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EDITORIAL

Nanoparticles for grain protection: Biological activity against stored product insects and their mode of action

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Global food production losses during the post-harvest process cost the world a trillion US dollars every year (Gustavsson et al., 2011). The estimated annual grain loss caused by the stored product pests in most of the developing countries ranges from \$500 million to \$1 billion (Campbell et al., 2004). According to the estimated global population upraising to reach 9.1 billion by the year 2050 food production needs to increase by 60% (Alexandratos and Bruinsma, 2012). Accordingly, the improvement of pest control is one of the crucial solutions to increase food production (Lusk and McCluskey, 2018). The excessive use of synthetic insecticides resulted in significant negative implications on insect, human, and environment (Belhamel et al., 2020).

Nowadays, emerging alternative approaches such as insecticides from natural resources and nano-insecticides are in demand (Hashem and Ramadan, 2021). Nanoparticles (NPs) provides promising solutions for insect control (Athanassiou et al., 2018). There are a large number of studies concerned their toxicity against various insects, and rarely studies discussed their modes of action. In the current highlight report (in preparation by the biology group of ESlab-8, Egypt Scholars Organization), we have summarized the recent literature that emphasis the biological activity of NPs against the stored product insects and their modes of action.

An enormous number of rehearses have investigated the toxicity of various nanomaterials (natural or synthesized) against the stored product insects. The nano-emulsions of essential oils (EO) such as chamomile, cumin, fennel, mint, sweet orange as well as solid lipid NPs loaded by EO showed a toxicity against *Tribolium castaneum* and *Rhyzopertha dominica* (Hashem and Ramadan, 2021; Giunti *et al*., 2021; Lima *et al*., 2021 and Hosseinpour et al., 2020). In addition, silica, alumina, zinc oxides, green synthesized silver, and lead NPs expressed high insecticidal activity against *Sitophilus oryzae* (Gamal, 2018; Sankar and Abideen, 2015 and Keratum *et al*., 2015). Furthermore, nanoformulations act as repellents and antifeedants (Giunti et al., 2021; Elango et al., 2016). Also, these nanoformulations reduced progeny production (Hashem and Ramadan, 2021).

The main routes of NPs towards the stored product insects are physical contact and ingestion (Shahzad and Manzoor, 2021). Nanostructured alumina reported to cause dehydration of *Sitophilus oryzae* by adhering to the cuticle throughout triboelectric and absorbing the external wax layer which produce splits and scratches on the cuticle (Buteler et al. 2015; Arumugam et al., 2016 and Stadler et al., 2017). While *Pimpinella anisum* EO nanoemulsion toxicity occurred as a result of cuticle layers and midgut deterioration (Hashem et al., 2018). Also, depigmentation of the cuticle in *Trogoderma granarium* found to be resultant of silver NPs treatment (Al-Naami et al., 2017).

Silica NPs treated with various pulse seeds toxicity against *Callosobruchus maculatus* reported to be attributed to delayed growth and diminished oviposition (Arumugam et al., 2016). Zinc oxide NPs coated with *Bacillus thuringiensis* reported to reduce fecundity and certain enzymes activities in *C. maculatus* (Malaikozhundan et al., 2017). NPs could provide environmentally friendly agents for grain protection. Considering the rapid development in nano-agrochemicals research and production the current work is interestingly helpful for every researcher involved in this field.

Conflict of Interest

The authors declare no conflict of interest.

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