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EFFICACY OF VEGETABLE OILS AGAINST DRY BEAN BEETLES *Acanthoscelides obtectus*

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ABSTRACT

Acanthoscelides obtectus (Say) is a major pest of stored dry beans (*Phaseolus vulgaris* L.) and other legumes world wide. The objective of this study was to assess the efficacy of castor (*Ricinus communis* L.) and cottonseed (*Gossypium hirsutum*) oils against *A. obtectus* on stored dry beans under laboratory conditions. Castor and cottonseed oils at 0, 3, 4.5, 6, 7.5 and 9 ml kg^{-1} were tested against *A. obtectus.* All bioassays were conducted at 28 ± 1 °C and 65 ± 5% relative humidity, and mortality recorded after 24, 48, 72, 96 and 120 hr of exposure. After the 120 hr mortality count, all the adults were removed and the vials were maintained at the same conditions for 35 days to assess progeny production. Mortality of *A. obtectus* significantly (P<0.05) increased with increase in dose of oil treatments and exposure interval. After 120 hr of exposure, mortalities were 99.1 and 74.1% at the highest dose (9 ml kg^{-1}) with castor oil and cottonseed oil, respectively. The lowest LC_{50} value of 2.95 ml kg^{-1} and complete suppression in progeny production were achieved on beans treated with castor oil at 9 ml kg^{-1}. However, in all treatments, the percentage of progeny reduction was more than 80%. In conclusion, results indicate that vegetable oils have great potential for *A. obtectus* control.

Key Words: Cameroon, castor, cotton, *Phaseolus vulgaris*, progeny reduction

RÉSUMÉ

Acanthoscelides obtectus (Say) est un important ravageur des haricots secs et autres légumineuses stockées à travers le monde. L'objectif de cette étude était d'évaluer l'efficacité des huiles de ricin (*Ricinus communis* L.) et coton (*Gossypium hirsutum*) contre *A. obtectus* peste de haricots secs dans des conditions de laboratoire. L'huile de Ricin et l'huile de coton à 0, 3, 4, 5, 6, 7.5 et 9 ml kg^{-1} ont été testés contre *A. obtectus*. Tous les essais biologiques ont été effectués à 28 ± 1 °C et 65 ± 5% h.r. et de la mortalité a été enregistrée 24, 48, 72, 96 et 120 heures après exposition. Après 120 hr, tous les adultes ont été retirés et les flacons ont été maintenus dans les mêmes conditions pendant 35 jours pour évaluer l'effet des huiles sur la production et la descendance. La mortalité des *A. obtectus* a augmenté de façon significative (P<0.05) avec l'augmentation de la dose de traitements et le temps d'exposition. Après 120 heures d'exposition, les mortalités étaient de 99,1 et 74,1% à la dose la plus élevée (9 ml kg^{-1}) avec de l'huile de ricin et l'huile de coton, respectivement. La plus basse valeur de concentration létale 50 (CL_{50}) de 2,95 ml kg^{-1} et une suppression complète de la production de la descendance ont été réalisées sur des graines traitées à l'huile de ricin à 9 ml kg^{-1}. Cependant, dans tous les traitements, le pourcentage de réduction de la descendance était supérieur à 80%. En conclusion, les résultats indiquent que les huiles végétales ont un grand potentiel pour le contrôle *A. obtectus*.

Mots Clés: Cameroun, castor, coton, *Phaseolus vulgaris*, la réduction de la descendance

INTRODUCTION

Dry beans (*Phaseolus vulgaris* L.), is an important food legume and an essential component of cropping systems in the drier and marginal areas of the tropics and subtropics. With their high protein content (21 to 25%), dry beans are natural supplements to cereals, root and tuber staples in the human diet in sub-Saharan Africa (Cherry *et al*., 2005).

The beetles of the family Bruchidae are closely associated with the plant family, Leguminosae, and many species are important primary insect pests of stored legumes (Rajapakse and Van Emden, 1997). The dry bean beetle, *Acanthoscelides obtectus* (Say), is an important pest of dry beans. The entire life cycle of this pest insect can be completed on stored seeds, without return to the field. This beetle is characterised by a high reproductive capacity, which leads to high population levels in a relatively short period (Balachowsky, 1962). Economic damage caused by larvae developing inside beans is extremely important in some countries where seeds of Leguminosae represent a fundamental food resource (Romero-Arenas *et al*., 2013).

The control of *A. obtectus* relies mainly on the application of synthetic insecticides on stored grains. These insecticides are primarily organophosphorous and pyrethroid compounds, and the residues from a single application can often prevent insects from establishing in stored grain. However, use of residual insecticides is becoming less desirable because of the resistance in major insects (Pimentel *et al*., 2007), regulatory restrictions on use of insecticides, awareness of environmental pollution, the increasing cost of storage insecticides, erratic supplies, worker safety and consumer desire for a pesticide-free product. This has led to pest management specialists reappraising natural products (Lorini and Galley, 1999; Ayvas *et al*., 2010).

Plant products have played an important role in the traditional methods of protection against crop pests and disease vectors (Haghtalab *et al*., 2009; Céspedes *et al*., 2014). In ancient times, oils obtained from locally available plants were used for stored grain protection against insect attack. Similarly, in recent years, attention has been given to the use of vegetable oils as post harvest grain protectants against insects (Obeng-ofori *et al*., 2000; Oben-ofori *et al*., 2005; Kumar *et al*., 2007). Insecticidal vegetable oils kill insects on contact by disrupting gas exchange (respiration), cell membrane function or structure. They also kill them by disrupting their feeding on oil-covered surfaces or even act as insect growth regulators (IRGs) by affecting metamorphosis (Weaver and Subramanyam, 2000).

The objective of this study was to assess the efficacy of castor (*Ricinus communis* L.) and cottonseed (*Gossypium hirsutum*) oils against *A. obtectus* on stored dry beans under laboratory conditions.

MATERIALS AND METHODS

Inoculation with *A. obtectus*. The initial insect (*A. obtectus*) stock culture was obtained from the Faculty of Agriculture and Agricultural Sciences (FASA), University of Dschang, Cameroon. Insect cultures were maintained in plastic containers (4 L) with 5 kg of insecticide-free organic dry beans, *P. vulgaris* var. *Cannellino* obtained from a commercial supplier. About 1500 unsexed adult bean weevils were placed in 10 four-liter plastic containers, each containing 5 kg of beans and covered with nylon mesh. The insects were allowed for two-week oviposition and then transferred to fresh bean grain in order to produce sufficient amount of progeny weevils of the same batch. Each plastic container, where the adult bean weevils oviposited, was kept for progeny emergence.

Thirty five days after introduction of weevils, those that emerged were removed daily, until the progeny emergence ceased; those that emerged on the same day were transferred to fresh grain in small glass jar (1 L) and were kept at room conditions (28 ± 1 °C and 65 ± 5% relative humidity until sufficient number of weevils were obtained. Infested grains were incubated at natural photoperiod. Every 2 months, 150–200 unsexed adults were transferred into a similar jar containing fresh beans to perpetuate the strain. Pure Castor (*Ricinus communis* L.) and cottonseed (*Gossypium hirsutum*) oils (Premier Oils Mills Ltd.) were purchased from a local supermarket.

Bioassays. Six lots of 400 g of beans were placed in separate cylindrical jars and treated with appropriate oil formulation. On the basis of preliminary tests, the following bioassay treatments were used; 0, 3, 4.5, 6, 7.5 and 9 ml kg^{-1} of oils. All jars were shaken manually for approximately 5 min to achieve equal distribution of the oils in the entire grain mass.

Four samples of 50 g of beans each were taken from each jar as replication. Thirty adult beetles of similar age were used for each replication. Mortality was enumerated every 24 hr. All experiments were carried out in 28 ± 1 °C and 65 ± 5% relative humidity. After the 120 hr mortality count, all adults (dead and alive) were removed from the vials and the vials were left at room conditions for further 35 days to assess progeny production.

Statistical analysis. The mortality counts were corrected by using Abbott's formula (Abbott, 1925). Percentage of reduction in progeny production was determined by the formula (Aldryhim, 1990).

$$\text{RPP (\%)} = \frac{N^o \textit{ progeny in control} - N^o \textit{ progeny in treatment} \times 100}{N^o \textit{ progeny in control}}$$

Where:

RPP = Reducation in progeny production

The mortality rate of adults and percentage of reduction in progeny production were arcsine transformed to normalize the data. The data were analysed using Analysis of Variance. Means were separated by Tukey Multiple Range Test at P = 0.05. The dose required to kill 50% of the insects (LC_{50}) was estimated using probit analysis (SPSS, 1999).

RESULTS AND DISCUSSION

Mortality in the control treatment was very low and did not exceed 4.1% in all the experiments (Table 1). There was a general increase in cumulative insect mortality with an increase in oil concentrations between the first and the fifth day of bioassay. Castor oil exhibited the highest contact activity against the dry beans beetles. The highest mortality level (99.1%) was recorded at 9 ml kg^{-1} after 120 hr exposure interval (Table 1).

Cottonseed oil also induced significantly high (P < 0.05) mortality rate (74%) at the highest dose

TABLE 1. Mean mortality (% ± ESM) of *A. obtectus* adults infesting dry beans treated with castor oil after 24, 48, 72, 96 and 120 hours of exposure

Time	Commercial castor oil (ml kg^{-1} of dry beans)					
	0	3	4.5	6	7.5	9
24 hr	0.0 ± 0.0a	7.5 ± 1.5b	13.3 ± 3.0b	13.3 ± 1.9b	11.6 ± 1.6b	20.8 ± 2.0b
48 hr	0.8 ± 0.8a	14.1 ± 2.0b	21.6 ± 4.4b	24.1 ± 2.0b	25.0 ± 3.4b	54.1 ± 2.5b
72 hr	2.5 ± 0.8a	20.8 ± 3.4b	30.0 ± 4.9b	34.1 ± 3.4b	40.0 ± 5.2b	75.8 ± 0.8b
96 hr	4.1 ± 1.5a	34.1 ± 4.3b	45.8 ± 5.6b	52.5 ± 5.5b	59.1 ± 6.4b	96.6 ± 2.3b
120 hr	4.1 ± 1.5a	50.8 ± 4.1b	72.5 ± 7.8b	85.0 ± 7.2b	90.8 ± 3.6b	99.1 ± 3.4b

Means followed by the same letter in the same row do not differ statistically at P < 0.05

(9 ml kg^{-1}) that was comparable with mortality induced by castor oil at the concentrations of 4.5 and 6 ml kg^{-1} (Table 2). Dead insects from oil-treated grain showed signs of rapid immobilisation, with their legs flexed and clinging to either the grain or the container surface.

Previous studies have demonstrated the effectiveness of different vegetable oils in protecting grains against major stored-product insect pests (Obeng-ofori and Amiteye, 2005; Wanyika *et al*., 2009). These characteristics were similar to those observed in other studies (Haghtalab *et al*., 2009), the mode of action of vegetable oils is not clearly understood, but it has been suggested by Don-Pedro (1989) that insect death caused by oils is due to anoxia or interference in normal respiration resulting in suffocation (Schoonhoven, 1978). The oils could also act as antifeedants or modify the storage micro-environment, thereby discouraging insect penetration in the grain and feeding (Obeng-ofori, 1995; Haghtalab *et al*., 2009). These results highlight the need for additional screening of more plant materials such as neem oil for use in insect pest management of stored products.

Castor oil had the lowest lethal concentration (LC_{50}) value (2.95 ml kg^{-1}), following the 120 hr exposure period; while LC_{50} of cottonseed oil was 5.95 ml kg^{-1} (Table 3). Application of oils significantly (P<0.05) reduced progeny production in dry beans. The effect was significant in both oils, castor and cotton, with reduction of 93-100% and 85-98%, respectively. For both oils and at all the doses, percentage reduction in progeny production was 85% for cottonseed oil and 93% with castor oil, even at the low application rate. The highest progeny reduction of 100% was observed in dry beans treated with castor oil at the rate of 7.5 and 9 ml kg^{-1} (Fig. 1).

Pacheco *et al*. (1995) used refined soybean and crude castor oils to control infestations of beetles *Callosobruchus maculatus* and *Callosobruchus phaseoli* (Gyllenhal) in stored chickpea (*Cicer arietinum* L.). They observed that both oils inhibited population growth of the two insect species, with castor oil being more effective than soybean oil. Credland (1992) explained the ovicidal effect of oils on bruchids in terms of asphyxiation by occluding a funnel which is probably the major route of gas exchange

TABLE 2. Mean mortality (% ± ESM) of *A. obtectus* adults infesting dry beans treated with cotton seed oil after 24, 48, 72, 96 and 120 hours of exposure

Time	Cotton seed oil (ml kg^{-1} of dry beans)					
	0	3	4.5	6	7.5	9
24 hr	0.0 ± 0.0a	4.1 ± 1.5b	6.7 ± 1.3b	10.8 ± 2.0b	11.6 ± 2.1b	15.0 ± 1.0b
48 hr	0.8 ± 0.8a	10.0 ± 1.3b	14.1 ± 2.8b	18.3 ± 3.1b	21.7 ± 2.1b	40.8 ± 3.6b
72 hr	2.5 ± 0.8a	11.7 ± 2.1b	21.7 ± 2.1b	24.1 ± 2.1b	29.1 ± 3.4b	51.6 ± 2.1b
96 hr	4.1 ± 1.5a	22.5 ± 5.1b	25.8 ± 3.1b	29.1 ± 2.8b	46.6 ± 2.3b	66.7 ± 4.9b
120 hr	4.1 ± 1.5a	35.0 ± 3.1b	35.8 ± 2.8b	41.7 ± 4.0b	53.3 ± 2.0b	74.1 ± 5.1b

Means followed by the same letter in the same row do not differ statistically at P < 0.05

TABLE 3. The lethal dose for 50% (LC_{50}) of *A. obtectus* adult populations infesting dry beans treated with caster and cottonseed oils after 120 hours

Oils	Probit parameters ± SE			
	LC_{50} (ml kg^{-1})	LC_{95} (ml kg^{-1})	Intercept	P value
Castor oil	2.95	9.25	-1.56 ± 0.30	0.0001
Cottonseed oil	5.95	42.56	-1.49 ± 0.24	0.0001

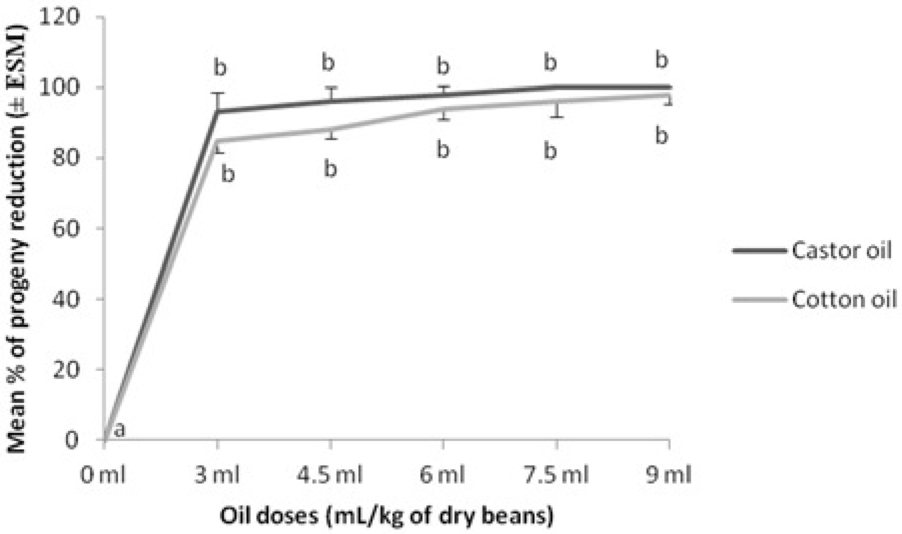

Figure 1. Mean reduction (% ± ESM) in progeny production (F1) of *A. obtectus* infesting dry beans treated with castor and cottonseed oils.

between a thin area of the chorion and the outside. Rajapakse and Van Emden (1997) demonstrated that corn, groundnut, sunflower and sesame oils reduced oviposition of three bruchid species by over 70% at a concentration of 10 ml kg^{-1} of seeds.

The application of oils may minimise insecticide usage to protect stored food product and hence reduce health hazards due to applicators. Treatment of grains with vegetable oils could have important practical applications in the parts of the world where insecticides are expensive, in short supply or where vegetable oils are readily available.

CONCLUSION

This study has shown that castor and cottonseed oils, when added to dry beans, render good protection to the grain by killing various life stages of *A. obtectus* via contact. Further research into the bioactivity of these two oils, the mechanism of action and identification of the active constituents against other stored product insects is needed before commercial application can be considered.

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