J. Agric. Sci. Mansoura Univ., 34 (4): 3367 - 3382, 2009

ALLELOPATHIC EFFECT OF PEARL MILLET AND SUDAN GRASS ON SOME WINTER CROPS

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ABSTRACT

Laboratory, greenhouse experiments were carried out in Giza Research Station during 2006 and field experiments were carried out at Sids Research Station during 2005/2006 and 2006/2007 to investigate the allelopathic effect of pearl millet and Sudan grass on some winter crops; (wheat, barley, flax, faba bean, Egyptian clover and sugar beet) through 2005 and 2006 seasons. Laboratory experiments showed that, pearl millet and Sudan grass had a significant inhibitory effect on seed germination of all winter crops, except Egyptian clover. Seedling growth of flax, berseem and sugar beet was also inhibited by both extract. Greenhouse experiment indicated that all crops were affected by pearl millet and Sudan grass root extracts. Field experiment results indicated that wheat, barley and sugar beet were only the crops affected by root extracts. Three chemical components were detected and identified in pearl millet root extract; (2 benzylthio 2- imidazoline monohydrochlorid) , (pentyl acetate) and (glucoronic acid sodium salt hydrate) and another three were detected and identified in Sudan grass root extract (2,6 diemethyl cyclohexane methanol), (4 – Amidinodinopyriodine menohydrochloride) and (6 – Alpha-L-arbinozyl – 5 , 7- dihydroxy - 8- beta d – glucopyranozyl flavone).

INTRODUCTION

Roots of Pearl millet and Sudan grass have been reported to possess allelopathic effect on seed germination and plant growth of some other crops .The release of toxic compounds from roots of both crops have been documented. The five phenolic acids; ferulic, p-coumaric, syringic, vanilic, and p-hydroxybenzoic were quantified in sorghum residues. The concentration of coumaric acid was greatest and sufficient to reduce growth of other species (Guenzi and McCalla 1966. Allelochemicals are compounds synthesized by an organism that stimulate or inhibit other organisms. Plant allelochemical substances are secondary metabolites and have been classified into five major groups: Terpenes, steroids, acetogenines, phenylpropanes and alkaloids.The allelochemicals of forage plants may affect other plants insects, fungi, bacteria, nematodes or animals (Barnes and Gustine 1973. Putnam and De Frank (1983) found that sorghum residues reduced weed ability to grow in cucumber by 70-98 %. Weston *et al*. (1987) reported that root extracts of sudex (sorghum X Sudan grass) decreased germination and plant growth of weed and some vegetables. The added phytoinhibitors were isolated and identified as P- hydroxyl benzoic acid and P- hydroxyl benzaldhyde. Woodhead (1983) found that sorghum tissues contain P-hydroxy benzaldhyde and waxes with short carbon chain. Hedge and Miller (1990), reported that, the interference of one plant species by another, occurs in several crops that are grown in rotation. The detrimental interference of pearl millet and Sudan grass on the growth of winter crops has been demonstrated in the field and under controlled conditions. Roth *et al* (2000) indicated that allelopathy by grain sorghum frequently harms wheat (*Triticum aestivum* L.) when the crops are grown in rotation. Vidal and Trezzi (2004) found that living plants of sorghum and pearl millet produced chemical compounds from root extracts that suppress weeds. Thirty days after seeding 41 % of weed infestation was reduced. They also indicated that lack of suppressive effect of exudates was observed under field conditions. Javaid *et al*. (2006) mentioned that, the inhibitory effects may be due to the direct production of toxic substances by pearll millet and Sudan grass such as dhurrin component, which arise from the decay of Sudan grass materials in the soil. Arshad and Tehmina (2006) found that aqueous extracts of *Sorghum halepense* roots at 25 % concentraion completely inhibited seed germination of *Parthenium hysterophorus* L., Toaima (1996) mentioned that *sorghum halepense* root extracts inhibited germination and seedling growth of alfalfa, sweet clover, red clover, triticale and wheat. Urbano *et al*; (2006) found that sorghum Sudanense grown as cover crop reduced weeds density up to 75 %.

The objectives of these investigations were:

1-**In the laboratory:**

a) to study the effect of pearl millet and Sudan grass root extracts on germination and seedling growth of some winter crops (wheat, barley, flax, berseem clover (Meskawi var.), faba bean and sugar beet) after 7 days.

b) To separate and identify allelochemicals through the organic solvents; benzene, methyl acetate and chloroform.

2-**In the green house:**

To study the effect of pearl millet and Sudan grass root residues after harvest, on germination and seedling growth of the succeeding winter crops after 30 days, compared with those grown in sterilized soil.

3-**In the field:**

To study the effect of pearl millet and Sudan grass residues on plant height and yield of the succeeding winter crops.

MATERIALS AND METHODS

Laboratory and greenhouse experiments were conducted only in 2006 season, whereas field experiments were conducted in 2005/2006 and 2006/2007 seasons.

1-Laboratory experiments:

Two laboratory experiments were conducted in the laboratory of Forage Crops Research Dept., Field Crops Research Institute, at Giza during 2006 season. The experimental design was a randomized complete block design with four replications. The treatments were two different extract (pearl millet (*Pennisetum americanum L.*) and Sudan grass (*Sorghum sudanensce (P.) Stapf.*) with four concentration (0, 5, 10 and 20 % root extract) and six winter crops wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), flax (*Linum* *usitatissimum* L.), Egyptian clover (*Trifolium alexandrinum* L.), faba bean (*Vicia faba* L.) and sugar beet (*Beta vulgaris* L.). to study the allelopathic effect of root extracts of pearl millet and Sudan grass on seed germination and seedling growth and seedling weight.

a. Root extracts:

At the end of pearl millet and Sudan grass life, roots were obtained and transferred directly to the lab. The roots were washed and cut into small pieces, Two hundred gm of fresh homogenous materials from roots were blended with 1000 ml distilled water for one day at room temperature (22 ^{0}C). Then, blended in electric blender for three minutes. The homogenous extracts were filtered through four layer cheese cloth. The resulted filtrate was kept as the crude extract (100 % conc.), whereas the pellet was discarded. The crude extracts centrifuged for fifteen minutes at 8000 r.p.m. The crude extracts divided into two parts: 500 ml was used to isolate and study seed germination and seedling growth of six winter crops and 500 ml to identify the allelochemicals components according to Putnam and Defrank (1983).

b- Seed germination:

Fifty seeds of each winter crop were germinated during 2006 season on Watman No. 1 filter paper in a 10 cm. diameter Petri dishes. A completely randomized block design with four replicates was used for each winter crop in both laboratory experiments. Ten ml. of crude extracts at the concentration of 20, 10, 5 and 0 % were added to each Petri dish. Germination percentage, seedling length and fresh weight of 10 seedlings were recorded after 7 days of germination for all studied crops. Inhibition % was calculated according the following equation.

$$\textbf{Inhibition \%} = \frac{\text{Control - treated}}{\text{Control}} \times 100$$

c- Allelochemicals isolation and identification:

Crude extracts were purified by fractionation in three different solvent solutions ranging from non polar to polar according to Gilles and Thompson, (1982). Hundred ml of the crude extract mixed with the same volume of benzene in a separatory funnel were shacked by electric shaker for 15 min. The layers were separated from each other and the benzene layer (upper layer) was designated as fraction (I). The lower layer was mixed with the same volume of ethyl acetate in a separatory funnel and shacked for 15 min.. The upper layer was separated as fraction (II). The lower layer was mixed with the same volume of chloroform and shacked for 15 min. The upper layer was separated and designated as fraction (III). The analysis was conducted at the Micro Analytical Center, Faculty of Science Cairo University to identify allelochemical components by using Mass/ charge and IR apparatuses to determine the spectrum, chemical structure, molecular weight and formula, then nomenclature of the detected compounds.

2- Green house experiments:

These experiments were conducted during 2006 season to study allelopathic effects of root residues of pearl millet and Sudan grass on succeeding six winter crops. The experimental design was a randomized complete block design with four replications.. The pots which used were 10 cm diameter and 20 cm length filled with sterilized 1 : 1 : 1 clay: sand: beat. Twenty four pots were used for pearl millet and another twenty four were used with Sudan grass. Fifty seeds of pearl millet and Sudan grass were germinated in each pot. The pots irrigated at four days intervals by tap water. After one month, the plants were pulled from each pot. Five grams of roots were taken as random samples from each pot. Afterward, the same numbers of pots were filled with the sterilized soil which was incorporated with the root samples in 4 pots of each crop. Also, another group was used without any residues (control). All pots were left for seven days for the degradation of root residues. Fifty seeds of each winter crop were sown into each pot and irrigated at four days intervals. Germination percentage, plant height and dry weight of 10- plants/ pot were recorded after one month. The inhibition percentage for each character was calculated as follows:

$$\textbf{Inhibition \% =} \frac{\text{Control - treated}}{\text{Control}} \times 100$$

3- Field experiments:

Field experiments were carried out through 2005/2006 and 2006/2007 seasons at Sids Experimental Research Station in Beni Suief Governorate to evaluate the effect of residues of pearl millet and Sudan grass plant as preceding crops on the succeeding crops; wheat, barley, flax, faba bean, Egyptian clover (Helaly var.) and sugar beet. All agricultural practices were followed as recommended for each crop and the experimental design was strip design.

At harvest time, ten plants of each following winter crops were randomly sampled from each plot to determine plant height and yield. Wheat and barely yields were determined as grain yield / fad. Flax yield was determined for whole plants yield. Yield of berseem was determined as total fresh weight of 4 cuts, yield of faba bean was determined as weight of seeds / fad. Yield of sugar beet was determined as weight of fresh roots / fad.

Relative yield was calculated as follow:

$$\text{Relative yield =} \frac{\text{Total yield in crop residue}}{\text{Total in fallow treatment}} \times 100$$

The experimental design was strip design, the experiment was divided into three strips, one for growing pearl millet , one for growing Sudan grass and the third one was left as fallow . Pearl millet and Sudan grass were sown in first May,2005 and 2006 in both seasons and harvested in the end of August . At the winter six winter crops were chosen and grow after pearl millet and Sudan grass as will as at the fallow strip as the control. All the winter crops were grown on ridges, except berseem clover which was grown as broadcast. .Data were statistically analyzed according to the procedure outlined by Gomez and Gomez (1984). Multiple range test was used to compare between means at 5 % level of significance (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Pearl Millet

1.Laboratory experiments:

Results of the effect of pearl millet root extracts on seed germination and seedling growth of winter crops are presented in Table 1.

A. Germination:

Data revealed that seed germination of the tested crops significantly inhibited by pearl millet root extracts, except for berseem clover. The inhibitory effect increased with increasing the extract concentration. The calculated inhibitory effect values at the 10 % concentration were 29.3, 13.6, 6.9 , 14.8 and 20.1 % for wheat , barley , flax , feba bean and sugar beet , respectively . However, the inhibitory effect of pearl millet root extract at the 5 % concentration was insignificant on seed germination of barley flax and sugar beet. These results are in agreement with those obtained by Vidal and Trezzi (2004).

B. Seedling length.

Root extract of pearl millet at the 10 % concentration inhibited seedling length of flax and berseem by 45.2 and 58.9 % respectively. Seedling length of sugar beet was inhibited only at the 20 % concentration by 31.3 %. Pearl millet root extract did not significantly affect seedling length of wheat, barely or faba bean at any concentration (Table 1).

C. Fresh weight of seedlings:

Root extract of pearl millet at the 10 % concentration inhibited fresh weight of 10 seedlings of flax, berseem and sugar beet by 21.7, 11.1 and 15 % respectively. Fresh weight of seedlings for the same crops was also inhibited at the 5 % concentration by 8.6, 5.5 and 10%, respectively. Seedlings fresh weight of wheat barley and faba bean was not significantly affected at any concentration (Table 1) these results are coincided with those obtained by Rice (1987).

2- Greenhouse experiments:

A. Germination:

Pearl millet root residues inhibited seed germination of all crops under investigation. However , the inhibition effect was much more pronounced on wheat , barley and flax (Table 2) , The results are in accordance with those reported by Chad *et al* (2000).

B. Plant height:

Plant height of all tested crops was inhibited by pearl millet root residues (Table 2). The Inhibition effect was highest for wheat (20.6 %) and berseem (17.8 %) and lowest (10.7 %) for sugar beet (Table 2).

C. Dry weight of plant:

The dry weight of all tested crops was also reduced by pearl millet root residues (Table 2). The dry weight reduction was much higher for sugar beet, flax, and feba bean than for wheat, barely or berseem, (Table 2).

Laboratory and greenhouse experiments results confirmed that there are some allelochemicals that secreted and leached from pearl millet roots to exert many harmful effects on germination indices of the following winter crops.

1+2

In this respect Fayed *et al* (1999) showed that the inhibitory impact of allelochemicals may be due to their hazardous effect on division and elongation of meristemic cells in germinated crop seeds , in addition to their early impact on biochemical processes of germination of crop seeds.

4-Field trials (long term allelopathy):

Plants of all tested crops grown after pearl millet were shorter relative to those grown after fallow , (Table 3) . Highest reduction in plant height was observed for sugar beet (17.8 %) whereas lowest reduction was for faba bean and barely (4.3 and 4.7 %, respectively). Whole plant weight for all crops following pearl millet was also lower relative to those grown after fallow, (Table 3). Highest reduction in whole plant weight (22.2 %) was obtained for flax, whereas least reduction was for barely (5%). Crop yield / fad followed the same trend of plant height and plant weight, (Table 3). However, highest yield reduction in yield per fadden was obtained for sugar beet (15.5 %), whereas least reduction was for flax (4.6 %) , These results are in harmony with those of Guenzi and McCalla (1966) and Toaima (1996).

Table 3: Effect of pearl millet root residues in the field on six succeeding winter crops (average - 2 years) .

Character	Plant height (cm)				Weight of plant yield (g)				weight of yield /fad (kg)			
Succeeding Crop	After fallow	After millet	F test	Relative reduction %	After fallow	After millet	F test	Relative yield	After fallow	After millet	F test	Relative yield
Wheat	128.1	116.1	*	9.4	1.8	1.5	*	83.3	3150.0	2760.0	*	87.6
Barley	120.3	114.6	Ns	4.7	2.0	1.9	Ns	95.0	1824.0	1568.0	*	86.0
Flax	91.5	84.5	Ns	7.7	0.9	0.7	*	77.8	650.3	620.2	Ns	95.4
Berseem	60.7	56.8	Ns	6.4	2.3	2.0	*	86.96	32,300	30,100	*	93.2
Faba bean	90.1	86.2	Ns	4.3	44.2	40.6	*	91.8	1600.0	1500.0	*	93.7
Sugar beet	43.3	35.6	*	17.8	1.4	1.2	*	85.7	33.600	28.400	*	84.5

***Plant height of Sugar beet was calculated as top fresh height**

3. Chemical analysis:

Spectrophotometer, infrared reading and mass charge apparatuses were used to determine the spectrum, chemical structure, molecular weight and formula, then nomenclature of the detected compounds. Three complex chemical compounds were detected in pearl millet root extract. The first [2 – (benzylthio) 2- imidazoline , monohydrochlorid] had the molecular weight 228.74 and formula C10 H13 ClN2S and was detected in the crude extract dissolved in benzene , (Fig 1).

The second (pentyl acetate) had the molecular weight 130.19 and formula C7H14O2 and was detected in crude extract dissolved in ethyl acetate (Fig 2).

Fig. (1): First allelochemical copmpound detected in pearl miiet root extract: 2-benzylthio-2-imidazline, monohydrochloride

Fig. (2): Second allelochemical compound detected in pearl millet root extract : pentyl acetate

Fig.(3) : Third allelochemical compound detected in pearl millet root extract : glucuronic acid, sodium salt, hydrate Sudan grass

The third compound (glucoronic acid, sodium salt hydrate) had the molecular weight 234.14 and formula C6H11NaO8 and was detected in the crude extract dissolved in chloroform. (Fig 3). The inhibitory effect of pearll millet on the succeeding crops under field condition may be attributed to the release of such compounds into the environment (soil). These results are in agreement with those reported by Alborn and Stenhagen (1987).

Sudan grass

1. Laboratory experiments:

A. Seed Germination:

Data in Table 4 indicate that seed germination of all tested crops was reduced by Sudan grass root extract at all extract concentration. Reduction in seed germination was higher for wheat, flax, sugar beet and barely than for berseem and faba bean. Wheat was the most affected crop among all tested crops. Increasing the extract concentration increased the inhibitory effect on seed germination of all crops. These results are in agreement with those reported by Toaima (1996) and. Sukumar *et al* (2006)

B.Seedling length.

The inhibitory effect of Sudan grass root extract was indicated on seedling length of flax, berseem clover and sugar beet, whereas wheat, barely and faba been were not significantly affected, (Table 4). The response to increasing the extract concentration on seedling length followed the same trend of seed germination.

4+5

C. Weight of seedlings.

Sudan grass root extract significantly reduced weight of 10 seedlings of flax, berseem clover and sugar beet relative to the control. The inhibitory effect was more pronounced at the 7.5 and 10 % than at te 5 % concentration. The effect of Sudan grass root extract on weight of 10 seedlings of wheat, barely, and faba bean was not significant. These results are in agreement with those obtained by Hedge and Miller (1990) and Toaima (1996) .

2- Greenhouse experiments:

A- Seed germination:

Data in Table 5 indicate that seed germination of all tested crops was inhibited by Sudan grass root residues compared with the control. The inhibitory effect was higher on flax (25.5 %) , barely (25.1 %) and wheat (23 %) but lower in sugar beet (16.8 %) , berseem clover (15.6 %) and faba bean (15 %). These results are in accordance with those reported by Vidal and Trezzi (2004).

B- Plant height:

Sudan grass root residues also inhibited plant height of all tested crops. The inhibition effect was higher for wheat (29.4 %) , flax (28.7 %) and berseem clover (28.2 %) , but lower on barely (19.9 %) sugar beet (18 %) and faba bean (16.7 %), (Table 5).

C. Dry weight plants:

Sudan grass root residues inhibited dry weight / 10 plant of all tested crops (Table 5). However the inhibition percentage was higher for sugar beet (24.9 %), faba bean (33.3 %) and flax (25 %) but lower for berseem clover (20 %), barely (19.2 %) and wheat (10.7 %) (Table 5).

Field trials (long term Allelopathy):

Data in Table 6, Indicated that all tested crops grown after Sudangrass were shorter relative to those grown after fallow (Table 6). Highest reduction in plant height was observed for Sugar beet (26.56%) whereas lowest reduction for barley (7.90%) and faba bean (8.54 %) . weight of plant yield for all crops following Sudan grass was also lower relative to those grown after fallow (Table 6). Highest reduction in weight of plant (22.22 %) was obtained for flax, whereas least reduction was for wheat (11.11 %) and 12.5 % for sugar beet. Crop yield /fad. recorded that the highest reduction was obtained with sugar beet (20.09 %) , while the lowest reduction was obtained with flax (7.61 %) . These results are in harmony with Guenzi and McCalla (1966) and Toaima (1996).

The results of the present study concluded that pearl millet and Sudan grass had negative effect on growth and yield of the succeeding winter crops. The negative effect of Sudan grass was higher than of pearl millet. The negative effect of both crops obtained from field results was more severe on sugar beet , barely and wheat than on flax , berseem clover , or faba bean. Growing sugar beet after pearl millet or Sudan grass should be reconsidered, since yield reduction ranged between 15.5 and 20.1 %.

Table 6. Effect of Sudan grass root residues on six succeeding winter crops in the field (2- year average)

Characters	Plant height (cm)				Weight of plant yield (g)				weight of yield /fad (kg)			
Succeeding crops	After fallow	After millet	F test	Relative reduction %	After fallow	After millet	F test	Relative yield	After fallow	After millet	F test	Relative yield
Wheat	128.1	113.3	*	11.55	1.8	1.6	*	88.89	3150.0	2710.0	*	86.03
Barley	120.3	110.8	*	7.90	2.0	1.7	*	85.00	1824.0	1518.0	*	83.22
Flax	91.5	81.6	*	10.82	0.9	0.7	*	77.78	650.3	600.8	Ns	92.39
Berseem	60.7	52.6	*	13.35	2.1	1.8	*	85.71	32,300	28,100	*	87.00
Faba bean	90.1	82.4	Ns	8.54	44.2	37.5	*	84.84	1600.0	1385.00	*	86.56
Sugar beet	43.3	31.8	*	26.56	1.6	1.4	*	87.5	33.600	26.850	*	79.91

***Plant height of Sugar beet was calculated as top fresh height**

C. Chemical analysis:

Spectrophotometer, infrared reading and mass charge apparatuses were used to determine the spectrum, chemical structure, molecular weight and formula, then nomenclature of the detected compound. Three complex chemical compound were detected in Sudan grass root extract. The first 2,6 diemethyl cyclohexane methanol had the molecular weight 142.24 and formula C9H18O and was detected in the crude extract dissolved in benzene (Fig 4) .

Fig. (4) : First allelochemical compound detected in Sudangrass root extract : 2,6 dimethyle cyclohexane methanol

The second (4 – Amidinodinopyriodine , menohydrochloride)had the molecular weight 157,60and formula C6H8 Cl N3 and was detected in the crude extracted dissolved in ethyl acetate , (Fig 5) .

The third compound (6 – Alpha-L-arbinozyl – 5 , 7- dihydroxy - 8- beta d – glucopyranozyl flavon) had the molecular weight 548.50 and formula C26H28O13 and was detected in the crude extracted dissolved in the chlorophorme , (Fig 6) .

The inhibitory effect of Sudan grass on succeeding crops may be related to the release of such compounds into the soil . The results are located under the chemical groups which confirmed by Rice (1987).

Fig.(5) : Second allelochemical compound detected in Sudangrass root extract : 4-amidinopyridine, monohydrochloride

Fig.(6) : Third allelochemical compound detected in Sudangrass root extract: 6-alpha-l arabinosyl-5,7-dihydroxy-8-beta-d-glucopyranosyl flavone

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التأثير الأليلوباثى للدخن و حشيشه السودان على بعض المحاصيل الشتوِية اللاحقة

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أقيمت تجربتين بالمعمل وتجربتين بالاصص عام ٢٠٠٦ وتجربتين عام ٢٠٠٦/٢٠٠٥ و ٢٠٠٧/٢٠٠٦ بالحقل لدراسة التأثير الاليلوباثى للدخن وحشيشة السودان على بعض المحاصيل الشتوية اللاحقة (القمح – الشعير – الكتان – الفول البلدى بنجر السكر – البرسيم) أوضحت نتائج التجارب المعملية أن الدخن وحشيشة السودان كا لهما تاثيراً مثبطاً على انبات بذور هذه المحاصيل عدا البرسيم المصرى كما كان لها نفس التاثير على نمو بادرات البرسيم المصرى و الكتان وبنجر السكر. كما اوضحت نتائج تجارب الاصص الاستجابة المعنوية السالبة لجميع المحاصيل الشتوية للاثر المتبقى لكل من الدخن وحشيشة السودان فى التربة .

واوضحت نتائج التجارب الحقلية للاستجابة المعنوية السالبة لكل من القمح – الشعير – بنجر السكر عند زراعتها عقب الدخن او حشيشة السودان وقد تم فصل وتعريف ثلاث مركبات كيماوية من مستخلص جذور الدخن (2 benzylthio 2- imidazoline, monohydrochlorid) , (pentyl acetate) and (glucoronic acid sodium salt hydrate) وثلاث مركبات من مستخلص جذور حشيشة السودان (2,6 diemethyl cyclohexane methanol),(4- Amidinodinopyriodine menohydrochloride) and (6 – Alpha-L-arbinozyl – 5 , 7- dihydroxy - 8- beta d – glucopyranozyl flavone)

وذلك بمعمل التحاليل الدقيقة بكلية العلوم جامعة القاهرة و التى قد يعزى اليها التاثير المثبط لكل من الدخن وحشيشة السودان على المحاصيل الشتوية اللاحقة.

J. Agric. Sci. Mansoura Univ., 34 (4): 3367 - 3382, 2009

Table 1: Effect of pearl millet root extract on germination and seedling growth of six winter crops after 7 days.

Character	Germination %					Seedling Length (cm)					Seedling weight (g/10 seedlings)				
Succeeding Crop	**20 %**	**10 %**	**5 %**	**C**	**L.S.D**	**20 %**	**10 %**	**5 %**	**C**	**L.S.D**	**20 %**	**10 %**	**5 %**	**C**	**L.S.D**
Wheat	63.8	66.7	76.8	94.3	5.4	8.47	9.27	9.53	9.73	N.S	0.77	0.85	0.93	1.06	N.S
Barley	84.1	81.1	92.3	93.6	3.8	10.43	10.50	10.97	11.17	N.S	0.80	0.84	0.92	0.96	N.S
Flax	76.1	88.0	92.0	94.5	3.1	5.50	5.60	7.93	10.27	1.6	0.16	0.18	0.21	0.23	0.03
Berseem clover	97.8	97.3	100.0	100.0	N.S	3.13	3.15	3.53	7.67	1.4	0.14	0.16	0.17	0.18	0.02
Faba bean	85.2	85.2	96.2	100.0	3.7	2.37	2.87	3.53	3.63	N.S	5.90	6.07	6.28	6.95	N.S
Sugar beet	64.7	76.7	95.1	96.0	4.2	6.60	8.60	7.90	9.60	1.9	0.16	0.17	0.18	0.20	0.02

Table 2: Effect of Pearl millet Root residues on six winter crops after 30 days:

Character	Germination %				Plant height (cm)				Dry weight / 10 plants (g)			
Succeeding Crop	**Con-trol**	**Resi-dues**	**F test**	**Inhib-ition%**	**Con-trol**	**Resi-dues**	**F test**	**Inhib ition%**	**Con-trol**	**Resi-dues**	**F test**	**Inhib ition%**
Wheat	94.5	76.3	*	19.3	30.6	24.3	*	20.6	0.27	0.25	Ns	7.4
Barley	96.3	74.2	*	22.9	28.6	24.2	*	15.4	0.25	0.23	Ns	8.0
Flax	95.6	72.3	*	24.4	27.2	23.1	*	15.1	0.23	0.20	*	13.0
Berseem	97.8	84.2	*	13.9	16.3	13.4	*	17.8	0.19	0.17	*	10.5
Faba bean	98.7	85.4	*	13.5	12.2	10.3	*	15.6	0.16	0.14	*	12.5
Sugar beet	93.4	80.5	*	13.8	10.3	9.2	*	10.7	0.12	0.10	*	16.7

***Plant height of sugar beet was calculated as top fresh height**

Table 4: Effects of Sudan grass root extract on germination and growth of 7 days old seedlings of six winter crops

Character	Germination %					Seedling Length (cm)					Weight of 10 seedlings (g)				
Succeeding Crop	20 %	10 %	5 %	C	L.S.D	20 %	10 %	5 %	C	L.S.D	20 %	10 %	5 %	C	L.S.D
Wheat	61.8	64.5	74.2	94.3	4.5	8.47	9.27	9.50	9.73	N.S	0.78	0.82	0.90	1.06	N.S
Barley	79.3	82.3	90.3	93.6	3.1	9.43	10.30	10.50	11.17	N.S	0.80	0.84	0.88	0.96	N.S
Flax	74.2	75.3	85.1	94.5	2.8	6.50	6.60	8.90	10.27	1.6	0.15	0.17	0.20	0.23	0.03
Berseem clover	92.8	95.3	100.0	100.0	N.S	4.13	4.15	4.50	7.67	1.4	0.15	0.17	0.18	0.18	0.02
Faba bean	80.1	83.2	95.3	100.0	3.1	4.37	4.52	4.87	6.63	N.S	5.60	6.00	6.25	6.95	N.S
Sugar beet	61.5	73.4	93.1	96.0	3.7	7.60	9.60	10.80	9.60	1.9	0.18	0.19	0.20	0.20	0.02

Table 5. Effect of Sudan grass root residues on 30- day old plants of six winter crops

Character	Germination %				Plant height (cm)				Dry weight/ 10 plants (g)			
Succeeding crop	**Con-trol**	**Resi-dues**	**F test**	**Inhib-ition%**	**Con-trol**	**Resi-dues**	**F test**	**Inhib-ition%**	**Con-trol**	**Resi-dues**	**F test**	**Inhib-ition%**
Wheat	96.5	74.3	*	23.00	31.6	22.3	*	29.43	0.28	0.25	Ns	10.71
Barley	96.3	72.1	*	25.13	27.6	22.1	*	19.93	0.26	0.21	*	19.23
Flax	95.8	71.4	*	25.47	28.2	20.1	*	28.72	0.24	0.18	*	25.00
Berseem	97.4	82.2	*	15.60	17.3	12.4	*	28.22	0.20	0.16	*	20.00
Faba bean	98.1	83.4	*	14.98	12.0	10.0	*	16.67	0.18	0.12	*	33.33
Sugar beet	94.4	78.5	*	16.84	10.0	8.2	*	18.00	0.14	0.08	*	42.86

***Plant height of Sugar beet was calculated as top fresh height**