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Growth Inhibitors of *Sorghum vulgare* Pers. from *Striga hermonthica* (Del.) Benth.

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ABSTRACT. Observations of the effects of *Striga hermonthica* (Del) Benth. on *Sorghum vulgare* Pers. before emergence of the parasite above the soil and the characteristic symptoms on sorghum of white blotches or chlorosis which differs from those due to mineral deficiency suggest that the parasite is allelopathic to its host. Investigation on the presence of growth inhibitors in *S. hermonthica* shoots or seeds was carried out, using inhibition of sorghum seed germination and seedling growth. Aqueous extract from striga seeds reduced the percent germination of sorghum seeds with greater effects than shoot extract. The growth of sorghum shoots and rootlets was also reduced. Aqueous extracts from striga seeds reduced the growth of sorghum shoots, but extracts from striga shoots reduced the growth of sorghum rootlets more than seed extracts.

Extracts from the shoots of striga infected sorghum also reduced the growth of shoots and rootlets of sorghum seedings. Aqueous extracts from shoots of non-infected sorghum plants did not affect the growth of either shoots or rootlets of the seedlings tested. This result indicates that *S. hermonthica* contains chemical inhibitors of *S. vulgare*. These inhibitors are present in the shoots and seeds of *S. hermonthica*.

Various concentrations (5%, 10%, and 20%) of aqueous extracts from *S. hermonthica* shoots reduced the growth of the shoots of the five *S. vulgare* cultivars examined to different degrees. Shoot growth of cultivars Debaikri, Dabar and Framida were reduced more than Dobbs and IS9830. The growth of the rootlets of the five cultivars was more affected than shoot growth, and significant reduction of root development was found for all seedlings and with all concentrations. The mean effect of treatments on the growth of shoots and rootlets as percentage of controls showed that susceptible cultivars Debaikri and Dabar were more affected than tolerant cultivars Framida and IS9830, and the intermediate cultivar, Dobbs. The response of the five sorghum cultivars to treatment with striga plant extracts resembles to some degree their response to striga infection. This proves that the effects of the parasite on its host resulted from inhibiting substances present in its seeds and/or its shoots.

The effects of Striga on its host plants have long been recognized (Kumar 1946, Andrews 1947, Wilson-Jones 1953, Last 1960, Williams 1961, Parker 1965, and

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Elhiweris 1979). Infected plants became stunted, slender, wilted and turned yellow. At this stage, the damage was obvious and control would probably not be effective even if it was possible. The parasite deprived the host of minerals and organic matter (Rogers and Nelson 1962 and Okonkow 1966). Toxic effects of the parasite on its host have been suggested as an alternative explanation for the observed symptoms of infection on the plant. Donald and Fawcett (1967) succeeded to separate three fractions from water extracts of red bartsia leaves (non-parasitic weed from the striga family) which inhibited the growth of alfalfa seedlings. Also, inhibiting substances have been extracted from striga seeds (Kust 1966) and from *S. lutea* (lour) roots which caused wilting and death of rice seedlings (Uttaman 1950). An aqueous extract from *S. hermonthica* inhibited the growth of some *S. vulgare* seedlings (Elhiweris 1979). Toxins released from the parasite that affect the host could explain why host plants continuously suffer from the parasite even before the parasite has emerged above the soil surface. Such toxins could be transferred to the host through the rhizosphere or directly across the haustoria of the parasite, but this is not yet clear. The experiments described in this paper were designed to investigate the presence of substances toxic to sorghum in the seeds or the shoots of *S. hermonthica* plants which, in part, may be the cause of the damage observed on *S. vulgare*. Such toxic substances might explain the presence of the characteristic symptoms of infection on host plant even before the emergence of the parasite from the soil.

Materials and Methods

Experiment 1

S. hermonthica plants parasitizing *S. vulgare* plants were collected from University of Khartoum, Faculty of Agriculture, Demonstration Farm. Shoots of striga or sorghum were separated from the roots, weighed and air dried. The air dried plant materials were milled to a fine powder and stored in dry, well-stoppered, sterile bottles until they were required for bioassay. Shoots from sorghum plants (var. Debaikri) not infected by striga and of the same age as parasitized sorghum plants were collected from the same farm. The fine powder of the air-dried healthy sorghum shoots was also kept in dry, clean, sterillized, and well-stoppered glass bottles. Seeds from mature *S. hermonthica* plants found in the farm were also collected and air-dried (but not milled) and kept in a clean-dry bottle till they were required for bioassay.

Twenty grams from the milled shoots of *S. hermonthica* or *S. vulgare* var. Debaikri infected or non-infected as well as *S. hermonthica* seeds were extracted with sterile distilled water using the method described by Donald and Fawcett (1967). The dried material was soaked for 24 hr in two 50 ml sequential volumes and was put in an incubator adjusted at 20 ± 2°C. The combined extracts were filtered using a Buchner funnel and stored in a bottle in the refrigerator. These

extracts represented the 20% (= x) concentation. Series of dilutions were prepared to give 10%, 5%, 2.5% aqueous extracts ($\frac{1}{2}$ x, $\frac{1}{4}$ x, $\frac{1}{8}$ x) together with distilled water as a control.

Seeds of *S. vulgare* (var. Debaikri) of equal shape and size were selected and surface sterilized with 0.5% sodium hypochloride for 5 min. These seeds were thoroughly washed with sterile distilled water and twenty-five of them were transfered to sterile petri dishes containing a double layer of germination filter paper. Equal volumes of test solutions or distilled water, just enough to keep the paper moist, were added. Five replicates from each concentration of each plant extract were prepared. The dishes were carefully wrapped in sterile plastic bags and incubated at 25°C for 7 days. The test solutions or distilled water were added to the appropriate dishes every day (= 5 ml). At the end of the experiment the number of germinating seeds were counted and calculated as percentage to total number of seeds per dish. The lengths of shoots or roots were measured and the values were calculated as percentage relative to the control. Data of the shoot and root lengths with five replicates and five aqueous extract concentrations from four different plant extracts were statistically analysed.

Experiment 2

Aqueous extracts from the shoots of *S. hermonthica* were prepared as described in experiment 1. *S. vulgare* seeds from five cultivars varying in susceptibility to infection with *S. hermonthica* were used in the biological tests. The cultivars Debaikri and Dabar are susceptible and Framida and IS 9830 are tolerant to infection by *S. hermonthica* (Kambal and Musa 1969). Dobbs is intermediate to infection (Doggett 1960).

Series of concentrations, 20%, 10%, 5%, (x, $\frac{1}{2}$ x, $\frac{1}{4}$ x) together with 0% aqueous extracts were prepared as described above. Twenty-five sterilized sorghum seeds were spread on the surface of double filter paper and wetted with equal volumes of the aqueous shoot extract. Petri dishes were incubated at 20°C and received 5 ml of test solution or distilled water daily for 7 days. The length of shoots and rootlets were measured (4 & 5). The experiment was statistically designed and an analysis of variance were performed.

Results and Discussion

The data in Table 1, showed that shoot extracts from sorghum plants infected or non-infected with striga generally did not affect the percentage germination of sorghum seeds at 2.5%, 5% and 10% concentrations as compared with the control (0%). Slight reductions in germination were observed at the lowest and highest concentrations. The effects of shoot extracts from striga plants on germination of sorghum seed were similar to the effects of sorghum extracts except at the 20%

concentration that had greater reducing effect on the percent germination of sorghum seeds than that caused by the same concentration from sorghum shoot extracts. However, extracts from striga seeds markedly reduced the germination percent especially at high concentrations (Table 1). The mean effect of the treatment with the different concentrations proved that extracts from striga seeds were more inhibitory to sorghum seed germination than extracts of striga shoots. The latter was slightly more toxic to the germinating seeds than the two sorghum extracts (Table 1). The mean germination percent was 74.98, 93.16, 94.04, and 94.28% for seeds treated with aqueous striga seeds extract, striga shoots extract, shoot extracts from infected sorghum and shoot extracts from non-infected sorghum plants respectively.

Table 1. Effect of *Sorghum vulgare* or *Striga hermonthica* aqueous extracts on the germination percent of *Sorghum vulgare* seeds. Data represent the mean germination percent of five replicates of 25 seeds/replica

Plant part extracted / Extract conc. (%)	Striga shoot	Striga seed	Shoot of infected sorghum	Shoot of uninfected sorghum	Mean treatment effect
0	96.0	95.0	95.3	96.6	94.23
2.5	93.391.6	93.3	95.0	91.6	93.53
5	96.6	80.0	93.3	95.0	89.98
10	88.3	76.6	95.0	96.6	91.20
20		30.0	91.6	91.6	75.38
Mean plant extract effect	93.16	74.98	94.04	94.28	

Aqueous extracts of striga seeds significantly reduced the length of sorghum shoots in comparison to the other extracts (Table 2). The mean shoot lengths of treated plants, estimated as percentage of the lengths of the untreated seedlings, were 63.99, 76.01, 82.48 and 86.66% for the aqueous extract from striga seeds, striga shoots, shoots of infected and of non-infected sorghum plants respectively (Table 2).

The rootlet lengths of the treated sorghum seedlings were also reduced. Their lengths were significantly reduced with increased extract concentration, *i.e.* the reduction was more pronounced at higher extract concentration (Table 3). However, rootlets and shoots did respond differently to the different types of extracts. The aqueous striga shoot extracts significantly reduced the length of roots in all concentrations followed by the extracts from the striga seeds and then the extracts from the shoots of infected sorghum plants. The effects of the latter were significant at concentrations higher than 2.5% (Table 3). However, aqueous

extracts of the uninfected sorghum shoots had no effect on the root lengths of treated and non-treated plants as no significant differences were noticed. Data reported in Table 3 indicated that striga shoot extracts were toxic to sorghum roots followed by extracts of striga seeds, then extracts of sorghum shoots infected with striga plants. These values were 63.38, 80.96, 84.14 and 95.69% for the three extracts respectively (Table 3).

Table 2. Effect of *Sorghum vulgare* or *Striga hermonthica* aqueous extracts on the growth in length of *Sorghum vulgare* shoots. (A) Data represent the mean lengths of shoot in cm. (B) lengths of treated seedlings as percent relative to the control

	Plant part extract / Extract conc. (%)	Striga shoot	Striga seed	Shoot of infected sorghum	Shoot of uninfected sorghum	Mean treatment effect
A	0	7.933	8.287	8.003	7.833	8.014
	1/8X	6.466	7.610	6.603	7.170	6.962
	1/4X	5.510*	3.218*	6.437	6.440	5.651
	1/2X	5.080*	4.355*	6.447*	6.370	5.563
	X	5.155*	3.047*	5.513*	6.127	4.961
Mean plant extract effect		6.029	5.303*	6.601	6.79	
B	0	100	100	100	100	100
	1/8X	81.50	91.79	82.51	91.54	86.84
	1/4X	69.50	38.83	80.43	82.22	67.70
	1/2X	64.04	52.55	80.56	81.32	69.62
	X	64.98	36.77	68.89	78.22	62.22
Mean plant extract effect		76.01	63.99	82.48	86.66	

Source	*Significance*	*L.S.D. (P=0.05)*
Plant extract	*	1.43
Concentration	N.S.	–
Interaction	N.S.	–

Moreover, it is evident, from the results given in Tables 2 and 3, that striga extracts are toxic to sorghum growth, and that the toxic substances in striga shoots are more inhibitory to sorghum roots than shoots while the opposite is true in case of extracts from striga seeds which inhibited the shoot growth more than the root growth. Extracts of infected sorghum were also inhibitory to the growth of both roots and shoots.

Extracts from shoots of uninfected sorghum did not affect the growth of either sorghum shoots or roots. This may indicate that allelopathy in sorghum plant was improbable and that inhibitory substances present in the aqueous extracts from

striga shoots or seeds reduced the growth of sorghum shoots and roots. This may be the reason for the stunted appearance of host plants parasitized by striga. This data are similar to the results reported by Kust (1966) and by Uttaman (1950) who extracted toxic substances from *S. lutea* roots which caused wilting and death of rice seedlings. These data are in agreement with Elhiweris' (1979) results in which she proved that extracts from *S. hermonthica* shoots reduced the growth of both shoots and rootlets of seedlings from five plant species (*Sorghum vulgare*, var. YE-90L) *Hordium vulgare*, var. Wing; *Helianthus annus*, var. Polestar; *Brassica oleraceae*, var. May King and *Lepiderm sativum*, var. Sutton Curly leaf). However, the inhibition of sorghum growth in response to treatment with extracts from striga shoots and seeds and with extracts from shoots of striga infected sorghum plants has indicated that substances toxic to sorghum growth are present in the striga plant and may be transferred during infection to the sorghum plant and caused its reduced growth.

Table 3. Effects of *Sorghum vulgare* or *Striga hermonthica* aqueous extracts on the growth in length of *S. vulgare* roots. (A) Mean length of roots in cm. (B) Root lengths of treated seedlings as percent relative to control

Plant part extracted / Extract conc.		Striga shoot	Striga seed	Shoot of infected sorghum	Shoot of uninfected sorghum	Mean treatment effect
	0	8.467	10.24	9.700	9.61	9.504
	1/8X	7.700*	9.62**	8.77 **	9.07	8.790
A	1/4X	3.700**	9.21**	7.33 **	9.60	7.460**
	1/2X	4.20 **	6.68**	7.26 **	8.93	6.893**
	X	2.80 **	5.70**	7.27 **	8.77	6.135**
Mean plant extract effect		5.37 *	8.29*	8.17 *	9.196	
	0	100	100	100	100	
	1/8X	90.9	93.95	80.10	94.38	89.83
B	1/4X	43.36	89.94	75.57	99.89	77.19
	1/2X	49.59	65.23	80.00	92.92	71.94
	X	33.06	55.66	85.26	91.26	66.31
Mean plant extract effect		63.38	80.96	84.19	95.69	

Source	*Significance*	*L.S.D. (P=0.05)*
Plant extract	*	1.25
Concentration	**	1.41
Interaction	N.S.	–

Chemical analysis of striga for inhibitory substances such as abscisic acid (ABA) and farnesol revealed their presence in low concentrations even lower than

that naturally present in the sorghum plant (Elhiweris 1979). This indicated that the toxic substances inside striga plants were compounds other than ABA or farnesol. The inhibition of sorghum growth caused by treatment with striga aqueous seed extracts could explain the reduction in growth in infected host plant even before the emergence of the parasite. Water soluble toxins in striga seeds are leached out and diffused within the host rhizosphere, thus, affecting its growth and resulting in the characteristic symptoms of infection. The white blotches appearing on the leaves of infected sorghum are quite characteristic and unlike all known symptoms of mineral element deficiencies previously described. They could be due to the presence of certain toxic substances in the plant rhizosphere that had come from the striga seeds, or inside the striga plant body which were transferred to the host plant after attachment to it.

The specificity of the effect of striga to some cultivars rather than others was tested in experiment 2. The results given in Tables 4 and 5 showed that aqueous extracts from striga shoots significantly reduced the growth in length of both shoots and roots of the five sorghum cultivars seedlings. The inhibition of growth increased with increased extract concentration. Sorghum cultivars responded differently to the treatment with the extract. Treatment with 5% extract reduced the lengths of Debaikri and Framida shoots compared with the other three varieties, while the 10% extracts was only significantly effective on Debaikri shoot length. Higher concentration of the extract (20%) reduced the shoot length equally for the five cultivars. The mean effect of striga shoot extracts on the growth in length of the shoots of treated seedlings as percent relative to untreated ones, showed that Dabar shoot growth was reduced the most followed by Debaikri, Framida, Dobbs and IS 9830. These values were 75.97, 78.33, 79.03, 85.23 and 86.36% for the sorghum cultivars, Dabar, Debaikri, Framida, Dobbs and IS 9830 respectively (Table 4).

On the other hand, the results given on Table 5 showed that root lengths of the five sorghum cultivars were significantly reduced with increased extract concentrations and behaved equally to treatment with the striga aqueous extracts. There was no significant differences between the five cultivars. Although these differences were not significant, it could be concluded that the roots of treated Dabar in relation to untreated plants were more reduced followed, in order of diminishing effects by the roots of Dobbs, then Debaikri, Framida and IS 9830. These values were 69.79, 72.28, 75.17, 78.18 and 79.69% for the five sorghum cultivars respectively (Table 5). It is worth mentioning that the shoot growth of susceptible cultivars, Debaikri and Dabar, was more inhibited by the striga extracts than that of the tolerant cultivar, Dobbs.

It was clear that *S. hermonthica* extracts have inhibitory substances in both shoots and seeds. The responses of the five tested cultivars to striga extracts were similar to their responses to striga infection.

Table 4. Effects of *Striga hermonthica* aqueous shoot extract on the growth in length of shoots of five *Sorghum vulgare* varieties. (A) Mean lengths in cm. (B) Lengths of treated seedlings as percent relative to control

	Extract conc. % / Sorghum variety	0	1/4 X	1/2 X	X	Mean variety effect
A	Debaikri	7.460	6.267*	6.310**	3.333**	5.84*
	Dabar	8.600	7.233	6.833**	3.467**	6.53
	Framida	8.433	6.367**	6.867**	4.990**	6.60
	Dobbs	8.033	7.933	7.767	4.000	6.93
	IS 9830	7.467	7.927	6.633*	3.767*	6.45
Mean treatment effect		7.99	6.949**	8.603	4.889*	
B	Debaikri	100	84.05	84.58	44.68	78.33
	Dabar	100	84.10	79.45	40.32	75.97
	Framida	100	75.50	81.43	59.17	79.03
	Dobbs	100	98.76	96.69	49.81	85.23
	IS 9830	100	106.160	88.83	50.45	86.36
Mean treatment effect		100.0	89.71	86.20	48.89	

Source	*Significance*	*L.S.D. (P=0.05)*
Variety	*	1.08
Treatment	**	1.54
Interaction	N.S.	–

Table 5. Effect of *Striga hermonthica* aqueous shoot extract on the growth in length of roots of five *Sorghum vulgare* varieties. (A) Mean root lengths in cm. (B) Root lengths of treated seedlings as percent relative to control

	Extract conc. % / Sorghum variety	0	1/4 X	1/2 X	X	Mean variety response
A	Debaikri	9.567	9.433	6.40 **	3.367	7.192
	Dabar	8.967	7.467**	6.00 **	2.600**	6.289
	Framida	8.000	6.667**	6.867**	3.967**	6.375
	Dobbs	9.800	8.067**	7.167**	3.30 **	7.084
	IS 9830	7.867	8.133**	6.000**	2.633**	6.158
Mean treatment effect		8.841	7.953**	6.487**	2.381**	
B	Debaikri	100	98.59	66.89	35.19	75.17
	Dabar	100	83.27	66.91	28.99	69.79
	Framida	100	83.33	85.84	49.59	79.69
	Dobbs	100	82.32	73.13	33.67	72.28
	IS 9830	100	102.96	76.27	33.47	78.18
Mean treatment effect		100.0				

Source	*Significance*	*L.S.D. (P=0.05)*
Variety	N.S.	–
Treatment	**	.67
Interaction	N.S.	–

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مواد مثبطة لنمو نبات الذرة الرفيعة *(Sorghum vulgare)* من طفيل نبات البوده *(Striga hermonthica)*

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من متابعة تأثيرات نبات البوده على عائلة نبات الذره اتضح أن الأثر الضار للطفيل يبدو على الشكل الظاهري للعائل قبل ظهور الطفيل فوق سطح التربة. هذا بالإضافة إلى أعراض المرض التي تبدو في أوراق نبات الذرة كاصفرار أو ابيضاض في شكل خطوط مميزة لا تشبه أعراض نقص أي من العناصر المعدنية يشير إلى أن بالطفيل مواد سامة للعائل.

وباستخدام دراسة تأثير مستخلصات من نبات البوده على معدل الإنبات ونمو طول الجذير والسويقه تمت دراسة احتمال وجود مواد سامة تثبط نمو نبات الذرة *Sorghum vulgare* من عينة ديباكرى (Debakri) ومن نتائج التجارب اتضح أن للمستخلص المائي لبذور نبات البوده أو لمجموعه الخضري تأثيراً مثبطاً على معدل إنبات بذور نبات الذرة، كما تبين نقص طول الجذر والسويقة لنبات الذرة عند المعاملة بالمستخلصات المائية سابقة الذكر. ولقد كان النقص في معدل الإنبات وطول السويقه بدرجة أكبر عند معاملة النبات بمستخلص بذور نبات البوده منه عند معاملته بمستخلص المجموع الخضري لها. ولقد أثر مستخلص المجموع الخضري على نمو الجذير بدرجة أكبر من تأثيره على طول السويقه. كما أثر كذلك المستخلص المائي للمجموع الخضري لنبات الذرة المصاب بالطفيل على طول السويقه وطول الجذير لكنه لم يؤثر على معدل إنبات البذور. هذا ومن ناحية أخرى فلقد كانت المعاملة بالمستخلص المائي للمجموع الخضري لنبات الذرة غير المصاب بطفيل البوده أقل تأثيراً من المعاملات الأخرى على معدل الإنبات.

وأثبتت التحاليل الإحصائية وجود فروقات غير معنوية بين أطوال السويقة والجذير التي تمت معاملتها بالمستخلص المائي والأخرى التي لم تعامل مما يشير إلى عدم تأثر نمو بادرات الذرة المعاملة بالمستخلص المائي لنباتات الذرة غير المصابة بالطفيل.

وأدت معاملة خمسة أصناف من نبات الذرة بمستخلص مائي للمجموع الخضري لطفيل البوده بتركيزات ٥٪ و ١٠٪ و ٢٠٪ إلى إنخفاض نمو بادراتها بدرجات متفاوتة. فلقد نقص نمو بادرات الذرة من صنف ديباكري، دبر، وفراميدا بدرجة أكبر مما تأثر صنف دوبس وآى اس ٩٨٣٠. ولقد كان تأثير المعاملة على نمو الجذير للخمسة أصناف المدروسة أكبر من تأثيرها على نمو السويقة للأصناف النباتية نفسها عند المعاملة بنفس التركيزات. وبالنظر إلى حساب متوسط تأثير المعاملات على نمو السويقة للأصناف الخمس يتضح أن الأصناف التي تتميز حساسيتها للتعرض للتطفل بنبات البوده (صنف ديباكري وصنف دبر) كانت أكثر تأثراً بالمعاملة بالمحلول المائي للمجموع الخضري للطفيل مقارنة بالأصناف الأخرى المقاومة (فراميدا وآى اس ٩٨٣٠) أو الصنف متوسط الاستجابة للتطفل بنبات البوده (دويس).

هذا وتشابه هذه الاستجابة ـ معاملة نبات الذرة بالمستخلص المائي لطفيل البوده ـ الاستجابة الطبيعية للعائل عند مهاجمة طفيل البوده له في بيئته الطبيعية. مما يفيد بأن تأثير العائل للتطفل ينتج عن وجود مواد مثبطة لنموه في خلايا الطفيل.