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Efficacy of castor bean oil (*Ricinus communis* L.) against maize weevils (*Sitophilus zeamais* Mots.) in northwestern Ethiopia

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ABSTRACT

The maize weevil, *Sitophilus zeamais* Mots. (Coleoptera: Curculionidae), undermines food security. The biocidal activity of castor bean oil (*Ricinus communis* L.) against *S. zeamais*, was studied at various doses at Dembecha, northwestern Ethiopia in 2013/14 (November–April). In the castor bean oil efficacy test, weevil mortality steadily increased with castor bean oil dose. According to the results of the ANOVA, number of dead weevils significantly varied between castor bean oil doses 1 h after treatment ($F_{10, 21} = 117.6$, $p < 0.0001$). Just 53% of the weevils were killed in one hour by applying 2 ml of the oil while doses higher than 2 ml killed greater than 85% of the weevils. Using Probit analysis, the LD_{50} of using castor bean oil against maize weevils was calculated to be 2.04 ml. Therefore, 2 ml of castor bean oil was found sufficient to destroy 50% of the weevils. Higher doses of castor bean oil significantly reduced maize seed germination.

1. Introduction

The maize weevil, *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae) is one of the most destructive insect pests of stored cereals in tropical and sub-tropical regions (Throne, 1994). Post harvest losses due to this insect pest have become an increasingly important constraint in Africa (Markham et al., 1994). Adult weevils attack whole grains, and larvae feed and develop within grains. The huge post-harvest loss and quality deterioration caused by this pest is a major obstacle for achieving food security in developing countries (Rouanet, 1992). Initial infestations of maize grain can occur in the field just before harvest and insect pests transported to storage areas (Adedire and Lajide, 2003).

The application of traditional products such as botanical insecticides and plant-derived pesticides to protect stored products against insect infestation is a common and an age-old practice in small-scale grain storage (Gwinner et al., 1990; Tadesse, 1995; Bekele et al., 1997; Shaaya and Kostyukovysky, 2006). The wide-scale commercial use of plant extracts as insecticides began in the 1850s with the introduction of nicotine from *Nicotiana tabacum*, rotenone from *Lonchocarpus* sp., derris dust from *Derris elliptica*, pyrethrum from the flower heads of *Chrysanthemum cinerariaefolium*, *Tagetes* sp, *Capsicum* sp, and *Lanthana* sp. Some plant families may accumulate a restricted number of anti-insect chemicals, so called secondary metabolites, whilst others possess a wide variety of different structural compounds.

Generally, botanical pesticides can be used as crude extracts, in development of prototypes of known active ingredients, and as sources of known active ingredients (Tadesse, 2003). The main advantages of botanical pesticides are that they are ecofriendly, easily bio-degradable and plant-derived natural products that are toxic to insect pests could be produced from locally available raw materials.

Weevil damage of grains leads to reduced nutritional value, seed germination rate, seed weight and commercial value of the product (Yuya et al., 2009). The present study was therefore carried out to assess the efficacy of castor bean oil against *S. zeamais*.

2. Materials and methods

The study was carried out in the Dembecha district, northwestern Ethiopia, 10′33″N latitude and 37′29″E longitude, 2083 m above sea level, annual average rainfall of 1006 mm and temperature of 18.01 °C. Insect cultures was maintained in glass jars filled with clean and undamaged maize grains. Adults of *S. zeamais* were obtained from naturally infested maize grains. Whole grains of local

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variety were obtained from local farmers. *S. zeamais* were introduced into the rearing jars that contained 2 kg maize grains. The jars were covered with muslin cloth and fastened with rubber bands. Five kg newly harvested maize seeds and 1 kg good quality castor beans were used for the study. The castor bean seeds were collected from farmers' agricultural fields in the study area. The seeds were then crushed with mortar and pestle and then added to boiling water. As it boiled, the floating oil was separated and used for treating grains or sprayed onto Petri dishes the inside of which was lined with filter paper.

This study was focused on determining the effectiveness of castor bean oil as protectant of stored maize seeds against *S. zeamais*. Adult mortality tests were carried out under laboratory conditions. The study was done from November 2013 to April 2014. Adult *S. zeamais* were isolated from infested maize grains and cultured/reared on undamaged maize seeds in ambient temperature and humidity. The treatments (the five doses of the oil), i.e., 0 ml, 2 ml, 4 ml, 8 ml, and 16 ml were laid out in a completely randomized design (CRD) in the laboratory with three replications.

A random sample of 300 maize seeds were kept in jam bottles covered with muslin cloth to allow air circulation. The same procedure was done for each of the 15 jam bottles. Each treatment was left in the laboratory for daily observation (Oparaeke, 1996). Each dose was sprayed onto the seeds and shook to mix the oil and the maize seeds. Soon after spray, 20 weevils were introduced into each bottle. Starting from one day after oil treatment and introduction, mortality was recorded daily for the next five days.

The contact toxicity of castor bean oil on adult *S. zeamais* was investigated as described by Tapondjou et al. (2005) and directly applied onto the weevils themselves without seeds involved. The experiment was laid out in a completely randomized design (CRD) with eleven treatments (doses), i.e., 0, 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 ml, replicated three times. The inside of a total of 33 Petri dishes with ventilated lids were lined with filter paper on which 5 freshly emerged adult weevils were introduced. The required doses of the oil were then sprayed and dead weevils were counted, removed and their numbers recorded daily starting from 1 h after application for the next three days, and weekly for the next month.

The effect of castor bean oil on the rate of seed germination was determined as described by Tapondjou et al. (2005). Tests were done in a completely randomized design (CRD) with five treatments (doses) replicated three times. A random sample of 300 maize grains were kept in jam bottles lined with filter paper and treated with different doses of castor been oil, i.e., 0, 2 ml, 4 ml, 8 ml and 16 ml. These were thoroughly mixed to ensure the homogeneity of the oil on the treated maize seeds. The total number of jam bottles was 15. It was then followed for 2 months and the germination determined for a random sample of 10 seeds out of 300 seeds in each bottle.

The efficacy of different oil doses on weevil mortality and germination rate was statistically analyzed using one-way analysis of variance followed by mean separation (Tukey Honestly Significant Difference test at $\alpha = 0.05$). In the case of the bioassay test, a probit analysis was done. First percent mortalities were converted to Probits. This was done by looking up those corresponding to the percent responded in Finney's table (Finney, 1952). For example, for a 17% response, the corresponding probit would be 4.05; for a 50% response (LD50), it would be 5.00. The log of the doses was calculated and a regression line fitted between the probits versus the log of the doses. Then at Probit 5 on the Y-axis, a line was drawn parallel to the X-axis until it touched the regression line. Starting at that point, another line was drawn at 90° angle down to the X-axis and the corresponding log dose determined on the X-axis. The inverse of the log was calculated to determine the LD50, a dose that killed 50% of the weevils.

3. Results and discussion

In the castor bean oil efficacy test, mortality increased steadily with castor bean oil dose. More weevils died at the first day when treated with 16 ml oil and at the third day when treated with other rates. Without treatment, mortality was negligible (Table 1). The highest dose (16 ml) had a fast knock down effect on weevils while lower doses acted relatively slowly. The higher the rate, the quicker the knockdown and the greater the mortality.

The number of dead weevils was significantly different between castor bean oil doses starting 1 h after treatment ($F_{10, 21} = 117.6$, $p < 0.0001$). Just 53% of the weevils were killed within one hour by applying 2 ml of the oil and 85% 4 ml. Oil treated weevils were usually dead in one day. Furthermore, rates of application between 6 ml and 20 ml responded in exactly the same way; 100% mortality was achieved in all these rates. Weevil mortality did not vary on untreated maize seeds throughout the observation period.

Similar observations were reported from previous researches applying castor bean oil and other insecticidal plant oils against *Callosobruchus maculatus* on cowpea (Swella and Mushobozy, 2007; Ramzan, 1994). Aheer et al. (1996) reported 97.5% mortality of *Callosobruchus analis* due to castor oil in the laboratory during an evaluation carried out to determine the efficacy of different plant derived oils. Even other less toxic plant oils such as groundnut oil were found effective; Singh et al. (1978) reported that 5 ml groundnut oil applied per kg cowpea protected cowpea seeds from *C. maculatus* for 180 days. Shukla et al. (1988), for example, mentioned that coconut, sesame, rape, soybean, groundnut, mustard and palm oils were effective in protecting cowpea seeds against attack by *C. maculatus*. Neem oil at 2% completely protected maize grains against *Sitophilus oryzae*, *Sitophilus cerealella*, *Rhyzopertha dominica* and *Tribolium castaneum* for up to 9 months (Sharma, 1999). Raghvani and Kapadia (2003) used eight vegetable oils (coconut, groundnut, mustard, sesame, castor, been neem, Koranj and sunflower) against *C. maculatus*. The neem and coconut oils at 10 ml/kg seed protected seeds completely against *C. maculatus* for 6 months. Cruz and Cardona (1981) used soybean oils against *Callosobruchus chinensis* in stored seeds of cowpea. These treatments protected the cowpea seeds and decreased their weight loss. In general, the results of the present investigation corroborate reports of previous workers (Sowunmi and Akinnsi, 1983; Ketker, 1989; Maredia et al., 1992).

By examining Probit 5 along the Y-axis and drawing a line until it touched the dotted curve (Fig. 1), and then drawing a vertical line from the point of contact on the dotted line down to the X-axis, the corresponding estimated log scale value was found to be 0.31. Taking the inverse of the log, the corresponding LD50 was found to be 2.04 ml. Therefore, 2 ml of castor bean oil per 300 seeds would kill 50% of exposed *S. zeamais*.

With regard to LD50, toxicity of castor oil to animals has long been established. For example, castor bean oil and pure compounds of *Ricinus communis* exhibit high toxicity to target animals (Olsnes, 2004; Bigalke and Rummel, 2005; He et al., 2007; Kumar et al., 2007). The toxicity of the plant is ascribed to the presence of ricin, a water soluble glycoprotein concentrated in the seed endosperm but present in lesser concentrations in other parts of the plant and reputed to be one of the most poisonous of the naturally occurring compounds (Darby et al., 2001; Frederiksson et al., 2005; Kozlov et al., 2006; El-Nikhely et al., 2007). This fact explained the comparatively high effects recorded in oil and seed kernel extract compared to the leaf and root extract. According to Tokarnia et al. (2002), while the seeds are the primary source of toxin, the rest of the plant may also be considered to be slightly toxic which requires investigation.