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THE IMPACT OF INSECTICIDES ON EARTHWORMS: A REVIEW

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ABSTRACT

As the main factors for the increase agricultural productivity in the 20th century are considered insecticides. However, many insecticides are toxic not only to the target species, but also to non-target organisms, mainly due to physiological similarities between them. In recent years, numerous ecotoxicity studies have been carried out on aquatic and soil organisms. Among terrestrial invertebrates, Lumbricidae are one of the most important groups. They have great ecological, economic and social importance. They play key role in decomposition of organic matter along with microorganisms, are vital members of ecosystem food webs and valuable ecosystem indicators. They also contribute to the quality of the soil and that is why it is very important to study the sublethal effects of pollutants, which may have an impact on their activities. The present review includes the diverse effects of different type of insecticides on earthworm biology, impact on the parameters of the life cycle and indirect impacts on ecosystem functions. The application of insecticides in agriculture represents a major threat to wildlife and ecosystems, because even when used in small quantities, their multiplicity, their toxicity and persistence have a harmful effect on ecological systems. With these results, we also highlighted the fact that the use of chemical substances must be carried out with maximum responsibility.

Keywords: *earthworm, insecticide, ecotoxicity, life cycle, ecosystem.*

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INTRODUCTION

Conventional agriculture has the task of providing maximum production in terms of food quantity and quality. For these purposes, man uses numerous, very intensive agrotechnical and zootechnical measures. As the main factors for the increase agricultural productivity in the 20th century are considered insecticides (Pimentel, 2005). The effects of insecticides on natural pests are usually associated with direct determinations of effects such as mortality or survival over a given time period. However, the indirect or delayed effects of insecticides provide information about the long-term stability and overall success of biological control (Kumar et al., 2024). The same is true for effects on non-target organisms, mainly due to the physiological similarities between target and non-target organisms (Wang et al., 2012). That is why the risk assessment is done associated with their use is carried out on many water and land organisms (Yasmin and D'Souza, 2010). Among soil organisms, research is focused on earthworms, because they make up more than 80% of the total invertebrate biomass in many eco-systems temperate regions. Also, they contribute to the complex processes of organic decomposition matter and affect aeration, water transport and soil structure. They are special sensitive to chemicals (Blouin et al., 2013), so their protection can provide safety to other members of the fauna and an increase in concentration can be prevented of pesticides through food chains (Kızılkaya, 2005). The use of lumbricides in risk assessment programs is twofold. Apart from their protection as useful organisms, are also used to obtain information about the quality of the environment.

Today, it is known that changes community structure and population dynamics of earthworms have a profound impact on ecosystem functioning. The reason for this lies in the fact that earthworms are not a homogeneous entity and that they are clearly differentiated by ecological types. In other words, different species have different effects on soil processes. Formally, based on different ecological niches, earthworms can be classified into three main ecological forms (epigeic, endogeic, anecetic) (Bouchè, 1972). Epigeic species generally form temporary narrow and very short channels in the surface layer, so they do not have a major impact on soil structure. They mainly facilitate the decomposition of litter and the decomposition of organic matter, which increases the amount of available nutrients, which stimulates the activity of soil microorganisms (Stojanović-Petrović et al., 2020). Anecic species are very important mediators in the decomposition of organic matter, nutrient cycling and soil formation, accelerating pedological processes in the soil, due to the creation of deep vertical channels, sometimes reaching a depth of two meters (Stojanović-Petrović et al., 2020). Endogenous species are important in soil formation processes, including root decomposition, soil mixing and aeration. These species play a key role in the formation of soil aggregates, which contributes to the maintenance of soil structure. (Zicsi et al., 2011).

Regardless, the species *Eisenia fetida* (Savigny, 1826) is taken as a standard test organism in ecotoxicological tests. Relatively short life cycle, high cocoon production, continuous breeding and easy cultivation in laboratory conditions allowed them to be suitable model organisms, which is recommended by the Organization for economic cooperation and development (OECD) for laboratory tests.

Because of all of the above, a comprehensive understanding of the impact of chemical agents on soil ecosystem dynamics and soil ecology is necessary. The application of insecticides in agriculture represents a major threat to wildlife and ecosystems, because even when used in small quantities, their multiplicity, their toxicity and persistence have a harmful effect on ecological systems.

There fore the present review includes the diverse effects of different type of insecticides on earthworm biology, impact on the parameters of the life cycle and indirect impacts on ecosystem functions

EFFECTS ON MORTALITY

Mortality of earthworms is considered the most relevant endpoint in laboratory tests, although these data have low ecological relevance (Wang et al., 2012). Nevertheless, there are insecticides that have a strong initial efficacy and are so toxic that they are immediately lethal. This primarily depends on the insecticide's mode of action and absorption. For example, pyrethroids are more readily absorbed through the skin than by ingestion (Sekulić, 2017). Of the several classes of insecticides, neonicotinoids are the most effective against target organisms, but are also the most toxic to earthworms (Wang et al., 2012). Frampton et al. (2006) consider that acute mortality is not the most sensitive endpoint. It is known that the response in acute tests can be stronger in organisms that efficiently metabolize toxicants but do not excrete them, and some of the metabolites can cause sublethal responses (Roex et al., 2000). Some of the scientific reports of commonly used pesticides and their impact on mortality of earthworm are listed in Table 1.

Table1 Commonly used pesticides and their impact on earthworm mortality

Insecticides	Species	LC_{50} values	Reference
Organophosphate insecticides			
chlorpyrifos	*Perionyx excavatus*	7.3 mg/kg	Gupta et al., 2010
chlorpyrifos	*Eisenia fetida*	14.19 μg/cm	Wang et al., 2012
monocrotophos	*Perionyx excavatus*	13.04 mg/kg	Gupta et al., 2010
phoxim	*Eisenia fetida*	54.65 μg/cm	Wang et al., 2012
pyridaphenthion	*Eisenia fetida*	3.84 μg/cm	Wang et al., 2012
triazophos	*Eisenia fetida*	14.21 μg/cm	Wang et al., 2012
fenitrothion and malathion	*Eisenia fetida*	368.25 mg/kg	Milanović et al., 2014
Pyrethroids and pyrethrin			
cypermethrin	*Perionyx excavatus*	0.008 mg/kg	Gupta et al., 2010
cypermethrin	*Eisenia fetida*	10.63 μg/cm	Wang et al., 2012
deltamethrin	*Eisenia fetida*	1.04 mg/kg	Sekulić et al., 2020a
spinosad	*Eisenia fetida*	3.62 mg/kg	Sekulić et al., 2020b
bifenthrin	*Eisenia fetida*	8.83 mg/kg	Sekulić et al., 2023
Carbamate			
aldicarb	*Perionyx excavatus*	10.63 mg/kg	Gupta et al., 2010
carbaryl	*Perionyx excavatus*	6.07 mg/kg	Gupta et al., 2010
Neonicotinoid insecticides			
imidacloprid	*Eisenia fetida*	2-4 mg/kg	Capowiez et al., 2005
imidacloprid	*Eisenia fetida*	3.05 mg/kg	Wang et al., 2015a
acetamiprid	*Eisenia fetida*	2.69 mg/kg	Wang et al., 2015a
nitenpyram	*Eisenia fetida*	4.34 mg/kg	Wang et al., 2015a
clothianidin	*Eisenia fetida*	0.93 mg/kg	Wang et al., 2015a
thiacloprid	*Eisenia fetida*	2.68 mg/kg	Wang et al., 2015a

EFFECTS ON GROWTH

Haque and Ebing (1983) consider weight loss to be an important criterion for determining sublethal effects. Growth inhibition occurs due to reduced food intake, which also controls pesticide intake (Mosleh et al., 2003). This strategy is usually used to prevent poisoning of the organism (Ribeiro et al., 2001). Either the energy is used to defend the organism against the pesticide and is no longer available for growth (Mosleh et al., 2003). Some of the scientific reports of commonly used pesticides and their impact on growth of earthworm are listed in Table 2.

Table2 Commonly used pesticides and their impact on earthworm growth

Insecticides	Species	Impact on growth	Reference
Organophosphate insecticides			
profenofos	*Aporrectodea caliginosa* and *Lumbricus terrestris*	causes a reduction in growth rate	Mosleh et al., 2003
malathion	*Eisenia fetida*	significant loss of body mass	Navarro and Obregon, 2005
chlorphyrifos	*Eisenia fetida*	adverse effects on growth	Pawar and Ahmad, 2013
fenitrothion and malathion	*Eisenia fetida*	adverse effects on growth	Milanović et al., 2014
dimethoate	*Eisenia fetida*	significantly reducing weight	Rico et al., 2016
Pyrethroids and Pyrethrin			
deltamethrin	*Eisenia fetida*	significant effects on growth	Shi et al., 2007
deltamethrin	*Eisenia fetida*	significant effects on growth, even at recommended doses	Sekulić et al., 2020a
spinosad	*Eisenia fetida*	decrease in weight was recorded when applying higher concentrations	Sekulić et al., 2020b
bifenthrin	*Eisenia fetida*	had no effect on growth	Sekulić et al., 2023
Neonicotinoid insecticides			
imidacloprid	*Aporrectodea nocturna* and *Allolobophora icterica*	significantly decreased the weight	Capowiez et al., 2005
imidacloprid	*Lumbricus terrestris* and *Aporrectodea caliginosa*	body mass loss	Dittbrenner et al., 2010
guadipyr	*Eisenia fetida*	had no effect on the growth of earthworm at concentrations below 100 mg/kg.	Wang et al., 2015b

EFFECTS ON REPRODUCTION

Reproduction can be inhibited or stopped at concentrations of pollutants that are well below certain lethal concentrations (Sekulić, 2017). Thus, according to Zhou et al. (2007) reproduction parameters are clearly more sensitive endpoint tests than others for risk assessment. They pointed out that weight loss is an indicator of physiological stress, which depends on the pesticide concentration and exposure time. Often, endpoints such as growth and reproduction are considered separately. However, according to Jager et al. (2006) these endpoints are closely related.

Reproduction usually begins with a certain minimum body size. Some of the scientific reports of commonly used pesticides and their effects on reproduction of earthworm are listed in Table 3.

Table3 Commonly used pesticides and their impact on earthworm reproduction

Insecticides	Species	Impact on reproduction	Reference
Organophosphate insecticides			
parathion	*Eisenia fetida*	adverse effect on cocoon production, cocoon viability and hatching success rate	Bustos-Obreg and Goicochea, 2002
malathion	*Eisenia fetida*	decline in sperm viability	Navarro and Obregon, 2005
dimethoate,	*Eisenia fetida*	harmful to reproduction and development	Yasmin and D'Souza, 2010
dichlorvos	*Eisenia fetida*	reproduction significantly affected	Farrukh and Ali, 2011
dimethoate	*Eisenia fetida*	the decrease in cocoon production and coon viability	Pal and Patidar, 2013
chlorpryriphos	*Eisenia fetida*	hindering the development and reproduction	Pawar and Ahmad, 2013
Pyrethroids and pyrethrin			
cypermethrin	*Eisenia fetida*	notable decrease in the production of cocoons	Shiping et al., 2008
cypermethrin	*Eisenia fetida*	caused significant toxic effects in the reproduction	Zohu et al., 2008
spinosad	*Eisenia fetida*	the results of cocoon production and hatching juveniles showed no significant difference between the control and the treatments	Sekulić et al., 2020b
bifenthrin	*Eisenia fetida*	it was found that the number of cocoons decreased with increasing the concentration and time	Sekulić et al., 2023
Neonicotinoid insecticides			
imidacloprid	*Eisenia fetida*	had a highly significant effect on cocoon production	Wang et al., 2015a
acetamiprid	*Eisenia fetida*	had a highly significant effect on cocoon production	Wang et al., 2015a
nitenpyram	*Eisenia fetida*	had a highly significant effect on cocoon production	Wang et al., 2015a
clothianidin	*Eisenia fetida*	had a highly significant effect on cocoon production	Wang et al., 2015a
thiacloprid	*Eisenia fetida*	had a highly significant effect on cocoon production	Wang et al., 2015a
thiacloprid	*Eisenia fetida*	leading to a reduction in the number of offspring	Silva et al., 2017

CONCLUSIONS

The application of pesticides in agriculture represents a major threat to wildlife and ecosystems. Pesticides, even when used in small quantities, their multiplicity, their toxicity and persistence have a harmful effect on ecological system (Reddy and Rao, 2008).

Earthworms (family Lumbricidae) play a significant role in pedogenesis. They also contribute to the quality of the soil and that is why it is very important to study the sublethal the effects of pollutants, which may have an impact on their activities.

Studies on this aspect are important because earthworms are common prey for many species of terrestrial vertebrates, such as birds and small mammals, and therefore play a key role in the biomagnification process of several soil pollutants.

With these review, we also highlighted the fact that the use of chemical substances must be carried out with maximum responsibility. Information about chronic effects may be important to understand data from field tests, which normally show high variability and therefore they are difficult to interpret.

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