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Research review paper

Application of nanotechnology for the encapsulation of botanical insecticides for sustainable agriculture: Prospects and promises

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ABSTRACT

This review article discusses the use of nanotechnology in combination with botanical insecticides in order to develop systems for pest control in agriculture. The main types of botanical insecticides are described, together with different carrier systems and their potential uses. The botanical insecticides include those based on active principles isolated from plant extracts, as well as essential oils derived from certain plants. The advantages offered by the systems are highlighted, together with the main technological challenges that must be resolved prior to future implementation of the systems for agricultural pest control. The use of botanical insecticides associated with nanotechnology offers considerable potential for increasing agricultural productivity, while at the same time reducing impacts on the environment and human health.

Contents

Introduction

Sustainable food production for a rapidly growing human population is one of the major challenges faced by the agriculture sector globally (Godfray and Garnett, 2014; McClung, 2014). Therefore, the increased uses of pesticides and fertilizers have become essential to maximize the agricultural productivity. Despite their beneficial role in agriculture, pesticides can be hazardous to humans and other non-targeted organisms, depending upon their toxicity, the degree of contamination, and the duration of exposure (Kohler and Triebskorn, 2013). An estimated 2.5 million tons of pesticides are used on crops each year (FAO, 2012; Fenner et al., 2013). While the sporadic use of pesticides increases pest resistance and impacts food quality, their overuse and misuse generate considerable waste, adding to the cost and adversely affecting

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environment and public health (Abhilash and Singh, 2009; Kohler and Triebskorn, 2013). Moreover, it has been estimated that more than 90% of the applied pesticides are being lost to the air during the application stage itself and also as run-off, affecting both the environment and application costs to the farmers (Ghormade et al., 2011; Stephenson, 2003). Therefore, safe and efficient pesticide applications methods are essential for preventing the adverse effects of pesticides. In this direction, nanotechnology offers great promises and can be used as an innovative tool for delivering agrochemicals safely (Ghormade et al., 2011; Gonzalez et al., 2014). Moreover, developments over the years have focused on developing carriers systems that reduce the concentration of applied pesticides (Ghormade et al., 2011). Recent years have seen exponential growth in the development of nanometric-scale materials whose properties differ considerably from the corresponding bulk materials. Nanostructured systems have a wide range of uses, including disease diagnosis, electronic devices, and environmental and agricultural applications (Bakshi et al., 2014; Ma et al., 2013; Srivastava et al., 2011). In agriculture, such systems are used for the controlled release of agents for pest control, as well as plant nutrients (Ghormade et al., 2011; Gonzalez et al., 2014). Nanosensor systems have been developed for the monitoring of environmental conditions, as well as the interactions between pathogens and plants (Ghormade et al., 2011; Nair et al., 2010).

There have been several recent reviews concerning the use of nanometric systems as carriers for chemically synthesized pesticides (Campos et al., 2014; Kah and Hofmann, 2014; Kah et al., 2013). The benefits of nanomaterial based formulations: i) improve the efficacy due to higher surface area; ii), increase the systemic activity due to smaller particle size and higher mobility and iii) decrease the toxicity due to elimination of organic solvents in relation to conventionally used pesticides and their formulations (Sasson et al., 2007). The present work now considers the development of nanotechnological carrier systems for botanical insecticides (a plant-derived insecticidal biomolecules). The main biocides that have been used are described, together with the advantages that these systems offer over conventional approaches, and their future potential (Fig. 1).

Botanical insecticides

Throughout evolution, many plant secondary metabolites are believed to serve a defensive or protective function (ecologically) for the plants against attack by insects (Menezes, 2005).

The most common of these metabolites include alkaloids, phenolics and terpenoids. These substances, which may be present throughout the plant or isolated in certain tissues, can be obtained by extraction with aqueous or organic solvents or steam distillation (Castro et al., 2005; Dietrich et al., 2013; Menezes, 2005). Their mechanisms of action can vary, especially when the activity is due to a complex mixture of compounds that can be toxic or repellent to the target organisms and cause developmental changes including sterility, reduced growth, and altered behavior (Isman, 2000; Menezes, 2005).

The use of botanical insecticides to control pests is not a novel strategy; similar techniques were used 4000 years ago in India, while in China and Egypt botanical insecticides were used to control pests in stored grains around 3200 years ago (Venzon, 2010).

Table 1 lists some of the main species of plants that contain bioactive compounds, together with their effects on target organisms.

Amoabeng et al. (2014) undertook a cost/benefit analysis of the use of raw extracts composed of 30 g fresh weight each of four plants: mentrasto — *Ageratum conyzoides* (Asteraceae), Siam weed — *Chromolaena odorata* (Asteraceae), tobacco — *Nicotiana tabacum* (Solanaceae) and castor oil plant — *Ricinus communis* L. (Euphorbiaceae), compared to a synthetic insecticide, emamectin benzoate (Attack® — 1 L per hectare), during two different seasons (with high and low precipitation indices), for the control of two pests of cabbage: diamondback moth — *Plutella xylostella* L. (Plutellidae) and cabbage aphid — *Brevicoryne*

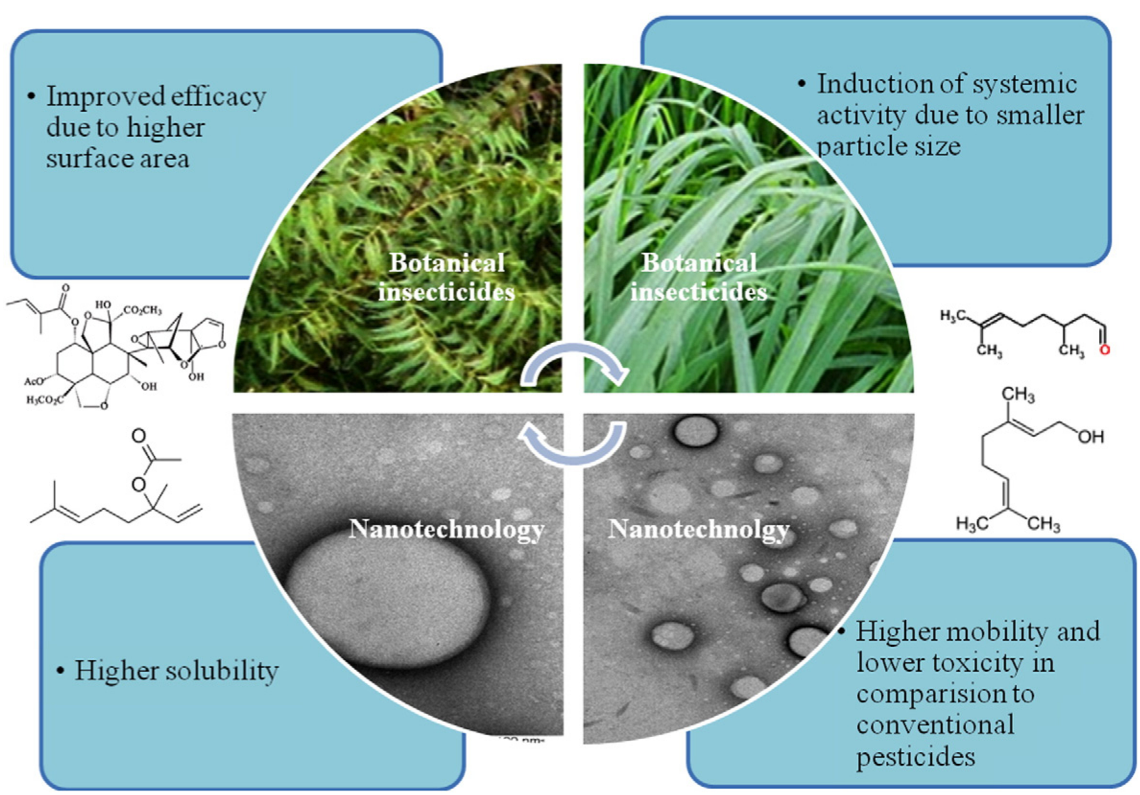

Fig. 1. Benefits of association between botanical insecticides and nanotechnology. A wide variety of bioactive compounds are represented in the figure. These compounds represent the main botanical insecticides used so far in association with nanotechnology in order to improve the properties of the compounds and increase their effectiveness in pest control.