Review articles & Short notes

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Hormesis- a weapon for improving insect natural enemies

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Constant pressure to feed the world's growing population has led to development of high-yielding varieties which caused crops to be stressed by various pests (Singh *et al.*, 2014). Although the call for using integrated pest management (IPM) is very sound and clear, still chemical management has been the first preference. This has led to excessive use of non-selective pesticides, thereby resulting in ecological backlash like natural enemies' destruction, resistance and resurgence of pests along with secondary pest outbreaks (Wang *et al*., 2012; Gowda *et al.*, 2021a). Although pesticides are applied at sufficient concentrations to manage the target insect pests, certain spatio-temporal changes in concentrations due to abiotic and biotic factors lead to altered targeted doses thereby causing lethal as well as sublethal effects in the arthropods exposed (Desneux *et al*., 2007, Ullah *et al*., 2019). This biological phenomenon is called hormesis or dose response phenomenon. It is a biphasic dose-response to low doses of stress that can stimulate biological activities (Fig.1) (Cutler and Rix, 2015). This hormesis has been seen in a wide range of organisms including insects (Calabrese, 2005; Cutler and Rix, 2015). In insects, it includes stimulation such as enhancement in longevity, fecundity at any life stage and with any pesticide active ingredient, thereby enhancing the growth of organisms (Cohen, 2006; Cutler, 2013; Ayyanath *et al*., 2013; Guedes and Cutler, 2014). Because of various ecological backlash and a huge impact on IPM-deciding strategy, the study of insect hormesis has been the center of research for insecticide toxicology with relatively less importance on toxicological impacts in natural enemies. The insecticide-induced insect hormesis is very detrimental whereas for the natural enemies it is a puissant weapon in optimizing mass rearing and enhancing the quality of bio-agents. Due to the high value of bio-agents in IPM, hormetic study or sublethal effect has garnered more attention.

It is very evident that commercial mass rearing and management of beneficial insects is a multi-billion dollar exclusive industry. Insects reared for biological and medical research, sterile insect release program, bio-control and many others have paved way for

the money-making industry. The collaboration of rearing with the hormetic principles can elevate the mass culture programs of insects such as by improving insect longevity, fecundity and parasitization rate (Cutler, 2013). The urge to study the insecticide induced hormesis in natural enemies, especially on the predators, started with the lacewing, *Chrysopa californica*, coccinellid beetle and *Habrobracon hebetor* (Fleschner and Scriven, 1957; Atallah and Newson, 1966; Grosch and Vacovic, 1967; Guedes and Cutler, 2013; Gowda *et al*., 2021b). The hormetic effects are more profound in insect predators than in parasitoids. For example, an increase in the reproductive outputs and reduction of the generation time of the predatory bug *Podisus distinctus* was seen with a single exposure to the sublethal dose of permethrin (Guedes *et al*., 2009). A similar trend was observed with the predator *Supputius cincticeps* (Zanuncio *et al*., 2005). In the case of parasitoids, *Trichogramma* which is an effective bioagent against various lepidopteran pests (Orr *et al*., 2000; Cabello *et al*., 2012; Chailleux *et al*., 2013; Gontijo *et al*., 2019; Nozad-Bonab *et al*., 2021; Gowda *et al*., 2021c), the knowhow about the potential of hormesis on the mass rearing and quality has now become a priority. For example, exposure to low lethal concentrations (LC_{30}) of chlorflurazuron and tebufenozide on *Trichogramma chilonis* Ishii increased the adult longevity and female fecundity (Wang *et al.*, 2012). Such advancement in rearing programs with hormetic principles can elevate the development of natural enemies.

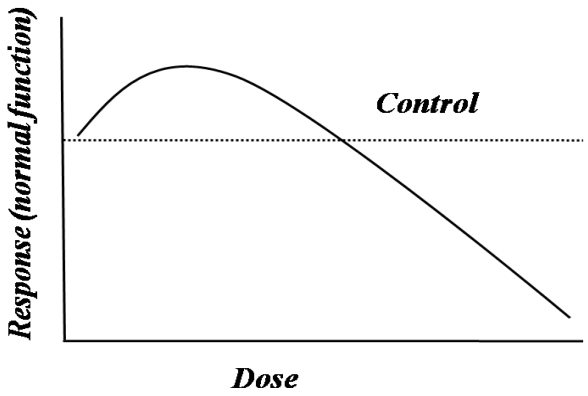

Fig. 1. Hormesis: A biphasic phenomenon (Guedes and Cutler, 2013)

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