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Effect of urea and common salt (NaCl) treated glyphosate on parthenium weed (*Parthenium hysterophorus* L.) at Western Hararghe zone, Ethiopia

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Field experiments were conducted from 2008 to 2011, at western Hararghe zone, Eastern Ethiopia to evaluate the effect of urea and common salt treated glyphosate on parthenium weed (*Parthenium hysterophorus*). The experiments were arranged in randomized complete block design with five replications. Glyphosate herbicide at 3 L/ha was applied with different rates (0, 50, 100 and 150 ml) of urea and common salt. From the pooled analysis of variance over years it was observed that there existed a significant difference among treatments ($p<0.05$) in which the total population of parthenium weed mortality was noted at 25 days after applications across years for 3000 ml of glyphosate treated with 150 ml of urea and 150 ml of common salt. Results from this experiment showed that treating 3000 ml of glyphosate with 150 ml of urea and 150 ml of common salt solutions and spraying at 6 to 8 leaves stages resulted in complete mortality of parthenium weed in short period of time by increasing the phytotoxicity of this herbicide. While spraying this solution at 50 and 75% flowering stages showed poor mortality rates on this weed. This study also elucidated the complete change of parthenium infested plots into soft weed species that suppresses the re-emergency of this noxious weed. This helps in reducing the soil seed bank of parthenium weed, thus its population declines over successive years. This finding helps in reducing the rate and frequency of glyphosate application in conservation tillage and plantation crops like coffee and fruit farms, thus managing cost of parthenium weed can be significantly reduced.

Key words: *Parthenium hysterophorus,* glyphosate, mortality rate, phytotoxicity, soil seed bank.

INTRODUCTION

Parthenium hysterophorus L. (Asteraceae), commonly known as parthenium weed, carrot weed or congress grass, is an aggressive annual herb native to tropical and subtropical America. It has become invasive in North America, South America, the Caribbean, Africa, Asia and Australia (Navie et al., 1996). In many introduced regions (e.g. Australia and India), *P. hysterophorus* has posed serious threats to crop production, natural biodiversity and human health, because of its prolific growth, rapid spreading and production of toxic allelochemicals (Chippendale and Panetta, 1994; Evans, 1997).

Parthenium is a major new agricultural weed in Ethiopia (Tamado et al., 2002; Taye et al., 2004 and Mohammed, 2010). It is believed to have been introduced into Ethiopia in 1970s during the Ethio-Somali war and has become a serious weed both in arable and grazing lands (Berhanu,

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1992; Fasil, 1994; Frew et al., 1996; Tamado et al., 2002). Parthenium can cause severe crop yield losses. In India, a crops yield reduction ranged between 40% up to 90% (Khosla and Sobti, 1981).

Presently the major maize, sorghum, tef, coffee, spice and wheat growing regions in Ethiopia, for example, are being infested by parthenium weed.

In Eastern Ethiopia, parthenium is the second most frequent weed (54%) after *Digitaria abyssinica* (63%) (Tamado and Milberg, 2000) and sorghum grain yield was reduced from 40 to 97% depending on the year and the location (Tamado et al., 2002). Other than direct competition with crops, parthenium poses allelopathic effect on different crops and other plants (Mersie and Singh, 1988; Evans, 1997; Wakjira et al., 2005; Adkins and Naive, 2006). Tadele (2002), Wakjira et al. (2005) and Wakjira (2009) studied the allelopathic effect of parthenium weed in Ethiopia on tef, lettuce and onion, respectively. It was found that this weed has a significant effect on germination capacity and seedling growth of these crops. This in turn has a significant yield reduction effect on these economically important crops. Thus, the spread of parthenium in Ethiopia would be a bigger risk to the expansion and sustainable production of many crops in the country which can potentially interfere with the food self-sufficiency and food security program envisioned (Wakjira, 2009).

Physical control methods of parthenium include manual weeding before flowering, or after flowering leads to increased seed dispersal and germination. Chemical control methods may lead to herbicide resistance by the weed (Adkins et al., 1997; Njoroge, 1991) in addition to their serious ecological problems like groundwater contamination and consequently leading to human health hazards.

Biological control methods like release of insect enemies and rust fungi also have limitations (Taye et al., 2004; Bekeko et al., 2012).

Management of this weed imparts huge economic burden on the countries where it has aggressively invaded (Review of progress towards implementation of Parthenium weed strategic plan 2006-2007). Moreover, allelopathic effect of *P. hysterophorus* on other species makes it difficult for the weed management strategies (Mahadevappa, 1997 and Wakjira et al., 2005). As no single method of control has been successful, an integrated approach is suggested for its effective control (Mahadevappa, 1997; Bekeko et al., 2012).

Although the agricultural methods have been developed for parthenium control has limitation effect. For instance, removing parthenium by slashing or mowing as soon as or before it flowers though it prevents seed production results in regeneration of new shoots leading to a repeated operation. Manual and mechanical uprooting also prove to be of limited value owing to enormous amount of labour and time required (Berhanu, 1992) and vulnerability of workers engaged in the operation to the various kinds of allergies caused by the weed (Kololgi et al., 1997). Chemical control, though effective, is temporary and needs repeated application, besides have problems of residues, selectivity, availability and cost of application (Singh, 1997).

Different chemicals are used in management of parthenium weed such as bromacil, diuron or terbacil, at 1.5 kg/ha (Kanchan and Jaychandra, 1980), diquat at 0.5 kg/ha were reported to effectively control parthenium weed. Spraying 2 kg/ha of 2,4-D sodium salt or 2 l/ha of MCPA were effective to control parthenium at the seedling stage (Bhan et al., 1997). Bhan et al.(1997) also reported 1 to 2% solution of glyphosate with or without surfactant and Metribuzin at 1 to 2 kg/ha gave 90 to 98% visual toxicity on parthenium and advocated the supremacy of chemical control over other control measures on the bases of quick relief, time saving and cost effectiveness.

Chemical pollution of the environment, enormous cost, danger of toxicity to non-target plants, necessity of the chemical application in non-agricultural areas, rapidity of re-invasion of treated areas soon after the effect is diminished are the draw backs of chemical control (Singh, 1997). Similarly, Bhan et al. (1997) reported that chemical control alone is not justifiable as the effect of herbicide will always be of temporary nature and repeated operations are required which will not remain cost effective.

Nevertheless, a number of herbicides were registered to control parthenium (Navie et al., 1996), but for the smallholder farmers of eastern Ethiopia, where the average farm size is 0.65 ha (CSA 2002), use of herbicides to control parthenium is not economically feasible. Instead, parthenium is currently controlled mainly through hand hoeing and hand pulling and sometimes by interrow oxen cultivation. Hoeing by hand involves effort and time (Tamado et al., 2002). Uses of additives such as urea, oils, and common salt in glyphosate help in increasing the efficacy and the phytotoxicity of the herbicide which help overcome the effect of noxious weed species including parthenium weed and increase farmers' productivity (Rao, 1979).

As parthenium is a weed of wasteland, a common man will never invest his money in this venture. Moreover, plants suppressed by chemicals have been observed to regenerate after remaining dormant for a few days (Adkins et al., 2006). Chemical treatment can only kill existing population at the given sites but can not prevent the entry of the seeds from neighbouring places. Use of additives help in increasing phytotoxicity of herbicides through enhancing absorption and translocation of herbicides leading to long term management of weeds by changing the weed spectrum into soft weed species including parthenium weed (Rao, 1979).

Therefore, developing cost effective ways of managing plantation crops such as coffee and fruit farms remains the crux of the matter. So far, very limited information

Table 1. Mortality percentage of parthenium by glyphosate (3l/ha) tank mixed with urea and common salt at Chiro Campus, at 25, 35, 45 and 55 days observation.

Treatments	25 days	35 days	45 days	55 days
Gly.+ 0 ml of urea/ salt	15	35	20	25
Gly.+ 50 ml of urea/Salt	25	52	38	48
Gly.+ 100 ml of urea / salt	40	84	64	75
Gly.+ 150 ml of urea/ salt	55	72	88	94
CV	8.5	12.2	7.8	8.2
LSD	4.8	8.7	3.4	5.3

Table 2. Effect of glyphosate on parthenium weed leaves discoloration at 25, 35 and 55 days after spraying.

Growth stage (% flowering)	Percentage of leaf discoloration at 25 days (% color change)	35 days	55 days	Total
0	85	15	-	100
25	25	45	5	75
50	15	20	10	45
75	5	15	8	28

exists in Ethiopia regarding parthenium weed parthenium weed for smallholder farmers' field and management through chemicals. Except the investigation made by Tamado and Tamado (2004) using 2.4-D in sorghum fields no experiments were conducted using additives to increase phytotoxicity of glyphosate in controlling parthenium weed in Ethiopia. Therefore, the objective of this experiment was to evaluate effect of glyphosate tank mixed with urea and common salt (NaCl) solutions on parthenium weed at western Hararghe zone, Oromia Regional State, eastern Ethiopia.

MATERIALS AND METHODS

Description of the study area

West Hararghe is located between 7° 55' N to 9° 33' N latitude and 40° 10' E to 41° 39'E longitude. The major crops grown in the study area are sorghum, maize, chat, field beans, potato and tef. The area is characterized by Charcher Highlands having undulating slopes and mountainous in topography. The mean annual rainfall ranges from 850 to 1200 mm/year with minimum and maximum temperatures of 12 and 27°C, respectively.

Experimental design and procedures

Field experiments were conducted to assess the efficacy of Glyphosate tank mixture with urea and common salt solution against parthenium weed (*P. hysterophorus* L.) at different growth stages in non-cropped area of Chiro Campus, during summer 2008 to 2011. The experiments were arranged in Randomized Complete Block Design (RCBD) with five replications. A plot size of 6 m×6 m (36 m^2) was used in this experiment (Gomez and Gomez, 1984). 3 L/ha of glyphosate was tank mixed with different rates of urea and common salt solution viz, 0 g of urea and 0 g of common salt, 50 ml of urea and 50 ml of salt, 100 ml of urea and 100 ml of salt, and 150 ml of urea and 150 ml of common salt solutions were sprayed to parthenium weed respectively at 6 to 8 leaves, 25% flowering, 50% flowering, and 75% flowering stages using knapsack sprayer (CP 15) on 10 April 2008, 5 May 2009, June 15, 2010 and July 10, 2011 for four years.

Data on mortality percentage of parthenium weed was taken every ten days for two months and percentage of weed spectrum shifted to another weed species were noted on the experimental plots and subjected to analysis of variance using SAS package (Table 1).

RESULTS

Parthenium weed control at different growth stages

The statistical analysis of the data showed that Glyphosate tank mixed with different concentration of urea and common salt solutions had significant effect on parthenium weed mortality under field conditions (p=0.05). The treatments provided 32 to 89% mortality at two weeks after treatment (WAT) and 43 to 96% mortality at 4 WAT (Table 2).

This result exhibited that maximum parthenium weed mortality (96%) at 4 WAT was recorded in glyphosate treated with 150 ml of urea and 150 ml of common salt solutions which was followed by 100 ml of urea and 100 ml of common salt solutions on treated plots scoring 80% mortality (Table 3).

Effects of the solutions on parthenium weed leaf discoloration

Spraying glyphosate treated with 100 ml of urea and 100 ml of common salt solution and 150 ml of urea and 150

Table 3. Field observation on mortality rate of parthenium weed due to effects of the treatments at different growth stages of parthenium weed.

Growth stage	Effect observed 35 days after spraying	Remark
6-8 leaf stage	96	Very rapid
25% flowering	80	Rapid
50% flowering	25	Fair
75% flowering	15	Poor

Table 4. Ground cover shift into different weed species at Chiro. 2008- 2011 after mortality of parthenium weed.

No	Dominant weed species /family	Mean number of seedlings/4 m^2			
		April	May	June	July
1	*Amaranthus hybridatus*	56	68	48	22
2	*Parthenium hysterophorus*	32	14	8	5
3	*Argemonium mexicana*	8	12	24	38
4	*Cynodon dactylon*	42	52	52	52
5	*Bidens pilosa*	46	68	34	12
6	*Digitaria abyssinica*	28	42	42	42
7	*Rumex abyssinica*	14	24	18	18
8	*Commelina bengalensis*	6	12	12	12
9	*Datuta stramonium*	4	10	10	10
10	*Galensoga palviflora*	54	54	28	10
11	*Guziotia scabra*	3	11	11	11
12	*Killinga bulbosa*	18	22	22	22

ml common salt solutions, caused 55 and 85% parthenium mortality, respectively at 0% flowering stage or 6 to 8 leaves stage 25 days after treatments (Table 2). While spraying these solutions at 25, 50 and 75% flowering stages had no significant effect on parthenium mortality at 25, 35 and 55 days after treatments. Spraying the solutions at 6 to 8 leaves stage caused completely (100% mortality) control of parthenium weed at 35 days after treatments (Table 2).

It appeared that spraying this mixture at the 6 to 8 leaves stage of parthenium weed and at 25% flowering stages, resulting in 96 and 80% weed mortality, respectively (Table 3). Observation on the rate of parthenium weed mortality, showed the existence of significant differences among treatments at different growth stages of this aggressive weed over years in which maximum mortality was noted in 2011 (Table 3).

Change on the weed spectrum (ground cover shift) in the treated plots

The experimental plots treated with the glyphosate solution had caused rapid death of parthenium weed. After the mortality of parthenium weed in the experimental plots it appeared that new weed species had emerged in which the population of *Amaranthus hybridatus* and *Bidens pilosa*, respectively reached 68% in the month of May (Table 4). New weed species such as *Amaranthus hybridatus, Bidens pilosa, Cynodon dactylon, Digitaria abyssinica* and *Galensoga palviflora* emerged dominantly in the treated plots after the death of parthenium weed. In addition another new weed species such as Rumex, Commelina, and Argemonium had emerged in these plots (Table 4). Generally it was observed that in the treated plots new weed species appeared 30 days after glyphosate tank mixture treatment which had resulted into complete change of the weed spectrum into soft weeds in the periods of April to July (Table 4).

DISCUSSION

The results indicated that parthenium plants can effectively be controlled with glyphosate tank mixed with low concentrations of urea and common salt (Table 1). So far studies conducted on management of this weed using other herbicides did not provide satisfactory control when applied at bolted stage, even high rates of herbicides failed to control parthenium weed. Singh et al., (2004) reported that 2,4-D, atrazine, metribuzin,

metsulfuron, chlorimuron, and glufosinate failed to control parthenium weed, while glyphosate at 2.7 and 5.4 kg ha^{-1} provided greater than 95% control of bolted plants at 18 WAT. Similarly Walia et al. (2002) reported that other herbicides with the exception of glyphosate applied to well establish parthenium weed plants did not provide satisfactory control.

Therefore, this finding is supported by the investigation made by Singh et al. (2004) and Walia et al. (2002). The rapid mortality of parthenium weed was due to enhanced phytotoxicity effect of the herbicide against this weed. Rao (1979) reported that the phytotoxicity of glyphosate can be increased by adding urea, oils and salt solutions to the glyphosate solution. In this study also lower concentrations of urea and common salt enhanced the phytotoxicity level of glyphosate on parthenium weed.

Foliar application of urea and micro nutrients like Na and Cl helps in rapid absorption and translocation of glyphosate so that faster effect is noticed in rapid leaf discoloration or chlorosis leading to decrement of the rate of photosynthesis in parthenium weed and rapid oxidation of the photo assimilate reserved in the leaves and stem of this weed. Some variations in parthenium weed control with treatments of treated glyphosate were recorded in 2008, 2009 and 2010 compared to 2011. This might have been partly due to differences in weather conditions among the years and growth stages of this weed.

In wasteland, non cropped areas, plantation crops and roadsides, the use of glyphosate has shown promising results. The stage/time of parthenium weed for herbicidal control is important. Therefore parthenium weed should be treated at 6 to 8 stage and/or before flowering to get maximum effect of this herbicide solution (Table 3). Generally all weeds were sensitive to the herbicide at vegetative stage particularly at 4 to 6 leaf stage.

Parthenium weed control at 6 to 8 leaves and before flowering stages was highest with glyphosate treated with150 ml urea and150 ml of common salt (96%) followed by100 ml urea and100 common salt solutions (80%) at 4 WAT and control was lowest with sole glyphosate (without urea and common salt) which resulted in (55 %) mortality at 4 WAT.

This result indicated that parthenium weed can effectively be controlled with glyphosate tank mixed with urea and common salt solution, while glyphosate alone used in the study did not provide satisfactory control when applied at all stages of this weed (5-55%). Parthenium weed is highly sensitive to amino acid synthesis and photosynthesis inhibitors compared to herbicides with other modes of action (Singh et al., 2004).This result has also shown the complete shift of the weed spectrum into weak weed species which can be easily controlled and helped in suppressing the re-establishment of parthenium weed in the treated plots (Table 4) thus, its soil seed bank can decline over successive years.

In this study, glyphosate treated with lower concentrations of urea and common salt is recommended for the control of parthenium weed in non-cropped areas and plantation crops such as coffee and fruit farms in all parts of Ethiopia. It is recommended that spread of parthenium weed should be prevented to avoid its harmful effect on the crop production, biodiversity, the environment and human health.

Therefore, by treating glyphosate (3 L/ha) with with 150 ml of urea and 150 ml common salt solutions can control parthenium weed. Using this combinations and its frequency of application can be help in the long term control of this noxious weed. However, further studies have to be conducted to evaluate the effect of these solutions on the physico chemical properties of the soil and soil micro organisms.

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