Effect of Gamma irradiation on morphology of antennal sensilla of Rhyzopertha dominica (Coleoptera: Bostrichidae)

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ABSTRACT

The effect of different dose levels of gamma irradiation on the morphology and distribution of the sensory receptors of the antennae of lesser grain borer, Rhyzopertha dominica (F.), was studied with the scanning electron microscope. The results obtained distinguished three types of sensilla: chaetica (ch1 "long" and ch2 "short"), basiconica (b), and ampucellaceous (am) present on the apical distal three segments of flagellomeres. Irradiation with a dose level of 75 Gy had no effect on the general distribution of different types of sensilla as compared with the control, whereas dose levels of 100, 150, and 200 Gy showed malformation which increased with the increased doses.

1. Introduction

Insect population can increase rapidly in warm and moist grain. Lesser grain borers (Rhyzopertha dominica), in particular, cause damaged kernels in wheat. The larvae feed inside the kernel until they mature into adults and burrow out of the kernel. Adults feed primarily on stored cereal seed including wheat, maize, rice, oats, barley, sorghum, and millet. They also infest a wide variety of foodstuffs including beans, dried chilies, turmeric, coriander, ginger, chips, biscuits, and wheat flour.

According to the function of the antennae where it bears sensilla such as chemoreceptors (the senses of smell – olfaction and taste – gustation), mechanoreceptors, thermoreceptors and hygroreceptors, and bearing sometimes sensors for CO₂ (Gullan & Cranston, 2003; Hansson, 1999). Therefore, Sawires, Meray, Elbassiouny, and Gharieb (2012) recorded morphological changes in the sensilla structure on the antennal segments of the worker honeybee, *Apis mellifera*. Moreover, Abdel-Megeed and Sawires (2015) illustrated and described the distribution of the various types of antennal sense organs of queen and worker honey bees. Receptors adjust feeding preferences (De Bore, 2006), recognize host plant odors (Skiri, Standen, Sandoz, Menzel, & Mustaparta, 2005), and also play important roles in insect survival. The same sensilla were elucidated on the adults of rice water weevil, *Lissorhoptrus oryzophilus* with fluted surfaces, occurring on the scape, pedicel, and funicular flagellum (Kang, Zhu, Cheng, & Way, 2012). *R. dominica* is a major pest of wheat and rice around the world (Chanbang, Arthur, Wilde, & Throne, 2008). Both larvae and adult produce feces where the fungus can grow on it and cause weight losses by feeding on grains. *R. dominica* infestation can reduce rice to dust (Emery and Nayak, 2007). Abdel-Kawy, Mohamed, and Soliman (2011) studied effects of gamma radiation doses applied to the adults of *R. dominica*. They found that percent adult mortality increased with increasing radiation dose, but no immediate mortality was found, causing that the adults irradiated with obvious doses ate less food than the unirradiated adults.

The main purpose of this study is to describe the types and distribution of sense organs on the antenna of *R. dominica* using scanning electron microscopy. Furthermore, the effect of gamma radiation with different dose levels on the morphological structure of antenna and sensilla was investigated.

2. Materials and methods

2.1. Rearing of *R. dominica*

The stock culture of the weevil, *R. dominica*, was obtained from a laboratory strain maintained at the Stored Product Insects Research Department, Ministry of Agriculture.

2.2. Irradiation technique

Adults of *R. dominica* were transferred to National Center for Radiation Research and Technology and were irradiated with dose levels 75, 100, 150, and 200 Gy of gamma radiation from cesium cell 137 source located in the NCRRT with the dose rate 1.25 rad/s.
2.3. Scanning electron microscopy

The antennae of the adults *R. dominica* were carefully cut by means of a sharp razor blade; the specimens were quickly dried then mounted on specimen stubs with gold conducting paints. Samples were gold coated in a layer of approximately 300 Å using a fine gold coating apparatus, ion sputtering device (JEOL-JFC-1100 E). Examinations of the parts of the antenna which distinguished as scape, pedicle, and flagella starting from the proximal part till the distal end of the *R. dominica* were examined carefully and carried out by a JOEL-JSM-5400 scanning electron microscope (SEM) with an accelerating voltage of 30 kV. The antennal sensilla were viewed and photographed; the side of the antenna against the head was defined as the upper side and the side away from the head as the underside. The micrographs of sensilla were made directly from the SEM video monitor.

3. Results and discussion

The obtained results of the present work showed different types of antennal sensilla of *R. dominica*, in both control (unirradiated) and irradiated insects. Subsequently, the induced changes in the antenna or sensilla of irradiated *R. dominica* were reported as follows:

3.1. The scape

Appear as an elongated segment carried on a small tubercle raised from head capsule and joined to the pedicle.

3.2. The pedicel

Round segment nearby the same size with the scape and larger than the basal segments of the flagellum. It joins the scape to the flagellum.

3.3. The flagellum

Consists of eight distinct segments (flagellomeres), where the basal five flagellomeres were slender and smaller than other segments of the antenna, the distal three flagellomeres were large, thick folded cuticle, flattened, and club shaped. Moreover, the outer surfaces were convex and the inner surfaces were concave (Figure 1).

3.4. Types of sensilla

Higher magnification using SEM and based on external morphology of sense organs showed three types of sensilla (Figure 2).

3.4.1. Sensilla chaetica (ch)

Two types of hair – first type ch1 long hair like structure and second type short hair ch2. Their base was surrounded by a membranous socket and extended from the antennal surface, smooth walled, and distally tapered with closed tips. They were present over the entire antennae, but it distributed in large numbers all over the entire three distal segments of antennal flagella. The sensilla chaetica were often slightly curved just above their bases and projected outward at about 40–50° angles from the base toward antennal shaft. Such sensilla act as mechanoreceptors (sensory “tactile” hairs) (Hill, Hansson, & Ignell, 2009).

3.4.2. Sensilla basiconica (b)

Appear as short peg-like structure and relatively stout pegged, partially blunt tipped, and smooth walled. These pegs were hollowed and straight toward the antennal shaft. These pegs were founded only on the three terminal segments of the flagella. Such sensilla probably act as mechanoreceptors (sensory pegs) (Merivee, Rahi, & Luik, 1999).

Figure 1. Scanning electron microscope of *Rhizopertha dominica* antenna showing scape (S), pedicel (P), and flagellum (F).
3.4.3. Sensilla ampucellaceous (am)

Pit like in appearance and distributed on entire flagellum, especially in large numbers all over the entire three distal segments of antennal flagella. The pits were deeply sunk and connected with the surface by a more or less elevated frustum of a cone ring. The sensilla are seemingly chemo- and thermoreceptors, as they perceive water vapors, carbon dioxide, and thermal changes in temperature (Romoser, 1981).

The antennal structure and its sensilla distribution of the *R. dominica* were studied and described in prior and postirradiation. The ultrastructure of the antenna showed that the cuticle of the distal three segments of flagellomeres was folded normally, moreover, detected three types of sensilla: sensilla chaetica (ch1 and ch2), sensilla basiconica (b), and sensilla ampucellaceous (am) (Figure 2).

Irradiated insects with 75 Gy of gamma radiation showed that either antennae or sensilla were not affected by irradiation as their structure was comparable to the unirradiated (control) (Figure 3).

The deformation of the antenna and sensilla structures start with the exposure to 100, 150, and 200 Gy of gamma radiation. Where deformations were induced in sensilla ampucellaceous (am) however the other sensilla were not affected, moreover, the antennal cuticle were looks like melt, disrupted, dwarfing of basiconica, scarcity of trichoid, empty pores, liquefaction cuticle, disrupted cuticle, impaired and shrinkage cuticle moreover dwarfed trichoid and also, appearance of grooves, depression and hollows on the distal three segments of flagellomeres (Figures 4–6).

The abnormality in the antennal structure and their associated sensilla may affect the behavior of the insect whether feeding or movement.

This point of study needs further investigation; Borawska et al., (2000) showed that various types of ionizing irradiation can cause damage to soft tissue as they were easier to penetrate. The highly emitted radiation could have only affected the soft cuticle in sensilla ampucellaceous. This sensillum acts as chemosensilla and therefore has to be of less thickness to respond properly. The other sensilla and mainly the mechanosensilla were of thicker cuticle.

The obtained results showed that gamma radiation that induces antifeedant effect can be applied as an effective method in control of *R. dominica*. Also, Haza (2010) revealed that combined treatment of gamma radiation and thermal treatment caused many malformation features in male antennal sensilla of the cotton leaf worm and these abnormalities or malformations were dose dependent. It also indicated that these malformations ranged from nodulation of sensilla fil, disorientation, liquefaction, degeneration, or falling leaving empty socket and bar areas. As Abdel-Kawy et al. (2011) studied the effect of gamma irradiation on adult mortality of *R. dominica*, adults were treated with 50, 100, 250, 500, and 750 Gy of gamma irradiation on the biological...
activities. They found that the exposure to gamma rays caused a significant elevation in the mortality status, reduction in the activity and food consumption, and pronouncing of sterility in the *R. dominica* via decreasing in the biological activity and changing in the biochemical parameters.

The percentage of malformations increased with the increase of dose and this may affect feeding behavior and the insect–plant interaction. Higher dose levels (100, 150, and 200 Gy) had many harmful effects and different types of sensilla as cheatica, basiconic, and ampucellaceous which are mechano-chemosensitive and olfactory in function and was dwarfed or shrank or it may be degenerated at their borders forming wide spaces or vacuoles. The scales may also fall leaving empty sockets or pores. The benefit of this study is to reduce the loss of grain as a result of malformation of antennal sensilla resulting from exposure to radiation and thus get an uninfected grain of insects.

**Figure 3.** SEM of antennal apical segment of *Rhizopertha dominica* irradiated with 75 Gy showing sensilla chaetica (ch1 & ch2), basiconica (b), and ampucellaceous (am).

**Figure 4.** SEM of antennal apical segment of *Rhizopertha dominica* exposed to 100 Gy showing trichoid, dwarfed chaetica (ch1 and ch2), basiconica (b), ampucellaceous (am), groove (G), shrink (Sh), and disrupted cuticle (Dc).
Disclosure statement
No potential conflict of interest was reported by the authors.

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Figure 5. SEM of antennal apical segment of *Rhyzopertha dominica* exposed to 150 Gy showing trichoid, dwarfed chaetica (ch1 and ch2), dwarfing of basiconica (Dw.b), ampucellaceous (am), shrink (Sh), groove (G), and disrupted cuticle (Dc).

Figure 6. SEM of antennal apical segment of *Rhyzopertha dominica* exposed to 200 Gy showing trichoid, dwarfed chaetica (ch1 and ch2), basiconica (b), ampucellaceous (am), groove (G), shrink (Sh), and disrupted cuticle (Dc).
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