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BIOLOGICAL ACTIVITY OF THE SHRUB *Boscia senegalensis* (PERS.) LAM. EX POIR (CAPPARACEAE) ON STORED GRAIN INSECTS

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Abstract—Biological activity of leaves, fruits and extract of the African shrub *Boscia senegalensis* (PERS.) LAM. ex Poir. was evaluated against five stored-grain insects. When added to cowpeas at 2.4% (w/w), fresh ground fruits and leaves caused 80–100% mortality in *Callosobruchus maculatus* (F.) adults and significantly reduced both emergence and damage of the F_1 progeny. Acetone fruit extract exhibited a potent fumigant effect on *Prostephanus truncatus* HORN., *C. maculatus*, and *Sitotroga cerealella* OLIV., with LT_{50} values of 3.0, 2.3, and below 1.5 hr, respectively. LC_{50} determinations for *B. senegalensis* fruits and leaves as well as pure methylisothiocyanate (MITC) on *Tribolium castaneum* HERBST., *Sitophilus zeamais* MOTSCH. and *C. maculatus* revealed a differential response of the insects to plant parts or MITC. Quantitative assessment of *Boscia* active components and LC_{50} values obtained for the plant tissues, compared to those of pure molecules, indicate that the biological activity of *B. senegalensis* is due to the liberation of MITC from a glucosinolate precursor glucocapparin contained in *Boscia* fruits and leaves.

Key Words—*Boscia senegalensis* (PERS.) LAM. ex Poir., glucosinolates, methylisothiocyanate, *Vigna unguiculata* (L.) WALP., *Callosobruchus maculatus* (F.), *Prostephanus truncatus* HORN., *Sitophilus zeamais* MOTSCH., *Sitotroga cerealella* (OLIV.), *Tribolium castaneum* HERBST coleoptera.

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INTRODUCTION

Insect infestation of stored ; in causes weight and quality losses that lead to a reduction of commercial va and seed germination. To reduce this damage, several control measures hav been taken, which mostly involv e chemical meth ods. Synthctic insecticides a . not only a drain on the farmer's meager resources but arc often frequently use beyond permissible safe limits. The incidence of insecticide resistance i s als a growing problem. Resistance to one or more insecticide(s) has b e e n rep ed i n at least 500 species of insects and mites (Georghiou, 1990). This s ution has increased t h e need for alternativ es to synthetic pesticides. Botani insecticides are a less expensive and biodegrad able option. The effectiven , of raw parts and plant extracts against stored-grain insects has been desc. ibed hy many authors (Jotuani and Sircar. 965; Singh et al., 1978; Jacobso 1983; Golob and Webley. 1980); Grainge et al., 1985; Lognay et al., *1991:* ck et al., 1991; Haubruge et al , 1989).

Wc investigated thc ! ogical activ ity o t *Boscia senegalensis* (PERS.) LAM. (Capparaceae), a pl: hat is found throughout north-central and northern Senegal (Bille and Poupon 1972), where it is traditionally used by farmers against stored grain insects , i addition. we isolated and identified biolog cally active components of this p it.

MATERIALS AND METHODS

Plant tnatcrial was ra. mly harvestcd in the region of Thies (Senegal). Our material has been ident ed and deposited at the Jardin Botanique National de Belgique (BR) as *B. sen alensis*. Leaves used f o r trial 1 were harvested in November 1990. Fruits an aves used for trials 2 and 3 were collected in May 1991.

Four cxperiments wer nducted with plant parts (trials 1 and 2), extracts (trial 3), and pure molecul tria1 4) using five stored-grain insect species. The test insects, *Callosobruch maculatus* (F.) (Col., Bruchidae), *Sitotroga cere-alella* OLIV. (Lep., Gele lac), *Prostephanus truncatus* HOKN. (Col Bos-trychidae), *Tribolium cast um* HERBST. (Col., Tenebrionidae), *Sitophilus zeamais* MOTSCH. (Col. arculionidae), were reared under controlled con-ditions (32" ± 2°C and ± 10% relative humidity) Bioassays were also carried out under these co ons. All chemicals and solvents were of ana y tical grade.

Trials 1 and 2. Thes rst t w o trials were performed with fresh ground leaves (FGL), fresh entir aves (FEL), dry leaf powder (DLP), and fresh ground fruits (FGF). The t materials were added to cow pea seeds, *Vigna unguiculata* (L) WALP (v Black Eyed) at 1- 32% for FGL, FEL, and DLP in trial] : and 0.5-2% for and FGL in trial 2. FGL and FGF were prepared

using a small laboratory
and then passed through a
2 0 g of cowpeas were
concentrations in Petri d
old *C. maculatus* adults
10 insects. Each treatme
Mortality assessment wa
when F, adults started t
10 days. Numbers of ho
damage was calculated.

Data were subjected
the means (Duncan's mu

Trial 3. Fifty gram
a Waring blender and k
then filtered and concen
a *B. senegalensis* aceto
by volume of water.

Bioassays were ca
ml of BAFE were depo
in another desiccator us
evaporated completely
were then introduced i
experimental condition
tality readings were re
(LT-,,) of the insects w
probita and calculating

Analysis of volatile
(100 g) were steam-di
extracted three times w
drated with anhydrous
the solvent at 38°C, an
using two types of col
was a CP-Wax 52CB
Chrompack; carrier ga
to 240°C at 10°C/min;
at 250°C; apparatus: H
Sil 8 CB (25 m long; 0
carrier gas was helium
5°C/min; cold "on-col
apparatus: Carlo Erba

Analysis of glucos
galensis FGF, FGL, an

<Moulinex) for 5 min. DLP was similarly
)-mesh laboratory sieve. Following this pro
oughly mixed with plant material at the
(ϕ 90 mm) and infested with 10 unsexed
reated cowpea seeds were similarly infested with
including the control, was replicated five times
de after one to two days. Twenty-two days later
erge, insects were removed daily and counted for
nd unholed seeds were also counted and percent

nalysis of variance followed by a comparison of
-range test) at $P = 0.05$.

Boscia fruits were ground with 200 ml acetone in
2 hr at room temperature. The supernatants were
under vacuum to a final volume of 50 ml to obtain
it extract (BAFE) containing approximately 30%

ut in 825-ml sealed glass desiccators in which 5
Five milliliters of acetone were similarly pipetted
ontrol. After 3 hr at room temperature, the solvent
control. One hundred adults of different species
desiccators, which were closed and placed under
r various time exposures, from 1.5 to 12 hr, mor-
for each treatment. The time required to kill 50%
n determined by transforming mortality data to
hal times (LT) (Snedecor and Cochran, 1967).

Boscia senegalensis *leaves*. Freshly ground leaves
for 45 min and the aqueous distillate (900 ml)
0 ml diethylether. The ether solution was dehy-
n sulfate, concentrated to 4 ml by distillation of
ty analyzed by gas–liquid chromatography (GLC)
nder the following conditions: The polar column
long, 0.32 mm ID, 0.2 μm film thickness) from
elium at 100 kPa; temperature program from 30
"on-column" injector and FID detector maintained
Packard HP 5880. The apolar column was a CP
m ID, 0.2 μm film thickness) from Chrompack;
kPa; temperature program: from 30 to 240°C at
injector and FID detector maintained at 300°C;
5160.

es. The glucosinolates were analyzed in *B. sene*
E by reverse-phase HPLC after enzymatic desul

fation according to the official EEC method (European Economic Community, 1990). Identification of BAFE glucosinolates w as performed by GC-MS anal yses of' trimethylsilylated molecules and by examination of' thcir degradation products liberated enzymatically under controlled conditions. For GC-MS inves- tigations, glucosinolates were enzy matically transformed to desulfoglucosino lates and trimethyl-sily lated for 20 m i n at 110°C with 50 μl of a reagent containing *N*-methyl-*N*-trimethylsilyltrifluorobuty ramide, 5% methylimidazole in acetone and trimethy lchlorosilane 30 : 15 :3 (v/v/ v). The chromatographic conditions were as follows: Column SE-53 (25 m long. 0.35 mm ID, 0.2 μm film thickness) was from Macherly-Nagel; carrier: helium at 50 kPa: temperature program: SO-780°C at 20°C/min: cold "on-column" injection. The mass spec tra were recorded in thc El mode on a Nermag R 10- 10C spectrometer 70 eV source at 130°C, interface at 280°C, mass range scanned from 100 to 800 amu coupled to a Delsi DI-700 gas chromatograph.

For enzymatic degradation of *B. senegalensis* glucosinolates, 0. 1 ml acetate buffer (pH 4.5) and 50 μl of 10 mg/ml buffered solution of thioglucosidase (EC 3.2.3. 1), purified from *Sinapis alba* L. according to Appelqvist and Josefson (1967), were added to 0. 1 ml of residual aqueous phase from BAFE or to a solution of pure methylglucosinolate (glucocapparin, Roth ref. 7485) After 24 hr. the degradation products were extracted w ith 2 ml diethylether and analyzed hy GLC on polar and apolar stationary phases. Methylisothiocyanate (MITC) from BAFE and glucocapparin were identified by comparison of their retention times with that of' a pure reference (Sigma ref M8632)

Detection of MITC in Volatiles Liberated during Biotests. Acetone solutions of BAFE (5 ml) were introduced into conical flasks. After evaporation of ace- tone, the vessels were hermetically closed and left for 24 hr at 32 $\pm$ 2°C. Headspace sampling was performed by purging the apparatus with nitrogen for 30 min. The volatiles were collected in 3 ml diethylether maintained in a cryogenic trap at -20°C. Ether solutions were submitted to GC-MS in the aforementioned conditions except that the temperature program rate was fixed at 5°C/min. MITC was identified on the basis of retention and mass spectral data. The mass spectra were compared with EPA-NIH and Wiley libraries.

Trial 4 . To study the dose–mortality responses to *B. senegalensis* tissues and MITC, various amounts of FGF and FGL from 0 t o X g/liter (w/v) and pure MITC from 0 to 3 mg/liter (w/ v) were deposited in 750-ml glass desiccators containing 25 adults of each insect species, in four replications. After 24 hr under the experimental climatic conditions, insects were transferred to clean Petri dishes and maintained in controlled conditions until thc next day for mor tality readings as indicated by Busvine (1981). Data were subjected to probit analysis (Finney, 1964). Log dose-probit line was analyzed for goodness of fit by the chi-square test (Busvine, 1981), followed by computation of LC_{50} values for each material.

RESULTS

Trial 1

Mortality. FGL at a concentration of 4% (w/w) caused 100% mortality after 24 hr. At 2%, 55.6% of the insects died within 48 hr, and at 1%, mortality ranged from 7.4 to 11.1% in one to two days. FEL scored 0–18.5% mortality and DLP 3.7–40.7% within 24–48 hr (Table 1).

Progeny. FGL completely inhibited the production of *C. maculatus* progeny at 2%, but at 1%, 21.6 adults emerged. At the same time, progeny ranged from 36.2 to 87.2 adults for FEL and from 40.2 to 53.2 for DLP (Table 1).

TABLE 1. BIOLOGICAL ACTIVITY OF *B. senegalensis* FRESH GROUND LEAVES (FGL), FRESH ENTIRE LEAVES (FEL) AND DRY LEAF POWDER (DLP) TO *C. maculatus* ADULTS, F_1 PROGENY, AND DAMAGE (MEANS)[a]

Treatment	Conc (%, w/w)	Corrected mortality (%)[b] 24 hr	Corrected mortality (%)[b] 48 hr	F_1 progeny	Damage (%)
FGL	1	7.4c	11.1c	21.6ab	22.0b
	2	63.0b	55.6b	0.0b	0.0b
	4	100.0a	100a	0.0b	0.0b
	8	100.0a	100a	0.0b	0.0b
	16	100.0a	100a	0.0b	0.0b
	32	100.0a	100a	0.0b	0.0b
	Control			61.6a	70.3a
FEL	1	7.4a	18.5a	36.2b	49.1a
	2	0.0a	7.4ab	43.6ab	36.9a
	4	0.0a	7.4ab	69.0ab	59.8a
	8	0.0a	0.0b	87.2a	64.8a
	16	0.0a	0.0b	62.4ab	52.9a
	32	0.0a	0.0b	71.8ab	60.5a
	Control			61.6ab	56.3a
DLP	1	11.1a	37.0a	53.2a	67.5a
	2	3.7a	18.5a	47.6a	44.4abc
	4	11.1a	25.9a	51.0a	52.4abc
	8	11.1a	33.3a	49.8a	33.6bc
	16	14.8a	33.3a	40.2a	39.7abc
	32	11.1a	40.7a	45.8a	30.8c
	Control			45.0a	65.1ab

[a] Means followed by the same letter within a column of each treatment are not significantly different at the 5% level (Duncan's multiple-range test).
[b] By Abbott's (1925) formula.

FGL significantly reduced *C. maculatus* progeny, compared to FEL and DLP (Figure 1).

Damage. FGL gave 100% protection at 2 4 and 23 % damage at 1 % in the same conditions. damage was 36.9-64.8% for FEL and 30.8-67.5% for DLP (Table 1).

Trial 2

Mortality. After 72 hr at concentration of 2%, mortality was 93.6% for FGF and 24.8%. for FGL. After 4X hr, it ranged from 3.X to 79.8% for FGF compared to O-24.2 % for FGL. After 24 hr, mortality ranged from 3.X to 73.8% for FGF and from 0 to 8 % for FGL (Table 2).

Progeny. At 2%, FGF showed no adult emergence while 7.8 and 133 8 adults emerged, respectively, in FGL and the control treatment. At 1 %. 12 adults emerged from FGF compared to 104 for FGL (Table 3).

Damage. A t 1 % concentration, damage was 8.7 % for FGF and 63% for FGL. At 2% concentration. FGF gave 100% protection, while 6.1 damage was noted in the FGI. treatment (Table 3).

Trial 3

LT_{50} values were 2.3 hr for *C. maculatus* and 3.8 hr for *P. truncatus* (Table 4). For *S. cerealella* all adults died within 1.5 hr.

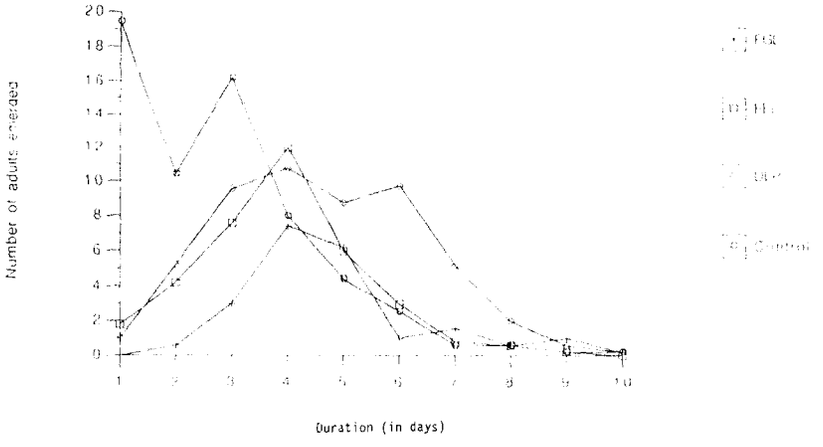

FIG. 1. Emergence pattern of *C. maculatus* from cowpea seeds treated with fresh ground leaves (FGL), fresh entire leaves (FEL), or dry leaf powder (DLP) of *Boscia senegalensis* at 1% conc. (w/w).

TABLE 2. COMPARATIVE TOXICITY OF *B. senegalensis* FRESH GROUND FRUITS (FGF) AND LEAVES (FGL) TO *C. maculatus* (MEANS)[a]

Treatment	Conc (%, w/w)	Corrected mortality after (%)[b]		
		24 hr	48 hr	72 hr
FGF	0.5	3.8b	3.8c	1.9c
	1	6.4b	24.9b	35.9b
	2	73.8a	79.8a	93.6a
FGL	0.5	0.0a	0.0b	23.4a
	1	3.8a	5.8ab	13.0a
	2	8.0a	24.2a	24.8a

[a]Means followed by the same letter within a column of each treatment are not significantly different at the 5% level (Duncan's multiple-range test).
[b]By Abbott's (1925) formula.

TABLE 3. EFFECT OF COWPEA TREATMENT WITH *B. senegalensis* FRESH GROUND FRUITS (FGF) OR LEAVES (FGL) ON *C. maculatus* EMERGENCE AND DAMAGE IN COWPEAS (MEANS)[a]

Treatment	Conc (%, w/w)	Number of emerged adults[b]	Percentage Damage (%)	Reduction (%)	
				Emergence	Damage
FGF	0.5	3.4a	22.7a	68.2a	73.0a
	1	1.6b	8.7a	90.7a	89.6a
	2	0.0c	0.0a	100a	100a
FGL	0.5	4.2a	46.0a	41.7b	45.2b
	1	4.6a	63.0a	22.3b	25.0b
	2	1.8b	6.1b	94.5a	92.7a
Control		4.9	84.0		

[a]Means followed by the same letter within a column of each treatment are not significantly different at the 5% level (Duncan's multiple-range test).
[b]Log (numbers).

Trial 4

Acute Toxicity of B. senegalensis *Fresh Ground Tissues and Pure MITC.* FGF, FGL, and MITC exhibited a differential acute toxicity against three stored-grain beetle species. LC_{50} values (in grams ground matter per liter volume) ranged from 1 to 4.23 for FGL and from 0.42 to 1.75 for FGF (Table 5). LC_{50}

TABLE 4. LETHAL TIME (LT) VALUES OF TWO STORED-GRAIN INSECTS EXPOSED TO VAPORS OF *B. senegalensis* FRUIT EXTRACT (BAFE)

Species[a]	Slope ± SE	LT_{50} (95% FL[b]), hr
C. maculatus	4.47 ± 1.71	2.31 (1.01–5.28)
P. truncatus	4.21 ± 1.16	3.80 (1.92–7.54)

[a]One-day-old *C. maculatus*; 2-week-old *P. truncatus*.
[b]Fiducial limits.

TABLE 5. ACUTE TOXICITY OF *B. senegalensis* FRESH GROUND FRUITS (FGF) AND LEAVES (FGL) TO ADULTS OF THREE STORED-GRAIN INSECT SPECIES

	FGF		FGL	
Species[a]	Slope ± SE	LC_{50} (95% FL)[b]	Slope ± SE	LC_{50} (95% FL)[b]
Tribolium castaneum	8.60 ± 1.00	1.75 (1.63–1.86)	6.14 ± 1.38	4.23 (1.11–16.15)
Sitophilus zeamais	7.12 ± 0.79	0.87 (0.80–0.94)		
Callosobruchus maculatus	4.91 ± 0.75	0.42 (0.36–0.47)	6.15 ± 0.93	1.00 (0.88–1.09)

[a]Four replications of 20 insects were exposed to plant materials for 24 hr before they were transfered to Petri dishes and placed in controlled conditions (30°C, 70% relative humidity). Mortality was counted after 24 hr of pest exposure (Busvine, 1981).
[b]Grams per liter volume, with Fiducial limits.

for MITC ranged from 0.73 to 2.38 ppm according to insect species, with *C. maculatus* being the most susceptible (Table 6).

Chemical Investigations

GLC analysis of the volatiles from FGL showed one major peak (92 % of the total area) at retention times of 3.3 min and 6.5 min, respectively on polar and apolar columns, which corresponded to those of an authentic sample of MITC. The detection of MITC from *B. senegalensis* leaves (Figure 2) suggested that methylglucosinolate (glucocapparin) may be the main precursor of the insecticidal compound. Glucosinolate enzymatic degradation leads to several by products among which isothiocyanates predominate (Tookey et al., 1980). To test the aforementioned hypothesis, we analyzed the residual water phase of BAFE following a three-step procedure (HPLC, identification of glucosinolate by-product, and GC-MS). The HPLC retention time of pure desulfomethylglucosinolate (2 min) corresponded to that of the major peak detected in BAFE. On the other hand, the elution profiles liberated enzymatically from BAFE

TABLE 6. ACUTE TOXICITY OF METHYL ISOTHIOCYANATE TO ADULTS OF THREE STORED-GRAIN INSECT SPECIES

Species[a]	Slope ± SE	LC_{50} (95% FL)[b]
Tribolium castaneum	7.05 ± 0.58	2.38 (2.24–2.52)
Sitophilus zeamais	7.22 ± 1.18	1.25 (1.14–1.34)
Callosobruchus maculatus	4.81 ± 0.59	0.73 (0.64–0.82)

[a]Four replications of 20 insects were exposed to plant materials for 24 hr before they were transfered to petri dishes and placed in controlled conditions (30°C, 70% relative humidity). Mortality was counted after 24 hr of pest exposure (Busvine, 1981).
[b]ppm, with Fiducial limits.

residual aqueous phase and methylglucosinolate are practically identical; MITC is distinguishable on the two chromatograms but is absent on the blank. The identitiention of glucocapparin in BAFE was finally validated by CC-MS A typical mass spectra is shown in Figure 3. The mass fragments at *m/e* = 103, 117, 137, 169, 204, 243, 271, 361 (base peak), and 451 were generated by the glucidic moiety of the molecule and were not of interest for the identification of the aglycone. Nevertheless, the ions recorded at *m/e* = 613 $(M)^+$, 598 $(M\text{-}CH_3)^+$, 524 (M-CH,-TMS) and 508 $(M\text{-}CH_3TMSOH)$ indicated clearly a glucosinolate bearing a methyl radical. As for all other alkylglucosinolates, the intensities of these characteristic mass fragments were low The methylglucosinolate content of *B. senegalensis* material tested in trial 4 represented 23.6 ± 0.8 μmol/g fresh leaves and 38 ± 1.2 μmol/g fresh fruits (HPLC determination with sinigrin as internal standard). Headspace sampling conducted under the same conditions as trial 3 and trapping the volatiles in diethyl ether at -- 20°C led to detection of MITC from the vapor phase. The total ion current (Figure 4) showed several peaks, among which was MITC (K_i = 16.6 min). The molecule was unambiguously identified by comparison of its mass spectrometric pattern with EPA-NIH and Wiley libraries and also on the basis of GLC retention time.

DISCUSSION

This research has demonstrated a significant biological effect of *B. senegalensis* plant parts and extracts. The evidence in support of these results was obtained from four experiments. First, B. *senegalensis* FGL (when added to cowpeas at 4% w/w) completely killed C. *maculatus* adults within 74 hr. inhibited the production of F_1, progeny and prevented bruchid damage. Under the same conditions. FEL and DLP had almost no effect. Second, comparative

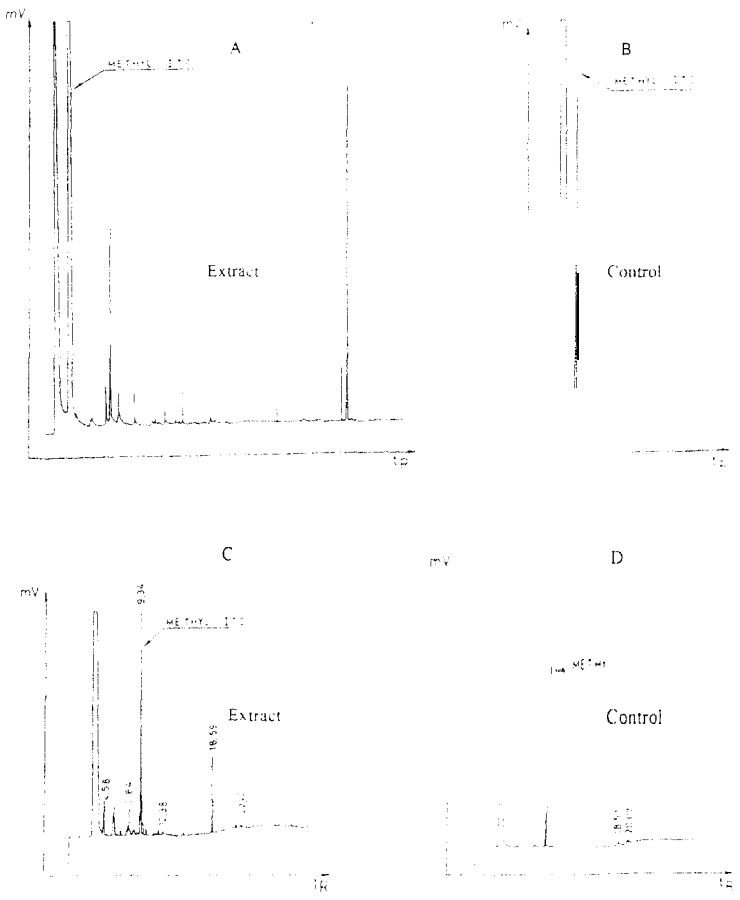

FIG. 2. Identification of methylisothiocyanate (MITC) from *Boscia senegalensis* leaves with apolar column (A and B) and polar column (C and D).

evaluation of' FGF and FGL revealed that fruits were more toxic to *C. maculatus* and reduced both progeny and damage to a greater extent, than did leaves Third, BAFE exhibited a high f'umigant effect on threc stored-grain insect species, which had a differential time–mortality response. Finally, we quantified the acute toxicity of *B. senegalensis* fresh ground fruits and leaves as well as pure MITC and obtained dose–mortality responses for three stored-grain beetles.

B. senegalensis is a shrub, growing up to 3 m high. that is frequently found on abandoned tennite mounds and on barren and fire-scorched soil of thc Sahel. It is distributed from Mauritania to Niger. northem Nigeria. the northwest Cameroons, and across Aftica to Sudan and Ethiopia (Booth and Wickens, 1988).

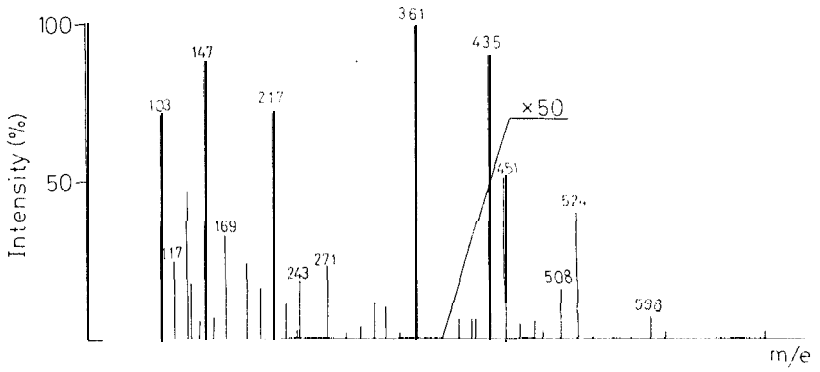

FIG. 3. Mass spectrum of silylated desulfoglucocapparin from *Boscia senegalensis* fruit extract.

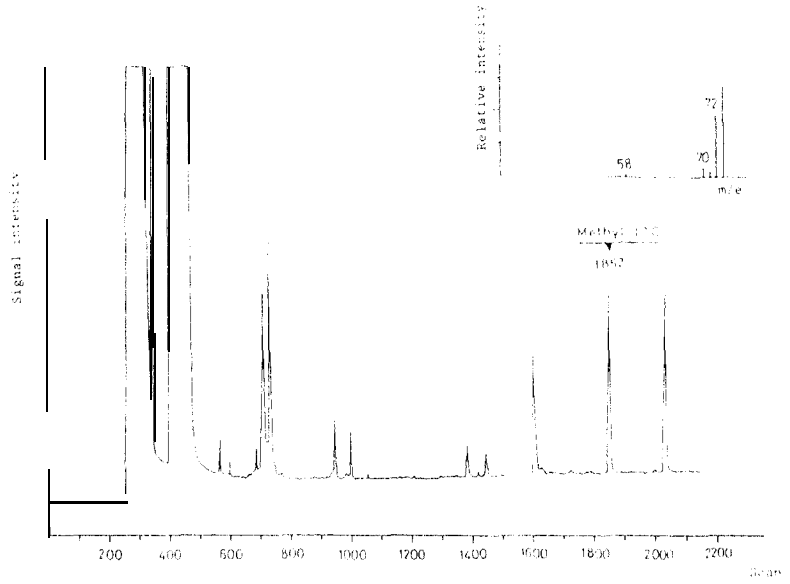

FIG. 4. GC-MS total ion current of the volatiles liberated during the bioassays of *Boscia senegalensis* fruit extract.

Leaves and fruits are used as human food and animal fodder (Bernus, 1979: Baumer, 1981; Maydell, 1983; Burkill, 198.5: Becker, 1983). The leaves, bark, and roots are widely used in northern Senegal for their medicinal properties (Kerharo and Adam, 1974; Hooth and Wickens, 1988).

Alzouma and Boubacar (1985) reported on the toxicity of *B. senegalensis* leaves from Niger, which also reduced *Bruchidius atrolineatus* Pic. and *C. maculatus* oviposition, but they gave no details about the active components. Kjaer et al. (1973) reported that *B. senegalensis* leafless twigs contained methyl and isopropyl glucosinolates.

Our bioassays, performed by comparing *Boscia* tissues and MITC, indicate that *B. senegalensis* fruits, leaves, and MITC were toxic to insects at various levels, according to the species and the plant tissue. They also indicate, considering LC_{99} values for FGF, FGL, and pure MITC on the one hand, and the amounts of glucocapparin found in the plant tissues on the other hand, that *Boscia* fruits and leaves contained sufficient glucocapparin to liberate MITC at levels comparable to the LC_{50} of the pure molecule.

These results indicate that in addition to its medicinal properties (Dalziel, 1948) and utilization as a famine food (Becker, 1986; Salih et al., 1991), *B. senegalensis* also has potential in stored-grain protection due to a potent fumigant effect on different insect species. *B. senegalensis* has been traditionally used by African fat-mers as a grain protectant, but the basis of its effectiveness has never been explained. We have shown that *B. senegalensis* biological activity is linked to the liberation of methyl isothiocyanate from a glucosinolate precursor, glucocapparin, contained in its fruits and leaves. As the plant grows spontaneously in some of the poorest areas of the world (mainly in the arid sahelian regions), this research suggests a natural insecticide from *B. senegalensis* as an alternative to synthetic pesticides in developing countries.

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REFERENCES

ABBOTT, W.S. 1925. A method of computing the effectiveness of an insecticide. *J. Econ. Entomol.* 18:265-267.

ALZOUMA, I., and BOUBACAR, A. 1985. Effet des feuilles vertes de *Boscia senegalensis* (Capparidaceae) sur certains aspects de la biologie de *Bruchidius atrolineatus* et de *Callosobruchus maculatus*. Comm. Colloque sur les Légumineuses Alimentaires. Niamey, Niger.

ANONYMOUS, 1990. Règlement CEE No. 1864/90. Graines oléagineuses--détermination des glucosinolates par chromatographie liquide à haute performance. *J. Off. Commun. Eur.* L170:27.

APPELQVIST, L.A., and JOSEFSON, E. 1967. Method for the quantitative determination of isothiocyanates and oxazolidinethiones in digests of seed meals of rape and turnip rape. *J. Sci. Food Agric.* 18:510.

BAUMER, M. 1981. Rôle de *Boscia senegalensis* (PERS.) LAM. dans l'économie rurale africaine: Sa consommation par le bétail. *Rev. Elev. Med. Vet. Pays Trop.* 34(3):325-328.

BECKER, B. 1983. The contribution of wild plants to human nutrition in the Ferlo (northern Senegal). *Agrofor. Syst.* 1:257-267.