Potency of Traditional Insecticide Materials against Stored Bean Weevil, *Acanthoscelides Obtectus* (Coleoptera: Bruchidae) in Tanzania

Costancia Peter Rugumamu
Department of Zoology and Wildlife Conservation
University of Dar es Salaam
E-mail: wrugu@udsm.ac.tz

Abstract: *The bean weevil, Acanthoscelides obtectus is a major insect pest of stored common bean, Phaseolus vulgaris an important source of plant protein in many parts of the world, Tanzania inclusive. In rural Tanzania, most smallholder farmers apply traditional insecticide materials in the protection of bean from insect pests. The laboratory study investigates the potency of the selected traditional insecticide materials employed by small scale farmers to reduce stored bean losses caused by A. obtectus. The materials were identified and collected from Kimuli and Mabira villages in Kagera region and from Dar es Salaam. The effect of the materials to A. obtectus at different doses and durations was determined by both the number of surviving insects in treated set-ups reflecting the insect mortality and by the insects' reproductive performance at first filial generation (F_1). The findings revealed effectiveness of the materials against A. obtectus to vary in the order: Azadirachta indica > Tephrosia vogelii> Nicotiana tabacum > Vegetation ash > Ocimum gratissimum > Crassocephalum crepidioides. Kruskal-Wallis test indicated significant differences in the number of A. obtectus survivors among the treatments at different doses during the study periods and also in the number of insects' progeny (F_1) produced at the end of their life cycle. It was concluded that the materials exhibit potency against A. obtectus at varying levels.*

Keywords: Traditional insecticide materials, *Acanthoscelides obtectus,* potency, *Phaseolus vulgaris*, mortality.

INTRODUCTION

The Bean Weevil, *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae) is a cosmopolitan insect and a major insect pest of common beans of various species, *Phaseolus* spp. widely distributed in almost all continents (Hill, 1989; 2009; Paul, 2007). *A. obtectus* causes considerable economic losses to beans particularly under small-scale subsistence farming systems in East Africa (Mphuru, 1981; Paul, 2007). Tanzania produces more common beans than any country in East Africa as acknowledged by Hillocks *et al*., (2006) and Fivawo and Msolla (2011). It is reported in KDC (2009) and KDCU (2011) that more than 90% of the crop isgrown by small scale farmers under traditional production systems where on average farm sizes range from 0.5 ha to 2 ha.

Adult female *A. obtectus* fecundity is about 40 – 60 dirty white and pointed eggs which are laid normally on the outside of the pods and should the pods be dehisced, eggs are laid scattered among potential host seeds (Parsons and Credland, 2003). If infested pods from farms are harvested and taken into farm stores, further mating and postembryonic development of the insect take place in the stored beans. It is reported byQuzi (2007) and Hill (2009) among others that infestations of beans by bruchidsmoreoften originate from farm stores as adults can fly for up to half a mile. As reported by Hill (1987), larvae *A. obtectus* have biting and chewing type of mouthparts hence the pair of mandibles are strong, bore their way into the seed for feeding and development and the whole life cycle is about 4 – 6 weeks at a temperature of about 28^0 C and 70% Relative Humidity. Bruchid attack causes weight losses; reduces quality and viability of bean seeds (Hill, 1996).

The common bean, *Phaseolus vulgaris* L. was introduced to Africa from the highlands of Central and South America more than four centuries ago (Paul, 2007; Fivawo and Msolla, 2011). It is grown mainly for subsistence in the Great Lakes Region and has the highest per capita consumption in different countries, namely: Tanzania, Kenya, Malawi, Uganda and Zambia. Beans are both palatable and cheap source of protein; they also provide some complex carbohydrates, dietary fibre and folic acid (Hill, 1996; Jones, 1999). It is further noted by Jones (1999) and Paul (2007) that besides its green tender leaves; green pods, immature and/or dry seeds are also a delicacy. It is reported in the Agricultural Compendium (1985) that in terms of nutritive value, the protein content in 100 grams of fresh broad beans and peas is 5.6 grams. Amongst the staple food crops, beans are reported to have the highest level of variation in seed characteristics, namely: size, shape and colour resulting in about 40,000 varieties yet they all give identical total calories per gram (Wortmann and Allen, 1994; Fivawo and Msolla, 2011).

As reported by Jones, (1999),before the Rwandan refugees obtaining any surplus in Kagera region, Tanzania, there were substantial exports of beans from the region to Europe and that according to national data in 1990 actual production of bean was 369,100 metric tons with a surplus of 46,100 metric tons against the nation requirement which was at 323,000 tons. In farms of controlled schemes under conditions of improved cultivation practices, the yields of *P. vulgaris* was estimated at 2 tones/ha (Hillocks *et al.*, 2006). Despite the low yield under unimproved systems of production by small holder farmers in Tanzania, the crop is susceptible to bruchid stored insect pests including *A. obtectus*. Other serious field pests of the bean crop include, Aphids, *Aphis fabea* (Scop.), pod borers, *Maruca testulalis* Geyer, *Heliothus armigera* Hb. and flower beetles, *Ootheca bennigseni* Weise (Hill, 2009).

Protection of stored grains by a small proportion and particularly large scale farmers employ approved operators to carry out fumigation by using Aluminium Phosphide, an imported chemical pesticide (NRI, 2006). Smallholder farmers and other stakeholders such as food protectionists are, however, increasingly questioning the safety and reliability of the industrial chemical pesticides. It is advanced by Akhabuhaya and Lodenius (1988); Chapman and Reiss (1999); Carson (2002); Rotimio and Evbuomwan (2012) among others, that whereas chemicals can control pests both in farm fields and in storage; they have many adverse environmental impacts including damaging the fragile Ozone layer, human health as well as developing insect resistance whilst being erratically supplied. The industrial pesticides further exacerbate production costs particularly amongst the rural poor. It is in this light that various authorities advocate an Integrated Pest Management (IPM) approach for crop protection in order to reduce hazards to the environments (Neuenschwander *et al*., 2003; Ekesi *et al*., 2003; Rugumamu, 2009)

In rural areas crop pest management is a prominent problem as most smallholder farmers are yet to fully integrate synthetic insecticides into their insect pest management systems due to the prevailing subsistence economy and hence reliance upon traditional knowledge systems in meeting their protection needs (Warren, 1991;Mihale *et al*., 2009; Machocho *et al*., 2012). Components of IPM commonly employed to protect harvested crops from insect's attack and damage include traditional insecticide materials and maintaining granary hygiene. It is, however, reported in NRI (2006) that traditional insecticides are not consistent and often produce poor results given the very scanty investigations done on appropriate doses and resultant effect on pests. As reported by Rutatora and Mattee (2001) and Paul (2007) pest management activities in Tanzania have rarely been supported by thoroughly controlled local studies given that most interventions have been conducted during outbreak of pests wherein data obtained elsewhere is predominantly used in the crisis.

It was imperative therefore to investigate the potential effectiveness of all the reported traditional insecticide materials in the communities in order to filling the gap.Laboratory experiments to test the potency of the different doses of the materials at varying durations in the *A. obtectus* life cycle were carried out. As Elwell and Maas (1996); Taylor *et al*., (2012) correctly assert, in order to institute technological packages in appropriate stored pest management, it is paramount to have the knowledge about the nature of the crop to be stored, the biology of the pest involved, the available traditional methods of pest control and required lengths of storage periods. It is in this context that, traditional knowledge which belongs to a specific cultural group is appropriate as supported by Scoones and Thompson (1994); Flavier (1995); Muzale (2011); Mshigeni and Kinabo (2012). Traditional knowledge is local knowledge that is unique to a given ethnicity or society and it is the information base for a society and hence the basis for local level decision-making in agriculture amongst rural communities. Basing on the above evidence, it was imperative to collect information and the materials from a specific area where common beans are produced. It is hypothesized that the study will contribute to the Integrated Pest Management (IPM) approach by using traditional materials to reduce losses, preserve nutritional value, reduce storage costs as well as minimize hazards in the storage ecosystems.

MATERIALS AND METHODS

Sampling Sites the of Traditional Insecticide Materials

Five insecticide materials used by smallholder farmers to control the insect pest of beans in storagewere*Crassocephalum crepidioides, Ocimum gratissimum,* vegetation ash, N*icotiana tabacum* and *Tephrosia vogelii.* These were collected from Mabira and Kimuli villages located at the intersection of 31^0 27' E and 01^0 14'

S and at 31^0 21' E and 01^0 19' S respectively (Fig. 1). Being found in Kyerwa district, Kagera region, these villages are renowned for the production of beans in northwest Tanzania (KDCU, 2011).The sixth material, *Azadirachtaindica* grows mainly in coastal monsoon climatic conditions and was hence randomly collected at Ubungo - Kibangu at the intersection of 39^0 2' E and 6^0 8' S in Dar es Salaam region.

Identification of Traditional Insecticide Materials

Identification of the materials used to control insect pests of stored beans in the villages was carried out using informal interviews. Twenty women were purposefully sampled from each village on the basis of age - 40 years and above, where the village leaders guided the exercise. The age limit as recommended by the village leaders is also supported by Endely (1991); URT (2010) advancing that this group frequently engages in agricultural practiceandthe groupis acknowledged for being highly knowledgeable and skilled in the traditional technology of stored pest management.

Materials (leaves) from the plants used by the farmers were scientifically identified by plant taxonomists as shown in Table 1. The materials were collected for laboratory experiments on *A. obtectus*. Selected leaves - free from obvious/apparent pest infestations and or infection by diseases pathogens - were sampled from the villages and packed in plastic bags for immediate transportation to the laboratory. Vegetation ash was obtained from fields whose vegetation was burnt in preparation for the next planting season.

Insecticide materials preparation for the experiments

The plant leaves were thoroughly washed with distilled water. They were then dried for one week in the shade to avoid photodegradation of active ingredients by Ultra Violet light (Khater, 2012). Thereafter they were ground in an electrical blender and sieved through a 1 mm. mesh sieve to obtain powder. They were ground to ensure a better distribution when powders mix with experimental beans and as reported by Paul (2007) powdered materials are more effective in this kind of treatments than whole leaves.

Investigation of potency of the insecticidal materialsto *A. obtectus*

Two parameters which were used to determine the response of *A. obtectus* to the applied traditional insecticide materials are:

- *A. obtectus* mortality in beans treated with different insecticide materials at three doses in different periods as reflected by the number of insects surviving in the treatments.
- Reproductive performance of *A. obtectus*in the treated bean samples by recording the number at the end of the insect life cycle indicating the progeny population where F_1 emerges.

Setting up of Insect Cultures for Laboratory Experiments

In order to raise insects required for the experiments, the common bean, *P. vulgaris* infested by bruchids were collected from farmers' stores in the two villages and appropriately set in Kilner jars in the laboratory.Thereafter, entomological keys were used to identify the insects infesting the beans. The Bean Weevil, *A. obtectus* was the dominant pest and was hence sampled for the investigation of its response to the selected traditional insecticide materials.

The common beans used in the experiments were purchased from both farmers and local markets. They were disinfested by deep freezing for seven days and later dried and equilibrated with the experimental conditions of ambient temperature and Relative Humidity of about 20^0C - 28^0C and 70 - 80% respectively to avoid future infections by fungi as advanced by (Mphuru, 1981;Swella and Mushobozy, 2009; Varma and Anandhi, 2010; Khater, 2012; Oluwafemi, 2012). *A. obtectus* sampled from the established cultures were introduced in the equilibrated bean samples in jars and kept for ten days to deposit eggs. They were then removed from the bean samples. Later the emerging adults referred to as parents were collected for seven days consecutively. The male and female parent insects were to be used in the pesticides treated set-ups to determine the insects responses to the different insecticide materials presented at different doses. Other parents were introduced in the bean samples set as controls that did not contain pesticide materials.

Treatment Set -ups

Bean seeds (100g) free from infestation were placed in separate bottles and each mixed thoroughly with either a dosage of 2.5%; 5.0% or 7.5% weight by weight (w/w) of each insecticidal material in powder form (Ogendo *et al*., 2004; IIoba and Ekrakene 2006; Khater, 2012). The treated beans were infested with seven to ten day old 12 pairs of female and male (sex ratio 1:1) parent *A. obtectus*. The bottles were tightly covered with perforated pieces of aluminium foil to contain insects while allowing adequate ventilation. Four replicates were set for each dose of the treatments for every period of 1-7; 8-14; 15-21; 22-28 and 29-35 days. Controls in four replicates for each period contained only the beans and insects. Observations were made after every two days and at the end of each period the survived insects in each treatment were recorded for the determination of effects of the insecticide material to *A. obtectus* as reflected by mortality at each period and reproductive performance at the end of its life cycle.

Data Analysis

Mean numbers of *A. obtectus* that survived were calculated at different doses of the materials and also in different time intervals of the experiments. A non-parametric analysis of variance test, Kruskal-Wallis according to Gomez and Gomez, (1984); Sokal and Rohlf (2012) was employed to test for differences among the means of *A. obtectus* recorded in the insecticide materials at doses 2.5% w/w, 5.0% w/w and 7.5% w/w during the whole period of the study.

RESULTS

Methods Employed to Control Stored Bean Pests in the Communities

The respondents revealed that storage of beans was carried out after the seeds had been dried to their own satisfaction based on experience. The different insecticide materials applied to beans were reported to control bruchid insects for a period ranging from three to six months and that stored bean seed for next growing season was treated specifically with relatively higher concentrations than beans stored for routine domestic consumption. It became clear during discussions that there were no set criteria for either choice or dose of the pesticide materials to be applied at any one season. Despite farmers being aware of the existence of industrial pesticides they were of the view that using their traditional materials reduced the cost of production.

Effect of the Traditional Insecticide to the Bean Bruchid in the Laboratory

A. obtectus was affected variously by the six insecticide materials at different doses as exhibited in table two to six. The insects which survived at all doses and periods were decreasing in the set-ups as follows: *C. crepidioides*> *O. gratissimum*>Vegetation ash> N. *tabacum*>*T. vogelii*>*A.indica.* At the end of the life cycle the insect numbers increased in the same order but in *A.indica* treatment there was no insect (F_1) during this period.

Number of *A. obtectus*in Beans Treated with the Materials during seven day period

There were varying numbers of *A. obtectus* recorded at 2.5% dose within the seven days of treatments in all insecticide treatments. At doses 5.0% and 7.5% there was no insect which survived in beans treated with *A.indica* while some insects survived in other materials (Table 2). It is further shown in table 2 that the number of insects which survived (out of 24 initial parents) during this period in the five materials decreased with the increase in doses of the materials. During the period, more insects survived in *C. crepidioides* treatment in the three doses, the mean number ranging from 9.2 ± 0.60 (SE) to 17.7 ± 0.80 (SE) out of the initial 24 parent insects. Analysis of variance by Kruskal-Wallis of the number of insects which survived in the set ups of different materials indicated very significant differences among the materials at doses of 2.5%, 5.0% and 7.5% where $H (5) = 19.40$, $P = 0.0016$; $H (5) = 20.30$, $P = 0.0011$ and $H (5) = 19.80$, $P = 0.0013$ respectively.

***A. obtectus*Numbers in the Treatments Between the 8th and 14th Day Period**

In all treatments during the 8th to 14th day experimental period there were varying numbers of insects which survived at all doses in the materials except in *A. indica* (Table 3). Kruskal-Wallis test indicated very significant differences of insect survivors among the insecticide materials at $P< 0.05$, 5 df. The Kruskal-Wallis statistic, $H (5)= 21.73$; 20.42 and 20.31 at 2.5%, 5.0% and 7.5% doses respectively. It was however observed that insect survivors in the materials were variously fewer than in the previous period. At the dose of 2.5% the mean insect numbers were 3.75 ± 1.70 (SE) in *T. vogelii* and 17.5 ± 1.19 (SE) in *C. crepidioides* out of the initial number of insect parentswhile at 5.0% and 7.0% doses the number of insect survivors exhibited a sharp decrease (Table 3).

Number of *A. obtectus*in the Treatments during the third week Period

Varying numbers of *A. obtectus* were recorded in the five materials at doses 2.5% and 5% while at 7.5%, a mean of 1.7 ± 0.47 (SE) insects were recorded only in *C. crepidioides* and there was no insect which survived in the other materials at the same dosage (Table 4). Kruskal-Wallis test indicated significant differences among numbers of insects that survived in the different materials at the three doses as indicated by the varying H values at $P< 0.05$, 5 df.

A. obtectusin Beans Treated with the Materials during the fourth week

There was a slight increase of insect numbers during this period in the materials compared to the previous period at the dose of 2.5% with the exception of *A. indica.* In *C. crepidioides* treatment, a mean number of21.7 ± 1.70 (SE) insects were recorded. There was however no insect observed in *T. vogelii* treatment at doses 5.0% and 7.5% and also in *N. tabacum* treatment at the dosage of 7.5% as shown in table 5. Analysis of variance indicated extremely significant differences in the number of insects recorded among the different insecticide treatments at the different doses. The Kruskal-Wallis statistic H values at $P < 0.05$, 5 df were 22.79; 21.94, and 22.52, at the doses of 2.5%, 5.0% and 7.5% respectively.

Number of *A. obtectus*in the Treatments duringthe Period of fifth week

The insects recorded during this period in the five insecticide materials at a 2.5% dosage increased in number in relation to the record during the fourth week of the experiment (Table 6). There was no insect recorded at the dose of 5.0% and at the dose of 7.5% in *T. vogelii* and *N. tabacum* treatments during this period. There were insects recorded in the other treatments although they were very few in number as the insecticide dosage increased. Analysis of variance of the insects in the materials showed significant differences at $P< 0.05$, 5 df and the H value ranged from 17.97 to 22.52.

Number of *A. obtectus* in Controls (Untreated) set ups

During the first three weeks of the experiment, the insect numbers (parents) in the controls were about the same as the initial infestations, ranging from 87% to 96% in the set ups. *A. obtectus* increased in number starting from the fourth week and during the fifth week the adult insects recorded were up to eight times the original number of parents in the control set ups.

DISCUSSION

Effect of the Insecticide Materials on *A. obtectus*

As shown in the preceding section, the response of *A. obtectus* to the traditional insecticide materials was demonstrated by two parametersnamely, first, the number of the parent insects which died in the beans treated with the insecticide materials at different doses in different periods and second, the number of insects which were recorded after the completion of the life cycle.

In beanstreatedwith *A. indica*, *T. vogelii*, *N. tabacum* and vegetation ash, most parent insects died during the early days of the experiment even at lower doses, a condition which could be explained by the rapid effect of the applied insecticide materials to the insect pest. Continued *A. obtectus* decrease in number due to mortality was recorded up to the third week but later the number of insects increased and this was undoubtedly due to progeny production with F_I emerging at the end of the insect life cycle (Chapman, 1998).

Further, very few or no any progeny were developed in the various treatments probably because the parent insects died before depositing eggs or may be the eggs were deposited at unsuitable sites as the applied materials might have occupied most of the suitable sites. It is noted by Hill (1987; 2009) for instance, that most bruchids are site specific in egg deposition even though Parsons and Credland (2003) claim that *A. obtectus* is a nonconformist bruchid in terms of egg oviposition site determination. Furthermore, some deposited eggs could probably not develop through the larval and pupal postembryonic stages to adulthood due to the insecticidal effects of the applied materials.

In crude Neem, the main insecticidal constituent is azadirachtin ($C_{35}H_{44}O_{16}$) which acts as an anti-feedant affecting insect physiology. Kazi *et al*., (2003) and Khater, (2012) noted that azadirachtin interferes with the peripheral nervous system and is also a toxicant when ingested by an insect. Besides, the potency of *A. indica* is linked to its action as a growth regulator on larval insects by disrupting the moulting process, growth inhibition and malformation that ultimately contributes to insect mortality. The bioactive constituents of the crude Neem and other plant pesticide materials are however, reported to be non-toxic to mammals and to have low persistence in the environment thus safe for use as an insecticide to protect stored products for human consumption (Raja *et al*., 2001). Indeed, *A.indica* was used in this study as a benchmark given its renowned effect as a traditional insecticide as accredited by (Kumar *et al*., 2005; Paul, 2007; Khater, 2012).

For the comparatively less effective materials, responses of the insects were indicated by more insect parents surviving and progeny production on and or after the fourth week of treatments. Specific properties of the different pesticide materials are considered to result in varied responses demonstrated by *A. obtectus* numbers recorded in beans treated with different pesticides at different doses. The same observation was reported by IIoba and Ekrakene (2006) on the effect of *A. indica*, *Hyptis suaveolens* and *Ocimum gratissimum* against *Sitophilus zeamais* and *Callosobruchus maculatus.*The botanical materials used in the study may either be chemically poisonous and/or physically repelling due to strong ordours that could inhibit insects from feeding, a situation which could lead to their ultimate death (Bekele *et al*., 1996; Elwell and Maas, 1996; Asawalam *et al*., 2008; Araya and Emana, 2009). It is reported that leaves of *T. vogelii,* an antifeedant insecticide contain rotenoids and flavonoid compounds which have profound effect on development and behaviour of insect pests and that at the rate of 0.1% w/w they controlled bruchids, maize weevils and the Larger Grain Borer, *Prostephanus truncatus*.

The ash material applied to the beans may have been corrosive to some areas of *A. obtectus* exoskeleton made up of the cuticle, a mucopolysaccharide material. When ash acts on the less sclerotized, membranous parts of the cuticle, particularly inter-sclerite areas it reduces the cuticle impermeability to water causing fluids loss and finally insect dehydration and death. Due to abrasion by ash, the cuticle might also become dysfunctional with respect to its role as a barrier to pathogens' direct entrance into the insect body (Elwell and Maas, 1996; Chapman, 1998). Some ash particles could as well get their way to the insect tracheal system through spiracles which are concentrated on insect lateral sides of abdomen tagmata up to tracheoles and hence impede the normal process of gaseous exchange where oxygen from the spiracles to the tissues must finally reach the mitochondria in order to accomplish the process of oxidation.

As reported by Chapman (1998), tracheoles contain specific column of fluids close to its terminal in muscle tissues and since the column ends lack cuticular material, gaseous exchange take place by diffusion at the gas fluid muscle interface where oxygen diffuses through fluids into tissues. This process could be interrupted by the ash particles and hence lower the insects' physiological activities which depend on appropriate gaseous exchange through the fluid medium. Ash materials were observed to also interrupt insects' mobility between and among bean seeds in search for egg oviposition sites and/ or food.

CONCLUSIONS AND RECOMMENDATIONS

The potency of materials at different doses was indicated by increased mortality and reduced reproductive performance of *A. obtectus* during the study period. It was revealed therefore that, mortality of *A. obtectus* in stored beans is dependent on the type of the traditional insecticide material used; the dose applied to the beans as well as the duration of the treatment. The decreased insect population is a condition of paramount importance in pest control strategies.

Basing on the increased mortality and/or reduced to no reproduction of *A. obtectus*,it is deduced that the materials in powder form has the potential to control the insect pest in rural storage systems at the determined doses which decrease the insect population.*A.indica, T. vogelii* and *N. tabacum* are very promising and therefore could be strongly promoted as the most effective control materials against *A. obtectus*while vegetation ash, *O. gratissimum* and *C. crepidioides* could also be employed particularly to protect beans stored for routine home consumption. It may be postulated that the potency of the materials adequately demonstrates the ingenuity of the smallholder farmers in combating stored bean loss and enhancing food security.

In the light of the findings and given that the materials are readily available, sustainable, environment friendly (as they are biodegradable) and cost effective, it is recommended that farm storage trials of the identified insecticide materials should form issues for next research. Further, investigations of integrating insecticide materials could be carried out in order to determine synergistic effects of various material combinations in the control of insect pests of stored beans.

ACKNOWLEDGEMENT

The author is grateful to the technical staff in the Department of Biological Sciences, Dar es Salaam University College of Education that supported in raising insect cultures and sampling of insects during laboratory experiments. Appreciations go to the plant taxonomists and smallholder farmers who identified the materials, to the local leaders for their assistance in rapport building in the villages.

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Table 1: Traditional insecticide materials used in the study

Common name	Scientific name	Family
Neem	*Azadirachta* i*ndica*	Meliaceae
Fish poison bean	*Tephrosia vogelii* Hook	Fabaceae
Tobacco leaves	*Nicotiana tabacum*	Solanaceae
Vegetation ash	-	-
African Basil	*Ocimum gratissimum*	Lamiaceae
Thickhead	*Crassocephalum crepidioides* (Benth.)	Asteraceae

Table 2: Mean number (±SE) of *A. obtectus* survivors (out of the initial 24) in the beans treated with insecticide materials at three different doses during the first week of the study (means of four replicates)

Insecticide material	Mean number of *A. obtectus* (±SE) in three doses (% w/w) (means of four replicates)		
	2.5%	5.0%	7.5%
Azadirachtaindica	1.0 ± 0.40	0.0	0.0
Tephrosia vogelii	7.5 ± 1.19	4.0 ± 0.91	1.7 ± 0.62
Nicotium tabasum	12.5 ± 1.32	4.2 ± 0.62	2.5 ± 0.64
Vegetation ash	13.0 ± 0.91	8.5 ± 1.25	4.5 ± 0.64
Ocimum gratissimum	14.0 ± 1.22	11.7 ± 1.93	5.7 ± 1.10
Crassocephalum crepidioides	17.7 ± 0.85	13.2 ± 1.65	9.2 ± 0.62

Table 3: Mean number (±SE) of *A. obtectus* survivors (out of the initial 24) in the beans treated with the insecticide materials at three different doses during the second week of the study (means of four replicates)

Insecticide material	Mean number of *A. obtectus* (±SE) in three doses (% w/w) (means of four replicates)		
	2.5%	5.0%	7.5%
Azadirachtaindica	0.0	0.0	0.0
Tephrosia vogelii	3.7 ± 1.70	1.0 ± 0.70	0.5 ± 0.28
Nicotium tabasum	7.2 ± 1.10	1.2 ± 0.62	0.2 ± 0.25
Vegetation ash	11.2 ± 0.47	4.0 ± 0.91	1.2 ± 0.25
Ocimum gratissimum	14.0 ± 0.91	9.50 ± 0.64	2.7 ± 0.47
Crassocephalum crepidioides	17.5 ± 1.19	13.7 ± 1.03	9.0 ± 0.91

Table 4: Mean number (±SE) of *A. obtectus* survivors (out of the initial 24) in the beans treated with insecticide materials at three different doses during the third week of the study (means of four replicates)

Insecticide material	Mean number of *A. obtectus* (±SE) in three doses (% w/w) (means of four replicates)		
	2.5%	5.0%	7.5%
Azadirachtaindica	0.0	0.0	0.0
Tephrosia vogelii	1.0 ± 0.40	0.2 ±0.25	0.0
Nicotium tabasum	3.7 ± 0.47	1.2 ± 0.62	0.0
Vegetation ash	7.7 ± 0.85	1.7 ± 0.47	0.0
Ocimum gratissimum	12.2 ± 1.79	3.7 ± 0.85	0.0
Crassocephalum crepidioides	14.5 ± 1.70	9.5 ± 0.64	1.7 ± 0.47

Table 5: Mean number (±SE) of *A. obtectus* recorded in the beans treated with insecticide materials at three different doses during the period the fourth week of the study (means of four replicates)

Insecticide material	Mean number of *A. obtectus* (±SE) in three doses (% w/w) (means of four replicates)		
	2.5%	5.0%	7.5%
Azadirachtaindica	0.0	0.0	0.0
Tephrosia vogelii	0.5 ± 0.28	0.0	0.0
Nicotium tabasum	5.0 ± 0.91	0.2 ± 0.25	0.0
Vegetation ash	10.5 ± 0.64	2.2 ± 0.47	0.25 ± 0.25
Ocimum gratissimum	15.0 ± 0.70	6.25 ± 1.10	0.50 ± 28
Crassocephalum crepidioides	21.7 ± 1.70	11.50 ± 0.64	2.50 ± 0.64

Table 6: Mean number (±SE) of *A. obtectus* recorded in the beans treated with insecticide materials at three different doses during the fifth week of the study (mean of four replicates)

Insecticide material	Mean number of *A. obtectus* (±SE) in three doses (% w/w) (means of four replicates)		
	2.5%	5.0%	7.5%
Azadirachtaindica	0.0	0.0	0.0
Tephrosia vogelii	3.5 ± 0.28	0.0	0.0
Nicotium tabasum	9.7 ± 1.79	0.7 ± 0.25	0.0
Vegetation ash	24.7 ± 2.13	6.5 ± 0.64	0.75 ± 0.47
Ocimum gratissimum	58.2 ± 1.25	10.5 ± 0.64	1.00 ± 0.40
Crassocephalum crepidioides	71.2 ± 1.31	19.5 ± 2.90	4.50 ± 1.19