Rwanda Journal of Agricultural Sciences, Vol 3, No. 1

Farmer Knowledge of *Tagetes sp.* and Its Potential Use as Alternative to Synthetic Insecticides for the Control of Maize Weevils in Rwanda

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Abstract

This study addresses storage pest challenges maize producers face in Rwanda, specifically *Sitophilus zeamais*. It aims to explore the potential of Marigold (*Tagetes species*) as a botanical pesticide for maize weevil control. The prevailing reliance on synthetic insecticides, which are costly and environmentally hazardous, necessitates alternative pest management strategies. The research involves two phases: a survey and bioassays. The survey evaluates the availability of pesticidal plants and farmer awareness regarding their use as botanical pesticides, emphasizing Marigold. Five districts (Rusizi, Muhanga, Gicumbi, Musanze, Gasabo, and Bugesera) are covered, with thirty farmers randomly selected from sectors within these districts. The survey assesses awareness of both pesticidal plants and maize weevils as pests. Bioassays are conducted in the University of Rwanda-College of Agriculture, Animal Sciences, and Veterinary Medicine laboratories, employing a Complete Randomized Design (CRD) with eight treatments and three replications. Maize grains infested with weevils are treated with varying doses of air-dried and ground Marigold biomass and positive control (Malathion). Over four weeks, weevil survival and grain damage are monitored every two days, alongside recording temperature and relative humidity. Survey results indicate the presence of pesticidal plants but low awareness (10%) of Marigold's potential as a botanical pesticide. Similarly, only 31% of farmers know maize weevils as pests. Bioassay findings reveal Marigold's comparatively lower effectiveness (40% and 53%) in contrast to Malathion (90%) for weevil control. Nonetheless, studies in Zimbabwe highlight Marigold's potential, achieving 100% weevil mortality after 56 days. While this study showcases Marigold's potential in achieving notable weevil reduction (40-53%), factors like humidity, temperature, dose, and bioassay duration may have influenced outcomes. Further investigations are recommended to encompass diverse climatic conditions, increased dosages, extended bioassay periods, and alternative formulations to validate Marigold's efficacy as a maize weevil control method in stored grains. This research signifies a significant step towards developing sustainable alternatives to synthetic insecticides for pest management in Rwandan maize production.

Keywords: *Marigold (Tagetes species); Maize weevils (Sitophilus zeamais); alternative control product*

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Introduction

The economic situation in a developing country (such as Rwanda) has been affected mainly by post-harvest losses of agricultural products, which are usually encountered especially during storage and could be caused by pests and other spoilage agents (Arannilewa *et al*., 2002). Post-harvest losses due to storage insect pests such as the maize weevils, *Sitophilus zeamais* have been recognized as an increasingly important problem in Africa (Markham *et al.,* 1994). Affordable and effective methods for reducing *S. zeamais* damage are needed in these countries (Danho *et al*., 2002). Infestation by this weevil commences in the field (Demissie *et al.,* 2008), but most damage is done during storage. Damaged grains by post-harvest insects, including Maize weevils, have reduced nutritional values, low percent germination, and weight and market values, respectively. Worldwide seed losses ranging from 20 to 90% have been reported for untreated maize due to the maize weevil *S. zemais* (Delima, 1987; Giga *et al.,* 1991).

Synthetic chemical insecticides have been widely used to control pests of stored grain, particularly *S.zeamais*. This is of global concern concerning environmental hazards, insecticide resistance development, chemical residues in food, side effects on non-target organisms, and the associated high costs are among the consequences of those methods (Cherry *et al.,* 2005). The increasingly severe problems of resistance and residue of pesticides and contamination of the biosphere associated with large-scale use of broad-spectrum synthetic pesticides is another serious challenge. Now, that is what has led to the need for effective biodegradable pesticides with excellent selectivity. This awareness will create a worldwide interest in developing alternative strategies, including discovering newer insecticides (Cherry et al., 2005).

However, newer insecticides will have to meet entirely different standards. They must be pest-specific, no-phototoxic, no-toxic to mammals, eco-friendly, less prone to pesticide resistance, relatively less expensive, and locally available. This has led to re-examining the century-old practices of protecting stored products using plant derivatives, which have been known to resist insect attacks. Plant-derived materials are more readily biodegradable, less likely to contaminate the environment, and may be less toxic to mammals. There are many examples of very toxic plant compounds. Therefore, today, researchers are seeking new classes of naturally occurring insecticides that might be compatible with newer pest control approaches (Yallappa *et al.,* 2012). Thus, this research was conducted to evaluate the effect of *Tagetes minuta* on the control of *Sitophilus zeamais* in stored maize grains.

Materials and Methods

A survey to assess farmer knowledge on Marigold as a bio-pesticide and Maize weevil as a storage pest was performed in six districts (Musanze and Gicumbi (high altitude), Muhanga and Rusizi, Gasabo (Medium altitude) and Bugesera (Low altitude). Interviews with key informants were conducted using questionnaires. At least 30 respondents (farmers) were selected in each village of the three villages selected per sector for this study's six districts of focus, meaning a total of 540 respondents. The respondents were selected from the list of farmer cooperatives available.

Bioassays for this research were carried out in the laboratories of the University of

Rwanda, College of Agriculture located in Huye Campus (alt: 1,646 masl, t^0: 20^0C and RH: 83.4%) and Busogo campus (alt: 2,200 masl, t^0: 15.6^0C and RH: 86%). Maize weevils, *Sitophilus zeamais,* were collected from stored maize grains, healthy maize grains were collected from Rubilizi (Kigali), while Marigold (*Tagetes minuta)* were collected from the Eastern Province. The experiment was laid out in a Completely Randomized Design (CRD) with eight (8) treatments and three (3) replications.

Samples of mature marigold biomass (whole plant with flowers) were cleaned using tap water to remove soil on roots and dried in the shade at room temperature for two weeks. Dried marigold biomass was divided into (1) roots and stems, (2) leaves and flowers, chopped, ground using an electrical grinder, and sieved using a 2mm sieve. One hundred (100) maize grains (average: 41.82 gr) and different doses (2grs, 4grs, and 6grs) of marigold powder were mixed in buckets. This was followed by releasing ten (10) maize weevils into each bucket covered with perforated lids and kept under room conditions. It is important to note that, for comparison purposes, ten maize weevils were released on 100 untreated maize gains (negative control). In contrast, ten maize weevils were released on 100 maize grains treated with Malathion (positive control). Each treatment was repeated three times.

Data collection focused on reproduction and death of maize weevils as well as on grain damage every two days for one month. Micro-Soft Excel was used for data processing, while the analysis of variance (ANOVA) was performed using GenStat 2013 (14th Edition).

Results and Discussion

Farmer awareness of *Sitophilus zeamais* as a crop pest in selected study areas

A range of major pests, including *Sitophilus zeamais*, damage crops, leading to economic yield loss in selected study areas. For this research, the interest was to know farmer awareness of the pest status of *Sitophilus zeamais.* The results revealed that 31% of interviewed farmers reported that *Sitophilus zeamais* is among the pests that damage maize grains under storage conditions (Figure 1). Previous studies reported that insect pest damage to stored grains, including maize, results in major economic losses in Africa, where subsistence grain production supports the livelihoods of the majority of the population (Udo, 2005).

In addition, insect infestation of maize grains reduces the quality and quantity of harvested crops and, in most cases, pre-disposes the stored grains to secondary attack by disease-causing pathogens such as aflatoxins (Hill, 1987). It is essential to indicate that the level of farmer awareness of *S. zeamais* (31%) was relatively lower compared to field crop pests (White grubs: 70%; Caterpillars: 72%; Aphids: 75% and White flies: 62%) (Figure 1). The lower level of farmer awareness of S. zeamais can be supported by the fact that not many farmers have huge amounts of maize grains to store for an extended period due to small-sized arable lands.

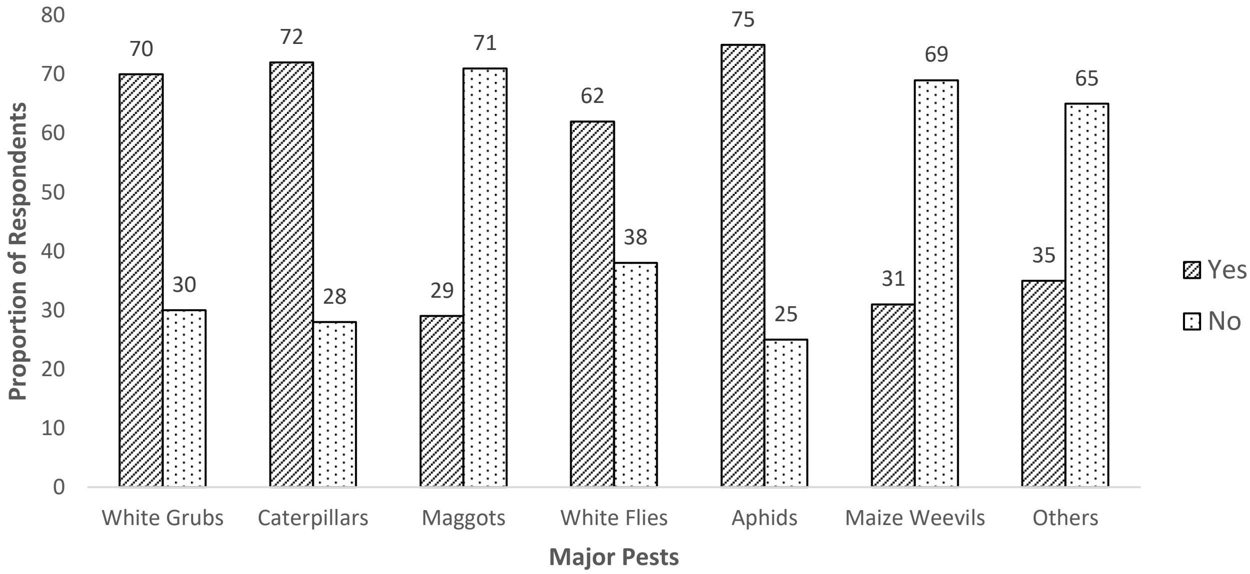

Figure 1. Proportion of Respondents that are Aware of Damages Inflicted by Major Crop Pests in Selected Study Areas

Farmer Awareness of Marigold (*Tagetes spp*) as a Botanical Pesticide

Pyrethrum, tephrosia, garlic, neem, tobacco, pepper, and marigold are common in the farming system in Rwanda. Apart from pyrethrum, that is mainly grown for the extraction of 'pyrethrin', which is an insecticide. The remaining is also produced for other farming purposes, except marigold (*Tagetes minuta*), which is a fallow weed. However, all these plants are reported to have pesticidal properties. The results of a survey that intended to determine farmers' level of awareness of marigolds as a pesticidal plant revealed that only 10% of respondents knew that marigolds can be used to protect crops, including stored grains (Figure 2).

Naturally, botanical insecticides are believed to possess specific attributes that give them a higher advantage over conventional ones. These include low mammalian toxicity, less environmental persistence, selectivity toward target pests, and non-phytotoxicity (Rosenthal, 1986; Isman, 2004). Tagetes flowers are also used as insect repellent, while its oil obtained from leaves is more toxic to mosquito larvae than DDT (Macedo *et al.*, 1997). Tagetes roots have fungicidal and nematocidal characteristics (Pawada *et al.*, 2012). Tagetes minuta can protect stored maize grains against maize weevils (Lale, 1995; Golobo *et al.*, 1982).

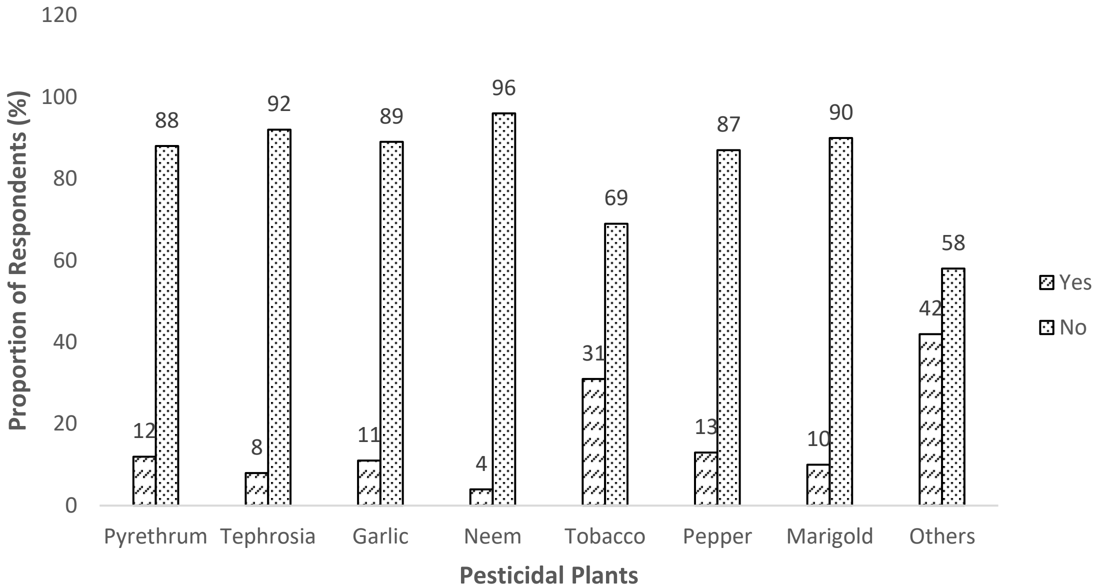

Figure 2. Proportion of Farmers that are Aware of Pesticidal Plants Commonly Occurring in the Study Areas

Mortality of *Sitophilus zeamais*

Maize weevils start active feeding on the third day after hatching. The bioassay results, whereby various treatments were applied, revealed that the death rate was higher when 4 grams were used for both Tagetes powder obtained from leaf and flowers and root and stems (Table 1). The death slowed down on the tenth through the sixteenth day as, during this period, feeding is reduced due to the beginning of pupation. More active weevils were observed from the nineteenth and 22 days because new adults emerge after the pupation period. The high weevil mortality due to *Tagetes minuta* showed the complexity of the physical effect of *Tagetes minuta* powder on weevils (Parwada *et al.*, 2012).

Table 1. ***Weevil Mortality Rate throughout the Seven Treatments as Result of a One-month Observation Period. Means Followed by the Same Letter in the Column are Not Statistically Different***

Treatment	Observation Period						
	Day 4	Day 7	Day 10	Day 13	Day 16	Day 19	Day 22
To (0g): Control	0a	0a	1a	0a	1.3b	1.6b	2.3b
T1 (2g): Root & Stem	0.3a	1.3a	0a	0a	2.3bc	0a	4c
T2 (4g): Root & Stem	4b	0.3a	0a	0a	1.6ab	0.3	3.6c
T3 (6g): Root & Stem	1.6a	0a	0a	0.3a	1.3b	1b	5.3cd
T4 (2g): Leaves & Flowers	1a	1.3a	0.3a	1a	1.3b	1.3b	3.6c
T5 (4g): Leaves & Flowers	5.3b	0.6a	0.3a	0.3a	1b	0.3a	2b
T6 (6g): Leaves & Flowers	3.3b	1.3a	0.6a	0a	0.3a	0.6a	1.6b
T7 (Malathion)	9c	0a	0a	0a	0a	0a	0a

Treatment Effect on the Reproduction of *Sitophilus zeamais*

The reproduction of weevils was sensibly affected for nearly the first two weeks with less reproduction where 4 grams of Tagetes from both root-stem and leaves-flowers were applied, while the application of Malathion completely did not allow any reproduction till the end of the bioassay period. However, the reproduction tended to increase toward day 22, possibly due to a reduction in the active ingredient of Tagetes that may have coincided with newly emerged weevils from the pupal stage. It is worth noting that stored product insect pests generally do not feed or reproduce at temperatures below 18°C. Lower temperatures can also cause mortality (Fields *et al.*, 1992).

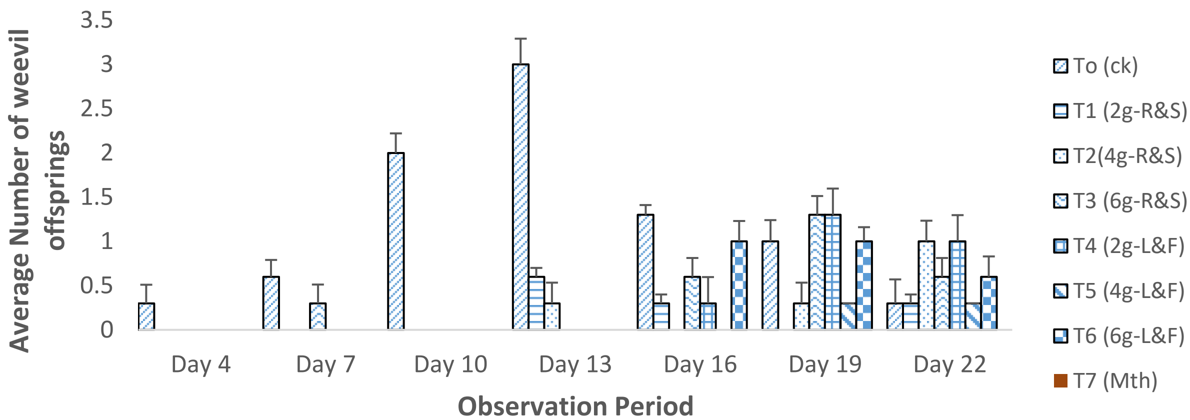

Figure 3. The Effect of the Various Treatments on the Reproduction (average number of offspring) as recorded for nearly three weeks of the Observation Period. The Error Bars stand in for the Standard Error of the Means.

Grain Damage Due to *Sitophilus zeamais*

As for the observations from the other parameters, the application of 4 grams of *Tagetes* from root, stem, leaves, and flowers resulted in reduced grain damages (< 10%) for the first two weeks, whereas for malathion, no case of grain damage at all (Figure 4). Conversely, grain damage in controls without treatment applied was higher, up to 60%.

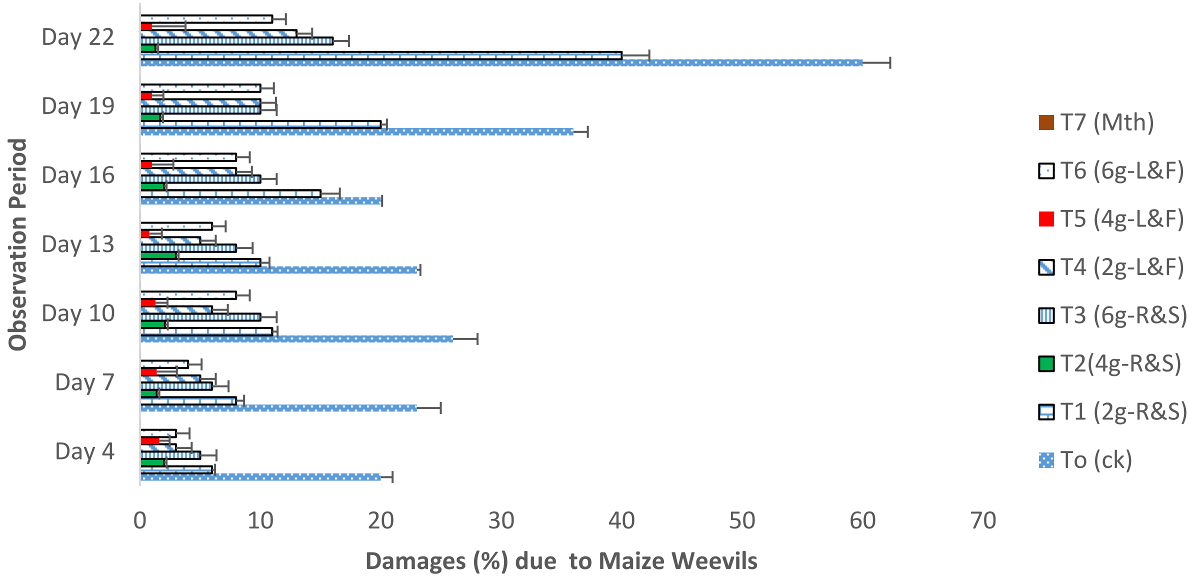

Figure 4. Percentage of damaged grain due to feeding of Sitophilus zeamais for one-month period

Conclusion and Recommendations

Post-harvest losses due to *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae) have been recognized as an essential constraint to grain storage in Africa (Markham *et al.,* 1994; Oduor *et al.,* 2000). The current study has demonstrated that Volatile Organic Compounds from *Tagetes minuta* have great potential for controlling maize weevils (53%) versus 90% recorded for Malathion. It is important to note that Malathion has high toxicity toward weevils. However, Malathion is too expensive for many poor farmers in developing countries; on top of that, it is hazardous and has caused insecticide resistance problems (Pasalu et al., 1993; Halliday et al., 1988). This calls for the development of alternative solutions for maize weevil control.

Several control measures are currently used, but each has challenges and limitations. Due to high costs and labor, farmers are often resigned to using no control measures. Though botanical insecticides comprise only a tiny portion of the total volume of insecticides used annually, they remain essential in insect pest management because they are believed to provide the most effective control against insect pests that have become resistant to other insecticides (Weinzierl, 2000). Specific plant essential oils and their constituents have broad activity spectra against insect and mite pests, fungi, and nematodes (Isman, 2000). For the current study, the optimum application dose of 4g/100g led to better results for both root and stem and leaf and flower powder.

Further studies to identify and isolate the active volatile compounds from *T. minuta* through GC-ms will significantly contribute to formulating safer and environmentally friendly pesticides to control maize weevils and reduce the risk of aflatoxin. So far, previous reports from phytochemical analysis of aerial parts of *Tagetes minuta* showed the presence of terpenoids, saponins, tannins, flavonoids, and alkaloids (Shahzadi *et al.,* 2010). The main constituents of *T. minuta* oil include limonene and (Z) - ocimene (monoterpenes); dihydrotagetone (E)-and (Z) - tagetone (E) - and (Z) - tagetenone (also known as (E) - and (Z) -

ocimenone) (Shahzadi et al., 2010). Essential oils from bloomed plant leaves and flowers contain β ocimene and tagetenone, whereas non-bloomed plant leaves and flowers mainly have dihydrotagetone (Chamorro *et al*., 2008).

Studies involving a Y-tube olfactometer will shed more light on the behavioral responses of maize weevils as emitted from T minuta. Studies on OBPs and CSPs can help understand the mode of action of Tagetes Organic Volatile Compounds. Similarly, potential adjuvants and surfactants that should be added to pesticide formulations to improve performance characteristics of formulations of Tagetes extracts need to be assessed to increase their effectiveness for a relatively long period during grain storage.

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