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ORIGINAL PAPER

Phytosynthesized Gold Nanoparticles-*Bacillus thuringiensis* (Bt–GNP) Formulation: A Novel Photo Stable Preparation Against Mosquito Larvae

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Abstract
It is well-known that the sunlight irradiation damages the spores and toxin produced by *Bacillus thuringiensis* (Bt), which leads to loss of their insecticidal activity. This photodegradation problem is addressed in the present investigation by use of green phytosynthesized gold nanoparticles (GNP) as a photoprotectant. The efficiency of Bt with GNP before and after exposing to sunlight was evaluated against the larvae of *Aedes aegypti* and *Anopheles subpictus*. The bioassay results focused that after sunlight irradiation the Bt significantly lose their activity for *Ae. aegypti* (23.13%) and *An. subpictus* (27.08%). Although the individual GNP showed very less activity against tested larvae, it was observed that in combination with Bt it significantly enhances activity and consequently reduced the LC_{50} of Bt–GNP. Similarly, even after irradiation of Bt–GNP formulation, the enhanced activity was found against *Ae. aegypti* (23.10%) and *An. subpictus* (27.24%). Henceforth in the case of Bt–GNP formulation, the GNP it was not only protecting the Bt from sunlight but enhances its larvicidal potential. The interactions between the GNP and Bt toxin which might be the main reason to protect the Bt from sunlight and can help to locate the Bt toxin at the target site.

Keywords *Bacillus thuringiensis* · GNP · *Aedes aegypti* · *Anopheles subpictus* · Photoprotection

Introduction

Arthropods are vectors of various pathogens and parasites and evolved as excellent bloodsuckers providing elegant transportation mode for spreading a number of devastating diseases [1]. In particular, mosquitos represent a key threat which is responsible for malaria, dengue, chikungunya and many more [2]. On this background vector control is an important preventive strategy. In agriculture and vector disease control program, consumption of pesticides was nearly about two million tons per year [3, 4]. In contrast to chemical pesticides, the biopesticide used as a major trade to control the pest. The eco-friendly biological control programme has been recently focused on mosquito control with major emphasis on behavior-based control programs and plant-borne mosquitocidal, including green-synthesized nanoparticles [2]. Nevertheless, the research efforts on the control of mosquito vectors are experiencing a serious lack of eco-friendly and highly effective pesticides, as well as the limited success of most biocontrol tools currently applied [5].

Bacillus thuringiensis (Bt) products are the most substantial member of biopesticide who contributed more than 60% of biological trade of pesticides [6, 7]. *Bacillus thuringiensis* subsp. *israelensis* (Bti) is most widely known

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