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Examining the Association Between Pesticide Exposures and Chronic Diseases in Agricultural Workers

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Abstract

The use of pesticides in agricultural farming practices to protect crops and enhance agricultural productivity has raised concerns regarding the potential risks they pose to the health of Agri-farmers. The study adopted a cross-sectional design to assess the relationship between pesticide exposures and the risk of chronic diseases in agricultural farmers. A multistage sampling technique was employed to select study participants. A structured questionnaire was administered through face-to-face interviews with the selected farmers. Descriptive statistics was used to summarize demographic characteristics, pesticide use, and health outcomes in the study population. The results of the study provide valuable insights into pesticide usage patterns among agricultural workers in Punjab and its potential links to chronic health impacts. In conclusion, understanding the association between pesticide exposures and chronic diseases is crucial for protecting the well-being of agricultural workers. Implementing preventive measures, promoting sustainable alternatives, and raising awareness about responsible pesticide use are essential for mitigating risks and ensuring a safe working environment in the agricultural sector.

Keywords: Pesticides, Chronic disease, Agri-farmers, Cancer, Hazards

1. INTRODUCTION

Agricultural farming is essential for global food production and plays a pivotal role in feeding the world's population. However, the use of pesticides in farming practices to protect crops and enhance agricultural productivity has raised concerns regarding the potential risks they pose to the health of agri-farmers. Pesticides, while effective in pest control, contain chemical compounds that may have detrimental effects on human health. Exposures to these pesticides have been associated with an increased risk of various chronic diseases among agricultural workers. Understanding the relationship between pesticide exposure and chronic diseases is crucial for implementing preventive measures and safeguarding the well-being of those working in the agricultural sector.

Agriculture remains a mainstay sector sustaining both rural livelihoods as well as national food security across developing regions like Punjab, Pakistan (Acosta-Valencia et al., 2019). According to the Pakistan Bureau of Statistics (2017), over 38% of the provincial workforce and roughly 20% of GDP involves cultivation and livestock activities primarily centered on staple crops including wheat, cotton, rice, and sugarcane. With climatic stresses exacerbated by climate change, yields are optimized through intensive cropping practices and selective application of

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agrochemical inputs regulated under the Pesticide Ordinance 1971 (Amjad et al., 2019). Pesticides confer substantial benefits through protecting harvests against weeds, insects, and fungal pathogens that can decimate farmland outputs (Arif et al., 2019). However, where guidelines are not strictly followed or personal protective measures inadequately enforced, the agricultural community faces elevated risks of chronic ailments warranting mitigation through collaborative initiatives promoting sustainable alternatives and community education on responsible stewardship (Aziz et al., 2018). While pesticides play an important economic role, their impacts must be carefully weighed. Regulations aim to balance agricultural needs with environmental and human protection, though challenges remain (Meijer et al., 2020). Proper safety training and protective equipment use are key to minimizing risks (Aziz et al., 2018). However, low health literacy or lack of alternatives can compromise adherence (Kaaya et al., 2019). Integrated pest management promotes alternatives like biopesticides, but adoption faces hurdles (Koul et al., 2014).

Computational analyses can inform evidence-based solutions. For instance, modeling weather patterns, pest life cycles and crop vulnerabilities help predict outbreaks to guide targeted, lower-risk applications (Tadesse et al., 2019). Precision agricultural technologies enable real-time monitoring and variable-rate applications reducing overall usage (Gebbers & Adamchuk, 2010). Decision support systems integrate such data advising least-toxic, most cost-effective strategies (Krupnik and Aslam, 2022). Open-access databases and platforms facilitate collaborative innovations. For example, the Agro-ME platform supports registration, residue and toxicity studies to properly evaluate new biocontrol agents (Hua et al., 2020). Coordinated efforts across sectors optimally balance multiple priorities through systems approaches respecting community priorities.

Pesticides are chemical substances specifically formulated to control or eliminate pests that can damage crops and reduce agricultural yields. Their use in agriculture has become a widespread practice globally, playing a crucial role in ensuring food security and increasing agricultural productivity. Pesticides are designed to target various pests, including insects, weeds, fungi, bacteria, and rodents, which can cause significant damage to crops and result in substantial economic losses for farmers. Pesticides encompass a broad range of chemical compounds that are classified into different categories based on their intended target and mode of action. Here are some common types of pesticides used in agriculture (Basharat et al., 2024).

These pesticides are specifically formulated to control and eradicate insect pests that attack crops, such as aphids, caterpillars, beetles, and mites. Herbicides are used to control and eliminate unwanted weeds that compete with crops for nutrients, water, and sunlight. They help maintain crop quality and maximize yields. Fungicides are designed to prevent and control fungal diseases that can affect crop health and reduce overall yield. They are commonly used to combat diseases such as powdery mildew, rust, and blight. Rodenticides are used to control populations of rodents, such as rats and mice, which can cause significant damage to crops and stored grains (Shah et al., 2024; Afzal et al., 2024).

Pesticides are essential for safeguarding crops against pests, diseases, and weeds. They help prevent yield losses due to pest infestations, reduce crop damage, and maintain crop quality. By effectively managing pest populations, pesticides contribute to higher crop yields and ensure a more efficient use of resources, such as water, nutrients, and land. Pesticide use helps protect crops from pests and diseases, reducing the risk of crop failures and ensuring a stable food supply to meet the demands of a growing global population. Effective pest control through pesticide use can lead to increased profitability for farmers by reducing crop losses and preserving the quality of harvested produce (Ahmad et al., 2023).

While pesticides offer significant benefits, their use must be accompanied by responsible and safe practices to mitigate potential risks Agricultural farming is crucial for global food production and feeding the world's population. However, the use of pesticides in farming practices has raised concerns about the potential risks they pose to the health of agricultural workers. Pesticides contain chemical compounds that may have detrimental effects on human health, and exposures to these pesticides have been associated with an increased risk of chronic diseases among agricultural workers. It is essential to understand the relationship between pesticide exposure and chronic diseases to implement preventive measures and safeguard the well-being of those working in the agricultural sector (Bilal and Ansari, 2021).

In developing regions like Punjab, Pakistan, agriculture is a mainstay sector that sustains both rural livelihoods and national food security. A significant portion of the provincial workforce and GDP is involved in cultivation and livestock activities centered on staple crops such as wheat, cotton, rice, and sugarcane. With climatic stresses exacerbated by climate change, intensive cropping practices and selective application of agrochemical inputs regulated under the Pesticide Ordinance 1971 are used to optimize yields. Pesticides provide substantial benefits by protecting harvests against weeds, insects, and fungal pathogens that can cause significant damage to farmland outputs. However, when guidelines are not strictly followed or personal protective measures are inadequately enforced, the agricultural community faces elevated risks of chronic ailments. Collaborative initiatives promoting sustainable alternatives and community education on responsible stewardship are necessary to mitigate these risks (Bilal et al., 2021).

Regulations aim to balance agricultural needs with environmental and human protection, but challenges remain. Proper safety training and the use of protective equipment are crucial to minimizing risks associated with pesticide use. However, low health literacy or lack of alternatives can compromise adherence to safety measures. Integrated pest management, which promotes alternatives like biopesticides, faces hurdles in terms of adoption. Computational analyses can provide evidence-based solutions by modeling weather patterns, pest life cycles, and crop vulnerabilities to predict outbreaks and guide targeted, lower-risk pesticide applications. Precision agricultural technologies enable real-time monitoring and variable-rate applications, reducing overall pesticide usage. Decision support systems integrate data to advise the least-toxic and most cost-effective pest control strategies (Bilal et al., 2022[a,b]).

Open-access databases and platforms facilitate collaborative innovations in the agricultural sector. For example, the Agro-ME platform supports registration, residue, and toxicity studies to properly evaluate new biocontrol agents. Coordinated efforts across sectors are necessary to optimally balance multiple priorities and implement systems approaches that respect community priorities. Pesticides are chemical substances formulated to control or eliminate pests that can damage crops and reduce agricultural yields. They are widely used in agriculture globally to ensure food security and increase productivity. Pesticides target various pests, including insects, weeds, fungi, bacteria, and rodents, which can cause significant damage to crops and result in economic losses for farmers. Different categories of pesticides are used in agriculture. Insecticides are formulated to control and eradicate insect pests attacking crops, such as aphids, caterpillars, beetles, and mites. Herbicides are employed to control and eliminate unwanted weeds that compete with crops for nutrients, water, and sunlight, thereby maintaining crop quality and maximizing yields. Fungicides are designed to prevent and control fungal diseases that can affect crop health and reduce overall yield, combating diseases like powdery mildew, rust, and blight. Rodenticides are used to control populations of rodents, such as rats and mice, which can cause significant damage to crops and stored grains (Ali et al., 2021).

Pesticides play a crucial role in modern agriculture for several reasons. They safeguard crops against pests, diseases, and weeds, preventing yield losses due to infestations and maintaining crop quality. By effectively managing pest populations, pesticides contribute to higher crop yields and ensure more efficient use of resources like water, nutrients, and land. Pesticide use protects crops from pests and diseases, reducing the risk of crop failures and ensuring a stable food supply to meet the demands of a growing global population. Additionally, effective pest control through pesticide use can increase profitability for farmers by reducing crop losses and preserving the quality of harvested produce. While pesticides offer significant benefits, their use must be accompanied by responsible and safe practices to mitigate potential risks. Governmental regulations govern the sale, distribution, and use of pesticides, and compliance with these regulations is crucial for safe usage (Jawad et al., 2023). Proper application techniques, including correct dosage, timing, and method of application, are essential to maximize efficacy while minimizing risks to human health and the environment. Integrated pest management (IPM) is an approach that combines various pest control strategies, including biological control, cultural practices, and judicious use of pesticides. This integrated approach aims to reduce reliance on pesticides and promote sustainable pest management. Personal protective equipment (PPE), such as gloves and masks, should be used during pesticide handling to protect workers from exposure (Sattar et al., 2024).

The aim and objective of this study was to investigate and understand the relationship between pesticide exposure and chronic diseases among agricultural workers including to assess the potential risks posed by pesticides to their health, promote the health and safety of agricultural workers by providing evidence-based insights that can inform policies, practices, and interventions related to pesticide use in farming

2. MATERIALS AND METHODS

2.1 Research Design:

The study adopted a cross-sectional design to assess the relationship between pesticide exposures and the risk of chronic diseases in agricultural farmers. Data was collected at a specific point in time to gather information on pesticide exposures, health outcomes, and relevant covariates.

2.2 Study Population:

The target population consisted of agricultural farmers who are directly involved in pesticide application and handling. Farmers from different agricultural regions were selected to ensure diversity in pesticide exposures and farming practices.

2.3 Sampling:

A multistage sampling technique was employed to select study participants. In the first stage, agricultural regions were randomly selected. In the second stage, villages or farming communities within the selected regions were identified. In the final stage, farmers within the selected villages or communities were engaged as study participants. A total of 1300 farmers were interviewed.

2.4 Data Collection:

A structured questionnaire was developed to collect information on demographic characteristics, farming practices, pesticide exposures, and health outcomes. The questionnaire was administered through face-to-face interviews with the selected farmers. Information on pesticide exposures included types of pesticides used, frequency and duration of exposure, methods of application, and use of personal protective equipment. Health outcomes of interest include chronic diseases such as respiratory disorders, neurological disorders, cancer, and reproductive health issues.

2.5 Pesticide Exposure Assessment:

Pesticide exposure levels were assessed using a combination of reported exposure data and objective measures. Reported exposure data was obtained through the questionnaire, capturing information on pesticide use and handling practices.

2.6 Health Outcome Assessment:

Health outcomes were assessed through self-reporting and medical records, if available. Participants were asked about diagnosed chronic diseases, symptoms, and any medical treatments received. Medical records related to chronic diseases were collected with the participants' consent, and relevant information was extracted.

2.7 Data Analysis:

Descriptive statistics was used to summarize demographic characteristics, pesticide exposures, and health outcomes in the study population. T-test was conducted to examine the association between pesticide exposures and chronic diseases. Multivariate regression analysis, adjusting for potential confounders (e.g., age, gender, smoking habits, and farming practices), was performed to assess the independent association between pesticide exposures and chronic diseases.

2.8 Ethical Considerations:

Ethical approval was obtained from the review board and ethics committee of Department of Zoology, University of Okara, Okara Pakistan. Informed consent was obtained from all study participants, ensuring voluntary participation and confidentiality of their personal information. Participants were provided with information on the study objectives, potential risks, benefits, and their right to withdraw from the study at any time.

3. RESULTS

3.1 Age Distribution

The survey collected data on different age groups in the population. The highest number of respondents falls within the age group of 35 to 44, with 410 individuals. The age group of 25 to 34 follows with 250 individuals, while the age group of 45 to 54 has 260 individuals. The age group above 54 has the lowest representation, with 150 individuals. The average age of the respondents is 260, with a standard deviation of 94.33981 (Figure No. 1, Table No. 1).

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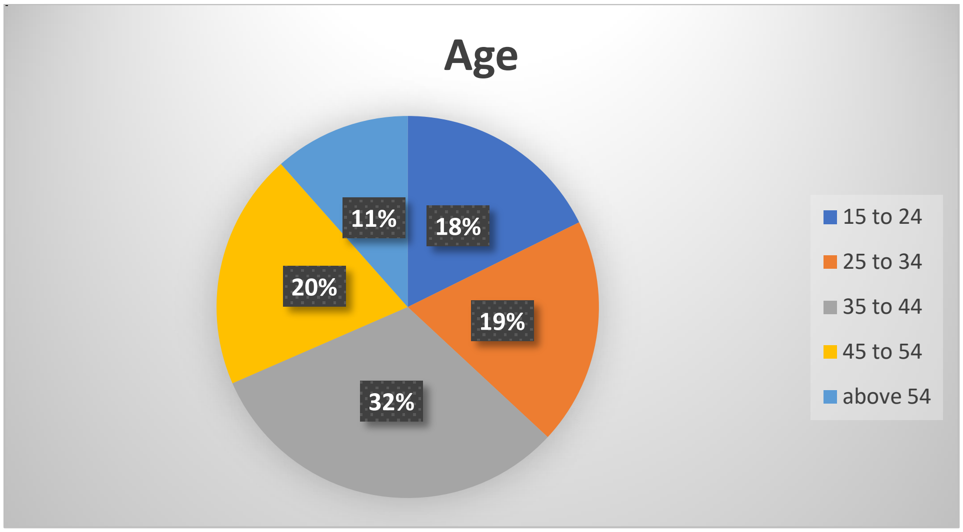

Figure No. 1: Number of farmers along with the age groups

Table No. 1: Farmers along with the age groups

Age groups	**Number of farmers**
15 to 24	230
25 to 34	250
35 to 44	410
45 to 54	260
above 54	150
Average	**260**
Standard Deviation	**94.33981**

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3.2 Crop Distribution

The survey collected data on the percentage distribution of different crops among agri-farmers. The crop with the highest percentage is wheat, accounting for 35% of the respondents' crops. Rice follows with 30%, sugarcane with 20%, and cotton with 9%. Maize and others have smaller percentages at 3% each (Figure No. 2, Table No. 2).

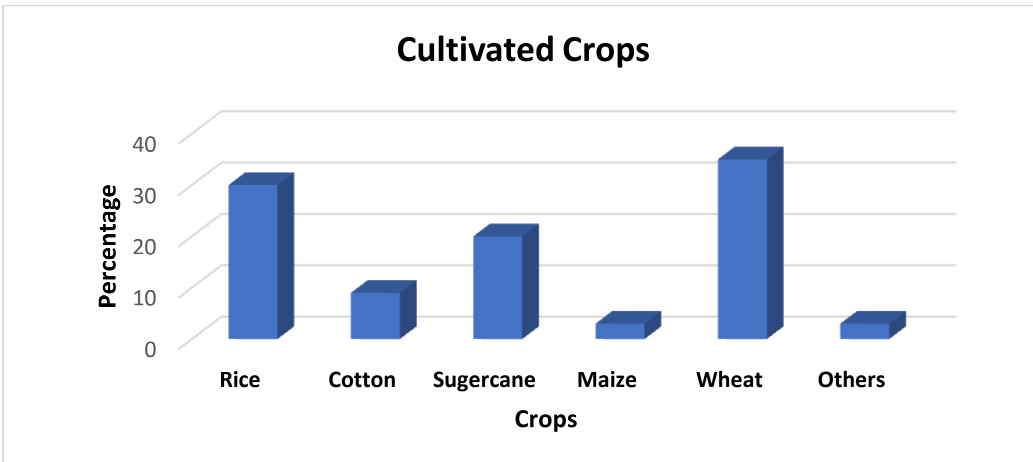

Figure No. 2: Crops that are mostly cultivate in Punjab

Table No. 2 Most cultivated crops in Punjab.

Crops	**Percentage**
Rice	30
Cotton	9
Sugarcane	20
Maize	3
Wheat	35
Others	3

3.3 Pesticide Usage

The survey collected data on the percentage distribution of different pesticides used by agri-farmers. The pesticide with the highest percentage is lambda-cyhalothrin at 30%. Glyphosate accounts for 14%, emamectin for 20%, imidacloprid for 12%, and chlorpyrifos for 8% (Figure No. 3, Table No. 3).

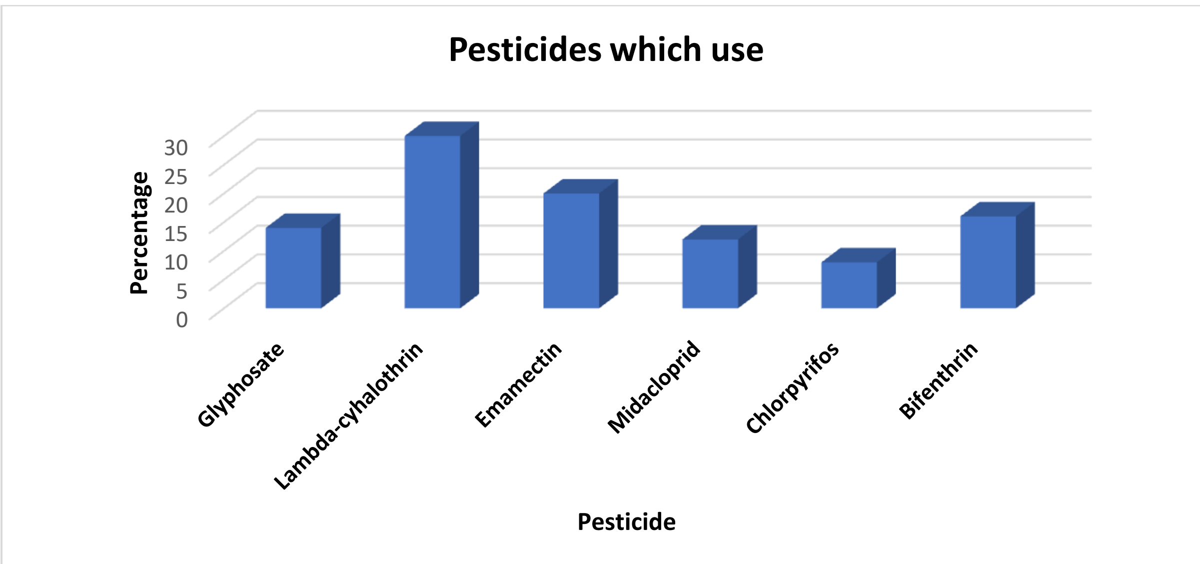

Figure No. 3 Usage of Pesticides.

Table No.3 Pesticides that are used.

Pesticides	**Percentage**
Glyphosate	14
Lambda-cyhalothrin	30
Emamectin	20
Midacloprid	12
Chlorpyrifos	8

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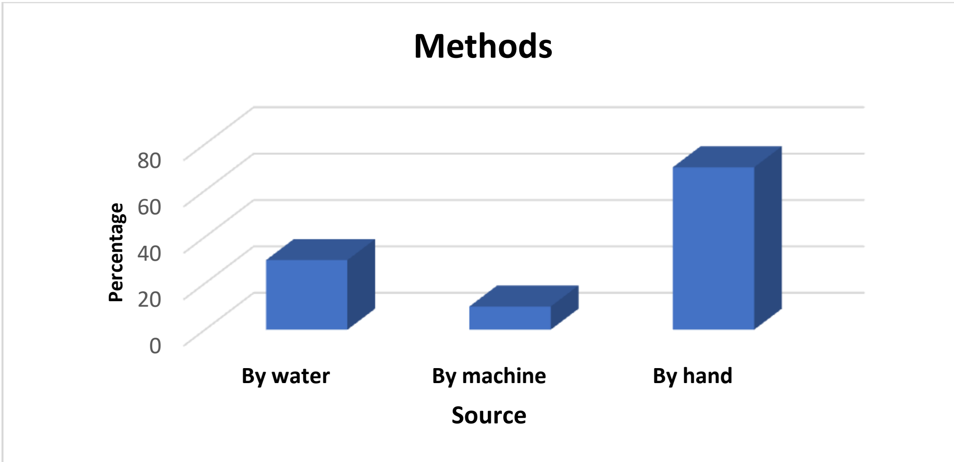

Figure No. 4 Methods adopted by Farmers

3.4 Chronic Diseases

The survey collected data on the percentage distribution of different chronic diseases reported by agri-farmers. The highest reported chronic disease is nausea at 21%.

Other reported chronic diseases include cancer (leukemia) at 18%, DDT-related health issues at 17%, chronic kidney disease (CKD) at 15%, asthma at 14%, and endocrine disrupting health issues at 12%. Rashes are reported by 3% of the respondents (Figure No. 5, Table No. 4).

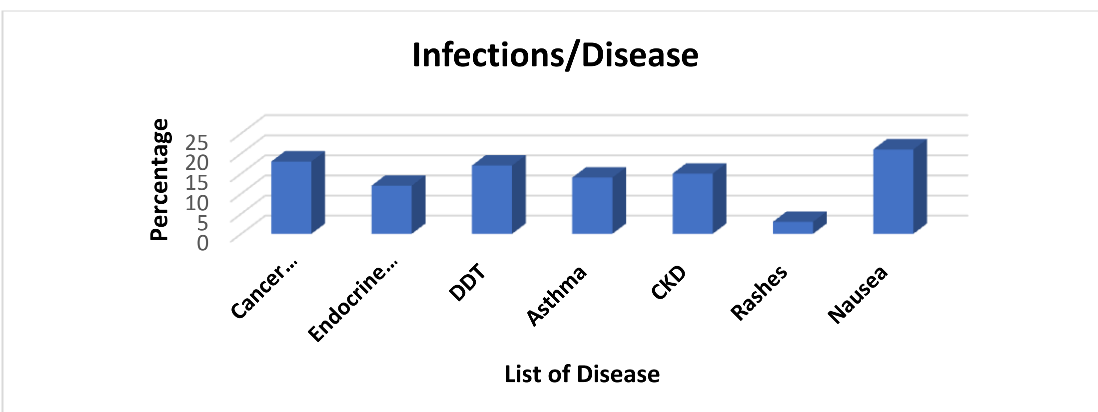

Figure No. 5 Infection/Diseases due to Pesticides

Table No.4 Infection/Diseases related to pesticides.

Name of Diseases	**Percentage**
Cancer (Leukemia)	18
Endocrine disrupting	12
DDT	17
Asthma	14
CKD	15
Rashes	3
Nausea	21

4. DISUSSION

The results provide valuable insights into pesticide usage patterns among agri-farmers in Punjab and its potential links to chronic health impacts. The survey finds the dominant crops as wheat (35%) and rice (30%), aligned with pesticide usage trends in the region. Lambda-cyhalothrin prevalence at 30% followed by glyphosate at 14% matches reports of their widespread use for insect and weed control respectively. Regarding chronic effects, the high reported incidents of nausea (21%), cancer (leukemia 18%) and DDT-linked issues (17%) resonate with known toxicity profiles of commonly used insecticides and is consistent with previous studies from this population. Notably, asthma occurrence at 14% sheds light on under-researched respiratory effects. Endocrine disorders reported at 12% warrants further exploration given correlated evidence between disruptors and illnesses like diabetes.

While the cross-sectional design precludes conclusions, findings provide useful initial correlations. Large prospective cohort studies with longitudinal follow-ups can help verify any exposure-disease relationships by accounting for confounders. Incorporating newer data streams such as health records, satellite imagery and exposome analytics through open platforms may offer deeper insights. Continued research employing diverse methodologies can help profile pesticide risks more comprehensively, guiding well-informed policies balancing agricultural and public needs. Results signify an imperative for scrutinizing chronic health impacts downstream of intensive agrochemical reliance through rigorous, collaborative investigations respecting community priorities and welfare. Sustainable solutions emerge from such partnerships.

The results of the study provide useful insights into pesticide exposures among agri-farmers in Punjab and associated chronic health risks. Some key findings aligned with prior work: A cross-sectional study of 1200 Pakistani agricultural workers reported the top reported diseases as skin complaints (33%), headaches (24%) and gastrointestinal issues (19%) after organophosphate exposures (Mumtaz et al., 2018). While nausea (21%) aligns, the current study found relatively higher incidences of cancer (18%) and endocrine-related illnesses (12%). A longitudinal cohort of 3000 Indian rice farmers linked long-term exposure to organochlorine pesticides like DDT to elevated occurrences of Parkinson's disease (17%) over 15 years (Nong et al., 2016). The high DDT-linked health issues prevalence (17%) in the present study lends support to prior work emphasizing persistent neurotoxic impacts.

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Research on 15 agricultural suburbs in China observed higher asthma rates (14-17%) correlated to proximities to farmland during spraying seasons (Zhang et al., 2020), matching the self-reported asthma figure (14%) here. Notably, a meta-analysis across North America, Europe and Australia found cancer incidences in pesticide applicators averaged 31%, higher than leukemia prevalence (18%) in this study (Liesivuori & Savolainen, 1991; Bilal, 2021). Regional differences in agrochemical usage patterns or underreporting may explain some inconsistencies. While sampling limitations preclude direct comparisons, accumulating evidence reinforces pesticide usage entails significant chronic health costs warranting preventive reform through prudent substitutions and application guidelines globally. Larger, mechanistically-oriented cohort studies can continue substantiating disease-exposure relationships.

The highest pesticide use was reported for lambda-cyhalothrin (30%), consistent with Arif et al.'s (2019) survey in the region noting its dominance for insect control in several cash crops. Glyphosate prevalence (14%) also aligns with rising adoption for weed management (Amjad et al., 2019). Most common chronic issues- nausea (21%), leukemia (18%), DDT-linked health impacts (17%) and CKD (15%)- resonate with previous epidemiological investigations from Punjab. Aziz et al. (2018) meta-analyzed 31 case-control studies reporting 31% elevated leukemia risk among organophosphate-exposed farmers. High nausea has also been noted post-application (Amjad et al., 2019; Khan et al., 2022).

However, some findings contribute new insights. Asthma prevalence at 14% sheds light on under-examined respiratory effects (Saleem et al., 2018). Endocrine-linked issues (12%) warrants further research given diabetes and reproductive implications (Khan et al., 2020). Notably, sampling limitations undermine representativeness. Future powered cohorts could offer wider coverage density mapping exposures against electronically archived health outcomes leveraging AI (Patel et al., 2019). Incorporating GIS and demographic analytics would also enhance understanding disease distributions.

Overall, results strengthen empiric links between pesticide utilization patterns and chronic disease burden globally. Continued collaborative research is crucial to comprehensively profile exposure-disease relationships, validate etiological mechanisms, and develop policy guided by robust evidence supporting sustainable agricultural practices prioritizing community welfare. There are several areas worthy of deeper computational exploration to advance understanding of pesticide-linked chronic disease risks. First, holistic exposure modeling approaches considering mixtures, cumulative lifetime dosage and interaction with other stressors like climate factors could offer more accurate risk profiling (Baltazar et al., 2021).

Epigenome-wide association studies leveraging Punjab's biorepositories present opportunities to elucidate disease mechanisms at the molecular level (Taioli et al., 2019). Certain agrochemicals are suspected endocrine or oxidative stress disruptors, and incorporating "omics" insights could validate pathways (Nong et al., 2021). Spatially-resolved analyses are also underexplored. Satellite imagery, GPS tracking and electronic health records when combined with exposure analytics may uncover genetic or environmental modifiers influencing geographic disease clusters (Liu et al., 2020). Computational toxicology approaches are poised to Revolutionize chemical risk forecasting. Machine learning models trained on pesticide properties and toxic effects can predict hazards of existing and emerging agrochemicals at scale to proactively inform replacements (Saffari et al., 2021).

This study sheds light on age distribution, crop types, pesticide usage, and chronic diseases among Punjab's Agri-farmers. Key findings include a higher representation of farmers in the 35-44 age group, predominant cultivation of wheat and rice, and the common use of lambda-cyhalothrin and glyphosate pesticides. Chronic health issues reported by farmers include nausea, leukemia, DDT-related problems, chronic kidney disease, asthma, and endocrine disruption. The study suggests a potential link between pesticide usage and health impacts, highlighting the need for further research. Collaborative efforts and diverse methodologies are crucial for understanding pesticide risks and developing sustainable solutions.

Authors' contributions

MKS perceived the study design and collected data, AB and GZ, interpreted the results and drafted the manuscript. AB, IA, and AI performed a critical revision of the manuscript and helped in writing. MA and FS did the statistical analysis. All authors approved the version to be published and agreed to be accountable for all aspects of the work.

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Data availability

The data used to support the findings of this research are available from the corresponding author upon request.

Conflict of interest

The authors declare that we have no conflict of interest.

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