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Allelopathic Effects of Sweet Basil (*Ocimumbasilicum* L.) on Seed Germination and Seedling Growth of some Poaceous Crops

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Abstract— *Laboratory and greenhouse experiments werecarried out at the Faculty of Agricultural Sciences, University of Gezira, Sudan in season 2014/15 to study the allelopathic effectsof aboveground parts ofsweet basil (Ocimumbasilicum 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 ofsweet basilon seed germination of sorghum (Sorghum bicolor [L.] Moench), millet (Pennisetumglaucum [L.]R. Br.), maize (Zea mays L.) and wheat (TriticumvulgareL.).Six concentrations (0, 20, 40, 60, 80 and 100%) of the aqueous extract of the aboveground parts of sweet basilwere 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 experimentswere conducted to study the allelopathic effects of powder of aboveground parts ofsweet basil on seedling growth of the same poaceous 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 the plant height, number of leaves and root length of crop seedlings were measured as well as plant 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 sweet basil 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 powder of aboveground parts into the soil significantly decreased plant height and root length of crop seedlings as well as seedling 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 sweet basil has allelopathic affects on seed germination and seedling growth of the poaceous crops.*

Keywords—* *Allelopathic; Allelochemicals; Sweet Basil;Ocimum; Poeaeae; sorghum; millet; maize; wheat.

I. INTRODUCTION

The genus *Ocimum*, Lamiaceae, collectively called basil, is comprises more than 30 species of herbs and shrubs from the tropical and subtropical regions of Asia, Africa, and Central and South America, but the main center of diversity appears to be Africa (Paton, 1992). It is a source of essential oils and aroma compounds (Simon *et al.*, 1984, 1990), a culinary herb, and an attractive, fragrant ornamental (Morales *et al.*, 1993; Morales and Simon, 1996). The seeds contain edible oils and a drying oil similar to linseed (Angers *etal.*, 1996). Extracts of the plant are used in traditional medicines, and have been shown to contain biologically active constituents that are insecticidal, nematicidal, fungistatic, or antimicrobial (Simon*et al.*, 1990; Albuquerque, 1996).

The *Ocimum* plants have been investigated as potential allelopathic plants (Baličević*et al.*, 2015). 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.

Baličević*et al.*(2015) demonstrated that aromatic plants show allelopathic effect toward germination, root and shoot length and fresh weight of weeds, both inhibitory and stimulatory. The allelopathic effect depended on donor and target species.Đikić (2005) reported inhibitory effect of caraway, dill, basil and coriander on germination of hoary cress(*Lepidiumdraba*L.). Dhima *et al.* (2009) found that water extracts of aboveground mass of basil, coriander and oregano reduced germination and growth of barnyardgrass(*Echinochloa crus-galli*[L.] PB.), while in field experiments reduced plant number of different weed species when incorporated as green manure.

Understanding well the mechanism of allelopathic interactions between aromatic plants andcrops will enable to come up with proper and effective management of the agricultural ecosystem. Considering the economic importance of poaceouscrops, these studies were carried out to investigate the allelopathic effects of sweet basil (*Ocimumbasilicum* L.), on seed germination and seedling growth of some poaceouscrops, particularly sorghum (*Sorghum bicolor* [L.] Moench), millet (*Pennisetumglaucum* [L.]R. Br.), maize (*Zea mays* L.) and wheat (*Triticumvulgare*L.).

II. MATERIALS AND METHODS

2.1. Experimental site

A series of experiment wascarriedout 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).

2.2. Materials collection

Mature plants of sweet basil plants were collected from Experimental Farm of the FAS in season 2014/15. The plants were transferred to the biology laboratory of theFAS. 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 distill water for several times and stored at room temperature till used.

2.3. Laboratory experiments

These experimentswere conducted in the biology laboratory to study the allelopathic effects of aqueous extract of aboveground parts of sweet basilon seed germination of sorghum, millet, maize and wheat. Fifty grams of the powder of aboveground parts of sweet basilwere placed in a conical flask,sterilized distill water was added to give a volume of 1000 ml and then the flasks wereshaken 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 WhatmanNo-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 aqueous extract of aboveground parts of sweet basil, 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.

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2.4. Greenhouse experiments

These experiments were conducted at the greenhouse of horticulture nursery to study the allelopathic effects of powder of aboveground parts ofsweet basil 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 powder of aboveground parts ofsweet basilwas incorporated into the soil at rate of 0, 1, 2, 3, 4 and 5% on w/w bases.Five seedsof each cropwere sownin 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 measuredas well as seedlings fresh and dry weight (g).

2.5. 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).

III. RESULTS

3.1. Laboratory experiments

The results of laboratory experimentsshowed that the aqueous extract of aboveground parts of sweet basilsignificantly ($P \leq 0.05$) reduced seed germination of the tested poaceouscrops compared to the controls(Table 1).The reduction in seed germination increased with concentration of aqueous extract of aboveground parts. The highest seed germination was observed in the corresponding controls.However, the highest concentration (100%) displayed lowest seed germination which was71.5, 74.3, 58.3 and 67.3 % in sorghum, millet, maize and wheat, respectively. Maize seeds were highly affected by the aqueous extract of aboveground parts of sweet basil in comparison to other tested crops.

3.2. Greenhouse experiments

The results of the greenhouse experiments showed that incorporatedpowder of aboveground parts of sweet basil into the soil significantly ($P \leq 0.05$) decreased seedling growth attributes of tested poaceouscrops in comparison to the controls(Table 2, 4, 5 and 6).

3.2.1. Effects onplant 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 wheatin the control treatmentswere37.5, 30.3, 43.5 and 24.3cm, respectively.However, increasing the concentration of powder of aboveground parts of sweet basilinto the soil exhibited lowest plant height in all tested crops.The powder of aboveground parts of sweet basilwhen incorporated into the soil at rate of 1 to 5% decreased the plant height of poaceouscrops in comparison to control treatments(Table 2). Moreover, the reduction in the plant height was increased as powder of aboveground parts increased in the soil. The greatest reduction in plant height was observed when powder of aboveground parts was incorporated intothe soil at the rate of 5%. At high concentration of powder of aboveground parts, the plant heights were significantly($P \leq 0.05$) decreased to 31.3 cm in sorghum, 15.0 cm in millet, 35.8 cm maize and 10.8 cm in wheat seedlings.

3.2.2. Effects on number of leaves

At 30 days after sowing, the results showed that incorporated powder of aboveground parts of sweet basilinto the soil at rate of 1, 2, 3, 4 and 5% negatively affected the leaves number of seedlings of all testedcrops 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 6.8, 7.5, 7.0 and6.0, respectively(Table 3). Incorporating powder of aboveground parts of sweet basil into soil at the rate of3% or more significantly ($P \leq 0.05$) reduced leaves number of seedlings of milletin comparison to the control treatments. While, significant reduction in leaves number of seedlings of maize and wheatwere obtained as powder of aboveground parts incorporated into soil at the rate of 5%. However, sorghum seeds were not significantly affected by incorporated powder of aboveground parts of sweet basilinto the soil at rate of 1 to 5% in comparison to other tested crops.

3.2.3. Effects on root length

Incorporation of powder of aboveground parts of sweet basilinto the soil significantly ($P \leq 0.05$) reduced root length of seedlings of all testedpoaceous crops (Table 4). The reduction in root lengths was increased with concentration of powder of aboveground parts in the soil.At 30 days after sowing, the longest root lengths of crop seedlings were observed in the control treatmentsand amounted to 21.0, 25.8, 20.3 and 15.8 cm in sorghum, millet, maize and wheat, respectively.The root length was decreased to

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10.3cm in sorghum, 15.5cm in millet, 15.3 cm maizeand 7.8 cm in wheatseedlingswhen powderof aboveground parts of sweet basil was incorporated into the soil at concentration of 5%.

3.2.4. Effects on fresh weight

The greatest fresh weights of crop seedlings, at 30 days after sowing, were recorded in control treatments (Table 5). The incorporationpowder of aboveground parts of sweet basil into soil at the rate of 2% or more significantly ($P \leq 0.05$) reduced fresh weight of sorghum, millet, maize and wheatin comparison to control treatments.Moreover, the reduction in the fresh weight was increased as the powderincreased in the soil.The incorporation of powder of aboveground parts of sweet basil into the soil at rate of 5% resulted in seedling fresh weights amounted to 6.2, 5.2, 9.3 and 4.3 g in sorghum, millet, maize and wheat, respectively.

3.2.5. Effects on dry weight

The results of incorporatedpowder of aboveground parts of sweet basil 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 powder of aboveground parts of sweet basil intothe soil at rate of2% or more significantly reduced fresh weight of sorghum, millet and wheatin comparison to the control treatments. While, significant reduction in dry weight of maizeseedlings were obtained when the powder incorporated intothe soil at rate of 3% or more compared to the control treatments. The incorporation of powder of aboveground parts of sweet basil into to the soil at concentration of 5% (w/w) decreased the seedlingdry weight to 1.1 g in sorghum, 1.1 g in millet, 2.2 gmaizeand 0.8 g in wheat seedlings.

IV. DISCUSSION

The results of these studies revealed that the aqueous extract of aboveground parts of sweet basil significantly reduced seed germination of the tested poaceouscrops and there was a direct relationship between concentration and reduction in germination. These findings were in agreement with observation made by Sharmal and Singh (2003) that evaluated the allelopathic effects of basil (Tulsi) (*Ocymumsanctum*) on the germination of someweedspecies. They found that the germination of radish, redroot pigweed, hairy beggarticksandguineagrass was completely inhibited with addition of 7.5 g basil leaf powder to 100 gofsand as compared to plants grown in sand alone or in a mixture of sand and sphagnum. Also, the germination of seeds was significantly inhibited in redroot pigweed and hairybeggarticks when grown in 10% (w/v) basil leaf extract as compared to distilledwater. Baličević*et al*., (2015) studied the allelopathic effect of basil (*Ocimumbasilicum*] on germination and early growth of weeds under laboratory conditions and found that basil reduced germination of hoary cress from 13.8 to 27%. These effects of basil powder were possibly due to the release of allelochemicals after decaying (Chou and Patrick, 1976).

This study indicated that incorporating powder of aboveground parts of sweet basil 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 results are in lined with the findings reported by Đikić (2005) and Dhima *et al.* (2009). The study pertains to the exploration of the phytotoxic (allelopathic) potential of aqueous extracts derived from leaf, root and seeds of *Ocimum* on some commercially important agricultural crops like wheat, gram lentil, mustard, barley, okra and pea, in terms of seed germination, root and shoot elongation. The inhibitory effect was exhibited by all the extracts with maximum in leaf followed by root and seed extract (Verma*et al*., 2012). Baličević*et al*. (2015) reported that the extracts from dry plant biomass of basil in higher concentration completely (10%) inhibited germination and weed seedling growth of scentless mayweed (*Tripleurospermuminodorum*[L.] C.H. Schultz). On average, the extracts from dry plant biomass had higher inhibitory effect. Reduction in weed seed emergence and growth was recorded when dry plant residues in rates of 10 and 20 g/kg were incorporated in the soil.

Moreover,the aqueous leaf extract of Basil (*Ocimum sanctum* L.) plants was prepared in different concentrations and was tested on some legumes like Green gram (*Phaseolusradiata*[L.]Wilczek), Cow pea (*Phaseolusunguiculata*(L.)Walp), Pigeon pea (*Cajanuscajan*L.), Chickpea (*Cicerarietinum L.*), Black gram (*Phaseolusmungo*(L.) Heeper) and Moth bean (*PhaseolusaconitifoliusJacq.).* Some concentrations were also used to see the effect on *Dichanthiumannulatum*L., *Chlorisbarbata*L., *Acalyphaindica*L .and *Amaranthusspinosus*L. The study was conducted at laboratory condition to see the effect of extracts on seed germination and seedling growth. The objective of the study was to find out suitable concentration which inhibits weed germination but not of legume crops. The study showed that Basil had differential effects on each legume at different concentration.Based on results supported by different studies, it was concluded that sweet basil has allelopathic affects on seed germination and seedling growth of the tested poaceouscrops(Purohit and Pandya, 2013).

V. CONCLUTION

- The aqueous extract of the aboveground parts of sweet basil, significantly, reduced seed germination of the poaceouscrops;sorghum, millet, maize and wheat.
- Incorporating powder of the aboveground parts of sweet basil into the soil, significantly, decreased plant height, number of leaves and root length of crop seedlings as well as seedlings fresh and dry weight of all tested crops.
- The reduction in seedling growth was increased as seed powder increased in the soil.
- Sweet basil has allelopathic effects on seed germination and seedling growth of the testedpoaceouscrops.
- More studies related to the effects of sweet basil allelochemicals over cultivated plants and other weed plants are required.

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Table.1: Allelopathic effects of aqueous extract of aboveground parts of sweet basil on seed germination of some poaceouscrops

Concentration extracts (w/v)	Seed germination (%)			
	Sorghum	Millet	Maize	Wheat
0%	97.3 a	98.8 a	96.5 a	94.5 a
20%	92.5 b	97.8 a	92.5 a	91.3 a
40%	89.3bc	94.0ab	81.3 b	81.3 b
60%	86.3 c	89.8bc	77.5bc	72.0 c
80%	81.5 d	85.0 c	76.3 c	63.0 d
100%	71.5 e	74.3 d	58.3 d	67.3 e
$SE_{\pm}$	1.45	1.90	1.51	2.05
$CV_{\%}$	3.4	4.2	3.8	3.7

* 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 sweet basilinto soil on plant height of some poaceouscrops

Concentration the powder (w/w)	Plant height (cm)			
	Sorghum	Millet	Maize	Wheat
0 %	37.5 a	30.3 a	43.5 a	24.3 a
1 %	37.0 a	25.0 b	39.0 b	23.8 a
2 %	36.5 a	22.0 c	37.3 b	22.5 a
3 %	35.8ab	21.3 c	36.8 b	16.8 b
4 %	33.8 b	17.3 d	36.0 b	11.8 c
5 %	31.3 c	15.0 e	35.8 b	10.8 c
$SE_{\pm}$	0.81	0.67	1.00	1.17
$CV_{\%}$	4.5	6.1	5.2	12.8

* 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 sweet basilinto soil on number of leaves of some poaceouscrops

Concentration the powder (w/w)	Number of leaves			
	Sorghum	Millet	Maize	Wheat
0 %	6.8 a	7.5 a	7.0 a	6.0 a
1 %	6.0 a	7.5 a	7.0 a	5.8ab
2 %	6.0 a	7.0ab	6.3ab	5.5ab
3 %	5.8 a	6.0bc	6.3ab	5.3ab
4 %	5.5 a	5.0 c	5.5ab	4.8ab
5 %	5.3 a	5.0 c	5.0 b	4.3 b
$SE_{\pm}$	0.46	0.41	0.48	0.50
$CV_{\%}$	15.7	12.9	15.5	19.1

* 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 sweet basilinto soil on seedlings root length of some poaceouscrops

Concentration the powder (w/w)	Seedlingsroot length (cm)			
	Sorghum	Millet	Maize	Wheat
0 %	21.0 a	25.8 a	20.3 a	15.8 a
1 %	17.8 b	22.5 b	19.8ab	15.5 a
2 %	15.8 c	18.8 c	17.8bc	13.8ab
3 %	14.0 cd	17.8 cd	16.8 cd	12.0bc
4 %	12.8 d	17.3 cd	16.5 cd	10.5 c
5 %	10.3 e	15.5 d	15.3 d	7.8 d
$SE_{\pm}$	0.64	0.87	0.67	0.73
$CV_{\%}$	8.3	8.9	7.6	11.6

* 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.5: Allelopathic effects of incorporated powder of aboveground parts of sweet basilinto soil on seedlings fresh weight of some poaceouscrops

Concentration the powder (w/w)	Seedlingsfresh weight (g)			
	Sorghum	Millet	Maize	Wheat
0 %	12.7 a	10.4 a	14.4 a	8.3 a
1 %	12.1 a	10.2 a	14.3 a	8.3 a
2 %	10.6 b	8.1 b	12.3 b	6.2 b
3 %	8.2 c	8.1 b	12.3 b	6.1 b
4 %	7.1 d	6.2 c	11.3 c	5.2 c
5 %	6.2 e	5.2 d	9.3 d	4.3 d
$SE_{\pm}$	0.20	0.13	0.21	0.13
$CV_{\%}$	4.1	3.2	3.4	4.0

* 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.6: Allelopathic effects of incorporated powder of aboveground parts of sweet basilinto soil on seedlings dry weight of some poaceouscrops

Concentration the powder (w/w)	Seedlingsdry weight (g)			
	Sorghum	Millet	Maize	Wheat
0 %	3.9 a	2.4 a	3.2 a	1.9 a
1 %	3.7 a	2.3 a	3.2 a	1.7ab
2 %	3.0 b	2.0 b	3.1 a	1.6bc
3 %	1.8 c	1.5 c	2.7 b	1.3 cd
4 %	1.4 d	1.3 cd	2.4 c	1.2 d
5 %	1.1 e	1.1 d	2.2 c	0.8 e
SE±	0.11	0.08	0.08	0.08
CV%	8.7	9.3	5.4	11.1

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