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Health Impacts of Pesticide Exposure Among Farmers: A Systematic Review and Implications for Agronursing Practice

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Abstract:
Pesticide exposure among farmers poses significant health risks globally; however, comprehensive recent evidence on the role of nursing in mitigating these hazards remains underexplored. This systematic review aims to synthesize empirical findings from 2024 to 2025 on the health impacts of pesticide exposure in farming populations and discusses implications for agronursing practice. Following the PRISMA 2020 guidelines, a systematic search was conducted across Scopus, PubMed, and ProQuest using the keywords "pesticide," "farmer," and "nursing." From an initial pool of 2,757 records, 10 original research articles published between 2024 and 2025 met the inclusion criteria: full-text, English-language, open-access, peer-reviewed research articles with ethical clearance, an active DOI, and no study design restrictions beyond excluding non-original works. The 10 included studies were conducted in Thailand, Spain, Greece, Ethiopia, Indonesia, Türkiye, and India. These studies revealed consistent associations between pesticide exposure and adverse health outcomes, including sleep disorders, depression, suicide attempts, oxidative stress, DNA damage, elevated inflammatory markers, and increased stroke risk biomarkers. Behavioral assessments indicated widespread deficiencies in safe pesticide handling and low risk perception. Importantly, nurse-led interventions demonstrated effectiveness in improving occupational health service delivery and farmer knowledge. Pesticide exposure continues to pose a risk to farmers' health across diverse global settings. Agronursing emerges as a vital interdisciplinary approach to address this challenge through education, early detection, advocacy, and community-based prevention. Integrating agronursing competencies into primary healthcare and nursing curricula is crucial for protecting agricultural workers and promoting sustainable rural health.

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INTRODUCTION

Agriculture remains a cornerstone of global food security and economic stability, particularly in low- and middle-income countries (Miladinov, 2023). However, the intensive use of chemical pesticides to enhance crop yields has introduced significant health hazards for those working closest to the land, namely farmers (Zhou et al., 2025). Despite their essential role in feeding populations, agricultural workers are frequently exposed to a wide array of synthetic chemicals without adequate protection, training, or awareness of long-term consequences (Lari et al., 2023). This occupational exposure places them at heightened risk for both acute poisoning and chronic health conditions, raising urgent concerns for public health and occupational safety (Keleb et al., 2024).

Pesticides, while effective in controlling pests and diseases, contain toxic compounds that can adversely affect multiple organ systems (Ahmad et al., 2024). Emerging evidence suggests that prolonged or repeated exposure can lead to neurological, reproductive, cardiovascular, and immunological disorders (Cestonaro et al., 2022). Of particular concern are organophosphates and organochlorines, which have been linked to oxidative stress, DNA damage, and inflammatory responses (El-Gameel et al., 2023). Moreover, the psychological toll of pesticide exposure, including depression and sleep disturbances, is increasingly recognized as a critical yet underaddressed dimension of farmer health (Cancino et al., 2023).

Despite growing scientific documentation of these risks, protective measures in many farming communities remain inadequate (Kangavari et al., 2024). Safe handling practices, the use of personal protective equipment, proper storage, and the disposal of chemical containers are often neglected due to limited access to resources, insufficient training, or cultural norms that normalize exposure to hazardous materials (Chekol, 2025). Additionally, farmers' risk perception tends to be low, further hindering the adoption of preventive behaviors (Sarma, 2022). These gaps underscore the need not only for stronger regulatory frameworks but also for community-based, culturally sensitive interventions that empower farmers to protect their own health (Aslam et al., 2024).

In this context, the role of healthcare professionals, particularly nurses, becomes pivotal. Traditional nursing models, however, are often ill-equipped to address the unique challenges of rural and agricultural settings (Brito et al., 2024). This has given rise to agronursing, an integrative discipline that merges agricultural knowledge with nursing science to promote health, prevent disease, and improve safety among farming populations (Ramadhani et al., 2025). Agronurses can serve as educators, advocates, and frontline providers who understand both clinical care and the realities of farm life, enabling them to deliver relevant, effective, and sustainable health services (Dewi et al., 2025).

Given the timeliness and global relevance of this issue, a systematic review of recent evidence is essential to synthesize current findings on pesticide-related health impacts and evaluate how agronursing can respond. This review aims to consolidate empirical data on the physical, mental, and behavioral effects of pesticide exposure among farmers worldwide and to explore practical implications for agronursing practice, education, and policy. By doing so, it aims to inform a more proactive, integrated, and farmer-centered approach to rural occupational health (Halbleib & Dinsdale, 2023).

METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. A comprehensive literature search was performed across three electronic databases: Scopus, PubMed, and ProQuest. The search strategy utilized the following keywords: “pesticide” AND “farmer” AND “nursing”. Only original research articles published between January 2024 and December 2025 were considered for inclusion.

Studies were included if they met the following criteria: (1) published as a full-text, peer-reviewed research article; (2) written in English; (3) openly accessible (open access); (4) assigned an active Digital Object Identifier (DOI); and (5) reported ethical clearance or approval from a recognized institutional review board. Conversely, studies were excluded if they were duplicates, abstracts without full text, case reports, conference proceedings, narrative or systematic reviews lacking original data, editorials, or expert opinions.

Following the initial database search, records were screened based on publication year, study design, and relevance to the research topic. Full-text articles that passed the title and abstract screening were then assessed against the eligibility criteria. The final selection of studies was determined through consensus among the review team, ensuring methodological rigor and adherence to the predefined protocol.

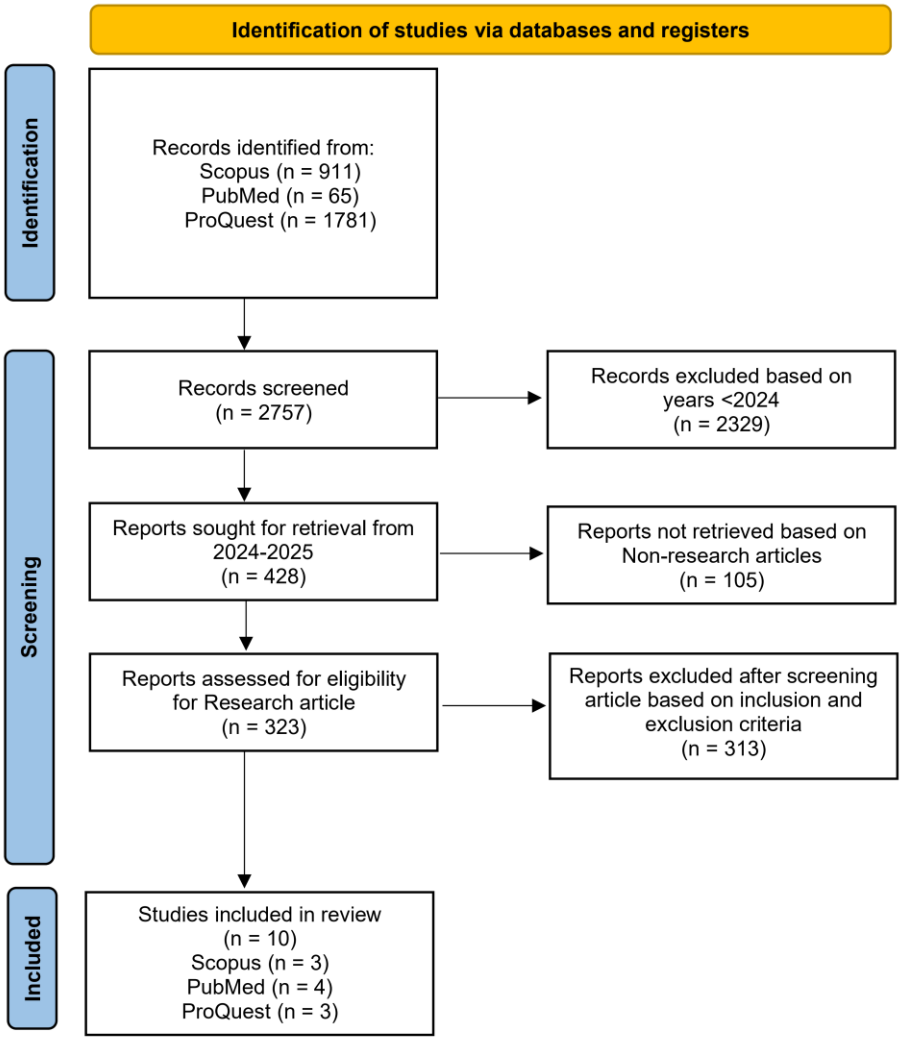

Figure 1. PRISMA flow diagram of literature search and selection

RESULTS

The PRISMA 2020 flow diagram outlines a systematic process for identifying and selecting studies published between 2024 and 2025 for inclusion in a review. Initially, a total of 2,757 records were identified from three databases: Scopus (n = 911), PubMed (n = 65), and ProQuest (n = 1,781). After excluding 2,329 records published before 2024, 428 reports from the target period remained. Of these, 105 were excluded as non-research articles, leaving 323 research articles for eligibility assessment. Following full-text screening against inclusion and exclusion criteria, 313 articles were excluded, 10 leaving in studies for final inclusion: 3 from Scopus, 4 from PubMed, and 3 from ProQuest. This rigorous selection process highlights a highly focused and time-bound review strategy, ensuring relevance to the most recent scholarly output.

Table 1. Main characteristics of the 10 included studies

Author, year, country	Design	Sample (n)	Sampling	Instrument assessment	Statistical analysis	Main results
Juntarawijit, C. (2025), Thailand	Cross-sectional	27.334	Multistage sampling	Agricultural Health Study Questionnaire	Multivariable logistic regression analysis	a positive association of pesticide exposure with sleep disorders. Women are at a higher risk of sleep-related issues with pesticide exposure compared to males
Zheng, R. (2024), Spain	Cross-sectional	453	Purposive sampling	Beck Depression Inventory	Multiple logistic regression analysis	Farmers exposed to pesticides showed significantly increased risk of moderate/ severe depression and suicide attempts compared to non-farmers
Costopoulou, D. (2024), Greece	Cohort study	947	Purposive sampling	Blood and serum samples	Spearman correlation	Children were exposed in utero to pesticides (DDT/DDE) and possibly through breastfeeding and food intake during the first years of their lives.
Temesgen, A. (2025). Ethiopia	Cross-sectional	603	Multistage sampling	KoboCollect toolbox	Bi-variable and multivariable logistic regression analyses	Safe handling practices of pesticides among farmers in the study area were found to be low
Putri, E.R. (2025), Indonesia	Cross-sectional	74	Purposive sampling	Blood sample, Urine sample	Spearman correlation tests	Farmers experience high oxidative stress and DNA damage due to chronic pesticide exposure
Setyopranoto, I. (2024), Indonesia	A cross-sectional	106	Purposive sampling	blood sampling	Linear regression	There is a significant association between organophosphate exposure and increased plasma fibrinogen levels, which may in turn raise the incidence of stroke.
Pumsopa, N. (2025), Thailand	Quasi-experi-mental	60	Simple random sampling	perceived self-efficacy	Independent t-test	The SNPCOHS program is well-suited for self-directed learning for nurses, supporting effective occupational health service delivery to agricultural workers exposed to pesticides in primary care units (PCUs)
Gurbuz, I. B. (2024), Türkiye	A cross-sectional	323	Multistage sampling	The questionnaire was modified to reflect farmers' attitudes and behaviors	Logistic regression	The farmers' overall perception of pesticide risk was low. Farmer characteristics and pesticide application behaviors had a significantly positive effect on pesticide residue risk perception.
Gosavi, G. A., & Kothare, S. (2024). India	Pre-experi-mental one-group pre-test post-test design	60	Non-probability convenience sampling	structured interview schedule and inventory checklist.	Anova	Planned teaching was effective in improving the knowledge and practices of farmers on the health hazards of pesticides.
Kumboyono, K. (2024). Indonesia	Cross-sectional	312	Normal random sampling	Blood sampling	Multivariate linear regression	Pesticide exposure induces vascular inflammation, evidenced by increased inflammatory markers in conventional farmers.

This systematic review synthesized findings from 10 original research articles published between 2024 and 2025 that examined the intersection of pesticide exposure, farmers, and nursing or health-related outcomes. The included studies originated from diverse geographical contexts namely Thailand (Juntarawijit et al., 2025; Pumsopa et al., 2025), Spain (Zheng et al., 2024), Greece

(Costopoulou et al., 2024), Ethiopia (Temesgen et al., 2025), Indonesia (Putri et al., 2025; Setyopranoto et al., 2024; Kumboyono et al., 2024), Türkiye (Gurbuz, 2024), and India (Gosavi & Kothare, 2024) which highlighting the global relevance of pesticide-related health risks among agricultural populations.

A consistent theme across multiple studies was the adverse health impact of chronic pesticide exposure. Juntarawijit et al. (2025) identified a significant positive association between pesticide exposure and sleep disorders among Thai farmers, with women exhibiting greater vulnerability than men. Similarly, Zheng et al. (2024) reported that Spanish farmers exposed to pesticides faced a markedly elevated risk of moderate to severe depression and suicide attempts compared to non-farmers. Biological evidence further corroborated these clinical observations: Putri et al. (2025) demonstrated increased oxidative stress and DNA damage (measured via malondialdehyde and 8-OHdG levels) in Indonesian farmers, while Kumboyono et al. (2024) found elevated inflammatory markers (MCP-1, IL-1β, and ACTH), indicating early vascular inflammation due to pesticide exposure. Setyopranoto et al. (2024) extended this by linking organophosphate exposure to higher plasma fibrinogen levels, which is a known risk factor for stroke.

Beyond direct physiological effects, several studies addressed behavioral and systemic dimensions. Temesgen et al. (2025) reported alarmingly low rates of safe pesticide-handling practices among Ethiopian farmers, despite awareness campaigns. Gurbuz (2024) noted that Turkish farmers generally exhibited low risk perception regarding pesticide residues, although certain demographic and behavioral factors positively influenced their awareness. In contrast, Gosavi and Kothare (2024) demonstrated that structured educational interventions significantly improved farmers' knowledge and practices related to pesticide hazards in rural India, underscoring the potential of preventive health education.

Importantly, two studies emphasized the role of nursing and primary healthcare in mitigating these risks. Pumsopa et al. (2025) evaluated the "Strengthening Nurse Practitioners' Competency in Occupational Health Service" (SNPCOHS) program in Thailand. They found it effective in enhancing nurses' self-efficacy and capacity to deliver occupational health services to pesticide-exposed agricultural workers. This aligns with the broader call for integrating nursing expertise into agricultural health surveillance and intervention frameworks.

Finally, Costopoulou et al. (2024) provided critical insights into intergenerational exposure, showing that Greek children in the Rhea birth cohort had detectable blood levels of DDT/DDE, likely due to in utero exposure and early-life dietary intake, raising concerns about long-term developmental and public health consequences even in regions where such pesticides are no longer in active use.

Collectively, these findings highlight a multifaceted public health challenge that encompasses neurobehavioral, cardiovascular, inflammatory, and genetic impacts of pesticide exposure, exacerbated by inadequate safety practices and limited risk awareness. They also highlight promising avenues for intervention through nursing-led programs, community education, and policy-level monitoring of both current and legacy pesticide residues.

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Table 2. Gender, Age, Education Level, Cigarette smoking, PPE-status, and Experience in using pesticides in the 10 included studies

Author, Year, Country	Gender (n)	Age (n)	Education Level (n)	Cigarette Smoking (n)	PPE-Status	Experience In Using Pesticides
Juntarawijit, C. (2025), Thailand	Male 12,798; Female 14,484	20-29 Years (739); 30-39 Years (2311); 40-49 Years (5113); 50-59 Years (8738); 60-69 Years (7333); ≥70 Years (3048)	Not Attend School (1796); Primary School (19,618); High School (5431); College Degree Or Higher (437)	Non-Smoker (22293); Ex-Smoker (1460); Current Smoker (3529)	-	-
Zheng, R., (2024). Spain	Male (453) Female (0)	Farmer (Mean=38.38); Non-Farmer (Mean 38.85)	No Studies (Farmer=53; Non Farmer=36); Low (Farmer=82; Non-Farmer=83); Medium (Farmer=71; Non Farmer=85); High (Farmer=19; Non Farmer=24)	Smoker (Farmer=85; Non Farmer=109); Non-Smoker (Farmer=111; Non Farmer=98); Former Smoker (Farmer=28; Non Farmer=21)	-	Areas With High Pesticide Use (Farmer=167; Non Farmer=180); Areas With Low Pesticide Use (Farmer=61; Non Farmer=45)
Costopoulou, D., 2024, Greece	Males (556); Females (391)	4 Years Old (375); 6.5 Years Old (239), And 11 Years Old (333)	-	-	-	-
Temesgen, A., (2025). Ethiopia	Male (534); Female (60)	15–44 Years (581); >44 Years (13)	Unable To Read And Write (218); Can Read And Write (134); Primary Education (127); Secondary And Above (115)	-	-	<5 Years (166); 5–10 Years (242); >10 Years (186)
Putri, E.R., 2025, Indonesia	Male (74); Female (0)	Grup A (49 (23–70)); Grup B (51 (30–74)	-	Grup A (Smoker=28; Non Smoker=8); Grup B (Smoker=22; Non Smoker=16)	Using PPE (Grup A= (35 Grup B=31); Not Using PPE (Grup A=1; Grup B=7)	Spraying Frequencies In A Year, Group A (48); Grup B (36)
Setyopranoto, I., 2024, Indonesia	Male (71); Female (35)	Mean 52.92 (13.5)	0–5 Years (20); 6–9 Years (76); >10 Years (9)	Smoking (43); Non-Smoking (63)	Mean 46.15 (20.39)	-
Pumsopa, N., 2025, Thailand	Experimental Group (Male=1; Female 29); Comparison Group (Male=1; Female 29)	Experimental Group (45.70±8.24); Comparison Group (43.83±9.03)	Bachelor's Degree (Experimental Group=27; Comparison Group=27); Master's Degree (Experimental Group=3; Comparison Group=3)	-	-	-
Gurbuz, I. B., 2024, Türkiye	-	M = 51.13 SD = 11.06	Education In Years (M = 6.76 SD = 3.06)	-	-	Years (M = 18.95 SD = 10.95)
Gosavi, G. A., & Kothare, S., 2024, India	Male (48); Female (12)	31-50 Years	13 Samples Were Illiterate	Smoking (31); Non-Smoking (29)	-	-
Kumboyono, K., (2024). Indonesia	Conventional Farmers (Male=98; Female=58); Organic	Conventional Farmers (38.38 ± 4.62) Organic Farmers (40.12 ± 5.96)	Bachelor (Conventional Farmers=24; Organic Farmers=48);	-	-	-

Author, Year, Country	Gender (n)	Age (n)	Education Level (n)	Cigarette Smoking (n)	PPE-Status	Experience In Using Pesticides
	Farmers (Male=84; Female=72)		High School (Conventional Farmers=48; Organic Farmers=48); Junior High School (Conventional Farmers=60; Organic Farmers=36); Elementary (Conventional Farmers=24; Organic Farmers=24);			

The included studies reveal significant heterogeneity in farmer demographics and safety practices across global agricultural settings. Gender distribution was notably skewed in several studies, as evidenced by Zheng et al. (2024) in Spain and Putri et al. (2025) in Indonesia, which exclusively sampled male farmers, reflecting the gendered labor divisions in specific farming systems. In contrast, Juntarawijit et al. (2025) in Thailand reported a predominantly female cohort (14,484 women vs. 12,798 men), suggesting regional variation in agricultural participation. Similarly, Kumboyono et al. (2024) in Indonesia included both conventional and organic farmers, ensuring balanced gender representation and enabling comparative insights into exposure patterns by farming type.

Age profiles indicate that most participants were middle-aged or older adults actively engaged in farming. For instance, Juntarawijit et al. (2025) found the largest age group to be 50–59 years (n = 8,738), while Setyopranoto et al. (2024) reported a mean age of 52.92 years. In Türkiye, Gurbuz (2024) reported a mean age of 51.13 years, and Temesgen et al. (2025) in Ethiopia observed that over 97% of farmers were under 44 years old, highlighting generational differences in workforce composition. Notably, Costopoulou et al. (2024) shifted their focus to children (ages 4–11) in Greece, emphasizing intergenerational exposure through legacy pesticides such as DDT/DDE, thereby expanding the scope beyond active applicators to vulnerable secondary populations.

Educational attainment varied widely and often correlated with safety awareness. In Ethiopia, Temesgen et al. (2025) found that 36.5% of farmers were illiterate (unable to read or write), while only 19.2% had secondary education or higher, a factor likely contributing to poor pesticide handling practices. Conversely, in India, Gosavi and Kothare (2024) reported that 13 of 60 participants were illiterate. However, their structured teaching program significantly improved knowledge, suggesting that low literacy does not preclude effective health education when appropriate methods are used. In Thailand, Pumsopa et al. (2025) studied nurses with bachelor's or master's degrees, underscoring the importance of professional training in occupational health delivery.

Cigarette smoking, a potential confounder in oxidative stress and inflammatory outcomes, was prevalent in several cohorts. Putri et al. (2025) reported high smoking rates (28/36 in Group A), while Gosavi and Kothare (2024) noted 31 smokers out of 60 farmers. Smoking may synergistically exacerbate pesticide-induced toxicity, particularly in studies that measure biomarkers such as malondialdehyde (Putri et al., 2025) or inflammatory cytokines (Kumboyono et al., 2024). However, few studies have statistically controlled for this variable.

Critically, PPE usage remained inconsistent. Putri et al. (2025) documented that while 35 of 36 farmers in Group A used PPE, 7 of 38 in Group B did not, raising concerns about compliance even when equipment is available. Other studies (e.g., Temesgen et al., 2025; Gurbuz, 2024) did not report PPE use at all, indicating a gap in standardized occupational safety monitoring. This omission limits the ability to correlate protection behaviors with health outcomes.

Finally, farming experience with pesticides was substantial. Gurbuz (2024) reported a mean of 18.95 years of pesticide use in Türkiye, and Temesgen et al. (2025) found that 61.7% of Ethiopian farmers had over 5 years of experience with pesticides. A longer exposure duration is likely to increase cumulative health risks, as evidenced by biological markers in Indonesian studies (Setyopranoto et al., 2024; Kumboyono et al., 2024). However, experience did not consistently translate into safer practices, underscoring the need for continuous education rather than relying solely on tenure.

DISCUSSION

The findings of this systematic review underscore the profound and multifaceted health risks associated with pesticide exposure among farming populations, while simultaneously highlighting critical opportunities for agronursing to play a central role in prevention, education, and occupational health support. Agronursing, an emerging interdisciplinary field that integrates agricultural knowledge with nursing science, is uniquely positioned to address the complex interplay between environmental hazards, rural health disparities, and sustainable farming practices (Kurniawan et al., 2022).

Consistent evidence from diverse global contexts demonstrates that pesticide exposure significantly contributes to both physical and mental health burdens. For instance, Juntarawijit et al. (2025) reported a strong association between pesticide use and sleep disorders among Thai farmers, with women disproportionately affected; a finding that aligns with broader literature on gender-specific vulnerabilities in agricultural settings. Similarly, Zheng et al. (2024) documented elevated rates of depression and suicide attempts among Spanish farmers exposed to pesticides, reinforcing the neurotoxic and psychological consequences of chronic chemical exposure. These outcomes are not merely clinical concerns but public health emergencies requiring integrated, community-based responses; precisely where agronursing can intervene.

Biological markers further validate these clinical observations. Studies from Indonesia have demonstrated that chronic pesticide exposure results in oxidative stress (Putri et al., 2025), DNA damage, and vascular inflammation (Kumboyono et al., 2024). Additionally, Setyopranoto et al. (2024) linked organophosphate exposure to increased plasma fibrinogen levels, a known predictor of stroke. These subclinical changes often precede overt disease, offering a crucial window for early detection and intervention. Nurses trained in agronursing principles can monitor such biomarkers, educate farmers on protective behaviors, and collaborate with primary care teams to implement preventive strategies tailored to the specific needs of agricultural communities.

Behavioral and systemic gaps also emerged as key challenges. Temesgen et al. (2025) found alarmingly low adherence to safe pesticide-handling practices among Ethiopian farmers, despite the presence of awareness programs. Likewise, Gurbuz (2024) observed that Turkish farmers generally underestimated the risks associated with pesticide residues, although certain demographic and behavioral factors positively influenced their risk perception. These findings suggest that knowledge alone is insufficient; effective interventions must be culturally grounded, context-specific, and sustained over time. Here, agronursing's emphasis on community engagement, health literacy, and participatory education becomes vital. The success of Gosavi and Kothare's (2024) structured teaching program in India, which significantly improved farmers' knowledge and practices, exemplifies how nurse-led educational initiatives can bridge the gap between awareness and action.

Moreover, the quasi-experimental study by Pumsopa et al. (2025) provides compelling evidence for institutionalizing agronursing competencies within primary healthcare systems. Their SNPCOHS program enhanced nurses' self-efficacy in delivering occupational health services to pesticide-exposed agricultural workers in Thailand. This model demonstrates that when nurses are equipped with specialized training in agricultural health hazards, they become effective frontline agents in mitigating occupational risks, thereby fulfilling the core tenets of agronursing: prevention, advocacy, and holistic care in rural ecosystems.

Even in regions where certain pesticides, such as DDT, are no longer used, legacy contamination remains a concern. Costopoulou et al. (2024) detected DDT/DDE residues in Greek children from the Rhea birth cohort, likely due to historical use and dietary exposure. This underscores the long-term, intergenerational impact of agrochemicals and reinforces the need for ongoing environmental health surveillance, another domain in which agronurses can contribute through community monitoring, policy advocacy, and maternal-child health outreach.

The convergence of toxicological, behavioral, and systemic evidence from these 10 studies confirms that pesticide exposure is a pressing occupational and public health issue that requires multidisciplinary solutions. Agronursing offers a transformative framework by merging clinical expertise with agricultural insight, enabling nurses to serve not only as caregivers but also as educators, researchers, and policy influencers in rural health systems (Kurniyawan et al., 2023). Future efforts should prioritize integrating agronursing into academic curricula, strengthening nurse-farmer partnerships, and scaling evidence-based interventions, such as those piloted by Pumsopa et al. (2025) and Gosavi & Kothare (2024). Only through such integrated approaches can we safeguard the health of those who feed the world.

CONCLUSSION

This systematic review highlights the significant health risks faced by farmers due to pesticide exposure, including sleep disorders, depression, oxidative stress, DNA damage, vascular inflammation, and elevated stroke risk. Moreover, behavioral gaps such as poor handling practices and low risk perception further exacerbate these hazards, particularly in low- and middle-income countries. Crucially, the evidence also demonstrates that targeted nursing interventions can effectively improve knowledge, practices, and occupational health service delivery in agricultural communities.

These findings affirm that agronursing, a specialized domain that integrates agricultural health, environmental science, and nursing practice, is not only relevant but also essential in addressing the complex health challenges faced by farming populations. Agronursing bridges the gap between clinical care and rural occupational safety, positioning nurses as frontline advocates for preventive education, early detection of pesticide-related health effects, and policy engagement in agricultural settings.

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