



International Journal of Biology Sciences

ISSN Print: 2664-9926
 ISSN Online: 2664-9934
 NAAS Rating (2026): 4.82
 IJBS 2026; 8(5): 30-35
www.biologyjournal.net
 Received: 15-02-2026
 Accepted: 20-03-2026

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Impact of pesticide exposure on honey bees (*Apis mellifera*) populations: A survey- based study in Muzaffarpur, Bihar

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DOI: <https://www.doi.org/10.33545/26649926.2026.v8.i5a.824>

Abstract

Honey bees (*Apis mellifera*) play a crucial role in pollination, contributing significantly to agricultural productivity and ecological balance (Sharaf El-Din et al., 2025). However, in recent years, pesticide exposure has emerged as a silent threat, adversely affecting honey bee health and endangering food security (Almasri et al., 2022). This study highlights a critical disconnect between beekeepers, who report severe hive disruptions, and farmers, some of whom may unknowingly contribute to the problem. Conducted in Muzaffarpur, Bihar, the study surveyed 39 beekeepers and 64 farmers to understand their awareness, practices, and perceptions regarding pesticide impacts on honeybee populations.

Results from the beekeepers' survey showed that 61.5% of beekeepers observed increased mortality during pesticide use, while 56.4% of them reported disoriented flight and 53.8% noticed reduced foraging. Although 69.2% of beekeepers were aware of pesticide risks, only 35.9% of them had received formal training. Moreover, 48.7% of beekeepers reported declines in brood development, and 25.6% reported queen loss—clear signs of colony stress. Among farmers, a relatively small proportion maintained buffer zones and avoided spraying during flowering, indicating limited adoption of mitigation strategies.

This study underscores the urgent need for targeted education, improved pesticide management practices, and stronger collaboration between beekeepers and farmers to promote pollinator-friendly agriculture and long-term ecological and food system sustainability (Zhang et al., 2023)

Keywords: Honeybee (*Apis mellifera*), pesticide exposure, beekeepers-farmers interaction, pollinator decline, agro-ecosystem management

Introduction

The relationship between pollinators and flowering plants is fundamental to our planet's ecological balance and global crop production (Shaden et al., 2021). Animal pollinators are estimated to increase the yield of more than 70% of globally important commercial crops, whereas insect pollination produces approximately 87.5% of global flowering plant species (Yoori Cho et al., 2021) [2].

Among these pollinators, honey bees (*Apis mellifera*) stand as a vital species, acting as a vigorous workforce in the pollination of a wide array of essential crops such as apples, cherries, grapes, broccoli, sunflowers, etc. (Boyko Neov et al., 2019) [10], and play a crucial role in ecosystem sustainability (Nagma Praveen). Often regarded as a symbol of an efficient, dynamic and sedulous workforce, honey bees significantly contribute to the welfare of society (JJM Van der Steen, 2015). Honey bees are one of about 200,000 existing species of plant pollinators (Boyko Neov et al., 2019) [10], pollinating 3/4th of the world's angiosperm plants and increasing crop yield by 1/3rd (Mulatu Wakgari & Gebissa Yigezu, 2021) [14]. They provide resources such as honey, wax, propolis, royal jelly, and venom, and support food, employment, apitherapy, and environmental protection (FAO Report, 2019). Honeybees contribute significantly to the global economy in a lesser-known way, i.e., by providing pollination services (Shaden A.M. Khalifa et al., 2021) [13]. Although bees are ecologically and economically important, extinction rates are 100 to 1000 times higher than normal due to multiple interferences such as habitat loss, monocropping, lack of nutrition,

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pesticides, and electromagnetic radiation (Yagya Prasad Paudel *et al.*, 2015) [11]. Improved agriculture practices, such as rampant pesticide use, affect foragers and different life stages of honey bees (*A. mellifera*), leading to impaired behaviours such as reduced egg laying, disrupted homing and waggle dance communication, and forager disorientation, as reported in studies on Gaucho-treated sunflower crops and neonicotinoid exposure (Minh-Ha Pham-Delegue *et al.*, 2002; Boyko Neov *et al.*, 2019) [8, 10].

Thus, while modern agricultural practices enhance productivity, they pose a grave threat to honey bee populations by altering essential behaviors and reducing survival (Margaoan *et al.*, 2024) [18]. Despite growing global evidence linking pesticide exposure to pollinator decline, region-specific studies in the intensive litchi-growing belts of Bihar remain limited, particularly those integrating both beekeeper observations and farmer practices. In light of these concerns, the present survey study sets out with the following objectives: (1) To understand the awareness and perceived impacts of pesticide exposure on honey bees among local farmers and beekeepers. (2) To document the observed impacts of pesticide usage on honeybee populations in the field. (3) To identify patterns of honeybee decline associated with agricultural practices. (4) To suggest sustainable practices to protect honeybee health and ensure ecological balance.

Materials and Methods

Study Area

The study was conducted in Muzaffarpur district, Bihar, India (26.120° N, 85.380° E) with field surveys conducted across selected agricultural belts in Saraiya, Karza, Vaishali, Marwan, and Paroo blocks, chosen for the coexistence of pesticide-intensive farming and managed apiaries.

Saraiya block primarily comprised litchi orchards, a major bee-pollinated crop, while Karza block consisted of mixed cropping systems dominated by bee-pollinated crops such as cucumber, brinjal, etc. grown near active apiaries. The Vaishali-Marwan belt was characterized by litchi orchards with intermittent vegetable cultivation, whereas the Paroo block comprised mustard and sunflower crops with variable pesticide application practices near apiaries.

Only agricultural fields located within a 3 km radius of apiary sites were included, corresponding to the effective foraging (catchment) range of honey bees and ensuring ecological relevance for assessing pesticide exposure.

Study design and sampling procedure

This study is a cross-sectional survey designed to understand the perceived impact of pesticide exposure on honey bee populations in Muzaffarpur, Bihar. A stratified random sampling method was used to ensure a representative sample of both beekeepers and farmers, capturing diverse experiences and perspectives. The study

spans from November to July 2024, coinciding with the flowering season of major bee-pollinated crops such as litchi, mustard, sunflower and vegetables, when pesticide use is at its peak, and honey bees are actively foraging.

A descriptive survey method was employed using structured questionnaires tailored to each group. The Beekeepers Survey focuses on apiculture practices, pesticide exposure, and observed bee health, while the Farmers Survey emphasizes pesticide usage patterns, awareness, and mitigation efforts.

A total of 39 beekeepers and 64 farmers were selected based on their active engagement in beekeeping and pesticide use. Surveys were conducted through face-to-face interviews and physical form distribution, with data quality ensured through response monitoring and follow-ups on unclear and incomplete responses. Participation was voluntary and informed consent was obtained from all respondents prior to data collection.

Statistical Analysis

The questionnaires were checked, coded, and analysed using R statistical software, which has been extensively applied in pollinator research (e.g., Traynor *et al.*, 2016) [7]. Descriptive statistics were used to summarize categorical variables, consistent with methods employed in related studies (Dassou *et al.*, 2020) [3]. Association between variables such as awareness of pesticide impact, training, hive damage, and adherence to recommended guidelines was tested using the chi-square test of independence. Fischer's exact test was applied when expected cell frequencies were low. Statistical significance was set at $p < 0.05$.

Results and Discussion

Demographic Profile

The research interviewed 103 participants from Muzaffarpur, Bihar—39 beekeepers and 64 farmers, all with first-hand experience in apiculture and agriculture, providing key insights on honeybee health and pesticide exposure.

Beekeepers were aged 32-52 years, with 77% male. The findings of Mujuni *et al.* (2012) [9] in Uganda similarly indicated a strong gender imbalance in apiculture, with 95% of the beekeepers in the study area being male. Their experience ranged from 7 to 22 years. Educationally, 41% were graduates, 36% had completed high school, and 23% had completed intermediate education. Farmers ranged from under 25 to over 60 years. Most cultivated 1-5 hectares of land, growing litchi, mustard, sunflower, cucumber, and brinjal. Male farmers made up 78% of the group. These characteristics were summarised using descriptive statistics. No inferential statistical tests were applied as these variables were included for contextual characterisation of the study population.

Table 1: Socio-demographic profile of beekeepers

Variables		Percentage
Gender	Male	76.92
	Female	23.08
Educational Qualification	Graduate	41.03
	High School	35.89
	Intermediate	23.08
Experience	10-15 years	48.72
	16-20 years	20.51
	<10 years	20.51
	>20 years	10.26

Table 2: Socio-demographic profile of farmers

Variable		Percentage (%)
Gender	Male	78.1%
	Female	21.9%
Age Group	25 to 40	40.6%
	41 to 60	31.3%
	Above 60	15.6%
	Below 25	12.5%
Farm Size	1 to 5 hectares	34.4%
	5 to 10 hectares	31.3%
	More than 10 hectares	21.8%
	Less than 1 hectare	12.5%
Crop	Litchi	28.1%
	Mustard	25.0%
	Sunflower	21.9%
	Cucumber	15.6%
	Brinjal	9.4%

Pesticide Awareness and Usage Patterns of Beekeepers

Among 39 beekeepers surveyed in Muzaffarpur, Bihar, 69.2% were aware of pesticide effects on honeybee health, though only 35.9% had formal training. Despite high awareness, structured education remains limited.

Regarding hive impacts, 46.2% of beekeepers reported pesticide-related losses, 35.9% were unaware and 17.9% were unsure. Familiarity with pesticides varied: 38.5% were very familiar, 35.9% somewhat, and 25.6% not familiar. Consistent with Sharma *et al.* (2020), most respondents reported routine pesticide application in farms near apiaries, indicating high agricultural farming input costs and, at the same time, potential risk to honey bee colonies. For causes of bee mortality, 41.0% of beekeepers attributed pesticides as the cause of bee mortality. These findings emphasize the

need for better training and stronger beekeeper- farmer collaboration to reduce risks.

As presented in Table 3.1, beekeepers who were aware of pesticide impacts reported a higher incidence of hive damage (55.6%) than those who were not aware (16.7%); however, this association was marginally non- significant ($\chi^2 = 3.65$, $p = 0.056$). This suggests a possible trend indicating that awareness may be shaped by direct experience of colony loss rather than preventive knowledge. Additionally, no significant relationship was found between pesticide-related training and awareness of pesticide impacts ($\chi^2 = 0.00$, $p = 1.00$), indicating that existing training programs may not sufficiently enhance practical understanding of pesticide risks.

Table 3: Pesticide Awareness and Usage Patterns of Beekeepers

Variable	Category	Percentage
Aware of Pesticide Impact on Bees	Yes	69.2%
	No	30.8%
Receives Pesticide Training	Yes	35.9%
	No	64.1%
Hives Affected by Pesticides	Yes	46.2%
	No	35.9%
Familiarity with Pesticides	Can't Say	17.9%
	Very Familiar	38.5%
	Somewhat Familiar	35.9%
	Not Familiar	25.6%
Most Important Reason for Bee Mortality	Pesticides	41.0%

Table 3.1: Association between awareness, pesticide training, and hive damage among beekeepers

Comparison	Category	n (%)	χ^2 (df)	p-value
Awareness × Hive damage	Aware	15 (55.6)	3.65(1)	0.056
	Not Aware	2 (16.7)		
Training × Awareness	Trained	9 (69.2)	0.00 (1)	1.00
	Not Trained	8 (30.8)		

Pesticide Awareness and Usage Patterns of Farmers

Among the 64 surveyed farmers, insecticides were the most commonly used pesticides (60.9%), followed by fungicides (21.9%) and herbicides (12.5%). Applications were largely occasional or monthly, with the highest frequency during the harvesting (42.2%) and flowering (34.4%) stages. Manual spraying was the primary application method (76.6%), while only 20.3% of farmers reported consistent adherence to recommended pesticide guidelines. In addition, only 37.5% of farmers reported receiving formal training on

safe pesticide use, and just 60.9% were aware of the potential harmful effects of pesticides on honeybees. The limited training may contribute to improper pesticide application practices, increasing the risk of exposure and toxicity to honey bee populations.

As shown in Table 4.1, a statistically significant association was observed between receipt of pesticide-related training and awareness of pesticide impacts among farmers ($\chi^2 = 10.51$, $p = 0.001$). However, a higher level of awareness was reported among untrained farmers (77.5%) compared to

those who had received training (33.3%). This counterintuitive finding may reflect informal knowledge exchange, experiential learning, or increased field-level exposure to pesticide impacts rather than structured training initiatives. It also suggests potential gaps in the content, implementation, or effectiveness of existing training programs. A highly significant association was also identified between awareness of pesticide impacts and

adherence to recommended pesticide practices ($p < 0.001$). All farmers who were aware of pesticide impacts demonstrated good adherence to recommended guidelines, whereas none of the unaware farmers reported good adherence. These findings indicate that while awareness is strongly linked to safer pesticide practices, existing training programs may be inadequate in effectively improving awareness among farmers.

Table 4: Pesticide Awareness and Usage Patterns of Farmers

Variable	Category	Percentage (%)
Type of pesticide used	Insecticides	60.9
	Fungicides	21.9
	Herbicides	12.5
	Others	4.7
Frequency of application	Occasionally	31.3
	Monthly	23.4
	Bi-weekly	18.8
	Rarely	17.2
	Weekly	9.3
Crop growth stage during application	Harvesting	42.2
	Flowering	34.4
	Sowing	17.2
	Growing	6.2
Method of application	Manual spraying	76.6
	Machine spraying	23.4
Adherence to recommended guidelines	Always	20.3
	Sometimes	40.6
	Rarely	26.6
	Never	12.5
Received training on safe pesticide use	Yes	37.5
	No	62.5
Awareness of pesticide effects on honeybees	Yes	60.9
	No	39.1

Table 4.1: Association between pesticide-related training, awareness, and adherence to recommended practices among farmers

Comparison	Category	n (%)	χ^2 (df)	p-value
Training x Awareness	Trained	8(33.3)	10.51 (1)	0.001
	Not trained	31(77.5)		
Awareness x Adherence	Aware	39 (100)	59.87 (1) †	<0.001
	Not Aware	8 (100)		

Note: Percentages are calculated within comparison groups.

† Fisher's Exact Test was used due to zero cell frequencies; Chi-square results were consistent.

Observations on Bee Health and Behavior by Beekeepers

Among 39 beekeepers, 61.5% reported increased honeybee mortality during active pesticide use, with dead or weakened bees near hive entrances. Disoriented flight (56.4%) and reduced foraging (53.8%) were common during nearby spraying. Additionally, 48.7% observed declines in brood development, and 25.6% reported queen loss or

replacement—signs of colony stress. Abnormal clustering (46.2%) and increased aggression (23.1%) also reflected behavioral disruptions from pesticide exposure. These findings suggest that pesticide use leads not only to immediate mortality but also long-term behavioral and developmental challenges in colonies (Tokach *et al.*, 2024) [19].

Table 5: Observations on Bee Health and Behaviour by Beekeepers

Observation	Percentage (%)
Increased mortality near hives	61.5%
Disoriented flight patterns	56.4%
Reduced foraging activity	53.8%
Abnormal clustering behaviour	46.2%
Brood development decline	48.7%
Queen loss/replacement	25.6%
Increased worker bee aggression	23.1%

Observations on Bee Health and Behavior by Farmers:

A majority of farmers (59.4%) reported a noticeable decline in honeybee populations near their farms in recent years.

Frequently observed indicators included dead bees near treated crops (48.4%), erratic flying behaviour (40.6%), reduced bee numbers (39.1%), and difficulty in locating

bees (25.0%), suggesting both acute and sublethal impacts on honeybee health.

Most respondents (65.6%) identified pesticide use as the primary cause of these changes, while fewer attributed them to habitat loss or climate variability. Notably, 62.5% of farmers perceived a direct correlation between pesticide

application and reduced honeybee activity.

These farmer-reported observations strongly support earlier findings of intensive insecticide use, improper application timing, and low guideline compliance, collectively reinforcing the link between current pesticide practices and declining honeybee health.

Table 6: Observations on Bee Health and Behaviour by Farmers

Variable	Category	Percentage (%)
Change in honeybee population near farms	Decrease	59.4%
	Increase	15.6%
	No change	14.1%
	Not sure	10.9%
Observed effects honeybees	Dead bees near crops	48.4%
	Erratic flying behaviour	40.6%
	Reduced numbers	39.1%
	Difficulty in finding bees	25.0%
Perceived causes of honeybee decline	Pesticide use	65.6%
	Habitat loss	18.8%
	Climate change	15.6%
Perceived correlation between pesticide application and honeybee activity	Yes	62.5%
	No	23.4%
	Not Sure	14.1%

Mitigation Measures

Among the 64 farmers surveyed, 58.3% of them did not maintain buffer zones around fields while 66.7% of farmers continued pesticide spraying during the flowering period, hence increasing the risk of pesticide exposure. Additionally, 75% of farmers did not inform nearby beekeepers before spraying, while 86.7% did not adopt bee-friendly pesticides.

These findings highlight significant shortcomings in the implementation of pollinator protection measures. The low adoption of essential practices suggests inadequate

awareness, limited access to bee-safe inputs, or lack of structured guidelines. Such gaps may contribute to continued pesticide exposure and associated risks to honeybee populations.

Despite the valuable insights generated, this cross-sectional survey-based study relies on reported observations and respondent perceptions. Therefore, future longitudinal investigations and residuebased experimental analyses are recommended to validate exposure pathways and quantify pesticide residues within hive matrices.

Table 7: Mitigation Measures and Policy Recommendations

Mitigation Measures	Percentage (%)
Maintain buffer zones	58.3% (No); 41.7% (Yes)
Avoid spraying during flowering	66.7% (No); 33.3% (Yes)
Inform beekeepers before spraying	75% (Yes); 25% (No)
Use bee-friendly pesticides	86.7% (No); 13.3% (Yes)

Conclusion

This study highlights critical intersections between pesticide usage patterns, farmer practices, and honeybee health in Muzaffarpur, Bihar. The demographic profiles of beekeepers and farmers revealed substantial experience in apiculture and agriculture but varying levels of formal education and pesticide awareness. While awareness of pesticide impacts on honeybees was moderately high among beekeepers, structured training remained limited. Similarly, although farmers demonstrated some understanding of pesticide risks, unsafe practices and irregular adherence to recommended guidelines persisted.

Field observations provided further evidence of the detrimental effects of pesticide exposure, including increased honeybee mortality, disoriented flight behavior, reduced foraging activity, and declines in brood development. These behavioral and health disruptions threaten the sustainability of local honeybee populations, with direct implications for pollination services and agricultural productivity. The observed mortality and behavioural aberrations, including disorientation and heightened aggression, are consistent with well-documented

sublethal effects of agrochemicals on arthropods (Fine *et al.*, 2023). Specific herbicides such as bentazone and metamitron have been shown to induce increased aggression and impair mobility in bees, further supporting these observations (Belsky & Joshi, 2020).

Both beekeepers and farmers suggested a range of mitigation strategies, such as maintaining buffer zones, avoiding pesticide application during flowering, adopting bee-friendly pesticides, and improving farmer-beekeeper communication. However, a substantial proportion of respondents reported not adopting these practices, indicating that while awareness is growing, widespread behavioural change is still needed.

The findings underscore the urgent need for integrated approaches combining farmer education, strengthened pesticide regulations, promotion of organic and integrated pest management (IPM) practices, and enhanced cooperation between agricultural and apicultural communities. Implementing these strategies at both local and policy levels will be crucial to ensuring the health of pollinators and the resilience of agricultural ecosystems in the region.

Acknowledgments

The authors are grateful to all respondents (beekeepers and farmers) for their cooperation and valuable input. The authors also acknowledge support from the University Department of Zoology, Muzaffarpur, Bihar.

References

1. Belsky J, Joshi KN. Effects of fungicide and herbicide chemical exposure on *Apis* and non-*Apis* bees in agricultural landscape. *Front Environ Sci*. 2020.
2. Cho Y, Jeong S, Lee D, *et al*. Foraging trip duration of honey bee increases during a poor air quality episode and the increase persists thereafter. *Ecol Evol*. 2021;11(4):1492-1500.
3. Dassou AG, *et al*. Farmer knowledge and perceptions of agrochemicals use on honeybees community and honey production in Benin. *Research Square*. 2020.
4. FAO. FAO report. 2019.
5. Fine JD, *et al*. Indirect exposure to insect growth disruptors affects honey bee (*Apis mellifera*) reproductive behaviour and ovarian protein expression. *PLoS One*. 2023.
6. Van der Steen JJM. The foraging honey bee. *Br Bee J*. 2015.
7. Traynor KS, *et al*. In-hive pesticide exposome: assessing risks to migratory honeybees from in-hive pesticide contamination in the Eastern United States. *Sci Rep*. 2016.
8. Pham-Délégué MH, *et al*. Behavioural methods to assess the effects of pesticides on honey bees. *Apidologie*. 2002;33:425-432.
9. Mujuni A, Natukunda K, *et al*. Factors affecting the adoption of beekeeping and associated technologies in Bushenyi district, Western Uganda. *Livest Res Rural Dev*. 2012;24(8).
10. Neov B, Georgieva A. Biotic and abiotic factors associated with colonies mortalities of managed honey bee (*Apis mellifera*). *Diversity*. 2019;11(12):237.
11. Paudel YP, *et al*. Honey bee (*Apis mellifera* L.) and pollination issues: current status, impacts and potential drivers of decline. *J Agric Sci*. 2015;7(6).
12. Khalifa SA, Elshafiey EH. Overview of bee pollination and its economic value for crop production. *Insects*. 2021;12:688.
13. Sharma A, Shukla RK, *et al*. Global trends in pesticides: a looming threat and viable alternatives. *Ecotoxicol Environ Saf*. 2022;201:110871.
14. Wakgari M, Yigezu G. Honey bee keeping constraints and future prospects. *Cogent Food Agric*. 2021;7:1872192.
15. Sharaf HED, Radawan H, *et al*. A novel fish protein hydrolysate supplement enhances honeybee foraging activity and colony strength: a pilot study. *PLoS One*. 2025.
16. Almasri H, Liberti J, Brunet J, Engel P, Belzunces LP. Mild chronic exposure to pesticides alters physiological markers of honey bee health without perturbing the core gut microbiota. *Sci Rep*. 2022.
17. Zhang G, Olsson RL, *et al*. Strategies and techniques to mitigate the negative impacts of pesticide exposure on honey bees. *Environ Pollut*. 2023.
18. Margaoan R, Papa G, Nicolescu A. Environmental pollution effect on honey bees and their derived

products: a comprehensive analysis. *Environ Sci Pollut Res*. 2024;32:10370-10391.

19. Tokach R, Smart A. Honey bee colony behaviour and ontogeny are adversely affected when exposed to a pesticide-contaminated environment. *J Insect Sci*. 2024;24.