

Bioefficacy of insecticidal nematodes against stored grain pests-an overview

Abstract:For protection of stored agricultural products in ware house, grain store and food processing factory from insect damage, control measures should be taken. Stored grain insect pests are difficult to control. Though chemical insecticides are effective in controlling pests, other environment friendly methods have been advocated. Entomopathogenic nematodes are potential biocontrol agent for management of insect pests. In this review research work done so far for management of stored grain pests has been highlighted so that further work can be preceded.

Key words: Stored grain pests, biological control agent, entomopathogenic nematodes (EPNs), bioefficacy.

Introduction

In storage and post harvest processing large quantities of stored grains and products are destroyed by insect pests. Insects bore and feed the kernel of the grain, reduce the grain quality, spread mold contamination, and cause grain rancidity. It has been estimated that in stores, an average of 1% losses caused by pests in industrialized countries and 10-30% losses in developing countries (Scholler *et al.*, 1997). "These insect pests conceal themselves in cracks and crevices of the storehouse, and machinery used and thus difficult to control them. Therefore, there is a need to protect stored food products from attack by insects. Chemical substances for pest control in storage should provide a residue-free technology. To minimize the use of toxic chemicals and to provide better protection of the environment, application of bio control agents have been advocated. Among the biocontrol agents such as bacteria, fungi, viruses and nematodes, nematodes are measured as important for control of several stored product insects" (Athassiou *et al.*, 2010).

Stored grain pests

In a store house different types of insects are present which show different activity and nature of damage. The female lays eggs inside the kernels and develop inside kernels,larvae feed on the inner endosperm,and producing holes in the kernel through which the adult insects exist and the female lays eggs. The kharpa beetle (*Trogoderma granarium*) and the warehouse beetle (*Trogoderma variabile*), larvae feed on dried cereal grains, dried spices and food products. The rice weevil(*Sitophilus oryzae*),granary weevil(*Sitophilus granarius*),lesser grain borer(*Rhyzopertha dominica*),maize weevil, the Angoumois moth feed and develop inside the kernels.The sawtoothed grain beetle(*Oryzaephilus surinamensis*),the red flour beetle (*Tribolium castaneum*),the confused flour beetle (*T.confusum*), the Indianmeal moth(*Plodia interpunctella*),the Mediterranean flour moth (*Ephestia kuehniella*), the Mealworm (*Tenebrio molitor*), and the larger black flour beetle feed on damaged grain or products (Scholler *et al.*,1997).Due to their survival potential in dry condition, they are destructive and difficult to control. Some fumigants, have found to be effective at lowercost. However, public concern about chemical pesticide related risks increases the development of alternative, environment friendly disinfestations methods such as high temperatures.The use of biological control agentshave been utilized effectively.Arbogast (1984)stated that“bio control agent or any organism has been considered as an undesirable contaminant of stored product”

Entomopathogenic nematodes(EPNs)

Laboratory experiments showed that entomopathogenic nematodes (EPNs)are considered as potential biological agents for killing of stored grain pest. Entomopathogenic nematodes (EPNs) *Steinernema* and *Heterorhabditis*from familiesSteinernematidae and Heterorhabditidae respectively are lethal parasitesof a wide range of insect pests. *Photorhabdus* (Boemare, 2002)

and *Xenorhabdus* (Thomas and Poinar, 1983) are symbiotically associated “bacteria with *Heterorhabditis* and *Steinernema*, respectively”. “The third-stage infective juvenile, which are free-living stage, seek out and invade potential hosts and release their pathogenic bacteria into the nutrient-rich hemolymph. They can kill target insects within 48 h” (Kaya and Gaugler, 1993). “The bacteria proliferate; the nematodes feed on bacteria and insect tissues, and reproduce. When the host cadaver is depleted of resources, nematodes associated with pathogenic bacteria emerge and search for new hosts to infect. These biocontrol agents have received much attention in many countries, as these agents have special character such as searching for the insect pests in cryptic habitats, massive reproductive ability, easy mass-production, safety to humans, and other vertebrates as well non-target insects” (Akhurst and Smith 2002). Efficacy against stored grain pests depend on host biology and surrounding environmental condition. It is well-known fact that storage environment are dry and application of entomopathogenic nematodes to dry storage environment is risky. Entomopathogenic nematodes have solved this problem through proper application technology and now become a consistent alternative for commercial applications in warehouses and storage facilities.

Entomopathogenic nematodes against stored grain pests

Research work conducted in different parts of the world revealed that Entomopathogenic nematodes (EPNs) effective against different species of stored grain insects. The rate of desiccation (RD) among IJs of different EPN species, at different range of relative humidity (RH) influences nematode efficacy against those pests. Ramakrishnan *et al.*, (2022) observed that “at RH equivalent to 74%, IJs of *S. carpocapsae* are a better adaptable than *S. feltiae* and *H. bacteriophora* while an optimal RH of > 90% is required for *S. feltiae* and *H. bacteriophora*. Thus entomopathogenic nematodes (EPN) species differ in their capability to withstand rapid

desiccation (RD). Moreover, host searching ability is an important factor for entomopathogenic nematode efficacy". "Cruiser entomopathogenic nematode, *H. bacteriophora* and *H. megidis* are more virulent against adults of Indian meal moth (*Plodia interpunctella*) than against larvae" (Mbata & Shapiro-Ilan 2005). "Intermediate foraging entomopathogenic nematode *S. feltiae* was moderately effective against the granary weevil (*Sitophilus granarius*) and caused low mortality to *T. confusum* larvae" (Alikhan *et al.*, 1985). "*S. feltiae* can cause over 90% larval mortality of Indian meal moth, Mediterranean flour moth, red flour beetles" (Ramos-Rodriguez *et al.*, 2006). However, they found that *S. carpocapsae* was more effective than *S. feltiae* for killing of larvae of *E. kuehniella*. Athanassiou *et al.*, (2008) found that virulence of different strains of *S. feltiae* varied, against adults and larvae of *T. confusum* (79% larval mortality) and larvae of *E. kuehniella*. In that study, they observed that the most effective strain against *T. confusum* larvae was not effective against *E. kuehniella* larvae. Similarly, intermediate foraging entomopathogenic nematodes, *S. riobrave* have a potential to kill over 65% larvae of Indian meal moths, Mediterranean flour moths, sawtoothed grain beetles, mealworms, red flour beetles and warehouse beetles. "Generally entomopathogenic nematodes are considered more effective against the larval stage than adults as most of the adults are more mobile and may avoid the contact with entomopathogenic nematodes" (Kakouli-Duarte *et al.*, 1997, Athanassiou *et al.*, 2008). Ramos-Rodriguez *et al.*, (2006) found that "entomopathogenic nematodes were found to be more effective against larvae of the red flour beetle, *Tribolium castaneum* than against adults". Pathogenic level and prevailing temperature are important factors for efficacy of entomopathogenic nematodes. Mortality rates of adults of rice weevil, *S. oryzae* depend on temperature and doses of nematode, *S. feltiae* as well as on the strain of nematodes *S. feltiae* B30, B49 and 3162 (Laznik *et al.*, 2010). In the case of adults of *S. oryzae*, the mortality was very low

at all doses and temperatures and did not exceed 9%. Mortality of *T. confusum* adults did not exceed 17% regardless of the entomopathogenic nematode species tested. Trdan *et al.*, (2006) noted that higher doses of *S. carpocapsae* were required to achieve a high level of mortality of sawtoothed grain beetle (*Oryzaephilus surinamensis*). *S. feltiae* was more effective against *S. granaries* and *O. surinamensis* at 20°C and 25°C than at 15°C. At 100 IJs per ml at 20°C or at 30°C, *S. feltiae* provided mortality of *E. kuehniella* larvae (36.7% to 78.3%) and at 20°C very few larvae were dead with *H. bacteriophora* whereas no mortality was observed with *S. carpocapsae* in wheat treatments. "The mortality of adults of *Rhyzopertha dominica* at 20°C, at 20,000 IJs per ml in wheat treated with *S. feltiae* and *S. carpocapsae* did not exceed 23.3 and 41.7%, respectively. Mortality of *T. confusum* larvae was notably higher and exceeded 56% in wheat treated with 10,000 or 20,000 IJs per ml of *S. feltiae* at 20°C. Unlike *S. feltiae* and *S. carpocapsae*, the application of *H. bacteriophora* resulted in lower mortality levels" (Athanassiou *et al.*, 2010). *S. feltiae*, *S. carpocapsae* and *H. bacteriophora* cause mortality 87.8, 63.3, and 60.0% respectively of exposed large larvae (*T. granarium*) on stored wheat treated with 50,000 IJs/ml after 8 days of exposure at 30°C under laboratory condition (Karanastasi *et al.*, 2020). All four species of EPNs, viz., *S. pakistanense* (LM-07), *S. bifurcatum* (LM-30), *S. affinae* (GB-14) and *S. cholashanense* (GB-22) were able to cause mortal effects of adults of *T. confusum* and *R. dominica*. *S. pakistanense* (LM-07) and *S. bifurcatum* (LM-30) were the most effective at 150 IJs/beetle at 30°C and *S. affinae* (GB-14) and *S. cholashanense* (GB-22) at the same concentration at 20°C (Javed *et al.*, 2020). Hundred per cent mortality of *T. confusum* and *R. dominica* was observed at a concentration of 150 IJs of *S. pakistanense* per adult at 30°C. *S. riobrave*, *H. bacteriophora* showed various levels of efficacy against cowpea weevil (*Callosobruchus maculatus*), khapra beetle (*Trogoderma granarium*), and rust red flour beetle

(*Tribolium castaneum*).The highest mortality rate 16.67% was recorded with *S.riobrave* (2000 IJs / ml) after 72 hours post-treatment of *C. Maculates*, while the lowest rate of mortality (1.33%) of adult insects for rusty flour beetle at the dose of 500 IJs / ml after 24 hours (Qader *et al.*, 2021).

Conclusion

Better knowledge of the nature of the grain storage system and the pest complexes that occur in them is necessary to achieve success in their implementation of bio control measures.To avoid insect infestation and facilitate control operations at an early stage, the design of factories, granaries, and warehouses should be improved.Environmental conditions in the grain storage buildings are very important along with good sanitary measures and good monitoring system in order to render the conditions unfavourable for development of the insects (Scholler *et al.*, 1997). Since stored product environments are enclosed, biological control options are restricted to augmentative biological control.Augmentation or inundative release of the EPNs keeps insect damage within acceptable limits. The EPNs should be released at level of consumer's acceptance on pathogen - treated food while insect pest populations are small(Athanassiou *et al.*, 2008).Before release or treatment, proper sampling should be done in order to locate insect infestation, their identification up to developmental stages. For large scale application, bioinsecticides have to be ready to use and easy to apply by means of simple equipment.Acondition of an aqueous environment is required for entomopathogenic nematode so that the nematode can reach the target.Usually, only a single nematode species or strain is not equally effective against all major stored product insect pests, as the virulence of entomopathogenic nematodes against post harvest insects varies depending on the nematode species and strains. Therefore,specific species and time of application is necessary. With the

discovery of new, virulent, heat-tolerant strains, with improved methods of formulation and application, could enhance the exploitation of entomopathogenic nematode in storage amenities against post-harvest insects.

References

- Akhurst R, Smith K 2002. Regulation and safety. In: Gaugler R (ed.) Entomopathogenic Nematology, CABI, New York, pp 311-332.
- Alikhan MA., Bednarek A., Grabiec S. 1985. The physiological and morphological characteristics of *Neoaplectana carpocapsae* (Nematoda: Steinernematidae) in two insect hosts. *Journal of Invertebrate Pathology*. 45: 168-173
- Arbogast RT. 1984. Biological control of stored product insects: status and Prospects. In: Baur FJ(Ed). *Insect Management for Food Storage and Processing*, American Association of Cereal Chemists, Inc., St. Paul, Minneapolis, USA. pp.225-238.
- Arbogast RT. 1984a. Natural enemies as control agents for stored product insect. In: Mills RB., Wright VF, Pedersen JR, McGaughey WH, Beeman RW, Kramer KJ, Speirs RD, Storey CL(Eds.). *Proceedings of the 3rd international working conference on stored product Entomology*, Oct23-28, Kansas State University, Manhattan, Kansas, USA. Pp. 360-374.
- Athanasius CG., Palyvos NE., Kakouli-Duarte T. 2008. Insecticidal effect of *Steinernema feltiae* (Filipjev) (Nematoda: Steinernematidae) against *Tribolium confusum* du Val (Coleoptera: Tenebrionidae) and *Ephestia kuehniella* (Zeller) (Lepidoptera: Pyralidae) in stored wheat. *Journal of Stored Product Research* 44:52-57.
- Athanassiou CG., Kavallieratos NC., Menti H., Karanastasi E. 2010. Mortality of four stored product pests in stored wheat when exposed to doses of three entomopathogenic nematodes. *Journal of Economic Entomology*. 103(3) :977-984. DOI: 10.1603/EC09202

- Begley JW. 1990. Efficacy against insects in habitats other than soil, pp. 215-231. In: R. Gaugler and H.K. Kaya (eds.), Entomopathogenic nematodes in biological control. CRC, Boca Raton, FL.
- Boemare N. 2002. Biology, taxonomy and systematics of *Photorhabdus* and *Xenorhabdus*. In: Gaugler R (ed.) Entomopathogenic nematology, CABI, New York, pp 35-56.
- Brower JH., Smith L., Vail PV., Flinn PW. 1996. Biological control. Pp. 223-286. In: B.H. Subramanyam and D.W. Hagstrum, eds. Integrated management of insect in stored products pest. Dekker, New York .
- Fayyaz S., Javed S., Rumbos CI., Athanassiou C.G. 2017. Control of stored grain pests by entomopathogenic nematodes. In: Biocontrol agents: entomopathogenic and slug parasitic nematodes. Abd-Elgawad MMM, Askary TH, Coupland J (editors). CABI. pp. 208-222 .doi: 10.1079/ 9781786390004.0000.
- Fayyaz S., Javed S. 2009. Laboratory evaluation of seven Pakistani strains of entomopathogenic nematodes against a stored grain insect pest, Pulse beetle *Callosobruchus chinensis* (L.). Journal of Nematology .41:255-260.
- Glazer I. 1992. Survival and efficacy of *Steinernema carpocapsae* in an exposed environment. Biocontrol Science and Technology.2: 101-107.
- Javed S., Khanum TA., Khan S. 2020. Biocontrol potential of entomopathogenic nematode species against *Tribolium confusum* (Jac.) (Coleoptera: Tenebrionidae) and *Rhyzopertha dominica* (Fab.) (Coleoptera: Bostrichidae) under laboratory conditions. Egyptian Journal of Biological Pest Control. 30:5. doi.org/10.1186/s41938-020-0206-9.

- Kakouli-Duarte T., Labuschagne L., Hague NGM.1997. Biological control of the black vine weevil, *Otiorhynchus sulcatus* (Coleoptera: Curculionidae) with entomopathogenic nematodes (Nematoda: Rhabditida).Annals of Applied Biology.131: 11-27.
- Karanastasi E., Kavallieratos NG., Boukouvala MC., Christodouloupoulou AD., Papadopoulou AA.2020.Effect of three entomopathogenic nematode species to *Trogoderma granarium* Everts (Coleoptera: Dermestidae) larvae on stored wheat. Journal of Stored Products Research 88:101641.
- Kaya HK., Gaugler R.. 1993.Entomopathogenic nematodes. Annual Review of Entomology. 38: 181Ð206
- Laznik Z., Toth T., Lakatos T.,Vidrih M.,Trdan S.2010.The activity of three new strains of *Steinernema feltiae* against adults of *Sitophilus oryzae* under laboratory conditions. Journal of Food, Agriculture & Environment. 8(1): 150-154.
- Mbata GN., Shapiro-Ilan DI. 2005. Laboratory evaluation of virulence of heterorhabditid nematodes to *Plodia interpunctella* Hubner (Lepidoptera: Pyralidae). Environmental Entomology. 34:676-682.
- Qader F., Mohammed B., Ameen H.2021. Efficacy of entomopathogenic nematodes against three species of stored product insects. IOP Conf. Series: Earth and Environmental Science 910.012047. IOP Publishing. DOI:10.1088/1755-1315/910/1/012047.
- Ramakrishnan J., Salame L., Nasser A, Glazer I., Ment D.2022. Survival and efficacy of entomopathogenic nematodes on exposed surfaces. Scientific Reports 12:4629. <https://doi.org/10.1038/s41598-022-08605-2>

- Ramos-Rodriguez O., Campbell JF., Ramaswamy SB. 2007. Efficacy of the entomopathogenic nematodes *Steinernema riobrave* against the stored product pests *Tribolium castaneum* and *Plodia interpunctella*. *Biological Control*.40:15-21.
- Ramos-Rodriguez O., Campbell JF., Ramaswamy SB. 2006. Pathogenicity of three species of entomopathogenic nematodes to some major stored product insect pests. *Journal of Stored Products Research*.42:241-252.
- Rumbos CI., Athanassiou C. 2017. The use of entomopathogenic nematodes in the control of stored-product insects. *Journal of Pest Science*. 90(1): DOI: 10.1007/s10340-016-0795-y.
- Scholler M., Prozell S., Al-Kirshi AG., Reichmuth C. 1997. Towards biological control as a major component of integrated pest management in stored product protection. *Journal of Stored Product Research*. 33(1):81-97.
- Svendsen TS., Steenberg T. 2000. The potential use of entomopathogenic nematodes against *Typhaea stercorea*. *Biocontrol*. 45: 97-111.
- Thomas GM, Poinar GO Jr 1983. Amended description of the genus *Xenorhabdus* Thomas and Poinar. *International Journal of Systematic and Evolutionary Microbiology* 33(4):878-879.
- Tradan S., Vidric M., Valic N. 2006. Activity of four entomopathogenic nematodes against young adult of *Sitophilus granarius* (Coleoptera: Curculionidae) and *Oryzophilus surinamensis* (Coleoptera: Silvanidae) under laboratory condition. *Plant Disease and Protection*.113:168-173.
- Yuksel E., Canhilal R., Imren M. 2019. Potential of four Turkish isolates of entomopathogenic nematodes against three major stored products insect pests. *Journal of stored Products Research* . 83:317-321.