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REVIEW ARTICLE

Do farmers overuse pesticides? A critical review from their perspective

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Abstract

Excessive pesticide use by farmers is a critical issue influenced by psychological, behavioural, socioeconomic and regulatory factors. This study employs a bibliometric analysis and systematic review to assess key factors driving excessive pesticide use, focusing on research trends and behavioural influences. A total of 43 peer-reviewed articles from the Scopus database (2000-2024) were selected using PRISMA methodology, based on relevance to psychological and behavioural factors influencing pesticide use. Findings indicate that peer influence, farmers' risk perceptions, financial constraints and limited awareness of sustainable alternatives like Integrated Pest Management (IPM) contribute significantly to pesticide overuse. Moreover, reliance on chemical pesticides, psychological stress from market uncertainties and risk-averse decision-making further contribute to overuse, highlighting the need for targeted interventions. Bibliometric analysis highlights a fragmented research landscape with limited interdisciplinary collaboration. China emerges as a leading contributor, demonstrating a strong national research focus with a significant number of studies conducted by Chinese researchers and institutions, while other countries show varying levels of cooperative engagement. This study underscores the importance of enhancing farmers' awareness of non-chemical pest control methods, strengthening regulatory frameworks and fostering community-led initiatives. Future research should prioritise the exploration of education, economic conditions and social norms to better understand their impact on pesticide use behaviours. These insights aim to inform policy and interventions that promote sustainable pest management while balancing agricultural productivity with environmental and public health priorities.

Keywords: farmer behaviour; Integrated Pest Management; pesticide overuse; psychological factors; sustainability

Introduction

Pesticides play an important role in modern agriculture, helping to manage pests, weeds and plant diseases, thereby improving crop yield and food quality. Annually, over 4 million tons of pesticides are used in agriculture, underscoring their role in ensuring food security for a population expected to reach 9 billion by 2050 (1). However, the extensive and inappropriate use of pesticides leads to serious concerns, including human health risks, environmental contamination and disruption in agricultural ecosystems, such as biodiversity loss and soil degradation (2, 3). Pesticide consumption varies across regions, with China being the world's largest consumer due to its intensive agricultural practices and high demand for food production (4). Limited expertise, budgetary constraints and limited access to agricultural advisory services are the main causes of high reliance on pesticides in many countries (5). Another important concern associated with excessive pesticide use is the risk to humans (6, 7). Chronic exposure to residues that exceed permissible levels has been linked to major health consequences, especially in areas without good monitoring systems (8, 9). Although international standards such as the FAO's and WHO's Maximum Residual Limits (MRLs) exist, many nations struggle to implement them (1).

Addressing excessive pesticide use requires an in-depth understanding of the underlying behavioural, economic and regulatory factors driving farmers' decisions. Research shows that farmers frequently place more importance on immediate advantages like increased yields and financial profits than on the long-term dangers of pesticide abuse (10, 11). Key drivers of pesticide overuse include risk aversion, profit-driven decision-making and inadequate knowledge of sustainable alternatives (12–15). Furthermore, social effects such as peer behaviour, advice and community standards play an important role in determining farmers' decisions (16, 17). Pesticide use is further influenced by socioeconomic and demographic characteristics. Factors like gender, farm size, income and education frequently influence decisions on the use of pesticides (18, 19). For instance, financial limitations may prevent farmers in lower-income areas from accessing safer substitutes and training, sustaining their dependence on chemical pesticides (20). In contrast, areas with more robust regulatory structures and advanced technology are better able to support environmentally friendly pest control methods like IPM (21).

Researchers and policymakers are looking into several approaches to address these issues. Advancements in biotechnology and sustainable pest management practices offer effective solutions to mitigate the negative impacts of pesticide use while maintaining agricultural productivity (21, 22). The effectiveness of these strategies, however, relies on discussing the psychological and behavioural issues that contribute to farmers' dependence on pesticides. For example, the intention of farmers to adopt sustainable techniques is largely dependent on their risk perceptions, sense of social responsibility, as well as understanding its effects on the ecosystem (23). This article focuses on the psychological and behavioural variables that contribute to farmers' excessive pesticide use. This study aims to perform a bibliometric analysis to map research trends, key contributors and interdisciplinary collaborations in the field of pesticide overuse and it critically examines the psychological and behavioural factors driving excessive pesticide use among farmers. A comprehensive understanding of these factors is essential for designing pesticide management strategies that balance agricultural productivity with environmental and public health concerns.

Table 1. Shows the combination of keywords used and number of publications from databases

Database	Keywords	Number of articles
Scopus	"Pesticide usage" AND "behaviour" AND "farmers" OR "perception" AND "pesticide" AND "agricultural workers"	2624

Methodology

This study uses a bibliometric analysis and literature review to investigate the psychological and behavioural aspects of pesticide overuse in a comprehensive manner. Data was gathered methodically from the Scopus database, which is well-known for having a large collection of peer-reviewed publications. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) criteria were used to ensure repeatability and transparency in the selection of pertinent research. R Studio and VOS viewer, an effective tool for data visualisation, were used to conduct a bibliometric analysis. This analysis made it easier to identify important themes, authors and trends in the literature on pesticide overuse. Table 1 presents the list of keywords used in the bibliometric analysis to identify the most frequently studied topics and to further narrow down the search. To ensure the relevance and quality of the included studies, specific inclusion and exclusion criteria were applied, as outlined in Table 2. Studies were selected based on their focus on the psychological and behavioural aspects of pesticide use, with priority given to peer-reviewed articles published in reputable journals. After thorough screening, 43 articles were selected for inclusion, offering valuable insights into the factors that drive pesticide overuse behaviour.

The PRISMA flowchart, as illustrated in Fig. 1, provides an organised method for finding, evaluating and choosing studies for a review. The Scopus database was first searched with particular phrases like "pesticide usage", "behaviour", "farmers", "perception", "pesticide" and "agricultural workers" to yield 2624 records. The dataset was reduced to 224 records for additional analysis in the first step by excluding 2400 records based on predetermined criteria, such as publication date, subject relevancy, document type, language and stage of publishing. After that, the titles,

Table 2. Represents the inclusion and exclusion criteria

Particulars	Inclusion criteria	Exclusion criteria
Range	2000-2024	Before 2000
Subject area	Environmental Science Agricultural and Biological Sciences Multidisciplinary Social Sciences Psychology	Medicine Biochemistry, Genetics and Molecular Biology Pharmacology, Toxicology and Pharmaceutics Energy Veterinary Immunology and Microbiology Engineering Earth and Planetary Sciences Computer Science Chemical Engineering Arts and Humanities
Document type	Article	Review Conference paper Note Retracted
Language	English	Portuguese Spanish Chinese German
Source type	Journal	Conference proceeding Trade journal Book series
Publication stage	Final	
Open access	All open access	Gold Green Hybrid gold Bronze

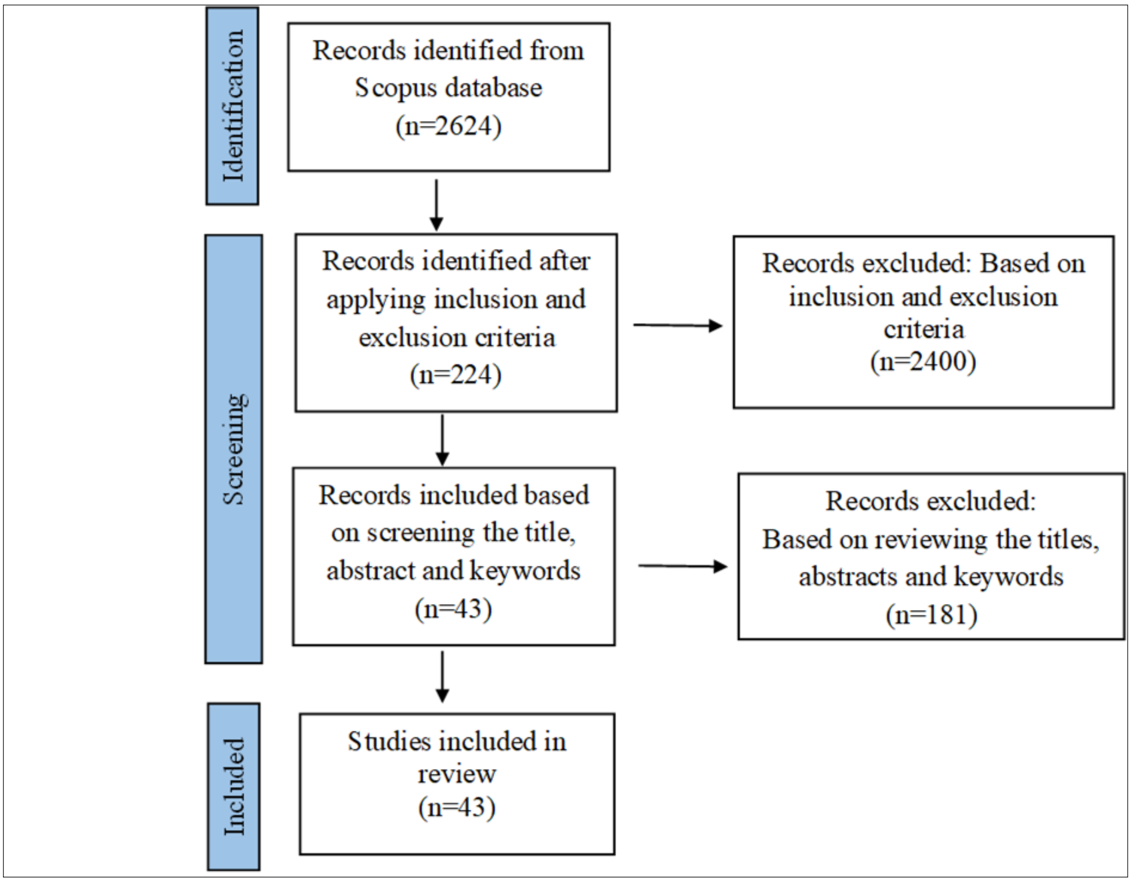

Fig. 1. PRISMA flowchart.

abstracts and keywords of the records were carefully examined. A total of 43 studies met the requirements for inclusion in the final review after 181 records that did not satisfy the necessary standards or relevance were excluded as a result of this process.

Results and Discussion

Countries scientific production

Fig. 2 illustrates the distribution of scientific publications on pesticide use, revealing significant disparities in research contributions among countries. China (36 articles) leads global research on pesticide use, driven by the extensive agriculture sector, increasing concern over pesticide-related environmental and health risks and a strong research focus on IPM and alternative pest control strategies. South Africa and the USA (13 articles each) have also made notable contributions, focusing on sustainable farming practices, environmental impacts of pesticides and regulatory measures for pesticide control. Nigeria (12 articles), along with Australia, Ghana, Kenya and Morocco (each with 10 articles), exhibit moderate research activity. Their studies primarily focus on pesticide safety, farmer decision-making behaviours and challenges related to pesticide resistance in crops and pests. The Netherlands and Pakistan each contribute 9 articles. The Netherlands' research focus aligns with its stringent pesticide regulations, whereas Pakistan's growing research interest may reflect increasing concerns

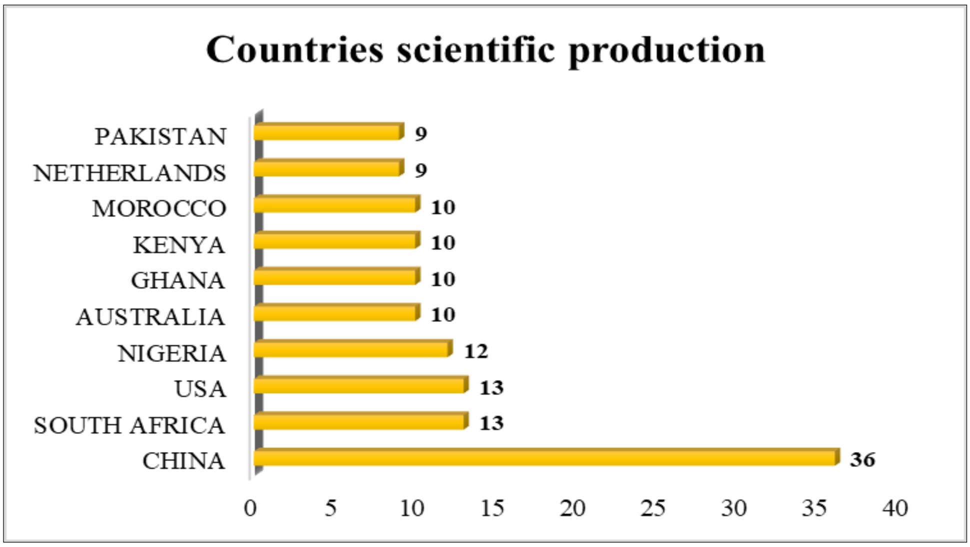

Fig. 2. Representation of the countries' scientific production.

over pesticide use and its impact on agriculture and public health. This uneven research distribution suggests that while some nations lead in pesticide-related studies, others, despite their significant agricultural output, remain underrepresented in scientific literature. For instance, major agricultural producers in South Asia and Sub-Saharan Africa have relatively low research contributions. A lack of comprehensive research in developing countries highlights the need for more international collaboration to better understand pesticide application from farmers' perspectives across varied farming systems.

Author's citation network

The scientific production across various countries, reflecting their contributions to global research, is depicted in Fig. 3. This visualisation identifies key researchers based on their citation impact and collaborative networks. Each node (circle) represents an author, while connecting lines indicate citation relationships, demonstrating how researchers reference each other's work. An author's impact in this field of study is indicated by the size of each node, which reflects the total number of citations they have received. Each colour represents a group of authors who are connected because they work on similar topics, use similar methods, or are from the same region, leading them to reference each other's work more frequently. Fig. 3 identifies Cecchini, Massimo as a key researcher, with multiple citations indicating their strong influence in pesticide research. Other influential researchers in the network include Bedini, Roberto; Ahmed, Nur; and Nasrin, Sultana who also have important links, suggesting that their work is frequently cited. The existence of several clusters, each represented by a different colour, emphasises multidisciplinary collaboration, with authors from a range of fields including toxicology, environmental studies, health sciences and agriculture contributing to the knowledge of pesticide overuse. The network reflects a global research effort, with contributing authors from many universities and nations.

Co-authorship organisation networks

Fig. 4 depicts a network of co-authorship organisations demonstrating collaboration among different organisations conducting research that analyses the farmers' behaviour related to pesticide usage. While the connecting lines indicate co-authorship ties and each node represents an organisation. The size of the nodes indicates each institution's proportional contribution, where larger nodes indicate organisations involved in a higher number of partnerships within the research network. The co-authorship network highlights the interdisciplinary nature

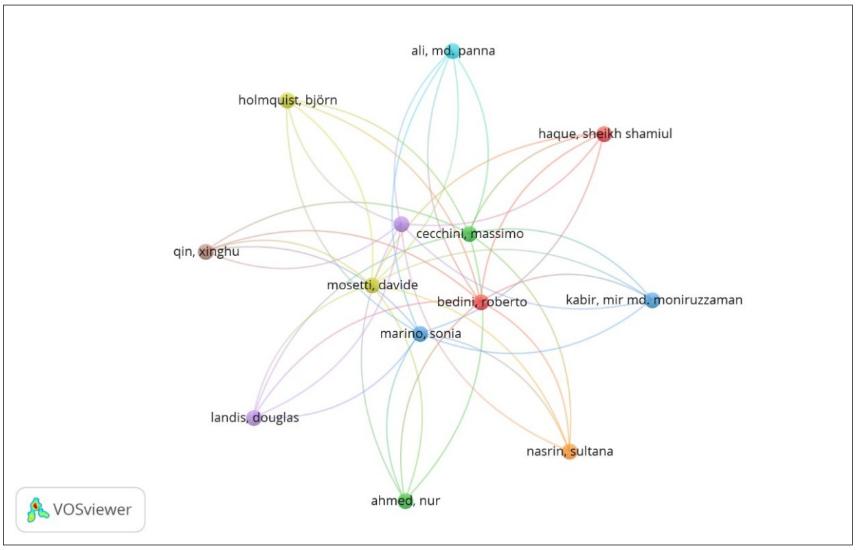

Fig. 3. Authors' citation network.

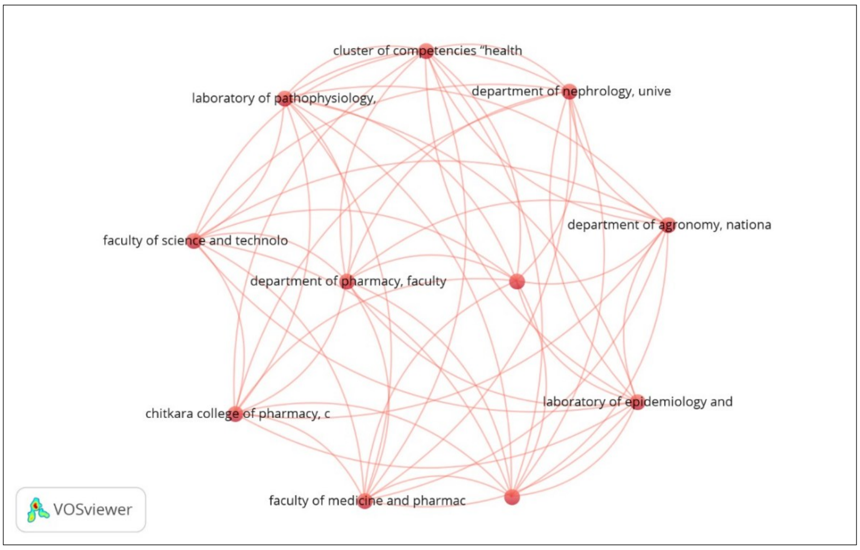

Fig. 4. Co-authorship organization networks.

of pesticide application research, with strong collaboration among institutions specialising in agronomy, pharmacy, medicine and epidemiology, each contributing unique perspectives on pesticide impacts and management. Key institutions, such as medical, pharmacy and scientific universities, appear to play a vital role in developing research in this subject. Within the network, the density of linkages indicates a long-standing international research collaboration on pesticide use and its effects. Organisations with numerous strong links act as hubs, playing an important role in knowledge sharing and scientific contributions. The inclusion of nephrology and epidemiology institutions indicates an increasing worry about pesticide overuse's health effects, in addition to its agricultural significance. The co-authorship network highlights the interdisciplinary nature of pesticide research, integrating expertise from agricultural, environmental and health sciences. This collaborative approach enriches the field by fostering a comprehensive understanding of pesticide usage patterns and their broader implications.

The findings from bibliometric analysis provide a detailed mapping of the research landscape, ensuring that the systematic review process covers all relevant studies. Together, these methods enable a more robust and informed approach to evaluating the factors influencing pesticide overuse behaviour among farmers.

Psychological and behavioural factors for excessive pesticide usage

Behavioural norms & peer influence

Peer pressure has a significant impact on farmers' decisions about pesticide types and rates of application (24). Farmers mimic their peers' pesticide application techniques, which leads to the continuation of risky and excessive practices (25). Approximately 90% of farmers rely on personal experience or peer guidance rather than scientific information, reinforcing behaviours that lack critical examination (26). They rely on more experienced peers for direction and frequently obey commands without questioning procedures (22). Peer-driven norms are further reinforced by the fact that 91.4% of respondents consult shopkeepers rather than extension officials (27).

Pesticide retailers often encourage overuse, prioritising profit over efficacy (24). Despite possible risks and inefficiencies, a lot of farmers believe that the retailer's advice is the best for their crops. Decisions are also influenced by sales promotions and advertisements, which give marketing preference over technical advice (26). Extension agents may also use pesticides in the same way, which would encourage misuse (28). When extension agents fail to promote Integrated Pest Management (IPM) or safer options, communities become more chemically dependent. Additionally, agricultural social services often prioritise synthetic chemical pesticides over sustainable alternatives, discouraging the adoption of IPM (29).

The use of safer pesticides by farmers is also influenced by social networks and trust (30). A high level of trust in community standards discourages alternative pest control approaches, which reinforces its usage. Due to community acceptability, dangerous and unregulated pesticides are frequently used in some areas (31). As a result of this normalisation, risks are neglected in favour of immediate remedies (25). So, it is challenging to implement safer and more efficient pest management techniques because of this compliance, which upholds current pesticide usage standards.

Lack of knowledge and awareness

Farmers overuse pesticides due to uncertainty regarding precise dosages and application timing, believing that it assures increased yields. The common misunderstanding that "more is better" leads to the overuse of pesticides at levels above what is advised (24). This misunderstanding is fuelled by limited educational opportunities, which keep farmers from using best practices. The usage of pesticides is greatly influenced by education, as knowledgeable farmers make safer decisions. Farmers with greater education levels are more likely to grasp pesticide hazards and use safer ways, whereas farmers with lower education levels are unaware of best practices (30). Farmers use pesticides excessively owing to concerns about revenue stability and yield loss, which are sometimes caused by a lack of technical expertise (24). Due to a lack of technical expertise and formal instruction, many farmers utilise improper products or use pesticides at the wrong times (28).

Effectiveness is decreased by improper product selection and timing, which results in excessive chemical usage. Many farmers are unaware of the chemical makeup of pesticides and their effects on the environment and human health (32). Improper dose estimations due to a lack of information about recommended application rates result in excessive pesticide use (27). Many farmers frequently fail to read or interpret pesticide labels, safety instructions or application guidelines, resulting in increased usage (14). They unintentionally put themselves, workers and ecosystems in danger by continuing to use toxic pesticides without considering their long-term consequences. Pesticide overuse is made worse by reliance on chemical control techniques without investigation of mechanical or biological alternatives (32). Due to ignorance or lack of interest, sustainable options, including mechanical solutions and biological control, are still neglected, while chemical pesticides are the default choice. A substantial knowledge gap was highlighted by the fact that only 10% of farmers were aware of natural predators as biological pest control agents (26). Adoption of sustainable alternatives is slowed down by a lack of knowledge about organic farming and integrated pest management (IPM), which encourages the excessive use of conventional pesticides (29).

Risk perception

Pesticides are believed to protect crops and secure revenues, which encourages the use of excessive pesticides. Farmers are hesitant to lower application rates because they believe that pesticides are necessary to sustain good yields and profitability (24). Most farmers believe pesticides are essential to maintaining agricultural productivity, even in spite of health and environmental risks (13). Farmers continue to overuse pesticides despite being aware of their risks because they are worried about crop losses and pest infestations (33, 34). These misunderstanding disregards the dangers of pest resistance and environmental damage. Fears about short-term production overwhelm worries about sustainability. Concerns about pesticide resistance lead some farmers to increase application rates, believing that higher dosages compensate for lower efficacy (28). In order to handle resistance effectively, integrated pest management is required rather than increased pesticide use.

Instead of evaluating proper application methods, farmers incorrectly assume that higher doses help pest control, worsening its misuse (35). Almost 99% of farmers used pesticides without explicit targeting and spraying numerous times per week in response to perceived pest concerns (26). Regular applications are made because it is thought that regular spraying is required, even in situations where insect populations do not demand it. Fear of failing to fulfil market demands increases their reliance on pesticides. The market's demand for flawless produce drives excessive pesticide use for income crops like fruits and vegetables (31). Farmers are concerned about losing money if their crop does not match aesthetic standards.

Overconfidence in Pesticides

Farmers rely heavily on chemical control measures due to their belief that pesticides are the most effective method for pest management (24). This overreliance stems from the perception that pesticides provide immediate pest control solutions, often disregarding alternative methods. Farmers use pesticides more frequently than necessary because of their urgent need to protect crops in unpredictable market and weather conditions (27). Many farmers adopt a preventive overuse strategy, believing that pesticides provide complete protection against crop damage (25). Some farmers believe that better pest management results from spending more money on pesticides, thus, they correlate higher prices with greater efficacy. This misconception that higher spending on pesticides ensures better pest control further encourages excessive use (26). However, excessive spending typically leads to inefficient practices, environmental damage and pesticide resistance.

Studies have shown that mixing pesticides can result in negative reactions, decreased efficacy and environmental contamination. Despite this, many farmers still believe that combining pesticides enhances their effectiveness. Earlier research also proves that mixing different brands of pesticides does not increase their efficiency, refuting a popular myth (13). Farmers often use their own discretion when applying pesticides, which might result in overconfidence in their choices without adequate scientific support (27). Due to their self-confidence, some farmers disregard professional advice, which can lead to inappropriate application techniques, overuse and possible environmental and health risks. Some farmers overestimate the effectiveness of pesticide combinations, viewing them as the ultimate pest-control solution (34). This misconception discourages the adoption of sustainable alternatives like IPM, leading to frequent spraying and improper pesticide mixing.

Economic anxiety

Despite the environmental and human health consequences of pesticide overuse, farmers continue excessively due to concerns over financial loss from crop failure or fluctuating market prices. Farmers see pesticides as necessary investments to safeguard production and ensure quick returns. Farmers prioritise short-term financial advantages over sustainability due to economic uncertainties, which leads to an overuse of pesticides. Large-scale farmers are compelled to use pesticides often in order to maintain steady harvests. Because of worries about crop consistency and profitability, larger farms use more pesticides (24). Economically vulnerable farmers prioritise short-term production over long-term sustainability due to financial constraints (35). In areas with limited resources, illegal or unregistered pesticides are frequently utilised because of concerns about price (36). Although they are less expensive, unregulated pesticides can be dangerous. Farmers who are struggling financially might turn to these methods.

Strict quality standards for international markets drive excessive pesticide use, particularly among cash crop producers (34). Frequent pesticide treatments are necessary to meet quality standards because of market expectations for perfect produce, even though excessive use may have long-term adverse impacts. In order to prevent financial losses or insolvency, farmers are forced to maintain or increase pesticide applications due to a lack of market bargaining power (37). Adoption of alternative pest management techniques is hindered by financial limitations (30). Because it is thought to be more expensive and have unknown efficacy when compared with conventional pesticides, many farmers are hesitant to use them. Despite being aware of the risks of pesticide overuse, many farmers cannot adopt organic or integrated pest management practices due to financial constraints.

Resistance to change

Farmers strongly prefer traditional pesticide-based farming methods and often resist adopting safer alternatives, such as Integrated Pest Management (IPM) and organic farming (32). Crop protection has been achieved over the decades by long use of pesticides, which frequently results in resistance to change. Many farmers use traditional pesticides because they are well-known and have been shown to be effective. Farmers who are older and less educated are especially resistant to change, continuing to use traditional approaches rather than implementing modern, sustainable ones (38). Because of their extensive expertise with traditional ways, older farmers are frequently resistant to change. Farmers with limited education may lack confidence or knowledge in adopting new techniques, preferring familiar methods instead.

Fear of production losses is a common reason given by farmers who are reluctant to try new methods, which strengthens their resistance to change (39). The worry that new pest management techniques won't offer sufficient pest control and will result in lower yields is a significant concern. Farmers perceive the risks of using unfamiliar pest control methods as too high compared to the reliability of conventional pesticides. Their fear of yield loss further discourages them from adopting alternative pest management practices. Limited exposure to Integrated Pest Management (IPM) tactics leads to resistance to other pest control methods (40). IPM, which employs a variety of approaches such as biological controls and crop rotation, encounters resistance, since many farmers lack exposure or adequate training to execute it. Farmers frequently view IPM as complex and less successful than conventional pesticide treatments. Because of this unfamiliarity, people continue to use pesticides because they believe they are simpler and more dependable. Despite the availability of safer, more sustainable alternatives, this deeply rooted dependency on pesticides continues.

Six important elements that contribute to excessive pesticide use have been identified based on the literature. This analysis sheds light on the major factors contributing to pesticide overuse.

actors influencing excessive pesticide usage are shown in Fig. 5. Behavioural Norms & Peer Influence (30%) is the most important component, showing that farmers are heavily influenced by their peers and community practices, resulting in habitual pesticide overuse. Economic anxiety (25%) comes in second, indicating that farmers are compelled to use pesticides as a preventative measure due to financial instability and crop loss fears. Risk Perception (20%) implies that uncertainty regarding insect assaults leads to over-application of pesticides, whereas Pesticide Overconfidence (12%) represents that increased usage results in better pest control. Furthermore, a lack of knowledge and awareness (8%) leads to incorrect pesticide application because of a lack of awareness of safe and efficient methods. Finally, farmers' unwillingness to implement alternative pest management techniques is highlighted by resistance to change (5%). The results indicate that in order to reduce excessive pesticide use, it is necessary to promote Integrated Pest Management (IPM) as a sustainable alternative, enhance farmer education, implement behavioural change interventions and establish financial support systems.

Conclusion

The study concludes that farmers' excessive use of pesticides is influenced by a multifaceted combination of psychological, behavioural, socioeconomic and regulatory factors. It emphasises the importance of understanding farmers' perceptions, risk awareness and sense of moral responsibility in encouraging the adoption of sustainable pest management practices. The bibliometric analysis reveals a fragmented research landscape, highlighting the need for greater interdisciplinary collaboration to address knowledge gaps and advance innovative pest control strategies. Future studies should prioritise evaluating the impact of educational programs designed to enhance farmers' knowledge of alternative pest control methods, such as Integrated Pest Management (IPM). Additionally, investigating the role of socioeconomic conditions, social norms and peer influences on pesticide usage behaviour will be crucial. Addressing these challenges will provide critical insights for policymakers and researchers in developing interventions that balance agricultural productivity with environmental sustainability and public health protection. These efforts are crucial for ensuring the long-term sustainability of global farming systems.

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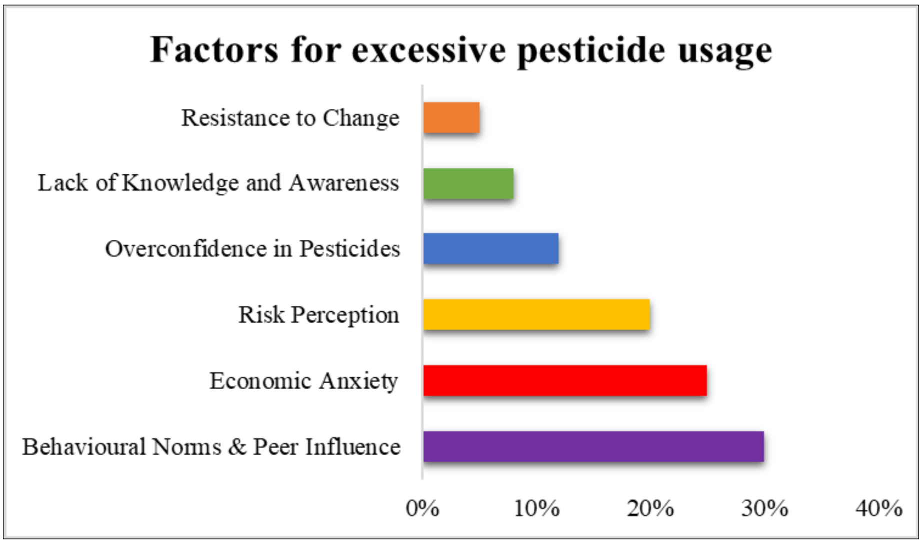

Fig. 5. Factors influencing excessive pesticide usage.

Authors' contributions

NN carried out the survey, analysed the data and formulated the manuscript. MR assisted in data collection and analysis as part of the research study. JRA contributed by developing ideas, reviewing the manuscript and assisting with procuring research grants. AM helped in summarising and revising the manuscript. SE contributed to summarising. PS provided additional support and contributions to the research study. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used QuillBot to check grammatical errors. After using this tool, the authors reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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