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Toxicologyical and physiological activity of plant extracts against *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae) larvae

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The hexane, petroleum ether and ethyl alcohol extracts of three species of weed plants were tested for insecticidal toxicity and antifeedant activity in fourth instar larvae of Egyptian cottonworm (*Spodoptera littoralis*). All extracts showed a certain degree of larval toxicity. The hexan extracts of *Sonchus olearcues* L., the petroleum ether extracts of *Brassica niger* Koch., and the ethyl alcohol extract of *Raphanus sativa* var. *surtus* L., were highly toxic (LC50s = 218.36, 96.11 and 5574.66 ppm respectivily).

The antifeeding activity of crude extracts of selected weed plants, petroleum ether and hexane extracts of *B. niger* were chosen based on their high insecticidal activity to be tested for antifeeding activity. The antifeeding activity of crude extracts hexane more effect than petroleum ether extracts of *B. niger*.

The extracts significantly affected the growth indexes [consumption index (C.I.), efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD)]. But the extracts not affected niether on growth rate (GR) nor on approximate digestibility (A.D).

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INTRODUCTION

Pest control represents a critical factor and highly productive inputs for increasing crop yields and preventing crop losses before and after harvest. Till now chemical control has a main role in pest control programmes in both developing and undeveloping countries. The great majority of pesticides employed in Egypt are used to protect cotton which is still the cash crop for exportation. The often and indiscriminate use of pesticides has led to several adverse consequences and the environmental quality has been deteriorated to a great extent.

The Egyptian cotton leafworm, *Spodoptera littoralis* (Boisduval) (Lep., Noctuidae), is a major pest of cotton and other cultivated crops in Egypt as well as Mediterranean and Middle East countries (Campion *et al*. 1977; Nasr *et al*. 1984; Ahmad, 1988). The fact that the insect infests more than 87 host plants belonging to 40 plant families (Brown and Dewhurst, 1975) makes it a model of serious polyphagous pests.

Serious problems of genetic resistance by insect species, pest resurgence, residual toxicity, widespread environmental hazard and increasing costs of application of the presently used synthetic pesticides have directed the need for effective, biodegradable pesticides (Badr *et al*. 2000; Amr 2001; Fatope *et al*. 2002; Abd Elgaleil and Nakatani, 2003; Sadek 2003; Pavela 2004; Pavela and Chermenska, 2004; Ghatak *et al*. 2005; Ntonifor *et al*. 2006; Shadia *et al*. 2007: Pavela *et al*. 2008). This awarness has created worldwide interest in the development of alternative strategies, including the re-examination of using plant derivatives against agriculturally important insect-pests. Plant-derived materials are more readily biodegradable. Some are less toxic to mammals, may be more selective in action and may retard the development of resistance. Their main advantage is that the may be easily and cheaply produced by farmers and small-scale industries as crude, or partially purified extracts. In the last two decades, considerable efforts have been directed at screening plants in order to develop new botanical insecticides as alternatives to the existing insecticides.

Although these plant extracts had not strong insecticidal activity against insect tested, they showed a definite disruption with one or more of physiological processes. Accordingly, recent efforts by pesticide chemists have been shifting emphasis from killing to management. Therefore, our research efforts in the present study aimed to explore this principal approach for evaluation of insecticidal activity, antifeeding activity and growth index of certain plant extracts against *S. littoralis*.

MATERIALS AND METHODS

MATERIALS

Test insect

The larvae used in the present study were obtained from laboratory colony continuously reared away of insecticidial contamination since 1990 in Sakha (North of Egypt) Agriculture Research Station, Egypt. Rearing of insects were conducted following the technique described by El-Defrawi *et al*. (1964). Larvae were fed on fresh castor bean *Ricinus communis* L., leaves until pupation. Moths were fed on 10% sugar solution offered in a piece of cotton tissue soaked in this solution. Each jar was provided with branches of tafla, *Nerium oleander,* as an oviposition site. The rearing room was kept at constant temperature of 25±2 ºC and relative humidity of 65±5 %, a photoperiod of 16:8 (L:D) h.

Plant Extracts

Plant materials

Based on results of our preliminary tests conducted in the present study, three plant species were chosen including annual sowthistle, *Sonchus olearcues* (L.) (Solanaceae), black mustard, *Brassica niger* (Koch.), and red radish, *Raphanus sativa* var. *surtus* (L.) and both of them from family Cruciferae, for extraction.

Preparation of plant extracts

Plant extracts were prepared according to method adopted by Freedman *et al*. (1979) and Abo-Elghar (1985) with some modifications. Leaves of the tested plants were dried under room temperature, grounded in an electrical mil and sieved through 0.5 mm sieve. Three solvents varied in their polarity were used for extraction process following this order: Hexane 90%., Petroleum ether 80% and Ethanol 95%.

A sample of 50 g powder was soaked in 350 ml of hexane for 72h in brown-colored bottle (1.5 liter), provided with tight stoppers, then the bottle was shaken for 30 min. by using a shaker and then filtered. The extracted powder (merc) was soaked, again two times in an additional volumes of the same solvent (hexane) for 24h, and filtered by using filter paper (Whatman). The filterate portions were mixed and the solvent was evaporated until dryness. The crude gum obtained was weighed and stored in a refrigerator until needed.

The merc resulted after extraction by hexane was spread on a sheet of paper to dry at room temperature, then was reextracted with the second solvent, petroleum ether following the same technique previously described. The same steps were carried out using the third solvent, ethyl alcohol.

Preliminary Formulation

Considering the obtained crude gum as 100 % a.i., a known weight of one gram was redissolved in 20 ml of the appropriate solvent to give 5 percent stock solution of each extract which were kept in a refrigerator until used. The stock solutions were prepared fresh by prior to doing the experiments. Tween-20 emulsifier was added at a concentration of 0.02 % to the first dilution before preparing different successive concentrations for bioassays.

METHODS

Assessment of insecticidal activity of selected weed extracts against *S. littoralis* larvae under laboratory conditions

Based on results of the preliminary test, three plant species (i.e. *R. s.* var. *surtus, B. niger* and *S. olearcues*) were chosen to examine precisely their insecticidal activity against *S. littoralis* larvae. Crude extracts obtained from leaves of each selected plant were prepared as previously described using three different solvents; hexane, petroleum ether and ethyl alcohol.

For each extract, at least 7 successive water dilutions (concentrations), were prepared from stock solution. Fresh castor bean leaves were dipped in the water dilution (concentration), for 10 seconds. The treated leaves were left to dry before being offered to 20 larvae/replicate in 400 ml glass jar. Five replicates were used for each concentration. The larvae were allowed to feed on treated leaves for only 48h, then untreated fresh leaves were used for continuous feeding until death or pupation occurred. Control larvae were fed on water-treated castor bean leaves at the same way. Mortality percentages were recorded at 48h intervals and corrected for natural mortality in control, using Abbott's formula (ABBOTT, 1925). The lc-p regression lines were drawn on a log concentration-probit paper and LC_{50} values were calculated at 4, 6 and 8 days post treatment and data were subjected to statistical analysis according to Finney (1971).

Assessment of antifeeding activity of the selected crude extracts of weed plants

The purpose of this experiment was to evaluate the antifeeding activity of hexane - petroleum ether - extract from *B. niger* against *S. littoralis* larvae. These extracts were chosen on the basis of their strong insecticidal activity.

The reduction in weight of leaves following feeding was recorded daily and the antifeeding activity of the tested treatments was calculated using SALEH *et al.* (1986b) formula as follows:

$$\text{Antifeeding activity} = \left[1 - \frac{\%\text{ of treated leaf eaten}}{\%\text{ of untreated leaf eaten}}\right] \text{X } 100$$

Assessment of the effect of crude extracts from selected weeds on food consumption, growth rate and food utilization by *S. littoralis* larvae

In all feeding experiments, newly moulted 4th instar larvae weighed 20±2 mg were used. Clear glass jars (350 ml), with a large piece of filter paper (ca. 6 cm diam.), on the bottom, were used as containers for larvae and food. Leaves of castor bean were used for feeding larvae in all experiments. The leaf dipping technique was adopted in all experiments, for ca. 10 sec., in each tested concentrations of 4000, 8000, 10000 and 12000 ppm, and then left to dry. Leaves dipped in water served as control. For each treatment (concentration), 25 larvae/replicate were placed into the rearing jar in each of four replicates. Larvae were allowed to feed on treated leaves for only 48h; then the dead larvae were discarded and the survivors were fed daily on untreated fresh leaves until death or completing their development to pupation. In each jar, introduced fresh leaves, surviving larvae, faeces and uneaten leaves were weighted daily and related to the number of survivors. A known weight of fresh leaves was kept in a similar rearing jar without larvae under the same conditions to estimate the natural loss in moisture, which was used for calculating the corrected weight of consumed leaves.

Nutrition indices were calculated using standard gravimetric procedures described by WALDBAUER (1968) as follows:

1) The corrected wt of leaf consumed = [1- a / 2] [W – (L + b L)]; where a = the ratio of loss of water to the initial weight of the aliquot, b = the ratio of water to the final weight of the aliquot, W = wt of food introduced, L = wt of untreated food.
2) Consumption index (CI) is a measuring the amount of food eaten per unit time relative to mean weight of larvae during the feeding period, CI= C/ [(T)(A)].

Where: C= fresh weight of leaf consumed, T= duration of feeding period and A= mean fresh weight of the larvae during the feeding period.

3) Growth rate (GR) measures amount of weight gained per unit time relative to the mean weight of the larvae during the feeding period; GR=G/[(T)(A)].
   Where G= fresh weight gain of the larvae.
4) Efficiency of conversion of ingested food to body tissue (ECI) is an overall measure of the larvae's ability to utilize ingested food for growth, ECI=(G/C)(100%).
5) Efficiency of conversion of digested food to body tissue (ECD) is an overall measure of the larvae's ability to utilize digested food for growth, ECD = [G/(C-F)](100%). Where F= faeces weight during the feeding period.
6) Approximate digestibility (AD), is a measure of the larvae's ability to digest the introduced food, AD= [(C–F) /C] (100 %).

All feeding experiments were carried out under conditions of 27±2 ºC, 60±5 %RH and a photoperiod of L: D (12:12) h. Data was subjected to analysis of variance (ANOVA) and means were separated by Duncan's (DUNCAN, 1955) multiple range tests.

RESULT AND DISCUSSION

Toxicological and physiological activity of plant extracts against *S. littoralis* larvae

Insecticidal activity of 3 plant extracts against *S. littoralis* under laboratory conditions

The toxicity of 9 solvent extracts obtained from two weeds (*B. niger* and *S. olearcues*) and one vegetable plant (*R. s.* var. *surtus*), were evaluated against the 4th instar larvae of *S. littoralis* from laboratory strain using leaf dipping technique. The prementioned plants were chosen on the basis of the potent combined effect, when fresh leaves, were treated with selected insecticides against *S. littoralis* larvae. The toxicity data were recorded at 4, 6 and 8 days post treatment and LC_{50} values were calculated and presented in Tables 1, 2 and 3.

Hexane extracts

Data presented in Table 1, show that LC_{50} values, reported after 4 days of treatment indicated that hexane extract of *S. olearcues* was 1.2 and 25.5 fold more toxic than that of *B. niger* and *R. s.* var. *surtus,* respectively, whereas it reached 3.57 and 1.05 fold based on 6 days-LC_{50} values. Comparison of the cumulative effect on the basis of 8-days-LC_{50} values, it was obvious that still hexane extract of *S. olearcues* was the most toxic one and was followed closely by hexane extract of *B. niger* whereas hexane extract of *R. s.* var. *surtus* was the least effective one.

Petroleum ether extracts

Data in Table 2, reveals that based on LC_{50} values at 8, 12 and 16 days post treatment, the most toxic extract was that of *B. niger* whereas it showed the least LC_{50} values and exhibiting the highest toxicity.

*Ethyl alcohol extracts*_

Data presented in Table 3, indicate that based on 8-day-LC_{50} values the ethyl alcohol extract of *R. s.* var. *surtus* was the most toxic one and was 95.79 and 1.36 fold more toxic than that of *B. niger* and *S. olearcues,* respectively, whereas it reached 7.68 and 1.85 fold based on 12-day-LC_{50} values. However, at 16 days post treatment ethyl alcohol extract of *R. s.* var. *surtus* was still

Table 1. **LC_{50}'s, slope values and stander error of three hexane plant extracts against 4th instar larvae of *S. littoralis* at different days post-treatment**

Extracted plant	Days after treatment	LC_{50} (ppm)	Slope ± S.E
R. s.* var. *surtus	4	17856.47	2.26 ± 0.46
	6	7520.09	0.94 ± 0.35
	8	2807.83	0.97 ± 0.35
B. niger	4	377430	0.54 ± 0.41
	6	2215.41	0.97 ± 0.36
	8	341.96	0.55 ± 0.38
S. olearcues	4	14588.32	3.00 ± 1.32
	6	317.19	0.91 ± 0.45
	8	218.36	0.40 ± 0.36

Table 2. **LC_{50}'s, slope values and stander error of three petroleum ether plant extracts against 4th instar larvae of *S. littoralis* at different days post-treatment**

Extracted plant	Days after treatment	LC_{50} (ppm)	Slope ± S.E
R. s.* var. *surtus	8	8770.89	3.54 ± 0.49
	12	7846.82	3.07 ± 0.46
	16	7781.45	3.11 ± 0.46
B. niger	8	353.68	0.66 ± 0.35
	12	289.58	0.60 ± 0.35
	16	96.11	0.39 ± 0.35
S. olearcues	8	8996.97	2.88 ± 0.37
	12	4777.96	1.68 ± 0.36
	16	3672.63	1.52 ± 0.36

Table 3. **LC_{50}'s, slope values and stander error of three ethyl alcohol plant extracts against 4th instar larvae of *S. littoralis* at different days post-treatment**

Extracted plant	Days after treatment	LC_{50} (ppm)	Slope ± S.E
R. s.* var. *surtus	8	18260.14	1.99 ± 0.42
	12	9928.86	1.95 ± 0.42
	16	5574.66	2.26 ± 0.36
B. niger	8	1771000	0.39 ± 0.53
	12	76308.14	0.52 ± 0.41
	16	6784.07	2.44 ± 1.27
S. olearcues	8	18933.73	2.06 ± 0.86
	12	14207.38	2.09 ± 0.88
	16	8690.17	2.88 ± 0.44

the most toxic one, whereas *S. olearcues* and *B. niger* extracts came next, respectively.

In general, comparison based on type of solvent used in extraction revealed that hexane was the most potent solvent in this respect, where hexane-extracts of the three tested plants were more effective than when the two other solvents were used in extraction, based on 8-day-LC_{50} values. (Tables 2 and 3). Also, the maximum accumulated mortality was achieved early with hexane extracts at 8 days post treatment versus 16 days post treatment in case of petroleum ether and ethyl alcohol extracts. The forementioned data reveal the nonpolarity of the extracted bioactive compounds.

Generally, the toxic action or/and larval mortality by the tested plant extracts recorded here by weed plant extracts is in full agreement with results of several researchers using various non-host plant extracts on *S. littoralis*. For example, BARLOW (1978) used Jojoba extracts; EL-KABBANY (1980) using turpin, garlic, onion and spearmint extracts; MOHAMED (1983) used black pepper, fennel, lupin and cumin extracts; BARAKAT *et al*. (1985) used devil's apple and caraway extracts; ISMAIL *et al*. (1990) used nettle canna and shoak el deeb extracts. ALSO KANDIL *et al*. (1984) studied the insecticidal activity of seven plant extracts belonging to different species against the cotton leafworm and found that carawy extract was the most effective against the 4th instar larvae. SALEH *et al*. (1986b) investigated the insecticidal activity of 53 plant species from 23 different families against *S. littoralis*. Using either organic solvents of variable polarities or steam distillation, 22 plants showed significant insecticidal activity. However, nonpolar extracts (petroleum ether, diethyl ether) of *A. fragrantissima, A. monosperma* and *T. erecta* were the most effective. BADR *et al*. (2000) used four seed oil extracts, *i.e*., soyabean, cotton, castor and sunflower. AMR (2001) used chloroform and ethanol extracts of *Salvia aegyptiaca*. FATOPE *et al*. (2002) used extracts of the leaves, twigs, stems and roots of *Lantana camara* Linn. SADEK (2003) using crude methanolic extracts of *Adhatoda vasica* leaves. PAVELA (2004) used methanol extracts of eight species of medicinal plants. GHATAK *et al*. (2005) used petroleum ether extracts from seeds of *Pachyrhizus erosus* and *Annona squamosa*. NTONIFOR *et al*. (2006) using the extracts *Piper guineense* (Piperaceae), *Aframomum melegueta* (Zingiberaceae), *A. citratum* (Zingiberaceae) and *Afrostyrax kamerunensis* (Huaceae) seeds. SHADIA *et al*. (2007) used the extract of four Egyptian wild plants/weed. PAVELA *et al*. (2008) using methanolic extracts from three *Reynoutria* species.

Antifeeding activity of crude extracts of selected weed plants

Based on the insecticidal activities (Table 4-5), of the tested extracts, only the petroleum ether and hexane extracts of *B. niger* were chosen as representatives of the most potent extracts. Four successive concentrations (4000-12000 ppm), that resulted in slight or no larval mortality (Table 4), were chosen and tested to determine the antifeeding activity against 4th instar larvae (1- day-old) of *S. littoralis*.

Data in Table 5, shows the deterrent effect against *S. littoralis* 4th instar larvae after 24h feeding period on treated leaves. It was obvious that the least deterrent effect was achieved by hexane extract of *B. niger*, recording 3.09 to 23.08% antifeeding effect. However, petroleum ether *B. niger* extract at 4000-12000 ppm resulted in slight to moderate antifeeding effect of 14.15-36.86%. Similar performance but of higher magnitude was almostly achieved after 48h feeding on treated leaves where the respective values of deterrent effect were 7.18-21.1 and 30.19-51.73%, for the prementioned treatments, respectively.

In this respect, ABO ELGHAR (1985), found that petroleum ether extracts of *Argemone mexicana, Poinciana regia*, *Tagetes erecta* and *T. patula* were the most potent antifeedant when twenty seven wild plants species were extracted with solvents of variable polarities.

Continuous feeding of the surviving larvae on untreated fresh leaves for additional 4 days resulted in gradual increase, coincidentally with the last day in the 5th and 6th larval instar. The data in general, revealed that the two tested extracts in addition to the standard exhibited latent deterrent effect that lasted till the 6th day posttreatment, recording an average of 8.08-31.11% for *B. niger* petroleum ether extract, 18.29-38.4% and *B. niger* hexane extract when each was tested at concentrations of 4000-12000 ppm. Similar

Table 4. **Acumulated larval mortality after feeding of *S.littoralis* 4th instar larvae for 48h on treated leaves followed by feeding for 4 dayes on untreated leaves.**

Treatment	Conce. (ppm)	% Acumulated larval mortality at indicated time on					
		treated leaves		untreated leaves			
		24h	48h	72h	96h	120h	144h
B.niger (petroleum ether extract)	12000	1.25	1.25	1.25	2.5	3.75	8.75
	10000	———	———	1.25	5	7.5	10
	8000	———	———	———	1.25	1.25	1.25
	4000	———	———	2.5	5	5	8.75
B.niger (hexane extract)	12000	———	1.25	1.25	1.25	3.75	3.75
	10000	———	1.25	1.25	2.5	3.75	5
	8000	———	2.5	2.5	2.5	3.75	5
	4000	———	2.5	5	5	5	8.75
Control		———	———	———	———	———	1.25

Table 5. **Antifeedant activity of selected extracts from *B. niger* against *S. littoralis* larvae.**

Treatment	Conce. (ppm)	Antifeedant activity (%)						
		24h	48h	72h	96h	120h	144h	Mean
B.niger (petroleum ether extract)	12000	23.08	21.1	35.46	42.34	20.85	43.85	31.11
	10000	11.83	20.46	34.21	41.16	19.23	37.53	27.40
	8000	11.56	19.46	14.98	33.33	8.33	19.13	17.79
	4000	3.09	7.18	3.83	20.27	1.62	12.13	8.02
		12.39	17.05	22.12	34.27	12.5	28.16	
B.niger (hexane extract)	12000	36.86	51.73	33.04	49.91	25.73	33.17	38.40
	10000	34.32	45.17	31.4	42.46	22.15	32.21	34.61
	8000	27.39	40.51	24.9	39.63	21.98	29.69	30.68
	4000	14.15	30.19	21.98	16.23	8.13	19.11	18.29
		28.18	41.9	27.83	37.05	19.49	28.54	

$$\text{Antifeedant activity} = 1 - \frac{\%\ \text{treated disk eaten}}{\%\ \text{nontreated disk eaten}} \times 100$$

Saleh *et al*., (1986b)

results were obtained by EL-BAROTY (1984), AHMED (1985), SALEH *et al*. (1986a) and EID *et al*. (1991-1992) working on the antifeedant activity of different plant extracts against some insect pests. EL-BAROTY (1981) found that among 19 plant extracts tested against *S. littoralis* larvae, the hexane extracts of *Senecio desfontainia, Cotula cinerea, Diplatraxis harrar, Reaumaria hirtella, Euphorbia retusa, Achillae freagrantiusim* and *Asteriscus gravelen* were found to be the most active antifeedant for the larvae. However, none of petroleum ether extracts showed any antifeeding activity.

AHMED (1985) studied the antifeeding activity of 8 desert plants against *S. littoralis* larvae. The auther recorded powerful antifeeding effect on larvae with extracts of *Artemisia*

Table 6. **Cumulative daily food consumed by *S. littoralis* 4th instar larvae after feeding for 48h on leaves treated with petroleum ether and hexane extracts of *B.niger*.**

Treatment	Conce. (ppm)	Mean cumulative food consumption (mg / larva) at indicated day after treatment. 1	2	3*	4	5**
B.niger (petroleum ether extract)	4000	0.051 a	0.143 a	0.258 bc	0.427 cd	0.732 bc
	8000	0.047 a	0.130 a	0.242 abc	0.432 cd	0.751 bc
	10000	0.059 a	0.178 ab	0.278 c	0.514 d	0.801 bc
	12000	0.055 a	0.151 a	0.262 bc	0.441 cd	0.726 bc
B.niger (hexane extract)	4000	0.060 a	0.156 a	0.282 c	0.500 d	0.826 c
	8000	0.050 a	0.134 a	0.237 abc	0.368 bc	0.627 bc
	10000	0.054 a	0.139 a	0.244 abc	0.390 cd	0.706 bc
	12000	0.045 a	0.122 a	0.229 abc	0.351 abc	0.596 b
Control		0.093 b	0.224 b	0.375 d	0.685 e	1.126 d

Means in each column following by the same letter(s) are not significantly different (P= 0.05; Duncan's [1955] multiple range test)
* The beginning of 5th larval instar.
** The beginning of 6th larval instar.

Table 7. **Consumption index by *S. littoralis* larvae after feeding of 4th instar for 48h on leaves treated with petroleum ether and hexane extracts of *B.niger*.**

Treatment	Conce. (ppm)	Mean consumption index (mg/larva) at indicated days after treatment. 1	2	3*	4	5**	Mean
B.niger (petroleum ether extract)	4000	0.95a	0.92a	0.77c	0.65cd	0.69bc	0.79ab
	8000	0.87a	0.89a	0.74bc	0.71d	0.71bc	0.78ab
	10000	0.84a	0.89a	0.58a	0.69d	0.62abc	0.72a
	12000	0.89a	0.89a	0.67abc	0.67d	0.69bc	0.76ab
B.niger (hexane extract)	4000	1.04a	0.90a	0.69abc	0.69d	0.69bc	0.75ab
	8000	1.00a	0.93a	0.69abc	0.59bcd	0.68bc	0.77ab
	10000	1.05a	0.91a	0.69abc	0.65cd	0.78c	0.81ab
	12000	0.91a	0.93a	0.75bc	0.59bcd	0.71bc	0.77ab
Control		1.34b	0.92a	0.75bc	0.71bd	0.67bc	0.88b

Means in each column following by the same letter(s) are not significantly different (P= 0.05; Duncan's [1955] multiple range test)
* The beginning of 5th larval instar.
** The beginning of 6th larval instar.

monosperma, Calotropia procera and *Tagetes patula*. Extracts of *T.erecta* and *Argemone maxicana* were found to have a delay antifeeding effect against *S. littoralis*. Also, SALEH *et al*. (1986a) found that extracts of 12 plant species tested showed significant antifeeding activity (more than 50% effect), against *S. littoralis* larvae and *S. gregaria*. In bioassay tests of Duck-weed *Lemna minor*, extracts against the 4th instar larvae of the mosquito *Culex pipiens pipiens,* EID *et al*. (1991-1992) found that n-hexane extract was more toxic than those of acetone and methanol.

HEGAZY *et al*. (1992) recorded potent feeding deterrent effects of ethanol and methanol extracts of dumb-cane and bestachia against

Table 8. **Growth rates (GRs) for *S. littoralis* larvae after feeding of 4th instar for 48h on leaves treated with petroleum ether and hexane extracts of *B.niger*.**

Treatment	Conce.	Mean growth rates (GRs) at indicted days after treatment.					
	(ppm)	1	2	3*	4	5**	Mean
B.niger (petroleum ether extract)	4000	0.47a	0.45bc	0.34bcd	0.41ab	0.37cd	0.41bc
	8000	0.39a	0.41bc	0.38cd	0.43ab	0.35cd	0.40b
	10000	0.69bc	0.46c	0.29abc	0.39ab	0.31bcd	0.42bc
	12000	0.71bcd	0.37bc	0.37cd	0.38ab	0.37cd	0.44bc
B.niger (hexane extract)	4000	0.76cd	0.45c	0.40d	0.39ab	0.34cd	0.46bc
	8000	0.74bcd	0.43bc	0.39cd	0.34ab	0.35cd	0.45bc
	10000	0.77cd	0.43bc	0.38cd	0.32ab	0.44d	0.46bc
	12000	0.73bcd	0.41bc	0.42d	0.31ab	0.39cd	0.44bc
Control		0.81d	0.44d	0.36bcd	0.50b	0.34cd	0.49c

Means in each column following by the same letter(s) are not significantly different (P= 0.05; Duncan's [1955] multiple range test)
* The beginning of 5th larval instar.
** The beginning of 6th larval instar.

Table 9. **Efficiency of conversion of ingested food to body tissue (ECI) after feeding of 4th instar larvae of *S. littoralis* for 48h on leaves treated with petroleum ether and hexane extracts of *B.niger*.**

Treatment	Conce. (ppm)	Efficiency of conversion of ingested food to body tissue (ECI%) at indicted days after treatment.					
		1	2	3*	4	5**	Mean
B.niger (petroleum ether extract)	4000	49.62a	49.66cd	44.99bcd	65.2cd	53.05cd	52.5bc
	8000	45.44a	46.78cd	51.59de	60.64bcd	55.97cd	51.95bc
	10000	83.62cd	50.98cd	50.06cde	56.07abcd	50.19cd	58.18c
	12000	82.12cd	47.32cd	50.09de	55.69abcd	49.45cd	57.33c
B.niger (hexane extract)	4000	73.18bc	50.78cd	58.02e	55.7abcd	50.62cd	57.66c
	8000	74.95bc	46.78cd	56.39e	58.86bcd	50.06cd	57.4c
	10000	73.92bc	48.39cd	54.14de	48.76abc	55.96cd	56.23c
	12000	81.33cd	41.66cd	56.56e	50.84abc	54.47cd	56.97c
Control		61.32ab	57.38d	48.76cde	72.39d	50.05cd	57.97c

Means in each column following by the same letter(s) are not significantly different (P= 0.05; Duncan's [1955] multiple range test)
* The beginning of 5th larval instar.
** The beginning of 6th larval instar.

the 2nd and 4th instar larvae of *S. littoralis*. It was found that the bioactive compounds in both plants were phenol, thiocyanate, tannine and alkaloids. The prementioned chemical bioactive groups were seperated from some plants and proved their efficiency as antifeedants (HOSOZAWA *et al*. 1974; EL-SEBAE *et al*. 1981; SCHOONHOVEN 1982; LIDERT *et al*. 1985; ALFORD *et al*. 1987; ISMAIL *et al*. 1990). Recently, EL-SEBAE *et al*. (1997) found that petroleum ether extract of *Rosmarinus officinalis* leaves and the methanol extract of the weed *Chenopodium ambroisides* showed the highest antifeeding activity against the 4th instar larvae of *S. littoralis* after feeding for 24h while aceton extract of

Cymbopogon citratus leaves was the least. ABD ELGALEIL and NAKATANI, (2003) indicated that the antifeedant activity was dose-dependent in some of the isolated compounds. NTONIFOR *et al*. (2006) found that the hexane and methanol extracts of *Aframomum melegueta* showed potent dose-dependent antifeedant activity at concentrations of more than or equal to 300 ppm and the water extract at more than or equal to 500 ppm, as illustrated by significantly lower leaf consumptions.

Effect of crude extracts of selected weed plants on food consumption, growth rate and food utilization by *S. littoralis* larvae

It has been shown in a number of instances that, the choice of food is guided by the presence of secondary plant substances typical of the plant which is the insect's preferred or exclusive food. At the same time non-food plant is characterized not only by the absence of specific chemical attractants or feeding stimulants, but also by the presence of other secondary plant substances which act as repellants (DETHIER, 1954; FRAENKEL, 1959; SOO HOO and FRAENKEL, 1966). SCHROEDER (1976) indicated that the insect whose diet includes such compounds may suffer some shortage in their nutritional requirements leading to some physiological changes in the normal consumption and conversion of the food to the larval tissue.

WALDBAUER (1968) pointed out that an overall understanding of the utilization of a food requires answers of the following questions: At what rate is the food eaten? How much the eaten food is actually digested? What part of the food is incorporated as body substance? These questions cannot be answered without a reliable and accurate method for determining the weight of the food ingested the weight of the feces which correspond to the ingested food and the weight gained by the insect during the experiment. These three measurements are basic and necessary for the calculation of the rate of feeding, the digestibility and efficiency of conversion of food to body substance.

The results indicating the effect of bioactive compounds in the tested plant extracts on different physiological parameters, i.e. Food consumption, growth rate, approximate digestibility and efficiency of conversion of ingested/digested food to insect biomass were calculated and tabulated in Tables (6 - 11).

Food consumption

Table 6 shows that feeding of *S. littoralis* 4th instar larvae for 48h on leaves treated with petroleum ether and hexane extracts of *B. niger* was remarkably reduced when compared with feeding of larvae in control. However, hexane extract of *B. niger* came next whereas petroleum ether for the same plant was the least in this respect.

In agreement, ABO ELGHAR (1985) found that chloroform and petroleum ether extracts of *S. oleracea* showed strong phago deterrent effects manifested by over 50% inhibition of the larval feeding rate when compared with feeding rates recorded in the control larvae.

Consumption index (C.I.)

Data in Table 7 show that the consumption index (C.I.), at 24h post treatment was significantly decreased for larvae fed on all extracts tested below that of control. Where the C.I. was significantly higher than that in all treatments tested and in control. Generally, the mean C.I. during the 4th, 5th instars of larvae fed on leaves treated with all tested compounds and concentrations as well as the larvae in control was generally similar. However, a remarkable decrease in C.I. was significantly recorded between larvae in all concentrations of hexane extracts of *B. niger* and larvae in control.

Growth rate (G.R.)

Based on mean growth rate, all higher concentrations (8000-12000 ppm), of the extracts significantly decreased the growth rate below that recorded for treatments of other and control during the whole testing

Table 10. **Efficiency of conversion of digested food to body tissue (ECD) after feeding of 4th instar larvae of *S. littoralis* for 48h on leaves treated with petroleum ether and hexane extracts of *B.niger*.**

Treatment	Conce. (ppm)	Efficiency of conversion of digested food to body tissue (ECD%) at indicted days after treatment.					
		1	2	3*	4	5**	Mean
B.niger (petroleum ether extract)	4000	65.71a	75.15ab	73.22abc	100.74a	92.72c	91.44d
	8000	63.27a	71.94ab	83.58bcde	88.58a	94.5c	80.37abcd
	10000	112.5ab	77.87ab	78.62abcd	85.92a	90.86c	90.89d
	12000	115.58ab	74.86ab	84.06bcde	87.39a	92.65c	89.15cd
B.niger (hexane extract)	4000	91.05a	75.28ab	94.36de	76.61a	92.53c	87.31cd
	8000	96.81a	63.32ab	98.22de	100.22a	98.63c	90.92d
	10000	94.34a	65.44ab	93.37cde	76.94a	96.07c	89.16cd
	12000	112.26ab	58.5ab	102.93e	80.54a	91.57c	85.74bcd
Control		75.26a	115.62b	72.03ab	108.26ab	95.23c	93.28d

Means in each column following by the same letter(s) are not significantly different (P= 0.05; Duncan's [1955] multiple range test)
* The beginning of 5th larval instar.
** The beginning of 6th larval instar.

Table 11. **Approximate digestibility (AD) of *S. littoralis* larvae after feeding of 4th instar for 48h on leaves treated with petroleum ether and hexane extracts *B.niger*.**

Treatment	Conce. (ppm)	Approximate digestibility (AD %) at indicted days after treatment.					
		1	2	3*	4	5**	Mean
B.niger (petroleum ether extract)	4000	75.68abcd	67.29a	62.2de	67.52ab	57.19a	63.3a
	8000	71.94ab	63.96a	61.77de	68.38ab	59.24a	65.05a
	10000	74.31abcd	65.2a	65.48e	65.26ab	53.64a	64.77a
	12000	71.25a	62.93a	62.07de	63.67ab	53.3a	62.64a
B.niger (hexane extract)	4000	80.33de	67.47a	61.43de	66.76ab	54.78a	66.15a
	8000	77.8bcde	74.13a	57.59cde	59.82ab	53.34a	64.55a
	10000	78.42cde	73.36a	57.98cde	63.24ab	56.75a	65.95a
	12000	73.15abc	71.34a	55.21bcd	63.09ab	59.53a	64.46a
Control		82.2e	62.94a	66.79e	66.55ab	52.52a	66.2a

Means in each column following by the same letter(s) are not significantly different (P= 0.05; Duncan's [1955] multiple range test)
* The beginning of 5th larval instar.
** The beginning of 6th larval instar.

period (Table 8). However, petroleum ether and hexane extracts of *B. niger* at different concentrations tested exhibited insignificant relatively slight decrease when compared with growth rate of larvae in control treatment. The data of mean growth rate (GR), show a proportional relationship between food consumed and values of both consumption index and growth rate, particularly in case of petroleum ether extracts treatments. In this respect Woodring *et al*. (1978) and Sundramurthy (1977) indicated that the amount of growth reduction was proportional in general to reduced food consumption.

This explanation was confirmed by results of REESE and BECK 1976 a,b and c) and DAHLMAN, (1977) who suggested that reducing the conversion efficiency of ingested and assimilated food results in a depression of growth rate.

Efficiency of conversion of ingested food (ECI)

Data in Table 9 show that the highest decrease in E.C.I. was recorded in larvae fed for 24h on leaves treated with 4000 and 8000 ppm of petroleum ether extract of *B. niger* which was lower insignificantly than that of larvae in control. Petroleum ether extract of *B. niger* to 1000 and 12000 ppm and hexane extract of *B. niger* at 12000 ppm, resulted in E.C.I. values higher significantly than that in control larvae. Whereas the treatments of both petroleum ether and hexane extracts resulted in ECI similar to that in control. Similar trend in ECI was achieved laterly after 2 days feeding on treated leaves followed by 3 days feeding on untreated leaves.

The data also showed that ECI values varied with larval age progression in all treatments in petroleum ether extract of *B. niger* whereas the increase in ECI was at the 3rd day post treatment in hexane extracts of *B. niger.* In this respect, ABO ELGHAR (1985) recorded significant decrease in ECI values in 4th instar *S. littoralis* larvae when fed on castor bean leaves treated with petroleum ether extracts from tested plants; whereas feeding the larvae on ethanolic extracts resulted insignificant increase in the food utilization.

Efficiency of conversion of digested food (E.C.D)

Data in Table 10 show that the efficiency of conversion of digested food to body tissue (ECD). In general, all concentrations tested of petroleum ether and hexane extracts of *B. niger* showed that ECD values were almost similar to that in the control.

One of the possible cause of the lower ECD for larvae is a reduced ability to detoxify an allelochemical(s) occurring in the plant foliage or its extract which consequently had a deleterious effect on the conversion of absorbed food to biomass. A reduction in ECD was associated with allelochemical ingestion is a common occurrence (e.g., REESE 1978, LINDROTH *et al*. 1988, KOUL *et al*. 1990, APPEL and MARTIN, 1992). This may result from, for example, direct interference of the allelochemical with some metabolic process (SLANSKY, 1992) or an indirect slowing of growth, thereby diverting a greater proportion of the absorbed food to respiration (APPEL and MARTIN, 1992).

Approximate digestibility (AD)

Data in Table 11 show that the approximate digestibility (AD) values recorded for larvae fed for 24h on all tested concentrations of petroleum ether extract of *B. niger* in addition to the higher concentration (12000 ppm) of *B. niger* hexane extract resulted in AD significantly lower than that in control or other treatments.

No considerable difference in AD values was achieved between all treatments tested following feeding for 48h on treated leaves. Further feeding for additional day (3rd) on untreated leaves resulted in significant reduction of AD values in all concentrations tested of hexane extract of *B. niger* when compared with the other treatments including control. However, the overall mean for all experimental period revealed insignificant variation in AD values between all treatments and control.

In general our results were agree with, AMR (2001) found that the significant reduction in the efficiency of larvae to convert digested and ingested food into body tissues, hence to a reduction in total body weight gain of treated individuals. SADEK (2003) indicated that the crude extract significantly reduced consumption, growth, utilization of ingested and digested food, and approximate digestibility. PAVELA (2004) and PAVELA & CHERMENSKA, (2004) determinated that the extracts significantly affected the growth indexes [relative growth rate (RGR), efficiency of conversion of ingested food (ECI), efficiency of conversion of digested food (ECD)].

RESUMEN

HATEM, A. E., S. S. M. ABDEL-SAMAD, H. A. SALEH, M. H. A SOLIMAN, A. I. HUSSIEN. 2009. Actividad toxicológica y fisiológica de los extractos de plantas contra larvas de *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae). *Bol. San. Veg. Plagas*, **35**: 517-531.

Se probó la toxicidad y efecto antialimentario de extractos en hexano, en éter de petróleo y en alcohol etílico de tres especies de plantas (malezas comunes en Egipto) sobre larvas de cuarto instar de la rosquilla negra (*Spodoptera littoralis*). Todos los extractos mostraron un cierto grado de toxicidad. El extracto de *Sonchus olearcues* L. en hexano, el de *Brassica niger* Koch en éter de petróleo y el *Raphanus sativa* var. *surtus* L. en alcohol etílico fueron altamente tóxicos (CL50s = 218,36, 96,11 y 5574,66 ppm respectivamente). Por su alta actividad insecticida, los extractos crudos de *B. niger* en éter de petróleo y en hexano fueron probados como antialimentarios y se observó mayor efecto en el segundo que en el primero. Ambos extractos afectaron significativamente el crecimiento [índice de consumo (IC), la eficiencia de la conversión de alimento ingerido (ECI) y la eficiencia de la conversión de alimento digerido (ECD)], pero no a la tasa de crecimiento (GR), ni la digestibilidad aproximada (AD).

Palabras clave: Actividad insecticidas, extracto de las hojas, actividad antialimentaria, índices de crecimiento.

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