Bulletin of Pure and Applied Sciences
Zoology (Animal Science), Vol.41A, No.2,
July-December 2022: P.312-319

Print version ISSN 0970 0765
Online version ISSN 2320 3188
DOI: 10.5958/2320-3188.2022.00035.3

Content Available online at: https://www.bpasjournals.com/zoology

Review Article

Adverse Effects of Chemical Fertilizers on the Biology of Macrofauna with a Special Reference to Earthworms: A Review

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Article Info:
Received on 18.05.2022
Revised on 08.10.2022
Accepted on 07.11.202
Published on 15.12.2022

ABSTRACT:
Soil macro-fauna is an important contributor to soil health. Macrofauna supplements important nutrients to the soil and mixes the nutrients with the soil as well. In addition, the macrofauna's biological activity brings about positive changes in the soil such as increased soil porosity. Earthworms are agriculturally very important among all the soil fauna in terms of their contribution to soil health. The life table attributes of earthworms, however, are posed with several challenges due to over-exposure to chemical pesticides and fertilizers. Several reports have now confirmed that the chemicals used in the soil cost the soil-resident earthworms in terms of their longevity and reproductive potential. The present review covers the harmful effect of chemical fertilizers with a special focus on macrofauna- i.e earthworms.

Keywords: Macrofauna, Soil, Chemical fertilizers, Earthworm, Agriculture.

How to cite this article: Passi M., Shukla V., Deswal P. (2022). Adverse Effects of Chemical Fertilizers on the Biology of Macrofauna with a Special Reference to Earthworms: A Review. *Bulletin of Pure and Applied Sciences-Zoology*, 41A (2), 312-319.

INTRODUCTION

The world's population is growing, with comparatively little expansion of resources. Decreased mortality rate and exponential nature of growth curve demands increased food production and consumption for the ever growing population. Globally, there is a rising demand for food. The agriculture industry is burdened by the gap between food production and food deficit. To meet the increasing food-demand, modern agricultural Industry employ use of various chemical input on crops such as application of weedicides; herbicides; pesticides ;chemical fertilizer; the introduction of novel high yielding varieties and disease resistant versions to prevent crop damage. The improvements were widely adopted and known as the "Green Revolution," which was started by Dr. M.S. Swaminathan (2017).

LIMITATIONS OF THE USE OF CHEMICALS IN AGRICULTURAL PRACTICES

The use of chemical fertilizers, herbicides, and pesticides in agriculture has its limitations. The chemical fertilizer changes the soil chemistry including pH and chemical composition. The soil pH is important for the nutrient availability and growth of the plants. Though, buffering

capacity of soil prevent sudden change in the soil pH. However, prolonged use of the chemicals makes the soil acidic. Further, the uncontrolled use of fertilizers ends up causing an imbalance in the soil nutrients. The harmful effects of the chemicals on the soil macroflora have also been reported (Bunemann *et al*., 2006).

The chemical fertilizers in addition to the phosphates, nitrates, ammonium, and potassium salts, may also supplement non-radioactive (mercury, cadmium, arsenic, lead, etc.) as well as radioactive heavy metals such as ^{238}U, ^{232}Th, and ^{210}Po (Sonmez I, *et al*., 2007; Aoun M, *et al*., 2010; Savci, 2012a,b). Accumulation of these heavy metals in the soil would be taken up by the crop plant itself or by the soil microflora and macrofauna and find their way into the food chain besides poisoning the soil itself. The endogenous levels of nitrosamines in cabbage, spinach, and broccoli were found to be lesser in the crops grown upon organic fertilizers (Coffacci *et al*., 2013; Ajmal *et al*., 2018).

Excess chemicals in soil when run with water contaminate the water bodies. Urea in water bodies is known to be responsible for the algal bloom leading to the release of high toxins in the water bodies (Coombs, A. 2008). According to an estimate, up to 10% of chemical fertilizers used for the agriculture process contaminate the surface as well as the groundwater (Sonmez I, *et al*., 2007). The excess nitrogen of the fertilizers can also leach into the soil especially, in the arid and semi-arid regions. The nitrogen gets converted into nitrates by the action of the soil biota (Wang *et al.,* 2009). . These nitrates being, water-soluble contaminate the groundwater easily. Other contaminating forms of nitrogen include nitrites and nitrogen oxides (Liang *et al*., 2008).Nitrogen leaching is also reported in forests with compost amendments (Borken *et al*., 2004). Nitrogen leaching is not the sole problem associated with the use of chemical fertilizers, phosphorous leaching in soil has also been reported (Corman *et al*., 2018; Liang *et al*., 2013).

The use of chemicals is reported to be harmful to the user or employees in the manufacturing units (Tomkins and Bird, 2002). The crops grown on soil in which indiscriminate use of fertilizers was carried out, may have adverse effects on human as well as animal health (Jarup *et al.,* 2003; Tomkins and Bird, 2002). The effects of chemical fertilizer-treated food have been reported to have effects on the nervous, respiratory, and digestive systems (Ajmal *et al*., 2018; Talukdar N *et al*., 2003). The urea is toxic just not for humans but to the soil macrofauna as well. The toxic effects of urea on epigeic species of earthworms have already been reported (Long *et al*., 2017; Yasmin S and D'Souza, 2010). The toxicity, however, is concentration-dependent (Xiao *et al.,* 2004).

The residual chemicals in soil are a cause of concern. The residual chemicals can contaminate the water bodies and be taken up by the aquatic animals via mouth or gills, or by soil macrofauna such as earthworms and may enter the food chain and bioaccumulate (Maurya and Malik, 2016, Esaivani *et al*., 2017; Antoniadis *et al.,* 2019; Lehmann *et al*., 2020; Khan *et al*., 2021). Earthworms are known to bio-accumulate organic pollutants (Jager *et al.,* 2005), heavy metals (Nahmani *et al.,* 2007), and nanoparticles (Canesi and Prochazkova, 2014).

The bioaccumulation in aquatic conditions is different from that of the bioaccumulation of the terrestrial type (Kelly *et al*., 2007). In terrestrial organisms, the chemical uptake is a factor of the soil carbon content that too varies with several factors (Johnson *et al.,* 2009). The bioaccumulation, as well as biomagnification of chemicals in food chains, is more severe in the case of the terrestrial setup (Kelly *et al*., 2007; Gertje Czub and Michael S McLachlan, 2004; Nico van den Brink *et al.,* 2016). The bioaccumulation in a terrestrial setup is well understood in the macrofauna of the soil including earthworms due to the simplicity of their biology (Nico van den Brink *et al.,* 2016). The pesticides have been reported to accumulate in *Eisenia* sp. (Jager *et al*., 2005). Earthworms may absorb the pesticides and fertilizers in the soil directly through the skin or simply ingest them. The tolerance of earthworms to different chemical fertilizers varies from fertilizer to fertilizer (Edwards and Lofty, 1982).The effect of chemical fertilizers on earthworms is also reported to vary from species to species

(Yahyaabadi *et al*., 2018). These worms being suitable and easy food for the birds can easily result in the incorporation of pesticides into the food web (Katagi and Ose, 2015).

ANNELIDS

The earthworms belong to subclass Oligochaeta; class Clitellata of the phylum Annelida. The subclass Oligochaeta has nearly 10,000 species, with wide habitats including freshwater, marine water, and terrestrial. Among the terrestrial species, fifty percent are earthworms (Reynolds and Wetzel, 2004). India is very diverse in earthworms with nearly 11% percent of the world's earthworm diversity. In India, we have nearly 67 genera of earthworms (Kathireswari, 2016).

The earthworms are chiefly responsible for enriching the soil with nutrients by decomposing the dead and decaying material into vermicast (Kaushal *et al*., 1995), which is called black gold (Lim *et al*., 2015; Patangray, 2014). The earthworms positively influence the hydraulic conductivity, porosity, bulk density, infiltrability, aggregate stability, etc. (Devkota *et al*., 2014). The worms enhance the activity of microorganisms (Bhaduria and Saxena 2010). The earthworm castings are rich in calcium carbonates and thereby, also maintain the pH of the soil (Ashiya *et al*., 2015; Tiwari, 1993).

The earthworms can be classified into three groups based upon their ecological niche (Bottinelli *et al*., 2020). The three groups are (i) epigeic, (ii) endogeic, and (iii) anecic worms. The epigeic earthworms include *Lumbricus rubellus*, *L. castaneus*, *Dendrobaena octaedra*, etc. These earthworms thrive in the upper soil layer and decaying organic matter. The endogeic earthworms include *Aporrectodea caliginosa*, *Allolobophora chlorotica* etc. The endogeic earthworms feed upon organic matter mixed with minerals in the soil. The anecic earthworms include *Lumbricus terrestris*, *Aporrectodea longa,* etc. The anecic earthworms feed on surface litter during night time and live in long sub-vertical burrows. Recently Bottinelli (2020) and his coworkers reviewed this classification and elaborated too.

Charles Darwin pointed out the importance of earthworms in maintaining the soil. The earthworm casting alone can contribute to 20% of the topsoil (Darwin, 1881). Earthworms act as soil quality indicators (Iordache and Borza, 2010; Van Groenigene *et al.,* 2014). The presence of earthworms is indicative of healthy soil (Ashworth *et al*., 2017).Agricultural practice involving the Synthetic chemicals input disturb the composition of earthworm communities by impacting their ecological groups (Smith *et al.,* 2008; Spurgeon *et al*., 2016; Kahneh *et al*., 2022).

PROBLEMS FACED BY EARTHWORMS IN SOIL

A number of chemical pesticides are shown to be harmful to non-target species. Agrochemicals interfere with the biology of earthworms. The effect of pesticides on earthworms is reviewed in detail by Miglani and Bisht (2019).Fertilizers, Insecticides and Pesticides alter the physiology of the not only the aquatic animals, as well to other terrestrial animals also. Therefore have implications on the longevity and other life table attributes of the worms (Sabra and Mehana 2015; Passi *et al*., 2021). The concentration of pesticides above 25mg/Kg is especially detrimental to earthworms. However, the variations exist from one species to another (Roriguez-Campos *et al*., 2014). Besides, longevity, pesticides are detrimental to the overall growth and reproductive potential of earthworms as well (Yasmin & D'Souza, 2010).

EFFECT OF UREA FERTILIZER ON EARTHWORMS

The effect of urea on the soil biota is always of interest to scientists. The effect of urea on various soil macrofauna has been reported by a number of workers (Roberts and Dorough, 1984). However, the studies focused on the effects of urea on earthworms are limited. Edward and Lofty (1982) reported a positive effect of urea on the earthworm population in maize fields. The increase in the earthworm population with the application of urea was attributed to the increase in the fallen residues of the crop on the ground ensuring high availability of food to the earthworms. Though long-term exposure of the earthworm to the

urea has negative effects (Iordache and Borza, 2010).The direct contact of the urea to the earthworm is toxic even in small concentrations (Abbirammy and Ross, 2013). However, other studies propose that urea in higher concentrations is highly lethal (Rai *et al*., 2014; Rani, 2016). It may be worth mentioning over here that the actual use of urea in agriculture is far greater than the recommended dose of 120 kg/hectare in agricultural fields.

Das and Mohapatra (2018) studied the toxic effects of urea in a laboratory by carrying out a paper toxicity assay. The lethal concentration of urea against earthworms was estimated to be 28 $\mu g/cm^2$. 1 mg/ml was reported to be safe for earthworms however, 2 mg/ml was found to be lethal to the earthworms. The toxicity brought morphologically visible changes such as lesions, inflammations, and disjointing of the posterior body parts. All these changes may lead to the death of the earthworm (Das and Mohapatra, 2018).

Long *et al*. (2017) studied the toxicity of urea under natural conditions. The authors used a series of urea concentrations ranging from 50 to 250 mg/kg soil. The authors observed a concentration-dependent increase in mortality. At high concentrations of urea, the worms were either dead or sluggish, or weakened (Long *et al*., 2017).In addition, the urea also affected the weight of the worms negatively. Similar was the observation concerning the number of juveniles. Moreover, the growth of the juveniles was also compromised upon exposure to urea (Bhattacharya and Sahu, 2014; Long *et al*., 2017).

A study carried out by Passi *et al*., (2021) entails the effect of different concentrations of two chemical fertilizers and two organic fertilizers on the growth and other life-table attributes of earthworm, *Eisenia fetida*. The study estimated an LC50 value 876.56 mg/kg for urea and 2098.69 mg/kg of soil for DAP against *E. fetida*. Further, the earthworms were allowed to rear on urea and DAP concentrations half their LC50 concentrations. The results revealed a significant decrease in the biomass of earthworm culture upon exposure to the chemical fertilizers while the organic nitrogen supplements led to an increase in the biomass. The negative influence of the chemical fertilizers on the biomass was attributed to a decrease in the bodyweight of the earthworms as well as reduced longevity. The authors recommended organic manure to support the earthworm culture in the agriculture fields.

CONCLUSION

The review highlights the ill effects of chemical fertilizers on earthworms which are an important alternative to natural fertilizers. Various studies are coming up that demonstrate how chemicals used in agriculture are adversely affecting not only the macrofauna of the soil but also taking a toll on their ecology. Policymakers must ensure controlled use of pesticides and fertilizers in agricultural soil and discourage their usage altogether, wherever, possible. Several alternatives to chemical fertilizers are now available. The use of these nature-friendly alternatives must be encouraged for sustainable development.

Acknowledgment:
The authors are thankful to AAiM Edupoint, New Delhi for providing editorial support to the review.

Declaration of competing interest:
The authors declared that they have no conflicts of interest to this work.

Funding: Not applicable

REFERENCES

1. Abbiramy, K. S., Ross, P. R., & Wing, Z. (2013). Determination of acute toxicity of urea to Eisenia fetida by a simple paper contact method. *International Journal of Science, Environment and Technology*, *2*(5), 886-891.
2. Ajmal, M., Ali, H. I., Saeed, R., Akhtar, A., Tahir, M., Mehboob, M. Z., & Ayub, A. (2018). Biofertilizer as an alternative for chemical fertilizers. *Research and Reviews: Journal of Agriculture and Allied Sciences, 7*(1), 1-7.
3. Antoniadis, V., Shaheen, S. M., Levizou, E., Shahid, M., Niazi, N. K., Vithanage, M., ... &

Rinklebe, J. (2019). A critical prospective analysis of the potential toxicity of trace element regulation limits in soils worldwide: Are they protective concerning health risk assessment?-A review. *Environment international*, *127*, 819-847.

4. Aoun, M., El Samrani, A. G., Lartiges, B. S., Kazpard, V., & Saad, Z. (2010). Releases of phosphate fertilizer industry in the surrounding environment: Investigation on heavy metals and polonium-210 in soil. *Journal of Environmental Sciences*, *22*(9), 1387-1397.

5. Ashiya, P., Rai, N., Rathore, D. S., & Jain, S. (2015). Influence of chemical fertilizers and organic fertilizers on ph and available nitrogen content of vermicompost with earthworm Eisenia foetida. *Intl J Adv Res*, *3*(7), 1030-1036.

6. Ashworth, A. J., Allen, F. L., Tyler, D. D., Pote, D. H., & Shipitalo, M. J. (2017). Earthworm populations are affected from long-term crop sequences and bio-covers under no-tillage. *Pedobiologia*, *60*, 27-33.

7. Bhadauria, T., & Saxena, K. G. (2010). Role of earthworms in soil fertility maintenance through the production of biogenic structures. *Applied and environmental soil science*, *2010*.

8. Bhattacharyya, P. N., & Jha, D. K. (2012). Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture. *World Journal of Microbiology and Biotechnology*, *28*(4), 1327-1350.

9. Borken, W. X. Y. J., Xu, Y. J., & Beese, F. (2004). Ammonium, nitrate and dissolved organic nitrogen in seepage water as affected by compost amendment to European beech, Norway spruce, and Scots pine forests. *Plant and soil*, *258*(1), 121-134.

10. Bottinelli, N., Hedde, M., Jouquet, P., & Capowiez, Y. (2020). An explicit definition of earthworm ecological categories–Marcel Bouché's triangle revisited. Geoderma, 372, 114361.

11. Bouche MB (1977) Strategies lombriciennes. In: Lohm U, Persson T (eds) Soil organisms as components of ecosystems, vol 25. Ecological Bulletins, Swedish Natural Science Research Council, Stockholm, pp 122–132.

12. Bünemann, E. K., Schwenke, G. D., & Van Zwieten, L. (2006). Impact of agricultural inputs on soil organisms—a review. *Soil Research*, *44*(4), 379-406.

13. Canesi, L., & Procházková, P. (2014). The invertebrate immune system as a model for investigating the environmental impact of nanoparticles. In *Nanoparticles and the immune system* (pp. 91-112). Academic Press.

14. Coffacci, L., Codognoto, L., Fleuri, L. F., Lima, G. P., & Pedrosa, V. A. (2013). Determination of total nitrosamines in vegetables cultivated organic and conventional using diamond electrode. *Food Analytical Methods*, *6*(4), 1122-1127

15. Coombs A. (2008).Urea pollution turns tides toxic.Nature.https://doi.org/10.1038/news.1190.

16. Corman, J. R., Bertolet, B. L., Casson, N. J., Sebestyen, S. D., Kolka, R. K., & Stanley, E. H. (2018). Nitrogen and phosphorus loads to temperate seepage lakes associated with allochthonous dissolved organic carbon loads. *Geophysical Research Letters*, *45*(11), 5481-5490

17. Darwin C. (1881). The formation of Vegetable Mound through the actions of worms with observations on their habits. London: Murray

18. Dash, A., & Mohapatra, S. S. (2018) Toxic Effect of Urea on Earthworms Determined By a Simple Paper Contact Method. *Journal of Agri. Sci.* 6(1): 16-18.

19. Devkota, D., Dhakal, S. C., Dhakal, D., Dhakal, D. D., & Ojha, R. B. (2014). Economics of production and marketing of vermicompost in Chitwan, Nepal. *International Journal of Agricultural and Soil Science*, *2*(7), 112-117.

20. Edwards, C.A. & Lofty, J.R. (1982). Nitrogenous fertilizers and earthworm populations in agricultural soils. *Soil Biology and Biochemistry*, 14(5), 515-521. doi:10.1016/0038- 0717(82)90112-2.

21. Esaivani, C., & Vasanthi, K. (2017).Comparative histological studies in the gut of earthworms exposed to chemical fertilizer and organic manure. *Indian Journal of Applied Research,* 7(2), 641-644.

22. Iordache, M., & Borza, I. (2010). Relation between chemical indices of soil and earthworm abundance under chemical

fertilization. *Plant, Soil and Environment*, *56*(9), 401-407.

23. Jager, T., van der Wal, L., Fleuren, R. H., Barendregt, A., & Hermens, J. L. (2005). Bioaccumulation of organic chemicals in contaminated soils: evaluation of bioassays with earthworms. *Environmental science & technology*, *39*(1), 293-298.

24. Järup, L. (2003). Hazards of heavy metal contamination. *British medical bulletin*, *68*(1), 167-182.

25. Johnson, M.S., Salice ,C.J., Sample, B.E, Robidoux, P.Y. (2009). Bioconcentration, bioaccumulation, and biomagnifications of nitroaromatic and nitramine explosives in terrestrial systems. In: Sunahara GI, Kupermand RG, Hawari J, editors. *Ecotoxicology of explosives*. Boca Raton (FL): CRC Press. p 227–252

26. Kahneh, E., Shirinfekr, A., Ramzi, S., & Salimi, K. M. (2022). Effects of long-term tea (Camellia sinensis) cultivation on the earthworm populations in northern Iran. *Eurasian Journal of Soil Science*, *11*(3), 234-240.

27. Katagi, T., & Ose, K. (2015). Toxicity, bioaccumulation and metabolism of pesticides in the earthworm. *Journal of pesticide science*, D15-003.

28. Kathireswari P. (2016). DNA Barcoding of Earthworms. In Science Communicators meet (103rd ISCA), Mysore.

29. Kaushal, B.R., Bisht, SPS. & Kalia S. (1995). Population dynamics of the earthworm *Amynthasalexandri* (Megascolecidae: Annelida) in cultivated soils of the Kumaun Himalayas. *Applied Soil Ecoogyl.* 2(2): 125–30.

30. Kelly, B. C., Ikonomou, M. G., Blair, J. D., Morin, A. E., & Gobas, F. A. (2007). Food web specific biomagnification of persistent organic pollutants. *Science*, *317*(5835), 236-239.

31. Khan, S., Naushad, M., Lima, E. C., Zhang, S., Shaheen, S. M., & Rinklebe, J. (2021). Global soil pollution by toxic elements: Current status and future perspectives on the risk assessment and remediation strategies–A review. *Journal of Hazardous Materials*, *417*, 126039.

32. Lehmann, J., Bossio, D. A., Kögel-Knabner, I., & Rillig, M. C. (2020). The concept and future prospects of soil health. *Nature Reviews Earth & Environment*, *1*(10), 544-553.

33. Liang, X. Q., Li, H., Chen, Y. X., He, M. M., Tian, G. M., & Zhang, Z. J. (2008). Nitrogen loss through lateral seepage in near-trench paddy fields. *Journal of environmental quality*, *37*(2), 712-717.

34. Liang, X. Q., Li, L., Chen, Y. X., Li, H., Liu, J., He, M. M., & Lundy, M. (2013). Dissolved phosphorus losses by lateral seepage from swine manure amendments for organic rice production. *Soil Science Society of America Journal*, *77*(3), 765-773.

35. Lim, S. L., Wu, T. Y., Lim, P. N., & Shak, K. P. Y. (2015). The use of vermicompost in organic farming: overview, effects on soil and economics. *Journal of the Science of Food and Agriculture*, *95*(6), 1143-1156.

36. Long, W., Ansari, A., & Seecharran, D. (2017). The effect of urea on epigeic earthworm species (Eisenia foetida). *Cell Biology and Development*, *1*(2), 46-50.

37. Maurya P and Malik D.(2016). Accumulation and distribution of organochlorine and organophosphorus pesticide residues in water, sediments and fishes, Heteropneustisfossilis and Puntius ticto from Kali River, India. *J of Toxico and Environ Health Sci*, 8(5), 30–40.

38. McLachlan, M. S., Czub, G., MacLeod, M., & Arnot, J. A. (2011). Bioaccumulation of organic contaminants in humans: a multimedia perspective and the importance of biotransformation. *Environmental science & technology*, *45*(1), 197-202.

39. Miglani, R., & Bisht, S. S. (2019). World of earthworms with pesticides and insecticides. *Interdisciplinary Toxicology*, *12*(2), 71-82.

40. Nahmani, J., Hodson, M. E., & Black, S. (2007). A review of studies performed to assess metal uptake by earthworms. *Environmental pollution*, *145*(2), 402-424.

41. Nayak, T., Jain, R., Patangray, A. J., & Rathore, A. K. (2014). Vermicompost: beneficial tool for sustainable farming. *Asian Journal of Multidisciplinary Studies*, *2*(8), 255.

42. Passi, M. (2022). Lethal Concentration 50 (LC_{50}) Of Urea Fertilizer and Induced Morphological Changes on *Eisenia*

fetida.Sailesh Iyer. Futuristic Trends for Sustainable Ecosystem (First edition., 2022 ,359-367) CRC press;Taylor and Francis group.

43. Passi, M., Shukla, V., & Deswal, P. (2021). Effect of chemical and bio-fertilizers on the life table attributes of Eisenia fetida. *Journal of Applied and Natural Science*, *13*(4), 1524-1530. https://doi.org/10.31018/jans.v13i4.2973

44. Rai, N., Ashiya, P., & Rathore, D. S. (2014). Comparative study of the effect of chemical fertilizers and organic fertilizers on Eisenia foetida. *International Journal of Innovative Research in Science*, *3*(5), 12991-12998.

45. Rani S. (2016). Effect of urea on soil macro fauna, juvenile earthworms. Haryana, India. *J Intl Acad Res Multidisciplinary,* 4 (5), 15-19.

46. Reynolds, J. W., & Wetzel, M. J. (2004). Terrestrial Oligochaeta (Annelida: Clitellata) in North America north of Mexico. *Megadrilogica*, *9*(11), 71-98.

47. Roberts, B. L., & Wyman Dorough, H. (1984). Relative toxicities of chemicals to the earthworm Eisenia foetida. *Environmental Toxicology and Chemistry: An International Journal*, *3*(1), 67-78.

48. Rodriguez-Campos, J., Dendooven, L., Bernal, D., Ramos, C.R. (2014). Potential of earthworms to accelerate removal of organic contaminants from soil: A review. *Applied Soil Ecology*, 79, 10-25. DOI:10.1016/j.apsoil.2014.0 2.010

49. Sabra, F. S., & Mehana, E. S. E. D. (2015). Pesticides toxicity in fish with particular reference to insecticides. *Asian Journal of Agriculture and Food Sciences*, *3*(1).

50. Savci, S. (2012). An agricultural pollutant: chemical fertilizer. *International Journal of Environmental Science and Development*, *3*(1), 73.

51. Savci, S. (2012). Investigation of effect of chemical fertilizers on environment. *Apcbee Procedia*, *1*, 287-292.

52. Smith, R. G., McSwiney, C. P., Grandy, A. S., Suwanwaree, P., Snider, R. M., & Robertson, G. P. (2008). Diversity and abundance of earthworms across an agricultural land-use intensity gradient. *Soil and Tillage Research*, *100*(1-2), 83-88.

53. Sonmez, I., Kaplan, M., & Sonmez, S. (2007). An investigation of seasonal changes in nitrate contents of soils and irrigation waters in greenhouses located in antalya-demre region. *Asian Journal of Chem,* 19(7),5639-5646.

54. Spurgeon, D. J., Liebeke, M., Anderson, C., Kille, P., Lawlor, A., Bundy, J. G., & Lahive, E. (2016). Ecological drivers influence the distributions of two cryptic lineages in an earthworm morphospecies. *Applied Soil Ecology*, *108*, 8-15

55. Talukdar, N. C., Thakuria, D., & Goswami, C. (2004). Organic farming and quality of organic food. In *Bioprospecting of commercially important plants. Proceedings of the national symposium on" Biochemical approaches for utilization and exploitation of commercially important plants", Jorhat, India, 12-14 Nov. 2003* (pp. 61-72). Indian Society of Agricultural Biochemists.

56. Tiwari, S. C. (1993). Effects of organic manure and NPK fertilization on earthworm activity in an Oxisol. Biology and fertility of soils, *16*(4), 293-295.

57. Tomkins, P., & Bird, C. (2002). Chemicals, plants and man: the organic farming residue. *Secret life of plants*, 240-258.

58. Van den Brink, N. W., Arblaster, J. A., Bowman, S. R., Conder, J. M., Elliott, J. E., Johnson, M. S., & Shore, R. F. (2016). Use of terrestrial field studies in the derivation of bioaccumulation potential of chemicals. *Integrated environmental assessment and management*, *12*(1), 135-145.

59. Van Groenigen, J. W., Lubbers, I. M., Vos, H. M., Brown, G. G., De Deyn, G. B., & Van Groenigen, K. J. (2014). Earthworms increase plant production: a meta-analysis. *Scientific reports*, *4*(1), 1-7.

60. Wang, Y., Ke, X., Wu, L., & Lu, Y. (2009). Community composition of ammonia-oxidizing bacteria and archaea in rice field soil as affected by nitrogen fertilization. *Systematic and Applied Microbiology*, *32*(1), 27-36.

61. Xiao H, Zhou QX, Liang JD. (2004). Single and joint effects of acetechlor and urea on earthworm Eisenia foetida population in Phaiozem. *Environmental Geochemistry and Health*, 26(2), 277- 283

62. Yahyaabadi, M.,Hamidian, H.A & Ashrafi, S. (2018). Dynamics of earthworm species at different depths of orchard soil receiving

organic or chemical fertilizer amendments. *Eurasian J Soil Sci*, 7 (4), 318 - 325.

63. Yasmin, S., & D'Souza, D. (2010). Effects of pesticides on the growth and reproduction of earthworm: a review. *Applied and Environmental Soil Science*, *2010.*

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