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Allelopathic Effects of Aqueous Extracts of an Invasive Alien Weed Parthenium hysterophorus L. on Maize and Sorghum Seed Germination and Seedling Growth

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Abstract
Studies were carried out under laboratory conditions to investigate the allelopathic effects of aqueous extracts of *Parthenium hysterophorus* L. shoot (stem + branch), leaf, inflorescence, root and whole plant (leaf + shoot +inflorescence + root) at 0, 5, 10 and 15% (w/v) concentrations on maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L. Moench) seed germination, seedling growth (shoot and root length) and biomass production. The treatments were laid out in completely randomized design with factorial arrangement in four replications. The trial was conducted twice. Results showed that significant ($p < 0.01$) differences between plant parts and whole plant except for stems and root length of maize, where the effect was significant ($p < 0.05$) and non significant, respectively. Inflorescence and whole plant extracts at all concentration, shoot at 15% and leaf at 10 and 15%, completely inhibited seed germination of the crops. In contrast, aqueous extract of shoot and root at 5% proved to be lower deleterious effect, while at higher concentration greatly reduced the aforementioned parameters. The roots were more sensitive to allelopathic effect than shoot. In was suggested that integrated weed management practices should be designed and employed to control this invasive weed from maize and sorghum fields to sustain the production of the crops.
Keywords: Allelopathic, aqueous extract, maize, Parthenium, sorghum

Introduction

Parthenium (*Parthenium hysterophorus* L.) also known as congress grass, carrot weed, ragweed parthenium, white top, is an invasive poisonous herbaceous annual weed in the member of the plant family Asteraceae. It is native to Central America and now it is widely distributed in India, China, Australia and Africa (Navie *et al*., 1996). Its introduction to Ethiopia was probably via food grain aid from North America (Kassahun *et al*., 1999) and/or army vehicles during the 1976 - 1977 Ethio-Somalia war (Tamado and Milberg, 2000). Currently, the weed has come the most dominant weed and is ranked as the worst and more frequent species of weed in arable and grazing land, abandoned fields, open woodlands, flood plains and along river banks, roadsides and residential areas of the country (Rezene *et al*., 2005; Asresie *et al*., 2008, Ashebir *et al*., 2012). It has the ability to reduce the productivity of pastures (Besufekad *et al*., 2005; Rezene *et al*., 2005; Shashie *et al*., 2013), affect livestock health and quality they produces, human health and activities, ecology and biodiversity (Besufekad *et al*., 2005; Lakshmi and Srinivas, 2007) and causes tremendous yield loses of crops (Tamado *et al*., 2002) by competing with crop plants for available environmental resources, *viz.* light, nutrient, water, etc., and release allelochemicals into its immediate environment, which occurs via exudation and leaching of volatile soluble toxins from above and below ground parts by the action of rain water (Tadele, 2002; Mulatu *et al*., 2005; Maharjan *et al*., 2007; Mulatu *et al*., 2009; Ashebir *et al*., 2012) and by release of toxins from the living parts through leaching of litter decomposition or microbial by products results litter decomposition (Kaminsky, 1981) Previous investigation reported a yield decrease of 40% in agricultural crops and up to 90% reduction in forage production in grass lands due to this weed (Nath, 1988). Similarly, Tamado *et al*. (2002) demonstrated that a 40 to 90% sorghum yield reduction if Parthenium weed is left uncontrolled through the cropping season. It also inhibited growth and nodulation of legumes because of the inhibitory effect of allelochemicals on nitrogen fixing and nitrifying bacteria (Deyama, 1986).

Maize and sorghum are among the main food crops cultivated in Ethiopia covering 15 and 14% of the crop lands with an average yield of 2.2 and 1.2 t ha^{-1}, respectively (CSA, 208). Despite the significant contribution of the crops to the livelihood of people, the crops are seriously threatened by Parthenium invasion. It is, therefore, imperative to study the allelopathic effect of this weed on germination and seedling growth of both crops. The objective of this study was, therefore, to investigate the allelopathic effects of aqueous extracts of shoot, leave, inflorescent, root and whole plant part (leaf + shoot +inflorescence + root) of Parthenium on seed germination and seedling growth of maize and sorghum under laboratory conditions.

Materials and Methods

Experimental treatments and design

The experiment was conducted in the laboratory using three aqueous concentration of Parthenium (5, 10 and

10%) along with distilled water that was served as a control for each of leaf, shoot (stem + branch), inflorescence root and whole plant (leaf + shoot +inflorescence + root) parts and two crops (maize and sorghum). The treatments were laid out in a completely randomized design with factorial arrangement with four replications and kept at room temperature (21 - 22 °C) on a laboratory bench with 12 hour fluorescent light supply during the night. The experiment was repeated twice.

Preparation of aqueous extracts of Parthenium and its application

P. hysterophorus growing naturally along the roadside of Jima town, southwestern Ethiopia, were collected after flowering and brought into the Entomology Laboratory of Jima Agricultural Research Center, Ethiopia, and thoroughly washed with distilled water to remove inert particles. The plants were dried with blotting paper and immediately were separated into shoot, leaf, inflorescence, root and whole plants were also taken simeltinousl. Each part of the fresh plant was cut into 1 - 2 cm pieces and dried in oven at 70 ^{0}C for 24 hour and pounded separately using stainless steel mill. Five, 10 and 15 g powder of each plant part was weighted using sensitive balance and soaked in 100 ml of distilled water for 24 hour at room temperature (21 - 22 ^{0}C). The mixture containing 5, 10 and 15 g Parthenium extracts were collected by sieving through cheesecloth and designated as 5, 10 and 15% (w/v) aqueous extracts, respectively.

Maize and sorghum seeds, variety BH-660 and Aba Melko, were treated with sodium hypochlorite in a 500 ml flask for 3 minute and washed thoroughly with distilled water. Treaty seeds of both crops were separately placed in a Petri dish (9 cm diameter) lined with 9 cm Whatman filter paper. Then after, the seeds were treated with 10 ml of the 5, 10 and 15% (w/v) of aqueous extracts of shoot, leaf, inflorescence, root and whole plant and with 10 ml of distilled water as a control. Petri dish was regularly checked to keep them moistened by adding equal amount of distilled water to each.

Data collection and analysis

Data on germinated seeds (number of seedlings with visible shoot and root growth) was collected daily from the 7th to 12th and 5th to 10th days after treatment application for maize and sorghum, respectively. On the 12 and 10 days after treatments application to the respective crops shoot and root length (cm) were measured using a ruler by taking ten seedlings per treatment at random. Maize seedlings sampled from a treatment for measurement of shoot and root lengths were separated in to the respective plant parts and fresh weight of each part was measured using sensitive balance. Besides, germination rate (GR) was calculated following the method used by Wardle *et al*. (1991) as follows: $\mathbf{GR = (N1 * 1) + 1/2(N_2 – N_1) + 1/3(N_3 – N_2) +----+ 1/n(N_n – N_{n--1})}$, where N_1, N_2, N_3----- N_{n-1}, N_n is the proportion of germinated seeds obtained the first (1), second (2), third (3).----(n – 1), (n) days. Finally, the average data obtained from the two experiments were subjected to analysis of variance using SAS statistical software (SAS version 9.1, 2008). Means were separated using Duncan's Multiple Range Test whenever the 'F' test was significant (Mandefero, 2005).

Results and discussion

The result depicted that highly significant ($p < 0.01$) differences between Parthenium plant parts, concentration levels and their interaction for all the parameters considered except for shoot and root length of maize, where the effect was significant ($p < 0.05$) and non-significant, respectively. Aqueous extracts of shoot, leaf, inflorescence, root and whole plant parts of of Parthenium exhibited allelophatic effects on maize and sorghum seed germination, shoot and root growth and dry matter of seedlings. Similar findings have been reported for cabbage (Kohil *et al*., 1985), tomato (Mersie and Singh, 1988), multipurpose trees and arable crops (Swaminathan *et al*., 1990; Evans, 1997), teff (Tadle, 2002), lettuce (Mulatu *et al*., 2005) and kabuli chickpea and sesam (Ashebir *et al*., 2012). The allelophatic effect increased as concentration levels of the extracts increased. On the other hand, the allelophatic effect varied among plant parts from which the aqueous extracts taken. Inflorescence and whole plant part at 5, 10 and 15% concentration induced 100% failer of seed germination and shoot and root growth of crops. In contrast, the 5% shoot and root aqueous extracts have lower effects, while at higher concentration greatly reduced the aforementioned parameters (Table 1 and 2).

Although the allelopathic effect varies among the plant parts, all plant parts exhibited allelopathic effects (Table 1 and 2). This is attributed due to the release of allelochemicals, *viz.* sesquiterpenes lactones, mainly parthenin, and phenolics, from root (Guzman, 1988), stem (Mersie and Singh, 1987), leaves (Stephan and Sowerby, 1996; Blez *et al*., 2007) inflorescences, pollen and seeds (Evans, 1997). The higher allelophatic effects induced by aqueous extracts of flower and whole plant part at all concentration and leaf at 10 and 15% concentration levels, as indicated by a complete frailer of germination and seedling growth support the findings of Kanchan and Jaycharad (1980), Tadle (2002), Mulatu *et al*. (2005) and Ashebir *et al*. (2012) that high level of inhibitory compounds present in these parts of the plant as compared to stems and roots. Blez *et al*. (2007) also reports that parthnin released to the soil during decomposition of Parthenium leaves is the leading toxic compound causing phytotoxicity.

Maize and sorghum root appeared more sensitive to allelopathic effect than shoot (Table 1 and 2). This might be attributed to the direct contact of the root with the extracts and subsequently with inhibitory compounds, which their presence inhibit gibberellin and indoleacetic acid function (Tomaszewski and Thimann, 1966). Similar results have been reported for cabbage (Kohil *et al*., 1985), tomato (Mersie and Singh, 1988), multi purpose trees and arable crops (Swaminathan *et al*., 1990; Evans, 1997), Maize and soybean (Bhatt *et al.*, 1994), *Dicanthium annululatum,* and *Medicago polymorpha* (Hussain and Abid, 1991), tef (Tefera, 2002), lettuce (Mulatu *et al*., 2005) and kabuli chickpea and sesame kabuli chickpea and sesam (Ashebir *et al*., 2012).

On conclusion aqueous extracts of all plant parts of Parthenium (shoot, leaf, inflorescence, root and whole plant part inhibited the germination and growth of maize and sorghum demonstrating the allelophatic potential of Parthenium weed. However, the inhibitory effect varied among plant parts (whole plant part = inflorescence > leaf > shoot > root). The present findings has also far reaching implication in that in the light of its fast spread in maize and sorghum areas of the country it is going to be a menace in the prevention and management of fast spreading invasive weeds , such as Parthenium, call for the concerted effort of all affiliation to agricultural production. This also requires mass awareness programme among the stakeholders. Besides, more similar investigation should be conducted in the field to substantiate the present findings.

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Table 1. Effect of different concentration of aqueous extracts of Parthenium plant parts on maize seed germination, and seedling growth and biomass production

Plant part	Concentration level (%)	Germination (%)	Germination rate (GSPD)[A]	Shoot length (cm)	Root length (cm)	Shoot fresh weight (g)	Root fresh weight (g)
Control	0	94a	23.80a	2.51a	3.99	2.46a	2.75a
Shoot	5	21cd	8.30bc	2.10bc	2.48	2.05c	2.09c
	10	12de	5.36c	2.04cd	2.39	2.03c	2.05cd
	15	4ef	1.01d	2.01d	2.21	2..00c	2.02d
Leaf	5	13de	2.26d	2.02d	2.03	2.05d	2.01d
	10	0f	0e	0e	0	0d	0e
	15	0f	0e	0e	0	0d	0e
Flower	5	0f	0e	0e	0	0d	0e
	10	0f	0e	0e	0	0d	0e
	15	0f	0e	0e	0	0d	0e
Root	5	57b	13.29b	2.15b	2.56	2.38a	2.13b
	10	37bc	8.48bc	2.10bc	2.47	2.09b	2.06cd
	15	24cd	4.99c	2.04cd	2.28	2.10b	2.03cd
Whole plant part	5	0f	0e	0e	0	0d	0e
	10	0f	0e	0e	0	0d	0e
	15	0f	0e	0e	0	0d	0e
F-test		**	**	*	NS	**	**
SE (±)		1.42	1.48	2.01	1.15	2.01	2.01
CV (%)		25.23	24.08	24.96	9.05	31.13	12.86

NS = Non significant; *, ** = Significant at 0.05 and 0.01 probability level, respectively. Means within a column followed by the same letter(s) are not significantly different at 0.05 probability level. [A]GSPD = Germinated seeds per day.

Table 2. Effect of different concentrations of aqueous extracts of Parthenium plant parts on sorghum seed germination and seedling growth

Plant part	Concentration (%)	Germination (%)	Germination rate (GSPD)^{A}	Root length (cm)	Shoot length (cm)
Control	0	95.33a	23.09a	4.82a	3.38a
Shoot	5	63.33b	15.12b	1.17cd	1.21bc
	10	48.67c	11.68c	0.76de	0.64cd
	15	0f	0f	0f	0d
Leaf	5	5.33e	0.86f	0.07ef	0.12d
	10	0f	0f	0f	0d
	15	0f	0f	0f	0d
Flower	5	0f	0f	0f	0d
	10	0f	0f	0f	0d
	15	0f	0f	0f	0d
Root	5	63.33b	16.38b	2.03bc	1.83b
	10	44.67c	9.48d	2.12b	1.87b
	15	26.67d	5.84e	0.98de	0.63cd
Whole plant part	5	0f	0f	0f	0d
	10	0f	0f	0f	0d
	15	0f	0f	0f	0d
F-test		**	**	**	**
SE (±)		1.80	0.56	2.26	2.15
CV (%)		8.75	10.21	23.69	29.99

** = Significant at 0.01 probability level. Means within a column followed by the same letter(s) are not significantly different at 0.01 probability level. ^{A}GSPD = Germinated seeds per day.