Research Article

Harmful Effects of Pesticide Usage in Fruits and Vegetables Production in Pakistan

Muhammad Zeeshan Majeed[1]*, Muhammad Usman[2], Murtajiz Abbas[1], Muhammad Luqman[2] and Abu Bakar Muhammad Raza[1]

[1]*Department of Entomology, College of Agriculture, University of Sargodha, 40100 Sargodha, Pakistan;* [2]*Department of Agricultural Extension and Rural Studies, College of Agriculture, University of Sargodha, 40100 Sargodha, Pakistan.*

Abstract | Fruits and vegetables are an integral part of the human diet. Agricultural pesticides, including insecticides, fungicides, and herbicides, have been an inevitable and crucial part of plant protection being employed in fruit and vegetable production all over the world. However, various ecological consequences such as pest resistance, disruption of beneficial fauna, environmental contamination, and human health hazards are being manifested by the extensive use of highly persistent and hazardous synthetic pesticides. Pesticidal residues get adsorbed and absorbed in the treated fruits and vegetables and enter food chains and causing problems of bioaccumulation and biomagnification. In humans, these pesticidal residues cause many acute and chronic diseases ranging from eye irritation, skin itching, asthma, kidney failure, cancer, birth defects, infertility, lungs cancer, dementia, Alzheimer and many other neuro-muscular and endocrinal disorders. Therefore, the farming community should know about the do's and don'ts of pesticidal usage in fruit and vegetable production and should follow all the precautionary measures and recommendations to avoid the pesticidal exposure and to minimize the risks associated with these pesticidal products.

Received | February 04, 2025; **Accepted** | April 16, 2025; **Published** | July 18, 2025
***Correspondence** | Muhammad Zeeshan Majeed, Department of Entomology, College of Agriculture, University of Sargodha, 40100 Sargodha, Pakistan; **Email:** zeeshan.majeed@uos.edu.pk
Citation | Majeed, M.Z., M. Usman, M. Abbas, M. Luqman and A.B.M. Raza. 2025. Harmful effects of pesticide usage in fruits and vegetables production in Pakistan. *Sarhad Journal of Agriculture,* 41(3): 1123-1132.
DOI | https://dx.doi.org/10.17582/journal.sja/2025/41.3.1123.1132
Keywords | Fruits and vegetables production, Agrochemicals, Insecticides, Weedicides, Fungicides, Pre-harvest interval, Pesticidal residues, Human health hazards

Introduction

Pakistan is primarily an agricultural country with vast and fertile plains. The farmers here are very hardworking, working day and night to produce various types of agricultural crops, fruits, and vegetables, not only meeting the country's food needs but also playing an important role in obtaining foreign exchange for the country. In Pakistan, a wide variety of fruits and vegetables are being grown on a large scale. The country's economy benefits greatly from the production of high-quality fruits, including kinnow-mandarin, mango, banana, apple, apricot, guava, and vegetables, including potatoes, onions, okra, cauliflower, chilies, cucurbits, etc.

Fruits and vegetables have been an important part of the human diet. Their per-acre productivity and profitability are three to four times higher than other crops. In the world, the per capita annual consumption of fruits and vegetables is 105 kg. According to the WHO, this amount should be at least 73 kg per capita. In Pakistan, however, the consumption is only 50 kg per capita annually (Amjad and Akbar, 2023). One of the main reasons for this low consumption of fruits and vegetables in Pakistan is their low production both in terms of quality and quantity due to many factors including the incidence of various insect pests, diseases and weeds.

Farmers in the Indo-Pak region rely exclusively on the extensive applications of a wide range of agricultural pesticides, including insecticides, fungicides, bactericides and herbicides in order to save their fruits and vegetables from insect pests and diseases. It is inevitable to avoid the use of highly persistent synthetic pesticides in the fruits and vegetables production sector (Rashid *et al*., 2022).

Major insect pests and diseases of fruits and vegetables in Pakistan

There are many types of insect and mite pests that attack and cause substantial damage to fruit and vegetable crops in the Indo-Pak region. There are two major categories of these arthropod pests. One includes piercing-sucking or haustellate insect pests, which are usually sap- or phloem-feeding pests. Sucking pests suck sap from leaves, stem and fruits, and stunt growth and photosynthesis reaction of plants, while chewing pests prefer tender portion of plant and feed on them and some pests do bore into fruits and lay eggs inside it and cause damage to fruits (Ansari *et al*., 2019; Ankireddy *et al*., 2023; Parthasarathy *et al*., 2024). Some most common and economically important sucking pests include whiteflies, aphids, jassids, citrus psyllids, plant and leaf hoppers, thrips, mango leafhopper, mealybugs, red cotton bug, pentatomid or shield bugs and red spider mites (Figure 1) (Saha *et al*., 2020; Ghosal, 2022).

The other category is of chewing-biting or mandibulate pests which derive their food by cutting and chewing the plant tissues and by boring into different parts. These insect pests which commonly attack on fruit and vegetable plants include various lepidopterous pests (such as citrus caterpillar, citrus leaf-miner, brinjal fruit borer, cabbage butterfly, diamond-back moth, potato tuber moth and cutworms), dipterous pests (such as fruit flies, fungal gnats, shoot flies), coleopterous pests (such as cerambycid or long-horned stem borers, red pumpkin beetle, hadda beetle) and orthopterous pests (such as grasshoppers, katydids, locusts and field crickets) and different subterranean termite species (Figure 2) (Ali *et al*., 2023; Ofuya *et al*., 2023).

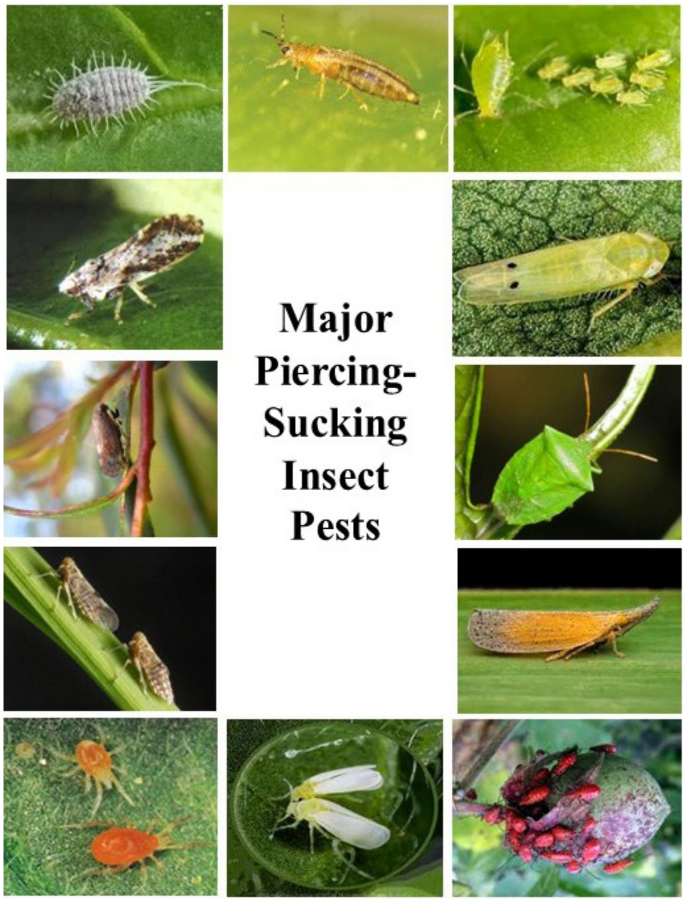

Figure 1: *Some major piercing-sucking (haustellate) insect and mite pests that commonly infest fruit and vegetable crops in Pakistan.*

Apart from insect and mite pests, fruit and vegetable production in Pakistan is also being hampered by an array of pathogens causing destructive diseases and abnormalities in crop plants and reducing both the quantity and quality of fruits and vegetables. Fruit and vegetable crops are usually susceptible to a variety of diseases caused by various microscopic organisms such as bacteria, fungi, viruses, and nematodes (Balali *et al*., 2020; Alegbeleye *et al*., 2022). The most commonly found diseases of fruits and vegetables in Pakistan include *Alterneria* leaf spots, anthracnose, *Rhizoctonia* root rot, gummosis, downy and powdery mildews, leaf blights, citrus canker, citrus greening, blotches, necrosis and scabs, and many viral diseases etc. (Shahid *et al*., 2017).

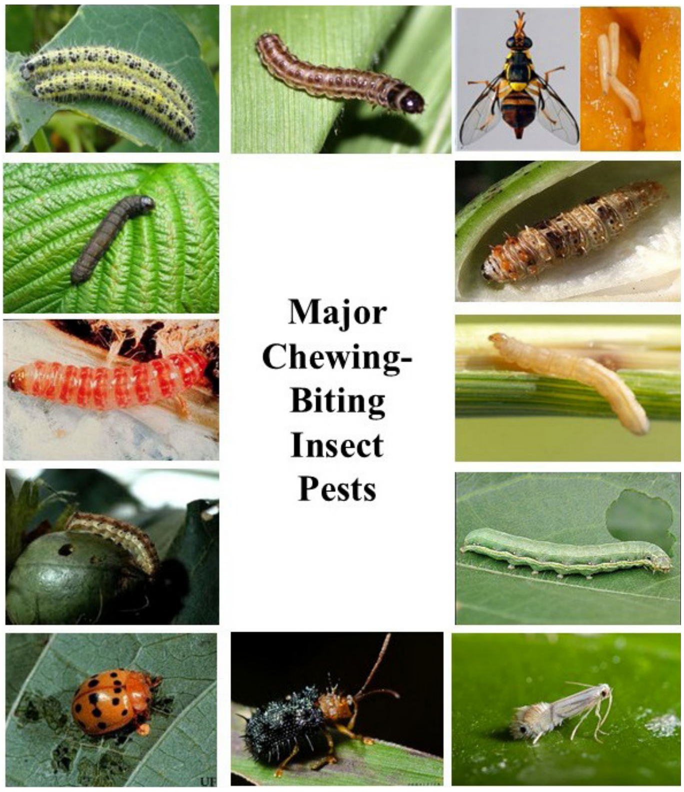

Figure 2: *Some major chewing-biting (mandibulate) insect pests that commonly infest fruit and vegetable crops in Pakistan.*

Pesticidal control of fruit and vegetable pests and diseases in Pakistan

For combating above mentioned arthropod pests and pathogenic diseases and for safeguarding their fruit and vegetable crops, farmers predominantly rely on the recurrent and excessive use of synthetic pesticides. In many areas, they often follow a prophylactic calendar spraying on a daily basis to control the pests and to protect their crops from insect pests and diseases. A wide variety of pesticidal formulations are available in the market for this purpose. These include insecticides (such as organophosphates, carbamates, pyrethroids, neonicotinoids, avermectins, thioureas, oxadiazines, spinosyns, IGRs, phenylpyrroles, sulfoximines, diamides and ketoenoles (Table 1) (Majeed *et al*., 2021, 2025; Iqbal *et al*., 2023), fungicides and bactericides (such as metalaxyl, ridomil, fosetyl aluminum, mancozeb, tebuconazole, carbendazim, copper oxychloride, pentachlorophenol, thiophanate methyl, difenconazole and propiconazole etc. (Haq *et al*., 2020; Ons *et al*., 2020; Adaskaveg *et al*., 2022; Gupta and Tripathi, 2024) and herbicides (such as clomazone, sulfurons, metribuzin, fluroxpyr, MCPA, 2,4-triazole-1-carboxamide, pendimethalin, butachlor, glyphosate, S-metolachlor, atrazine and mesotrione etc.) (Wakabayashi and Böger, 2002; Sheryar *et al*., 2022).

Table 1: *Most commonly used synthetic insecticides against different insect pests in fruits and vegetables production sector in Pakistan.*

Insecticide name	Brand name (™/®)	Target Insect Pests
Abamectin*	Alarm	Mites, leaf miner, sucking insects
Acephate	Commando	Aphids, armyworms, caterpillars
Acetamiprid	Mospilan	aphids, jassids, whiteflies
Bifenthrin	Talstar	Grasshoppers, thrips, beetles, aphids
Carbaryl	Sevin	Aphids, fleas, mites
Carbofuran	Furadan	Rice borers, whiteflies, white grubs
Carbosulfan	Advantage	Aphids, plant hoppers, mealybugs
Cartap	Padan	Thrips, whiteflies, jassids
Chlorantra-niliprole	Coraygen	Bugs, aphids, lepidopterous larvae
Chlorpyriphos	Lorsban	Termites, mosquitoes, beetles, larvae
Cyantra-niliprole	Cyazpyr	Fruit flies, leafhoppers, psyllids, aphids
Cypermethrin	Arrivo	Termites, flies, caterpillars/larvae
Cyromazine	Trigard	Colorado potato beetle, leaf miner
Deltamethrin	Decis Super	Mites, weevils, beetles
Diafenthiuron	Polo	Jassids, diamond-backed moth
Emamectin benzoate*	Proclaim	Bollworms, fruit borers
Esfenvalerate	Sumi-Alpha	Leafhoppers, fruit flies, moths
Fipronil	Regent	Termites, root worms, weevils
Imidacloprid	Confidor	Leafhoppers, aphids
Indoxacarb	Steward	Lepidopterous larvae
Lambda cyhalothrin	Karate	Jassids, thrips, borers, leafhoppers
Lufenuron*	Match	Termites, borers, armyworms, bugs
Methomyl	Lannate	Thrips, beetles
Methoxy-fenozide*	Runner	Leaf roller, armyworms, leaf miners
Nitenpyram	Paranol	Sucking insect pests
Pyriproxyfen*	Admiral	Fleas, ticks, mites, mosquitoes
Spinetoram*	Radiant	Psyllids, lepidopterous larvae, fleas
Spinosad*	Tracer	Caterpillars, leaf miners, thrips
Spiromesifen*	Oberon	Whiteflies
Spirotetramat*	Movento	Aphids, psyllids, mealybugs
Tebufenozide*	Topgun	Lepidopterous larvae
Thiamethox-am	Actara	Whiteflies, leafhopper, leaf miners
Trichlorfon	Diptrex	Cricket, leaf miners, leaf hoppers

* *softer or biorational insecticides with low- or reduced-toxicity profile and exhibiting more target-specificity.*

Non-target effects of pesticide usage in fruits and vegetables

All these agricultural pesticides that are being used to kill, repel, or suppress any insect, mite, pathogen, or weed pest are, no doubt, beneficial to farmers in the short term and help farmers to control the pests of their crops and to enhance the yield of fruits and vegetables. But in the long run, most of these agrochemicals exert a negative impact on the environment and other non-target living organisms, including humans. Residues of these highly persistent and hazardous synthetic pesticides in the fruits and vegetables cause the disruption of beneficial fauna including the elimination of predators and parasites of pests and eradication of useful soil microbes, contamination of environmental resources such as water, soil and air and the human health hazards (Desneux *et al*., 2007; Syed *et al*., 2014). When agricultural pesticides are sprayed on fruits and vegetables, their residues can either remain on the surface or penetrate them (Nguyen *et al*., 2020; Ssemugabo *et al*., 2022). According to a recent study, the highest levels of pesticide residues are found in fruits such as apples, grapes, peaches, mangoes, guavas, oranges, and strawberries, while vegetables like potatoes, spinach, cucumbers, tomatoes, bell peppers, green chilies, peas, and cauliflower contain them (Del Mar Gómez-Ramos *et al*., 2020; Mandal *et al*., 2023). Experts have set maximum residue limits (MRLs) for various agricultural pesticides (Table 2) to ensure that these harmful residues do not pose a risk to human health and to monitor their levels in the treated agricultural produce, including fruits and vegetables (Bhawan, 2022; Murali *et al*., 2023).

Agricultural pesticidal residues are a potential threat to human health

Although most of the pesticidal material applied to a crop gets decomposed by temperature, UV light, and soil microbes, a considerable portion becomes adsorbed in treated agricultural produce and may cause pesticidal biomagnification when it enters into the food web (Ray and Shaju, 2023; Tison *et al*., 2024). The residues of agricultural pesticides, particularly of insecticides and fungicides, can lead to various issues in the human body after their accumulation (Alengebawy *et al*., 2021; Kalyabina *et al*., 2021). In humans, these pesticidal residues cause many acute and chronic diseases such as headache, eyes stinging, itching, skin burning, chest pain, asthma, kidney failure, cancer, birth defects, infertility, spontaneous abortion, lungs cancer, dementia, Alzheimer and many other neuro-muscular and endocrinal disorders etc. (Upadhayay *et al*., 2020; Banerjee *et al*., 2021; Zhou *et al*., 2024).

Table 2: *Pre-harvest interval (PHI: the minimum time (in days) between the last application of a pesticide and when the crop can be harvested) of most commonly used pesticides in fruits and vegetables production sector in Pakistan.*

S. No.	Agricultural pesticide	PHI (days)	Sr. No.	Agricultural pesticide	PHI (days)	Sr. No.	Agricultural pesticide	PHI (days)
	Insecticides		_	_	_	_	Fungicides	
1	Abamectin*	7	18	Esfenvalerate	14	35	Bordeaux mixture	1
2	Acetamiprid	7	19	Fenpropathrin	1	36	Chlorothalonil	28
3	Azadirachtin*	0	20	Fenvalerate	12	37	Copper oxychloride/hydroxide	1
4	*B. Thuringiensis**	0	21	Imidacloprid	7	38	Difenoconazole + cyprodinil	14
5	Beta-cyfluthrin	7	22	Indoxacarb	7	39	Fosetyl Al	15
6	Beta-cyhalothrin	7	23	Malathion	7	40	Mancozeb	60
7	Bifenthrin	1	24	Methidathion	60	41	Potassium bicarbonate	0
8	Buprofezin*	3	25	Methomyl	1	42	Sulfur	1
9	Carbaryl	14	26	Methoxyfenozide*	1	43	Tebuconazole	14
11	Chlorpyrifos	35	28	Neem oil*	0	44	Thiophanate-methyl	7
10	Cyfluthrin	7	27	Permethrin	7	45	Bordeaux mixture	1
12	Cyhalothrin	7	29	Pyrethrin + PBO	When dry		weedicides	
13	Cypermethrin	5	30	Pyriproxyfen*	45	46	2,4-D	30
14	Deltamethrin	2	31	Rosemerry oil + peppermint oil*	0	47	Fenoxyprop-p-ethyl	65
15	Dicofol	7	32	Sabadila*	When dry	48	Isoproturon	60
16	Diflubenzuron	21	33	Spinosad*	1	49	MCPA	50
17	Dimethoate	45	34	Thiamethoxam	8	50	Metalaxyl-M and S-isomer	25

** softer or biorational insecticides with low- or reduced-toxicity profile and exhibiting more target-specificity.*

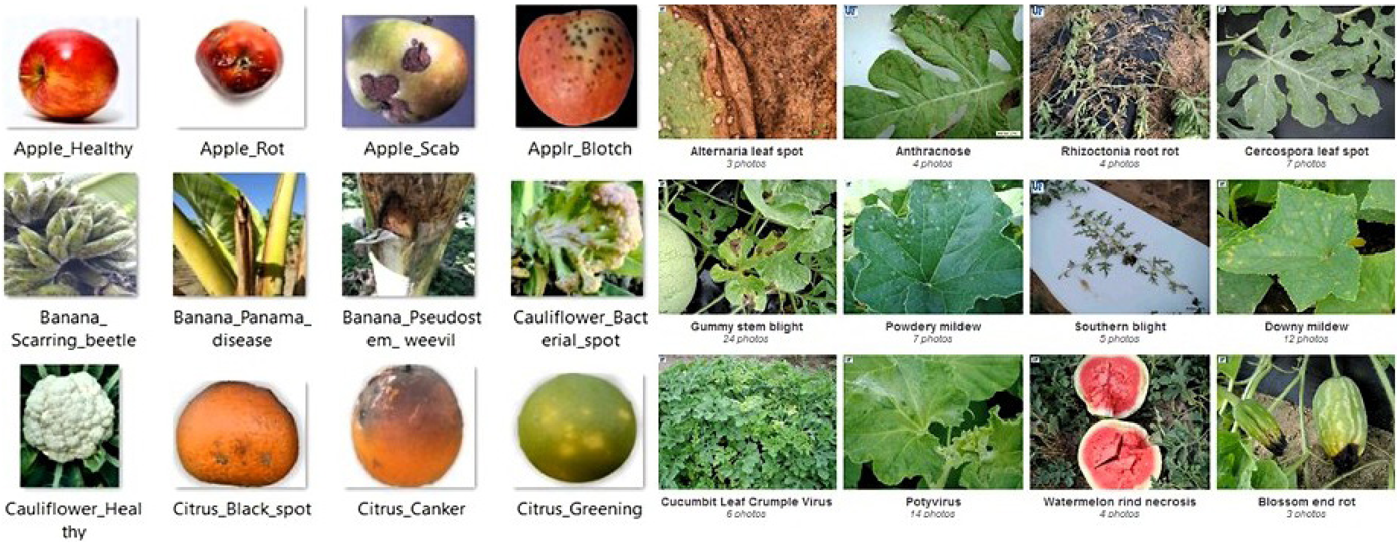

Figure 3: *Screenshots of some major and most commonly found diseases of fruits and vegetables in South-East Asia, including Pakistan (modified after Orwat, 2013; Ch et al., 2024).*

In addition, the residues of agricultural toxins can weaken the immune system, cause decreased intelligence, lead to low birth weight, contribute to premature baldness in children, and even result in infertility in women and young children (Want, 2022; Chowdhury *et al*., 2023). Indeed, the nervous and circulatory systems are quite similar in humans, mice, and insects. That's why agricultural pesticides used against harmful insects, worms, diseases, and rodents can certainly have negative effects on human health (Hashimi *et al*., 2020; Rani *et al*., 2021). According to a recent scientific report, every human body contains some level of chemical residue, and this proportion is higher among people in Africa and Asia as compared to those in America, Europe, and Australia (Olisah *et al*., 2020; Rajmohan *et al*., 2020; Rotimi *et al*., 2021; Schmidt *et al*., 2021). According to estimates, more than three hundred thousand people worldwide are affected by agricultural pesticides each year. Over twenty thousand of them lose their lives (Maggi *et al*., 2023; Verzeñassi *et al*., 2023).

Agricultural pesticides not only impact insects, the environment, wildlife, lakes, and groundwater, but also have adverse effects on human health, including the eyes, skin, lungs, liver, and can even be carcinogenic (Ahmad *et al*., 2024; Gulzar *et al*., 2024; Yarkwan *et al*., 2024). The most significant harmful effects of agricultural pesticides are related to cancer or damage to the nervous system (Lee and Choi, 2020) According to the recent scientific research, countries with high usage of agricultural pesticides have a higher incidence of various types of cancer, with one in every four cases being attributed to pesticide residues (Ali *et al*., 2021; Ashraf *et al*., 2023). Additionally, in areas where the use of agricultural pesticides is completely banned, a noticeable reduction in heart diseases has been observed (Donham and Thelin, 2006; Najam and Alam, 2023).

Some agricultural pesticides, especially chlorine-based chemicals such as aldrin, dieldrin, toxaphene, and mirex, are very persistent and can last in the environment for many years (Said and El-Zokm, 2024; Tonelli *et al*., 2024). These pesticides break down in the human and animal body and accumulate in fat, a process called bioaccumulation (Kamalesh *et al*., 2023; Arisekar *et al*., 2024). When the concentration of this poison exceeds a certain limit, it starts to show its effects. This is why the average human lifespan in Europe and America is 80 to 84 years, while in Pakistan, it is only around 60 years. One of the main reasons for this is the indiscriminate and unsafe use of agricultural pesticides (Khalil *et al*., 2023; Abbas *et al*., 2024).

Exposure to agricultural pesticides and their symptoms

It is crucial for the farmers to have thorough information about the potential harmful effects of agricultural chemicals on themselves, on their livestock, and to the surrounding environment. They should be aware of which agricultural pesticides can be damaging and toxic, and how to protect themselves and to mitigate the health risks associated with them. The harmful health effects of agricultural pesticides, when used excessively, can be transferred from our fields to the environment, homes, and even our bodies. These toxins can enter our bodies through the nose, ears, eyes, mouth, and skin during pesticide spraying or the preparation of pesticide solutions (AbuQamar *et al*., 2024; Kaur *et al*., 2024).

The immediate symptoms of harmful effects of agricultural pesticidal exposure include dizziness, muscle weakness, headache, excessive sweating, nausea, vomiting, fainting, trembling of hands and feet, restlessness, loss of appetite, decreased heart rate, burning sensation and irritation in the eyes, and difficulty in breathing (Okrikata and Nwosu, 2023; Mojisola *et al*., 2024). Therefore, the farmers need to exercise caution when using agricultural pesticides, and if by mistake, the poison enters our bodies, we should immediately consult a doctor. In case of pesticide exposure, the initial medical aid is to take the affected person or patient to fresh air, administer an injection of atropine sulfate and give them a mixture of egg in fresh milk to drink. Additionally, wash the affected skin with plenty of water and soap (Donham and Thelin, 2006; Alozi and Rawas-Qalaji, 2020).

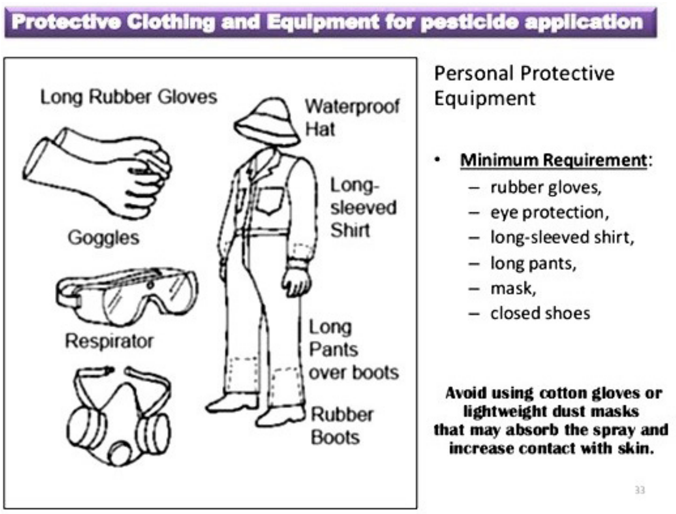

Figure 4: *Personal protection equipment recommended to be used while applying agricultural pesticides to avoid pesticidal exposure (courtesy to Wilen et al., 2006).*

Recommendations and instructions for safe use of agricultural pesticides in fruits and vegetable production

First of all, it is worth mentioning that farmers should opt for synthetic pesticides, particularly insecticides, as the last option for pest control. Firstly, they should try to go for other non-chemical pest control options such as mechanical, cultural, physical, legislative, and biological pest control strategies. Again, in the case of synthetic pesticides, they should opt for comparatively safer, softer, biorational, and more target-specific and low or reduced toxicity pesticides, such as botanical pesticides, biological-origin and differential-chemistry synthetic insecticides, insect growth regulators, etc. (Rosell *et al*., 2008; Majeed *et al*., 2021; Batool *et al*., 2022; Mahawer *et al*., 2024).

To avoid the side effects, the following is the list of general instructions and recommendations that should be followed by the fruit and vegetable growers while applying pesticides in their crops.

- Always read carefully the label instructions of any pesticidal product before its use.
- Use approved and recommended agricultural pesticides against any pest.
- Keep track of the expiry of the pesticides.
- Use the pesticides in the correct manner and the appropriate dosage.
- Do not exceed or decrease the recommended dose of the pesticides.
- Store the pesticides in a safe, cool, and dark place.
- Keep the pesticides out of the reach of children and minors.
- Do not store pesticides in water or other drink bottles or any food containers
- Always keep pesticides in their original bottle.
- Make a hole on the lower side of pesticide bottles to waste it for any other use.
- Do not throw pesticide-contaminated things in open areas or near animal shelters.
- During pesticide application, properly cover your eyes, face, ears, arms, and body.
- Follow minimum personal protection equipment (PPE) such as rubber shoes, mask, gloves, and waterproof overall during application as shown in Figure 4.
- Keep agricultural pesticides and spray machinery away from children.
- Before spraying, consider the economic threshold levels of target pests.
- After spraying, make sure to thoroughly wash your body and clothes with soap.
- Before using fruits and vegetables, wash them thoroughly with clean water or under a tap. Try to use peeled fruits and vegetables as residues of agricultural pesticides are often absorbed in the peels.
- When using pesticides on fruits and vegetables, choose ones with minimal environmental and human health impacts. These pesticides are also called softer or reduced-risk pesticides.
- Last but not least is that always opt for pesticides with minimum or shorter pre-harvest interval (PHI), which is the minimum time (in days) between the last application of a pesticide and when the crop can be harvested. PHI values (in days) of a few commonly used synthetic pesticides are given in Table 2.

Acknowledgements

Authors are grateful to Dr. Muhammad Asam Riaz (Department of Entomology, University of Sargodha, Sargodha, Pakistan) for the technical review of the first draft.

Novelty Statement

This review paper highlights the importance of knowing about the hazards that pesticidal residues can cause to human health and the environment, and summarizes the precautionary strategies for avoiding and minimizing the exposure and ecological consequences of synthetic pesticides.

Author's Contribution

Muhammad Zeeshan Majeed: Conceived the idea and technically revised the draft.
Muhammad Usman: Prepared the figures and tables.
Murtajiz Abbas: Wrote the first draft.
Muhammad Luqman: Technically revised the draft.
Abu Bakar Muhammad Raza: Supervised the research work.

Conflict of interest
The authors have declared no conflict of interest.

References

Abbas, M., S. Abbas, N. Hussain, M.T. Javeed, A. Ghaffar, M. Nadeem and H.A. Ghramh. 2024. Assessment of residues from common pesticides and associated risks in Pakistan. Environ. Monit. Assess., 196(11): 1061. https://doi.org/10.1007/s10661-024-13220-x

AbuQamar, S.F., M.T. El-Saadony, S.S. Alkafaas, M.I. Elsalahaty, S.S. Elkafas, B.T. Mathew and K.A. El-Tarabil. 2024. Ecological impacts and management strategies of pesticide pollution on aquatic life and human beings. Mar. Pollut. Bull., 206: 116613. https://doi.org/10.1016/j.marpolbul.2024.116613

Adaskaveg, J.E., T. Michailides and A. Eskalen. 2022. Fungicides, bactericides, biocontrols, and natural products for deciduous tree fruit and nut, citrus, strawberry, and vine crops in California. University of California Agriculture and Natural Resources. Accessed April, 3, 2023.

Ahmad, M.F., F.A. Ahmad, A.A. Alsayegh, M. Zeyaullah, A.M. AlShahrani, K. Muzammil and S. Hussain. 2024. Pesticides impacts on human health and the environment with their mechanisms of action and possible countermeasures. Heliyon, https://doi.org/10.1016/j.heliyon.2024.e29128

Alegbeleye, O., O.A. Odeyemi, M. Strateva and D. Stratev. 2022. Microbial spoilage of vegetables, fruits and cereals. Appl. Food Res., 2(1): 100122. https://doi.org/10.1016/j.afres.2022.100122

Alengebawy, A., S.T. Abdelkhalek, S.R. Qureshi and M.Q. Wang. 2021. Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications. Toxics., 9(3): 42. https://doi.org/10.3390/toxics9030042

Ali, M.A., I.M. Abdellah and M.R. Eletmany. 2023. Towards sustainable management of insect pests: Protecting food security through ecological intensification. Int. J. Chem. Biochem. Sci., 24(4): 386-394.

Ali, S., M.I. Ullah, A. Sajjad, Q. Shakeel and A. Hussain. 2021. Environmental and health effects of pesticide residues. Sustain. Agric. Rev., 48: https://doi.org/10.1007/978-3-030-54719-6_8

Alozi, M. and M. Rawas-Qalaji. 2020. Treating organophosphates poisoning: management challenges and potential solutions. Crit. Rev. Toxicol., 50(9): 764-779. https://doi.org/10.1080/10408444.2020.1837069

Amjad, M. and M. Akbar. 2023. The association between fruit and vegetable intake and socioeconomic factors in the households of Pakistan using quantile regression model. Soc. Work Publ. Health, 38(3): 248-258. https://doi.org/10.1080/19371918.2022.2134249

Ankireddy, J.R., N.N. Reddy and H.D. Yogesh. 2023. Insect pests of important fruit crops and their recent management strategies in emerging horticulture hub of Andhra Pradesh-Ananthapuramu. J. Appl. Entomol., 3(1): 7-14.

Ansari, M.S., R. Basri and S.S. Shekhawat. 2019. Insect pests' infestation during field and storage of fruits and vegetables. Health Saf. Asp. Food Proc. Technol., pp. 121-207. https://doi.org/10.1007/978-3-030-24903-8_7

Arisekar, U., R.J. Shakila, R. Shalini, B. Sivaraman, A. Karthy, M.M. Al-Ansari and S.N. Sangma. 2024. Diffusion of organochlorine (OCPs) and cypermethrin pesticides from rohu (*Labeo rohita*) internal organs to edible tissues during ice storage: A threat to human health. Environ. Geochem. Health, 46(4): 126. https://doi.org/10.1007/s10653-024-01891-x

Ashraf, S.A., D. Mahmood, O.E. Abd-Elmoneim, A.J. Siddiqui, M.I. Khan, F. Ashfaq and M. Adnan. 2023. Exposure to pesticide residues in honey and its potential cancer risk assessment. Food Chem. Toxicol., 114014. https://doi.org/10.1016/j.fct.2023.114014

Balali, G.I., D.D. Yar, V.G.A. Dela and P. Adjei-Kusi. 2020. Microbial contamination, an increasing threat to the consumption of fresh fruits and vegetables in today's world. Int. J. Microbiol., 2020(1): 3029295. https://doi.org/10.1155/2020/3029295

Banerjee, S., S. Mitra, M. Velhal, V. Desmukh and B. Ghosh. 2021. Impact of agrochemicals on the environment and human health: The concerns and remedies. Int. J. Exp. Res. Rev., 26: 125-140. https://doi.org/10.52756/ijerr.2021.v26.010

Batool, Z., M.A. Riaz., S. Sayed., M.Z. Majeed., S. Ahmed and S. Ullah. 2022. *In vitro* synergy of entomopathogenic fungi and differential-chemistry insecticides against armyworm *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae). Int. J. Tropic. Insect Sci., 42(2): 1997-2006. https://doi.org/10.1007/s42690-022-00751-4

Bhawan, F., 2022. Guidance document and standard operating procedures for fixation of maximum residue limits (MRLs) of pesticides in food commodities. India: Food Safety and Standards Authority of India (FSSAI).

Ch, R., N.V. Karnati, E.C. Pinjala and C. Kothapalli. 2023. Ensuring privacy preservation for various plants multi-product disease detection and pesticides recommendation data using inception V3. SN Compt. Sci., 5(1): 6. https://doi.org/10.1007/s42979-023-02345-4

Chowdhury, F. and T. Choden. 2023. Infertility of women in focus: Risk factors and predictive outcome among women diagnosed with PCOS of Bangladesh (Doctoral dissertation, Brac University).

del Mar Gómez-Ramos, M., C. Nannou, M.J.M. Bueno, A. Goday, M. Murcia-Morales, C. Ferrer and A.R. Fernández-Alba. 2020. Pesticide residues evaluation of organic crops. A critical appraisal. Food. Chem. X., 5: 100079. https://doi.org/10.1016/j.fochx.2020.100079

Desneux, N., A. Decourtye and J.M. Delpuech. 2007. The sublethal effects of pesticides on beneficial arthropods. Annu. Rev. Entomol., 52(1): 81-106. https://doi.org/10.1146/annurev.ento.52.110405.091440

Donham, K.J. and A. Thelin. 2016. Health effects of agricultural pesticides. Agric. Med. Rural Occup. Environ. Health Saf. Prev., pp. 205. https://doi.org/10.1002/9781118647356.ch6

Ghosal, A., 2022. Management guide of sucking insect pest. In: Insecticides in pest control-impact, challenges and strategies. IntechOpen. https://doi.org/10.5772/intechopen.108599

Gulzar, M.W., R. Maqsood, H. Abbas, M. Manzoor, M. Suleman, H.A. Bajwa and N. Aslam. 2024. Use of insecticides and their impact on viral diseases in humans, animals and environment. Hosts Viruses, 11: 64-77. https://doi.org/10.17582/journal.hv/2024/11.64.77

Gupta, S. and A.K. Tripathi. 2024. Fruit and vegetable disease detection and classification: Recent trends, challenges, and future opportunities. Eng. Appl. Artif. Intell., 133: 108260. https://doi.org/10.1016/j.engappai.2024.108260

Haq, I.U., M.K. Sarwar, A. Faraz and M.Z. Latif. 2020. Synthetic chemicals: Major component of plant disease management. Plant Dis. Manage. Strat. Sustain. Agric. Tradit. Mod. Approaches., pp. 53-81. https://doi.org/10.1007/978-3-030-35955-3_4

Hashimi, M.H., R. Hashimi and Q. Ryan. 2020. Toxic effects of pesticides on humans, plants, animals, pollinators and beneficial organisms. J. Asian Plant Res., 5(4): 37-47. https://doi.org/10.9734/aprj/2020/v5i430114

Iqbal, Q., A.I. Durrani, S. Rubab, I. Liaqat and M.M. Hassan. 2023. Detection and estimation of pesticides in seasonal fruits and vegetables. Hamdard Med., 66(1): 36-48.

Kalyabina, V.P., E.N. Esimbekova., K.V. Kopylova and V.A. Kratasyuk. 2021. Pesticides: formulants, distribution pathways and effects on human health. A review. Toxicol. Rep., 8: 1179-1192. https://doi.org/10.1016/j.toxrep.2021.06.004

Kamalesh, T., P.S. Kumar and G. Rangasamy. 2023. An insights of organochlorine pesticides categories, properties, eco-toxicity and new developments in bioremediation process. Environ. Poll., pp. 122114. https://doi.org/10.1016/j.envpol.2023.122114

Kaur, R., D. Choudhary, S. Bali, S.S. Bandral, V. Singh, M.A. Ahmad and B. Chandrasekaran. 2024. Pesticides: An alarming detrimental to health and environment. Sci. Total Environ., pp. 170113. https://doi.org/10.1016/j.scitotenv.2024.170113

Khalil, M., S. Noor., Z. Ahmad and F. Ahmad. 2023. Fate of Pakistani exported mango due to its toxicity (heavy metals, pesticides, and other toxic organic components). J. Appl. Organomet. Chem., 3(2): 86-107.

Lee, G.H. and K.C. Choi. 2020. Adverse effects of pesticides on the functions of immune system. Comp. Biochem. Physiol. Toxicol. Pharmacol., 235: 108789. https://doi.org/10.1016/j.cbpc.2020.108789

Maggi, F., F.H. Tang and F.N. Tubiello. 2023. Agricultural pesticide land budget and river discharge to oceans. Nature, 620(7976): 1013-1017. https://doi.org/10.1038/s41586-023-06296-x

Mahawer, S.K., H. Karakoti, P. Bargali, R. Kumar, P. Koli, O. Prakash and M.K. Chitara. 2024. An introduction to biorational pest control agents. Biorat Biopestic. Pest Manage., pp. 1. https://doi.org/10.1515/9783111204819-001

Majeed, M.Z., M. Usman, L.Y. Feng, H. Aitzaz, F. Kaneez, T. Nazir and M. Abbas. 2025. Rotational use of insecticides: Elucidating modes of action of contemporary synthetic insecticides. Pak. J. Zool., (accepted manuscript).

Majeed, M.Z., M.I. Ullah, D. Hussain, M. Luqman, M. Qasim, G. Yousaf and M. Zeeshan. 2021. Laboratory evaluation of selected differential chemistry synthetic insecticides against some economically important insect pests. Pak. J. Agric. Res., 34(4). https://doi.org/10.17582/journal.pjar/2021/34.4.878.888

Mandal, S., R. Poi, D.K. Hazra, I. Ansary, S. Bhattacharyya and R. Karmakar. 2023. Review of extraction and detection techniques for the analysis of pesticide residues in fruits to evaluate food safety and make legislative decisions: Challenges and anticipations. J. Chromatogr. B., 1215: 123587. https://doi.org/10.1016/j.jchromb.2022.123587

Mojisola, A., B. Toyin and S.I. Kemi. 2024. Assessment of health impact on agricultural workers and rural inhabitants exposed to pesticide in selected towns in southern region of Ekiti State, Nigeria. Int. J. Res. Sci. Innov., 11(4): 224-236. https://doi.org/10.51244/IJRSI.2024.1104017

Murali, K., M. Shetty and H.M. Gurung. 2023. Addressing food safety: Addressing the concerns with maximum residue levels. SSRN 4544631.

Najam, L. and T. Alam. 2023. Pesticides and their impacts: Benefits and hazards. Environ. Poll. Impact Plants. Apple Academic Press. pp. 19-68. https://doi.org/10.1201/9781003304210-2

Nguyen, T.T., C. Rosello, R. Bélanger and C. Ratti. 2020. Fate of residual pesticides in fruit and vegetable waste (FVW) processing. Foods, 9(10): 1468. https://doi.org/10.3390/foods9101468

Ofuya, T.I., A.I. Okunlola and G.N. Mbata. 2023. A review of insect pest management in vegetable crop production in Nigeria. Insects, 14(2): 111. https://doi.org/10.3390/insects14020111

Okrikata, E. and L.C. Nwosu. 2023. Heavy Metals and Pesticides as Hazardous Wastes and Strategies for Minimizing their Hazards. Int. J. Res. Publ. Rev., 2582: 7421.

Olisah, C., O.O. Okoh and A.I. Okoh. 2020. Occurrence of organochlorine pesticide residues in biological and environmental matrices in Africa: A two-decade review. Heliyon, 6(3). https://doi.org/10.1016/j.heliyon.2020.e03518

Ons, L., D. Bylemans, K. Thevissen and B.P. Cammue. 2020. Combining biocontrol agents with chemical fungicides for integrated plant fungal disease control. Microorganisms, 8(12): 1930. https://doi.org/10.3390/microorganisms8121930

Orwat, M., 2013. U-scout: An excellent resource for vegetable disease diagnosis. https://nwdistrict.ifas.ufl.edu/phag/2013/08/02/u-scout-an-excellent-resource-for-vegetable-disease-diagnosis/

Parthasarathy, S., P. Lakshmidevi, P. Yashodha and C. Gopalakrishnan. 2024. Pests Dis. Veg. Crops. CRC Press. https://doi.org/10.1201/9781003504146-2

Rajmohan, K.S., R. Chandrasekaran and S. Varjani. 2020. A review on occurrence of pesticides in environment and current technologies for their remediation and management. Indian J. Microbiol., 60(2): 125-138. https://doi.org/10.1007/s12088-019-00841-x

Rani, L., K. Thapa, N. Kanojia, N. Sharma, S. Singh, A.S. Grewal and J. Kaushal. 2021. An extensive review on the consequences of chemical pesticides on human health and environment. J. Clean. Prod., 283: 124657. https://doi.org/10.1016/j.jclepro.2020.124657

Rashid, S., W. Rashid, R.X.S. Tulcan and H. Huang. 2022. Use, exposure, and environmental impacts of pesticides in Pakistan: A critical review. Environ. Sci. Poll. Res., 29(29): 43675-43689. https://doi.org/10.1007/s11356-022-20164-7

Ray, S. and S.T. Shaju. 2023. Bioaccumulation of pesticides in fish resulting toxicities in humans through food chain and forensic aspects. Environ. Anal. Health Toxicol., 38. https://doi.org/10.5620/eaht.2023017

Rosell, G., C. Quero, J. Coll and A. Guerrero. 2008. Biorational insecticides in pest management. J. Pestic. Sci., 33(2): 103-121. https://doi.org/10.1584/jpestics.R08-01

Rotimi, O.A., T.D. Olawole, O.C. De Campos, I.B. Adelani and S.O. Rotimi. 2021. Bisphenol A in Africa: A review of environmental and biological levels. Sci. Total. Environ., 764: 142854. https://doi.org/10.1016/j.scitotenv.2020.142854

Saha, T., N. Chandran and B.C. Anu. 2020. Major insect pests of vegetable crops and their management. In: Sustain. Agric. Apple Academic Press. pp. 395-429. https://doi.org/10.1201/9780429325830-23

Said, T.O. and G.M. El-Zokm. 2024. Classifications, sources, and significant features of POPs in aquatic environment with special reference to dirty dozen. In Persis. Org. Poll. Aqua. Sys. Classific: Toxic. Remedi. Future. Cham: Springer Nature Switzerland. pp. 1-26. https://doi.org/10.1007/978-3-031-53341-9_1

Schmidt, W., M. Commeh, K. Olonade, G.L. Schiewer, D. Dodoo-Arhin, R. Dauda and A. Rogge. 2021. Sustainable circular value chains: From rural waste to feasible urban construction materials solutions. Dev. Built. Environ., 6: 100047. https://doi.org/10.1016/j.dibe.2021.100047

Shahid, M., A. Zaidi, M.S. Khan, A. Rizvi, S. Saif and B. Ahmed. 2017. Recent advances in management strategies of vegetable diseases. Microb. Strat. Veg. Prod., pp. 197-226. https://doi.org/10.1007/978-3-319-54401-4_9

Sheryar, A.S., B. Chaudhary, M. Azam, C.M. Ayub and M. Yaseen. 2022. Comparison of effects of different herbicides on NPK uptake, yield, and quality of Kinnow mandarin plants.

Ssemugabo, C., D. Guwatudde, J.C. Ssempebwa and A. Bradman. 2022. Pesticide residue trends in fruits and vegetables from farm to fork in Kampala metropolitan area, Uganda. A mixed methods study. Int. J. Environ. Res. Publ. Health, 19(3): 1350. https://doi.org/10.3390/ijerph19031350

Syed, J.H., A. Alamdar, A. Mohammad, K. Ahad, Z. Shabir, H. Ahmed and S.A.M.A.S. Eqani. 2014. Pesticide residues in fruits and vegetables from Pakistan: A review of the occurrence and associated human health risks. Environ. Sci. Poll. Res., 21: 13367-13393. https://doi.org/10.1007/s11356-014-3117-z

Tison, L., L. Beaumelle., K. Monceau and D. Thiéry. 2024. Transfer and bioaccumulation of pesticides in terrestrial arthropods and food webs: State of knowledge and perspectives for future research. Chemosphere, pp. 142036. https://doi.org/10.1016/j.chemosphere.2024.142036

Tonelli, F.M.P., V.M.S. Delgado, V. de Oliveira Lourenço, C.S. Silva, G. da Costa Pinto, B. Santinelli and F.C.P. Tonelli. 2024. Main organic pollutants and their risk to living beings. In Nanotechnol. Sens. Detect. Environ. Poll. Elsevier. pp. 39-52. https://doi.org/10.1016/B978-0-443-14118-8.00003-6

Upadhayay, J., M. Rana., V. Juyal., S.S. Bisht and R. Joshi. 2020. Impact of pesticide exposure and associated health effects. Pestic. Crop Prod. Physiol. Biochem. Acta, pp. 69-88. https://doi.org/10.1002/9781119432241.ch5

Verzeñassi, D., A. Vallini, F. Fernández, L. Ferrazini, M. Lasagna, A.J. Sosa and G.E. Hough. 2023. Cancer incidence and death rates in Argentine rural towns surrounded by pesticide-treated agricultural land. Clin. Epidemiol. Glob. Health, 20: 101239. https://doi.org/10.1016/j.cegh.2023.101239

Wakabayashi, K. and P. Böger. 2002. Target sites for herbicides: Entering the 21st century. Pest Manage. Sci. Pestic. Sci., 58(11): 1149-1154. https://doi.org/10.1002/ps.560

Wilen, C.A., D.L. Haver, M.L. Flint, P.M. Geisel and C.L. Unruh. 2006. Pesticides: Safe and effective use in the home and landscape. Oakland, CA: University of California Agriculture Natural Resources.

Yarkwan, B., T.O. Isaac, A. Okopi and S.C. Izah. 2024. Evidence of the toxic potentials of agrochemicals on human health and biodiversity: Carcinogens and mutagens. Food Saf. Qual. Global South. Singapore: Springer Nature Singapore. pp. 331-359. https://doi.org/10.1007/978-981-97-2428-4_11

Zhou, W., M. Li and V. Achal. 2024. A comprehensive review on environmental and human health impacts of chemical pesticide usage. Emerg. Contam., pp. 100410. https://doi.org/10.1016/j.emcon.2024.100410