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Allelopathic effects of Jimsonweed (*Datua stramonium* L.) seed on seed germination and seedling growth of some poaceous crops

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Abstract

Laboratory and greenhouse experiments were carried out at the Faculty of Agricultural Sciences, University of Gezira, Sudan in season 2014/15 to study the allelopathic effects of Jimsonweed (*Datua stramonium* L.) seed on seed germination and seedling growth of some poaceous crops. Laboratory experiments were conducted to study the allelopathic effects of aqueous extract of Jimsonweed (*Datua stramonium* L.) seed on seed germination of sorghum (*Sorghum bicolor* [L.] Moench), millet (*Pennisetum glaucum* [L.] R. Br.), maize (*Zea mays* L.) and wheat (*Triticum vulgare* L.). Six concentrations (0, 20, 40, 60, 80 and 100%) of the aqueous extract of Jimsonweed seed were prepared from the stock solution (50 g / l). Treatments, for each crop, were arranged in completely randomized design with four replicates. The seeds were examined for germination at three days after initial germination. Greenhouse experiments were conducted to study the allelopathic effects of Jimsonweed seed powder on seedling growth of the same poaceous crops. The seed powder was incorporated into the soil at rate of 0, 1, 2, 3, 4 and 5% on w/w bases in pots. Treatments, for each crop, were arranged in completely randomized design with four replicates. The experiments were terminated at 30 days after sowing and the plant height, number of leaves and root length of crop seedlings were measured as well as plant fresh and dry weight. Data were subjected to analysis of variance procedure. Means were separated for significance using Duncan`s Multiple Range Test at $p \leq 0.5$. The results showed that the aqueous extract significantly reduced seed germination of the tested poaceous crops and there was direct negative relationship between concentration seed germination. Also, the results showed that incorporating seed powder into the soil significantly decreased plant height, number of leaves and root length of crop seedlings as well as seedling fresh and dry weight. In addition, the reduction in seedling growth was increased as seed powder increased in the soil. It concludes that Jimsonweed has allelopathic effects on seed germination and seedling growth of the poaceous crops.

Keywords: Allelopathic; Allelochemicals; Jimsonweed; *Datura*; Poeaeae; sorghum; millet; maize; wheat

Introduction

Jimsonweed (*Datua stramonium* L.), belonging to the family Solanaceae, is a naturally fast growing weed and is widely distributed in all warm regions of the world. Its presence has been sighted along the boundaries and hedges of the cultivating fields. Subsequently, seeds of this plant have been found as impurities in important cultivated crops (Ahmad, *et al.*, 2014 and Alexander *et. al.*, 2008).The plant competes for light, nutrients, moisture and space and thus causes severe losses to yield. (Ahmad, *et al.*, 2014). Beside this, the plant can manipulate partners, competitors and ecosystems through a biological natural phenomenon known as allelopathy (Elisante and Ndakidemi, 2014).

Allelopathy refers to direct or indirect negative effects of one plant on another through the release of chemical compounds into the environment (Delabays *et. al.*, 2004). These biochemicals are known as allelochemicals (Singh and Chaundhary, 2011). Allelochemicals are released from plant parts by means of leaching, root exudation, volatilization, residue decomposition and other processes in both natural and agricultural systems (Chou, 1990). The allelochemicals can reduce cell division or auxin that induces the growth of shoot and roots (Gholami *et al.*, 2011). Allelochemicals such as phenolic compounds inhibit root and shoot length (Hussain and Reigosa, 2011). Growth inhibition caused by these allelochemicals may probably be due to its interference with the plant growth processes (Gholami *et al.*, 2011). Allelochemicals released to the environment can either inhibit shoot and/or root growth, nutrient uptake, or may attack a naturally occurring symbiotic relationship thereby destroying the plant's source of a nutrient.

Jimsonweed plant is rich in a variety of secondary metabolites such as tannins, terpenoids, alkaloids, flavonoids, phenols, steroids, glycosides and volatile oils (Banso and Adeymo, 2006). All parts of plant, including seeds, contain a terpenoids, phenoloids and alkaloids, principally scopolamine and hyosciamine (Mothes, 1955) with atropine and meteloidine present in small amounts (Aplin, 1976), showing significant allelopathic activity (Narwal, 1994), sufficient to inhibit the germination and early radicle growth of many crops (Zheng *et al*., 2007 , Zheng and Li, 2008 and Wang, *et al*., 2009). The allelopathic interactions showed that the plant is dangerous and may cause great deal of lose to the economically important crops and its presence in the cultivating fields is a matter of concern (Ahmad, *et al.*, 2014). Tropane alkaloids produced by Jimsonweed have been detected as contaminant in many crops such as linseed and soybean. The tropane alkaloids present in Jimsonweed are hyoscyamine, atropine and scopolamine and the highest alkaloid concentration found in the seed (Alexander *et. al.*, 2008). Germination and growth of many crops were significantly inhibited by allelochemical extracts of Jimsonweed (You and Wang, 2011). Aqueous seed and leaf extracts of Jimsonweed have allelopathic effects on leaf chlorophyll content, root and shoot length, fresh and dry weight of grass species, *Cenchrus ciliaris* (Elisante *et. al.*, 2013).

Understanding well the mechanism of allelopathic interactions between weeds and crops will enable to come up with proper and effective management ways to prevent further infestations. Considering the economic importance of poaceous crops, these studies were carried out to investigate the allelopathic effects of Jimsonweed seed on seed germination and seedling growth of some poaceous crops, particularly sorghum (*Sorghum bicolor* [L.] Moench), millet (*Pennisetum glaucum* [L.] R. Br.), maize

(*Zea mays* L.) and wheat (*Triticum vulgare* L.).

Materials and Methods

Experimental site

A series of experiment was carried out at Faculty of Agricultural Sciences (FAS), University of Gezira (UofG), Sudan, comprised germination test and pot experiments. The germination test was conducted in the biology laboratory having an average temperature range of 25 - 30°C and the relative humidity ranging from 60 to 70 %. The pot experiment was conducted in a greenhouse of horticulture nursery under field conditions. The experimental site was located at Latitude 14° 24′ N, Longitude 33° 29′ E and 407m asl. The climate of the region is semi-desert with a mean annual precipitation of 100-250 mm/year, with the rainy season extended from June to October and the dry season from March to June. The mean annual evapotranspiration is 2400 mm/year. The mean annual minimum and maximum temperatures are 12 °C in January and 42°C in May, respectively. The soil of the area is characterized by heavy clay soil (clay 60%), with pH 8-8.5, low organic matter and nitrogen, adequate potassium and low available phosphorous (Elbasher, 2016).

Materials collection

Mature fruits of Jimsonweed plants were collected from Experimental Farm of the FAS in season 2014/15. The fruits were transferred to the biology laboratory of the FAS. Seeds were collected from the fruits were washed with sterilized distill water, air dried on bench for 15 days at room temperature and in a dark room to avoid the direct sun light that might cause undesired reactions. The dried seeds were then crushed into powder and kept in brown bottles till used. Certified commercial seeds of sorghum (cv. Tabat), millet (cv. Baladi), maize (cv. Hudeiba I) and wheat (cv. Imam), that have a germination percentage of 95-100% and purity of 100%, were obtained from the central market of Wed Medani city, Gezira state, Sudan. The seeds were surface sterilized by sodium hypochlorite, (NaOCl) 1% (v/v), solution, for 3 min continuously agitated to reduce fungal infection. Subsequently the seeds were washed with sterilized distill water for several times and stored at room temperature till used.

Laboratory experiments

These experiments were conducted in the biology laboratory to study the allelopathic effects of aqueous extract of Jimsonweed seeds on seed germination of sorghum, millet, maize and wheat. Fifty grams of seeds powder of Jimsonweed were placed in a conical flask, sterilized distill water was added to give a volume of 1000 ml and then the flasks were shaken for 24 hours at room temperature (27±3°C) by an orbital shaker (160 rpm). The extracts were drained through double layers of cheese cloth and then through 2 layers of Whatman No-2 filter paper to remove solid material. The filtrate was centrifuged at 3000 rpm for 20 min. The supernatant was collected and filtered through a 0.22 µm membrane filter paper. The stock solution was stored at 4°C until further use. Six concentrations (0, 20, 40, 60, 80 and 100%) of the aqueous extract were prepared from the stock solution. Seeds of sorghum, millet, maize and wheat (100 seeds each) were put on Glass Fiber Filter Paper (GFFP) (Whatman GF/C) placed in a glass Petri-dish (GPD), 9 cm internal diameter (i.d). Each GPD moistened with 20 ml of Jimsonweed seed aqueous extract, sealed with Parafilm, covered with black polyethylene bag and incubated at 30^0C in the dark. The treatments, of each crop, were arranged in completely randomized design with four replicates. The seeds were examined for germination at three days after initial germination for three days.

Greenhouse experiments

These experiments were conducted at the greenhouse of horticulture nursery to study the allelopathic effects of seeds powder of Jimsonweed on seedlings growth of sorghum, millet, maize and wheat. Plastic pots, 10 cm i.d. and 18 cm high with drainage holes at the bottom, were filled with Gezira soil and river silt that at the ratio 1:1, oven dried at 120 C for 48 h and screened to pass a 2-mm sieve. The seed powder of Jimsonweed was incorporated into the soil at rate of 0, 1, 2, 3, 4 and 5% on w/w bases. Five seeds of each crop were sown in pots. The pots were kept weed free, irrigated and then seedlings were thinned to 3 plants per pot, 7 days after emergence. Treatments, for each crop, were arranged in completely randomized design with four replicates. At 30 days after sowing the experiments were terminated and plant height (cm), number of leaves and root length (cm) of crop seedlings were measured as well as plant fresh and dry weight (g).

Statistical analysis

Data were collected and subjected to analysis of variance procedure. Means were separated for significance using Duncan`s Multiple Range Test at $p \leq 0.05$. The statistical analysis was done using the Statistical Analysis System software v.9.0 (SAS, 2004).

Results

Laboratory experiments

The results of laboratory experiments showed that the aqueous extract of Jimsonweed seeds significantly ($P \leq 0.05$) reduced seed germination of the tested poaceous crops compared to the controls (Table 1). The reduction in seed germination increased with concentration of aqueous seeds extract. The highest seed germination were observed in the corresponding controls .However, the highest concentration (100%) displayed lowest seed germination which were 65.3, 83.8, 74.5 and 54.3% in sorghum, millet, maize and wheat, respectively. Millet seeds were not highly affected by the aqueous extract of Jimsonweed seed in comparison to other tested crops.

Greenhouse experiments

The results of the greenhouse experiments showed that incorporated seeds powder of Jimsonweed into the soil significantly ($P \leq 0.05$) decreased seedling growth attributes of tested poaceous crops in comparison to the controls (Table 2, 4, 5 and 6).

Effects on plant height

At 30 days after sowing, the highest plant crop seedlings were observed in the control treatments (Table 2). The plant height of sorghum, millet, maize and wheat in the control treatments were 41.0, 45.3, 35.3 and 25.3 cm, respectively. However, increasing the concentration of seeds powder of Jimsonweed into the soil exhibited lowest plant height in all tested crops. The seed powder when incorporated into the soil at rate of 1 to 5% decreased the plant height of poaceous crops in comparison to control treatments (Table 2). Moreover, the reduction in the plant height was increased as seed powder increased in the soil. The greatest reduction in plant height was observed when seed powder was incorporated into the soil at the rate of 5%. At high concentration of seed powder, the plant heights were significantly decreased to 30.5 cm in sorghum, 30.3 cm in millet, 24.8 cm maize and 10.5 cm in wheat seedlings.

Effects on number of leaves

At 30 days after sowing, the results showed that incorporated Jimsonweed seed powder into the soil at rate of 1, 2, 3, 4 and 5% negatively affected the leaves number of seedlings of all tested crops compared to the control treatments (Table 3). The highest leaves numbers of crop seedlings were

obtained in the control treatments. The leaves number of sorghum, millet, maize and wheat in the control treatments was 7.5, 8.0, 7.3 and 6.0, respectively (Table 3). Incorporating seeds powder into soil at the rate of 4 and 5% significantly ($P \leq 0.05$) reduced leaves number of seedlings of sorghum and maize in comparison to the control treatments. While, significant reduction in leave number of seedlings of millet was obtained as seed powder incorporated into soil at the rate of 3% or more in millet and at the rate of 5% in wheat.

Effects on root length

Incorporation of Jimsonweed seed powder into the soil significantly reduced root length of poaceous crops (Table 4). The reduction in root lengths was increased with Jimsonweed seed powder concentration in the soil. At 30 days after sowing, the longest root lengths of crop seedlings were observed in the control treatments and amounted to 20.3, 25.3, 20.0 and 15.3cm in sorghum, millet, maize and wheat, respectively. The root length was decreased to 10.0 cm in sorghum, 15.0 cm in millet, 14.8 cm maize and 7.3 cm in wheat seedlings when Jimsonweed seed powder were incorporated into the soil at concentration of 5%.

Effects on fresh weight

The greatest fresh weights of crop seedlings, at 30 days after sowing, were recorded in control treatments (Table 5). The incorporation Jimsonweed seed powder into soil at the rate of 2% or more significantly reduced fresh weight of sorghum, millet, maize and wheat in comparison to control treatments. Moreover, the reduction in the fresh weight was increased as seed powder increased in the soil. The incorporation of Jimsonweed seed powder into the soil at rate of 5% resulted in seedling fresh weights amounted to 6.1, 5.1, 9.0 and 4.1g in sorghum, millet, maize and wheat, respectively

Effects on dry weight

The results of incorporated Jimsonweed seed powder into the soil at rate of 1, 2, 3, 4 and 5% on seedling dry weight had same trend as seedlings fresh weight (Table 6). Incorporating Jimsonweed seed powder into the soil at rate of > 3% significantly reduced fresh weight of sorghum, millet and maize in comparison to the control treatments. While, significant reduction in dry weight of wheat seedlings were obtained when seed powder incorporated into the soil at rate of 1% or more compared to the control treatments. The incorporation of seed powder into to the soil at concentration of 5% (w/w) decreased the seedling dry weight to 0.9g in sorghum, 0.9 g in millet, 2.0g maize and 0.8 g in wheat seedlings.

Discussions

The results of these studies revealed that the aqueous extract of Jimsonweed seed significantly reduced seed germination of the tested poaceous crops and there was a direct relationship between concentration and reduction in germination. These results are in lined with Ahmad *et al.* (2014) who found that the aqueous extracts of the aerial parts of Jimsonweed pose significant and varying allelopathic effects on seed germination and seedling vigour of wheat. The germination was inhibited as well as delayed according to the extract concentrations. The same authors also pointed out that the extracts inhibited germination process and the plant should be eradicated even if found near to the growing fields because the seeds contain the dangerous alkaloids and can be dispersed in the fields during seed dispersal. These seeds remain in dormant stage for years and when their dormant stage is over they grow vigorously and could make the precious fields toxic for the crop species.

This study indicated that incorporating seed powder of Jimsonweed into the soil at rate of 1, 2, 3, 4 and 5% (w/w) significantly

decreased plant height, number of leaves per seedling, root length of crop seedlings as well as plant fresh and dry weight. In addition, the reduction in seedling growth was increased as seed powder increased in the soil. These findings were in agreement with observation made by Elisante *et. al.*, (2013) who carried out a pot experiment to determine the allelopathic effects of Jimsonweed on leaf chlorophyll content, root and shoot elongation, fresh and dry weight of two wild plant species: *Cenchrus ciliaris* and *Neonotonia wightii*. They reported that the total chlorophyll content of *C. ciliaris* and *N. wightii* were significantly reduced in all treated plants, irrespective of concentrations, of aqueous seed and leaf extracts of Jimsonweed. Relative to the control treatments, there was greater reduction in root and shoot length which attributed to higher concentrations of aqueous seed and leaf extracts. Fresh and dry weight of tested species significantly decreased after being treated with both seed and leaf aqueous extracts of Jimsonweed. They found that the allelopathic effects of aqueous seed and leaf extracts from Jimsonweed on tested species was concentration-dependent. The inhibitory effects on all tested species increased as the concentration of both extracts increased from 0% to 100%. They concluded that aqueous seed and leaf extracts of Jimsonweed have allelopathic effects on leaf chlorophyll content, root and shoot length, fresh and dry weight of grass (*C. ciliaris*) and legume (*N. wightii*) species.

Conclution

- The aqueous extract of Jimsonweed seed significantly reduced seed germination of the poaceous crops; sorghum, millet, maize and wheat.
- Incorporating seed powder of Jimsonweed into the soil significantly decreased plant height, number of leaves and root length of crop seedlings as well as plant fresh and dry weight of all tested crops.
- The reduction in seedling growth was increased as seed powder increased in the soil.
- Jimsonweed has allelopathic effects on seed germination and seedling growth of the poaceous crops.

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Table 1. Allelopathic effects of seed aqueous extract of Jimsonweed on seed germination of some poaceous crops

Concentration of aqueous (w/v)	Seed germination (%)			
	Sorghum	Millet	Maize	Wheat
0%	98.3 a	99.3 a	99.0 a	96.8 a
20%	93.5 ab	98.3 a	93.8 a	92.5 a
40%	91.0 ab	93.3 ab	82.5 b	82.5 b
60%	87.5 b	89.0 bc	78.8 bc	73.3 c
80%	74.3 c	86.5 bc	77.5 bc	64.3 d
100%	65.3 d	83.8 c	74.5 c	54.3 e
$SE_{\pm}$	2.40	2.52	1.91	2.14
$CV_{\%}$	5.7	5.5	4.5	5.6

Table 2. Allelopathic effects of incorporated seeds powder of Jimsonweed into soil on plant height of some poaceous crops

Concentration seeds powder (w/w)	Plant height (cm)			
	Sorghum	Millet	Maize	Wheat
0 %	41.0 a	45.3 a	35.3 a	25.3 a
1 %	40.8 a	44.0 ab	35.0 ab	23.5 a
2 %	38.8 a	40.0 b	33.3 abc	22.0 a
3 %	39.0 a	34.8 c	29.8 bcd	16.5 b
4 %	37.3 a	31.5 c	28.0 cd	11.3 c
5 %	30.5 b	30.3 c	24.8 d	10.5 c
$SE_{\pm}$	1.73	1.64	1.69	1.43
$CV_{\%}$	9.1	8.7	10.9	15.7

Table 3. Allelopathic effects of incorporated seeds powder of Jimsonweed into soil on number of leaves of some poaceous crops

Concentration seeds powder (w/w)	Number of leaves			
	Sorghum	Millet	Maize	Wheat
0 %	7.5 a	8.0 a	7.3 a	6.0 a
1 %	6.3 ab	7.8 a	7.0 ab	5.8 a
2 %	6.0 ab	7.0 ab	6.3 abc	5.5 a
3 %	5.8 ab	6.0 bc	6.3 abc	5.3 a
4 %	5.5 b	5.0 cd	5.5 bc	4.8 ab
5 %	4.8 b	4.5 d	4.8 c	3.8 b
$SE_{\pm}$	0.34	0.47	0.50	0.61
$CV_{\%}$	19.5	14.7	16.2	19.4

Table 4. Allelopathic effects of incorporated seeds powder of Jimsonweed into soil on seedlings root length of some poaceous crops

Concentration seeds powder (w/w)	Seedlings root length (cm)			
	Sorghum	Millet	Maize	Wheat
0 %	20.3 a	25.3 a	20.0 a	15.3 a
1 %	17.0 b	22.0 a	19.3 a	15.0 a
2 %	15.3 bc	18.3 b	17.3 ab	13.3 ab
3 %	13.5 c	17.3 b	16.3 b	12.0 bc
4 %	12.3 cd	17.3 b	16.0 b	10.0 cd
5 %	10.0 d	15.0 b	14.8 b	7.3 d
$SE_{\pm}$	0.97	1.10	0.92	0.93
$CV_{\%}$	13.1	11.5	10.7	15.4

Table 5. Allelopathic effects of incorporated seeds powder of Jimsonweed into soil on seedlings fresh weight of some poaceous crops

Concentration seeds powder (w/w)	Seedlings fresh weight (g)			
	Sorghum	Millet	Maize	Wheat
0 %	12.3 a	10.2 a	14.3 a	8.1 a
1 %	12.0 a	10.2 a	14.2 a	8.1 a
2 %	10.4 b	8.1 b	12.0 b	6.0 b
3 %	8.2 c	8.0 b	12.0 b	6.1 b
4 %	7.1 d	6.2 c	11.1 b	5.2 c
5 %	6.1 e	5.1 d	9.0 c	4.1 d
$SE_{\pm}$	0.28	0.15	0.30	0.15
$CV_{\%}$	6.1	3.8	5.0	4.8

Table 6. Allelopathic effects of incorporated seeds powder of Jimsonweed into soil on seedlings dry weight of some poaceous crops

Concentration seeds powder (w/w)	Seedlings dry weight (g)			
	Sorghum	Millet	Maize	Wheat
0 %	3.8 a	2.3 a	3.1 a	1.8 a
1 %	3.6 a	2.2 a	3.1 a	1.6 b
2 %	2.9 b	1.9 b	3.0 a	1.5 b
3 %	1.7 c	1.4 c	2.6 b	1.2 c
4 %	1.4 d	1.2 c	2.2 c	1.1 c
5 %	0.9 e	0.9 d	2.0 c	0.8 d
$SE_{\pm}$	0.09	0.08	0.09	0.07
$CV_{\%}$	7.8	9.8	7.0	10.7

التأثير التضادي لبذور عشبة السيكران (*Datua stramonium* L.) على انبات البذور ونمو بادرات بعض المحاصيل النجيلية

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المستخلص

أُجريت مجموعة من التجارب في المعمل والبيت المحمي بكلية العلوم الزراعية، جامعة الجزيرة، السودان في موسم 2015/2014. أُجريت التجارب المعملية لدراسة التأثيرات التضادية للمستخلص المائي لبذور عشبة السيكران (*Datua stramonium* L.) على انبات بذرة الذرة الرفيعة والدخن الذرة الشامية والقمح. تم تحضير ستة تراكيز (0 و20 و40 و60 و80 و100%) من المستخلص المائي لمحلول الاساس (50 جم/ ليتر). أضيفت هذه التراكيز الي بذور محاصيل الذرة الرفيعه والدخن والذرة الشامية والقمح. وُضعت المعاملات، لكل محصول، في تصميم كامل العشوائية باربعة تكرارات. تم فحص البذور بغرض الانبات بعد ثلاثة ايام من بداية الانبات. أُجريت تجارب الاصص في البيت المحمي لدراسة التأثير التضادي لمسحوق بذور عشبة السيكران على نمو بادرات ذات المحاصيل. تم خلط مسحوق البذور في التربة بمعدل 0 و1 و2 و3 و4% على اساس وزن/وزن في الاصص. وُضعت المعاملات، لكل محصول، في تصميم كامل العشوائية باربعة تكرارات. تم انهاء التجربة عند 30 يوم بعد الزراعة وتم قياس طول النبات (سم) وعدد الاوراق وطول الجذر (سم) كما تم قياس الوزن الرطب والجاف للنبات (جرام). جمعت البيانات وأُخضعت لتحليل التباين (ANOVA). تمت مقارنة المتوسطات للمعنوية باستخدام إختبار دنكن متعدد المدى (DMRT) باحتمال ≥ 0.5. أوضحت النتائج أن المستخلص المائي خفض معنوياً انبات بذور المحاصيل النجيلية المختبرة وكانت هنالك علاقة مباشرة بين التركيز والنقص في انبات بذور المحاصيل التي اجريت عليها الدراسة. كما أوضحت النتائج أن خلط مسحوق البذرة في التربة أدى الى خفض طول النبات وعدد الاوراق وطول الجذر كما خفض الوزن الرطب والجاف للنبات انخفاضاً معنوياً مقارنة بالشاهد. اضافة الى ذلك انخفض نمو البادرات بزيادة تركيز مسحوق البذور في التربة. يستنتج من ذلك أن عشبة السيكران لها تأثير تضادي على انبات البذرة ونمو البادرة في المحاصيل النجيلية.