

(RESEARCH ARTICLE)



## Management of invasive alien weed (*Parthenium hysterophorus L*) through allelopathic and competitive plants and chemicals in Ethiopian agriculture

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### Abstract

The study conducted evaluated potential of extracts of selected plant species and chemicals on growth of *P. hysterophorus*. Since the impact of *parthenium* weed has become to the status of being an extensive economic and social problems of Ethiopian farmers. The experiment identified herbicidal potential of *Aregemon mexicana* leaf, stem and root extracts and 2, 4-D on seed germination and early seedling growths of *parthenium* at under field pot condition. Aqueous extracts of 6, 8 and 10 % (w/v), obtained from dry leaves, stem root of *Aregemon mexicana* plants and 0.3, 0.5 and 0.7 % of 2, 4-D herbicide. The overall germination, shoot and root growth means of *A. mexicana* extract and 2, 4-D, herbicidal treatments were significant ( $p < 0.0001$ ). Germination hinder by 2, 4-D and *A. mexicana* stem extracts, which inhibited the germination by (74.4 and 69.3 %) respectively from the control (82.2 %) and the lowest was *A. mexicana* root extract (54.8 %) in invitro. In the pot experiment the overall growth parameter means of plant extract and herbicidal treatments were significantly lower than the distilled water treated plants. *A. mexicana* stem resulted 100 % mortality at active growth stage of the *parthenium* plant, and 2, 4- D also showed best suppressed growth effects. *A. mexicana* leaf and root gave remarkable seed suppression of (93-94%) at 10 % concentration. Then we conclude that species like *A. Mexicana* and chemicals like 2, 4-D and are good candidates for future *parthenium* management. The Small holder farmers adopted mechanical control measures, while, it is most serious is not tackled by these farmers, integrate with other management options such as competitive plants and chemicals may appear to be satisfactory. However further research is required to progress our understanding of the interference mechanisms between *parthenium* and these species, on how to integrate with other management options and cost effectiveness of the methods.

**Keywords:** *Aregemon mexicana*; Herbicide; *Parthenium Hysterophorus*; Plant Extracts; 2; 4-D

### 1. Introduction

*Parthenium hysterophorus* is an aggressive weed of family Asteraceae. It is native to the subtropics of North and South America but now has invaded Asia, Africa and Australia during the last 50 years (Javaid *et al.*, 2007). Since its introduction in the mid-1950s, *p. hysterophorus* has achieved status as a major weed in India and Australia within a relatively short period (Dhileepan, 2009). *Parthenium* has become the worst weed since its discovery in Ethiopia at Dire Dawa in Harerge province of Eastern Ethiopia in 1988 (Tamado, 2001). Then a second major center of infestation was subsequently found near Desse, Wello and North eastern Ethiopia. *Parthenium* is know wide spread in Eastern Ethiopia, the central rift valley and neighboring localities of Afar Region, East Shewa, Aresi and Bale in Southern Ethiopia (Rezene *et al.*, 2005). Similarly, from Kemisse down to Shewa Robit, dense infestation was observed along the main road, village and waterways.

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**Figure 1** Map for distribution of parthenium in Ethiopia (Source: Map prepared by collaboration of USAID, Virginia State University, Excellence Research and development, EIAR, Haramaya and Mekelle University)

As invasive alien species *Parthenium* can seriously affect the integrity of ecosystem by changing community structures, ecosystem function through extinction or reduction of native species, and altering ecosystem services hence productivity (Taye, 2007). They may threaten native species as direct predators or competitors, as vectors of disease, or by modifying the habitat or altering native species dynamics. In the last decade, invasive alien species issues have been contentious globally due to their profound effects on agriculture, livestock and fisheries production; and also, their adverse effects on human and ecosystem health (Kuma, 2008). Biodiversity conservationists are currently pre-occupied with loss of native species and biological resources, and habitats because ecologically compromised habitats are easily colonized by invasive alien species, which are less preferred (Odeny and Lusweti, 2009).

*Parthenium* offers a major challenge to all attempts of control because of its high regeneration capacity, production of huge amount of seeds, high seed germinability and extreme adaptability to a wide range of ecosystems (APFISP, 2007). Several methods are being recommended in suppressing the growth of *parthenium* but none of them appeared to be satisfactory, as each method tried during the period from mid-sixties to eights suffered with one or the other limitations such as inefficiency, high cost, impracticability, polluting the environment, temporary relief. The various approaches employed so far include manual, chemical, biological and integrated methods (Wahab, 2005).

Recently some studies carried out have shown very encouraging results regarding the use of allelopathic plants in *Parthenium* management. Javaid *et al.*, (2005) and Anjum *et al.*, (2005) showed that the allelopathic grasses *Imperata cylindrica*, *Dicanthium annulatum*, *Cenchrus pennisetiformis* and *Sorghum halepense*. There are hundreds of secondary metabolites in the plant kingdom and many are known to be phytotoxic (Einhelling, 2002). Allelopathic effects of these compounds are often observed to occur early in the life cycle, causing inhibition of seed germination and/or seedling growth. The compounds exhibit a wide range of mechanisms of action, on DNA, photosynthetic and mitochondrial function, and phytohormone activity, ion uptake and water balance. In the course of an extensive survey carried out to assess the distribution of *Parthenium* in India in the years 1987-1990 (Aneja, 1991), it was observed that *Parthenium* does not grow in proximity to particular plant species. This suggests a natural antagonism of these species towards *Parthenium* (Knox *et al.*, 2010).

Well known herbicides such 2, 4-D sodium salt, arsenate compounds, paraquat, bromacil, glyphosate and sodium chloride are reported to kill the standing *parthenium* populations (Wahab, 2005). According to (Reddy *et al.*, 2007). Halosulfuron, MSMA, bromoxynil, 2, 4-D, and flumioxazin controlled 58 to 90 % rosette *R. parthenium* at 3 weeks after treatment. *R. parthenium* control with all other post herbicides was less than 38%. At bolted-stage, glyphosate, glufosinate and trifloxysulfuron controlled 86 to 95% *R. parthenium* and control was 61 to 70 % with chlorimuron,

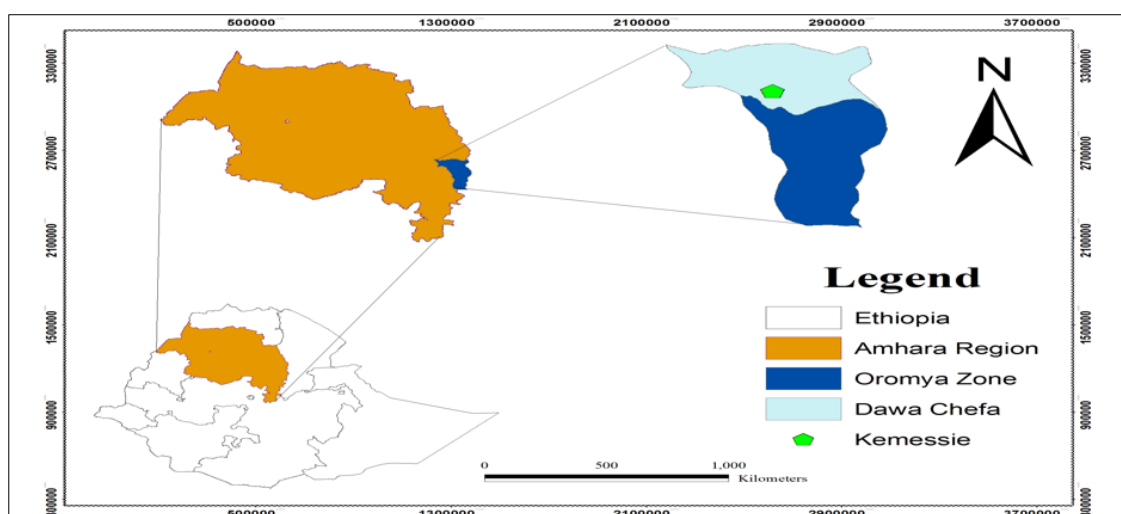
halosulfuron and 2, 4-D. In Ethiopia, spraying 2kg/ha of 2 4 D sodium salt or 2L/ha MCPPA in 400L of water were found effective to control *parthenium* at seedling stage (Taye, 2002).

However, the small holder farmers in the study area adopted mechanical control measures like slashing in farm lands; the problem in wastelands, plantation, irrigation and drainage ditches, fence lines, poorly managed crop fields, roadside, park and grass land where it is most serious is not tackled by these farmers. Management efforts including competitive plants will at best delay widespread processes. Hence, study conducted on suppression of this invasive weed is of paramount importance for the resource poor farmer mainly and different stakeholder in terms of giving feasible solution to the existing problem. In addition, it could help to fill the gap of information for those concerned, to study controlling methods in other parts of the country.

## 2. Material and methods

### 2.1 Site description

The field study was conducted in Amhara Region, Oromia Zone, Dawa Chefa Woreda in central part of Kemisse town, which is the zonal capital of Oromia zone. Geographically it is located 10°43'32" N latitude and 39°52'52" E longitude. The altitude of the area ranges from 600 to 3200 m above sea level and the mean annual rainfall ranges from 600-1100 mm. The texture of soil of area at 0-50 cm depth is loamy sand near the hill and loam at the alluvial deposit (downstream of the catchments) and sandy loam at 50-100 cm depth on both locations. The population of the Woreda is estimate a total of 147000 residents (Bureau of Agriculture, 2000). The invitro test was conducted in Meklle University.



**Figure 2** Map of Ethiopia and the study site Kemisse

### 2.2 Experimental procedure

For *A. Mexican*, leaf, stem and root parts matured plants were collected from heavily infested range land by Aregemon mexicana around Borkena valley near to Kemisse and the parts were carefully separated. After thorough washing with water, it was kept to dry in light shade. Then prior to extraction the plant parts were kept to dry well to its appropriate moisture level at the laboratory of Leather and Leather product Institute of Maazama oils in Addis Ababa. In most cases the moisture content of the material was below 12% (personal communication with chemists). The samples were chopped into pieces using grinder for extraction. Each sample (10g) were weighted using aluminum tray and transferred to a juice maker, distilled with 100ml per sample and run to extract for 10 minutes by using blender mode (Shafique *et al*; 2005) to obtain a 10% (w/v) aqueous extract, 10 g crushed dry leaf, stem and root material *A. Mexican* was soaked in 100 ml).

The whole materials were then transferred into flask and placed on a shaker for 10 hours. The extracts were allowed to settle for 1 hrs before filtration. Then (95 %) ethanol is added to the filtrate to avoid the growth of fungus. Further final dilutions of 8 %, and 6 % (Shafique *et al*; 2005), were prepared by adding appropriate quantity of distilled water to the 10 % stock solution, then the dilutions were mixed by shaking for certain minuets and stored at 4°C. For 2 4 D herbicide dose level 0.3, 0.5 % and 0.7 % were taken considering literature on herbicides such as glyphosate (0.75-1.00 %),

metribuzin (0.3-0.5 %), 2 4 D (0.5 %) have given satisfactory control of the weed under diverse agro climatic conditions (Yaduraju *et al.*, 2005).

### 2.3 Collection of *parthenium* seed

*Parthenium* seeds were collected from Ambo weed science research center. The seeds were harvested in plastic bags. Then by considering its maturity the first invitro test were done in Mekkle University at the phyto pathology laboratory using these seeds. However, only 15% of the seeds germinated. Then another *parthenium* seeds were collected from Kemisse, Alamata, Adigudom and mekkle. The seeds were dried in shade area and the germination percent of each seed from four sites were checked. Seeds which were collected from mekkle germinated around 90 %, this might be due to viability of the seed related to time of collection, so these seeds were used for the final experiment.

### 2.4 Treatment application

The top of paper method was used for germination test of *Parthenium* seed. Petridish (9 x 18cm size) were washed with 70% ethanol and *cleaned* three times with distilled water and incubated until it dries for Invitro test. The Petridish were arranged in completely randomized designed design with three replications. The moistened capacity of filter paper was checked by distilled water, the filter paper lined in each sterilized Petridish moistened with 1.2 ml of different extracts and thirty seeds of *parthenium* in each Petridish were arranged on the top of moistened paper and placed in 23°C temperature. The control treated similarly with distilled water and the plates were regularly checked for moisture. The solutions of different extracts and chemicals were applied to each plate ever two days. *Parthenium* seeds were seeded on 0.125 m<sup>2</sup> large plastic bucket seed bed for transplanting purpose.

Thus, another pots (27 x 25cm size) were filled with 2 kg of sandy loam, 3 kg of decomposed forest soil and 3 kg of black top soil from Dewa Chefa nursery site under natural condition. When the seedling attended three to four true leaves on, two *parthenium* seedlings in each pot were transplanted to minimize the risk of germination failure on the above pots. The seedlings were watered every two days interval starting from sowing up to the stage of maturity. Finally, when the seedling was reached at actively growth stage. By taking a single plant checked the amount of solutions that well moistened whole area of the leaf using distilled water. Then one plant was well moistened by 40 ml treatment solution, so for two *parthenium* seedling in a single pot 80ml extract were sprayed. Similarly, the second round spray were carried out after three weeks of the first spray at flowered plants.



**Figure 3** First round spray at actively growth stage

### 2.5 Data collection

The number of seeds exhibiting radicle and plumule emergence were recorded at 3 days interval during the germination test period of 15 days. In addition, shoot and root length were measured by taking 10 randomly selected plants for each Petridish for Invitro test. For natural field pot experiment plant height were measured from pot ground level to the top of the shoot. The numbers of dead plant were recorded for two months after spray to know the mortality date of the plant after spray. In addition, the spikelet that drop every day at maturity were recorded for the last 20 days of maturity since the plant has characteristics of some spikelet's drop before the whole plant fully matured and finally when the whole plant fully matured the whole spikelet was counted. The biomass was taken by measuring above ground whole weight of the plant. At end the seed yield were measured by golden Bean balance.

## 2.6 Statistical analysis

The collected row data's normality was checked, and then transformation performed. After data transformation for all growth parameters of invitro and field pot data the analysis of variance, coefficient of variation and comparisons of treatments means were done by using SAS version 9 computer software, at probability significance level of  $\alpha=0.05$  (SAS Institute, 202).

## 3. Results and discussion

### 3.1 Invitro test

Analysis of invitro test data showed that all treatments (plant extract and herbicides) had significant ( $P<0.0001$ ) inhibition effect on germination, shoot and root growth of *parthenium* (Table 1). The overall seed germination means of plant extract and herbicidal treatments were significantly lower than the water treated (controls), the highest germination suppression was and 2, 4-D, and *A. mexicana* stem extracts; and the lowest was *A. mexicana* root extract. The findings indicated that the effective treatment in suppressing germination was 2, 4-D herbicide, where, germination was reduced by (74.5%) compared to control (82.2%). Moreover *A. mexicana* stem reduced germination by (73%) compared to control (Table 1). The effect may probably due potential disrupting of chemicals on the plant's ability to germination.

The above results indicated that allelopathic effect of various plant extracts from different parts and chemicals appeared to be different depending on the plant species and chemicals. Such difference may be related to specific allelopathic compounds being produced in each plant parts. Singh *et al.*, (2005) studied the herbicidal effect of volatile oils from leaves of *E. citriodora* against the noxious weed *P. hysterophorus* and found that a concentration of 5.0 nL ml<sup>-1</sup>Eucalyptus oil completely inhibited the germination. Uremis *et al.*, (2005); Anjum, 2006) have reported significant suppression of *Physalis angulata* L., a problem weed in maize, cotton and soybean fields in Turkey, by aqueous extracts.

**Table 1** Effect of plant extracts and chemicals on germination shoot and root growth

Plant extracts & chemicals	Germination (%)	Shoot growth (cm)	Root growth (cm)
Control	9.084 <sup>a</sup>	1.550 <sup>a</sup>	0.4567 <sup>a</sup>
<i>A. mexicana</i> leaf	4.850 <sup>bc</sup>	0.122 <sup>bc</sup>	0.0667 <sup>bc</sup>
<i>A. mexicana</i> stem	3.497 <sup>e</sup>	0.244 <sup>b</sup>	0.1333 <sup>b</sup>
<i>A. mexicana</i> root	5.257 <sup>b</sup>	0.000 <sup>c</sup>	0.0000 <sup>c</sup>
2 4 D	2.788 <sup>f</sup>	0.000 <sup>c</sup>	0.0000 <sup>c</sup>
LSD (0.05)	0.7072	0.1711	0.0923
<i>P-Value</i>	***	***	***
R <sup>2</sup>	0.956	0.913	0.806

Shoot and root growth was highly suppressed by all applied plant extract and chemical. The damage was most pronounced by *A. mexicana* root and 2 4 D, each which totally suppressed shoot and root growth (Table 1). The reductions in seedlings root and shoot length may be attributed to the reduced rate of cell division and cell elongation due to the presence of allelochemicals in the aqueous extracts which ultimately reduced elongation. Generally, the findings revealed that all tested herbicide inhibit germination and early growth, the effect was most pronounced by 2, 4-D chemicals, followed by *A. mexicana* plant extracts compared to control (Distilled water) treated seeds.

### 3.2 Pot experiment under natural condition

Analysis of the pot experiment data revealed that the tested *A. mexicana* plant extracts and chemicals had significantly ( $P<0.0001$ ) reduced biomass, harvesting index seed yield, number of spikelet's per plant and increased mortality percentage of *parthenium* plant (Table 2). Moreover, effect of different concentration was significantly varied in their effects on the growth parameters of *parthenium*. The overall growth parameter means of plant extract and herbicidal treatments were lower than the water treated (controls) plants. 2, 4- D at all concentration level and *A. mexicana* stem

extracts concentration resulted 100% mortality at active growth stage of the *parthenium* plant. The six above treatment had the maximum potential to inhibit the different growth parameters of *parthenium* weed.

**Table 2** Pot experiment under natural condition

Herbicides	Concentration	Biomass	Harvesting index	Seed yield	Spikelet number
Control	0%	49.17 <sup>a</sup>	4.992 <sup>a</sup>	2.460 <sup>a</sup>	983.7 <sup>a</sup>
	8%	0.00 <sup>d</sup>	0.00 <sup>h</sup>	0.00 <sup>g</sup>	0.00 <sup>g</sup>
	10%	0.00 <sup>d</sup>	0.00 <sup>h</sup>	0.00 <sup>g</sup>	0.00 <sup>g</sup>
<i>A. mexicana leaf</i>	6%	31.00 <sup>b</sup>	4.283 <sup>bc</sup>	1.330 <sup>b</sup>	531.7 <sup>cde</sup>
	8%	25.83 <sup>bc</sup>	2.878 <sup>bcd</sup>	0.737 <sup>de</sup>	294.3 <sup>de</sup>
	10%	6.00 <sup>bcd</sup>	0.797 <sup>efgh</sup>	0.143 <sup>g</sup>	57.2 <sup>bc</sup>
<i>A. mexicana stem</i>	6%	13.33 <sup>cd</sup>	2.396 <sup>cdef</sup>	0.413 <sup>efg</sup>	164.0 <sup>efgh</sup>
	8%	0.00 <sup>d</sup>	0.00 <sup>h</sup>	0.00 <sup>g</sup>	0.00 <sup>g</sup>
	10%	0.00 <sup>d</sup>	0.00 <sup>h</sup>	0.00 <sup>g</sup>	0.00 <sup>g</sup>
<i>A. mexicana root</i>	6%	33.17 <sup>b</sup>	4.590 <sup>b</sup>	1.488 <sup>b</sup>	594.3 <sup>bc</sup>
	8%	28.67 <sup>b</sup>	3.204 <sup>cd</sup>	0.955 <sup>cd</sup>	381.7 <sup>cd</sup>
	10%	6.50 <sup>bcd</sup>	0.815 <sup>efgh</sup>	0.165 <sup>g</sup>	65.7 <sup>b</sup>
2 4 D	0.30%	0.00 <sup>d</sup>	0.00 <sup>h</sup>	0.00 <sup>g</sup>	0.00 <sup>g</sup>
	0.50%	0.00 <sup>d</sup>	0.00 <sup>h</sup>	0.00 <sup>g</sup>	0.00 <sup>g</sup>
	0.70%	0.00 <sup>d</sup>	0.00 <sup>h</sup>	0.00 <sup>g</sup>	0.00 <sup>g</sup>
LSD 0.05%		6.5463	0.883	0.219	87.545
CV (%)		37.6	39.1	33.7	33.7
<i>P-Value</i>		***	***	***	***
R <sup>2</sup>		0.938	0.927	0.964	0.964

The highest biomass suppression was *A. mexicana* stem and modest suppression was *A. mexicana* root extract. The findings revealed that at 10 % concentration *A. mexicana leaf and root* extracts remarkably suppressed biomass of *parthenium* by (87.8 and 86.7%) from the control (49.17gm per plant); followed by *A. mexicana stem* at 6 % was also providing effective reduction on biomass by 73%) compared from the control (Table 2). According to (Shafique *et al.*, 2005) reported that aqueous extracts of *A. indica* leaf of low concentrations were least toxic exhibiting not strong impact on biomass. At 10 % concentration *A. mexicana leaf and root* extracts remarkably suppressed *parthenium* seed production by (94.2 and 93.2 %) respectively from the control (2.46 gm per plant) (Table 2). The concomitant decrease in seed yield of the plant may be explained by the fact that as less shoot and root fresh yield was produced by the plant, less assimilates were partitioned to the shoot portion and resulted in less photosynthesis, thereby decrease seed yield. This may also be associated to the lower number of branches per plant, number of capsules per plant, and number of seeds weight per capsule, which thus contribute to reduced seed yield. The mode of action might be by inhibiting respiration energy then Chlorosis and necrosis cause loss of chlorophyll from leaves. Cause photo bleaching of chloroplasts and allelochemicals. Inhibition of photosynthetic process depletes food reserves, and then proteins and other compounds can serve as respiratory substrates (Knox *et al.*, 2010).

Among tested treatment *A. mexicana* root and leaf extract at 10 % reduced by (4.17 and 4.2) the harvesting index respectively compared to control 4.99 (Table 2). Followed by, *A. mexicana stem* at 6 % reduced the harvesting index by (2.6) compared to control. This could be most likely due to assimilation and utilization of growth factors after extract application might have disfavor the movement of nutrients in the plant and stressed growth of productive tillers this result decrease in the harvesting index. At 10 % *A. mexicana leaf and A. mexicana root*, and at 8% *A. mexicana stem*, reduced the number of spikelet's per plant by (927, 916, 717) respectively compared to control 983. This could be due

to the development of short stature, lower number of leaves as well as lower number of branches resulted from spray of plant extract might have an effect on flower development and finally on the number of spikelet's per plant.

The survival existence means of plant extracts after spray were significantly lower than the water treated (controls). In case of *A. mexicana* stem treated plants, the plant died within 5 days and 6 days respectively (Table 2). Effects of herbicides were monitored till all the plants in herbicidal treatment are died. Since the plants did not regenerate after death that also increases the importance of these herbicides for their selection against *parthenium*. This might be resulted due to more and vigorous allelopathic potential of plant that disfavor regeneration of *parthenium* weed.



**Figure 4** *Parthenium* plants sprayed with *A. mexicana* stem

The present study results showed consistence effect at invitro and pot experiments. Interestingly both the invitro and pot result realizes the observation of poor *parthenium* density near exotic tree plantation such as *A. mexicana* and waste land weed like *A. mexicana*. So allelochemicals release from living dead plant materials of thesis tree and weeds accumulate in the soil beneath adversely affect the germination and growth of *parthenium*. The present study also revealed that the possibility of using the allelochemicals directly or as a structural lead for the discovery and development of environmentally friendly bioherbicide and chemicals to control one of noxious weeds of *P. hysterophorus* in the country.

#### 4. Conclusion

The study identified that germination, shoot and root growth of plant extract and chemical treatments were significantly lower than the control (distilled water). The invitro findings revealed that the tested plant extract and chemicals suppressed the germination, shoot and root growth, the effect was most pronounced by 2, 4-D chemicals, followed by *A. mexicana* plant extracts compared to control (Distilled water) treated seeds. Further the pot study revealed that 2, 4-D, and extracts from *A. mexicana* stem at 8 and 10 % concentrations resulted 100 % mortality at actively growth stage of the *parthenium* plant. In addition, the plant extracts indicated the highest suppressions on different growth parameters and seed production of *parthenium* plant. From the results of the present investigations we conclude; that species like *A. mexicana* some chemicals like 2 4 D, are good candidates for future *P. hysterophorus* management.

#### Compliance with ethical standards

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