Contact Toxicity and Repellent Activity of a Powder Extracted from Tridax Daisy (*Tridax procumbens*) against Maize Weevil (Coleoptera: Curculionidae)[1]

Ruchuon Wanna[2], Benjapon Kunlanit, Darika Bunphan, Phirayot Khaengkhan, Parinda Khaengkhan[3], and Hakan Bozdoğan[4]

Department of Agricultural Technology, Faculty of Technology and Resource Management in Agricultural Technology Research Unit, Mahasarakham University, Kantarawichai District, Maha Sarakham 44150, Thailand

J. Entomol. Sci. 60(4): 000–000 (Month 2024)
DOI: 10.18474/JES24-75

Abstract The maize weevil (*Sitophilus zeamais* Motschulsky) is a significant pest affecting stored seeds and grains, leading to substantial losses in both quantity and quality. Utilizing crushed plant powders derived from specific natural plants offers a promising alternative to synthetic insecticides, which pose risks to both consumers and the environment. This study aimed to evaluate the contact toxicity of Tridax daisy (*Tridax procumbens* L.) plant powder derived from its aerial parts against *S. zeamais* when incorporated into jasmine brown rice, *Oryza sativa* L., grains. Laboratory experiments were conducted at 30°C ± 5°C and 70% ± 5% relative humidity following a completely randomized design with four replications and five treatments. Jasmine brown rice grains were treated with different application rates of 0 (control), 20, 40, 60, and 80 g/kg, with five pairs/replicate of 7-d-old *S. zeamais*. Results showed that *T. procumbens* powder exhibited a contact toxicity of 93.08 g/kg of grain after 12 d, resulting in a mortality of 27.5%. Additionally, the F1 generation comprised 51 adults, indicating an 85% reduction in adult progeny emergence. These findings demonstrate the potential of *T. procumbens* powder as a natural grain protectant to control *S. zeamais* populations in storage.

Key Words Asteraceae, *Sitophilus zeamais*, *Tridax procumbens*, toxicity, stored product insects

Stored products, such as grains and flour, are a crucial source of carbohydrates worldwide. However, they are often susceptible to infestations by various types of insect pests, resulting in a decrease in both quantity and quality (Boyer et al. 2012). One significant factor contributing to these high storage losses is the presence of storage insect pests such as the maize weevil, *Sitophilus zeamais* (Motschulsky) (Tefera et al. 2011). This pest is a significant threat to stored maize grains in the tropics and subtropics worldwide (Sagheer et al. 2013), showing a cosmopolitan distribution in numerous warm and humid regions (López-Castillo et al. 2018). Infestation typically

[1]Received 21 July 2024; accepted for publication 2 September 2024.
[2]Correspondng author (email: ruchuon.w@msu.ac.th).
[3]Division of Plant Production Technology, Faculty of Agricultural Technology, Kalasin University, Kalasin 46000, Thailand.
[4]Vocational School of Technical Sciences, Department of Plant and Animal Production, Kırşehir Ahi Evran University, Kırşehir 40100, Turkey.

starts in mature crops when the grain's moisture content has decreased to 18–20% (Radha 2014), resulting in reduced production and compromised storage quality (Arrahman and Saenong 2021). It can cause losses ranging from 20 to 40% during cultivation and 30 to 90% postharvest and during storage (Odendo et al. 2001).

In addition to causing significant losses due to grain consumption, *S. zeamais* also creates elevated temperature and moisture conditions that accelerate the growth of molds, including toxigenic species (Chu et al. 2013), and the production of allergens (Yang et al. 2020). As a result, the nutritional quality, weight, and germination rates of seeds are reduced, which poses food safety concerns related to the transmission of fungi and various types of bacteria. According to CAB International (2005) and Markham et al. (1994), both adult weevils and larvae feed on undamaged grains, reducing them to powder. This results in the creation of holes in previously intact grains, rendering them nonviable and reducing their market value. Infested seeds with compromised germs fail to germinate, further compounding the losses. The damage caused by the feeding activities of adult weevils and the development of immature stages within the grain are the primary impacts on the grain (Longstaff 1981).

To combat these losses, the control of this pest has heavily relied on synthetic insecticides. However, this approach has led to environmental disturbances, increased costs of application, pest resurgence, resistance to pesticides, and adverse effects on nontarget organisms, including direct toxicity to users. Consequently, there is a growing urgency to develop new strategies that minimize environmental harm and reduce the likelihood of the development of insecticide tolerance (Nayak et al. 2021). The use of botanicals has emerged as a biorational management practice (Aboelhadid and Youssef 2021; Babarinde et al. 2018, 2021), with studies such as Adarkwah et al. (2017) exploring the combination of botanical powder with diatomaceous earth for control purposes. This shift has led researchers to investigate the efficacy of plant powders, extracts, and oils, offering economical and ecofriendly options for crop protection (Damalas and Koutroubas 2020, Riyaz et al. 2022). Plant-derived substances are gaining popularity due to their effectiveness in safeguarding agricultural commodities, low toxicity to mammals and vertebrates, and limited persistence without adverse effects on animals and humans (Kedia et al. 2015).

Botanical powders offer promise for wider acceptability, as their production requires minimal technical expertise beyond drying and pulverization, making them accessible to resource-poor farmers. Furthermore, their compatibility with other control strategies makes them suitable for integrated pest management approaches. Despite these advantages, a significant challenge with botanical powders is their limited persistence. Their efficacy tends to diminish over time postapplication (Babarinde et al. 2008). Therefore, there is a need to investigate botanical powders that offer both cost effectiveness and sustained efficacy. In the selection of botanical species for pesticide purposes, factors such as availability, affordability, ecological compatibility, and ethnobotanical characteristics of the species should be carefully considered. The chosen botanical species for this study, Tridax daisy (*Tridax procumbens* L.), is a tropical plant species readily available locally. Its ethnobotanical characteristics suggest ecofriendliness, making it a suitable candidate for pesticide use. Thus, this study aims to evaluate the contact toxicity of plant powder from *T. procumbens* against *S. zeamais*, contributing to the ongoing efforts to develop sustainable and effective pest management strategies.

Materials and Methods

Insect rearing. Maize kernels (*Zea mays* L.) were disinfected at 5°C for 1 wk to eliminate any previously infested seeds before being used to feed *S. zeamais*. Unsexed adults (150–200 individuals) were then released into 2-L plastic buckets containing 1 kg of kernels as food material. The plastic buckets were sealed with lids and placed in a growth chamber at 30°C ± 5°C, 70% ± 5% relative humidity (RH), and a 12:12 h light:dark cycle at the Department of Agricultural Technology, Faculty of Technology, Mahasarakham University, Maha Sarakham, Thailand, following the method described by Wanna and Kaewduangta (2022). *Sitophilus zeamais* populations were raised to increase their numbers and abundance. To ensure uniformity of the test insects in the experiment, *S. zeamais* were separated and reared again. Twenty pairs of *S. zeamais* were released into plastic buckets containing 250 g of kernels and placed in a growth chamber to facilitate mating and egg laying in the kernels for 6 d. Afterward, the adults were removed and the eggs were allowed to hatch and develop into 7-d-old adults for further bioassays.

Plant powder. The aerial parts (stems, leaves, and flowers) of *T. procumbens* were collected from the agricultural experimental field of the Department of Agricultural Technology, Faculty of Technology, Mahasarakham University, Maha Sarakham, Thailand. They were then cleaned and dried in a hot-air oven at 30°C to dry for 3 d. Following the method outlined by Wanna and Kaewduangta (2022), the dried plant material was ground into a powder using an electric grinder and sieved through a 0.5-mm sieve. The resulting plant powder was then stored in a sealed dry bag until further use in further bioassays.

Contact toxicity and effect on newly emerged adult progeny (F1). The experiment was designed as a completely random design with four replicates, five treatments, and a total of 20 experimental units. A series of concentrations of plant powder from *T. procumbens* had 0 (control), 20, 40, 60, and 80 g/kg grain. Plant powder was mixed with 50 g of jasmine brown rice grains in a 250-mL glass bottle, shaken, and thoroughly mixed by hand for 15 min. Subsequently, five pairs of adult *S. zeamais* (7 d old) were released into the 250-mL glass vials containing jasmine brown rice grains mixed with *T. procumbens* powder or not mixed with plant powder (control). The glass bottles were covered with cheesecloth and placed in a growth chamber maintained at 30°C ± 5°C, 70% ± 5% RH, and a 12:12 h light:dark cycle following the method outlined by Wanna and Kaewduangta (2022). The numbers of deaths of *S. zeamais* adults were recorded every 24 h at 3, 6, and 12 d after initiation of the test. After 14 d, a sieve was used to separate jasmine brown rice grains from *S. zeamais*. Seeds were separated and kept in a growth chamber until the newly emerged adult progeny (F1) of *S. zeamais* emerged. The number of adult F1 progeny in each treatment was counted every 24 h until no additional emergence of adult progeny (F1) was observed, depending on the life cycle of *S. zeamais* under control treatment.

Data analysis. The mortality data recorded were adjusted for mortality in the control using Abbott's formula when it exceeded 5% and expressed as a percentage (Abbott 1925). Contact toxicity (50% lethal concentration [LC_{50}] and 95% LC [LC_{95}]) was assessed for concentration–mortality response using probit analysis (Finney 1971), expressed as g/kg grain. Mortality data were expressed as means ± standard error. The rate of reduction of the newly emerged adult F1 of *S. zeamais* or the

Table 1. Contact toxicity of *Tridax procumbens* powder against *Sitophilus zeamais* adults.*

Time (days)	*n*	LC_{50} (50% CL) (g/kg grain)	LC_{95} (95% CL) (g/kg grain)	Intercept	χ^2
3	200	100.50 (90.04–130.07)	126.33 (107.69–187.38)	−8.39	0.61
6	200	94.66 (89.20–102.36)	123.97 (113.93–139.66)	−5.31	12.38
12	200	93.08 (86.68−102.27)	123.65 (112.26−142.35)	−5.0	20.50

* n = 320 insects (adult *S. zeamais*) tested; LC_{50}, LC_{95} = lethal concentration (g/kg grain) that will cause 50% and 95% mortality of *S. zeamais* adults, respectively; CL = confidence limit.

inhibition rate (%IR) was calculated using the formula %IR = (Cn − Tn) × 100/Cn (Tapondjou et al. 2002), where Cn = number of newly emerged adult F1 of *S. zeamais* in the control treatment and Tn = number of newly emerged adult F1 of *S. zeamais* in the treatment that received *T. procumbens* powder. The significance of mean differences between treatments and the control was statistically compared using an analysis of variance at $P \leq 0.05$, with means compared using the least significant difference test through Statistix, version 9.0 (Analytical Software, Tallahassee, FL).

Results

Contact toxicity. The contact toxicity of *T. procumbens* powder on *S. zeamais* adults was evaluated using the seed dressing method. The results showed that after 3, 6, and 12 d of exposure, the contact toxicity values were LC_{50} = 100.5, 94.66, and 93.08 g/kg, and LC_{95} = 126.33, 123.97, and 123.65 g/kg grain, respectively (Table 1). No mortality was observed in *S. zeamais* adults exposed to Khao Dawk Mali 105 (KDML) brown rice treated with 20, 40, and 60 g/kg grain over 3, 6, and 12 d; thus, these data could not be statistically analyzed (Table 2). However, at a concentration of 80 g/kg grain, the mortality of *S. zeamais* adults was recorded at 7.5% ± 5.00% after 3 d, increasing to 22.5% ± 5.00% after 6 d, and reaching 27.5% ± 9.57% after 12 d.

Effect on newly emerged adult F1. Using *T. procumbens* powder mixed with jasmine brown rice grains for 14 d influenced the number of progeny adult emergence of *S. zeamais*, with significant differences observed. The *T. procumbens* powder at a rate of 80 g/kg grain yielded the least number of progeny adult emergence of *S. zeamais*, with 51.00 ± 28.96 adults, which was statistically different when compared with the rates of 60 and 40 g/kg grain (102.0 ± 29.08 and 142.75 ± 23.54 adults, respectively). Furthermore, a significant difference was observed when comparing it with a rate of 20 g/kg grain (218.0 ± 22.68 adults). In the control (0 g/kg grain), the number of progeny adult emergence of *S. zeamais* was as high as 347.75 ± 40.43 adults and was found to be significantly different when compared with all concentrations of the plant powder tested (Table 3). Furthermore, it was determined that a plant powder rate of 80 g/kg grain exhibited the highest inhibition rate of progeny adult emergence of *S. zeamais*, with a value of 85.33%. This was followed by rates of

Table 2. Mean (±SE) percent mortality of *Sitophilus zeamais* after contact with *Tridax procumbens* powder in jasmine brown rice grains.

Concentration (g/kg grain)	Mortality (%) of *S. zeamais* 3 d	6 d	12 d
0 (Control)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
20	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
40	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
60	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
80	7.50 ± 5.00	22.50 ± 5.00	27.50 ± 9.57
F test	N/A*	N/A	N/A

* N/A = not applicable.

60, 40, and 20 g/kg grain, which resulted in inhibition rates of 70.67%, 58.95%, and 37.31%, respectively.

Discussion

The contact toxicity varied depending on the concentration of the plant powder and the duration of exposure. Throughout Thailand's history, plant powders have been commonly mixed with stored grains, offering a natural, safe, and cost-effective method to shield grains from insect infestations. Previous experiments have primarily concentrated on assessing the effectiveness of plant products over short periods. However, for the

Table 3. Mean (±SE) *Sitophilus zeamais* progeny emergence after exposure to *Tridax procumbens* powder coated on jasmine brown rice grains.

Concentration (g/kg grain)	Progeny adult emergence (adults)	Progeny adult emergence inhibition (%)
0 (Control)	347.75 ± 40.43 a	—
20	218.00 ± 22.68 b	37.31
40	142.75 ± 23.54 c	58.95
60	102.00 ± 29.08 c	70.67
80	51.00 ± 28.96 d	85.33
F test	**	—
LSD	44.651	—
CV (%)	10.84	—

** = significant difference at $P \leq 0.01$. Means within the column followed by the same letter are not significantly different (least significant difference [LSD]): $P > 0.05$). CV = coefficient of variation.

practical application of plant materials in safeguarding stored grain products, there is a need for additional information on the residual effects of these biorational agents over extended periods against significant insect species (Ilboudo et al. 2010). In this study, the application of *T. procumbens* plant powder resulted in a reduction in the number of newly emerged adult F1 of *S. zeamais*. This decrease may be attributed to the contact effects disrupting specific stages of embryo development. These findings agree with studies by Tapondjou et al. (2005) and Ukeh et al. (2008), suggesting that reproductive inhibition could occur because of the toxic impact of crushed plant powder on larvae hatching from eggs laid on seeds, ultimately leading to a decline in offspring (F1). This relationship is mirrored in a prior investigation by Wanna et al. (2021) on the impacts of plant powder derived from the climbing wedelia (*Wedelia trilobata* [L.] A.S. Hitchcock), a member of the same Asteraceae family as *T. procumbens*. At a rate of 80 g/kg grains, the climbing wedelia plant powder reduced the F1 adult emergence of *S. zeamais* by up to 89.96%. This decline might be attributed to plant toxins entering the insect's body through contact with joints, legs, antennae, and other structures, ultimately permeating the insect's cells and tissues, leading to its demise (Guo et al. 2016). Furthermore, Ramsewak et al. (1999) noted that the plant *Acmella oleracea* L., also from the Asteraceae family, possesses high toxicity evident in insect stings. This heightened toxicity could act as a deterrent to insects, inducing starvation and, ultimately, death.

Conclusion. The plant powder derived from the aerial parts of *T. procumbens*, at a concentration of 80 g/kg of grain, exhibited potential for controlling newly emerged adult F1 of *S. zeamais* through its contact toxicity to adult insects when mixed with jasmine brown rice grains. However, it is necessary to conduct a comprehensive study on other effects, such as the residual effect or the persistence of the effectiveness of *T. procumbens* powder in inhibiting the growth of the *S. zeamais* population during each storage period. This further evaluation will help determine the appropriate dosage for controlling *S. zeamais* in the future.

Acknowledgments

This research project was financially supported by Mahasarakham University, Maha Sarakham, Thailand. The authors acknowledge the Department of Agricultural Technology, Faculty of Technology, Mahasarakham University, Maha Sarakham, Thailand for laboratory support. Laboratory assistance from Mr. Suphanat Wongkangchurit and Miss Jiraporn Krasaetep is gratefully acknowledged.

References Cited

Abbott, W.S. 1925. A method for computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265–267.

Aboelhadid, S.M. and I.M. Youssef. 2021. Control of red flour beetle (*Tribolium castaneum*) in feeds and commercial poultry diets via using a blend of clove and lemongrass extracts. Environ. Sci. Pollut. Res. 28(23): 30111–30120.

Adarkwah, C., D. Obeng-Ofori, V. Hörmann, C. Ulrichs and M. Schöller. 2017. Bioefficacy of enhanced diatomaceous earth and botanical powders on the mortality and progeny production of *Acanthoscelides obtectus* (Coleoptera: Chrysomelidae), *Sitophilus granarius* (Coleoptera: Dryophthoridae) and *Tribolium castaneum* (Coleoptera: Tenebrionidae) in stored grain cereals. Int. J. Trop. Insect Sci. 37: 243–258.

Arrahman, A. and M.S. Saenong. 2021. Controlling maize weevil in corn plants by improving cultivation technology and postharvest handling. IOP Conf. Ser. Earth Environ. Sci. 648: 012034.

Babarinde, S.A., K.A. Kemabonta, I.A. Aderanti, F.C. Kolawole and A.D. Adeleye. 2018. Synergistic effect of spinosad with selected botanical powders as biorational insecticides against adults of *Tribolium castaneum* (Herbst), 1797 (Coleoptera: Tenebrionidae). J. Agric. Sci. (Belgr). 63: 39–51.

Babarinde, S.A., O.S. Olabode, M.O. Akanbi and O.A. Adeniran. 2008. Potential of *Tithonia diversifolia* with pirimiphos methyl in control of *Sitophilus zeamais* (Coleoptera: Curculionidae). Afr. J. Plant Sci. Biotechnol. 2(2): 77–80.

Babarinde, S.A., O.A. Olaniran, A.T. Ottun, A.E. Oderinde, A.D. Adeleye, O. Ajiboye and E.O. Dawodu. 2021. Chemical composition and repellent potentials of two essential oils against larger grain borer, *Prostephanus truncatus* (Horn.) (Coleoptera: Bostrichidae). Biocatal. Agric. Biotechnol. 32: 101937.

Boyer, S., H. Zhang and G. Lempérière. 2012. A review of control methods and resistance mechanisms in stored-product insects. Bull. Entomol. Res. 102: 213–229.

CAB International. 2005. Crop Protection Compendium Global Module. 2nd ed. CABI Publishing, Wallingford, UK.

Chu, S.S., S.S. Du and Z.L. Liu. 2013. Fumigant compounds from the essential oil of Chinese *Blumea balsamifera* leaves against the maize weevil (*Sitophilus zeamais*). J. Chem. 2013: 289874.

Damalas, C.A. and S.D. Koutroubas. 2020. Botanical pesticides for eco-friendly pest management: Drawbacks and limitations, Pp. 181–193. *In* Srivastava, P.K. (ed.), Pesticides in Crop Production: Physiological and Biochemical Action. John Wiley & Sons, Ltd., Hoboken, NJ.

Finney, D.J. 1971. Probit Analysis. 3rd ed. Cambridge Univ. Press, London.

Guo, S., W. Zhang, J. Liang, C. You, Z. Geng, C. Wang and S. Du. 2016. Contact and repellent activities of the essential oil from *Juniperus formosana* against two stored product insects. Molecules 21: 1–11.

Ilboudo, Z., L.C. Dabiré, R. Nébié, I. Dicko, S. Dugravot, A. Cortesero and A. Sanon. 2010. Biological activity and persistence of four essential oils towards the main pest of stored cowpeas, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). J. Stored Prod. Res. 46: 124–128.

Kedia, A., B. Prakash, P.K. Mishra, P. Singh and N.K. Dubey. 2015. Botanicals as ecofriendly biorational alternatives of synthetic pesticides against *Callosobruchus* spp. (Coleoptera: Bruchidae)—A review. J. Food Sci. Technol. 52(3): 1239–1257.

Longstaff, B.C. 1981. Biology of the grain pest species of the genus *Sitophilus* (Coleoptera: Curculionidae): A critical review. Prot. Ecol. 3(2): 83–130.

López-Castillo, L.M., S.E. Silva-Fernández, R. Winkler, D.J. Bergvinson, J.T. Arnason and S. García-Lara. 2018. Postharvest insect resistance in maize. J. Stored Prod. Res. 77: 66–76.

Markham, R.H., N.A. Bosque-Perez, C. Borgemeister and W. Meikle. 1994. Developing pest management strategies for *Sitophilus zeamais* and *Prostephanus truncatus* in the tropics. FAO Plant Prot. Bull. 42(3): 97–116.

Nayak, M.K., R. Jagadeesan, V.T. Singarayan, N.S. Nath, H. Pavic, B. Dembowski, G.J. Daglish, D.I. Schlipalius and P.R. Ebert. 2021. First report of strong phosphine resistance in stored grain insects in a far northern tropical region of Australia, combining conventional and genetic diagnostics. J. Stored Prod. Res. 92: 101813.

Odendo, M., H. De Groote and O.M. Odongo. 2001. Assessment of farmers' preferences and constraints to maize production in Moist Midaltitude Zone of Western Kenya. Paper presented at the 5th international conference of the African crop science society, Lagos, Nigeria.

Radha, R. 2014. Toxicity of three plant extracts against bean weevil, *Callosobruchus maculatus* (F.) and maize weevil, *Sitophilus zeamais* Motsch. Int. J. Curr. Res. 6(4): 6105–6109.

Ramsewak, R.S., A.J. Erickson and M.G. Nair. 1999. Bioactive N-isobutylamides from the flower buds of *Spilanthes acmella*. Phytochem. 51(6): 729–732.

Riyaz, M., P. Mathew, S.M. Zuber and G.A. Rather. 2022. Botanical pesticides for an eco-friendly and sustainable agriculture: New challenges and prospects, Pp. 69–96. *In* Bandh, S.A. (ed.), Sustainable Agriculture, Springer, Cham, Switzerland.

Sagheer, M., A. Khaliq, F.Z.A. Khan, H.T. Gul and K. Ahmad. 2013. Assessment of relative resistance in advanced rice genotypes in response to variation in a biotic factors and development of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae). Int. J. Biol. Sci. 3(12): 33–38.

Tapondjou, L.A., C. Adler, H. Bouda and D.A. Fontem. 2002. Efficacy of powder and essential oil from *Chenopodium ambrosioides* leaves as postharvest grain protectants against six-stored product beetles. J. Stored Prod. Res. 38: 395–402.

Tapondjou, L.A., C. Adler, D.S. Fontem, H. Bouda and C. Reichmuth. 2005. Bioactivities of cymol and essential oils of *Cupressus sempervirens* and *Eucalyptus saligna* against *Sitophilus zeamais* Motschulsky and *Tribolium confusum* du Val. J. Stored Prod. Res. 41(1): 91–102.

Tefera, T., S. Mugo, P. Likhayo and Y. Beyene. 2011. Resistance of three-way cross experimental maize hybrids to post-harvest insect pests, the larger grain borer (*Prostephanus truncatus*) and maize weevil (*Sitophilus zeamais*). Int. J. Trop. Insect Sci. 31(1–2): 3–12.

Ukeh, D.A., G.A. Arong and E.I. Ogban. 2008. Toxicity and oviposition deterrence of *Piper guineense* (Piperaceae) and *Monodora myristica* (Annonaceae) against *Sitophilus zeamais* (Motsch.) on stored maize. J. Entomol. 5(4): 295–299.

Wanna, R., D. Bunphan, W. Kaewduangta, M. Wongsawas and P. Khaengkhan. 2021. Toxicity and bioactivity of powder and essential oil of climbing wedelia against maize weevil. J. Sustain. Sci. Manag. 16(2): 106–114.

Wanna, R. and W. Kaewduangta. 2022. Fumigant activity of *Tridax procumbens* (Asterales: Asteraceae) essential oil against *Sitophilus zeamais* (Coleoptera: Curculionidae) and its effects on Thai rice seed germination. J. Entomol. Sci. 57(4): 561–572.

Yang, Y., M.B. Isman and J.H. Tak. 2020. Insecticidal activity of 28 essential oils and a commercial product containing *Cinnamomum cassia* bark essential oil against *Sitophilus zeamais* Motschulsky. Insects 11(8): 474.