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Full Length Research Paper

Allelopathic effects of an invasive alien weed *Parthenium hysterophorus* L. compost on lettuce germination and growth

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The present study was conducted to determine allelopathic effects of parthenium compost and to investigate whether ratio of parthenium composted with other plant materials have an influence on allelopathic potential of parthenium. Two emergence and growth experiments were conducted using lettuce as a model plant. Fresh parthenium reduced lettuce emergence percentage and rate and radicle and plumule lengths by 93, 95, 97 and 93%, respectively. Composted parthenium however reduced emergence percentage and rate and radicle and plumule lengths by 0, 33, 35 and 43%, respectively. Composting parthenium with other plant materials reduced allelopathic inhibition effects of parthenium on lettuce emergence rate and radicle and plumule lengths more than composting parthenium alone. Our results clearly showed that composting greatly reduced allelopathic effects of parthenium compared to fresh parthenium. Furthermore, composting parthenium with other plants resulted in lower inhibition of emergence rate and radicle and plumule lengths compared to composting parthenium alone. Hence, we suggest parthenium composting with locally available plant materials as a means to reduce its allelopathic inhibitory effect and as a way of parthenium management by utilization.

Key words: Allelopathy, compost, germination, invasive alien weed, *Parthenium hysterophorus*, seedling growth.

INTRODUCTION

Parthenium (*Parthenium hysterophorus* L., Asteraceae) is an aggressive invasive alien weed species (Kohli et al., 2006), native to the Americas but now widely spread in Asia, Africa and Australia (Evans, 1997). Parthenium weed was first introduced accidentally into Ethiopia in the 1970s. It was first reported from Ethiopia in 1988 at Dire-Dawa and Harerge, Eastern Ethiopia (Seifu, 1990) and subsequently found near Desse, North-eastern Ethiopia.

Both are major food-aid distribution centers and there is a strong assertion that parthenium weed seeds were imported from subtropical North America as a contaminant of grain food aid during the 1980s famine and distributed with the grain (Seifu, 1990; Tamado and Milberg, 2000). Afterwards it spreads rapidly in all regions of the country, along roads and railways, through grazing areas and arable lands, adversely affecting crop production, animal husbandry and biodiversity (Tefera, 2002).

The successful spread of parthenium in so many parts of the world including Ethiopia has mainly been attributed to its allelopathic properties, which enables it to compete effectively with crops and pasture species (Singh et al., 2003; Batish et al., 2005a,b). Parthenium is considered a noxious weed because of its allelopathic effect (Kohli et al., 2006), its strong competitiveness for soil moisture and nutrients and the hazard it poses to humans (Wiesner et al., 2007) and animals (Narasimhan et al., 1977). Study by Wiesner et al. (2007) indicated that parthenium causes general illness, asthmatic problems, irritations of skin and pustules on hand balls, stretching and cracking of skin and stomach pains on humans. It was also reported to cause severe crop losses. Sorghum grain yield losses between 40 and 97% were reported in Ethiopia if parthenium is left uncontrolled throughout the season

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(Tamado et al., 2002). Parthenium weed seed is also a contaminant of grain, pasture and forage seeds. Hence, it results in restricted sale and movement of these produces (Chippendale and Panetta, 1994). Parthenium is also known by its environmental impacts. Because of its invasive capacity and allelopathic properties, it has the potential to disrupt natural ecosystems. It is an aggressive colonizer of wasteland, road sides, railway sides, water courses, cultivated fields and overgrazed pastures (Wiesner et al., 2007).

The allelochemicals released from parthenium affecting many plant species are sesquiterpene lactones and phenolics (Swaminathan et al., 1990). Parthenin is the major sesquiterpene lactone whereas caffeic, vanillic, ferulic, chlorogenic and anisic acids are the major phenolics (Kanchan and Jayachandra, 1980; Batish et al., 2002, 2007; Singh et al., 2002). These two synergistically acting groups of allelochemicals signifi-cantly decrease the seed germination and subsequent growth in many crops (Batish et al., 2005a, b; Singh et al., 2003).

Currently, parthenium is one of the noxious weeds threatening crop production in Ethiopia. The rapid spread of parthenium in Ethiopia would be a bigger risk to the expansion and sustainable production of many crops. Control of parthenium is therefore crucial to boost productivity of many crops in the country. Hand-weeding mostly used by small-scale farmers is more difficult due to the allergic effects of parthenium on human body. Furthermore, resource poor farmers of Ethiopia can not afford the purchase of herbicides and the use of herbicides is unsafe in terms of health and environmental considerations. Mechanical control on the other hand is rather costly in terms of labour and time requirement. Therefore, other options must be sought for sustainable parthenium management in Ethiopia. One option is utilizing parthenium for the purpose it is suitable, management by utilization. Parthenium composting is therefore one of these options.

Parthenium composting experiments were conducted in India and it is reported to have high N, P and K (Son, 1995; Biradar et al., 2006). Channappagoudar et al. (2007) reported that parthenium composted pre-flowering has higher N content (2.95%) compared to poultry manure (2.02%), vermi compost (1.21%) and farm yard manure (0.54%). The same study indicated that parthenium compost has higher P content (0.82%) compared to FYM (0.26%) but lower as compared to poultry manure (1.6%) and vermi compost (0.86%) . Its K content is also higher (1.39%) compared to Vermi compost (0.55%) and FYM (0.34%) whereas lower compared to poultry manure (1.42%) (Channappagoudar et al., 2007).

On the other hand, parthenium is known to have allelopathic inhibitory effect on germination and growth of crops (Tefera, 2002; Singh, 2003; Batish et al., 2005_a; Batish et al., 2005_b; Wakjira et al., 2005; Wakjira, 2009). It is therefore important to look for options that minimize its allelopathic effect so that it could be utilized as compost. In this regard, we hypothesized that composting parthenium reduces its allelopathic potential. Furthermore, composting parthenium with different plant materials with various ratios further reduces its allelopathic potential. Therefore, the objectives of this study were to determine allelopathic effects of parthenium compost and to investigate whether parthenium composted with other plant materials at different ratios have an influence on allelopathic inhibitory potential of parthenium.

MATERIALS AND METHODS

A lathhouse study was conducted at Jimma University, Jimma, Ethiopia from July 2006 to June 2007. Jimma University is located at about 7^{o}, 41' N latitude and 36^{o}, 50' E longitude at an altitude of 1710 m above sea level. The mean minimum and maximum temperatures in the lathhouse were 12^{o} C and 25^{o}C during the experimental period. The relative humidity ranged from 31 to 91%. The soil used for the experiment was obtained from 'Eladale' teaching and experimental farm of JUCAVM. The soil was clay-loam in texture with an organic matter content of 3 - 5% and a pH of 5.6 - 6.5.

Fresh parthenium plants were collected before flowering from around Jimma University campus and cut to 15 cm size. Other locally available and easily decomposable plant materials like grasses, *Bidens pilosa*, *Ageratum conyzoids* , *Phytolacca dodecandra*, and banana leaves were collected and chopped. The prepared parthenium was mixed with chopped plant materials at the ratio of 1:1, 1:2, 1:3, 1:4 and 1:5 (w/w). Six pits of 1 m depths were prepared and the mixed compost ingredients were added to pits. Parthenium was also composted alone. A thorough turning was made after 21 days. When it matures at 60 days it was taken out.

The first experiment was designed to test whether composting parthenium reduces its allelopathic potential. In this experiment the treatments were fresh parthenium immediately harvested and chopped and composted parthenium. The second experiment was conducted to investigate whether ratio of parthenium composted with other plant materials at different ratios have an influence on allelopathic potential of parthenium on lettuce, model plant. The treatments include fresh parthenium, composted parthenium and parthenium composted with other plant materials at ratios of 1:1, 1:2, 1:3, 1:4 and 1:5. In both experiments soil alone was used as control.

Composted material and agricultural soil were added to half liter plastic pots at the ratio of 1:3 in both experiments. One hundred lettuce seeds were surface-sterilized by shaking them for five minutes in 1% sodium hypochlorite (NaOCl) solution and washed with de-ionized water for three minutes before use. The treatments were laid down in a randomized complete block design (RCBD) with four replications and kept under lathhouse conditions. The experiments were conducted twice and the average data were used for analysis.

Data on germinated seed were collected daily from the fourth to seventh days after sowing. Radicle and plumule lengths were recorded on the seventh day by taking 10 seedlings at random.

Rates of germination (GR) were calculated by the formula proposed by Maguire (1962) as:

$$\text{GR (seeds per day)} = \frac{\text{Number of normal seedlings}}{\text{Days of first count}} + \dots + \frac{\text{Number of normal seedlings}}{\text{Days of final count}}$$

The average data were subjected to one-way analysis of variance (ANOVA). Means were compared for all significant parameters using Least Significant Difference (LSD) test. All data analyses were performed using GenStat statistical package, GenStat for

Table 1. Allelopathic inhibitory potential of composted parthenium on lettuce seed emergence percentage and rate, and radicle and plumule lengths seven days after sowing under lathhouse conditions at Jimma, Southwestern Ethiopia.

Treatments	Emergence (%)	Emergence rate (seeds per day)	Radicle length (mm)	Plumule length (mm)
Soil alone (control)	97 a[1]	58 a	68 a	14 a
Composted parthenium	97 a	39 b	44 b	8 b
Fresh parthenium	7 b	3 c	2 c	1 c
LSD	3.15	6.19	3.70	0.76

[1]Means followed by different alphabets within one column differ significantly (*P* < 5%) as established by Fisher's protected LSD test.

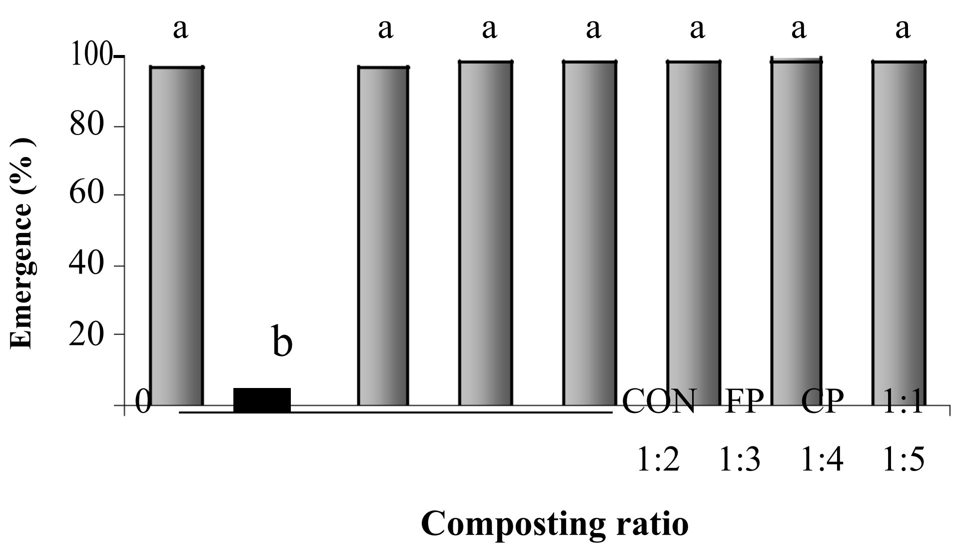

Figure 1. Allelopathic inhibitory potential of parthenium composted with other plant materials at different ratios (CON = control, FP = fresh parthenium, CP = composted parthenium and parthenium to other plant material ratios 1:1, 1:2, 1:3, 1:4 and 1:5) on lettuce seed emergence percentage under lathhouse conditions at Jimma, Southwestern Ethiopia. Means followed by different alphabets differ significantly (*P* < 5%) as established by Fisher's protected LSD test (LSD = 3.45).

Windows 11th Edition (VSN International LTD, 2008). Inhibition percentage was calculated using the following equation modified from Chung et al. (2001) as:

$$\text{Inhibition percentage} = \frac{\text{Treatment} - \text{Control}}{\text{Control}} * 100$$

RESULTS

Composting significantly reduced allelopathic inhibitory effects of parthenium on lettuce seed emergence percentage and rate and radicle and plumule lengths (p < 0.001) (Table 1). Lettuce emergence percentage was greatly reduced by fresh parthenium (by 93%). However, composted parthenium has no inhibition effect on emergence percentage compared to soil alone (control). Fresh and composted parthenium reduced lettuce emergence rate (by 95 and 33%, respectively), radicle length (by 97 and 35%, respectively) and plumule length (93 and 43%, respectively). Our result clearly showed that composting greatly reduced allelopathic effects of parthenium.

For lettuce emergence percentage, a significant effect of composting parthenium with other plant materials was observed (p < 0.001) (Figure 1). Lettuce emergence percentage was severely reduced by application of fresh parthenium (by 93%). However, composting parthenium with other plant materials at different ratios and composting parthenium alone resulted in a similar emergence percentage with control.

Composting with other plant materials significantly reduced allelopathic effects of parthenium on lettuce emergence rate (p < 0.001) (Figure 2). Compared to control and different ratios, fresh parthenium and parthenium composted alone greatly reduced lettuce emergence rate by 95 and 31%, respectively. No significant difference was observed between control and the ratios except 1:5

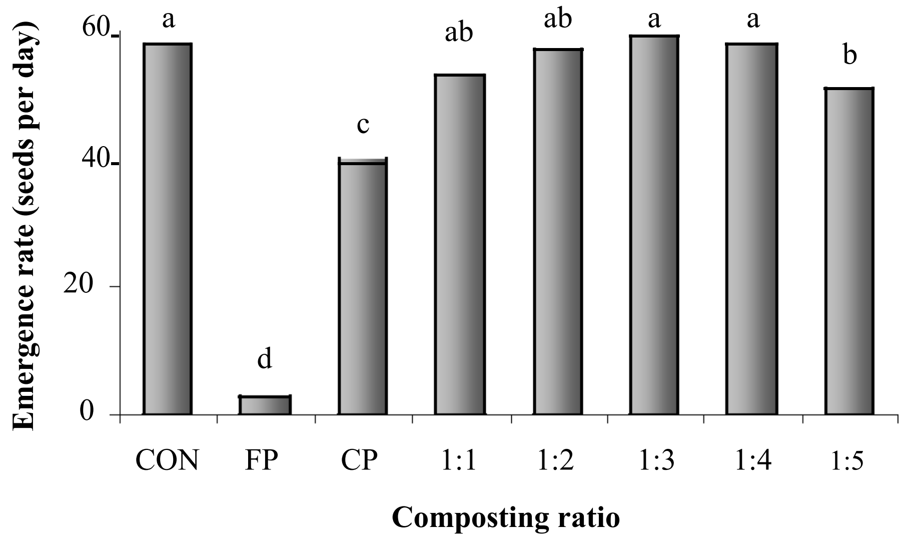

Figure 2. Allelopathic inhibitory potential of parthenium composted with other plant materials at different ratios (CON = control, FP = fresh parthenium, CP = composted parthenium, and parthenium to other plant material ratios 1:1, 1:2, 1:3, 1:4 and 1:5) on lettuce seed emergence rate under lathhouse conditions at Jimma, Southwestern Ethiopia. Means followed by different alphabets differ significantly ($P < 5\%$) as established by Fisher's protected LSD test (LSD = 6.41).

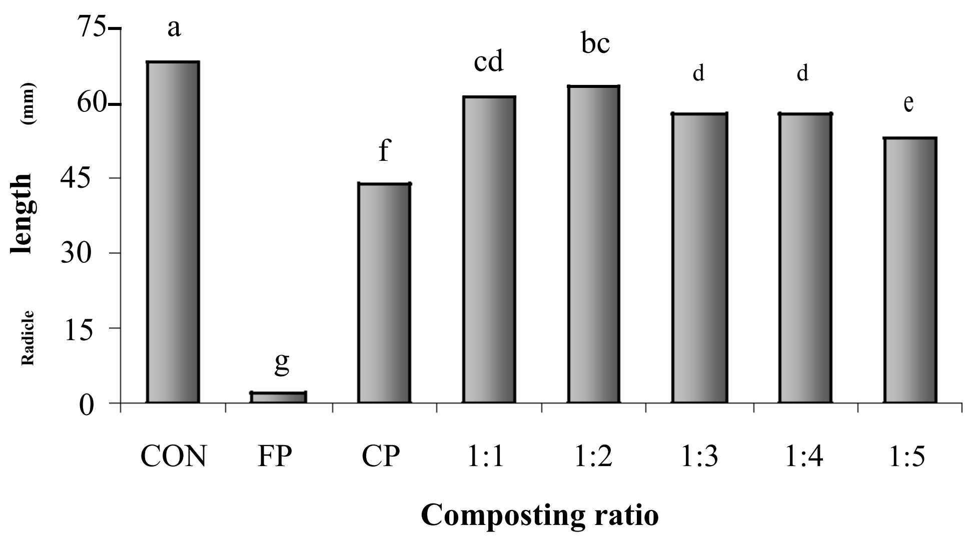

Figure 3. Allelopathic inhibitory potential of parthenium composted with other plant materials at different ratios (CON = control, FP = fresh parthenium, CP = composted parthenium, and parthenium to other plant material ratios 1:1, 1:2, 1:3, 1:4 and 1:5) on lettuce radicle length under lathhouse conditions at Jimma, Southwestern Ethiopia. Means followed by different alphabets differ significantly ($P < 5\%$) as established by Fisher's protected LSD test (LSD = 4.1).

in inhibiting germination rate. Compared to control, all treatments significantly reduced lettuce radicle (Figure 3) and plumule lengths (Figure 4) ($p < 0.001$). However, lettuce radicle length was greatly inhibited by fresh parthenium (by 97%) followed by parthenium composted alone (by 35%) (Figure 3). Whereas lettuce plumule length was greatly reduced by fresh parthenium followed by parthenium composted alone by 93 and 57%, respectively (Figure 4).

Our results clearly showed that composting greatly reduced allelopathic inhibitory effects of parthenium. Furthermore, composting parthenium with other plants farther reduced the allelopathic inhibitory effects of parthenium even more. As a result lower inhibitions of emer-

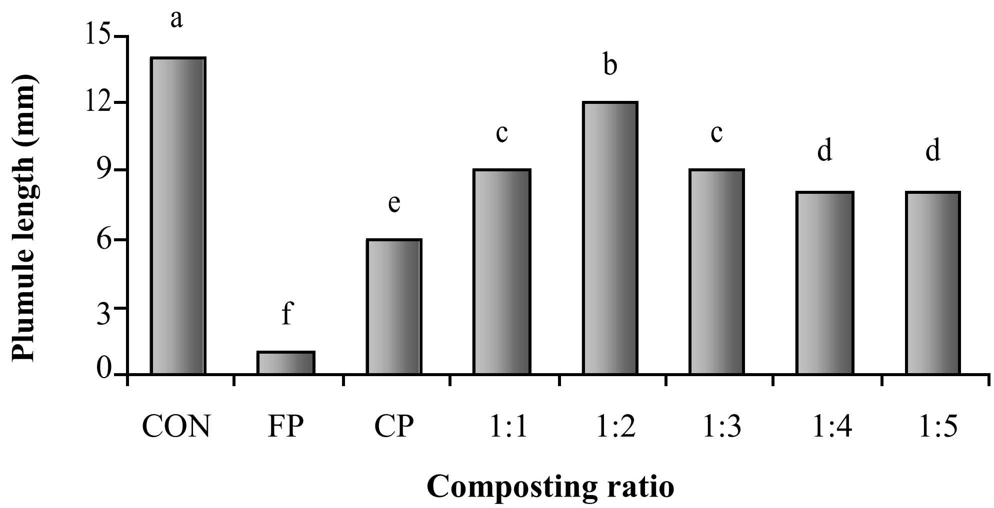

Figure 4. Allelopathic inhibitory potential of parthenium composted with other plant materials at different ratios (CON = control, FP = fresh parthenium, CP = composted parthenium, and parthenium to other plant material ratios 1:1, 1:2, 1:3, 1:4 and 1:5) on lettuce plumule length under lathhouse conditions at Jimma, Southwestern Ethiopia. Means followed by different alphabets differ significantly (P < 5%) as established by Fisher's protected LSD test (LSD = 0.81).

gence rate and radicle and plumule lengths were observed by parthenium composted with other plants compared to composting parthenium alone.

DISCUSSION

Parthenium residues have inhibitory effects on the germination and growth of many plants such as radish, mustard (Batish et al., 2005$_{a}$) and *Brassica* spp (Batish et al., 2005b) and other plants (An et al., 2001; Khalid, 2002; Kruidhof, 2008; Batish et al., 2006, 2009). It has also been reported that a decrease in phytotoxicity was observed with increasing age of residue (Batish et al., 2005b). The reduction in inhibitory activity of the allelochemicals over time is generally related to degradation mostly by soil microorganisms (An et al., 2001; Kobayashi, 2004). Allelochemicals are subject to various biotic and abiotic processes that reduce their persistence, concentrations, availability and biological activities after they are released into the soil. Such processes embody utilization by soil microorganisms (Blum et al., 1999), chemical transformation (Okumura et al., 1999) and polymerization (Wang et al., 1986) among others.

Rajbanshi and Inubushi (1998) reported nearly complete elimination of allelopathic potentials after composting of *Eupatorium adenophorum* and *Lantana camara* plant materials. Nawaz and George (2004) indicated detrimental effects of eupatorium green manure compared to its compost. Toxicity of parthenium residue to wheat diminished with increasing decomposition period and as a result residue decomposed for four weeks is less toxic than the undecomposed residue (Mersie and Singh, 1987). The present finding was congruent with previous reports and our hypothesis that stated composting reduces allelopathic effects of parthenium.

The present finding is also in agreement with our hypothesis that stated composting parthenium with other plant materials reduces its allelopathic inhibition potential on seed germination and seedling growth of the model plant lettuce. This could be explained by the fact that composting parthenium with other plant materials with less or no allelopathic potential reduces the amount of allelochemicals released into the soil and the corresponding allelopathic inhibition potential. Allelopathic potential vary from plant to plant (Hong et al., 2003; Brennan and Smith, 2005; Reeves et al., 2005; Batish et al., 2006; Stoll et al., 2006; Adler and Chase, 2007; Price et al., 2008). Therefore, it is important to consider plants having less or no allelopathic potential to use with the highly allelopathic parthenium.

Finally, we conclude that composting parthenium before flowering is a means to minimize its allelopathic inhibition potential and one way of management by utilization. Therefore, resource poor farmers could make use of the high nutrient contents of parthenium compost and could control parthenium by composting.

Furthermore, they can also use other plant materials decomposed with parthenium to minimize its allelopathic potential. Hence, we suggest parthenium composting with locally available plant materials known to have no or little allelopathic effect as a means to reduce its allelo-pathic inhibitory effect and as one way of management of parthenium weed by utilization.

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