PN-ADI-795

[1]PROGRESS RESEARCH REPORT

KENYAN PLANT CONSTITUENTS FOR BIOLOGICAL INSECT CONTROL

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Executive Summary
Insect pests pose the greatest threat to increased food grain production, quality storage and food security in sub-Sahara Africa. In an effort to address challenge of losses due stored-product insects, a joint Israel-Kenya CDR program embarked on documentation / selection of indigenous Kenyan plant genetic resources with ethno botanical and pesticidal value, bioassay guided phytochemical screening of plants for toxic (fumigant and contact), repellent, reproduction inhibition and residual activity against major coleopteran pests of stored cereal and legume grains. During the past year, a total of 30 indigenous Kenyan plant species in 12 families were identified and selected for phtyo-chemical screening against major coleopteran pests of stored food grains. Laboratory bioactivity studies were conducted simultaneously, in Israel and Kenya, to screen the volatile constituents (essential oils) of candidate plant species for toxicity (fumigant and contact), repellence (choice bioassay system), reproduction inhibition and chemical compositional analyses. Crude powders of some of the candidate plants were also evaluated for contact toxicity and repellence. Data generated on percentages (mortality and repellence) were first homogenized through angular transformations before performing ANOVA and means separated using LSD. Probit regression analyses of transformed data were used in estimation of LD_{50} values. Preliminary results showed that plant essential oils and crude powders have both toxic and repellent effects against major coleopteran pests of stored grains. If successfully conducted to its logical conclusion, a possibility exists that essential oil(s) will be identified with potential activity better or equal to synthetic fumigants such as methyl bromide and phosphine. Similarly, plant powders as effective as synthetic insecticides are likely to be identified, formulated and packaged for specific user needs in sub-Sahara Africa.

1.0 Project Objectives

The objectives of the project during the last year:

1) Documentation of Kenyan plant genetic resources with ethno botanical and pesticidal values against stored-product insect pests.
2) Screen Kenyan plant genetic resources for bioactivity (toxicity, repellence and reproduction inhibition) against major stored-product insect pests.
3) Conduct compositional analysis and identify major chemical constituents of selected test plant species.
4) Conduct bioassay guided bioactivity tests (toxicity, repellent, reproduction inhibition and related effects) of chemical compounds, individually or in blends, against insect pests of stored staple food grains.
5) Identify Kenyan plant species with potential industrial value, as source of botanical pesticide, and conduct agronomic studies.

2.0 Kenyan plant genetic resources

The CDR Program (Israel and Kenya) conducted her initial reconnaissance (exploratory) survey in the Kakamega forest, Kenya, in March-April 2005 during which over 50 potential test plants (with volatile and non-volatile constituents) were identified. In their follow-up visits (Sept/Oct. 2005; April-Jul. 2006), the CDR-Kenya team collected samples from over two (2) dozen test plant species for bioassay studies (crude powders and volatile constituents) currently running simultaneously in Kenya and Israel. In Kenya, the crude powders are being screened for contact toxicity, repellence and other effects against stored-product insects whereas the bioactivity of volatile plant constituents and chemical analysis are being conducted at The Volcani Center and Newe Ya'ar Research Station in Israel. A total 30 plant species in 12 families are being screened, namely; Zingiberaceae (EOP2), Piperaceae (EOP3), Rutaceae (EOP7;19), Solanaceae (EOP9), Verbenaceae (EOP14;35;64), Urticaceae (EOP16), Acanthaceae (EOP23), Lamiaceae (EOP27;45;49-50;62-63), Apiaceae (EOP28), Poaceae (EOP29;56), Asteraceae (EOP36;47-48), Boraginaceae (EOP53). Oleraceae (EOP54) and Fabaceae (EOP65).

Of the 30 test plant species, the GC-MS analysis of the essential oils from EOP19, 27-28, 48, 50, 63 and 65 has just been completed at the Newe Ya'ar Research Center (Prof. Uzi Ravid's Lab) and data will soon be subjected to appropriate descriptive statistical analysis and interpretation. These results will prove useful in the understanding of bioactivity (toxicity, repellence, reproduction inhibition, etc) effects of volatile plant constituents against laboratory maintained stored-product insect pests (Department of Food Science, The Volcani Center).

3.0 Laboratory bioassay studies

3.1 *Fumigant toxicity (Space fumigation)*

Laboratory cultures of *Sitophilus oryzae* L., *Rhyzopertha dominica* F., *Tribolium castaneum* (Herbst), *Oryzaephilus surinamensis* L. and *Callosobruchus chinensis* (F.) maintained at 30±2°C and 68±2% r.h. were subjected to space fumigation studies. Twenty unsexed adults of each test insect species were introduced into meshed metallic cages with food and suspended by hook in 3.4 L flat bottom glass space fumigation chambers according to Shaaya *et al.* (1991). Essential oils from different plant samples were separately applied at graded rates (0, 1, 5 and 10 µl/L air) on a small piece of Whatman No. 1 filter paper and then suspended in the chamber slightly below the cage. Magnetic stirrers were used during the 24-hour fumigation to ensure even distribution of fumigant. Treatments, each replicated four times, were arranged in a completely randomised design (CRD) with replicates nested within the space fumigation chambers. Percent adult mortality was recorded 24, 72, 120 and 168 hours from onset of fumigation. Probit regression analyses of transformed data (Finney, 1971) were used to estimate LD_{50} values. Preliminary results of essential oils of EOP27, 62, 63(leaf and fruit) and 65(leaf, fruit and stem) are reported.

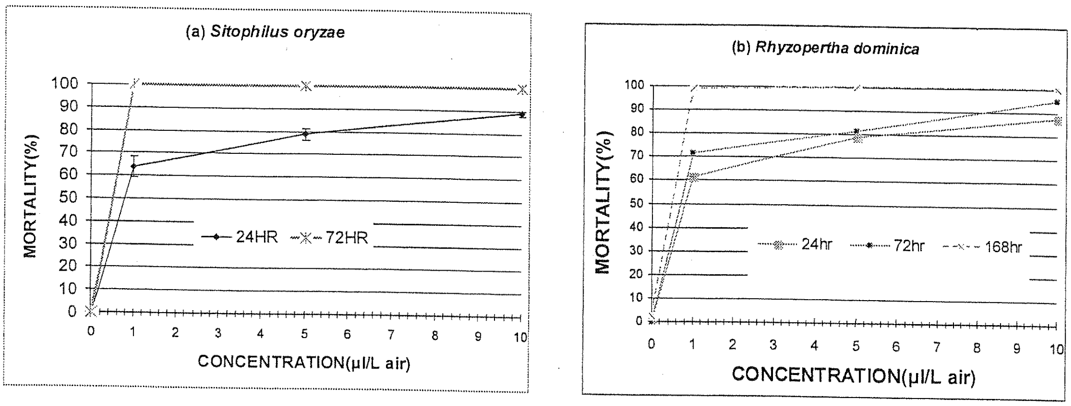
Results of space fumigant toxicity tests, as measured by percent mortality and LD_{50} values, are presented in Table 1 and Figure 1.
Results showed that test plant essential oils had significant fumigant effects that were dependent upon insect species, plant species, plant part from which oil was extracted, oil concentration applied and duration (hours) of insect-fumigant reaction. The cowpea weevil, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) and the red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) were the most susceptible and tolerant insect species, respectively. The other test insects, *Oryzaephilus surinamensis* L. (Coleoptera: Silvanidae), *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae) and *Sitophilus oryzae* L. (Coleoptera: Curculionidae), were more tolerant than *C. chinensis* but inferior to *T. castaneum*.

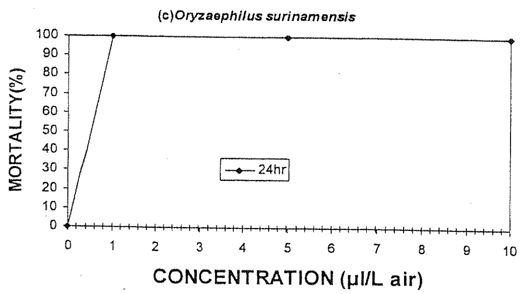
On the basis of LD_{50} values (Table 1), three promising essential oils (all Lamiaceae) from EOP27, EOP62 and EOP63leaf merit being tested further for bioactivity in grain fumigation and residual toxicity (fumigant and contact) studies.

Table 1: Variation of essential oil LD_{50} values (µl/L air) **with respect to duration of exposure by different stored-product insects in space fumigation chamber**[1].

Insect species	Duration (hours) after application of fumigant			
	24	72	120	168
EOP27 oil:				
S. oryzae	14.5	0.44	0.44	0.44
EOP62 oil:				
S. oryzae	17.7	0.51	0.39	0.38
O. surinamensis	0.50	0.50	-	-
R. dominica	0.50	0.50	-	-
T. castaneum	-	-	-	-
EOP65 Leaf oil:				
S. oryzae	-	2.64	-	1.60
C. chinensis	0.70	0.50	-	-
R. dominica	-	-	6.2	2.40
O. surinamensis[a]	-	-	-	-
*T. castaneum**	-	-	-	-
EOP65 Fruit oil:				
S. oryzae	-	-	-	>10
C. chinensis[a]	-	-	-	-
R. dominica	-	9.60	4.48	3.40
O. surinamensis	-	7.80	-	-
*T. castaneum**	-	-	-	-
EOP63 Leaf oil:				
S. oryzae	0.80	0.50	-	-
C. chinensis[a]	-	-	-	-
R. dominica	0.80	0.70	-	0.50
O. surinamensis	0.50	-	-	-
*T. castaneum**	-	-	-	-
EOP63 Fruit oil:				
S. oryzae	-	1.10	-	0.95
C. chinensis	1.60	-	-	-
R. dominica	9.30	7.10	4.95	4.58
O. surinamensis	7.20	6.10	5.60	-
*T. castaneum**	-	-	-	-
NB: Data presented here are preliminary and represent only a small fraction of the on going study.				

[a]Test insect was unavailable at time of experiment; *Response to essential oil insignificant.
[1]Twenty unsexed adult test insects, in four replicates, were used for each essential oil concentration (µl/L air).





LD_{50} and LD_{95} values:
See Table 1above

*Response of *T. castaneum* was insignificant and hence toxicity indices not be computed.

Fig.1a: Effect of EOP63 leaf essential concentration on adult mortality of *S. oryzae*, *R. dominica* and *O. surinamensis* over varied exposure times.

S. oryzae:
Response of *S. oryzae* to essential oils in space fumigation was a function of test oil, plant part, concentration applied and exposure duration (hours). Total adult insect mortality (100%) was recorded at 1 µl/L air (EOP63 leaf) and at 5 µl/L air (EOP27) after 72 and 168 hours, respectively. At 10 µl/L air, 80, 15 and <50% mortalities were registered after 72 hr for leaf, fruit and stem oils of EOP65. This response clearly demonstrates that plant part and by extension, variation in chemical composition, influences the fumigant activity of essential oils. After 72 hours, the LD_{50} values varied from 0.44 (EOP27) to 2.64 µl/L air (EOP65 leaf) (Table 1).

O. surinamensis:
Results showed *O. surinamensis* was susceptible to most oils tested. Total kill (100%) was observed at 1 µl/L air for EOP63 leaf and EOP62 after 24 and 120 hr, respectively. The EOP63 fruit oil was less effective with only 80% mortality observed after 120 hr at 10 µl/L air. Similarly, EOP65 fruit oil, at 10 µl/L air, produced 90% kill after 168 hr. After 72 hours, the LD_{50} values varied from 0.50 (EOP62), 6.10 (EOP63 fruit) to 7.80 µl/L air (EOP65 fruit) (Table 1). The EOP63 leaf oil was more toxic (LD_{50} = 0.50) than fruit oil from same plant.

R. dominica:
The EOP62 oil was the most effective with 100% mortality of adult *R. dominica* registered after 72 hr at 1 µl/L air. Response to EOP65 oils, at 10 µl/L air, varied according to plant part as follows 80, 97 and 50% mortality after 168 hr for leaf, fruit and stem, respectively. However, in the EOP63 oils, 99% mortality was recorded for leaf oil at 1 µl/L air after 168 hr compared to 74% mortality for fruit oil at 10 µl/L air after 168 hr. The results showed that EOP63 leaf oil has higher pesticidal potency with an LD_{50} value of 0.80 µl/L air after 24 hr.

C. chinensis:

Although only few oils were tested, *C. chinensis*, was the most susceptible insect species. At 5 µl/L air, total kill (100% mortality) was recorded after 24 hr for EOP63 fruit oil compared to 99% mortality after 72 hr for EOP65 leaf. The LD_{50} values were 0.70 and 1.60 µl/L air after 24 hr for EOP65 leaf and EOP63 fruit oils, respectively.

T. castaneum:

Of all the test insect species, T. castaneum was the most tolerant to plant essential oils. At the highest concentration of (10 µl/L air), only 22.5, 12.5, 50 and 8% adult mortality were observed after 168 hr for EOP62, EOP65 leaf, EOP63 leaf and EOP63 fruit oils, respectively. LD_{50} values were not computed due insignificant response to the test essential oils.

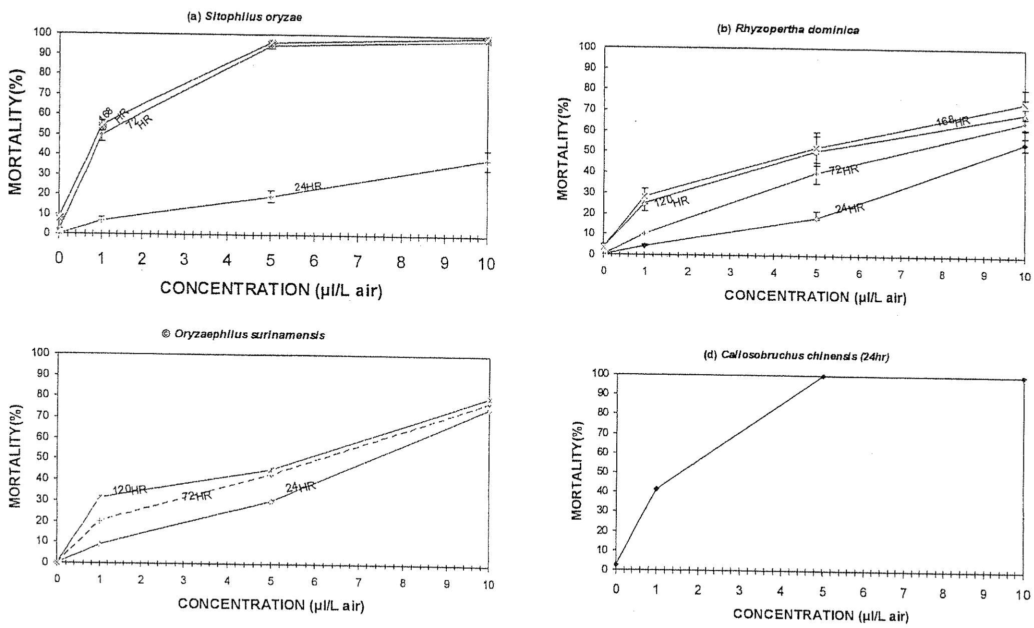


Fig.1b: Effect of EOP63 fruit essential concentration on adult mortality of *S. oryzae, R. dominica* and *O. surinamensis* over varied exposure times.

3.2 Contact toxicity

3.2.1 *Plant essential oils*

Twenty unsexed adult *S. oryzae* obtained from laboratory cultures (see section 2.1) were introduced into 1 L glass jars containing whole wheat grains admixed with varying amounts of test essential oils. Two test essential oils, EOP63 leaf and EOP63 fruit, were each applied at five rates (0, 0.25, 0.50, 1.0 and 1.2 µl/g) replicated thrice per treatment. A vegetable oil, crude soya oil and insects without food were included as control treatments. Percent adult insect mortality was recorded 1, 2, 4 and 6 days after treatment. Thereafter adult insects were removed and jars monitored for adult F1 progeny counts and survival 28, 35, 42 and 49 days after treatment. Data were subjected to ANOVA and means separated using least significance difference (LSD). Probit regression analysis of transformed data (Finney, 1971) used to estimate LD_{50} values. Preliminary results are reported in Fig.2.

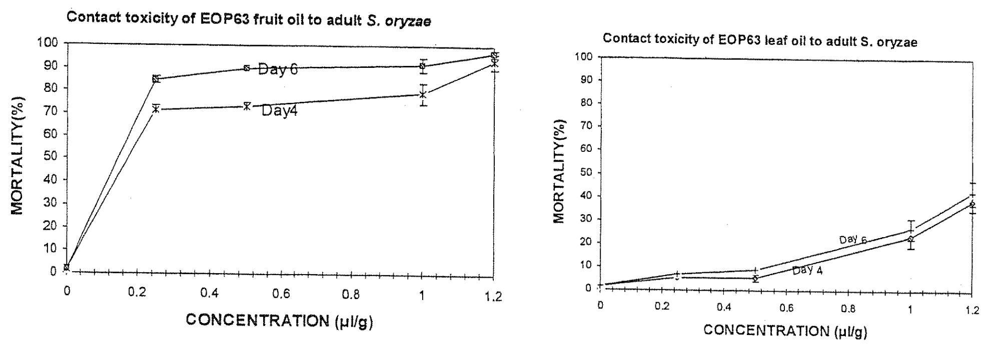


Fig. 2: Concentration x duration (day) of contact interaction effect of EOP63 fruit and leaf essential oils on mortality of adult *S. oryzae*.

The contact toxicity studies showed that efficacy was significantly influenced by plant part from which essential oil was extracted, concentration applied and the duration (days) of contact with plant oil. There was also significant concentration by duration of contact interaction effects on mortality. EOP63 fruit oil had higher contact toxicity to *S. oryzae* than oil extracted from the plant's leaves. At 1.2 µl /g, 96.7 and 42.4% mortalities were registered after 6 days for fruit and leaf essential oils, respectively. The LD_{50} values for fruit oil were 0.18 and 0.14 µl/g after 4 and 6 days, respectively. No LD_{50} values were computed for the leaf oil due to weak activity within range tested. Similar tests are being conducted for other stored-product insects and plant oils with a view to determining short- and log-term effects (toxicity, repellence, reproduction inhibition and feeding deterrence) and practical applicability.

3.2.2 Crude plant powders

Twenty unsexed adult *Sitophilus zeamsis* Motsch., *R. dominica* and *T. castaneum* obtained from laboratory cultures at Egerton University, Kenya, were introduced into 1 L kilner glass jars containing whole maize (*S. zeamais*) and whole/broken wheat (*R. dominica* & *T. castaneum*) grains admixed with varying amounts of crude powders of *Lantana camara* L. and *Tephrosia vogelii* Hook . The contact toxicity of each crude powder, obtained from different plant parts, was evaluated at five rates (0, 2.5, 5.0, 10.0 and 20%w/w) arranged in a completely randomised design (CRD) with four replicates per treatment. A synthetic insecticide, Spintor™ dust (naturalyte spinosad) at 0.056%w/w, was included as a positive control. Preliminary data on adult insect mortality were recorded 24, 72 and 120 hr after treatment. Data were first homogenised using angular transformation before being subjected to ANOVA and means separated by LSD. Probit regression analyses of transformed data (Finney, 1971) used to estimate LD_{50} values. Preliminary results presented in Figures 3 and 4 below.

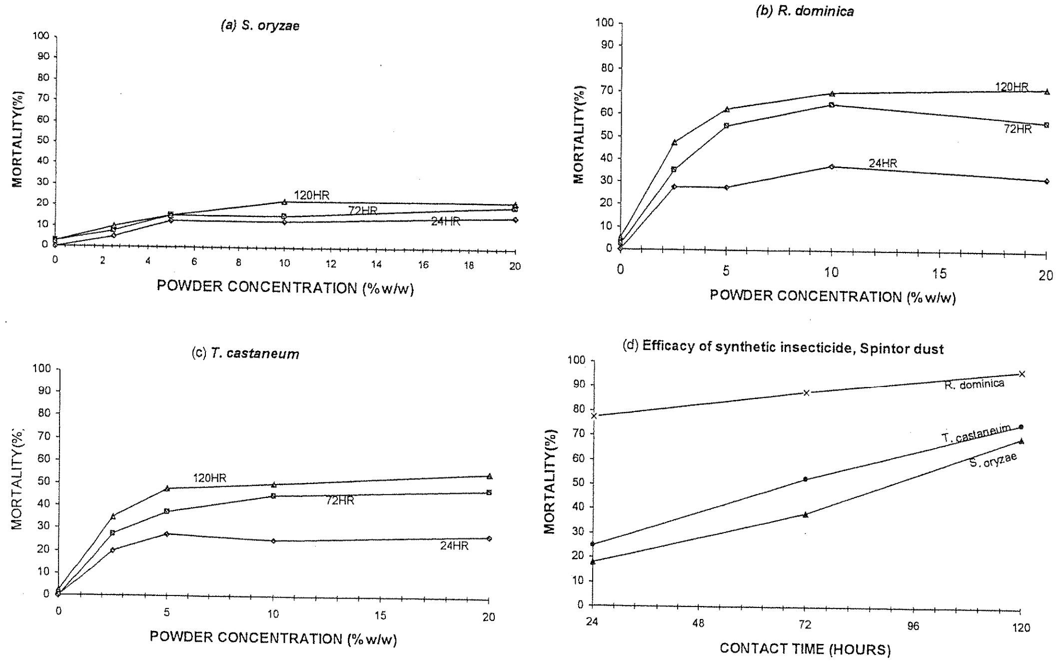
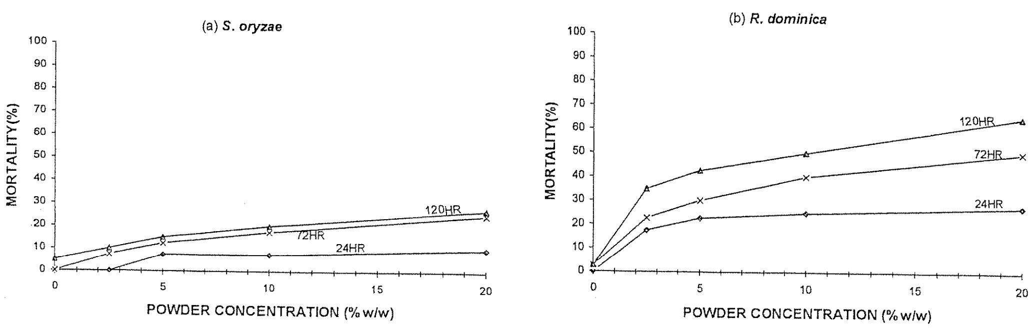
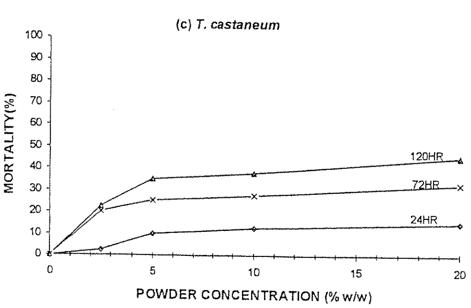


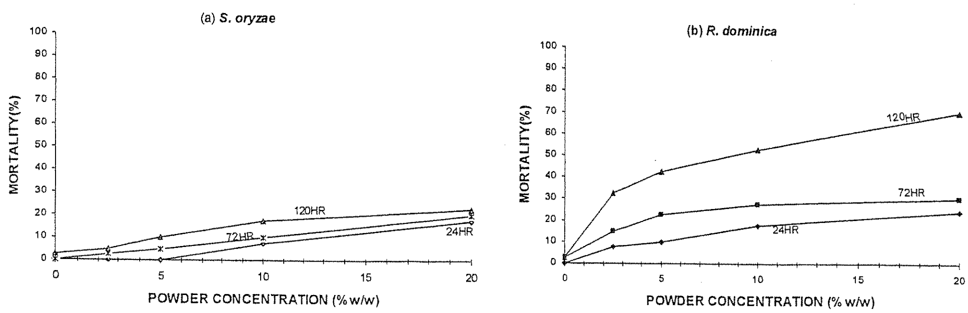
Fig.3(a): Efficacy of *L. camara* leaf powder against three stored-product insects compared to Spintor™ dust.

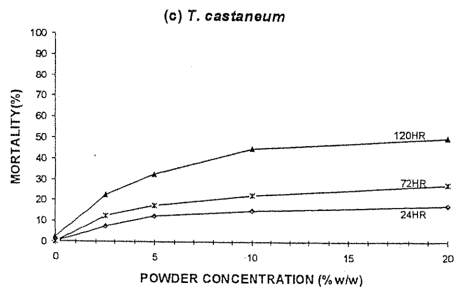




<u>NB:</u>
For comparison with Spintor™ dust see Fig.3(a)

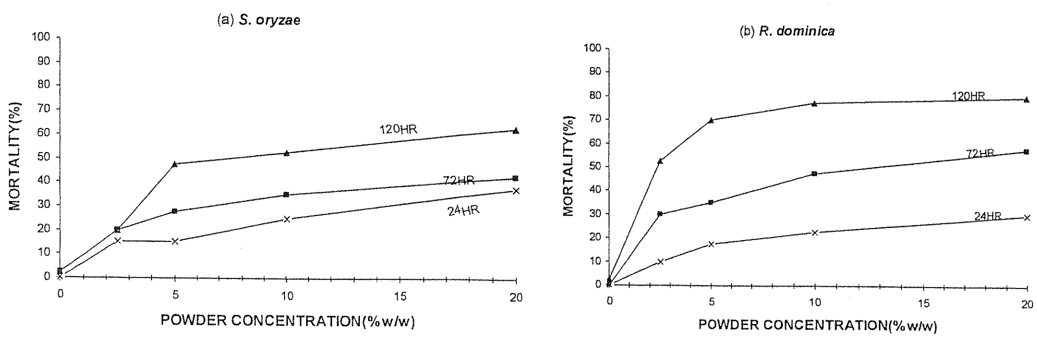
Fig. 3(b): Efficacy of *L. camara* stem powder against three stored-product insects

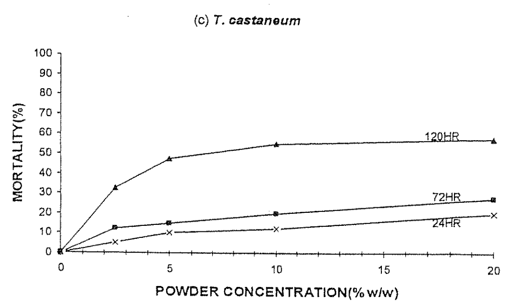




NB:
For comparison with Spintor™ dust see Fig.3(a)

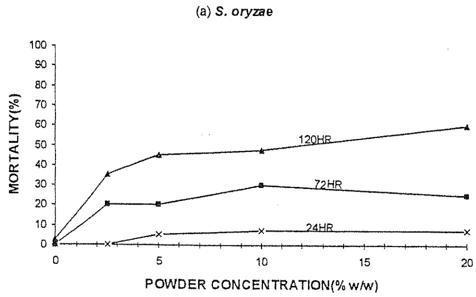
Fig. 3(c): Efficacy of mixture of leaf/stem/fruit powder of *L. camara* against three stored-product insects

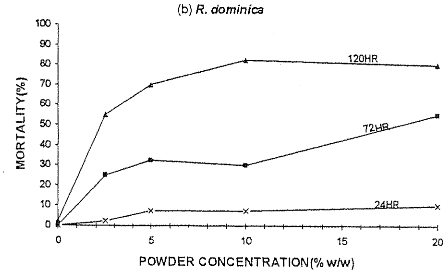


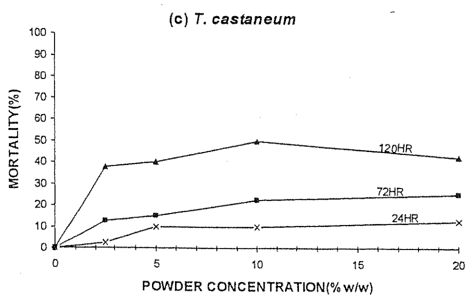


NB:
For comparison with Spintor™ dust see Fig.3(a)

Fig.4(a): Efficacy of *T. vogelii* leaf powder against three stored-product insects

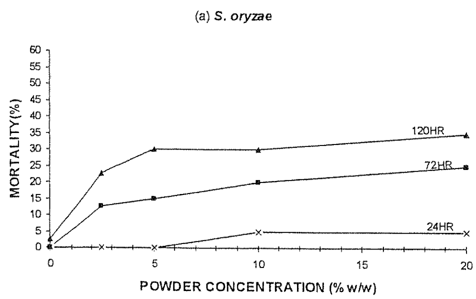


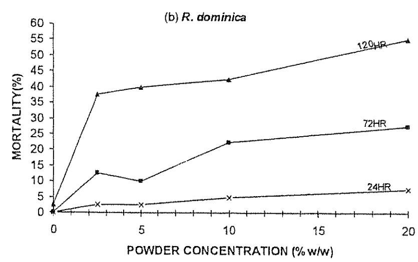


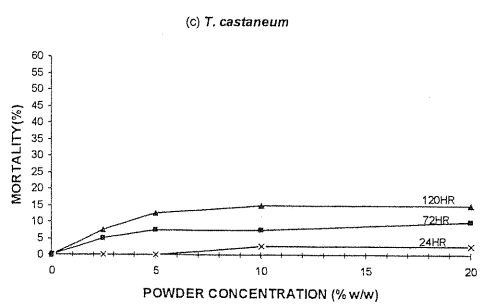


NB:
For comparison with Spintor™ dust see Fig.3(a)

Fig.4(b): Efficacy of *T. vogelii* fruit powder against three stored-product insects







NB:
For comparison with Spintor™ dust see Fig.3 (a)

Fig.4(c): Efficacy of *T. vogelii* stem powder against three stored-product insects

Table 2: Variation of crude powder LD_{50} values (%w/w) with respect to duration of contact with different stored-product insects in grain treatment[1].

Plant/Insect species	Duration (hours) after admixing grain with powder		
	24	72	120
***LANTANA CAMARA*:**			
Leaf power:			
S. oryzae	NC*	NC	NC
R. dominica	-	4.4	2.9
T. castaneum	-	-	5.0
Stem powder:			
S. oryzae	NC	NC	NC
R. dominica	-	20.0	10.0
T. castaneum	NC	NC	NC
Mixed (L/S/F) powder:			
S. oryzae	NC	NC	NC
R. dominica	-	-	8.5
T. castaneum	-	-	20.0
***TEPHROSIA VOGELII*:**			
Leaf power:			
S. oryzae	-	-	7.0
R. dominica	-	10.5	2.5
T. castaneum	-	-	6.0
Fruit powder:			
S. oryzae	-	-	11.6
R. dominica	-	17.6	2.4
T. castaneum	NC	NC	NC
Stem powder:			
S. oryzae	NC	NC	NC
R. dominica	-	-	15.2
T. castaneum	NC	NC	NC

*Available data insufficient for LD_{50} estimation. Figures presented are preliminary and likely to change once investigation process is complete.
[1]Twenty unsexed adult test insects, in four replicates, were used for each plant powder concentration (%w/w).

Preliminary results of contact toxicity studies with leaf, stem, fruit and / or mixed (leaf/stem/fruit) crude powders of two botanical plants, *L. camara and T. vogelii*, showed significant differential mortality of *S. oryzae*, *R. dominica* and *T. castaneum* adults (Fig.3-4; Table 2). Efficacy of powder applied was influenced by plant and insect species, part from which powder was obtained, dosage and duration (hours) of insect-treated grain contact. The leaf powders of both plants were more toxic to all test insects than stem, fruit and / or mixed (leaf/stem/fruit) powders. Irrespective of plant or part used, only <30-50% mortality of adult *S. oryzae* was recorded after 120 hr compared to 50-80 and <20-50% for *R. dominica* and *T. castaneum*, respectively. Based on mortality and LD_{50} values (Table 2 above), *R. dominica* was the most susceptible insect species. Further studies are underway in which additional control treatments, insects only with no food and a vegetable oil, are factored to enable us separate insect mortality due to anti-feeding activity. Also more information will be generated on the repellent activity based on different plant parts and dosage applied.

3.3 Repellence Tests

The repellent effect of EOP62 and EOP65 (leaf and fruit) essential oils were tested against the rice weevil, *S. oryzae*, in a choice bioassay according to Papachristos and Stamopoulos (2002) with modifications. The experimental units consisted of alternate treated (0, 0.1, 0.4, 0.8 and 1.2 µl/g) and untreated wheat grains (1 g) in small cups placed equidistant from the circular base of 1 L glass (12 cm diameter) jars. A no-choice control with untreated wheat grains was included among the treatments. Twenty unsexed adult *S. oryzae* (10-15d) were introduced at centre of each jar and top covered by towel paper held tightly with elastic bands. There were four replicates for each treatment arranged in a completely randomised design (CRD) in an insectary maintained at 30±2°C and 68±2% r.h. The numbers of insects that settled on the control, arena and treated grains were recorded after 24 hours. The percent repulsion (PR) was calculated (Papachristos and Stamopoulos, 2002 modified by Ogendo, 2006) as follows:

PR (%) = (C+A)

Where C and A represent percentage of insects in the control diet and arena, respectively. Positive (+) and negative (-) PR values interpreted as repellence and attraction, respectively.

Table 3: Mean percent repellence (±SE, n= 4) of EOP62 and EOP65 (leaf and fruit) essential oils against *S. oryzae* adults in choice bioassay

EXPOSURE TIME (HOURS)	PERCENT REPELLENCE (PR %)			
	CONCENTRATION OF ESSENTIAL OIL (µl/g)*			
	0.1	0.4	0.8	1.2
EOP62 OIL:				
1	44.8±14.3	59.1±7.5	41.1±14.7	29.4±10.7
3	68.9±8.0	74.8±10.5	52.4±13.5	61.4±13.7
5	79.5±5.5	73.2±12.5	65.7±11.3	51.8±13.9
24	72.6±9.8	89.7±2.6	74.6±7.4	54.1±8.4
LSD0.05	17.5	19.7	14.5	11.0
EOP65Leaf:				
1	70.8±11.2	79.2±9.3	86.7±4.9	78.3±10.2
3	76.7±7.8	73.3±12.0	79.2±4.6	75.0±7.5
5	66.7±8.1	60.0±16.0	73.3±5.4	70.8±10.0
24	55.0±7.2	50.0±14.1	72.5±4.6	79.2±7.9
LSD0.05	9.5	27.0	1.9	6.4
EOP65Fruit:				
1	75.0±7.6	93.3±1.7	76.7±11.7	90.0±0.0
3	73.3±6.0	80.0±5.0	75.0±10.0	83.3±4.4
5	70.0±7.6	71.7±4.4	80.0±5.8	76.7±13.3
24	40.0±16.1	48.3±4.4	46.7±8.3	90.0±5.0
LSD0.05	20.5	6.8	12.0	27.2

*The no-choice untreated control had a PR value of 0 and has been excluded from table.

All the three test essential oils were strongly repellent against the rice weevil, *S. oryzae*. The percent repellence (PR) was significantly influenced by the duration (hours) of exposure, concentration of oil applied to grain diet (µl/g) and the concentration by exposure duration interaction effects. Except for the highest concentration, the EOP62 oil showed a positive response to concentration and duration of exposure. However, EOP65 fruit oil showed positive response to increased concentration but the PR values decreased with duration of exposure. This observation is consistent with the findings of Ogendo *et al.*(2003) in which crude powders of *Tephrosia vogelii* Hook showed reduced PR values, at high concentrations, against the maize weevil, *S. zeamais* Motschulsky . This was explained by the arrestment of test insects in treated diets due contact toxicity. The results of contact toxicity studies (section 2.2 above) showed that EOP63 fruit oil was strongly toxic to S. oryzae. However, this is yet to be verified for EOP65 (fruit and leaf) oils.

3.4 On-going bioassay studies

The bioactivity studies reported above (2.1 to 2.3) represent only a fraction of activities being conducted as part of the wider objectives of the joint CDR program. In particular, the following research and training activities are currently in progress:

- Mr. Joshua O. Ogendo registered for his PhD studies at Egerton University, Kenya, in April 2005 and is currently at The Volcani Center, Israel, conducting laboratory studies. His PhD proposal is titled "**Bioactivity of essential oils of *Lantana camara* L., *Tephrosia vogelii* Hook and *Ocimum americanum* L. against major coleopteran pests of stored food grains**". His academic advisors comprise of Prof. A.L. Deng, Dr. A.W. Kamau (both of Egerton University) and Prof. Eli Shaaya (The Volcanic Center, Israel).
- Fumigant toxicity studies (space and grain) using crude plant essential oils and pure compounds isolated from a select few promising oils will be conducted.
- Contact toxicity studies with inbuilt reproduction inhibition (oviposition and feeding deterrence, F1 progeny) data collection.
- Repellence tests- choice bioassays using large (14-cm diameter) plastic Petri-dishes are planned for other stored-product insects.
- Anti-oviposition, egg-hatching and ovicidal/larvicidal tests on four major stored-product insects, *S. oryzae, R. dominica, T. castaneum* and *C. chinensis* are planned.
- Residual toxicity and repellence tests (short- and long-term) of individual test essential oils and their bioactive chemical constituents.

PLANT SAMPLES DELIVERED TO PROF. UZI RAVID FOR GS-MS (26/10/2006)

REF. NO.	Plant species	Family
1) EOP64F*	*Lantana camara* (leaf)	Verbenaceae
2) EOP64S*	*Lantana camara* (stems)	Verbenaceae
3) EOP68	*Hyptis spicigera*	Lamiaceae
4) EOP69	*Coriandrum sativum*	Umbelliferae/Apiaceae

*These samples form part of Joshua Ogendo's PhD study which requires partitioning bioactivity according different plant parts: leaf, stems and fruits.

PhD STUDY AUDIT CARD (LAB EXPERIMENTS) OCTOBER 25, 2006 ONWARDS

BIOACTIVITY TEST/OIL TESTED	INSECT SPECIES TESTED				
FUMIGANT TOXICITY TEST	SO	OS	RD	TC	CC
1) EOP65 LEAF	√		√	√	√
2) EOP65 STEM	√	√	√	√	
3) EOP65 FRUIT					
4) EOP63 LEAF	√		√	√	√
5) EOP63 STEM					
6) EOP63 FRUIT	√	√	√	√	√
7) EOP64 LEAF	√	√	√	√	√
8) EOP64 STEM					
9) EOP64 FRUIT					
REPELLENCE TEST (CHOICE BIOASSAY)					
1) EOP65 LEAF	√				
2) EOP65 STEM					
3) EOP65 FRUIT	√				
4) EOP63 LEAF	√		√	√	
5) EOP63 STEM					
6) EOP63 FRUIT					
7) EOP64 LEAF					
8) EOP64 STEM					
9) EOP64 FRUIT					
CONTACT TOXICITY/F1 PROGENY					
1) EOP65 LEAF					
2) EOP65 STEM					
3) EOP65 FRUIT					
4) EOP63 LEAF	√				√
5) EOP63 STEM					
6) EOP63 FRUIT	√		√	√	√
7) EOP64 LEAF					
8) EOP64 STEM					
9) EOP64 FRUIT					
ANTI-OVIPOSITION					
1) EOP65 LEAF					
2) EOP65 STEM					
3) EOP65 FRUIT					
4) EOP63 LEAF					
5) EOP63 STEM					
6) EOP63 FRUIT					
7) EOP64 LEAF					
8) EOP64 STEM					
9) EOP64 FRUIT					

PhD STUDY AUDIT CARD (LAB EXPERIMENTS) OCTOBER 25, 2006 ONWARDS

BIOACTIVITY TEST/OIL TESTED	INSECT SPECIES TESTED				
OVICIDAL/LARVAL SURVIVAL	SO	OS	RD	TC	CC
1) EOP65 LEAF					
2) EOP65 STEM					
3) EOP65 FRUIT					
4) EOP63 LEAF					
5) EOP63 STEM					
6) EOP63 FRUIT					
7) EOP64 LEAF					
8) EOP64 STEM					
9) EOP64 FRUIT					
FEEDING DETERRENCE					
1) EOP65 LEAF					
2) EOP65 STEM					
3) EOP65 FRUIT					
4) EOP63 LEAF					
5) EOP63 STEM					
6) EOP63 FRUIT					
7) EOP64 LEAF					
8) EOP64 STEM					
9) EOP64 FRUIT					
RESIDUAL CONTACT TOXICITY/F1 PROGENY					
1) EOP65 LEAF					
2) EOP65 STEM					
3) EOP65 FRUIT					
4) EOP63 LEAF					
5) EOP63 STEM					
6) EOP63 FRUIT					
7) EOP64 LEAF					
8) EOP64 STEM					
9) EOP64 FRUIT					
RESIDUAL FUMIGANT ACTIVITY					
1) EOP65 LEAF					
2) EOP65 STEM					
3) EOP65 FRUIT					
4) EOP63 LEAF					
5) EOP63 STEM					
6) EOP63 FRUIT					
7) EOP64 LEAF					
8) EOP64 STEM					
9) EOP64 FRUIT					