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Some Insights on the Effect of Pesticides on Earthworms

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Abstract

Agricultural expansion has led to an accelerated use of pesticides. However, apart from target pests, non-target organisms are also exposed to such agrochemicals. Several such non-target organisms help in the proper functioning of the soil ecosystem. Among these, earthworms need a special mention on account of the important ecosystem functions which they provide. At the same time, as earthworms always remain in close contact with the soil, they are also highly exposed to the toxicities of applied chemicals. These chemicals have numerous biochemical, physiological and morphological consequences on these organisms. But during the application of pesticides, their effects on earthworms are completely overlooked. However, if an earthworm population breaks down in a particular soil ecosystem, it is difficult to develop it again. Through the present review the hazardous impact of some commonly used pesticides on earthworms have been study elucidated and documented. It was found that chemical pesticides have several harmful impacts on these organisms.

Keywords: Earthworms, Effects, Pesticides, Soil.

Introduction

There has been a dramatic increment of pesticide application in tropical regions due to the agricultural expansion[1]. As a result, soil contamination arising due to the application of agrochemicals is a major issue in tropical ecosystems[2]. For example, Monocrotophos which is a widely used insecticide in the cultivation of vegetables, paddy, potatoes and sugarcane etc.[3] is likely to exert result in harmful impact on the invertebrate fauna of the soil. This might result in serious consequences as soil invertebrates, which are crucial for decomposition and cycling of nutrients, play an important role in sustaining soil qualities[1]. However, much less attention has been given to study the detrimental effects of these chemicals on such non-specific organims in tropical regions, although much priority has been given to the same in temperate regions[2].

Pesticides have been found to induce morphological, behavioural and physiological changes in reproductive, nervous, respiratory and osmoregulatory organs of different animals[4]. Earthworms are vulnerable to such chemicals and therefore act as model organisms in the evaluation of the impact of the pesticides[5]. These are a vital component of soil biomass and act as an important indicator of total soil metabolism as well as soil pollution and toxicity[6-11]. In fact, several earthworm species have been used as bio-indicators[12] and hence these are used in the evaluation of chemical environmental pollution[13]. Several experiments such as ring testing and standardization of toxicity test using earthworm as the test organisms[14] have contributed immensely towards toxicology studies. Earthworms have also been used as indicator species for eco-toxicological investigations, risk evaluation and scrutinizing the environment quality[15,16] and are key organisms in environmental toxicology[17]. However, the earthworm which has an unavoidable beneficial role in maintaining soil health is often neglected during application of these chemicals which could cause ceasing of their activity[18].

Therefore, the present review has been attempted to investigate the unfavorable effects of some of the commercially available pesticides on various earthworm species.

Role of earthworms in enhancing soil fertility and structure

Earthworms are a major constituent of soil invertebrate fauna and improve soil structure by breaking organic matter and releasing plant nutrient[19,20]. These add significantly towards nutrient cycling as well as in enhancing biological activity of the soil ecosystem[21]. The activities of the earthworms influence the cycling of the soil nutrients via their influence on biological and physical attributes of the soil. But it must be noted that various collateral factors such as the flora and fauna of the soil, nature of the soil and climate dictates the degree of this influence[22]. Moreover, they maintain soil status through their burrowing and casting activities[23]. Through their burrowing activities, the earthworms construct labyrinth of tunnels which enhances the soil's capacity to take up water and hence, the dearth of earthworm population necessities the application of costly materials such as gypsum or calcium to order to increase soil permeability. Besides, the action of the calciferous gland of the earthworms along with the buffering action of carbonic acid, helps in the maintenance of soil pH[18]. Thus, it is well understood that earthworms have an important impact on soil fertility and soil permeability[24].

However, what determines the strength of earthworm population as well their diversity and how this diversity influences various soil processes is still an enigma[25]. It is also a fact that once an earthworm population breaks down it becomes difficult to transfer earthworms into the soil and re-establish their population[26].

Some earthworm species like *Eisenia fetida* (Oligochaeta, Lumbricidae) are used for cow dung vermin-composting[27]. This is because these are easily found, have short life span and wide temperature and moisture tolerance ranges. In addition, these are less sensitive earthworms and can be handled without much difficulty[28]. As a result, *Eisenia fetida* is extensively used as test organism for ecotoxicological, physiological and genetical research[28].

Effects of pesticides on earthworms

Earthworms that remain in direct contact with the ground are at a high risk of absorbing applied agro-chemicals[19]. In fact, in addition to ingestion, earthworms could also absorb chemicals from pore water through skin[29]. Pesticides negatively affect earthworm growth and reproduction (number of cocoons produced, hatchlings arising from the cocoons etc)[30]. Pesticides also lead to cuticle rupture resulting in the release of coelomic fluid and may cause the swelling of body tissues of the earthworms[31].

The combination of different pesticides at various concentrations results in neurotoxic consequences[32]. Increased exposure period to elevated dosage of these chemicals may induce anomalies at the cellular level and result in incessant breakdown of proteins[32].

An organophosphate pesticide dimethoate has been found to have toxic effects upon the testicular histomorphology of earthworms[33] as well as their protein content and enzyme activities[34]. There are also many other reports on the toxic effects of pesticides on earthworms. Hans *et al*. (1993) found that three organochlorine insecticides (aldrin, endosulfan and lindane) have negative effects on the earthworm *Pheretima posthuma* which varied according to the duration of exposure[35]. Callahan *et al*. (1994) observed the mortality with respect to concentration of four different earthworms species - *Allolobophora tuberculata, Eisenia fetida, Perionyx excavates* and *Eudrilus eugeniae*[36]. They tested 62 pesticides and reported that chemical impact on organisms which indicated that all the species had similar tolerance.

Kuo reported that benomyl, hymexazol, metalaxyl, methasulfocarb and carbofuran pesticides have lethal effects on the earthworm *Bimastus parvus* (Eisen)[37]. They reported that carbofuran and methasulfocarb were more toxic. Lethal effect of benomyl varied with the time of feeding. Mortality of the earthworms decreased as the time of feeding delayed.

Likewise, Mosleh and coworkers reported the effects on the soluble protein of the LC_{25} treated earthworm due to the exposure to cypermethrin, chlorfluazuron, profenofos, aldicarb, metalaxyl and atrazine[34]. Among these chemicals, aldicarb was found to be the most toxic. Spurgeon *et al* have stated that copper, zinc, lead and cadmium have impacts on mortality, growth and cocoon production of *Eisenia fetida*[38]. For all the metals, mortality was comparatively less affected than cocoon production. Organophosphate pesticides such as diazinon and chlorpyrifos had been previously documented to exert toxic effects on earthworm *Aporrectodea caliginosato*[39].

However, chlorpyrifos, carbofuran and mancozeb have been found to be more toxic to *Perionyx excavates* than *Eisenia andrei* under tropical conditions[2]. Carbamates have been reported to have toxic effects on earthworms while organophosphates cause the breakdown of earthworm population[40]. Extensive exposure of earthworms to chlorpyrifos and azinphos has been found to drastically affect on them[41].

Research on earthworm

The innate capability of a toxicant to produce detrimental effect on an organism resulting in the impairment of its normal activity or function is called toxicity and one of the apropos ways to study the toxicity of a substance for the organism is by evaluation of the LC_{50} value[42]. A useful method to calculate The LC_{50} is by using 'probit' analysis[42]. A host of research have been conducted to study the toxic impact of different chemicals on earthworm activity[43-48]. Majority of the works were carried out to assess the potential risk of organophosphate pesticides like malathion, phorate, monocrotophos, fenitrothion by using earthworm as the test organism[49,50].

The toxic effects of imidacloprid, a common neonicotinoid insecticide, on earthworms have also been studied[51,52] in the tropical agro-ecosystem. In fact, a number of investigations have been undertaken to monitor the effect of some pesticides on earthworms[53].

Dimethoate is an extensively used organophosphate insecticide in India[54,55]. Some of the widely used earthworm species for toxicological studies are - *Eisenia andrei, Eisenia fetida*, *Lampito mauritii*, *Eudrilus eugeniae* and *Pontoscolex corethrurus*[2].

Need for further study on earthworms

Although literature has reported the investigations on the effects various pesticides, there are several which have not been. In this regard an important example is dimethoate-30% EC (Rogor), which is an extensively used systemic organophosphate insecticide with toxicity varying with purity[56]. At this point it can be reminded that the term organophosphate is used to cover all the toxic compounds which contain a phosphorous atom[57]. Most of the toxic organophosphates are esters of phosphoric, phosphorothoic or phosphonic acids or of their\ anhydrides, halides or amides[58]. According to Kulkarni *et al*, the organophosphate compounds can be represented with help of the following formula (Figure-1)[59]:

Dimethoate can have numerous toxicological and ecological impacts[60]. It has been found to exert several toxic effects on mammals (FAO) and fishes[61]. Dimethoate leads to the decrease of protein content in *Labeo rohita*[62], *Puntius ticto*[63] and *Heteropneustes fossilis*[64]. This is because free amino acids serve as supplementary energy source during stress and hence under such circumstances, protein metabolism is likely to increase[62]. The decline in the amount of protein content is indicative of the probable fact that the pesticide treatment causes the exhaustion of the organism's metabolic reserves resulting in the energy deficiency and in order to compensate this loss the proteins undergo catabolism leading to the production of required amount of energy[65].

Dimethoate is likely to be toxic to other organophosphates such as malathion[66] and parathion[13].

Conclusion

Pesticides have the potential to severely damage beneficial non-targeted soil fauna leading to the breakdown of their population and causing unwanted shifts of the community[2]. Earthworms, which are one of the important soil fauna, are extremely vulnerable to the adverse effects of pesticides and the consequences are evident at the species, population as well as community levels[5]. Such sensitivity of earthworms to pollutants has been well documented and it has been found that physiological, morphological and ecological characters are its important determinants[2].

However, there are a number of external factors that determine pesticide toxicity; among them are soil properties which determine the availability chemicals to soil invertebrates and in this way determine their toxicity[67]. In addition, higher temperatures elevate microbial activity and degradation of chemical compounds, leading to reduced toxicity[2].

Subjecting the test organisms to sub-lethal dose of the pesticide can be considered as a pragmatic approach to forecast the potential environmental consequences as in the field the organisms are usually exposed or come in contact with a lower concentration of the pesticides[68]. The harmful impacts of pesticides have also been also documented in case of other invertebrates like bees which are important pollinators[69].

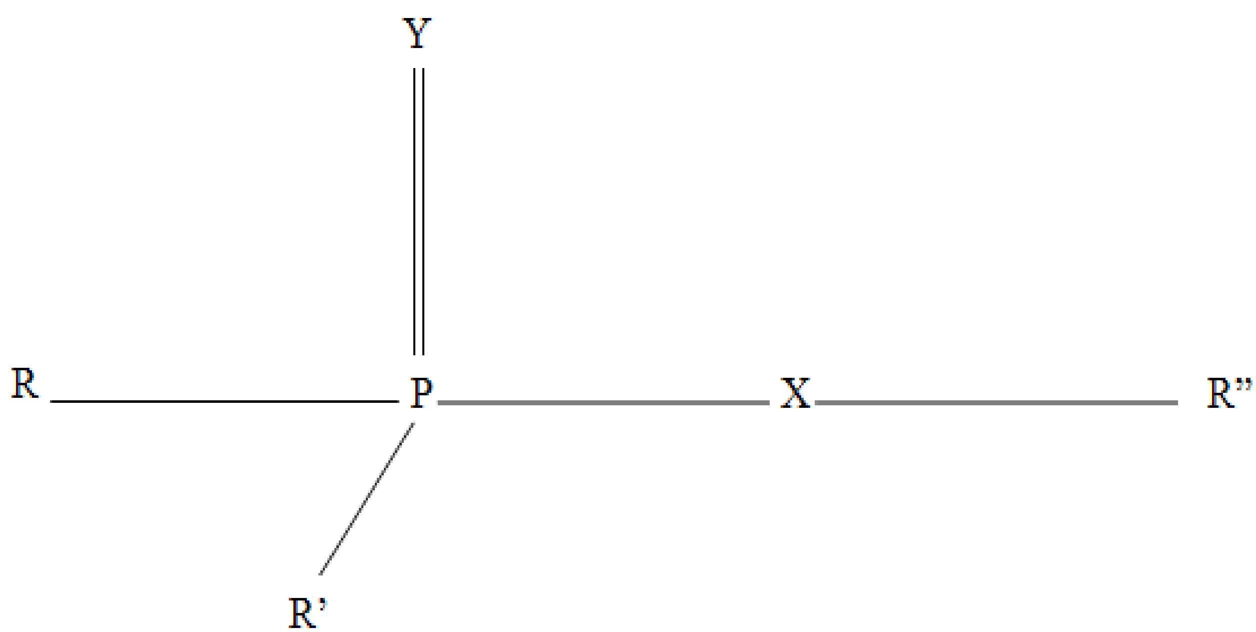

Figure-1
Structure of organophosphate compound (R, R' stands for the short hydrocarbon and oxygen groups respectively; X and Y can be either sulphur or oxygen whereas the group that is metabolized by the contact organism is represented by R". Phosphorous, which is highly electrophilic, forms the central atom to which all these groups are attached and play a critical role leading to physiological effects.)

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