Research Article

Toxic Effects of Pesticides on Non-Target Species; A Study of Tomato (*Solanum lycopersicum L.*) Orchard

Sohail Anjum[1*], Maryam Khalf M Althrwi[2], Sadeeq Ahmad[1], Muhammad Salman Khan[3], Murad Khan[3], Waseem Khan[3], Muhammad Abbas[1], Sundas Asghar[4], Babar Ali Khan[3] and Waqas Ahmad[1]

[1]Department of Zoology, Faculty of Biological Sciences, University of Malakand, Chakdara, Pakistan; [2]College of Nursing and Health Sciences, Clinical Nutrition Department, Jazan University, Kingdom of Saudi Arabia; [3]Department of Zoology, Faculty of Chemical and Life Sciences, Abdul Wali Khan University, Mardan, Pakistan; [4]Department of Zoology, Institute of Molecular Biology and Biotechnology, The University of Lahore, Sargodha Campus, Sargodha, Pakistan.

Abstract | Sustainable agriculture practices mean fulfilling the needs for food in current time with minimal effects on the environment and public health. This study provides the status of a tomato (*Solanum lycopersicum*) orchard, its wide benefits, and presents an insight into the use of pesticides and their effects on life as well as the wastage of food resources by the human population. The study was carried out in a tomato orchard located in Talash town of District Dir Lower, Pakistan. During the study, packs of all agrochemicals were collected, and specifications were noted. All bird, plant, and insect species were recorded and identified. The behavior of birds along with day-to-day pictures were taken for the record. The food cycle was constructed. Literature was studied to find relevant articles for agrochemicals. The results showed that a total of nine chemicals were used as pesticides, of which emamectin benzoate and mancozeb were most common. All used chemicals were found to have toxic effects on non-target organisms. House crow (*Corvus splendens*), Common myna (*Acridotheres tristis*), and Red-vented bulbul (*Pycnonotus cafer*) were the most common bird species of the orchard. A 70-day-long tomato cycle was also constructed. The results revealed that species are interdependent even in a small orchard. This study concludes that pesticides have direct and indirect drastic effects on life, as organisms are dependent on each other, and we should avoid wasting food to sustain life.

Received | July 30, 2024; **Accepted** | February 20, 2025; **Published** | July 09, 2025
***Correspondence** | Sohail Anjum, Department of Zoology, Faculty of Biological Sciences, University of Malakand, Chakdara, Pakistan; **Email:** brilliantqazi@gmail.com
Citation | Anjum, S., M.K.M. Althrwi, S. Ahmad, M.S. Khan, M. Khan, W. Khan, M. Abbas, S. Asghar, B.A. Khan and W. Ahmad. 2025. Toxic effects of pesticides on non-target species; A study of tomato (*Solanum lycopersicum L.*) orchard. *Sarhad Journal of Agriculture,* 41(3): 971-980.
DOI | https://dx.doi.org/10.17582/journal.sja/2025/41.3.971.980
Keywords |Dir lower, *Solanum lycopersicum*, Agrochemicals, Toxicity, Food wastage, Public health

Introduction

Decades ago, agrochemicals were introduced aiming at enhancing crop yields and protecting them from pests. Soil and water constitute the two basic needs over which life depends on. Modern agriculture practices including pesticides and fertilizers have the potential to bring unwanted harm to life on earth. Generally, laymen are unaware of the consequences of modern agriculture practices which include pesticides (with many classes like rodenticides, herbicides etc.) and are used many folds. Insects, nematodes, weeds and fungi are generally controlled using pesticides at large level. The unwanted practices have changed life in many ways by changing soil structure and composition, disturbance of chemical cycles, water loss, invasion of harmful insects and removal of beneficial.

The rise in population of humans over the past decades has urged mankind to produce more yields without foreseeing the effects. Water bodies are severely degraded and polluted using such chemicals without being added directly (mostly) to these water bodies. Acute and chronic toxicity becomes the fate of aquatic fauna and flora including human subjects. Scientific interest has been increased for the alternatives of pesticides to overcome the degrading effects of pesticides.

The industrialization of the agricultural sector has increased the chemical burden on natural ecosystems. Towards the achievement of sustainability in food production, pesticides play a very important role. Without the use of pesticides, there would be a 78% loss of fruit production, a 54% loss of vegetable production, and a 32% loss of cereal production. However, concerns are due to its effect on human health and the environment. As an example, in 2003, the global market for pesticides by worldwide regions was the following: European Union: 28%; North America: 25%; South America: 18%; Asia and Africa: 30%. It is expected that in 2050 the world will need 70% more food than in 2010, especially in Africa, and Asia (Zhang *et al*., 2011). A significant growth in chemical pesticides use is unavoidable. Nearly 50% of the world labor force is employed in agriculture as reported by the global market for pesticides by worldwide regions (Popescu *et al*., 2021), and therefore many subjects are directly exposed. For example, occupational exposure to pesticides in agriculture concerns product distributors, mixers and loaders, applicators, bystanders, and rural workers re-entering the fields shortly after treatment (Mamane *et al*., 2015). Insect pests are the major source of crop damage, yield and quality reduction in Pakistan and elsewhere in the world. Residues of pesticides can be found in a great variety of everyday foods and beverages, including for instance cooked meals, water, wine, fruit juices, refreshments, and animal feeds.

A wide range of population in Pakistan is connected to agriculture and so exposed to pesticides. Besides other consequences, the resistance development in pests is also a rising issue. As resistance increases, the amount of pesticides that are used also increases. About 954 weeds, arthropods etc. have developed resistance so far (Kole *et al*., 2019). Biological, genetic and operational factors are involved in the development of resistance. Humans are exposed to these pesticides via different ways including the consumption of meat, eggs, milk and seafoods. The effect is not direct but a long-term exposure to these chemicals causes health hazards. Some of the most rising challenges include resistance development, over-reliance, non-target toxicity, biodegradation and biomagnification due to pesticides. Integrated pest management provides a friendly way of crop protection in connection with life protection.

With the increase in diversity of plants in an ecosystem there is always a net increase in arthropod diversity (Ebeling *et al*., 2018; Venail *et al*., 2008), and in a laboratory ecosystem there is also a positive relationship (Kassen *et al*., 2000), however, another study of ants diversity shows that it is temperature, not productivity that controls diversity (Sanders *et al*., 2007). Diversity also increases carbon storage (Ruiz-Benito *et al*., 2014). The birds play a vital role in the ecosystem; from picking up seeds to a role in pollination and then a critical role as scavenger.

The food wastage lost millions of valuable resources, but still it is poorly understood and poorly taken as a serious issue. We are wasting food at all stages, from harvesting up to consumption of that food (Schneider, 2008). The food wastage ratio is high in developing countries where there is less availability of food storage facilities but developed countries have these facilities and are coping with these issues effectively (Schneider, 2008). Food and economic security of the region is essential regarding the health of people and animals and is a step toward conservation of endangered animals and plants. In southeast Asia, annually about 33% of the total food is wasted, however there is no rigid data available in literature (Teng and Trethewie, 2012) and it may be many folds high. Since the 20th century, the global human population has been increasing at an exponential level and therefore the need for food is also growing. Humans have developed ways for food production in many folds. This growth in population would not have been possible without the parallel increase in food production. The current research articles focus on the agrochemicals used at local level in small orchard in addition to the interdependence of fauna and flora.

It is difficult to assume any benefit or harm from an ecosystem while considering a single factor, especially from an agricultural ecosystem (Montoya *et al*., 2020). The current research study highlights the indirect and direct effects of some of the mostly used pesticides in agriculture as well as the wastage of food resources by the human population.

Materials and Methods

This study was carried out in a small town Talash of District Dir Lower of Khyber Pakhtunkhwa province of Pakistan from June to October 2023. Dir Lower is a district located at the northeast side of Khyber Pakhtunkhwa with borders connecting Pakistan with Afghanistan and China. The area is characterized by vegetables and fruits along with tall standing trees in mountainous and sub mountainous areas. The google coordinates for this area are 34.761° N, 71.930° E. The area has sparse vegetation with a diverse range of tree species. People here grow tomato, wheat, barley and other vegetables and cereals. The annual rainfall is about 1400mm.

In this study, an orchard of tomato was selected. All plants in the orchard have been shown Table 2. All species that attack tomato plants or feed on them are part of this study.

Pesticides that were used during the study duration were collected from its packs, as incorporated by (Hlihor *et al*., 2019). All the specifications including origin of pesticides, percentage and weight by weight composition were recorded and incorporated in Table 3.

Literature was surveyed for the recorded effects of pesticides and were compared to our study (Bibi *et al*., 2024; Toorang *et al*., 2024). Reported organisms, pesticides with specifications and all plants are presented in the tables given in results section.

All graphs and figures presented in this article were created using Microsoft Excel and Microsoft PowerPoint, respectively. The data visualization tools in Excel were utilized to generate informative graphs, while PowerPoint's design features were employed to prepare clear and concise figures, effectively communicating the research findings.

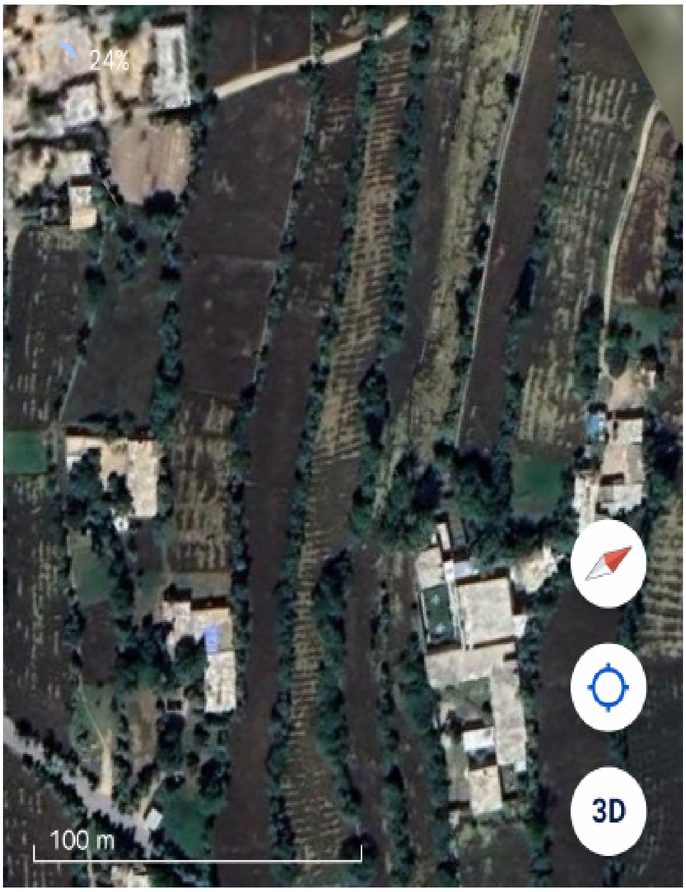

Figure 1: *Google Earth view of the study area.*

Results

The findings of this study which are presented below reveal an important correlation between exposure of organisms to pesticides, their cumulative effects and highlights the food wastage. This study highlights strict regulation and mitigation strategies to minimize environmental and health impacts. A pyramid of food was developed and imagined given in Figure 2. The pyramid highlights that at bottom all species are small but many in number. As we go from bottom to top, the number of species decreases while the size of species increases.

Table 1: *Species that were reported from the Orchard.*

Scientific Name	Common name	Role in Environment	Family	No. of individuals
Coccinella Septempunctata	Seven spotted ladybird	Farmer friendly	Coccinellidae	341
...	Long snouted weevil	Harmless	Curculionidae	197
...	Grass crab spider	Predator	Thomisidae	36
...	June Beetle	Harmless	Scarabaeidae	109
...	Leaf beetle	Eat leaves	Chrysomelidae	265
...	American sundy	Eat leaves	...	73
Acridotheres tristis	Common Myna	Friendly	Sturnidae	134
Pycnonotus cafer	Red-vented Bulbul	Harmless	Pycnonotidae	32
Corvous spelendens	House Crow	pest species	...	12

Table 2: *Plant species inhabited by Species.*

S. No.	Local Name	Scientific Name	Animal Species Supported
1	Spena Shandai	*Ailanthus altissima*	Two bird species supported for nests
2	Toot	*Morus alba*	Many species including nests.
3	Khona	*Olea ferruginea*	Some two species of ants
4	Gultoot	*Broussonetia papyrifera*	Only one invertebrate species
5	Teghaga	*Celtis australis*	Several invertebrate species and two bird nests.
6	Malki Shandai	*Melia azedarach*	Nests of House Crow and Common Myna
7	Enzar	*Ficus carica*	Several invertebrate species

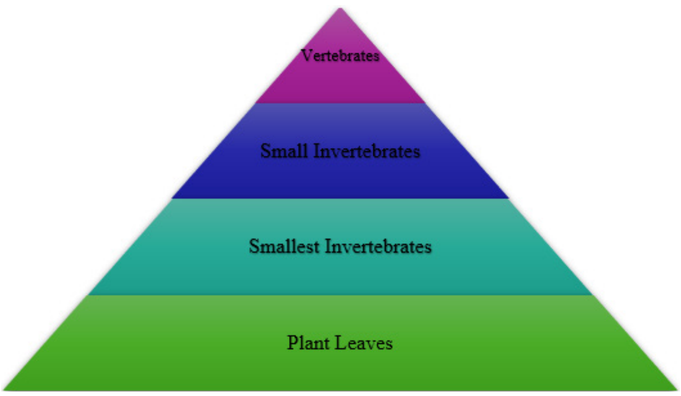

Figure 2: *Showing pyramid of organisms depending on each other, one above the other.*

Tomato crop cycle (from planting to first harvesting) has been summed up in Figure 2. Crops were planted on 9th of June 2023 while it was harvested for first fruiting on the 6th day with first insect infestation on 47th day, since then several chemicals classified as herbicides and insecticides were sprayed over the entire duration.

Faunal Composition of the Orchard

A total of nine species belonging to insects and birds were recorded in the orchard Figure 4. The species composition and their respective counts are presented in Table 1. The ladybird was the most abundant species, with a count of 341 individuals, while the house crow was the least abundant, with a count of 12 individuals. Among these species, the house crow and common myna are considered pest species (Anjum *et al*., 2021), whereas three species are harmless to plants. Table 1 also highlights the ecological role of each species, along with their common names.

Tree Species Composition

The study area comprised seven different tree species presented in Table 2, which support various organisms, including birds' nests, ants, and other invertebrate species.

Agrochemicals Used

During the study period, nine types of agrochemicals were used in the orchard presented in Table 3. The table lists the agrochemicals, their origin, weight, percentage, and adverse effects. A detailed discussion of these agrochemicals and their effects is provided in the Discussion section, along with relevant references.

Discussion

The overuse of agrochemicals has raised serious concerns regarding their unintended impacts on non-target species, specifically in sensitive ecosystems. In Dir Lower, Khyber Pakhtunkhwa, tomato (*Solanum lycopersicum*) orchards are extensively treated with agrochemicals for crop protection and yield enhancing. However, the potential toxic effects of these chemicals on beneficial organisms, soil health, and biodiversity remain largely unexplored. The purpose of this

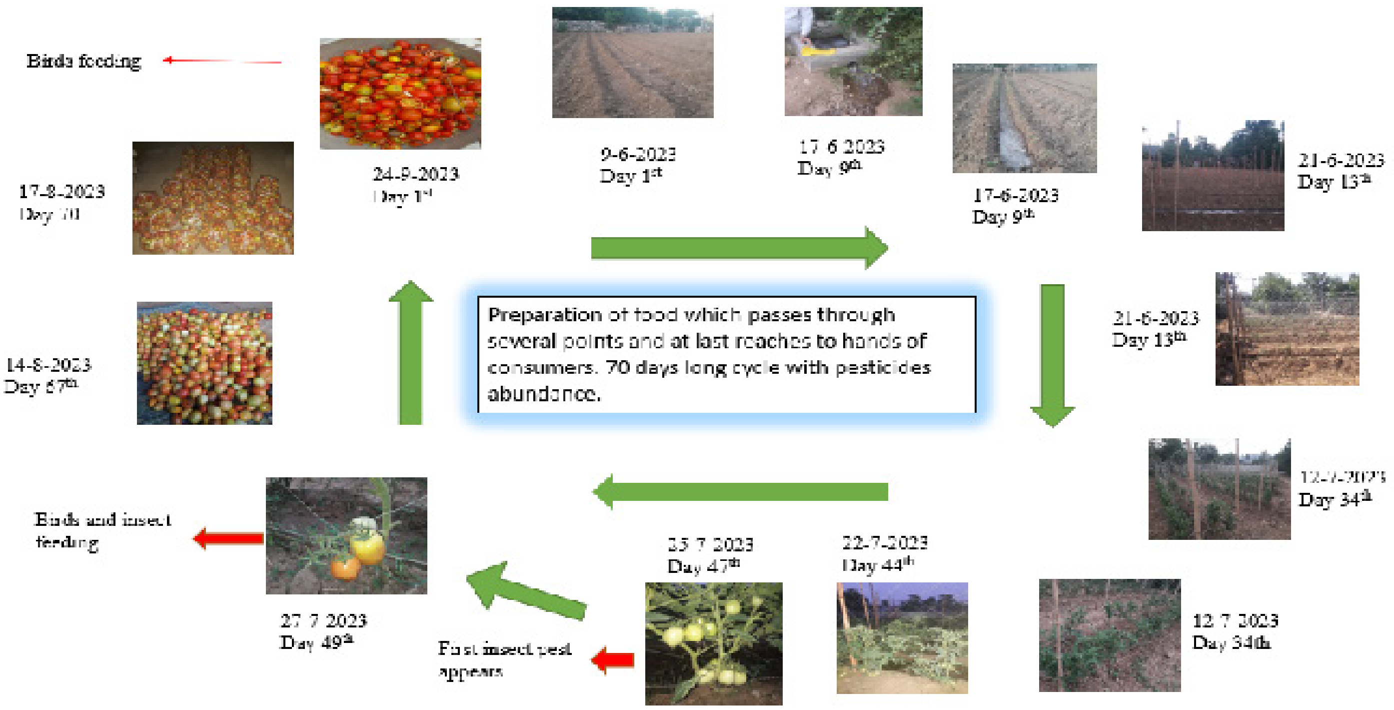

Figure 3: *Tomato crop cycle comprised of 70 days (planting to 1st harvesting) in the study area.*

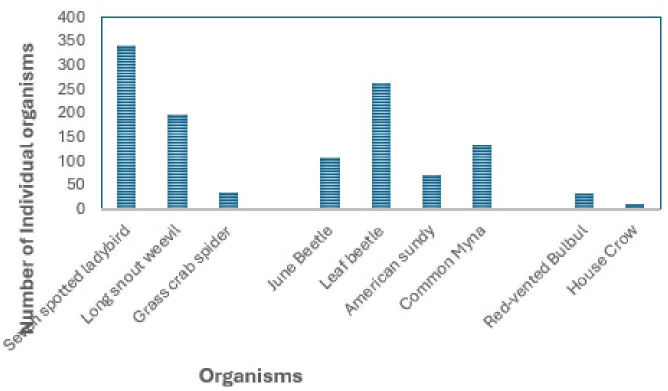

Figure 4: *showing organisms reported from tomato orchard.*

study was to assess the ecological risks associated with pesticide application in tomato orchards by analysing its impact on non-target species. To achieve this, field investigations were conducted to evaluate pesticide residues, species diversity, and physiological responses of affected organisms. This research aims to provide insights into the environmental consequences of pesticide use and contribute to the development of sustainable pest management strategies.

Common myna (*Acridotheres tristis*) has been reported with a state of being a pest and invasive in some new areas (Markula *et al*., 2009) by harming the crops but beside this it also helps to predate on invertebrates in the same ecosystem. In this study, common myna (n=134) is not enough to be called a pest.

Lufenuron (Table 3) is reported to have adverse effects on organisms like it is known to be chitin-synthesis inhibitor, intrude development of Drosophila melanogaster, its high perseverance of activity, toxic to larval and egg stage of Chrysoperla externa, while also used as a treatment for fungal infections of dogs and cats (Ben-Ziony and Arzi, 2000; Bueno and Freitas, 2004; Navarro-Llopis *et al*., 2004; Wilson and Cryan, 1997).

Kasugamycin (Table 3) is selective in its effects but also have minimal effects on amino acylation of sRNA (TANAKA *et al*., 1966), an effective antibiotic (McGhee and Sundin, 2011), it is generally known to be nontoxic to microorganism, but recent studies declare its effects on some bacteria, inhibiting growth of some bacteria while enhance growth of others (Huang *et al*., 2010).

Copper based compounds are extensively used in agriculture sector as pesticides. One of them is Copper Oxychloride which is reported to cause damage to endometrium and cervix, Earth worm is a farmer friend, but certain stages of earth worm were found affected by copper oxychloride (Beltran-Garcia *et al*., 2000; de Oliveira-Filho *et al*., 2004; Reinecke *et al*., 2002).

Mancozeb is an ethylene-bis-dithiocarbamate complex with manganese and zinc fungicide which has

Table 3: *List of agrochemicals used and their respective adverse effects with amount. References given in the discussion section.*

S.No	Origin	Active ingredients	% composition	w/v composition	Effects
1	China	Emamectin Benzoate	0.90%	10g/L	irreversible immobilization in copepods which is a non-target species, severely affect zebra fish, bee, partridge and silkworm.
2	China	Lufenuron	1.80%	20g/L	intrude development of *Drosophila melanogaster*, chitin-synthesis inhibitor
3	China	Kasugamycin	2%	N/A	amino acylation of sRNA, inhibit growth of bacteria
4	China	Copper Oxychloride	45%	N/A	drastically affect earth worm; a friend to farmer
5	China	Mancozeb	64%	640g/kg	apoptosis in mice, development of Parkisnon's disease and cancer, increase in ROS
6	China	Metalaxyl	8%	80g/kg	causes leaf necrosis, lethal effects on earth worm, affect soil quality, decrease in protein and albumin level, causes increase in WBCs.
7	China	Thiamethoxam	25%	250g/kg	high toxicity for *Epitrix fuscula*, affect gills of *Gammarus kischineffensis*, and causes deletorious effects on freshwater biota
8	China	Emamectin Benzoate	2.04%	19g/L	irreversible immobilization in copepods which is a non-target species, severly affect zebra fish, bee, partridge and silkworm.
9	N/A	Acetamiprid	20%	N/A	generates toxic metabolites in brain, liver, plasma and urine of rodents. neurological, hepatorenal, immunological, genotoxic and reproductive effects in mammals

been reported to have toxic effects on different organisms. It is used extensively in United States as fungicide and has numerous effects on reproductive, nervous, endocrine and immune system (Tsang and Trombetta, 2007). In mice, it encourages embryo apoptosis and damage to oocytes and has an impact on fertilization (Paro *et al*., 2012), formulation effects on Perionyx excavates (De Silva *et al*., 2010), reduces sperm count in mice (Khan and Sinha, 1996), is also linked with the development of Parkinson's disease and cancer (Santos *et al*., 2009), it is also known to be neurotoxicant by increasing Reactive oxygen species (ROS) level (Domico *et al*., 2007), these data from scientists proves Mancozeb to be harmful in any combination to all forms of life.

Metalaxyl [N-(2,6-dimethylphenyl)-N-(methoxyacetyl) alanine methyl ester, a fungicide when tested on different decorative plants, mostly accumulated in leaves and caused leaf necrosis, therefore these may be used for phytoremediation (Wilson *et al*., 2001), in earthworm Eisenia foetida it has a lethal effect (Xu *et al*., 2011), affecting soil quality (Monkiedje *et al*., 2002), it also caused decrease in protein and albumin level, while increase in total WBC count (Al-Amoudi, 2012).

Thiamethoxam is a neonicotinoid pesticide which degrades readily to clothianidin causing harmful effects to non-target species (Cavallaro *et al*., 2017), presents a high toxicity level for Epitrix fuscula (McLeod *et al*., 2002), beside these, it is harmful for freshwater biota, where they have been reported to cause some deleterious effects (Saraiva *et al*., 2017), vacuolization and hemostatic permeation in the gills of *Gammarus kischineffensis* (Uğurlu *et al*., 2015).

Emamectin Benzoate, a pesticide which causes irreversible immobilization in a species of copepods which is a non-target species (Willis and Ling, 2003), it is very much exterminating to zebra fish, bee, partridge and silkworm (Cang *et al*., 2007), all of these are beneficial and play a vital role in ecosystem maintenance. The Emamectin Benzoate is reported to be toxic toward larval development, reduces feeding damage, but also helps to control secondary pest population (El-Sheikh, 2015; Ioriatti *et al*., 2009), it also shows some effects to avian communities, and shows to have induced changes on hematology of male rats (Cheng *et al*., 2015; El-Sheikh and Galal, 2015). Extensive data is limited about emamectin, but the current literature shows that this pesticide is harmful for the non-target organisms (Lumaret *et al*., 2012; Willis and Ling, 2003).

Acetamiprid generates toxic metabolites in the brain, liver, plasma and urine of rodents. It is also reported to have neurological, hepatorenal, immunological, genotoxic and reproductive effects in mammals (Phogat *et al*., 2022).

International Figures for Food Wastage

Food saving offers more positive and very fewer negative reimbursements with respect to people and nature. Different international organizations and journals have extensively presented data on food wastage. (Dou *et al*., 2016) reports that annually about seventy million metric tons of eatable food is wasted only in the USA. Another study shows that about 40% of food goes to waste (Dou Zhengxia *et al*., 2016). A study in Britain reveals that adult in a family waste more food than children (Wenlock *et al*., 2008). It is estimated that annually one quarter of the produced food is lost during the food supply chain (Kummu *et al*., 2012). Whatever the global estimates may be, it is obvious from the observer's eye that we are wasting our food at an exponential rate which is far alarming for us, the next generations and for all kinds of life on the globe.

Interdependence of organisms

Whether small or large ones, orchids have flowers which are only pollinated by specific flies (Weston *et al*., 2005). Several small and large organisms have been reported here which depend upon this small orchid and each other. Short as well as long food chains are formed due to these organisms and ultimately all food webs are managed and structured from these organisms. The plant is the ultimate source of food for these individuals. These species include both beneficial and harmful invertebrates and vertebrates in the form of insects, birds and so on.

In summary, this study has investigated the drastic effects of pesticides on non-target species that are applied to agricultural spots. These results underscore the importance of effects of pesticides on non-toxic organisms and contribute to our understanding of pesticides and their risks. As we move forward, it is important to suggest pre and post risk assessment of pesticides. Ultimately, this research highlights the need for strict follow up of pesticides industries and preparation of agrochemicals that have minimum effects. We hope that our findings will inspire future investigations and spark meaningful discussion in the field.

Conclusions and Recommendations

This study highlights the importance of prevention of food from wastage. Organisms are dependent on each other even in a small orchard too, therefore, use of chemicals should be monitored as to prevent biomagnification. The study concludes that agrochemicals, especially pesticides, have been known for their toxic effects on behavior, reproduction, normal function and physiology of non-target organisms. The question focused on this article was to assess the risk of pesticides on non-target species and urge to use food in sustainable ways. The study urges a complete risk assessment of all pesticides used in Pakistan and abroad. The study suggests that future research should focus on food preservation, minimal loss of food and control over the population for having food for all.

Novelty Statement

This study exposes the toxic effects of agrochemicals on non-target organisms in a tomato orchard ecosystem, highlighting the need for sustainable practices. It reveals the alarming impact of pesti-cides on species interdependence, emphasizing the importance of eco-friendly alternatives for food security.

Authors' Contribution

Sohail Anjum: Writing original draft, writing, review and editing, supervision con-ceptualization, formal analysis, methodology.
Maryam Khalf M Althrwi: Data curation, in-vestigation, writ-ing, review and editing
Sadeeq Ahmad: Writing, review and editing, formal analysis, investiga-tion
Muhammad Salman Khan and Babar Ali Khan: Formal analysis, writing, review and editing
Murad Khan and Waseem Khan: Data curation, formal analysis
Muhammad Abbas: Writing, review and editing.
Sundas Asghar: Data curation, writing, review and editing
Waqas Ahmad: Investigation, writing, review and editing

Conflict of interest

The authors declare no conflict of interest related to this research manuscript.

References

Al-Amoudi, W.M. 2012. Haematological and biochemical effects of metalaxyl fungicide on albino mice. Am. J. Biochem., 2(5), 62-66 https://doi.org/10.5923/j.ajb.20120205.03.

Anjum, S., A. Ahmad., F. Bibi and H. Ali. 2021. Ecology of house crow (*Corvus splendens*) in dir lower, khyber pakhtunkhwa, pakistan. P. J. Zool., 54(1), 447-450. https://doi.org/10.17582/journal.pjz/20190716190702

Beltran-Garcia, M.J., A. Espinosa., N. Herrera., A.J. Perez-Zapata., C. Beltran-Garcia and T. Ogura. 2000. Formation of copper oxychloride and reactive oxygen species as causes of uterine injury during copper oxidation of Cu-IUD. Contracept., 61(2), 99-103. https://doi.org/10.1016/S0010-7824(00)00085-8

Ben-Ziony, Y and B. Arzi. 2000. Use of lufenuron for treating fungal infections of dogs and cats: 297 cases (1997–1999). J. Am. Vet. Med. Assoc., 217(10): 1510-1513. https://doi.org/10.2460/javma.2000.217.1510

Bibi, A., F. Anjum, S.R. Hussain, A. Ahad, A.U. Deen, M. Suleman and B. Jan. 2024. Surveillance of pesticide residues in tomato and eggplant and assessment of acute and chronic health risks to the consumers in Pakistan. Environ. Sci. Pollut. Res. Int., 31(4): 6385-6397.

Bueno, A.F and S. Freitas. 2004. Effect of the insecticides abamectin and lufenuron on eggs and larvae of *Chrysoperla externa* under laboratory conditions. BioControl, 36(2): 277-283. https://doi.org/10.1023/B:BICO.0000025375.07428.0b

Cang, T., X. Zhao and C. Wu. 2007. Toxicity and Safety Evaluation of Emamectin Benzoate on Four Types of Non-target Organism. Pesticides-Shenyang-, 46(7): 481. https://api.semanticscholar.org/CorpusID:88457082

Cavallaro, M.C., C.A. Morrissey., J.V. Headley., K.M. Peru and K. Liber. 2017. Comparative chronic toxicity of imidacloprid, clothianidin, and thiamethoxam to *Chironomus dilutus* and estimation of toxic equivalency factors. Environ. Toxicol. Chem., 36(2): 372-382. https://doi.org/10.1002/etc.3536

Cheng, X., X. Liu., H. Wang., X. Ji., K. Wang., M. Wei and K. Qiao. 2015. Effect of emamectin benzoate on root-knot nematodes and tomato yield. PLoS One, 10(10), e0141235. https://doi.org/10.1371/journal.pone.0141235

De Oliveira-Filho, E.C., R.M. Lopes and F.J.R. Paumgartten. 2004. Comparative study on the susceptibility of freshwater species to copper-based pesticides. Chemosphere, 56(4): 369-374. https://doi.org/10.1016/j.chemosphere.2004.04.026

De Silva, P.M.C.S., A. Pathiratne and C.A.M. van Gestel. 2010. Toxicity of chlorpyrifos, carbofuran, mancozeb and their formulations to the tropical earthworm Perionyx excavatus. Appl. Soil Ecol., 44(1): 56-60. https://doi.org/10.1016/j.apsoil.2009.09.005

Domico, L.M., K.R. Cooper., L.P. Bernard and G.D. Zeevalk. 2007. Reactive oxygen species generation by the ethylene-bis-dithiocarbamate (EBDC) fungicide mancozeb and its contribution to neuronal toxicity in mesencephalic cells. NeuroToxicol., 28(6): 1079-1091. https://doi.org/10.1016/j.neuro.2007.04.008

Dou, Z., J.D. Ferguson., D.T. Galligan., A.M. Kelly., S.M. Finn and R. Giegengack. 2016. Assessing U.S. food wastage and opportunities for reduction. *Glob. Food Secur.*, *8*: 19-26. https://doi.org/10.1016/j.gfs.2016.02.001

Dou Zhengxia, J.D. Ferguson, D.T. Galligan, A.M. Kelly, S.M. Finn, and R. Giegengack Z. 2016. A review of consumer food wasting behavior. Food Waste 110. Council for Agricultural Science and Technology, United States of America. ISBN 978-1-887383-35-6

Ebeling, A., J. Hines., L.R. Hertzog., M. Lange., S.T. Meyer., N.K. Simons and W.W. Weisser. 2018. Plant diversity effects on arthropods and arthropod-dependent ecosystem functions in a biodiversity experiment. Basic Appl. Ecol., 26: 50-63. https://doi.org/10.1016/j.baae.2017.09.014

El-Sheikh, E.S.A. 2015. Comparative toxicity and sublethal effects of emamectin benzoate, lufenuron and spinosad on Spodoptera littoralis Boisd. (*Lepidopter*a: Noctuidae). Crop Prot., 67: 228-234. https://doi.org/10.1016/j.cropro.2014.10.022

El-Sheikh, E.S.A and A.A.A. Galal. 2015. Toxic effects of sub-chronic exposure of male albino rats to emamectin benzoate and possible ameliorative role of *Foeniculum vulgare* essential oil. Environ. Toxicol. Pharmacol., 39(3): 1177-1188. https://doi.org/10.1016/j.etap.2015.04.008

Dou, Z., J.D. Ferguson., D.T. Galligan., A.M. Kelly., S.M. Finn and R. Giegengack. 2016. CAST, Ames, Iowa. https://cast-science.org/wp-content/uploads/2016/03/CAST-Food-Waste-Across-the-Supply-Chain-2016.
Huang, C.Y., C.H. Ho, C.J. Lin and C.C. Lo. 2010. Exposure effect of fungicide kasugamycin on bacterial community in natural river sediment. J. Environ. Sci. Health B., 45(5): 485-491. https://doi.org/10.1080/03601231003800412
Ioriatti, C., G. Anfora., G. Angeli., S. Civolani., S. Schmidt and E. Pasqualini. 2009. Toxicity of emamectin benzoate to *Cydia pomonella* (L.) and *Cydia molesta* (Busck) (*Lepidoptera*: Tortricidae): laboratory and field tests. Pest Manage. Sci., 65(3): 306-312. https://doi.org/10.1002/ps.1689
Kassen, R., A. Buckling., G. Bell and P.B. Rainey. 2000. Diversity peaks at intermediate productivity in a laboratory microcosm. Nature, 406(6795): 508-512. https://doi.org/10.1038/35020060
Khan, P.K and S.P. Sinha. 1996. Ameliorating effect of vitamin C on murine sperm toxicity induced by three pesticides (endosulfan, phosphamidon and mancozeb). Mutagenesis, 11(1): 33-36. https://doi.org/10.1093/mutage/11.1.33
Kole, R., K. Roy., B. Panja., E. Sankarganesh., T. Mandal and R. Worede. 2019. Use of pesticides in agriculture and emergence of resistant pests. Indian J. Anim. Hlth., 58(2): 53-70. https://doi.org/10.36062/ijah.58.2SPL.2019.53-70
Kummu, M., H. de Moel., M. Porkka., S. Siebert., O. Varis and P.J. Ward. 2012. Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. Sci. Total Environ., 438: 477-489. https://doi.org/10.1016/j.scitotenv.2012.08.092
Lumaret, J.-P., F. Errouissi., K. Floate., J. Rombke and K. Wardhaugh. 2012. A review on the toxicity and non-target effects of macrocyclic lactones in terrestrial and aquatic environments. Curr. Pharm. Biotechnol., 13(6): 1004-1060. https://doi.org/10.2174/138920112800399257
Mamane, A., I. Baldi., J.F. Tessier., C. Raherison and G. Bouvier. 2015. Occupational exposure to pesticides and respiratory health. EER., 24(136): 306-319. https://doi.org/10.1183/16000617.00006014
Markula, A., M. Hannan-Jones and S. Csurhes. 2009. Pest animal risk assessment: Indian myna, Acridotheres tristis. In (pp. 16 pp.). GPO Box 46, Brisbane 4001: Queensland Government.
McGhee, G.C and G.W. Sundin. 2011. Evaluation of Kasugamycin for Fire Blight Management, Effect on Nontarget Bacteria, and Assessment of Kasugamycin Resistance Potential in Erwinia amylovora. Phytopathol., 101(2): 192-204. https://doi.org/10.1094/PHYTO-04-10-0128
McLeod, P., F.J. Diaz and D.T. Johnson. 2002. Toxicity, Persistence, and Efficacy of Spinosad, Chlorfenapyr, and Thiamethoxam on Eggplant When Applied Against the Eggplant Flea Beetle (*Coleoptera*: Chrysomelidae). J. Econ. Entomol., 95(2), 331-335. https://doi.org/10.1603/0022-0493-95.2.331
Monkiedje, A., M.O. Ilori and M. Spiteller. 2002. Soil quality changes resulting from the application of the fungicides mefenoxam and metalaxyl to a sandy loam soil. Soil Biol. Biochem., 34(12): 1939-1948. https://doi.org/10.1016/S0038-0717(02)00211-0
Montoya, D., S. Gaba., C. de Mazancourt., V. Bretagnolle and M. Loreau. 2020. Reconciling biodiversity conservation, food production and farmers' demand in agricultural landscapes. Ecol. Model., 416: 108889. https://doi.org/10.1016/j.ecolmodel.2019.108889
Navarro-Llopis, V., J. Sanchis-Cabanes., I. Ayala., V. Casaña-Giner and E. Primo-Yúfera. 2004. Efficacy of lufenuron as chemosterilant against Ceratitis capitata in field trials. Pest Manag. Sci., 60(9): 914-920. https://doi.org/10.1002/ps.902
Paro, R., G.M. Tiboni., R. Buccione., G. Rossi., V. Cellini., R. Canipari and S. Cecconi. 2012. The fungicide mancozeb induces toxic effects on mammalian granulosa cells. Toxicol. Appl. Pharmacol., 260(2): 155-161. https://doi.org/10.1016/j.taap.2012.02.005
Phogat, A., J. Singh, V. Kumar and V. Malik. 2022. Toxicity of the acetamiprid insecticide for mammals: A review. Environ. Chem. Lett., 20: 1453-1478. https://doi.org/10.1007/s10311-021-01353-1
Popescu, A., C. Tindeche, A. Marcuță, L. Marcuță, A. Honțuş and C. Angelescu. 2021. Labor force in the European Union agriculture-traits and tendencies. Sci. Papers, Ser. Manag. Econom. Eng. Agric. Rural Dev., 21 (2): 475-486.
Reinecke, S.A., B. Helling and A.J. Reinecke.

2002. Lysosomal response of earthworm (*Eisenia fetida*) coelomocytes to the fungicide copper oxychloride and relation to life-cycle parameters. ET&C., 21(5), 1026-1031. https://doi.org/10.1002/etc.5620210519

Ruiz-Benito, P., L. Gómez-Aparicio., A. Paquette., C. Messier., J. Kattge and M.A. Zavala. 2014. Diversity increases carbon storage and tree productivity in Spanish forests. Glob. Ecol. Biogeogr., 23(3): 311-322. https://doi.org/10.1111/geb.12126

Sanders, N.J., J.P. Lessard., M.C. Fitzpatrick and R.R. Dunn. 2007. Temperature, but not productivity or geometry, predicts elevational diversity gradients in ants across spatial grains. Glob. Ecol. Biogeogr., 16(5): 640-649. https://doi.org/10.1111/j.1466-8238.2007.00316.x

Santos, P.M., T. Simões and I. Sá-Correia. 2009. Insights into yeast adaptive response to the agricultural fungicide mancozeb: A toxicoproteomics approach. PROTEOMICS, 9(3): 657-670. https://doi.org/10.1002/pmic.200800452

Saraiva, A.S., R.A. Sarmento., A.C.M. Rodrigues., D. Campos., G. Fedorova., V. Žlábek., C. Gravato., J.L.T. Pestana and A.M.V.M. Soares. 2017. Assessment of thiamethoxam toxicity to Chironomus riparius. Ecotoxicol. Environ. Saf., 137: 240-246. https://doi.org/10.1016/j.ecoenv.2016.12.009

Schneider, F. 2008. Wasting food–An insistent behavior. Urban Issues and Solutions. Conference Paper May 11-15 2008.

Tanaka, N., H. Yamaguchi and H. Umezawa. 1966. Mechanism of kasugamycin action on polypeptide synthesis. J. Biochem., 60(4): 429-434. https://doi.org/10.1093/oxfordjournals.jbchem.a128454

Teng, P and S. Trethewie. 2012. *Tackling urban and rural food wastage in Southeast Asia: Issues and interventions*. S. Rajaratnam School of International Studies. www.jstor.org/stable/pdf/resrep17171

Toorang, F., B. Sasanfar, H. Pouraram, and S. Eskandari. 2024. Pesticide residue in Iranian fruits and vegetables: A systematic review. J. Nutr. Food Secur. 9(1): 132-143.

Tsang, M. and L. Trombetta. 2007. The protective role of chelators and antioxidants on mancozeb-induced toxicity in rat *Hippocampal astrocytes. oxicol.* Ind. Health, 23(8): 459-470. https://doi.org/10.1177/0748233708089039

Uğurlu, P., E. Ünlü and E.I. Satar. 2015. The toxicological effects of thiamethoxam on Gammarus kischineffensis (Schellenberg 1937) (Crustacea: Amphipoda). Environ. Toxicol. Pharmacol., 39(2): 720-726. https://doi.org/10.1016/j.etap.2015.01.013

Venail, P.A., R.C. MacLean., T. Bouvier., M.A. Brockhurs., M.E. Hochberg and N. Mouquet. 2008. Diversity and productivity peak at intermediate dispersal rate in evolving metacommunities. Nature, 452(7184): 210-214. https://doi.org/10.1038/nature06554

Wenlock, R.W., D.H. Buss., B.J. Derry and E.J. Dixon. 2008. Household food wastage in Britain. Br J Nutr., 43(1): 53-70. https://doi.org/10.1079/BJN19800064

Weston, P.H., A.J. Perkins and T.J. Entwisle. 2005. More than symbioses: orchid ecology, with examples from the Sydney Region. Cunninghamia, 9(1): 1-15. https://www.botanicgardens.org.au/sites/default/files/2023-06/Cun9Wes001

Willis, K.J and N. Ling. 2003. The toxicity of emamectin benzoate, an aquaculture pesticide, to planktonic marine copepods. Aquac., 221(1): 289-297. https://doi.org/10.1016/S0044-8486(03)00066-8

Wilson, P.C., T. Whitwell and S.J. Klaine. 2001. Metalaxyl Toxicity, Uptake, and Distribution in Several Ornamental Plant Species. J. Environ. Qual., 30(2): 411-417. https://doi.org/10.2134/jeq2001.302411x

Wilson, T.G and J.R. Cryan. 1997. Lufenuron, a chitin-synthesis inhibitor, interrupts development of *Drosophila melanogaster*. J. exp. zool., 278(1): 37-44. https://doi.org/10.1002/(SICI)1097-010X(19970501)278:1<37::AID-JEZ4>3.0.CO;2-7

Xu, P., J. Diao., D. Liu and Z. Zhou. 2011. Enantioselective bioaccumulation and toxic effects of metalaxyl in earthworm Eisenia foetida. Chemosphere, 83(8): 1074-1079. https://doi.org/10.1016/j.chemosphere.2011.01.047

Zhang, W., F. Jiang and J. Ou. 2011. Global pesticide consumption and pollution: with China as a focus. Proc. Int. Acad. Ecol. Environ. Sci., 1(2): 125. http://www.iaees.org/publications/journals/piaees/piaees.asp