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Allelopathic effects of pigweed (*Amaranthus viridis* L.) on seed germination and seedling growth of some poaceous crops

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المستخلص:

أُجريت تجارب في المعمل والبيت المحمي بكلية العلوم الزراعية، جامعة الجزيرة، السودان في موسم 15/2014. أُجريت التجارب المعملية لدراسة التأثيرات التضادية للمستخلص المائي للاجزاء فوق سطح التربة لعشبة لسان الطير (*Amaranthus viridis* L.) على انبات بذرة الذرة الرفيعة (*Sorghum bicolor* [L.] Moench) والدخن (*Pennisetum glaucum* [L.] R. Br.)، والذرة الشامية (*Zea mays* L.) والقمح (*Triticum vulgare* L.). تم تحضير ستة تراكيز (0 و 20 و 40 و 60 و 80 و 100%) من المستخلص المائي للاجزاء فوق سطح التربة 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 البيوت المحمية لدراسة التأثيرات التضادية لمسحوق الاجزاء فوق سطح التربة لعشبة لسان الطير على نمو بادرات ذات المحاصيل. تم خلط المسحوق للاجزاء فوق سطح التربة في التربة بمعدل 0 و1 و2 و3 و4 و5% 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 وعدد الاوراق وطول الجذر كما تم قياس الوزن الرطب والجاف للنبات. جمعت البيانات وأُخضعت تحليل التباين (ANOVA). تمت مقارنة المتوسطات للمعنوية باستخدام إختبار دنكن متعدد المدى (DMRT) باحتمال ≤ 0.05. أوضحت النتائج أن المستخلص المائي للاجزاء فوق سطح التربة لعشبة لسان الطير خفض معنوياً انبات البذرة للمحاصيل النجيلية المختبرة وكانت هنالك علاقة مباشرة بين التركيز والانخفاض على الانبات. كما أوضحت النتائج أن خلط مسحوق الاجزاء فوق سطح التربة في التربة خفض طول النبات وعدد الاوراق وطول الجذر كما خفض الوزن الرطب والجاف للنبات. اضافة الى ذلك انخفض نمو البادرات بذيادة تركيز المسحوق في التربة. استناداً على النتائج المدعمة بالدراسات المختلفة يستنتج من ذلك أن عشبة لسان الطير لها تأثير تضادي على انبات البذرة ونمو البادرة في المحاصيل النجلية.

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 aboveground parts of pigweed (*Amaranthus viridis* L.) on seed germination and seedling growth of some poaceous crops. Laboratory experiments were conducted to study the allelopathic effects of aqueous extract of aboveground parts of pigweed 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 aboveground parts 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 powder of aboveground parts of pigweed on seedling growth of the same crops. The powder of aboveground parts 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 plant height, number of leaves and root length of crop seedlings were measured as well as seedlings fresh and dry weight. Data were collected and subjected to analysis of variance procedure. Means were separated for significance using Duncan`s Multiple Range Test at $p \leq 0.5$. The results showed that the aqueous extract of aboveground parts of pigweed significantly reduced seed germination of the tested poaceous crops and there was direct strong negative relationship between concentration and seed germination. Also, the results showed that incorporating powder of aboveground parts into the soil significantly decreased plant height, number of leaves and root length of crop seedlings as well as seedlings fresh and dry weight. In addition, the reduction in seedling growth was increased as the powder increased in the soil. Based on results supported by different studies, it was concluded that pigweed has allelopathic affects on seed germination and seedling growth of the tested poaceous crops.

Keywords: Allelopathic, Allelochemicals, Pigweed, *Amaranthus*, Poeaeae, millet, maize, wheat

1. Introduction

Pigweed (*Amaranthus viridis* L.), belonging to the family Amaranthaceae, is commonly known with different names such as Amaranth, Slender amaranth, Chinese spinach, Caruru, and Tampala. It is an annual herb, erect with height of 40 - 100 cm, little branched, slightly pigmented with thick stems and rather fleshy and it only multiplies by seeds (Lorenzi and Matos, 2008; Teutonico and Knorr, 2011; Pulipati, *et al.*, 2014). Pigweed is a common wild vegetable and weed of cultivation and it is distributed in the warmer parts of the world (Hussain *et al.* 2003, Tabriz and Yarnia 2011). It is one of the most important weed species in numerous agricultural areas, being the third widespread dicotyledonous weed species in the world (Namdari *et al*., 2012). It has been reported as a principal and troublesome weed of corn (*Zea mays* L.), sugarcane (*Saccharum officinarum* L.), sorghum (*Sorghum bicolor* L.), and vegetables (Holm *et al.*, 1991). Pigweed has the C4 photosynthetic pathway, which confers an ability to grow rapidly at high temperatures and high light levels, to tolerate drought, and to compete aggressively with warm-season crops for light, moisture, and nutrient (Horak and Loughin, 2000; Shrestha and Swanton, 2007). One to three pigweed plants per 3 m of row emerging with maize can cause significant yield losses (Massinga *et al.*, 2001). Research indicates that leaves and debris leaves, roots, pollen, flowers and stem of *Amaranthus* spp. have detrimental effects on germination and growth of different crop species (Hussain *et al.*, 2003; Tabrizi and Yarnia, 2011). The plant possesses certain allelopathic potential, both inhibitory and stimulatory. The effect depended on extract concentration and crop cultivar (Allemann and Denner , 2006).

Allelopathy refers to direct or indirect positive or negative effect 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. Allelochemicals released to the environment can either inhibit shoot/root growth, nutrient uptake, or may attack a naturally occurring symbiotic relationship thereby destroying the plant's source of a nutrient (Gholami *et al.*, 2011).

The phytochemical screening showed the presence of biologically active constituents belonging to the group of saponins, tannins and phenols, flavonoids, alkaloids, cardiac glycosides, steroids and triterpenoids in the extracts of *A. viridis* (Carminate *et al.*, 2012; Malik *et al.,* 2016). The allelopathic interactions showed that total chlorophyll content, number of developed leaves, stem length, and total plant dry matter were negatively affected by allelopathic effect caused by Amaranth aqueous extracts. Plants received greater concentrations of extract (15 and 20% w/v) matured later due to delayed flowering, but differential reactions were observed depending on the crop type. Considerable losses of grain yield were recorded at 15 and 20% extract concentrations (Amini *et al*., 2013).

Despite the attention paid to allelopathy by ecologists, biologists and herbologists, complicated relationship "competition - allelopathy" in the system "weed – crop plant" is not fully understood (Petrova *et al.*, 2015). 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 pigweed (*A. viridis*) 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.).

2. Material and Methods

2.1 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 under 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).

2.2 Materials collection

Mature plants of pigweed plants were collected from Experimental Farm of the FAS in season 2014/15. The plants were transferred to the biology laboratory of the FAS. The aboveground parts of plants were collected and then washed with sterilized distill water, air dried on bench for 15 days at room temperature in a dark room to avoid the direct sun light that might cause undesired reactions. The dried aboveground parts 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 distilled water for several times and stored at room temperature till used.

2.3 Laboratory experiments

These experiments were conducted in the biology laboratory to study the allelopathic effects of aqueous extract of aboveground parts of pigweed on seed germination of sorghum, millet, maize and wheat. Fifty grams of powder of aboveground parts of pigweed were placed in a conical flask, sterilized distill water was added to give a volume of 1000 ml and then 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 (50 g/l). 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 aqueous extract of aboveground parts of pigweed, 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.

3. Greenhouse experiments

These experiments were conducted at the greenhouse of horticulture nursery to study the allelopathic effects of powder of aboveground parts of pigweed on seedling 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. Powder of aboveground parts of pigweed 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).

4. 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).

5. Results

5.1 Laboratory experiments

The results of laboratory experiments showed that the aqueous extract of aboveground parts of pigweed significantly ($P \leq 0.05$) reduced seed germination of the tested poaceous crops compared to the controls (Table 1). Relative to the control treatments that achieved the highest germination percentages, there were greater reductions in seed germination which were observed in higher concentrations of aqueous seed extract. The corresponding germination in sorghum, millet, maize and wheat was 64.3, 82.8, 73.5 and 53.5%, respectively. Also, the results showed direct relationship between concentration and reduction in germination (Fig. 1).

5.2 Greenhouse experiments

The results of the greenhouse experiments showed that incorporating powder of aboveground parts of pigweed into the soil at rate of 1, 2, 3, 4 and 5% significantly decreased seedling growth of tested poaceous crops compared to control treatments (table 2, 4, 5 and 6).

5.3 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 was 40.5, 44.3, 36.3 and 27.0 cm, respectively. Incorporating powder of aboveground parts of pigweed into the soil at rate of 1 to 5% significantly ($P \leq 0.05$) decreased the plant height of poaceous crops in comparison to control treatments. Moreover, the reduction in the plant height was increased as powder increased in the soil. The greatest reduction in plant height was observed when powder was added to the soil at the rate of 5%. The plant height was decreased to 31.0 cm in sorghum, 30.0 cm in millet, 25.3 cm maize and 11.0 cm in wheat seedlings ($P \leq 0.05$).

5.4 Effects on number of leaves

At 30 days after sowing, the results showed that incorporating powder of aboveground parts of pigweed into the soil at rate of 1, 2, 3, 4 and 5% affected the leave number of seedlings of the tested poaceous crops compared to control treatments (Table 3). The highest leave numbers of crop seedlings were observed in the control treatments. The leave number of sorghum, millet, maize and wheat in the control treatments was 7.3, 7.8, 7.0 and 5.8, respectively (table 3). Incorporating powder in soil at the rate of 1 to 5% significantly ($P \leq 0.05$) reduced leave number of seedlings. Incorporating powder of aboveground parts of pigweed in soil at the rate 5% reduced leave number of seedlings of sorghum, millet, maize and wheat to 4.8, 4.8, 5 and 4, respectively.

5.5 Effects on root length

Significant reductions in the root length of crop seedlings of poaceous crops were shown when powder of aboveground parts of pigweed incorporated into the soil at rate of 1, 2, 3, 4 and 5% (Table 4). At 30 days after sowing, the longest root lengths of crop seedlings were observed in the control treatments. The root length of sorghum, millet, maize and wheat in the control treatments was 19.5, 24.5, 19.3 and 14.5 cm, respectively. Incorporating powder of aboveground parts of pigweed into the soil at rate of 1% significantly decreased the plant height of poaceous crops in comparison to control treatments. In addition, the reduction in the root length was increased with further increase of powder in the soil. The greatest reduction in root length was observed when the powder was added to the soil at the rate of 5%. The root length was decreased to 9.8 cm in sorghum, 14.5 cm in millet, 14.3 cm maize and 7.5 cm in wheat seedlings ($P \leq 0.05$).

5.6 Effects on fresh weight

The greatest fresh weights of crop seedlings, at 30 days after sowing, were recorded in control treatments (Table 5). Incorporating powder of aboveground parts of pigweed in soil at the rate of 2% 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 the powder increased in the soil and the most significant effect was observed at the rate of 5%. The corresponding seedling fresh weight in sorghum, millet, maize and wheat was 5.9, 5.0, 9.0 and 4.0g, respectively ($P \leq 0.05$).

5.7 Effects on dry weight

The results of incorporating powder of aboveground parts of pigweed into the soil at rate of 1, 2, 3, 4 and 5% on seedling dry weight were similar in trend to that shown in the results of the fresh weight (Table 6). Incorporating powder in soil at the rate of 1% significantly reduced fresh weight of wheat in comparison to control treatments. While, significant reduction in dry weight of sorghum and millet seedlings were obtained when powder of aboveground parts of pigweed incorporated in soil at the rate of 2% or more compared to control treatment. The dry weight was decreased to 1.2g in sorghum, 1.0 g in millet, 1.9g maize and 1.0 g in wheat seedlings ($P \leq 0.05$).

6. Discussion

The results of these studies revealed that the aqueous extract of aboveground parts of pigweed significantly reduced seed germination of the tested poaceous crops and there was a direct relationship between concentration and reduction in germination. Also, the study indicated that incorporating powder of aboveground parts of pigweed into the soil at rate of 1, 2, 3, 4 and 5% (w/w) significantly reduced seedlings growth. Moreover, the reduction in seedling growth was increased as the powder increased in the soil. This finding was in agreement with observation made by *de Souza et. al.*, (2011) who stated that *Amaranthus* spp. are plants with proven allelopathic potential. The release of allelochemicals from *Amaranthus* spp. in the environment can influence seed germination, photosynthesis rate, reduce growth and, consequently, the productivity of various plant species. Among the *Amaranthus* spp. with allelopathic potential is *A. viridis* (*de Souza et al.*, 2011).

Similar result was obtained by Mohnot and Soni (1979) who pointed out that aqueous extracts of dry leaves of *Amaranthus tricolor* L. retarded the germination and inhibited root and aerial part growth of sorghum seedlings. The inhibitory effect was directly related to the concentration of the extract. Moreover, residue concentration of 800 and 1600 ppm in soils severely inhibited root growth of sorghum. The growth of seedlings of sorghum was more drastically inhibited by leaf extracts than stem and root extracts (Mengues, 1988). Pigweed species can produce and eliminate allelochemicals from the environment that could be absorbed by other plans as reported in sorghum (Glass and Bohm, 1971), while often these residues can inhibit the growth of plant of the same species or cultivated (Mengues, 1988).

Samad *et al.* (2008) carried out an experiment at laboratory condition and found that the dried and aqueous extract of plant parts (whole plant, stem, leaf and root) of pigweed (*A. spinosus* L.) exhibited inhibition of seed germination, seedling height, radicle growth and dry matter production of maize crops. Moreover, the stem was more harmful than other the parts. In greenhouse studies, aqueous extracts of dry residues of *Amaranthus retroflexus* L. inhibited root elongation in maize. The residue incorporated in the soil significantly reduced the growth of seedlings, foliage area, the weight ratio of the leaves and the assimilation of nitrogen and phosphorous in maize until 28 days after planting (Bhowmik and Doll 1982; Bradow and Connick 1987). In addition, the aqueous extract made from the aboveground parts (leaves and stems) of *A. retroflexus* in concentrations of 25 g l^{-1} to 100 g l^{-1} had inhibiting effect on the growth and length of maize hypocotyl and epicotyl (Konstantinovi *et al*., 2014).

Residues of the aerial part of *Amaranthus* spp. incorporated in the soil inhibited the germination of wheat. The inhibitory effect and the concentration of residues were dependent on the part of the plant, with roots being more sensitive than the aerial part (Qasem, 1995). Extract of leaves and inflorescence of *Amaranthus* spp. drastically reduced seedlings growth of wheat (Ognjaconvic *et al.*, 1995). Moreover, residues of *A. viridis* diminished the growth and the productivity of millet (Sighal and Sen, 1981). Thus, *Amaranthus* spp. are plants with proven allelopathic potential, which require more studies related to the effects of their allelochemicals over cultivated plants and other weed plants. Isolation and identification of allelochemical compounds from these plants could provide means to minimize their negative effects over the cultures and potentially could provide structural models for the development of bioherbicides or semisynthetic herbicides (*de Souza et al.*, 2011).

7. Conclusion

- The aqueous extract of aboveground parts of pigweed significantly reduced seed germination of the poaceous crops; sorghum, millet, maize and wheat. There was a direct relationship between concentration and reduction in germination.
- Incorporating powder of aboveground parts of pigweed into the soil at rate of 1, 2, 3, 4 and 5% significantly decreased plant height, number of leaves and 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.
- More studies related to the effects of pigweed allelochemicals over cultivated plants and other weed plants are required.
- Isolation and identification of allelochemical compounds from this plant could provide means to minimize their negative effects over the cultures and potentially could provide structural models for the development of bio-herbicides.

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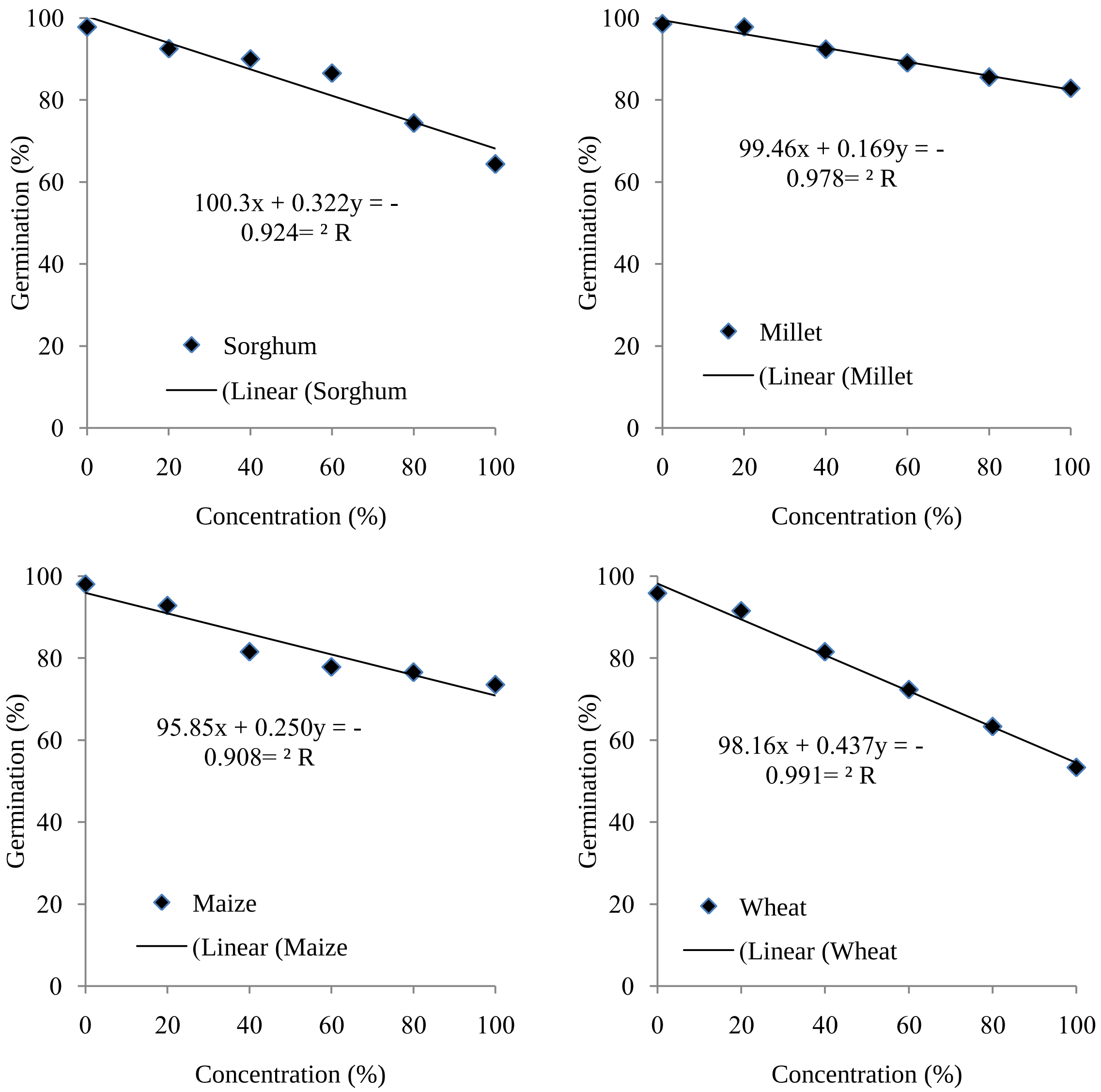

Fig. 1. Allelopathic effects of aqueous extract of aboveground parts of pigweed on seed germination of some poaceous crops

Table 1. Allelopathic effects of aqueous extracts of aboveground parts of pigweed on seed germination of some poaceous crops

Concentration of the aqueous extract (w/v)	Seed germination (%)			
	Sorghum	Millet	Maize	Wheat
0%	97.8 a	98.5 a	98.0 a	95.8 a
20%	92.5 ab	97.8 a	92.8 b	91.5 a
40%	90.0 b	92.3 ab	81.5 c	81.5 b
60%	86.5 b	89.0 bc	77.8 cd	72.3 c
80%	74.3 c	85.5 bc	76.5 cd	63.3 d
100%	64.3 d	82.8 c	73.5 d	53.3 e
$SE_{\pm}$	2.03	2.4	1.73	1.82
$CV_{\%}$	4.8	5.3	4.1	4.9

*** Means in the same column followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).**

Table 2. Allelopathic effects of incorporated powder of aboveground parts of pigweed into the soil on plant height of some poaceous crops

Concentration of the powder (w/w)	Plant height (cm)			
	Sorghum	Millet	Maize	Wheat
0 %	40.5 a	44.3 a	36.3 a	27.0 a
1 %	40.3 a	43.0 a	34.5 ab	26.0 a
2 %	38.0 a	40.0 a	32.5 b	25.8 a
3 %	38.0 a	33.8 b	28.8 c	16.5 b
4 %	37.3 a	30.8 b	27.0 c	12.3 c
5 %	31.0 b	30.0 b	25.3 c	11.0 c
$SE_{\pm}$	1.21	1.44	1.17	0.73
$CV_{\%}$	6.4	7.8	7.6	7.4

*** Means in the same column followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).**

Table 3. Allelopathic effects of incorporated powder of aboveground parts of pigweed into the soil on number of leaves of some poaceous crops

Concentration of the powder (w/w)	Number of leaves			
	Sorghum	Millet	Maize	Wheat
0 %	7.3 a	7.8 a	7.0 a	5.8 a
1 %	6.0 ab	7.5 a	6.8 a	5.8 a
2 %	5.8 b	7.0 a	6.3 ab	5.3 ab
3 %	5.5 b	5.8 b	6.0 ab	5.0 ab
4 %	5.3 b	5.0 b	5.3 b	4.5 ab
5 %	4.8 b	4.8 b	5.0 b	4.0 b
$SE_{\pm}$	0.44	0.40	0.45	0.46
$CV_{\%}$	15.3	12.6	14.7	18.3

*** Means in the same column followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).**

Table 4. Allelopathic effects of incorporated powder of aboveground parts of pigweed into the soil on root length of some poaceous crops

Concentration of the powder (w/w)	Seedlings root length (cm)			
	Sorghum	Millet	Maize	Wheat
0 %	19.5 a	24.5 a	19.3 a	14.5 a
1 %	16.3 b	21.3 b	18.8 ab	14.3 a
2 %	14.5 bc	18.3 c	16.5 bc	12.8 ab
3 %	12.8 cd	16.5 cd	15.5 c	11.5 b
4 %	11.5 de	16.3 cd	15.5 c	9.5 c
5 %	9.8 e	14.5 d	14.3 c	7.5 d
$SE_{\pm}$	1.72	0.74	0.79	0.57
$CV_{\%}$	12.3	8.0	9.5	9.8

*** Means in the same column followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test (P ≤ 0.05).**

Table 5. Allelopathic effects of incorporated powder of aboveground parts of pigweed into the soil on fresh weight of some poaceous crops

Concentration of the powder (w/w)	Seedlings fresh weight (g)			
	Sorghum	Millet	Maize	Wheat
0 %	12.2 a	10.0 a	14.1 a	8.0 a
1 %	12.0 a	9.9 a	14.0 a	7.8 a
2 %	10.3 b	8.0 b	12.0 b	5.9 b
3 %	8.0 c	7.9 b	11.8 b	5.9 b
4 %	7.0 d	6.1 c	11.0 c	5.1 c
5 %	5.9 e	5.0 d	9.0 d	4.0 d
$SE_{\pm}$	0.25	0.10	0.30	0.10
$CV_{\%}$	5.3	2.6	4.3	3.2

*** Means in the same column followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test (P ≤ 0.05).**

Table 6. Allelopathic effects of incorporated powder of aboveground parts of pigweed into the soil on dry weight of some poaceous crops

Concentration of the powder (w/w)	Seedlings dry weight (g)			
	Sorghum	Millet	Maize	Wheat
0 %	3.7 a	2.2 a	3.0 a	1.7 a
1 %	3.6 a	2.1 a	3.0 a	1.5 b
2 %	2.8 b	1.8 b	2.9 a	1.4 b
3 %	1.7 c	1.4 c	2.6 b	1.2 c
4 %	1.4 cd	1.1 d	2.1 c	1.0 cd
5 %	1.2 d	1.0 d	1.9 d	0.9 d
$SE_{\pm}$	0.12	0.07	0.06	0.11
$CV_{\%}$	10.3	9.2	4.7	10

*** Means in the same column followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test (P ≤ 0.05).**