application of treatment, weed population after application of treatments, weed population in control, and weed population in treated plot respectively.

Statistical analysis

The data, collected were analyzed statistically using Fisher's analysis of variance technique, and the difference among the treatment means were compared using LSD at 5% probability level (Steel *et al*., 1997) by using software MS Excel and Statistics version 8.1 (Analytical Software, 2005).

RESULTS and DISCUSSION

The experiment regarding efficacy of various chemical treatments for control of Parthenium weed was conducted on the natural vegetation of parthenium weed. In this population both the stages i.e., rosette and bolted of Parthenium weed were present.

Parthenium weed mortality (%) at rosette stage

The physical characteristics of weed plants at rossete stage are given in Table 2. The table showed that all the plots had almost homogeneous weed population except T8 and T9. However, there was mild variation in plant heights and diameter of the stems at rossete stage. On the other hand number of leaves per plant were fairly equal.

Table 2: Physical characteristics of Parthenium weed at the time of herbicides application

Treatments	Density (weeds/m^2)		Plant Height (cm)		Stem diameter (cm)		No. of leaves/ plant	
	Rossete stage	Bolted stage	Rossete stage	Bolted stage	Rossete stage	Bolted stage	Rossete stage	Bolted stage
T1=Control	56.00abcd	3.33ab	15.33b	28.00ab	0.44ab	0.34a	11.00a	9.67a
T2= glyphosate	64.67ab	1.00bc	33.33a	31.33ab	0.94a	0.78a	15.00a	13.33a
T3= atrazine	53.67bcd	0.33c	28.67ab	27.33b	0.53ab	0.61a	11.67a	13.67a
T4= metribuzin	52.33bcd	2.00abc	25.33ab	35.00ab	0.68ab	0.56a	11.33a	15.00a
T5= ametryne+atrazine	68.33a	1.00bc	20.67ab	34.67ab	0.49ab	0.70a	11.00a	14.00a
T6= acetachlor	61.33abc	3.00ab	17.00b	27.00ab	0.36b	0.71a	9.00a	15.67a
T7= paraquat	57.00abcd	3.33ab	29.00ab	32.33ab	0.64ab	0.60a	9.00a	10.33a
T8=pendimethalene	45.67d	1.33bc	29.33ab	51.67a	0.69ab	0.76a	9.67a	16.00a
T9= atrazine+s-metolachlor	44.67d	4.33a	21.33ab	36.67ab	0.37b	0.51a	9.33a	10.00a
T10=sodium Chloride	51.33cd	3.33ab	25.33ab	27.67ab	0.34b	0.70a	9.33a	14.00a
LSD	*13.32*	*2.36*	*14.68*	*24.27*	*0.50*	*0.51*	*6.05*	*6.76*
F	*8.19*	*8.53*	*4.05*	*2.39*	*3.62*	*1.71*	*2.38*	*3.10*
SE	*0.66*	*3.71*	*4.0955*	*6.77*	*0.1409*	*0.1433*	*1.6895*	*1.8863*
P	*0.0001*	*0.0001*	*0.0056*	*0.0552*	*0.0096*	*0.1581*	*0.0563*	*0.0197*

Note: LSD= Least significant difference at 5% level of significance, Means followed by the same letter in a column do not differ statistically ($p \leq 0.05$) according to Tukey's honest significant difference (HSD)

The statistical analysis of the data (Table 3) showed that different herbicidal treatments had significant effect on parthenium weed mortality.

The herbicidal treatments provided 0.00 (T6) to 35% (T5) mortality at 1 WAS. At 2WAS this %age raised to 62% (T2) and 57% (T5) which is almost double as compared to that of 1WAS. At 3WAS the mortality of weeds became three fold to that at 1WAS. At this time the other herbicides whose activity was minor before this also showed efficacy to a noticeable extent. At 3WAS and 4WAS the efficacy of all the herbicides remained almost unchanged.

Table 3: Parthenium weed Mortality (%) at Rossete & Bolted stages

Herbicides weeks after spray →	Mortality %age 1-WAS		Mortality %age 2-WAS		Mortality %age 3-WAS		Mortality %age 4-WAS	
	Rossete stage	Bolted stage	Rossete stage	Bolted stage	Rossete stage	Bolted stage	Rossete stage	Bolted stage
T1=Control	0.00c	0.00cd	0.00b	0.00c	0.00c	0.00d	0.00d	0.00d
T2= glyphosate	33.89a	26.50a	62.45a	55.29a	94.31a	89.98a	97.07a	95.83a
T3= atrazine	2.78c	3.39cd	2.69b	2.56c	27.43b	5.75d	28.79c	7.66d
T4= metribuzin	12.06b	13.78b	6.94b	6.94c	29.69b	25.59c	30.58c	26.64c
T5= ametryne+atrazine	35.17a	30.11a	57.11a	45.44b	81.23a	60.13b	82.20b	60.17b
T6= acetachlor	0.00c	1.11d	0.83b	0.00c	0.00c	0.00d	0.00d	0.00d
T7= paraquat	10.72b	9.56bc	3.83b	3.42c	0.00c	0.00d	0.00d	0.00d
T8=pendimethalene	0.11c	0.00d	0.33b	0.11c	0.00c	0.00d	0.00d	0.00d
T9= atrazine+s-metolachlor	0.94c	0.89d	1.00b	0.83c	28.52b	26.05c	29.44c	26.23c
T10=sodium Chloride	2.89c	1.89d	2.17b	1.61c	0.00c	0.00d	0.00d	0.00d
LSD at 5%	*7.15*	*7.48*	*10.05*	*8.43*	*14.69*	*11.02*	*14.81*	*10.82*
F	*28.69*	*20.43*	*45.91*	*46.88*	*44.70*	*62.74*	*45.98*	*70.85*
SE	*3.6190*	*3.5311*	*5.0893*	*4.2685*	*7.4345*	*5.5764*	*7.4948*	*5.4776*
P	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Note: WAS=week after spray, LSD= Least significant difference at 5% level of significance, Means followed by the same letter in a column do not differ statistically ($p \leq 0.05$)

The findings of this study are in line with those of Njoroge (1991) Balyan *et al*., (1998) Javed (2007) and Krishna *et al*., (2007) affirmed that at rosette stage, glyphosate provided greater than 93% control of parthenium weed after three weeks of treatment. These results are also in accordance with those of Tyson & Bryan (1987) who applied acifluorfen, bentazon, glyphosate, imazaquin, and metribuzin and controlled greater than 80% parthenium weed. The result of the present study are partially in accordance with Lalita and Kumar (2018) who noticed that glyphosate and metribuzin as vert effective treatments having higher effect at 28 days after the herbicide application.The results of present study are, however, not in conformity with those of Parsons and Cuthbertson, (1992) who reported that the herbicides, such as imazapyr, oxadiazon, oxyfluorfen, pendimethalin and thiobencarb were highly effective against *P. hysterophorus*. According to Khan *et al*., (2012) pendimethalan was the least effective treatment giving minimum mortality of parthenium weed at 4 weeks after treatment (WAT) which is quite in lines with the findings of present study. The same is the case with acetachlore, paraquat and sodium chloride solution. The least efficacy may be due to the fact that pendimethalin and acetachlore are generally used as pre-emergence herbicides. These herbicides showed effectiveness only to a little extent which suggests that these herbicide were effective as early post emergence to some extent.

The results are also not in conformity with those of (Khan *et al*., 2012) who obtained 71-80% control of parthenium weed at 4 WAT by use of 2, 4-D, triasulfuron+terbutryn, bromoxynil +MCPA and atrazine+s-metolachlor. According to them of atrazine and s-metolachor were statistically at par with each other (56.5% and 57.5% while in present study atrazine+s-metolachlor proved significantly better than atrazine alone.

Overall glyphosate performed the best with 97% mortality followed by ametryne+atrazine with 82% mortality. Whereas all of the other herbicides remained quite unsatisfactory in controlling the rossete stage of parthenium (Fig.1).

The present results suggest that glyphosate and ametryne+atrazine could be the best options to combat parthenium on non-cropped area. Also these herbicides are comparatively safer, easily available in the market and cheaper for growers in the study area.

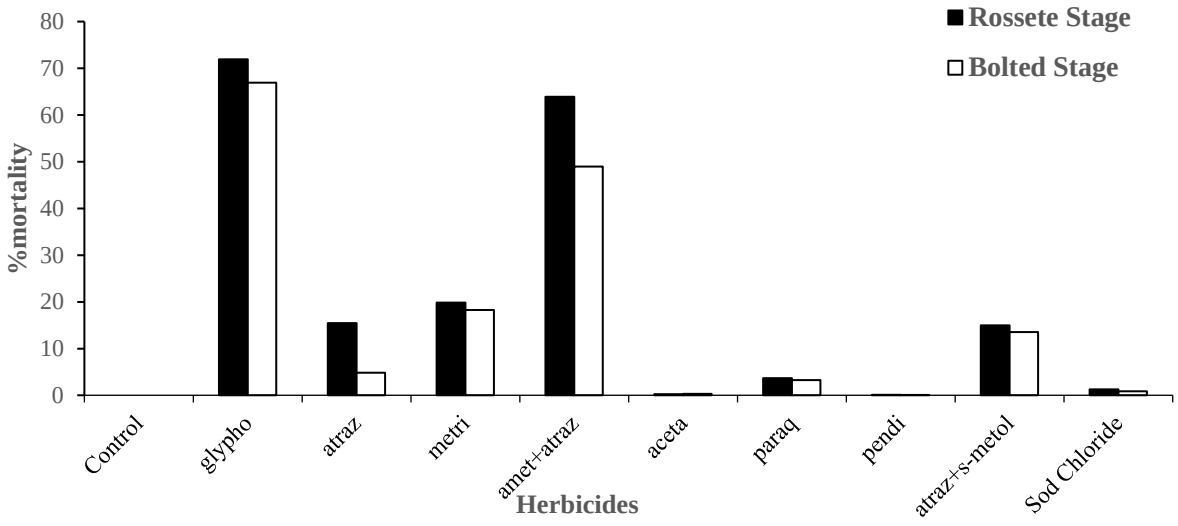

Figure 1: Average of four weeks mortality %age of Parthenium by herbicides at Rossete and Bolted stages

Parthenium weed mortality (%) at bolted stage

The physical characteristics of weed plants at bolted stage are given in Table 2. The table showed that plant population of bolted stage i.e., the plants which have emerged flowers was significantly different from each other being having differences among all the morphologically important features among the treatments. This may be attributed to the difference in availability of nutrition or space to the growing plants of parthenium.

The statistical analysis of the data (Table 3) depicted that different herbicidal treatments had significant effect on parthenium weed mortality in bolted stage during non-cropped conditions (8-96%). The glyphosate remained at top of list till fourth week and gave maximum mortality (96%) followed by ametryne+atrazine with 60% mortality and metribuzin & atrazine+s-metolachlor with 26% mortality. The results are in agreement with those of Krishna *et al*., (2007) who recorded 86 to 95% mortality at bolted stage with glyphosate, glufosinate, and trifloxysulfuron. It is also evident from the Table 3 that paraquat remained active (to a little extent) in first two weeks only whereas efficacy of atrazine+s-metolachlor increased with the passage of time and was maximum at 4WAS. The results in controlling weed by paraquat, atrazine, acetachlor, pendimethalene and by sodium chloride were very poor. Parthenium weed sprayed with glyphosate and atrazine, started getting yellowish, while sprayed with metribuzin, ametryne+atrazine, acetachlor, paraquat, pendimathalene, atrazine+s-metolachlor, sodium chloride showed the symptoms of leaves necrosis and low %age of mortality at 1WAS at bolted stages. The results exhibited that maximum weeds mortality (>96%) at 4 WAS, was recorded in glyphosate which was followed by ametryne+atrazine with 80% mortality at bolted stage.

Whereas no mortality was observed in cases of acetachlor, paraquat, pendimethalene and sodium chloride solution at 4 WAS. Although in control plot not even a single plant was observed dying. This may be due to absence of natural enemies (Javed *et al*., 2007) of this weed in experimental area or it could be due to of sprays of insecticides on other crops which directly or indirectly had hampered their population. The most important finding of this study is that acetachlore, paraquat, pendimethalane and sodium chloride solution control the rossete stage only when the plants were too small and were easy to be controlled. Afterword they were unable to control the weed at rossete or bolted stage.

The results of present study are completely in accordance with Singh *et al*., (2004) and Krishna *et al*., (2007) who recorded 86 to 95 % mortality of parthenium weed at bolted stage by use of glyphosate, glufosinate, and trifloxysulfuron. The results are also in lines of Khan *et al*., (2012) who revealed that the most effective treatments for parthenium weed control were glyphosate (91%) followed by atrazine+s-metolachlor (60%) and metribuzin (75%) at 4 WAT. They obtained 36.5% control with the use of atrazine. The results are also in agreement with of Mishra & Bhan (1995) and Muniappa *et al*., (1980) who claimed that atrazine up to 2.0 kg ha^{-1} failed to provide satisfactory control of bolted stage of parthenium weed.

The results are, however, against the findings of Khan *et al*., (2012) who recorded 30% mortality of blotted parthenium weed at 4 WAT by use of pendimathalene. The results are also in confront of Kaur *et al*., 2014 who reported that application of 15–20% solution of common salt (Sodium chloride) was effective in controlling parthenium. In present study a 5% solution of Sodium chloride was used which remained ineffective for the control of parthenium.

On an average of four weeks glyphosate performed the best with 67% mortality followed by ametryne+atrazine with 48% mortality. Whereas efficacy of all of the other herbicides remained very poor in controlling the bolted stage of parthenium (Fig.1). It has also become very clear that the herbicides which were effective at rossete stage were also effective in controlling the weeds at bolted stage. It is evident from the results of present study that the matured plants of parthenium weed can effectively be controlled with the use of glyphosate. Other herbicides used in the study failed to provide satisfactory control at bolted stage.

Regeneration of Parthenium weed after application of herbicides

Generally Parthenium plants regenerate after some period once its top is killed by an herbicide application (Dagar *et al*., 1976; Mahaderappa, 1999). Therefore, the treated plots were also observed for regeneration of parthenium after a period of two and then five months of application of herbicides.

It was observed that the plots treated with pendimathalene had lowest weed population after five months (Fig.2). This indicated that the pre-emergence herbicide pendimathalene has long lasting pronounced effect to control regeneration of parthenium even after a period of five months. This was followed by at atrazine+s-metolachlor and atrazine alone. The highest population of regenerated weeds were observed in plots treated with sodium chloride solution followed by untreated control and paraquat treated plots. These results are not in lines with those of Khan *et al*., (2012) who observed no regeneration in glyphosate and metribuzin treatments.

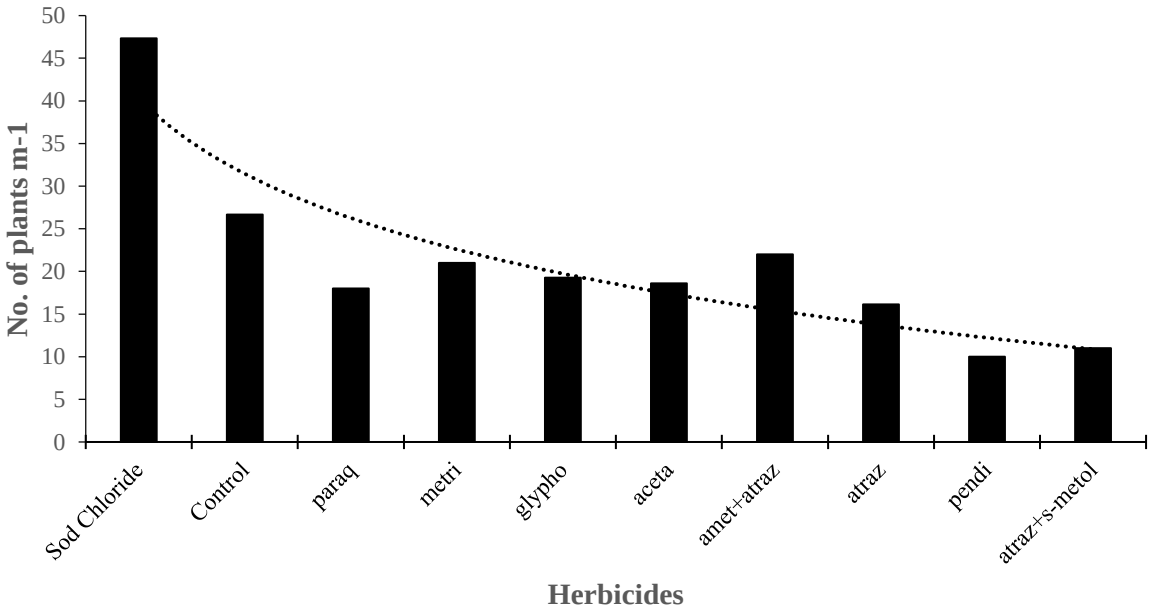

Figure: 2 Regeneration of parthenium weed after five months of herbicides application

Efficiency of herbicides in weed control

The percent Weed Control Efficiency (WCE) was determined according to equation 2. According to results (Fig. 3) at 4WAS glyphosate proved to be highly efficient followed by ametrin+atrazine, atrazine, atrazine+s-metolachlor, and metribuzin. The efficiency of other herbicides remained 0% which was statistically at par with control where there was also no control over weeds at 4WAS.

The results are partially in lines with those of Gaikwad *et al*., (2008) who achieved total eradication of Parthenium with the application of glyphosate (0.50 and 0.75%), atrazine (0.2 and 0.3%), 2,4-D (0.2 and 0.3%) and metribuzin (0.25 and 0.50%) at 30 days after spraying.

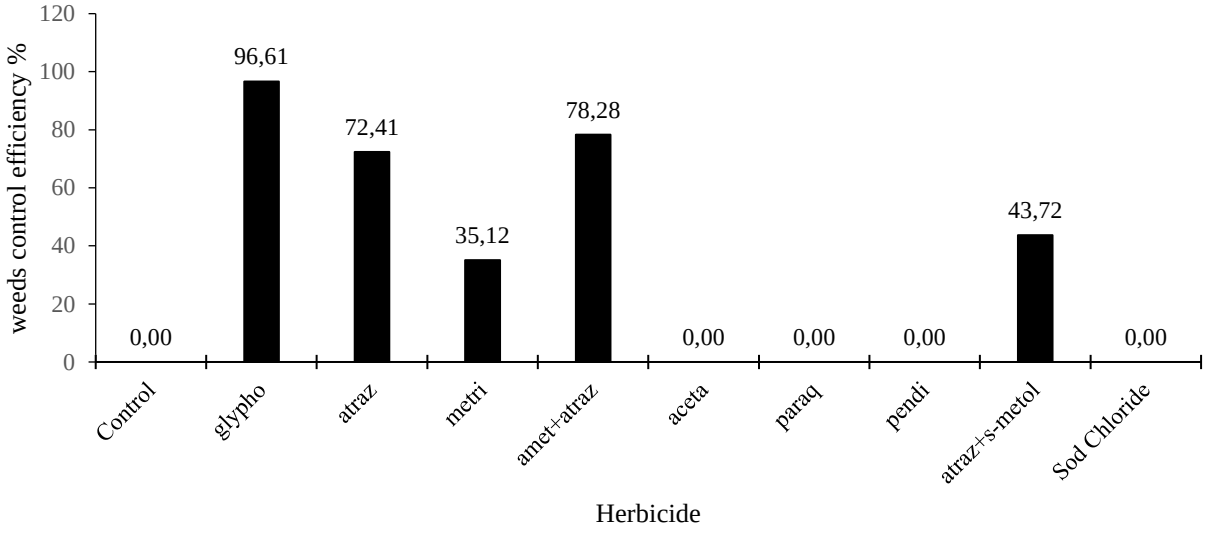

Figure 3: Percent Weed Control Efficiency four weeks after spray

CONCLUSION and RECOMMENDATION

The use of glyphosate and ametryne+trazine had shown promising results. All the herbicides tested gave control to more or lesser extent at rossete stage as compared to bolted stage. Therefore this stage of parthenium weed for herbicidal control is important. Parthenium weed control at rosette and bolted stages was highest with glyphosate (97% & 96%) followed by ametryne+atrazine (82% & 60%) at 4 weeks after spray by application of the post emergence herbicides. On the other hand among the pre-emergence herbicides pendimathaline and atrazine proved best with 10 & 16 plants m^{-2} respectively and inhibited the regeneration of weeds for a longer period of time of five months. It is recommended that parthenium weed can effectively be controlled with a mixture of glyphosate (non-selective) in pendimethalne or atrazine on wasteland, noncropped areas, along railway tracks, roadsides or water channels. Whereas in grassy land or in other valuable crops having narrow leaves the weeds can be controlled by use of or ametryne+atrazine in pendimethalne or atrazine at their recommended doses. It is also suggested that spread of parthenium weed should be prevented to avoid its huge threat to biodiversity and economic activities, such as agriculture development and tourism. Instant initiatives must be taken on emergency basis to educate the farmers and the general public on the methods to control Parthenium.

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