Efficacy of products derived from *Ricinus communis* (L.) and *Solanum nigrum* (L.) against *Sitophilus oryzae* (L.) and *Tribolium castaneum* (Herbst) in stored maize

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ABSTRACT

Toxicity, repellency, and reproductive inhibition induced by ground leaves, leaf extracts, and essential oil of *Ricinus communis* and *Solanum nigrum* against *Sitophilus oryzae* and *Tribolium castaneum* were investigated in the laboratory by using contact toxicity, grain treatment and repellency assays. Ground leaves, water or acetone extracts, and essential oil of the two plant species were acutely toxic to *S. oryzae* and *T. castaneum*. The crude extracts and essential oil applied topically on the insects were most active, inducing 100 per cent mortality of the two beetle species. Development of eggs and immature stages within grain kernels as well as progeny emergence were also inhibited in treated grain. Essential oil of the two plants induced moderate repellency against the beetles. Of the materials tested, the essential oil was most potent and provided the highest protectant potential of maize against pest infestation. Acetone leaf extract was more effective than the aqueous extracts. The protectant potential of products derived from the two plant species against insect pest infestation in traditional farm stored grain is discussed.

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RÉSUMÉ

OBENG-OFORI, D. & FREEMAN, F. D. K.: *Efficacité des produits dérivés de* Ricinus communis *(L.) et* Solanum nigrum *(L.) contre* Sitophilus oryzae *(L.) et* Tribolium castaneum *(Herbst) dans le maïs stocké.* La toxicité, le repoussement et inhibition reproductrice déclenchés par les feuilles moulues, les extraits de feuilles et l'huile essentielle de *Ricinus communis* et *Solanum nigrum* contre *Sitophilus oryzae* et *Tribolium castaneum* étaient enquêtés dans le laboratoire utilisant la toxicité de contact, le traitement de grain et les essais de repoussement. Les feuilles moulues, les extraits d'eau ou d'acétone et l'huile essentielle de deux espèce de plante étaient profondément toxiques à *S. oryzae* et *T. castaneum*. Les extraits bruts et l'huile essentielle appliqués actuellement sur les insectes étaient forts actives déclenchant 100 pour cent de mortalité de deux espèce de coléoptère. Le développement des œufs et les stades immatures dans les grains ainsi que l'apparition de progéniture étaient inhibés dans le grain traité. L'huile essentielle des deux plantes déclenchait le repoussement modéré contre les coléoptères. Entre les substances mises à l'essai, l'huile essentielle était la plus puissante et donnait le potentiel phytoprotecteur le plus élevé de maïs contre l'infestation d'insecte ravageur. L'extrait d'acétone de feuille était plus efficace que les extraits aqueux. Le potentiel phytoprotecteur des produits dérivés de deux espèce de plante contre l'infestation d'insecte ravageur dans les grains stockés au champ traditionnel est discutés.

Introduction

Sitophilus oryzae (L.) (Curculionidae) and *Tribolium castaneum* (Herbst) (Tenebrionidae) are serious pests of stored grain and grain products in the tropics (Dobie *et al.*, 1984). Insect infestation of durable stored products may cause serious nutritional and economic losses which can be diverse and intense (Howe, 1965). Unfortunately, the greatest proportion of storage losses are at the subsistence farmer's level in the developing countries because of the inherent weaknesses of traditional post-harvest operations (Obeng-Ofori, 1987). Insect pest control in stored products now relies heavily on the use of fumigants and residual insecticides. The development of insecticide-based techniques for protecting grains in small, traditional farm stores in Africa has only been partially successful because of high cost of synthetic insecticides.

The need to develop materials that are effective, readily available, affordable and relatively less detrimental to the environment has stimulated interest in evaluating medicinal plants grown locally. The use of locally available plant materials to reduce insect damage to foodstuffs is a common practice in traditional farm storage in developing countries (Egwuatu & Osemeke, 1986; Hassanali *et al.,* 1990; Poswal & Akpa, 1991; Niber, Helenius & Varis, 1992; Niber, 1994; Talukder & Howse, 1995). In Ghana, several workers have reported the effectiveness of different plant products against major stored product insect pests (Tanzubil, 1987; Cobbina & Appiah-Kwarteng, 1989; Owusu-Akyaw, 1991). The types of plants used by different communities vary from place to place and appear to depend on the type and efficacy of suitable materials available in different localities (Hassanali *et al.,* 1990).

Ricinus communis (L.) (Euphorbiaceae) and *Solanum nigrum* (L.) (Solanaceae) are widespread in many parts of Ghana, and have been used for the treatment of various ailments and as insect repellents particularly against mosquitoes (Abbiw, 1990). A comprehensive re-evaluation of different plant materials that are used in different localities in Ghana by local farmers to protect foodstuffs against pest infestation has been initiated to understand their biological activity, and also to develop more effective application methods that are appropriate to local conditions of storage for use by small scale farmers who cannot afford synthetic insecticides.

This paper describes the biological activity of powders, leaf extracts, and essential oil of *R. communis* and *S. nigrum* against *S. oryzae* (L.) and *T. castaneum* (Herbst) in stored maize.

Materials and methods

Rearing of insects

S. oryzae and *T. castaneum* were cultured in the laboratory at 27 ± 2 °C and 65 - 70 % rh without light. Parent adults were derived from laboratory stock culture maintained at the Entomology Laboratory, Department of Crop Science, University of Ghana, Legon. The food substrates used were whole maize grains for *S. oryzae* and wheat feed for *T. castaneum*. Fifty adults of each beetle species were put into 2-l glass jars containing 500 g of maize for *S. oryzae* and 25 g of wheat feed for *T. castaneum*. The jars were covered with a nylon mesh held in place with rubber bands.

Powdered leaves and leaf extracts

The leaves of *R. communis* and *S. nigrum* were collected from Achimota and Legon, respectively. A known weight of the leaves was air-dried in a well-ventilated screen house for 2 to 5 days to constant weight. The dry matter content was then calculated (dry weight/fresh weight × 100). The dried leaves were ground to fine powder with an electronic mill. Based on the dry matter content of 22 per cent, the ground leaves were applied at the rate of 5, 10, 50, and 100 g/kg of maize. For aqueous and acetone leaf extracts, 100 g of ground leaves of each plant was soaked separately in a 100 ml of water or acetone, for 48 h. The mixtures were then filtered into separate conical flasks through Whatman No. 1 filter paper and stored in a refrigerator until needed.

Extraction of essential oil

The essential oil was isolated from the leaves and inflorescences of the two plant species separately by steam distillation with the Clavenger apparatus. The condensing oils were collected in 95 % n-hexane (Aldrich HPLC grade) as the solvent which was later removed by Contes short path distillation apparatus. The oil was weighed in different doses into small glass jars and then dissolved in 10 ml of 95 % n-hexane and kept for 24 h before it was used.

Contact toxicity of essential oil and leaf extracts by topical application

Tests to determine the contact toxicity of the essential oil, acetone and water extract of the two plant species by topical treatment were carried out in the laboratory at 27 ± 2 °C, 60 - 70 % rh. The standard method described by McDonald, Guy & Speirs (1970) was used. Different dosages of the essential oil extract (1, 5 and 10 µl in 1 ml acetone) were prepared. Water and acetone extracts were used without further dilution. Three to 7-day-old insects of mixed sex were first transferred into Petri dishes lined with moist filter paper and chilled for 3 min to reduce their activity in readiness for topical treatment. The immobilized insects were picked individually for treatment. Two µl of essential oil solution, water or acetone extract was applied to the dorsal surface of the thorax of each insect with micro-applicator. Fifty beetles in five replicates of 10 insects each were treated with each dose. The same number of insects was treated with water or acetone only as controls. After treatment, the insects were transferred into 11.0-cm diameter glass Petri dishes (10 insects/Petri dish) containing food. The insects were examined daily for 2 days and those that did not move or respond to three probings with a blunt probe were considered dead. Insect mortalities were recorded at 24 and 48 h after treatment.

Mortality, progeny production, and damage assessment

The effect of powdered leaves, essential oil, water and acetone extract-treated maize grains on adult mortality of *S. oryzae* and *T. castaneum* was studied in the laboratory at 27 ± 2 °C, 60 - 70 % rh. The grains were separately treated with each plant material. Leaf powders were applied at the rate of 5, 10, 25, 50 and 100 g/kg of maize, and the essential oil at three doses of 0.05, 0.1 and 0.5 g in 10 ml 95 % n-hexane/kg of maize. Each material was mixed with 500-g samples of maize in 1-l glass jars and stirred continuously for 10 min to ensure even spread of the material over the surface of the grains. The grains were then infested with 3 to 7 day-old adult beetles of mixed sex (20 beetles per jar), and each jar was covered with a nylon mesh held with rubber bands. Both insects have a sex ratio of 1:1. Each treatment was replicated five times. Mortality counts were recorded after 24 and 48 h.

In a similar experiment, beetles were exposed to maize treated with 10 ml of water and acetone extracts of the two plant species, and mortality was recorded after 24 and 48-h exposure. Thereafter, the jars containing *S. oryzae* were kept until the mean oviposition period of 21 days before the parent adults were removed. The number of F1 progeny produced by *S. oryzae* which subsequently emerged was counted 56 days after the introduction of the parent beetles. Similarly, damage was assessed in treated and untreated maize grains. Samples of 100 grains were taken from each jar and the number of damaged (grains with characteristic hole) and undamaged grains were counted to estimate percent seed damage caused by *S. oryzae*.

Effect on hidden eggs and immature stages

The effect of crude leaf and essential oil extracts of *R. communis* and *S. nigrum* on the development of eggs and immature stages of *S. oryzae* inside maize kernels was bioassayed. Batches of 200 g of maize in 300-ml glass jars were infested with 50 unsexed adults (3-7 days old) to allow egg laying. The parent adults were removed after 7 days. One day after adult removal, four batches of the grain were treated with different dosages of essential oil of the two plant species as previously described. Thereafter, these treatments were repeated at 1, 2 and 3 weeks after adult removal. Adults subsequently emerging were counted for a period of 7 weeks after the removal of adults.

Repellency bioassay

The repellent action of the different plant materials was assessed in a choice bioassay system consisting of two 1-l glass jars connected together at their rims by means of a 30 cm × 10 cm nylon mesh tube. A 5-cm diameter circular hole was cut at the middle of the mesh to introduce test insects. Two hundred and fifty-gram samples of maize were treated separately with different dosages of leaf powder, acetone or water extract, and essential oil extract of the two plant species. One jar contained treated grains while the other jar had untreated maize and acted as the control. Twenty-five (3-7 days old) adults of mixed sex of *S. oryzae* or *T. castaneum* were introduced into the nylon mesh tube through the circular hole by a 5-cm diameter funnel. Beetles in the control and treated grains were counted after 1 h. After each test, the glass jars were thoroughly cleaned and dried at 100 °C. The assay for each dose of test material was replicated four times for each beetle species. Throughout the experiments, two blank controls were run periodically.

All repellency assays were carried out in the laboratory at 27 ± 2 °C and 60-70 % rh. Percent repellency (PR) values were computed as PR = $[(N_C - N_T/(N_C + N_T)] \times 100$ (Hassanali *et al.*, 1990). PR data were analysed using ANOVA after arcsin-transforming them. All negative PR values were treated as zero.

Results

Contact toxicity by topical application

Table 1 shows toxicity of essential oil and leaf extracts of *R. communis* and *S. nigrum* applied topically on *S. oryzae* and *T. castaneum*. High doses of essential oil of both plant species killed all the beetles exposed within 48 h. Acetone and water extracts of *R. communis* were also highly toxic to *S. oryzae* and *T. castaneum* and induced 100 per cent mortality in both species. Leaf extract of *S. nigrum* evoked moderate mortalities in both beetle species, with water extract being the least toxic. In all the tests, beetle mortality was dosage dependent.

Beetle mortality in grain

Table 2 shows the mortality of *S. oryzae* and *T. castaneum* in maize treated with leaf powder of *R. communis* and *S. nigrum*. The powders of both plant species were highly toxic to *S. oryzae* and *T. castaneum*. Toxicity was also dosage dependent, and maize grains treated with the highest dosage of 100 g/kg killed over 90 per cent of the beetles exposed. Table 2 also shows toxicity of essential oil and leaf extract-treated maize against the beetles. Maize treated with the highest dosage of essential oil induced 100 per cent mortalities in all the beetles tested. Acetone extracts of both plant species were moderately toxic to *S. oryzae* and *T. castaneum*, but the water extracts were least toxic and killed only 20 per cent of the beetles exposed (Table 2).

Seed damage

Table 3 shows assessment of percent seed damage caused by *S. oryzae*. All the plant

TABLE 1

Toxicity of Essential Oil and Leaf Extract of R. communis *and* S. nigrum *Applied Topically on* S. oryzae *and* T. castaneum

Treatment	*Percent adult mortality after 48 h (± SE)*			
	R. communis		S. nigrum	
	S. oryzae	T. castaneum	S. oryzae	T. castaneum
Essential oil (µl/beetle)				
1.0	40[c] ± 0.8	45[c] ± 0.7	49[c] ± 0.6	43[c] ± 0.6
5.0	100[a] ± 0.0	100[a] ± 0.0	100[a] ± 0.0	100[a] ± 0.0
10.0	100[a] ± 0.0	100[a] ± 0.0	100[a] ± 0.0	100[a] ± 0.0
Water extract	100[a] ± 0.0	96[a] ± 0.5	40[c] ± 0.6	36[c] ± 0.7
Acetone extract	100[a] ± 0.0	100[a] ± 0.0	70[b] ± 0.8	63[b] ± 0.8
Water only	0[d] ± 0.0	0[d] ± 0.0	0[d] ± 0.0	0[d] ± 0.0
Acetone only	3[d] ± 0.0	2[d] ± 0.0	2[d] ± 0.1	0[d] ± 0.0

Means followed by different letter(s) are significantly different at the 5 per cent level, LSD test

TABLE 2

Mortality of S. oryzae *and* T. castaneum *in Maize Grains Treated with Different Materials Derived from* R. communis *and* S. nigrum

Treatment	Percent adult mortality after 48 h (± SE)			
	R. communis		S. nigrum	
	S. oryzae	T. castaneum	S. oryzae	T. castaneum
Leaf powder (g/kg of maize)				
0	$0^{f} \pm 0.0$	$0^{f} \pm 0.0$	$0^{f} \pm 0.0$	$0^{f} \pm 0.0$
5	$15^{e} \pm 0.0$	$20^{e} \pm 0.4$	$16^{e} \pm 0.5$	$12^{e} \pm 0.4$
10	$40^{d} \pm 0.5$	$42^{c} \pm 0.7$	$43^{d} \pm 0.7$	$43^{d} \pm 0.6$
25	$61^{bc} \pm 0.9$	$58^{c} \pm 0.6$	$62^{bc} \pm 0.5$	$58^{c} \pm 0.5$
50	$65^{bc} \pm 0.7$	$69^{bc} \pm 0.6$	$67^{bc} \pm 0.6$	$69^{bc} \pm 0.5$
100	$95^{a} \pm 0.5$	$90^{a} \pm 0.8$	$89^{a} \pm 0.8$	$91^{a} \pm 0.6$
Essential oil				
0.05	$14^{e} \pm 0.7$	$12^{e} \pm 0.5$	$12^{e} \pm 0.5$	$14^{e} \pm 0.4$
0.10	$65^{bc} \pm 0.6$	$58^{b} \pm 0.7$	$61^{bc} \pm 0.6$	$55^{c} \pm 0.5$
0.50	$100^{a} \pm 0.0$	$100^{a} \pm 0.0$	$100^{a} \pm 0.0$	$90^{a} \pm 0.6$
Water extract	$20^{e} \pm 0.5$	$15^{e} \pm 0.6$	$18^{e} \pm 0.5$	$21^{e} \pm 0.4$
Acetone extract	$62^{bc} \pm 0.6$	$55^{c} \pm 0.8$	$65^{bc} \pm 0.5$	$63^{bc} \pm 0.5$
Water only	$0^{f} \pm 0.0$	$0^{f} \pm 0.0$	$0^{f} \pm 0.0$	$0^{f} \pm 0.0$
Acetone only	$0^{f} \pm 0.0$	$0^{f} \pm 0.0$	$0^{f} \pm 0.0$	$0^{f} \pm 0.0$

Means followed by different letter(s) are significantly different at the 5 per cent level, LSD test

TABLE 3

Percent Damage of Maize Grains Treated with Different Plant Materials Derived from R. communis *and* S. nigrum *and Stored for 60 Days Under Artificial Infestation with* S. oryzae

Treatment	Percent seed damage after 60 days	
	R. communis	S. nigrum
Leaf powder (g/kg of maize)		
0	$5.7^{a} \pm 0.1$	$6.0^{a} \pm 0.1$
5	$4.5^{b} \pm 0.2$	$4.6^{b} \pm 0.3$
10	$4.0^{bc} \pm 0.1$	$4.0^{bc} \pm 0.1$
25	$3.4^{cd} \pm 0.1$	$3.2^{d} \pm 0.2$
50	$2.8^{d} \pm 0.2$	$2.0^{d} \pm 0.1$
100	$1.2^{e} \pm 0.0$	$0.8^{e} \pm 0.1$
Essential oil (µl in 1 ml of solvent)		
0.05	$4.4^{b} \pm 0.3$	$4.2^{b} \pm 0.2$
0.10	$3.5^{cd} \pm 0.1$	$3.4^{cd} \pm 0.2$
0.50	$0.0^{e} \pm 0.0$	$0.1^{e} \pm 0.1$
Water extract	$3.8^{bc} \pm 0.2$	$4.0^{bc} \pm 0.2$
Acetone extract	$2.4^{d} \pm 0.0$	$1.6^{d} \pm 0.0$
Water only	$5.8^{a} \pm 0.3$	$5.6^{a} \pm 0.3$
Acetone only	$6.1^{a} \pm 0.2$	$5.8^{a} \pm 0.3$

Means followed by different letter(s) are significantly different at the 5 per cent level, LSD test

materials tested protected maize grains better compared to the untreated maize. Essential oil was the most effective protectant of maize against feeding by *S. oryzae*. No noticeable feeding damage was observed on grains treated with the highest dosage of 0.5 µl in 1 ml of solvent.

Progeny production

Table 4 shows the number of progeny produced by *S. oryzae* in untreated and maize treated with different plant materials. All the plant materials tested caused a highly significant reduction in the number of progeny produced by the rice weevil. Few or no F1 adults emerged in the essential oil-treated maize irrespective of the dosage applied. Essential oil provided the highest protectant potential against the weevil.

Effect on immature stages

Essential oil and leaf extracts of both plant species inhibited the development of eggs, larvae and pupae of *S. oryzae* hidden inside maize kernels (Table 5). Of the materials tested, essential oil and acetone extract were most potent. When maize containing eggs, first and second instars or

TABLE 4

Mean Number of F1 Progeny Produced by S. oryzae *in Maize Grains Treated with Various Materials Derived from* R.communis *and* S. nigrum

Treatment	*Number of F1 progeny* R. communis	S. nigrum
Leaf powder (g/kg of maize)		
0	$327^a \pm 2.5$	$334^a \pm 2.0$
5	$105^b \pm 1.6$	$110^b \pm 1.2$
10	$90^c \pm 1.4$	$95^c \pm 1.0$
25	$50^d \pm 1.0$	$60^d \pm 1.5$
50	$22^e \pm 1.0$	$10^e \pm 0.8$
100	$20^e \pm 0.9$	$10^e \pm 0.5$
Essential oil (µl in 1 ml of solvent)		
0.05	$9^e \pm 0.7$	$15^e \pm 0.9$
0.10	$0^e \pm 0.0$	$0^e \pm 0.0$
0.50	$0^e \pm 0.0$	$0^e \pm 0.0$
Water extract	$90^c \pm 1.5$	$85^c \pm 1.2$
Acetone extract	$50^d \pm 1.2$	$55^d \pm 0.7$
Water only	$350^a \pm 2.4$	$344^a \pm 2.3$
Acetone only	$367^a \pm 2.5$	$349^a \pm 2.0$

Means followed by different letter(s) are significantly different at the 5 per cent level, LSD test

Repellency

All the plant materials showed low repellent activity against *S. oryzae* and *T. castaneum*, except the essential oil extract which was moderately repellent to both species, particularly at the highest dosage tested (Table 6).

Discussion

Essential oil and leaf extracts of *R. communis* and *S. nigrum,* whether applied topically or mixed with maize, were highly toxic to various stages of *S.oryzae* and *T. castaneum.* The materials also caused a highly significant reduction in the number of progeny produced by the beetles. Few or no F1 *S. oryzae* adults emerged from maize treated with essential oils of the two plant species, and this could be attributed to either oviposition deterrence or toxicity of the materials to the eggs laid. Furthermore, the essential oil extract evoked moderate repellent activity against *S.oryzae* and *T. castaneum.* Of the materials tested, essential oil was the most potent and provided the highest protectant potential of maize against infestation by *S. oryzae* and *T. castaneum.* This rapid and complete mortality caused by essential oil extract, in particular, is noteworthy, since several

TABLE 5

Mean Adult Emergence of S. oryzae *in Maize Grains Treated with Leaf and Essential Oil Extracts of* R. communis *and* S. nigrum *at Different Times after Oviposition Period*

Treatment	*Time of treatment after one week oviposition period* *R.* communis				S. nigrum			
	24 h	*1 wk*	*2 wks*	*3 wks*	*24 h*	*1 wk*	*2 wks*	*3 wks*
Essential oil (µl in 1 ml of solvent)								
0.05	0^c	0^c	0^c	0^c	0^c	0^c	0^c	0^c
0.10	0^c	0^c	0^c	0^c	0^c	0^c	0^c	0^c
0.50	0^c	0^c	0^c	0^c	0^c	0^c	0^c	0^c
Water extract	134^b	125^b	131^b	150^b	143^b	156^b	146^b	144^b
Acetone extract	0^c	0^c	0^c	0^c	0^c	0^c	0^c	0^c
Water only	345^a	350^a	325^a	324^a	335^a	340^a	329^a	341^a
Acetone only	335^a	329^a	325^a	345^a	325^a	339^a	321^a	333^a

Data was transformed to log x + 0.5 before ANOVA. Means followed by different letter(s) are significantly different at the 5 per cent level, LSD test.

pupae were treated with essential oil or acetone extract of *R. communis* and *S. nigrum,* no progeny emerged compared with the untreated maize.

TABLE 6

Repellency of Different Materials Derived from R. communis *and* S. nigrum *against* S. oryzae *and* T. castaneum *in the Choice Olfactometer*

Treatment	*Mean percent repellency*			
	R. communis		S. nigrum	
	S. oryzae	T. castaneum	S. oryzae	T. castaneum
Leaf powder (g/kg of maize)				
5	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$
10	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$
25	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$
50	$5^{a} \pm 0.0$	$4^{a} \pm 0.2$	$5^{a} \pm 0.2$	$2^{a} \pm 0.1$
100	$25^{b} \pm 0.6$	$20^{b} \pm 0.8$	$20^{b} \pm 0.5$	$20^{b} \pm 0.6$
Essential oil (µl in 1 ml of solvent)				
0.05	$15^{b} \pm 0.5$	$15^{b} \pm 0.5$	$20^{b} \pm 0.6$	$20^{b} \pm 0.5$
0.10	$45^{c} \pm 0.7$	$40^{c} \pm 0.5$	$55^{cd} \pm 0.5$	$50^{c} \pm 0.6$
0.50	$65^{d} \pm 0.9$	$62^{d} \pm 0.6$	$64^{d} \pm 0.9$	$60^{d} \pm 0.9$
Water extract	$14^{b} \pm 0.4$	$15^{b} \pm 0.4$	$21^{b} \pm 0.5$	$15^{b} \pm 0.4$
Acetone extract	$45^{c} \pm 0.7$	$50^{c} \pm 0.7$	$50^{c} \pm 0.5$	$50^{c} \pm 0.6$
Control	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$	$0^{a} \pm 0.0$

Data was transformed to log x + 0.5 before ANOVA. Means followed by different letter(s) are significantly different at the 5 per cent level, LSD test.

alternative plant products for pest control require much longer than 24 h to reach their maximum effect, and few had 100 per cent kill (Hassanali *et al.*, 1990). Thus, suitable essential oil preparations could be used in severely infested grain bulks for immediate control of these insect pests.

The acetone extracts of both plants were more effective than the aqueous extracts, probably because being an organic solvent, the extraction of the biologically active constituents from the leaves was more efficient than water (McMillan *et al.*, 1969). The insecticidal activity of plant materials derived from *R. cummunis* is attributed to its major components of protein ricins and alkaloid ricinine which are lethal at very low concentrations (Abbiw, 1990).

The results suggest good potential for the use of materials derived from *R. communis* and *S. nigrum* as toxicant agents in storage pest management systems, particularly for resource-poor farmers in developing countries. Some essential oils extracted from various plants had been shown to possess insecticidal and protectant properties (Shaaya *et al.*, 1991). Small-scale farmers in most African countries mix stored foodstuffs, especially grains, with dry leaves of different plant species for protection against post-harvest damage. Several workers in Ghana have shown the efficacy of different plant products against major stored product pests (Tanzubil, 1987; Cobbina & Appiah-Kwarteng, 1989; Owusu-Akyaw, 1991). Niber (1994) showed the effectiveness of leaf and seed powders and slurries of several plant species, including *Azadiracta indica* Juss (Meliaceae), *R. communis* and *S. nigrum*, in protecting stored wheat and maize grains against damage caused by *S. oryzae* and *P. truncatus* (Horn). Bekele (1994) and Bekele *et al.* (1995, 1996, 1997) showed the effectiveness of ground leaves and essential oil extract of *Ocimum kilimandscharicum*, *O. suave*, and *O. kenyense* in protecting maize and sorghum against attack by *S. zeamais* (Mots.) (Curculionidae), *Rhyzopertha dominica* (Fab.) (Bostrichidae), and *Sitotroga cerealella* (Oliver) (Gellechidae).

The biologically active major constituents from the leaves of these plants were recently shown to be highly toxic and repellent against several stored product beetle pests (Obeng-Ofori & Reichmuth, 1997; Obeng-Ofori *et al.*, 1997). Some farmers in

Rwanda also protect farm-stored edible beans (*Phaseolus vulgaris* (L.) against insect damage by mixing them with the leaves of *O. canum.* Linalool is the major component of the essential oil of this annual mint, representing 60-90 per cent of the total volatiles collected (Weaver *et al.*, 1991), and is known to act as a reversible competitive inhibitor of acetylcholinesterase (Ryan & Byrne, 1988).

Most products derived from plant materials have very low persistent rate with highly significant loss of activity barely 24 h after application (Hassanali *et al*., 1990; Bekele *et al.*, 1995, 1996, 1997; Obeng-Ofori & Reichmuth, 1997; Obeng-Ofori *et al.*, 1997, 1998). The practical use of plant oils such as coconut, groundnut, and sunflower as grain protectants is also limited by the high rates required to disinfest grain (Don-Pedro, 1989). It is, therefore, possible to use reduced levels of plant oils combined with essential oil or leaf extracts of *R. cummunis* and *S. nigrum* to enhance their toxicity and persistence, thereby making their use more effective and economical.

The plant products tested in this study adequately protected maize against damage by *S. oryzae* and *T. castaneum.* Further trials are being carried out on a large scale to determine the feasibility of using different materials derived from several plant species, particularly *A. indica, R. cummunis* and *S. nigrum*, to protect stored grains at small-scale farmer level. Many plant compounds including alkaloids possess toxic or carcinogenic effects on mammals. Detailed toxicological studies are, therefore, needed to determine the side effects of the two plant materials on mammals and other beneficial organisms before they can be recommended for adoption by farmers.

The use of plant materials in pest control could become important supplements or alternatives to imported synthetic pesticides. It is, therefore, important that appropriate technology is developed to promote a direct preparation of traditional pesticides at the farm level for resource-poor farmers who have no access to commercial pesticides or cannot afford them.

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REFERENCES

Abbiw, D. (1990) *Useful plants of Ghana.* West African uses of wild cultivated plants. Intermediate Technology Publication and Royal Botanic Garden. 337 pp.

Bekele, J. A. (1994) *Effects and use of some* Ocimum *plant species and their essential oils on some storage insect pests* (Ph D Thesis). University of Nairobi. 200 pp.

Bekele, J. A., Obeng-Ofori, D., Hassanali, A. & Nyamasyo, G. H. N. (1995) Products derived from the leaves of *Ocimum kilimandscharicum* as post-harvest grain protectants against the infestation of three major stored product insect pests. *Bull. Ent. Res.* **85**, 361-367.

Bekele, J. A., Obeng-Ofori, D. & Hassanali, A. (1996) Evaluation of *Ocimum suave* (Willd) as soure of repellents, toxicants and protectants in storage against three stored product insect pests. *Inter. J. Pest Mgt* **42** (2), 139-142.

Bekele, J. A., Obeng-Ofori, D. & Hassanali, A. (1997) Evaluation of *Ocimum kenyense* (Ayobangira) as source of repellents, toxicants and protectants in storage against three stored product insect pests. *J. Appl. Ent.* **121** (3), 169-173.

Cobbina, J. R. & Appiah-Kwarteng, J. (1989) Effect of neem products on stored product maize weevil *Sitophilus zeamais* (Motsch.). *Insect Sci. Appl.* **10** (1), 89-92.

Dobie, P., Haines, C. P., Hodghes, R. J., Prevett, P. F. & Rees, D. P. (1984) *Insects and arachnids of tropical stored products: Their biology and identification (A training manual).* Natural Resource Institute, UK. 246 pp.

Don-Pedro, K. N. (1989) Mechanisms of action of some vegetable oils against *Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae) on wheat. *J. Stored Prod. Res.* **25**, 217-223.

Egwuatu, R. I. & Osemeke, N. E. (1986) Some effects of citrus peel powders, dried and ground pepper and groundnut oil on *Callosobruchus maculatus* (F.) (Coleoptera, Bruchidae) . *Ghana J. agric. Sci.* **14-19**, 131-135.

Hassanali, A., Lwande, W., Ole-Sitayo, N., Moreka, L., Nokoe, S. & Chapya, A. (1990) Weevil repellent constituents of *Ocimum suave* leaves and *Eugenia caryophyllata* cloves used as grain protectant in parts of Eastern Africa. *Disc. Innov.* **2**, 91-95.

Howe, R. W. (1965) Losses caused by insects and mites in stored foods and foodstuffs. *Nut. Abstr. Rev.* **35**, 285-302.

McDonald, L. L., Guy, R. H. & Speirs, R. D. (1970) Preliminary evaluation of new candidate materials as toxicants, repellents and attractants against stored product insects. *Marketing Research Report Number 882. Agricultural Research Service, US Department of Agriculture, Washington,* 8 pp.

McMillan, W. W., Bowman, M. C., Burton, R. L., Stark, K. J. & Wiseman, B. R. (1969) Extracts of China-berry leaf as feeding deterrant and growth retardant for larvae of the corn earworm and fall army worm. *J. Eco. Ent.* **62**, 708-710.

Niber, T. B., Helenius, J. & Varis, A. (1992) Toxicity of plant extracts to three storage beetles (Coleoptera). *J. Appl. Ent.* **113**, 202-208.

Niber, T. B. (1994) The ability of powders and slurries from ten plant species to protect stored grain from attack by *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) and *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae). *J. Stored Prod. Res.* **30** (4), 297-301.

Obeng-Ofori, D. (1987) *Use of attractants for monitoring beetles of stored products* (M Phil Thesis). University of Cambridge, UK. 40 pp.

Obeng-Ofori, D. & Reichmuth, C. H. (1997) Bioactivity of eugenol, a major component of essential oil of *Ocimum suave* (Willd) against four species of stored product Coleoptera. *Inter. J. Pest Mgt* **43** (1), 89-94.

Obeng-Ofori, D., Reichmuth, C. H., Jembere, B. & Hassanali, A. (1997) Biological activity of 1.8 cineole, a major component of essential oil of *Ocimum kenyense* (Ayobangira) against stored product beetles. *J. Appl. Ent.* **124**, 237-243.

Obeng-Ofori, D., Reichmuth, C. H., Jembere, B. & Hassanali, A. (1998) Toxicity and protectant potential of camphor, a major component of essential oil of *Ocimum kilimandscharicum* against four stored product beetles. *Inter. J. Pest Mgt* **44** (4), 203-209.

Owusu-Akyaw, M. (1991) Evaluation of plant products for the control of cowpea and maize storage insects. *Proc. Joint SAFGGRAD Res. Network Workshop, Niami, Niger.* pp. 8-11.

Poswal, M. A. T. & Akpa, A. D. (1991) Current trends in the use of traditional and organic methods for the control of crop pests and diseases in Nigeria. *Trop. Pest Mgt* **37**, 329-333.

Ryan, M. F. & Byrne, O. (1988) Plant-insect coevolution and inhibition of acetylcholinesterase. *J. Chem. Ecol.* **14**, 1965-1975.

Shaaya, E., Ravial, U., Paster, N., Juven, B., Zisman, U. & Pissarev, V. (1991) Fumigant toxicity of essential oils against four major stored product insects. *J. Chem. Ecol.* **17**, 499-504.

Talukder, F. A. & Howse, P. E. (1995) Evaluation of *Aphanamixis polystachya* as a source of repellents, antifeedants, toxicants and protectants in storage against *Tribolium castaneum* (Herbst). *J. Stored Prod. Res.* **31**, 55-61.

Tanzubil, P. B. (1987) The use of neem products in controlling the cowpea beetle *Callosobruchus maculatus*. In *Natural pesticides from the neem tree* (Azadirachta indica *A. Juss*) (ed. H. Schmutterer and K. R. S. Ascher), pp. 517-523. *Proc. 3rd Inter. Neem Conf.* Nairobi, Kenya, 10-15th July 1986.

Weaver, D. K., Dunkel, F. V., Ntezurubanza, L., Jackson, L. L. & Stock, D. T. (1991) The efficacy of Linalool, a major component of freshly milled *Ocimum canum* (Sims) (Lamiaceae), for protection against stored product Coleoptera. *J. Stored Prod. Res.* **27**, 213-220.