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Source: Southwestern Entomologist, 42(3):725-730.
Published By: Society of Southwestern Entomologists
https://doi.org/10.3958/059.042.0311
URL: http://www.bioone.org/doi/full/10.3958/059.042.0311

Plant Oils to Control *Sitophilus zeamais* Motschulsky[1]

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Abstract. The maize weevil, *Sitophilus zeamais* Motschulsky, is the most important pest of stored maize, *Zea mays* L. The pest causes estimated losses of 5-10% worldwide. Oil extracts from plants show promise to control maize weevil with important advantages over conventional insecticide, such as non-toxicity to humans, biodegradability, and ecosystem safety. The objective of this research on maize weevils in laboratory conditions was to determine the insecticidal effect of 10 plant oils: garlic, *Allium sativum* L.; cinnamon, *Cinnamomum verum* J.; hot pepper, *Capsicum annuum* L.; clove, *Syzygium aromaticum* L.; mint, *Mentha piperita* L.; black pepper, *Piper nigrum* L.; rosemary, *Rosmarinus officinalis* L.; rue, *Ruta graveolens* L.; thyme, *Thymus vulgaris* L. and allyl (commercial product). Residual film was used to test plant oils at five concentrations: 9,000, 7,000, 5,000, 3,000, and 1,000 ppm. The number of weevils killed was counted at 72 hours, and treatment means were compared using a Tukey multiple separation test. PC-Probit analysis determined LC_{50} and LC_{95}. Most weevils, 52.47 and 60.38%, were killed by garlic and black pepper oils, respectively; at 9,000 ppm; fewer than 50% were killed with the other plant oils. Use of garlic and black pepper oil might be an alternative method to manage this insect pest in stored maize.

Resumen. Una de las plagas más importantes en maíz almacenado es el gorgojo del maíz, *Sitophilus zeamais* Motschulsky; plaga de la cual se estiman perdidas en postcosecha de 5 a 10% de la producción mundial. Una alternativa a este problema es el uso de productos naturales derivados de plantas, que son biodegradables, no producen desequilibrio en el ecosistema ni efectos a la salud. El objetivo en la presente investigación fue determinar el efecto insecticida de diez aceites vegetales sobre poblaciones del gorgojo del maíz, a través de bioensayos y bajo condiciones de laboratorio. Se utilizaron los aceites de ajo, *Allium sativum* L.; canela, *Cinnamomum verum* J.; chile, *Capsicum annuum* L.; clavo, *Syzygium aromaticum* L.; menta, *Mentha piperita* L.; pimienta negra, *Piper nigrum* L.; romero, *Rosmarinus officinalis* L.; ruda, *Ruta graveolens* L.; tomillo, *Thymus vulgaris* L. y alilo (producto comercial). Se aplicó un bioensayo de película residual con cinco concentraciones: 9000, 7000, 5000, 3000, y 1000 ppm. La mortalidad se evaluó a

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las 72 h después de la aplicación de los tratamientos y se analizó mediante un análisis de varianza con separación de medias de Tukey y un análisis PC-Probit para la CL_{50} y CL_{95}. La mayor mortalidad se obtuvo en la concentración de 9000 ppm, donde los aceites de ajo y pimienta negra presentaron mortalidades de 60.38 y 52.47%, respectivamente, mientras que los demás aceites evaluados mostraron porcentajes de control menores al 50%. Los aceites de ajo y pimienta negra son alternativas útiles para el control de *S. zeamais*, en granos almacenados.

Introduction

Maize, *Zea mays* L., exhibits great biodiversity worldwide and is third in importance after wheat, *Triticum aestivum* L., and rice, *Oryza sativa* L. Countries producing the most maize are the United States, China, and Brazil that together account for ~73% of annual global production estimated at 456.2 million tons (ARS/USDA 2014). Mexico is the seventh-largest maize producer in the world, with 23,273,256.54 tons produced on 7,426,000 ha, or 3% of the maize produced in the world. Maize is the largest crop in Mexico and used for human, animal, and industrial consumption (SAGARPA- SIAP 2014).

In Latin America, 30 to 40% of maize is destroyed during storage (Lagunes 1994, Larraín 1994), which greatly exceeds the 5-10% loss reported worldwide. The maize weevil, *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae), is the most damaging insect pest of stored maize, mainly in warehouses that lack proper conditions for optimal storage (Cruz et al. 2015). Cerna et al. (2010) said control of maize weevil was based mainly on synthetic insecticide that is less effective over time.

To minimize loss, mixtures of chemical fungicide and insecticide protect grain during storage; however, applied dosages might be toxic to seeds and seedlings, frequently leading to problems of resistance by pests, pollution of the environment, and residue in food (Silva et al. 2003). An alternative to the problem is use of natural products from plants that are biodegradable and do not damage the ecosystem (Iannacone and Reyes 2001, Iannacone and Lamas 2003). Biological effectiveness of vegetable oils was evaluated against maize weevil to reduce reliance on and minimize adverse effects from conventional insecticide.

Materials and Methods

Effects of 10 vegetable oils to kill maize weevil adults were evaluated in a laboratory (Table 1). Each plant species was separately blended in an electric blender and sifted at 250 µm to obtain a fine, homogeneous powder. Aliquots of 100 g of powder were mixed with 300 ml of commercial cooking oil for homogeneity and stored for 30 days at ambient temperature in a dark room. The mixture was filtered for 24 hours to obtain 100% essential oil of each species (IRAC 2012, with slight modification).

Concentrations of 9,000, 7,000, 5,000, 3,000, and 1,000 ppm of each essential oil and Tween 80 (0.5%) as an emulsifier were used; the mixture was made with a Corning Homogenizer Stirrer at speed 3 for 5 minutes (Pontigo et al. 2015). Once the different concentrations were obtained from each plant species, 1 ml of mixture was spread in the bottom and top of a 9.0-cm-diameter Petri dish and let dry for 10 minutes at room temperature to form a residual film. Ten maize weevil adults were placed into each Petri dish.

A completely randomized block design was used with 11 treatments with 30 experimental units each with three replications including a check of only distilled water. A stereomicroscope was used to aid in counting dead insects at 24, 48, and 72 hours after treatment. An insect was dead if it did not move after being touched with a fine brush, or had detached appendices or a dehydrated body (FAO 1980). Mortality was evaluated at 72 hours after application and for standardization, the percentage values were transformed to arc-sin $\sqrt{x/100}$. Analysis of variance (ANOVA) and a Tukey multiple range test (p ≤ 0. 05) were used for mean separation, and PC Probit analysis was used to determine LC_{50} and LC_{95} using statistical software (SAS 2002).

Table 1. Numbers of *Sitophilus zeamais* Adults Killed by Vegetable Oils Applied to Stored Maize Grains under Laboratory Conditions

Vegetable product	Family	Common name	Mean
Allium sativum L.	Amaryllidaceae	Garlic	60.38 a
Piper nigrum L.	Piperaceae	Black pepper	52.47 ab
Ruta graveolens L.	Rutaceae	Rue	48.85 ab
Cinnamomum verum J.	Lauraceae	Cinnamon	47.57 ab
Rosmarinus officinalis L.	Labiatae	Rosemary	46.59 ab
Thymus vulgaris L	Lamiaceae	Thyme	40.28 ab
Syzygium aromaticum L.	Myrtaceae	Clove	35.55 ab
Mentha piperita L.	Lamiaceae	Mint	26.90 bc
Capsicum annuum L	Solanaceae	Hot pepper	25.55 bc
Allyl isothiocyanate	Commercial product	Allyl	21.15 bc
		Check	00.00 c

Means with the same letter are not significantly different (Tukey p ≤ 0. 05).

Results and Discussion

Significantly, more maize weevil adults were killed by garlic (60.38%) and black pepper oils (52.57%) (Table 1). In accordance with Lagunes (1994) who stated that promising treatments were those that killed more than 50%. Peña et al. (2013) found that garlic killed as many as 95% of *Aphis gossypii* Glover (Hemiptera: Aphididae) in beans *Phaseolus vulgaris* L. Var. calima. Vasquez (2005) mentioned that garlic was repellent and when ingested caused digestive disorders that prevented feeding. Cardoso et al. (2014) found that extracts of black pepper killed 60 to 98% of maize weevil adults. Estrela et al. (2006) evaluated the effect of oils of leaves of long pepper, *Piper affinis hispidinervum* C. DC, and soldier's grass, *Piper aduncum* L., and found them toxic by contact, topical application, and fumigation against maize weevils. Oils of rue, cinnamon, rosemary, thyme, clove, mint, hot pepper, and allyl killed fewer than 50% of maize weevils, which agrees with results by Silva et al. (2003, 2005), Salvadores et al. (2007), and Castillo et al. (2012).

Lethal concentrations and fiducial limits obtained by PC-Probit are in Table 2. The oil with the greatest insecticidal activity was garlic at a concentration of 9,000 ppm that killed 60.38% of maize weevil adults; Arannilewa et al. (2006) found extracts of garlic at 15,000 ppm killed 85% the third day after treatment. Black pepper oil at the same concentration of 9,000 ppm killed 52.47%; Silva et al. (2003), using Mexican pepper leaf, *Piper auritum* Knuth and bay laurel, *Laurus nobilis* L.

oils at a 10,000-ppm concentration, reported as much as 65.80% control of maize weevils. Regarding LC_{50} and LC_{95}, garlic and black pepper oils at 72 hours after application were most toxic at concentrations of 1,556 and 2,279 ppm, respectively.

Table 2. Lethal Concentrations of Vegetable Oils to Control *Sitophilus zeamais* Adults

			Fiducial limits			
Plant oil	N	LC_{50}	50	95	LC_{95}	χ^2
Thyme	30	5158	4025-6842	18314-104001	32156	<0.0001
Rue	30	3189	2217-4250	15722-105842	28785	<0.0001
Cinnamon	30	3844	1630-6519	7640-351584	13896	<0.0001
Clove	30	5708	4810-6862	12773-36507	18075	<0.0001
Rosemary	30	3491	2106-5251	26253-1622433	73838	<0.0001
Black pepper	30	2279	1219-3263	16350-246363	35007	<0.0001
Mint	30	26380	11311-5672406	101030-1.74142e13	1083703	<0.0092
Garlic	30	1556	839-2200	8618-38430	14010	<0.0001
Allyl	30	21362	11282-495767	51409-1411489874	255644	<0.0045
Hot pepper	30	40768	13470-4.47099e10	140525-1.45932e24	2660429	<0.0232

LC: Lethal concentrations. Fiducial limits: confidence intervals. $P \leq 0.05$.

For oils that killed fewer than 50% of the maize weevils, probit analysis showed the LC_{50} values for rue, rosemary, and cinnamon were 3,189, 3,491, and 3,844 ppm, respectively. The oils can be considered promising for pest control because they were less than the maximum concentration (5,000 ppm) recommended by the German Technical Cooperation Agency (GTZ) under laboratory conditions (Hellpap 1993). Thyme, cloves, mint, chili peppers, and allyl even at the greatest concentrations killed few maize weevils; thus, their use as control agents was not feasible.

Conclusions

Based on results of the study, garlic and black pepper oils were the most effective insecticides. Although rue, rosemary, and cinnamon oils did not provide the desired amount of control, the concentrations used can be promising for pest control. Thyme, clove, mint, hot pepper, and allyl under the conditions of the study did not show potential for insect control. Garlic and black pepper oils have good potential for use in integrated management of *S. zeamais* weevils in stored maize.

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