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Effectiveness of products from four locally grown plants for the management of *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boheman) (both Coleoptera: Bruchidae) in stored beans under laboratory and farm conditions in Northern Tanzania

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ABSTRACT

The effectiveness of whole or powdered leaves (botanicals) from four locally grown plant species applied at a rate of 1.5 kg per 100 kg beans (*Phaseolus vulgaris*) against *Acanthoscelides obtectus* and *Zabrotes subfasciatus* was compared under laboratory and farm conditions. In the laboratory, *Chenopodium ambrosioides*, applied as powder or as whole leaves, was the most effective, with 100% mortality of adult insects in less than three days and no progeny. Less *C. ambrosioides* (about 200 g per 100 kg beans) still resulted in 100% mortality within 24 h. *Tagetes minuta* applied as powder also increased mortality and reduced oviposition and progeny production significantly. The other treatments – *T. minuta* applied as leaves, and *Azadirachta indica* or *Cupressus lusitanica* applied as powder or as whole leaves – had no significant effects upon mortalities, oviposition rate, or progeny production compared with control treatments. When the rate of application was increased to about 8.3 kg per 100 kg beans, there was a slight increase in mortality using *T. minuta* and *A. indica*, but not with *C. lusitanica*. An additional trial with *C. ambrosioides* from different collections and with plants at different stages of development revealed considerable variations in the efficacy of the treatment.

In the on-farm trials, *A. indica*-seed powder was the most effective treatment, followed respectively by leaf powders of *C. ambrosioides*, *C. lusitanica* and *T. minuta*. All treatments were significantly more effective than the control in reducing the numbers of live insects; they also reduced numbers of damaged beans and maintained germination rates after 5 months of storage. The results of evaluations of the treatments made by farmers just after the trials and five years later are reported.

1. Introduction

Improvement of bean production and storage will enhance sustainable development in Eastern and Southern Africa in many ways. Beans form a major staple crop, providing the second most important source of human dietary protein and the third most important source of calories (Pachico, 1993). They are also an important part of the economy: in 1996/97, annual production of pulses in Tanzania was estimated at 374,000 tons, of which about 80% were common beans (*Phaseolus vulgaris* L.). In the Arusha region, bean production is approximately 16,000 tons. The export value of pulses from the Arusha region in the year 1995/96 was 3 million US dollars (Mashamba, 1998).

A major problem in attempting to increase the supply of beans in rural and urban households is high losses during storage caused by two species of bruchids: *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boheman) (Coleoptera: Bruchidae). These species are the most destructive storage pests of beans in Tanzania. Average dry weight losses during storage have been estimated at between 10 and 40%, but where management is poor, losses can be well above 50% (Kiula and Karel, 1985; Lima, 1987). Beans with multiple emergence holes of bruchid beetles and emitting a characteristic pungent odour are useless for consumption and have no

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commercial value (Giga et al., 1992). There is a need, therefore, to investigate environmentally acceptable methods for protecting beans against bruchids during storage.

A study of bean losses during on-farm storage in Eastern and Southern Africa revealed that all farmers used at least one direct method to protect their beans against bruchid attack. Some farmers used more than one method at the same time: 68% of farmers removed insects by spreading their beans in the sun to dry while 47% used commercial insecticides, 26% mixed ash with their beans and 20% added fine soil; 7% mentioned that they use materials extracted or obtained from plants (botanicals), and 2% used some other practice. However, most farmers still reported total loss of their beans after 4–5 months of storage (Giga et al., 1992). During the field surveys in the area of study, some farmers were observed to be innovative in designing additional control practices for use during storage. These included exposing beans to smoke, impregnating the storage bean sacks with hot chilli peppers or goat pellets, and mixing seed beans with kerosene or fungicides used in coffee plantations. The efficacy of such measures has not been proven and toxicity to humans could be a problem. Botanicals, on the other hand, could provide an effective alternative to these concoctions; these plant-derived materials have the advantages that farmers can grow them at very low costs and because most of them are used as local medicines, there is knowledge of their potential toxicity. In addition, more complex preparations such as combinations of substances present in botanicals are less likely to become ineffective because of the development of resistance (Regnault-Roger and Hamraoui, 1993; Regnault-Roger et al., 1993).

There are many publications on different plants or plant products used in storage against different storage insect pests (Golob et al., 1999). Although farmers have considerable traditional knowledge of botanicals, most scientific studies have only evaluated their efficacy in the laboratory. Such studies include the fumigant activity and/or contact toxicity of extracts or dried plant material on the various life stages of the insects, and also their repellent and oviposition-deterring properties. Some of these studies have used specific, isolated components, while others have used crude extracts or powdered plant material. This variety of approaches leads to problems of interpretation, since the insecticidal activity of specific compounds such as essential oils is not necessarily linearly correlated with the content of their main constituents. Very often, the LC_{50} of crude oils is lower than that found for each constituent by itself (Papachristos et al., 2004), but the studies report results for the most effective form of extract (Boeke et al., 2001). None of these approaches account for the reality experienced by small-scale farmers, who can only use simple methods for preparing botanicals (dried materials, possibly in powdered form).

Recent publications stress the importance of comparing laboratory and field studies for storage trials (Kestenholz et al., 2007). The present study evaluates the insecticidal properties of four botanicals under farm and laboratory conditions. Two of these – neem, *Azadirachta indica* A. Juss (Meliaceae), and wormseed, *Chenopodium* (=*Dysphania*) *ambrosioides* L. (Chenopodiaceae) – are known in north-eastern Tanzania as medicinal plants but have not been used traditionally by farmers, though *A. indica* is well known for its insecticidal properties and several industrial products containing *A. indica* extracts are available (Chiasson et al., 2004a; Isman, 2006). Farmers know it for its medicinal properties and it is locally called mwarobaini (Swahili), which means the "tree that cures forty illnesses". In the laboratory trials, to reflect likely local adoption practices, it was decided to use *A. indica* leaves in spite of knowing that there would be lower concentrations of the active component azadirachtin present as compared to seeds. This was also necessary to prevent introducing 'oil film on seed' as another factor involved in storage protection (Schoonhoven, 1976). However, in the on-farm trials, we used crushed seeds. This inconsistency was due to the demand of the extension services to encourage the adoption of neem seed, in which the active component azadirachtin is found at the highest concentration, as a grain protectant.

Chenopodium ambrosioides is also known to some farmers, who call it mangunu (Meru) or ol'kukunu (Maasai), both names meaning that it smells like crushed bedbugs (Cimicidae). *Chenopodium ambrosioides* and other *Chenopodium* spp. grow in East Africa and are used in small doses against intestinal worms, stomach aches, constipation, headaches, colds and liver diseases (Kokwaro, 1993). It has been used successfully in storage elsewhere (Golob et al., 1999; Tapondjou et al., 2002). The other two botanicals, cypress, *Cupressus lusitanica* var. *benthamii* Miller (Cuperaceae) and marigold, *Tagetes minuta* L. (Asteraceae) are traditionally used in the area for seed storage. Many highland farmers in Arusha apply *C. lusitanica* to stored maize and beans, and report that they first saw it used in this way in bags coming from Kenya (probably from the Kikuyu and Kamba ethnic groups). There are a few publications indicating that the essential oils derived from *Cupressus* spp. are moderately effective in protecting stored seeds against insect pests (Stamopoulos, 1991; Tapondjou et al., 2005). *Tagetes minuta* is also widely used by farmers in parts of Tanzania. Several papers have been written on the use of extracts of *T. minuta* (Weaver et al., 1994b; Keita et al., 2000; Boeke, 2004), and these also report a reasonably high level of effectiveness.

In this study dried plant material was used, since this is an easy mode of application for farmers to adopt. Trials were conducted in the laboratory and in the field under local conditions, and farmers were given an opportunity to evaluate the different treatments in their own environment and by their own standards. The two species of bruchids chosen for the study, *A. obtectus* and *Z. subfasciatus*, often occur together (Abate and Ampofo, 1996), but their relative abundance can change over time because of slightly different optimal living conditions (Schoonhoven, 1976). The life cycles and ecology of the two species are similar, but an important difference between them from a practical point of view is that *A. obtectus* scatters its eggs freely among the beans, without attaching them to the testa of the bean, while *Z. subfasciatus* firmly attach their eggs to the bean on which they were laid. When hatching, *Z. subfasciatus* larvae bore directly into the bean, and are therefore not or only minimally exposed to the surrounding of the beans, while *A. obtectus* larvae move freely among the beans and search for a place where two beans touch. Here they bore into the selected bean utilising the leverage available from neighboring beans (Zachariae, 1958; Labeyrie, 1962; Howe and Currie, 1964). Consequently, physical methods such as regularly sieving the beans reduce numbers of *A. obtectus* more than those of *Z. subfasciatus*. On the other hand, host plant resistance (with the resistance factor arcelin) works against *Z. subfasciatus* but not against *A. obtectus* (Minney et al., 1990; Cardona and Kornegay, 1999). It can be assumed that similar differences between the two species exist for most control methods. As they infest the same storage facilities (or even bean), a control method needs to control both species simultaneously.

The objectives of this study were (i) to assess the efficacy against *A. obtectus* and *Z. subfasciatus* of four locally available plant products (henceforth described simply as botanicals) which are traditionally used for medicinal purposes, and (ii) to find practical options for farmers to protect their beans safely and effectively.

2. Materials and methods for the laboratory trials

2.1. Insect specimens

Both species were reared at $20 \pm 2\,^{\circ}C$, $50 \pm 15\%$ relative humidity (r.h.) and under a 12 h:12 h (L:D) illumination cycle. The