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A review on effect of different pesticides on earthworm

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Abstract

This review seeks to raise awareness of the value of earthworms in sustainable agriculture as well as the impact of pesticides on their activity. Enhancing agricultural sustainability requires a high level of soil biodiversity. The immense diversity of soil organisms allows for the best possible utilisation of the resources found in the varied habitats at different resolution levels. By turning organic waste and biodegradable material into nutrient-rich vermicast, earthworms play a significant role in the growth and upkeep of the soil's nutritional value. They go under the name of ecological engineers as well. Earthworms are the primary agents of the process, modifying the microbial activity significantly by splintering the substrate and aerating the environment, even though microbes biochemically decompose organic materials. The biodiversity of invertebrates, particularly earthworms, has been negatively impacted by the widespread use of pesticides. Although they are impacted by intensive practices like pesticide usage, earthworms play a vital role in many ecosystem functions that promote the sustainability of agrosystems. Not only do pesticides rank among the most expensive and widely used soil toxicants, but they also directly impact soil structure through supplementing and indirectly affect it through loss of biodiversity and serious injury to non-target organisms like earthworms.

Keywords: Pesticides; Earthworm; Growth; Reproduction; Enzymatic activity

1. Introduction

An important factor in boosting agricultural sustainability is soil biodiversity. According to Ferris and Tuomisto (2015), soil organisms are incredibly diverse and enable the best possible use of the resources found in the varied habitats at different resolution levels. Pesticide residue prevalence in environmental matrices is always a problem for the environment, even though organic farming is becoming more and more popular. Synthetic pesticides are still applied in agriculture and for sanitation reasons (Srimurali et al. 2015). By transforming organic waste and biodegradable material into nutrient-rich vermicast, earthworms play a significant role in the growth and upkeep of the soil's nutritional value (Jansirani et al. 2012). Jones et al. (1994) refer to them as ecological engineers as well. According to Saranraj and Stella (2012), earthworms are capable of consuming a broad variety of unstable organic materials, including sewage sludge, industrial waste, and animal waste. Vermicast, often known as black gold, is a product that is produced when organic waste is modulated in the intestines of earthworms. It differs greatly from its original waste material (Patangray 2014). Earthworms constitute a larger portion (>80%) of the biomass of terrestrial invertebrates and are important for organising and improving soil nutrients. Because they function as useful bioindicators of chemical pollution of the soil in terrestrial ecosystems, earthworms therefore offer an early warning of decline in soil quality (Culy and Berry 1995; Sorour and Larink 2001).

Because earthworms are decomposers and exhibit a wide range of sensitive responses to environmental stimuli, they are frequently utilised as test organisms. Earthworms play a crucial role in ecology since many pollutants can cause secondary poisoning when they eat the worms. It is plausible that the worms experienced significant negative effects

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(Edwards and Bohlen 1996). he depletion of agro ecosystem sustainability is caused by overuse of pesticides and herbicides (Céline et al. 2014). The article examines research on the effects of many widely used pesticides on diverse earthworm species.

2. Effect on Growth

Earthworms are less able to carry out their important and vital roles in the soil ecosystem as a result of pesticide exposure (Rathore and Nollet 2012). According to Zhou et al. (2006), the earthworms' weight was a more sensitive indicator of the harmful effects of acetochlor and methamidophos than their mortality. When endosulfan was treated to soil at a regular treatment rate in both the field and the laboratory, Choo and Baker (1998) discovered that the weight of young *Aporrectodea trapezoides* was drastically reduced after 5 weeks. In contrast, fenamiphos accomplished the same thing at a normal application rate in the field alone. When administered at 10 usual rate, fenamiphos and methiocarb both decreased earthworm weight in the lab (Frampton et al. 2006). After 15 days, Panda and Sahu (1999) observed a considerable drop in *D. willsi* growth (57% in 2.2 and 80% in 4.4 mg malathion per kg soil). Pelosi et al. (2016) investigated epoxiconazole's sublethal effects on the earthworm *Aporrectodea icteric.* After 28 days of exposure, weight increases were 28, 19, and 13% of the starting weight in the D1 and D10 treatments (one and ten times the recommended dose, respectively).

Shi et al. (2016) investigated the oxidative defence enzyme catalase (CAT) and the biotransformation system phase II enzyme glutathione-S-transferase (GST) in earthworms (*Eisenia fetida)* exposed to polluted soils from a former DDT plant and reference soils. They also looked at the earthworms' development and survival.The earthworms exposed to the polluted soils had considerably greater rates of mortality, growth inhibition rates, GST, and CST activities than those in the reference soils, according to their findings.

3. Effect on Reproduction

When earthworms are exposed to different xenobiotics, a number of reproductive factors have been explored, including the formation of cocoons and hatchlings, the survivability of the worms generated, and sexual development. Bustos-Obregón and Goicochea (2002) investigated the impact of commercial parathion exposure on *Eisenia fetida* reproductive parameters, including sperm and cocoon production and genotoxicity on male germ cells. They found that significant changes in these parameters were evident in the quantity of sperm, cocoons, and worms born. According to Xiao et al. (2006), the number of juveniles per cocoon may be thought of as a sensitive indicator to assess the toxicity of acetochlor on earthworms. Choo and Baker (1998) also discovered that methiocarb, applied at ten times the normal rate, and endosulfan and fenamiphos at regular treatment rates hindered the generation of cocoons in *Aporrectodea trapezoides.*

When the organophosphate pesticide malathion was applied to *Eisenia fetida* in 2005, Espinoza-Navarro and Bustos-Obregón discovered that the treatment affected the DNA structure of spermatogonia and reduced spermatic viability in spermatheca. In their 2003 study, Gupta and Saxena examined the effects of the N-methyl carbamate pesticide carbaryl on the reproductive profiles of *Metaphire posthuma* earthworms. They discovered anomalies in the sperm heads of these worms even at the lowest test dosage of 0.125 mg/kg. At 0.125 mg/kg carbaryl, abnormalities with wavy heads were seen; at 0.25 mg/kg and 0.5 mg/kg, however, the sperm heads became amorphous and the head nucleus was transformed into granules that were deposited inside the wavy head.

According to a number of scientists, pesticides have a dose-dependent effect on worm reproduction, resulting in decreased mean and maximum number of hatchlings per cocoon, longer incubation times, and more worms producing cocoons (Addison and Holmes, 1995; Yasmin and D'Souza, 2007).

At field doses of 5–10 mg/, Xiao et al. (2006) demonstrated that acetochlor had no long-term influence on *Eisenia fetida* reproduction. Acetochlor (20–80 mg/kg) showed sublethal toxicity to *Eisenia fetida* at higher doses. After eight weeks, Zhou et al. (2007) evaluated and discovered that chlorpyrifos had a negative impact on fertility in earthworms exposed to 5 mg/kg of the chemical.

4. Effect on Enzymatic Behaviour

Since different kinds of enzymes prevent the harmful effects of chemicals from occurring by maintaining cell integrity and playing a critical part in neurocholinergic transportation, they are referred to as biomarkers (Sanchez-Hernandez 2006; Novais et al. 2011; Mekhalia et al. 2016). Dimethoate is an organophosphate insecticide that has been shown to have harmful effects on the protein profile, cellular enzyme system, and testicular histomorphology of *Eisenia kinneari* (Mosleh et al. 2003; Lakhani et al. 2012).

Numerous enzymatic processes have been carefully considered as indicators of pollution in the environment. According to Rahman (2007), these enzymes from living things have antioxidant properties and can protect cells from the damaging effects of reactive oxygen species (ROS). Damage to lipids, proteins, and DNA occurs when reactive oxygen species (ROS) such superoxide and H2O2 accumulate (Lopez et al. 2006). Atrazine produces reactive oxygen species (ROS), which are genotoxic because they damage DNA strands single and double (Song et al. 2009).

An essential enzyme involved in the transportation function of the nervous system is acetylcholinesterase. Acetylcholine is converted into choline and acetate at cholinergic synapses, where it initiates neurotransmission (Soreq and Zakut 1993). In general, pesticides containing carbamates and organophosphorus block the activity of AChE. *Eisenia fetida* exposed to two organophosphates, azodrin and chlorpyriphos, exhibits a time-dependent inhibition of AChE in the standardised paper contact test (Rao et al. 2003; Rao et al. 2004).

Through the breakdown of glutathione, the cytosolic enzyme glutathione-s-transferase (GST) aids in the detoxification and biotransformation of electrophilic chemicals. According to Lionetto et al. (2012), the disclosure of pesticides may hasten changes in the enzymatic activities that accompany metabolic disruptions and cell death in the targeted tissues. Because an elevated level of GST may produce sophisticated protection against the detrimental effects of pesticides, GST can be employed as biomarkers for monitoring pollution (Oruc et al. 2004).

Table 1 Effect of various pesticides on different aspects of earthworm

S.No	Chemical	Earthworm Species	Effect	Reference
1.	Carbaryl and Dieldrin	*Eisenia fetida*	Inhibition of growth and cocoon production	Neuhauser and Callahan (1990)
2.	Benomyl	*Eisenia fetida*	Sperm which have been underdeveloped or have aberrant acrosome development	Sorour and Larink (2001)
3.	Carbaryl	*Eisenia fetida*	Inhibition of cholinesterase (ChE) was seen even at the lowest dosage	Riberaa et al. (2001)
4.	Butachlor, malathion and carbofuran	*Drawida willsi*	Butachlor did not alter AChE activity. Maximum AChE inhibition after 9 days of malathion and after 12 days of carbofuran exposure.	Booth and O'Halloran (2001)
5.	Chlorpyriphos, Atrazine, Cyanazine	*Eisenia fetida*	Chlorpyrifos binary combinations with atrazine and cyanazine showed toxicity that was higher than additive.	Lydy and Linck (2003)
6.	Endosulphan and Aldicarb	*Lumbricus terrestris*	Loss in weight, Reduction in the growth rate. Aldicarb more toxic than endosulfan	Mosleh et al. (2003)
7.	Butachlor, Malathion and Carbofuran	*Drawida willsi*	When exposed to butachlor, no variation of AChE activity; on malathion exposure, maximum AChE inhibition (41% and 46%) after 9d and after 12d (54% and 62.9%) of carbofuran exposure	Panda and Sahu, (2004)
8.	Azodrin	*Eisenia fetida*	Dose-dependent inhibition of AChE activity. Co-relation between AChE activity and morphological damage.	Rao and Kavitha (2004)
9.	Malathion	*Eisenia fetida*	Significant reduction in body weight and decreased spermatic viability	Navarro and Obregon (2005)

1	Imidacloprid	*Aporrectodea nocturna and Allolob ophora icterica*	The LC50 for A. nocturna and A. icterica was between 2 and 4 mg kg−1 dry soil. Also, significant decrease in weight was observed.	Capowiez et al. (2005)
1	Acetochlor	*Eisenia fetida*	Growth and numbers of juveniles per cocoon were affected significantly.	Xiao et al. (2006)
1	Imidacloprid	*Aporrectodea nocturna and A.icterica*	The continuity of the burrow systems made by both species was altered. Gas diffusion through the A. nocturna soil cores was reduced but no difference in gas diffusion in A. icterica soil cores.	Capowiez and Berard (2006)
1	Carbofuran	*E. fetida*	Protein content and TChE (Total Cholinesterase activity) increased in low level and vice-versa. SOD reduced when carbofuran concentration increased and vice versa.	Ling (2006)
1	Chlorpyriphos and Azinphos methyl	*Aporrectodea caliginosa*	Cholinesterase (ChE) inhibition	Reinecke and Reinecke (2007)
1	Carbendazim, dimethoate, and glyphosate	*Eisenia fetida*	Independently and in combination is detrimental to the growth and reproduction	Yasmin and D'Souza (2007)
1	Benomyl	*Eisenia fetida*	Toxicity of benomyl was lower in tropical than temperate artificial soils No reproduction in tropical natural soil.	Rombke et al. (2007)
1	Lindane and deltamethrin	*Eisenia fetida*	Lindane proved to be more toxic than deltamethrin. Significant effects on growth and cellulase activity	. Shi et al. (2007)
1	Glyphosate and Chlorpyrifos	*Eisenia fetida andrei*	Glyphosate reduced cocoon production. NRRT (Neutral red retention test) and Comet assays revealed alterations at a subcellular level.	Casabe et al. (2007)
1	Carbaryl	*Eisenia andrei*	Dose-dependent inhibition of AChE activity	Gambi et al. (2007)
2	Cypermethrin	*Eisenia fetida*	Significant reduction in cocoon production. Juveniles more sensitive than adults	Shi-ping et al. (2008)
2	Butachlor	*Eisenia fetida*	As a result of the use of the chloragogen tissue's reserve energy, less biomass and cocoons are produced.	Gobi and Gunasekaran (2010)
2	Chlorpyrifos, Carbofuran andMancozeb	*Perionyx excavatus*	Toxicity decreased in the order- carbofuran> chlorpyrifos > mancozeb	De Silva et al. (2010)
2	Imidacloprid	*Lumbricus terrestris and A. caliginosa*	Decrease in body mass and cast production at higher concentrations	Dittbrenner et al. (2010)
2	Imidacloprid.	*Pheretima posthuma*	Increase in protein content in clitellum, inhibition of some proteins in head and no change in abdomen after exposure	Faheem and Khan (2010)
2	Cypermethrin, endosulfan, carbaryl, chlorpyrifos, aldicarb, monocrotophos	*Perionyx excavatus*	Order of toxicity Cypermethrin > endosulfan >carbaryl > chlorpyrifos > aldicarb > monocrotophos	Gupta et al. (2010)

2	Imidacloprid	*Lumbricus terrestris and A. caliginosa*	Burrowing effects on A. caliginosa even at lower concentrations but burrowing effects for L. terrestris observed only at higher concentrations.	Dittbrenner et al. (2011)
2	Mixture of Ni and Chlorpyriphos	*Lumbricoid*	Combinations of Ni and chlorpyrifos cause additive toxicity for earthworms. Worms accumulate Ni and chlorpyriphos in their tissues.	Lister et al. (2011)
2	R-metalaxyl and rac-metalaxyl	*Eisenia fetida*	Enantioselective bioaccumulation of metalaxyl in earthworm observed with preferetial accumulation of Senantiomer	Xu et al.(2011)
2	Azinphos methyl	*Eisenia andrei*	Reduction in burrowing activity and inhibition in cholinesterase activity	Jordaan et al. (2012)
3	Chlorpyrifos and Fenvalerate	*Eisenia fetida*	Cellulase and SOD (Superoxide dismutase) activity inhibited whereas CAT (Catalase) activity first increased and then decreased.	Wang et al. (2012)
3	Fomesafen	*Eisenia fetida*	Low doses could not lead to oxidative stress and peroxidation.	Zhang et al. (2013)
3	Chlorpryriphos	*Eisenia fetida*	At increasing concentrations, the earthworm body began to melt and decompose.influences development, growth, reproduction, and the process of digging, and it prevents	Pawar and Ahmad (2014)
3	Chlorpyrifos (OP), cypermethrin	*Eudrilus eugeniae*	Variation in morpho-behavioural changes such as coiling, clitellar swelling, mucus release, bleeding and body fragmentation . segments. Significant changes in stress markers AChE, SOD,CAT, GST etc	Tiwari et al (2019)
3	Triazophos and deltamethrin	*Eudrilus eugeniae*	Significant perturbations in oxidative stress parameters such as nonenzymatic (MDA, GSH) and enzymatic (SOD, CAT, GST, LDH, ACP, ALP, ALT and AST) were observed	Singh et al. (2020)
3	Malathion	*Eudrilus eugeniae*	The anatomical symptoms like coiling, abnormal swelling, mucous secretion, blooding, and fragmentation, etc., were noticed by the effect of malathion after exposure of 24 h and 48 h. Inhibited the AChE enzyme activity	Jeyaprakasam et al. (2021)
3	Chlorpyrifos, cypermethrin and Glyphosate.	*Eudrilus eugeniae*	oleic acid (~ 93.47%), lysine (~ 92.20%), glutamic acid (~ 91.81%), leucine (~ 90.20%), asparagine (~ 94.20%), methionine (~ 92.27%), malic acid (~ 93.37%), turanose (~ 95.04%), maltose (~ 92.36%), cholesta-3,5-diene (~ 86.11%), galactose (~ 93.20%), cholesterol (~ 91.56%), tocopherol (~ 85.09%), decreased significantly ($p < 0.05$), whereas myoinositol (~ 83%) and isoleucine (78.09%) increased significantly	Malla et al. (2023)
3	Quinalphos	*Eudrilus eugeniae*	Significant alterations in these stress markers. Morphological abnormalities like bulginess, coiling, and bleeding	Sujeeth et al. (2023)

5. Conclusion

The study emphasises how several ecological issues arise from the usage of pesticides in the agricultural sector. There is ample proof that pesticides have a wide-ranging effect on earthworm populations, generating unintended changes in the community. Pesticides were first employed to protect human life by boosting agricultural output and reducing infectious disease outbreaks, but their detrimental effects on the environment and public health were disregarded. The ecosystem and its elements are being harmed by the many and extensive usage of pesticides. One of the significant soil fauna, earthworms, are very susceptible to pesticide exposure. In the current review, it is well shown that earthworms are sensitive to pesticides.

Depending on the chemical category influencing the characteristics of the earthworm life cycle, certain insecticides are more or less harmful to earthworms. Because pesticides are persistent, they have affected our ecology as well, making their way up the food chain and into higher trophic levels where large mammals like humans and others live. Pesticide effects can be lessened by adding enough organic manures, which can be modified to maximise earthworm activity in the soil for healthy, rich soil, in place of chemical fertilisers. This will cause the least amount of disturbance to the soil. A little amount of work has gone into providing a thorough analysis of the pesticide's toxicity level to one of the non-target species, namely earthworms. Because of this, farmers need to be made aware of the advantages that earthworms bring and the need to use fewer or no pesticides in order to protect the ecosystem and biodiversity.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have no possible conflicts of interest.

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