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[1]Jimma Agricultural Research Center, Jimma, Ethiopia
[2]Department of Horticulture and Plant Sciences, Jimma University College of Agriculture and Veterinary Medicine, Jimma, Ethiopia

Allelopathic effects of *Parthenium hysterophorus* L. aqueous extracts on soybean (*Glycine max* L.) and haricot bean (*Phaseolus vulgaris* L.) seed germination, shoot and root growth and dry matter production

Anteneh Netsere[1], Esayas Mendesil[2]

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Summary

Aqueous extracts of shoot (stem + branch), leaf, flower and root of *Parthenium hysterophorus* L. at 0, 5, 10 and 15% (w/v) concentrations were applied on seeds of soybean (*Glycine max* L.) and haricot bean (*Phaseolus vulgaris* L.) to investigate their effect on percent germination, germination rate, and seedling growth (shoot and root length) and dry matter production under laboratory condition. The treatments were laid out in a completely randomized design with factorial arrangement in four replications. The trial was conducted twice, November 13 - 26 and December 1 - 14, 2008. Results depicted that significant ($P < 0.01$) difference between plant parts, concentration levels and their interaction for the aforementioned parameters. Aqueous extracts of flower at all concentrations, and leaf at 10 and 15% and shoot at 15% concentration levels 100% inhibited germination of both crops. In contrast, aqueous extracts from shoot and root at 5% had lower effect, while at higher concentrations greatly reduced germination percentage and growth of the crop. Roots of the crops were more sensitive to allelopathic effect than shoots. It is recommended that integrated weed management strategy should be designed and employed to combat the weed from soybean and haricot bean field to avoid poor germination and seedling growth and ensure sustainable production of the crops

Introduction

Parthenium (*Parthenium hysterophorus* L.) is an invasive annual weed which is native to Central America and now it is widely distributed in Kenya, India, China, Australia and Africa (Khosla and Sobti, 1981; Aneja et al., 1991). It was introduced to Ethiopia in the mid 1970s after noticeable occurrence in Eastern part of the country, where it has now emerged as one of the most trouble weed in arable and grazing land of the country as well as abandoned fields of the country (Mekbib et al., 1996; Tamado and Milberg, 2000; Tadesse et al., 2005; Rezene et al., 2005).

Parthenium can severely compete with annual crops and can cause tremendous yield loss. Accordingly, Nath (1988), respectively, reported a yield decrease of 40% in agricultural crops and up to 90% reduction in forage production in grass lands due to this weed. 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 (Kanchan and Jayachandra, 1980; Deyama, 1986). Besides, it adversely affects animal health, production and quality of their produces (Tadesse et al., 2005), human health and activities, ecology and biodiversity (Rezene et al., 2005).

Soybean (*Glycine max* L.) and haricot bean (*Phaseolus vulgaris* L.) is one of the most important traditional pulse crop in the mid- and low-land areas of Ethiopia. Its grain used for food and cash source for subsistence farmers and it by product, such as stalk and leaves, is used for firewood and feed. It provides an important source of protein and minerals, especially Fe and Zn, in the diet. As a leguminous crop, soybean and haricot bean is important due to its role for crop rotation in area where cereals sole cropping is a common practice in Southwestern Ethiopia, where maize is the major staple food crop and grown in mono-crop conditions. Moreover, as the crops are short maturing and have moderate drought tolerance, it is used as the main or the only food in short growing seasons and poor annual harvest area. Thus, it plays a vital role in farmers' risk aversion strategies. In spite of the importance of the crops, their productivity is seriously threatened by Parthenium weed invasion. This calls for further scientific investigation on the allelopathic potential of this weed on germination and seedling growth of the crops. The objective of this study was, therefore, to investigate the allelopathic effects of aqueous extracts of shoot, leave, flower and root of Parthenium on germination, seedling growth and dry matter production of soybean and haricot bean under laboratory condition.

Materials and methods

Preparation of aqueous extract of *P. hysterophorus*

Parthenium hysterophorus plants growing naturally along the roadside of Jimma town, southwestern Ethiopia, were randomly uprooted and collected at their flowering stage in November 1, 2008. The collected plants were brought into the Entomology Laboratory of Jimma Agricultural Research Center, Ethiopia, and were immediately partitioned into shoot (stem + branch), leaf, flower and root parts. Shoot and root part of the fresh plant was cut into 1-2 cm pieces. Then after, each plant part put in paper bags separately and dried in oven at 70 °C for 24 hours and pounded using electrical stainless steal Wiley mill. Five, 10 and 15 g powder of each plant part was weight using sensitive electronic balance and soaked in 100 ml of distilled water using 300 ml flasks and mixed thoroughly. After 24 hours of soaking at room temperature (21 - 22 °C), the mixture containing 5, 10 and 15 g Parthenium extracts were collected by sieving through cheesecloth and designated as 5, 10 and 15% aqueous extracts, respectively.

Bioassays and experimental design

One kilogram of soybean and haricot bean seeds, variety Roba 1 and Clerk 63K respectively, were obtained from Field Crop Agronomy Research Division of Jimma Agricultural Research Center was used for the study. The seeds of each variety were treated with sodium hypochlorite in a 500 ml flask for 3 minute and washed thoroughly with distilled water. The bioassay was conducted following the procedures of Tefera (2002) and Wakjira et al. (2005). One hundred uniform size 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% of aqueous extracts of shoot, leaf, flower and root parts and with 10 ml of distilled water as a control. The treatments were laid out in a completely randomized design with factorial arrangement in four replications and kept at room temperature (21 - 22 °C) on a laboratory bench. The experiment was conducted twice, November 13 - 26 and December 1 - 14. 2008.

Data collected and statistical analysis

Number of germinated seeds (number of seedlings with visible shoot and root growth) was collected 15th day after treatment application. Germination rate (GR) was calculated following the methodology of WARDLE et al. (1991) as follows:

$$\mathbf{GR = (N1 * 1) + 1/2(N_2 - N_1) + 1/3(N_3 - N_2) +\text{-----}+ 1/n(N_n - N_{n-1}),}$$

where N_1, N_2, N_3-----N_{n-1}, N_n is the proportion of germinated seeds obtained in the first (1), second (2), third (3),------(n – 1), (n) days.

Shoot and root length (cm) of the respective crop were measured on the same day using a ruler by taking ten seedlings per treatment at random. However, if the germination percentage was less than 10, all the seedlings were used as the sample. Seedlings sampled from a treatment for measurement of shoot and root lengths were partitioned in to the respective plant parts and oven dried at 70 °C for 24 hours to a constant weight and dry matter of each part was weighted separately using sensitive electronics balance.

Finally, the average data obtained from the two experiments were subjected to analysis of variance using SAS software (SAS Institute, 2001) and means separation was made using Duncan's Multiple Range Test at 0.01 probability level (MANDEFERO, 2005).

Results

The result depicted that significant ($P < 0.01$) difference between Parthenium plant parts, concentration levels and their interaction for all the parameters considered (Tab. 1 and 2). Aqueous extract of flower at all concentration levels, leaf at 10 and 15% and shoot at 15% concentration levels 100% inhibited seed germination and subsequent growth of haricot bean and soybean. Likewise, very low germination, shoot and root growth and dry matter of the seedlings recorded at 5% leaf extract. In contrast, the 5% shoot and root aqueous extract had lower effect on germination and growth of the crops, while at high concentration greatly reduced germination, growth and dry matter production of the crops. The result also depicted that soybean and haricot bean root was more sensitive to allelopathic effect than shoot (Tab. 1 and 2).

Discussion

Aqueous extracts of shoot, leaf, flower and root of Parthenium weed exhibited allelopathic effect on soybean and haricot bean seed germination, germination rate, and shoot and root growth and dry matter production of seedlings. The allelopathic effect varied among the concentration levels of the extracts and the part of the weed from which they were extracted. Aqueous extracts of flower at 5, 10 and 15%, shoot at 15%, and leaf at 10 and 15% concentration completely inhibited seed germination and subsequent shoot and root growth of the crops (Tab. 1 and 2).

Although the allelopathic effect varied among the plant parts, all plant parts exhibited allelopathic effects (Tab. 1 and 2). This is attributed due to the release of different kinds of phytotoxic compounds, *viz.* phenolics, sesquiterpenes and lactones, from root and vegetative part of living plants as well as from the achen by exudation (GUZMAN, 1988) and leaching (MERSIE and SINGH, 1987; STEPHAN and SOWERBY, 1996; EVANS, 1997; BELZ et al., 2007), respectively. The present study also showed that, aqueous extracts of flower at all concentration levels and leaf at intermediate and higher concentration levels induced the highest allelopathic effects as indicated by complete failure of germination and seedling growth. This could be due to the presence of high level inhibitory compounds

Tab. 1: Effect of different concentration of aqueous extracts of Parthenium plant parts on soybean bean seed germination, shoot and root growth and dry matter production

Plant part	Concentration level (%)	Germination (%)	Germination rate (NGSPD)§	Shoot length (cm)	Root length (cm)	Shoot dry matter (g)	Root dry matter (g)
Control	0	96a	23.45a	4.00a	8.41a	10.64a	31.75a
Shoot	5	48bc	11.75bc	1.66d	1.84d	1.51d	2.09e
	10	32cd	8.52d	1.34e	1.57e	1.05e	1.10ef
	15	0f	0f	1.01ef	1.11f	0.6f	0.86f
Leaf	5	0.4ef	0.55f	1.07ef	1.58e	1.05e	2.10e
	10	0f	0f	0f	0g	0f	0f
	15	0f	0f	0f	0g	0f	0f
Flower	5	0f	0f	0f	0g	0f	0f
	10	0f	0f	0f	0g	0f	0f
	15	0f	0f	0f	0g	0f	0f
Root	5	65b	14.87b	2.20b	4.30b	6.83b	11.01b
	10	40cd	9.90c	2.107c	2.57c	3.90c	9.01c
	15	25e	5.42e	1.04d	1.17f	1.89cd	3.79d
F-test		**	**	**	**	**	**
SE (+)		1.83	1.77	2.08	1.75	3.10	1.58
CV (%)		8.10	15.12	8.70	9.06	10.42	7.25

** = Significant at 0.01 probability level. Means within a column followed by same superscript letter (s) are not significantly different at 0.01probability level.
§NGSPD = Number of germinated seeds per day.

Tab. 2: Effect of different concentration of aqueous extracts of Parthenium plant parts on haricot bean seed germination, shoot and root growth and dry matter production

Plant part	Concentration level (%)	Germination (%)	Germination rate (NGSPD)§	Shoot length (cm)	Root length (cm)	Shoot dry matter (g)	Root dry matter (g)
Control	0	97a	22.03a	4.62a	11.49a	18.92a	40.21a
Shoot	5	60b	16.002b	1.15e	1.98e	1.94e	3.89e
	10	32cd	11.68c	1.07e	1.52f	1.77f	1.54ef
	15	0f	0f	0f	0g	0g	0f
Leaf	5	8ef	0.86f	0.02f	0.02g	0.33g	0.01f
	10	0f	0f	0f	0g	0g	0f
	15	0f	0f	0f	0g	0g	0f
Flower	5	0f	0f	0f	0g	0g	0f
	10	0f	0f	0f	0g	0g	0f
	15	0f	0f	0f	0g	0g	0f
Root	5	63b	15.62b	2.60b	5.30b	8.66b	14.74b
	10	39c	10.51d	2.07c	3.97c	5.16c	10.24c
	15	21de	3.76e	1.40d	1.78d	2.37d	5.79d
F-test		**	**	**	**	**	**
SE (+)		2.12	0.61	0.19	0.05	0.15	0.35
CV (%)		9.35	8.15	7.78	4.43	7.91	6.99

** = Significant at 0.01 probability level. Means within a column followed by same superscript letter (s) are not significantly different at 0.01probability level.
§NGSPD = Number of germinated seeds per day.

in these plant parts as compared to shoot and roots (Kanchan and Jaycharad, 1980). Similarly, Belz et al. (2007) report parthenin released to the soil during decomposition of Parthenium leaves is the leading toxic compound causing phytotoxicity.

Soybean and haricot bean roots were appeared more sensitive to allelopathic effect than shoot, which is in agreement with the results of Tefera (2002) and Wakjira et al. (2005). This may be due to direct contact of the root with the extracts and subsequently with inhibitory compounds (Qasem, 1995; Tefera, 2002). The reduction in seedling roots length may be attributed to the reduced rate of cell division due to the presence of allelochemicals, which might inhibit gibberellin and indoleacetic acid function (Tomaszewski and Thimann, 1966).

The findings of this study demonstrated that Parthenium weed has allelopathic effect on soybean and haricot bean as indicated by its inhibitory effect on germination, germination rate, growth and dry matter production of the seedlings. Similar results have been reported for cabbage (Kohli et al., 1985), pumpkin (*Cucurbita moschata*) (Guzman, 1988), tomato (Mersie and Singh, 1988), multi purpose trees and arable crops (Swaminathan et al., 1990; Evans, 1997), tef (*Eragrostis tef*) (Tefera, 2002) and maize and sorghum (Tamado et al., 2002). From the present preliminary investigation under laboratory condition, it can be concluded that Parthenium has the potential of inhibiting seed germination and seedling growth of soybean and haricot bean. This is a clear indication Parthenium is going to be a menace in the production of the crop. Hence integrated management strategy of Parthenium should be sought and this calls for a concerted effort of all institutions affiliated in agricultural production.

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Addresses of the authors:

Mr. Anteneh Netsere, Jimma Agricultural Research Center, P.O. Box 192, Jimma, Ethiopia, E-mail: anetsere@yahoo.com

Mr. Esayas Mendesil (corresponding author), Department of Horticulture & Plant Sciences, Jimma University College of Agriculture and Veterinary Medicine, P.O. Box 307, Jimma, Ethiopia, E-mail: emendesil@yahoo.com