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NATURAL PRODUCTS IN STORED PRODUCT PEST CONTROL: CHALLENGES AND OPPORTUNITIES

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ABSTRACT

Postharvest losses of stored grains are recognized as a major constraint in food security. Thus, the reduction of losses caused by stored product pests (insects, microorganisms and rodents) can increase available food supplies. The control of pests in storage and processing industry is mainly relying on the use of chemically synthesized pesticides and toxic fumigants. However, due a ban or restriction of a number of insecticides, there is an expansion in use of natural products (particularly inert dusts and botanicals). The efficacy of several inert dusts (diatomaceous earth - DE, kaolin clay - KA and vermiculite - VE (5, 7.5, 10, 15 and 20 gm-2)) and plant extracts of weed and invasive plant species (Erigeron cannadensis, Daucus carota and Halacsya sendtneri (0.5, 1 and 2%)) in suppressing the Sitophilus oryzae weevils was evaluated in contact toxicity tests. DE caused significant mortality at rates 10 (67.8%), 15 (75.3%) and 20 gm-2 (98.2 %), as well as KA (75%) at 10 gm-2, after 24 h. The mortality increased with the exposure period, so in both cases, after 72 h, the mortality was very high (97.8 – 100%), regardless on the applied rates. However, VE as well as plant extracts exhibited very low insecticidal activity, since the mortality was 0-17.5%, and 0-11%, respectively.
Keywords: inert dusts, botanicals, storage pests, Sitophilus oryzae.

INTRODUCTION

Postharvest losses (PHLs) of durable commodities such as stored grains represent a major constraint in food security. The losses caused by stored product pests (insects, microorganisms and rodents) amount from 20 to 80%, depending on the region, thus their reduction can increase available food supplies. This is crucial given the fact that due to the constant increase of the population, larger quantities of grains are required to fulfill the needs of the growing human population. (Schmidt et al., 2018). According to Nawaz and Chung (2020) 2.4% increase in crop yield is required to meet the global food demand by 2050. Therefore, reducing the PHLs is essential in improving food security (Schmidt et al., 2018, Chegere, 2018).

Major factors causing grain PHLs are: **biodeterioration** caused by insect pests and rodents (Lorenzo et al., 2020), **poor storage** and **transportation facilities** (Swai et al., 2019), **spillage** due to inadequate handling, **reused packaging** (Mwangi et al., 2017), use of **uncertified seeds** (Njonjo et al., 2019), planting mixed variety of seeds, **mixing old and new seeds**, inadequate and inappropriate **storage condition**s (Kumari et al., 2020) and lack of sufficient **postharvest management practices** (Fabi et al., 2021). Out all the above mentioned, insects represent major factor responsible for biodeterioration, causing both quantitative and qualitative losses (Banga et al., 2020).

The control of insect pests in storages and processing industry is mainly relying on the use of chemically synthesized insecticides with residual activity and toxic fumigants. However, number of these compounds are withdrawn from the market due to ecotoxicological concerns, and occurrence of insect resistance (Athanassiou et al., 2008). A ban of so far efficient insecticides, enabled the expansion of natural products (NPs) use. In general, NPs originate from natural sources, and two groups have the highest potential to be used in in stored product pest management:

i) **Mineral-derived NPs** include inert dusts (powders) of different origin that are chemically inactive in the nature (diatomaceous earth, kaolin clay, zeolite, silver nanoparticles etc.). The use of inert dusts for insect and mite control in stored products has been the subject of many reviews or research papers (Banks and Fields 1994, Golob 1997, Korunic 1998, Cook et al., 2004). IDs act as desiccants, as they destroy the wax layer in the insect's cuticle, causing the 60% loss of body water i.e. 30% loss of total body weight. IDs used in stored-product protection can be categorized into four groups: 1) ashes (paddy husk ash, wood ash etc.); 2) minerals (dolomite, magnesite, copper oxychloride, katelsous, lime, limestone etc.); 3) dusts that contain natural silica (diatomaceous earth, zeolites, clays, sand etc.), 4) dusts that contain synthetic silica. The efficacy of IDs depends on their origin and physio-chemical characteristics. Today, diatomaceous earth and silica gel are the predominant inert dusts used commercially. Both are composed of silicon dioxide and belong to group that contain natural silica. There are several factors which affect the efficacy of IDs: 1) air humidity and grain moisture content, 2) temperature in storage, 3) grain temperature, and 4) exposure time.

ii) **Plant-derived NPs** (botanicals) are developed from plants and/or plant secondary metabolites/volatiles (terpenes, phenolics, steroids, alkaloids etc.) that express biological activity against different storage pest groups. The most potent botanicals originate from plants belonging to families Meliaceae, Myrtaceae, Apiaceae, Lamiaceae, Lauraceae, Poaceae and Pinaceae (Talukder, 2006).

Although NPs have long been used as pesticides and have served as an inspiration for numerous commercial synthetic products, at some point in history they were neglected. At the moment IDs and botanicals are small contributors to the global plant protection product market. However, in the era of "green chemistry" as well in the light of more severe pesticide restriction, it is estimated that these products will take a higher market share in the future, if not as sole products, than as models for development of new synthetic pesticides. Therefore, there is a constant need for screening IDs and plants for potential biological activity. A special focus is given on invasive plant species as potential candidates for bioinsecticides. Additionally, the exploitation of national and local resources, can contribute greatly to circular economy.

This work aimed test several inert dusts (diatomeous earth, kaolin clay and vermiculite) and several extracts of weed and/or invasive plant species (*Erigeron cannadensis* L.), *Daucus carota* Dara and *Halacsya sendtneri* Boiss), as potential contact insecticides against the rice weevil (*Sitophilus oryzae*), the most destructive insect pest of cereals.

MATERIAL AND METHOD

The population of the rice weevil (*Sitophilus oryzae* L.) was reared for ~20 generations, on wheat kernels, under controlled conditions (26 ±1ºC, r.h. 6 ±10% and photoperiod 14 L:10 D) at the Institute of Field and Vegetable Crops, National Institute of the Republic of Serbia, Novi Sad.

The biological activity of different inert dusts and plant extracts was assessed in contact toxicity tests. The tests with three inert dusts: diatomaceous earth (uncalcinated diatomite) -DE (locally produced DE from Kolubara mine open pit, Serbia), kaolin clay - KA (kaolin mine Miličinica, Valjevo, Serbia) and vermiculite dust – VE (commercially available vermiculite) was carried out in glass Petri dishes (surface area, 153.5 cm2). IDs were dispersed over the glass surface at rates 5, 7.5, 10, 15 and 20 gm-2, and afterwards 20 7-10 days-old adult weevils were placed into Petri dishes. Tests with plant extracts (*Erigeron cannadensis* L. - Horseweed), *Daucus carota* Dara - Wild carrot and *Halacsya sendtneri* Boiss- Dorfler, (0.5, 1 and 2%) and pyrethrin (0.01, 0.02 and 0.05%) that served as standard, were performed according to a method described by Kouninki et al. (2007), with slight modifications. In glass tubes, previously "rinsed" with plant extracts and air dried, ten 7-10 days-old weevils were inserted. The tubes were sealed with para-film and placed in a horizontal position. Clean

Petri dishes and glass tubes rinsed with ethanol served as the controls. Mortality was presented as % of dead and paralyzed weevils out of total number (20 specimens), after 24, 48 and 72 h of exposure.

The differences between weevil mortality was analyzed using a one-way ANOVA analysis by performing Bonferroni test. All tests were performed at the level of significance of 95% in statistical software SPSS 19 (trial version).

RESULTS AND DISCUSSION

Insecticidal effect of different inert dusts and plant extracts on *S. oryzae* weevils is presented on Figures 1-3, as a percentage of mortality. In all treatments with DE and KA, insect mortality increased with the increase of concentration and exposure period. After 24 h (Fig. 1), DE caused significant mortality at rates 10 (67.8%), 15 (75.3%) and 20 gm-2 (98.2%). The mortality increased after 48h of exposure and ranged from 45% at the lowest rate (5 gm-2), 67.5% at 7.5 gm-2 to 100% at the highest rates (15 and 20 gm-2). After 72 h, in treatments with 10, 15 and 20 gm-2 of DE the mortality was 100%, while satisfactory and high mortality was also obtained in treatments with 5 and 7.5 gm-2 DE (68.5 and 93.2%, respectively). Kaolin clay was also very efficient in suppressing weevils, as the mortality reached 75% at 10 gm-2, 98% at 15 gm-2 and 100% at 20 gm-2, even after 24 h. After 48 h (Fig. 2), in treatment with 10 gm-2 KA, the mortality increased up to 89%. After 72h, regardless on the application rate, the mortality ranged from 97.8 to 100% (Fig 3). VE caused insignificant mortality (0-17.5%), regardless on the applied rates and exposure period.

Plant extracts used in this work exhibited very low insecticidal activity, since the mortality ranged from 0 to 11%, even when applied at the highest concentration. However, pyrethrin, as a standard among botanicals, was exceptionally efficient even at the lowest applied rate (0.01%), as the mortality was 94.5% after 24h h of exposure (Fig. 3).

The difference between the mortality in treatments with different inert dust and rates, and plant extract and concentrations, within the same exposure period (24, 48 and 72 h) was statistically highly significant (F=74.8**; 101.5**, 95.4**, respectively, p<0.01).

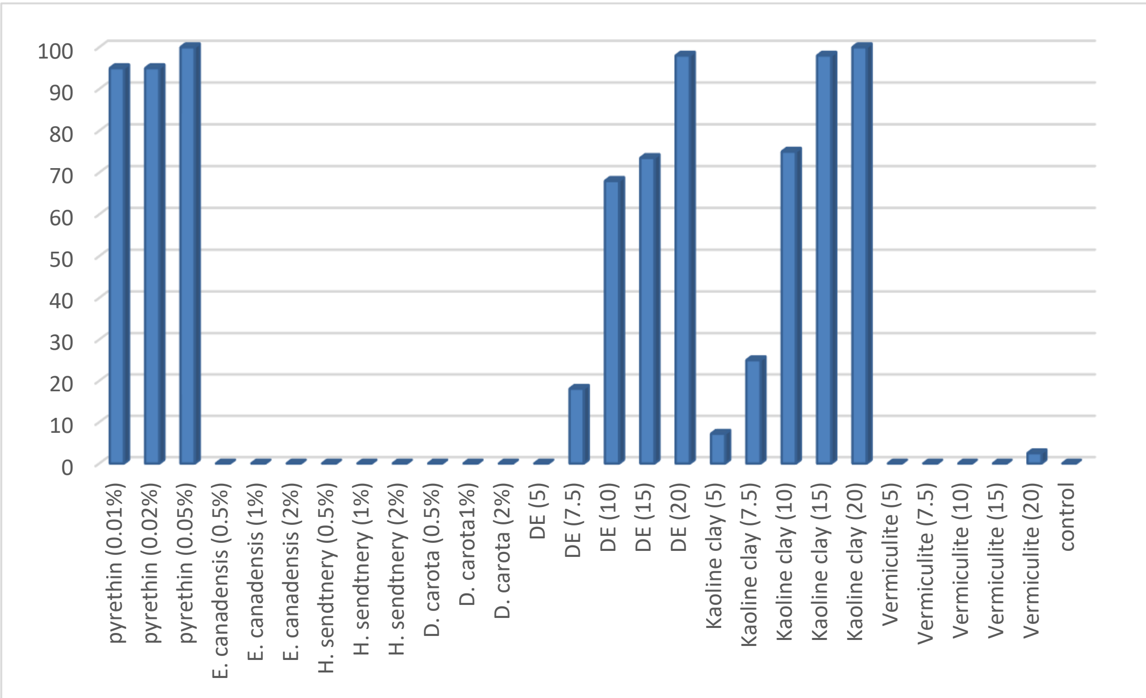

Fig. 1. Mortality of S. oryzae in treatments with different IDs and plant extracts after 24 h of exposure

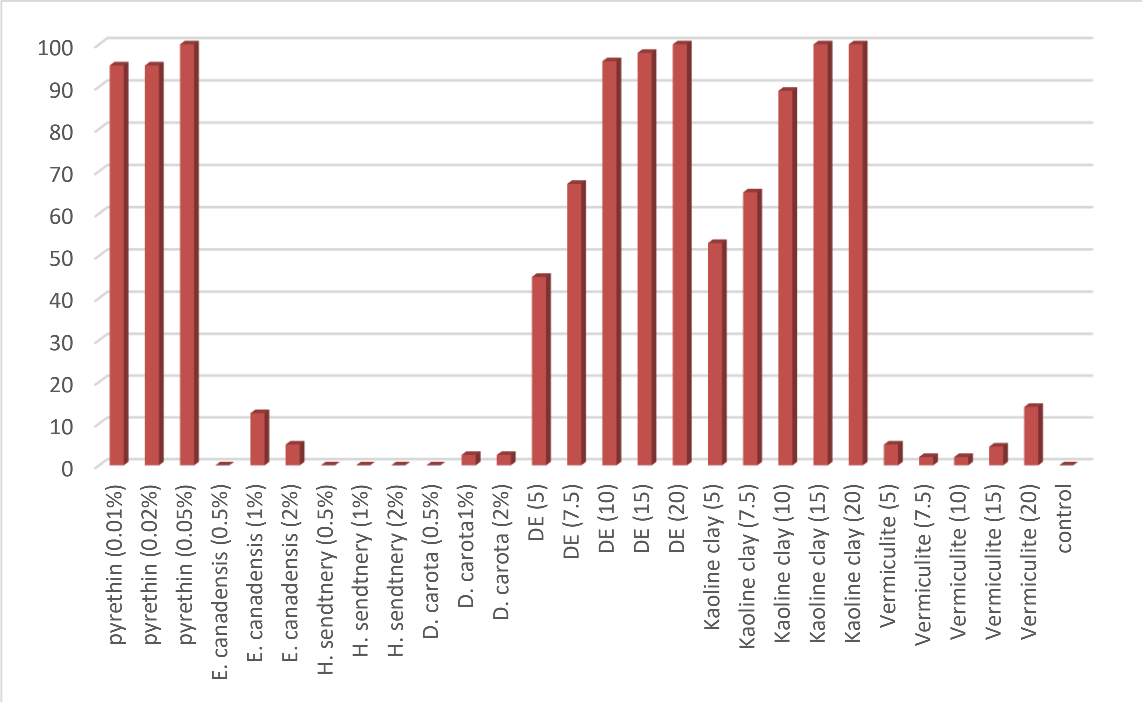

Fig. 2. Mortality of S. oryzae in treatments with different IDs and plant extracts after 48 h of exposure

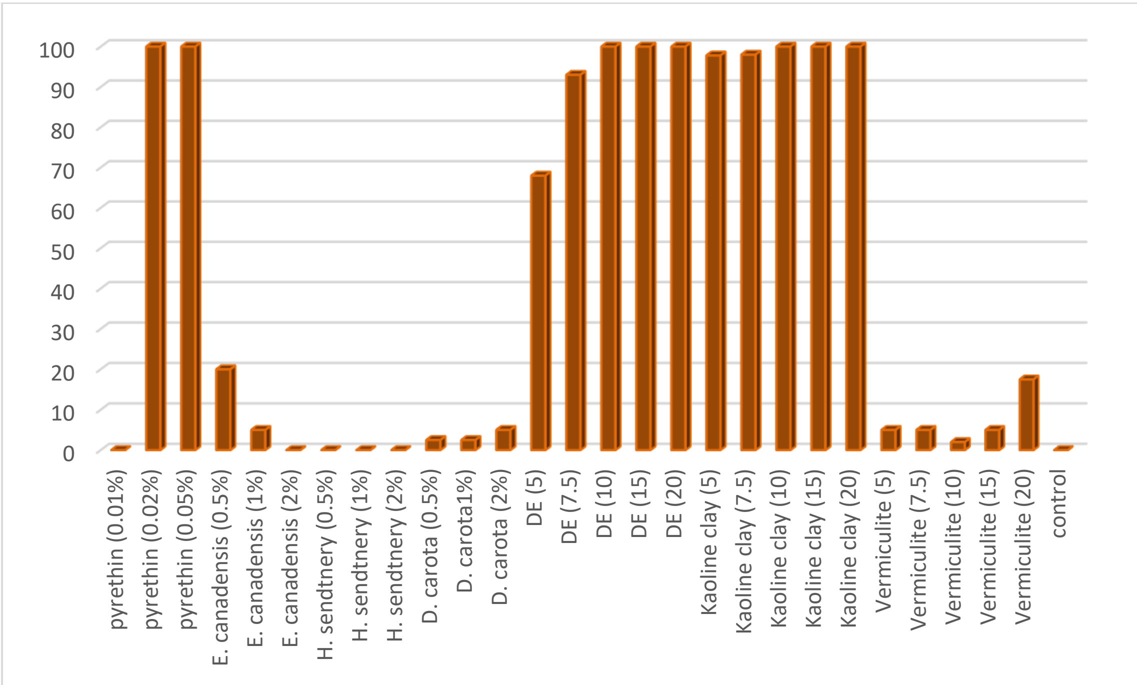

Fig. 3. Mortality of S. oryzae in treatments with different IDs and plant extracts after 72 h of exposure

The results presented in this work are in accordance with Gvozdenac et al. (2018) and El-Sayed (2010), according to whom the efficacy of DE rises with the exposure period. According to El-Sayed, lower concentrations (0.1 and 0.2% w/w) of DE caused low mortality (16.7, 32.0%) of *S. oryzae* adults after 24 h of exposure while after 48 h the mortality increased (86.7 to 100%), regardless on the concentration. Permual and Patourel (1990) found that *S. oryzae* was relatively tolerant to activated kaolin (8% w/w) when exposed for 72 h on treated paddy. However, after 96 h the mortality in kaolin treatment reached 90%, which is partially in accordance with the results of our work, showing increase in mortality with the prolongation of exposure period. Similar results were presented by Swamiappan et al. (1976) who report that kaoline clay activated by acid and heat treatments caused 100% mortality of several storage pests among which *S. oryzae* L. within 24 h, even at the minimal dose of 10 mg per Petri dish. The results obtained in this work are in agreement with El-Sayed et al. (2010) stating that, in general, DE was more effective than the kaolin against *S. oryzae*. Results of many studies confirm that the efficacy of inert dusts increases with the duration of exposure (Athanassiou et al., 2008; Andrić et al., 2012), which was also proven in this work. The insecticidal potential of plant extracts used in this work, have been, up to our knowledge, evaluated for the first time against *S. oryzae*, thus there are no relevant references to confer or dispute our results.

CONCLUSION

The results of this work indicate at good potential of DE and KA (10, 15 and 20 gm-2) to be used as a surface treatment in grain stores for prevention of infestation by *S. oryzae* weevils. On the other hand, vermiculite and ethanol extracts of . However, the prevention from stored product pests should not be relied only on the application of inert dusts as surface treatments, but other measures should be involved as well.

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