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Biopesticidal Effect of *Acokanthera schimperi* and *Nicotiana tabacum* on Maize Storage Insect, *Sitophilus zeamais*

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Abstract

Maize serves as a primary staple food for approximately one-third of the sub-Saharan population. Despite being the third most widely produced grain globally, various factors impede its production. Insects, particularly maize weevils (Sitophilus zeamais), play a crucial role in hindering maize production, especially during storage. This study investigates the efficacy of two medicinal plants, Acokanthera schimperi and Nicotiana tabacum, in managing the maize weevil, a significant pest affecting stored grain. Adult maize weevils (S. zeamais) were collected and reared in the entomological laboratory at Addis Ababa University. The medicinal plants, Acokanthera schimperi and Nicotiana tabacum, were processed into powder and applied to the laboratory-reared S. zeamais in varying amounts. Statistical analysis, using SPSS version 16's ANOVA, was conducted to assess mean differences among replicates and dose rates. The plant toxicity test employed the "corrected mortality (%)" formula. Results indicated that Nicotiana tabacum demonstrated effectiveness against the maize weevil, with approximately 59% mortality recorded among adult weevils during the experimentation. This highlights the potential for sustainable utilization of plant resources for affordable pest management, while simultaneously mitigating the environmental detriments associated with conventional methods.

Keywords/Phrases: Adult mortality, Maize weevil, Medicinal plants, Pest Management, Storage pests

1 Introduction

Corn (*Zea mays*) is a cereal grass closely related to rice, wheat, oats, and barley. It ranks second in global grain production, following wheat (Piperno, 2011). In sub-Saharan Africa (SSA), approximately one-third of caloric intake comes directly from maize (Tadele *et al*., 2011), which is used for animal feed, biofuel, and as a raw material in various industries. Originally cultivated as a subsistence crop, maize has evolved into a valuable cash crop relied upon by many sectors (Iken & Amusa, 2004).

In Ethiopia, maize (*Z. mays* L.) is a critical cereal crop for food, fodder, and income (Benti & Ransom, 1993; Seyoum *et al*., 2013). In the Oromia Region, maize cultivation covered 1.11 million hectares in the 2010/11 season, yielding 28.81 million quintals at a productivity rate of 25.97 quintals per hectare (Musa, 2013).

However, several factors hinder maize production, with insect pests being a major obstacle to optimal utilization of cereal crops in SSA. Stored grain damage is particularly severe, with annual losses in Ethiopia ranging from 20% to 30%. Key pests include the maize weevil (*S. zeamais*), grain moth (*Sitotroga cerealella*), rice weevil (*Sitophilus oryzae*), and red flour beetle (*Tribolium confusum*).

These pests can cause losses of 20–40% during cultivation and 30–90% during postharvest and storage (Wakitole & Amsalu, 2012).

Losses primarily result from insect feeding and reproduction, leading to contamination from excreta, discarded skins, and dead insects. Additionally, insect activity can increase temperature and moisture levels in the grain, creating warm, humid conditions that enhance respiration and fungal growth, further accelerating deterioration (Tefera *et al.*, 2010).

In many parts of SSA, these losses jeopardize household food security and reduce market profits, prompting farmers to seek ways to protect their grain during storage (Stathers *et al.*, 2008). The region's warm tropical climate and inadequate storage methods often exacerbate pest growth, leading to significant losses (Bekele *et al.*, 1997). In some cases, farmers are forced to sell their maize at low prices immediately after harvest due to anticipated storage losses, only to buy food later at higher prices. Furthermore, farmers in developing nations, constrained by the lack of modern storage facilities, often resort to traditional granaries that are ineffective against storage pests (Charles *et al.*, 2016; Midega *et al.*, 2015).

Maize weevils (*S. zeamais*), prevalent in both tropical and temperate regions, are the primary insect pest affecting stored maize grains (Alemnew, 2017; Charles *et al.*, 2016). Substantial infestations of adult maize weevils and their larvae lead to significant postharvest losses (Markham *et al.*, 1995; Shetie and Abrham, 2023). Despite numerous efforts directed at alleviating the impact of field pests (Charles *et al.*, 2016), the persistent issue of post-harvest losses caused by insects remains a significant challenge (Tefera *et al.*, 2010).

Controlling insect pests in stored grains largely relies on synthetic insecticides, favored for their quick action and ease of use globally. However, the frequent application of these chemicals leads to environmental pollution, pest resistance, and harm to non-target organisms. Additionally, it raises application costs and creates supply challenges in developing countries due to limited foreign exchange (Mishra *et al.*, 2012). Consequently, there is a growing need to explore alternative, environmentally friendly, and cost-effective pest management systems (Suleiman & Rugumamu, 2017).

Botanical pesticides are experiencing a resurgence in popularity, with certain plant-derived products being utilized worldwide as eco-friendly pest control agents. This revival is evident as some plant-based products gain acceptance as sustainable alternatives. Pyrethroids and neem products have long been recognized as effective botanical pesticides, while essential oils extracted from various plants have recently emerged as potent antimicrobials against storage pests. Their perceived safety and broad consumer acceptance have contributed to their adoption in pest management strategies (Dubey *et al.*, 2008).

The production and application of plant products are gaining traction due to their eco-friendly nature, adaptability, cost-effectiveness, and ability to extend seed storage life (Kumar *et al.*, 2015). Plant-based pesticides, which are easy to produce and implement, hold promise for natural crop protection, particularly benefiting small-scale farmers (Shetie & Abrham, 2023).

The primary aim of this study was to evaluate the efficacy of *Acokanthera schimperi* and *Nicotiana tabacum* in controlling *Sitophilus zeamais* infestations in stored maize within the Wodera district of the Oromia region, Ethiopia. These plants were selected for their traditional medicinal use in various parts of Ethiopia and their antimicrobial properties (Mamo *et al.*, 2021).

2 Materials and Methods

2.1 Insect rearing (IR)

Maize used for rearing was sourced from the local market in Debre Berhan and disinfected in a refrigerator at temperatures ranging from -20^{o}C to 0^{o}C for 48 hours. The maize grains, heavily infested with Sitophilus zeamais, were collected from voluntary farmers in the Wadera district of the Guji zone, Oromia region, Ethiopia, and stored at temperatures between 30^{o}C and 33^{o}C with a relative humidity of 70-75%.

Unsexed adults of *S. zeamais* were carefully collected from the infested maize samples and introduced into thoroughly washed and dried rearing containers with disinfected, uninfested maize grains.

The insect rearing was conducted at the entomological laboratory of Addis Ababa University's Department of Zoological Sciences. Adults of *S. zeamais* of known ages were multiplied in sufficient numbers to conduct the experiment, following the rearing procedures outlined by Mesele *et al.* (2013).

After a seven-day rearing period, the adult insects were removed, and new medium was added to stimulate the growth of the newly emerged generation (F1 progeny). The one-month-old offspring, excluding the parental generation, were ultimately used in the subsequent toxicity experiment.

2.2 Preparation of botanicals

In assessing the effectiveness of botanicals for managing insect pests in stored maize, medicinal plants were used as treatments, specifically tree and shrub species. The selected species included *Acokanthera schimperi* (arrow-poison tree) and Nicotiana tabacum (cultivated tobacco). Nicotiana tabacum was sourced from a home garden, while *Acokanthera schimperi* was collected from its natural habitat. The leaves of both plants were carefully washed and shade-dried in the laboratory to prepare them for grinding. After drying, the plant parts were finely ground using a grinder.

Thirty unsexed adults of *S. zeamais* were introduced into each treatment jar, while control jars contained 20g of disinfected maize seeds, with three replicates for each treatment. The prepared plant powders were applied separately through topical application at rates of 4g, 8g, and 12g for each replicate, following a completely randomized experimental design (CRED). Aluminum Phosphide (Tanphos 56%) served as the standard check, with 0.9g of powder applied in three replicates.

After 24 hours, the mortality of *Sitophilus zeamais* was recorded for both treatments and their respective controls at three time intervals (24, 48, and 72 hours). Insects showing no movement were considered deceased, while live ones were returned to their respective jars.

2.3 Toxicity test

In analyzing the insecticidal impact of the botanicals on maize weevils (*Sitophilus zeamais*), the percentage of insect mortality was determined using the following equation (Waktole, 2014)

$$\text{Corrected Mortality (\%)} = \left(1 - \frac{n\ in\ Co\ before\ treatment\ \ n\ in\ T\ after\ treatment}{n\ in\ Co\ after\ treatment\ \ n\ in\ T\ before\ treatment}\right) \times 100$$

Where: Co - Control, T - Treated, and n - insect population.

The efficacy of botanicals in inducing maize weevil mortality was assessed using a one-way analysis of variance (ANOVA) at a significance level of 5% ($P < 0.05$) with SPSS version 16. Significant differences among treatment means were evaluated using the Least Significant Difference (LSD) for post hoc multiple comparisons. Additionally, the corrected mortality percentage was calculated to determine insect mortality in the control group. This analysis aimed to further evaluate the effectiveness of the botanicals in reducing maize weevil mortality.

3 Results and Discussion

3.1 Description of plant material

Two botanicals, *Acokanthera schimperi* and *Nicotiana tabacum*, were employed for their bio-insecticidal activities against the target insect (Table 1). *Acokanthera schimperi* is native to Ethiopia and has traditionally been used in Ethiopian medicine for its antimicrobial properties (Mamo *et al.*, 2021).

Nicotiana tabacum, commonly known as tobacco, is native to the Americas and primarily cultivated for its leaves, which are processed into tobacco products. Beyond its traditional uses, tobacco has been studied for its chemical constituents and potential applications. Kırcı *et al.* (2022) isolated new sesquiterpenoids and diterpenoids from the flowers of *N. tabacum* and assessed their antifungal activity, underscoring ongoing research into its chemical properties and potential uses.

Table 1. Plants tested for their insecticidal effects on adult maize weevil (*Sitophilus zeamais*)

No.	Local name	Scientific name	Habit	Location	Part used	Insect treated
1	Tamboo	*Nicotiana tabacum*	Shrub	Cultivated	Leaf	Maize weevil
2	Qaraaruu	*Acokanthera schimperi*	Tree	Wild	Leaf	(*S.zeamais*)

3.2 Toxicity Effects of plants on Adult *S. zeamais*

The study findings indicate that locally available plants with bio-insecticidal properties can effectively reduce *S. zeamais* infestation. These plants demonstrate high efficacy in disrupting the insect's life functions, along with benefits such as easy accessibility, affordability, low cost, and minimal time requirements for farmers (Table 2). *Nicotiana tabacum* achieved a 59% mortality rate among adult maize weevils, while *Acokanthera schimperi* resulted in an 18% mortality rate. In contrast, Aluminum Phosphide, serving as the standard check, achieved a 100% mortality rate.

Table 2. The botanical efficacy tests resulted in the mortality of *S. zeamais*

No.	Treatment	Form	Av. dose (g/seeds)	IBT	IAT	MDI	Mortality (%)
1	*N. tabacum*	Powder	8	30	12	18.3	59
2	*A. schimperi*	Powder	8	30	24	6.0	18
3	Standard check /AlP	Powder	0.9	30	0	30.0	100
4	Control	-	-	30	29	0.7	0

* α= 0.05, df= 11, F= 124.27, P-value= 0.00; AlP - Aluminum Phosphide, Av- average, IBT- insects before treatment, IAT- insects after treatment, MDI- Mean of dead insects.

Several researchers have evaluated the impact of various plant-derived extracts on the repellency and mortality of storage insect pests. Shite and Abrham (2023) reported that leaf tinctures of *Brucea antidysenterica* and *Carica papaya* effectively manage *S. zeamais*. Tawose and Bagbe (2021) documented that extracts from four indigenous plants in Nigeria—*Andrographis paniculata*, *Chromolaena odorata*, *Mucuna pruriens*, and *Datura stramonium*—induced mortality in *S. zeamais* after a 22-day exposure period. Sori (2014) found that plant powders from *Chenopodium* sp., *Nicotiana* sp., and *Maesa lanceolata* had high efficacy in controlling maize weevils, causing adult mortality rates of 22.22% to 66.67% and reducing the emergence of new progeny from 80.00% to 23.00% in Jimma Zone, Ethiopia.

A study in Jimma highlighted the effectiveness of tobacco (*N. tabacum*) leaf powder in reducing pest infestation on stored maize, resulting in a 50% mortality rate. Actellic dust, a standard insecticide, demonstrated approximately 70% mortality of adult *S. zeamais*, similar to Aluminum Phosphide (Wakitole, 2014). In Nigeria, the potential of *N. tabacum* leaf powder as a plant-derived insecticide against maize weevils has been recognized. Its local availability and bio-pesticidal potential position it as a promising candidate for enhancing traditional post-harvest protection practices (Idoko and Adebayo, 2011). Additionally, a study in the Amhara region of Ethiopia identified *A. schimperi* as a botanical with insecticidal properties, presenting a viable alternative to conventional insecticides with high efficacy against *S. zeamais* (Pol, 2002).

3.3 Adult Insect Mortality at Different Dosage Rates

Statistical analysis revealed a significant difference in average insect mortality between the two botanicals. However, the variations in averages across dosage rates within each botanical were deemed insignificant (see Table 3). This finding may be attributed to the 72-hour treatment period, during which maize weevils, known for their robust exoskeletons, might have exhibited resilience to the insecticidal properties of the botanicals. Additionally, the innate behavior of these insects, such as evading or moving away from the powder towards the top of the treatment jars, could have reduced

Table 3. Mean of insect mortality across different doses of botanicals

No.	Dosage ranges	Insect experimented	Mean of death/g of dose (mean ± SE)
1	Nt_1	30	17.00 ± 1.53
2	Nt_2	30	18.33 ± 2.03
3	Nt_3	30	19.67 ± 5.13
4	As_1	30	3.33 ± 0.88
5	As_2	30	6.33 ± 1.45
6	As_3	30	8.33 ± 1.45

* Nt_1- *N. tabacum* dose1, Nt_2- *N. tabacum* dose2, Nt_3- *N. tabacum* dose3; As_1- *A. schimperi* dose1, As_2- *A. schimperi* dose2, As_3- *A. schimperi* dose3, Df-degree of freedom, LS- Level of significance, SE- Standard error. Df = 8, LS = 0.05, F =2.10, P-value = 0.42

their contact with the botanical substance, resulting in a gradual and less pronounced impact.

In a related study, Edelduok *et al.* (2012) also reported a lack of significance across various doses of melon cotyledon (*Citrullus vulgaris*) powder treatment, with the LSD test indicating no substantial difference ($P > 0.05$). The study concluded that the robust exoskeleton of the weevils could hinder the effective penetration of the testa powder. Furthermore, the ground testa powder settled at the bottom of the container, potentially prompting insects to move towards the top of the grains, thereby reducing their contact with the plant material.

Limitation of the study

In this study, *Acokanthera schimperi* and *Nicotiana tabacum* are known to contain toxic compounds effective against storage grain insects. However, the safety of these extracts for humans, animals, and the environment is not addressed in this research.

4 Conclusion and Recommendations

The use of ecologically safe, locally available plant-based insect pest management strategies in maize production is crucial for ensuring socio-economic stability and food security in Ethiopia and across sub-Saharan Africa. Laboratory tests showed that *Nicotiana tabacum* (tobacco) emerged as a promising bio-insecticide, effectively causing high mortality in *Sitophilus zeamais* within three days of exposure. The application of *N. tabacum* demonstrated significant potential in reducing damage and controlling *S. zeamais* infestations in stored maize.

Replacing synthetic insecticides with locally sourced plant-based bio-insecticides offers substantial benefits, including reduced environmental pollution, minimized harm to non-target organisms, and prevention of grain contamination. To maximize these advantages, it is essential to train farmers and agricultural extension agents on the effective use of botanical insecticides, a practice that should be widely adopted throughout the country.

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