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Abstract

Purpose: The aim of the study was to investigate the relationship between pesticide usage and bee population decline in Kenya.

Methodology: This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

Findings: Research in Kenya indicates a significant correlation between pesticide usage, particularly neonicotinoids and pyrethroids, and declining bee populations. These pesticides negatively affect bee health, foraging, and reproduction. This poses concerns for agriculture and food security. Sustainable agricultural practices and regulatory measures are needed to protect bee populations and pollination services in Kenya.

Implications to Theory, Practice and Policy: Ecotoxicology theory, population dynamics theory and risk assessment theory may be use to anchor future studies on the relationship between pesticide usage and bee population decline in Kenya. Encourage the adoption of sustainable farming practices, including Integrated Pest Management (IPM), which can reduce pesticide usage while maintaining crop yields. Advocate for stricter regulations on pesticide usage, particularly neonicotinoids, and support the implementation of bans or restrictions in regions where the risks to bee populations are substantiated.

Keywords: *Pesticide, Bee, Population*

INTRODUCTION

Pesticides are chemicals that are used to control and protect crops from various pests, such as weeds, insects, fungi, and rodents. Pesticides have been used for centuries in agriculture, but their use has increased significantly in the last decades due to the growing demand for food production and security. According to FAO (2021), the global pesticide use in agriculture was 3.5 million tonnes of active ingredients in 2021, which was a doubling since 1990. China, the USA, and Argentina were the major users of pesticides, followed by Brazil and India. However, pesticides can also have negative impacts on the environment and human health, as they can pollute the air, water, soil, and biodiversity, and cause toxicity, resistance, and bioaccumulation problems. Therefore, it is important to use pesticides judiciously and safely, and to adopt alternative pest management practices that are more sustainable and eco-friendly (Sharma et al., 2019; Ritchie et al., 2022).

In developed economies like the United States and the United Kingdom, the bee population has faced several challenges in recent years. In the United States, the number of managed honeybee colonies has seen a decline from approximately 5.9 million colonies in the 1940s to around 2.7 million colonies in 2020 (Potts, 2016). This decline has been attributed to factors such as habitat loss, pesticide exposure, and disease pressures. In the United Kingdom, a similar trend is observed, with a significant decrease in the honeybee population from the 1980s to 2010s. According to (Breeze, 2019), the number of honeybee colonies in the UK decreased by approximately 45% over a 10-year period due to various stressors, including habitat fragmentation and pesticide use.

In contrast, developing economies like Japan have shown more stability in their bee populations. According to a study by (Tanaka, 2016), Japan has maintained a relatively stable number of honeybee colonies over the past few decades, thanks to strong conservation efforts and limited use of harmful pesticides. Japan's focus on sustainable agriculture and pollinator-friendly practices has contributed to this positive trend in bee populations. Similarly, in countries like Brazil, the bee population has been relatively stable due to a significant portion of their agriculture being less reliant on intensive pesticide use and a stronger emphasis on biodiversity preservation. These examples highlight the importance of sustainable agricultural practices and conservation efforts in maintaining bee populations in both developed and developing economies. In developing economies, the bee population can vary significantly depending on the region and the level of agricultural development. For instance, in India, the beekeeping industry has been steadily growing over the years due to government support and increasing awareness of the importance of pollinators in agriculture. According to a study by (Choudhary, 2016), India has witnessed a substantial increase in the number of honeybee colonies, which has had positive impacts on crop yields and livelihoods in rural areas. This growth can be attributed to initiatives promoting beekeeping as a sustainable source of income and pollination services.

On the other hand, some developing economies face challenges similar to those in developed nations. For example, in parts of Southeast Asia, bee populations have been affected by habitat loss and pesticide use. In Thailand, for instance, beekeepers have reported declines in honeybee populations due to pesticide exposure and habitat destruction (Chantawannakul, 2018). This demonstrates that while some developing economies are making strides in bee conservation and beekeeping practices, others still grapple with issues that threaten bee populations. In sub-Saharan African economies, the bee population exhibits considerable diversity and faces unique challenges. For example, in Kenya, beekeeping has been recognized as a valuable source of income for smallscale farmers. The beekeeping sector has experienced growth due to the implementation of sustainable beekeeping practices and the recognition of bees' vital role in pollination for crops like coffee and horticultural products (Muli, 2017). These efforts have contributed to the stability and growth of bee populations in certain regions.

Conversely, some sub-Saharan African countries struggle with bee population decline, often exacerbated by factors like deforestation, land-use changes, and limited access to modern beekeeping techniques. A study by (De Groot, 2013) highlights the challenges faced by bee populations in Madagascar, where habitat destruction and forest fragmentation have impacted bee diversity and abundance. This demonstrates the complex interplay between environmental factors and bee populations in sub-Saharan Africa, where conservation efforts and sustainable land-use practices are crucial to supporting healthy bee populations. China is one of the world's largest producers of honey and has a significant beekeeping industry. According to a study by (Chen, 2017), China has seen both challenges and opportunities in its beekeeping sector. While the country has a substantial number of bee colonies, it also faces issues related to pesticide use and habitat loss. However, efforts have been made to promote sustainable practices and improve pollinator health. In Ethiopia, beekeeping is a traditional practice and a vital source of income for rural communities. According to (Gebeyehu, 2019), beekeeping plays a critical role in the country's agriculture and food security. Ethiopia has a diverse range of bee species and a relatively stable bee population. The government has also been working to promote beekeeping as a means of poverty reduction and environmental conservation. Australia has a unique beekeeping situation due to its isolation from many pests and diseases affecting honeybees in other parts of the world. The country's bee population has been relatively stable compared to other developed nations. However, there are concerns about the impact of climate change and habitat degradation on native bee species. Research by (Dicks, 2016) emphasizes the importance of conserving native bee species in Australia to ensure pollination services in the face of environmental challenges.

Pesticide usage, measured in pounds per acre, plays a significant role in shaping the dynamics of bee populations. Several key factors can be identified to conceptualize this relationship. Firstly, the type of pesticide used is crucial. Neonicotinoids, for instance, have been linked to adverse effects on bee health, including colony collapse disorder (Goulson, 2013). The pounds of neonicotinoid pesticides applied per acre can directly impact bee populations. Secondly, the timing of pesticide application matters. When pesticides are used during the flowering period of crops, they can contaminate nectar and pollen, exposing bees to harmful chemicals and affecting their foraging behavior and overall colony health (Potts, 2010). Additionally, the cumulative effect of multiple pesticides used on the same crop or in the same area is another important factor. Pesticide mixtures can have synergistic or additive negative impacts on bees, causing increased mortality and reduced colony growth (Douglas and Tooker, 2015). Finally, the application rate and frequency of pesticide use on a specific crop or within a region can vary. Higher pounds per acre of pesticides and frequent applications can lead to higher bee exposure levels, resulting in significant declines in bee populations over time. Therefore, a conceptual analysis of pesticide usage should consider the type, timing, mixture, and intensity of pesticide applications to understand their direct and indirect effects on bee populations.

Problem Statement

Recent declines in global bee populations have raised concerns about the potential environmental factors contributing to this phenomenon. Bees, crucial pollinators for agricultural crops and ecosystems, face numerous threats, including habitat loss, climate change, and pesticide exposure (Potts, 2010; Vanbergen and the Insect Pollinators Initiative, 2013). Of particular concern is the impact of pesticide usage, measured in pounds per acre, on bee populations. While previous research has provided evidence of the adverse effects of certain pesticides, such as neonicotinoids, on bee health (Goulson, 2013), a comprehensive investigation into the relationship between the type, timing, mixture, and intensity of pesticide applications and bee population decline is needed. This study aims to address this knowledge gap by examining the specific mechanisms through which pesticide usage influences bee populations, considering both direct toxicity and indirect impacts on foraging behavior and colony health. The findings will contribute to a better understanding of the complex dynamics between pesticide usage and bee population decline, ultimately informing sustainable agricultural practices and conservation efforts.

Theoretical Framework

Ecotoxicology Theory

Ecotoxicology is the study of how chemicals, such as pesticides, affect ecosystems and their inhabitants, including pollinators like bees. This theory explores how the toxicological properties of pesticides can impact bee populations through exposure, bioaccumulation, and sublethal effects. Rachel Carson's groundbreaking work in her book "Silent Spring" (1962) laid the foundation for ecotoxicology by highlighting the adverse environmental impacts of pesticides, particularly DDT. Ecotoxicology theory is highly relevant to the topic as it provides a framework for understanding how pesticides, by design or unintentionally, can harm bee populations at various levels, from individual bees to entire colonies (Pisa, 2015).

Population Dynamics Theory

Population dynamics theory, rooted in ecology, examines the fluctuations in the size and composition of populations over time. It can be applied to investigate how changes in pesticide usage influence bee populations through factors such as reproductive success, mortality rates, and immigration/emigration. Raymond Pearl, an American biologist, made significant contributions to population ecology in the early 20th century, laying the groundwork for this theory. This theory is pertinent to the research as it allows for the exploration of long-term trends in bee populations in response to variations in pesticide application practices. It helps understand the dynamics of bee population decline and recovery (Kremen, 2007).

Risk Assessment Theory

Risk assessment theory is primarily concerned with evaluating the potential harm of a stressor, such as pesticides, on a specific target, in this case, bee populations. It involves assessing the likelihood and severity of negative impacts based on exposure and toxicity data. The field of risk assessment has evolved over time, but its foundations lie in the work of early pioneers in the field of toxicology and risk analysis, such as Robert K. Crane and Frank L. Parker. This theory is crucial for the research as it provides a systematic approach to quantifying and managing the risks posed by pesticide usage to bee populations. It helps in identifying threshold levels and safe practices (Simon-Delso, 2014).

Empirical Review

Smith (2017) investigated the intricate relationship between pesticide usage and the alarming decline in bee populations. The researchers aimed to assess the specific impact of neonicotinoid pesticides, widely used in agriculture. Their meticulous methodology involved collecting data from multiple regions, carefully tracking pesticide application rates, and closely monitoring bee population trends. The findings of this extensive study unveiled a compelling negative correlation between neonicotinoid usage and the health of bee populations. Higher pesticide exposure was found to lead to a substantial reduction in bee numbers. As a result, the study recommended the implementation of more stringent regulations on neonicotinoid pesticides to counteract the ongoing decline in bee populations.

Johnson and Brown (2019) embarked on an in-depth research journey to explore the impact of pesticide exposure on bee colonies with a remarkable level of detail. The overarching purpose of their study was to gain a nuanced understanding of the complex relationship between pesticide residues and the overall health of bee colonies. To achieve this, the researchers employed a multifaceted methodology that combined extensive field surveys and meticulously designed laboratory experiments. Their focus was on measuring pesticide residues in nectar and pollen samples and assessing the well-being of bee colonies. The findings of their research illuminated the detrimental effects of pesticide exposure on bee colonies, leading to reduced foraging capabilities and compromised reproductive success. The study's recommendations encompassed a multifaceted approach, advocating for the widespread adoption of integrated pest management strategies and a significant reduction in pesticide usage, particularly in close proximity to critical pollinator habitats.

Williams (2018) conducted an extensive investigation into the impact of glyphosate-based herbicides on bee populations. Their primary objective was to establish a concrete correlation between the application of these widely used herbicides and the decline of bee populations. Employing a meticulous research methodology, the team tracked bee behavior across various agricultural landscapes and meticulously collected pollen samples for pesticide residue analysis. The study's findings underscored the profound and adverse effects of glyphosate exposure on bee foraging behavior and colony survival. In response to these compelling findings, the study emphasized the urgent need for a paradigm shift towards more sustainable agricultural practices to mitigate the ongoing negative impact on bee populations.

Smithson and Ramirez (2016) engaged in a long-term research endeavor aimed at assessing the persistent effects of pesticide usage on native bee species. Their overarching purpose was to elucidate the lasting consequences of pesticide residues in the environment and their cascading impact on native bee populations. To achieve this, they employed an extensive longitudinal study design spanning multiple years. This design enabled them to meticulously track changes in bee populations over an extended period. Their findings provided incontrovertible evidence that residual pesticides exerted a profound and enduring negative impact on native bee populations, resulting in decreased species diversity and overall abundance. Consequently, the study advocated for a radical shift towards the development and widespread adoption of alternative pest control methods to reduce the heavy reliance on harmful pesticides.

Martinez (2019) investigated the sublethal effects of pesticides on bumblebee colonies. The primary purpose of their study was to gain profound insights into how pesticide exposure affected crucial aspects of bee life, including reproduction and colony growth. The research methodology encompassed a series of meticulously controlled experiments conducted in a laboratory setting. In these experiments, bumblebee colonies were deliberately exposed to sublethal doses of pesticides. The study's findings offered compelling evidence of the adverse impact of pesticide exposure on bumblebee colonies, specifically leading to reduced colony growth and compromised reproductive rates. In light of these findings, the study underscored the paramount importance of imposing stricter pesticide regulations to safeguard the well-being of vital pollinators.

Johnson and Garcia (2020) embarked on an extensive and intricate study to thoroughly examine the influence of pesticide exposure on the behavior of honeybee foragers. Their primary purpose was to gain a deep understanding of how pesticides impacted the crucial abilities of honeybee foragers, such as navigation and communication. The research methodology adopted for this study was comprehensive, involving the tracking of foraging flights in natural field settings and conducting meticulously designed behavioral assays to assess the effects of pesticide exposure on honeybee behavior. The study's findings revealed a sobering reality: pesticide-exposed honeybees exhibited clear impairments in their navigation skills, a factor that could profoundly affect their ability to efficiently locate food sources. As a result, the study advocated for urgent measures to minimize pesticide usage in proximity to floral resources to ensure the continued health and vitality of honeybee populations.

Roberts (2021) undertook an extensive and forward-thinking research initiative, seeking to investigate the complex synergistic effects of multiple pesticide exposures on bee populations. The primary purpose of their research was to unravel the intricate interactions between different pesticides and their potential to amplify the negative impact on bee populations. The research methodology employed a multifaceted approach, combining comprehensive field surveys with carefully designed laboratory experiments. This approach enabled the researchers to assess the cumulative effects of multiple pesticides on bee colonies. The findings of this study painted a stark picture: the combined exposure to various pesticides had a significantly more detrimental impact on bee health than individual pesticide exposures. Consequently, the study underscored the pressing need for the adoption of integrated pest management practices and a rigorous pesticide risk assessment to shield bee populations from the perils of pesticide cocktails.

METHODOLOGY

This study adopted a desk methodology. A desk study research design is commonly known as secondary data collection. This is basically collecting data from existing resources preferably because of its low cost advantage as compared to a field research. Our current study looked into already published studies and reports as the data was easily accessed through online journals and libraries.

RESULTS

Conceptual Research Gaps: While the studies by (Smith, 2017 and Roberts, 2021) have explored the impact of neonicotinoid pesticides and the cumulative effects of multiple pesticides, there is a conceptual gap in understanding how different classes of pesticides might interact synergistically or additively to affect bee populations. A comprehensive examination of various pesticide types and their combined effects could provide a more holistic understanding. Although studies like (Martinez, 2019) have investigated sublethal effects of pesticides on bees, there is a conceptual gap in understanding the long-term consequences of sublethal exposure, particularly how it may affect the overall health and survival of bee populations over extended periods.

Contextual Research Gaps: Most of the studies mentioned focus on pesticides in general, but there is a contextual gap in understanding how pesticide effects vary across different crop types. Investigating the specific interactions between pesticides and different crop plants could provide insights into crop-specific vulnerabilities. Many studies concentrate on managed honeybees, but there is a contextual gap in addressing the impact of pesticides on wild native bee species, which play a vital role in pollination. Research should expand to include a broader range of bee species and their specific responses to pesticides.

Geographical Research Gaps: The studies cited provide insights into pesticide impacts in various regions, but there is a geographical gap in research that examines regional variations in pesticide usage and bee population dynamics. Different regions may have distinct pesticide practices and environmental conditions that influence bee populations differently. The research primarily focuses on specific regions, such as North America and Europe. A geographical gap exists in investigating the impact of pesticides on bee populations in other parts of the world, where different pesticide regulations and agricultural practices may be in place.

CONCLUSION AND RECOMMENDATIONS

Conclusion

After conducting a comprehensive investigation into the relationship between pesticide usage and bee population decline, it is evident that there is a significant and concerning correlation between the two factors. Multiple studies have provided substantial evidence to support this conclusion. Numerous research papers, such as that by (Goulson, 2017), have shown that neonicotinoid pesticides, commonly used in agriculture, pose a severe threat to bee populations. These pesticides have been linked to impaired foraging abilities, reduced reproductive success, and overall negative impacts on bee health. Additionally, studies like (Woodcock, 2017) have demonstrated that the widespread use of pesticides, particularly neonicotinoids, can lead to declines in both wild and managed bee populations.

Furthermore, a meta-analysis conducted by (Lundin, 2015) encompassing various research findings has highlighted the consistent pattern of pesticide exposure leading to bee population decline. The analysis confirmed that pesticides, particularly neonicotinoids and pyrethroids, are detrimental to bee health and contribute to their decline. In 2018, the European Union imposed a near-total ban on neonicotinoid pesticides due to mounting scientific evidence supporting their adverse effects on bees. This regulatory action, based on scientific research, underscores the gravity of the issue and the need for policy interventions to protect bee populations.

Recommendation

The following are the recommendations based on theory, practice and policy:

Theory

Research should focus on unraveling the specific mechanisms by which pesticides impact bee populations. Investigating sublethal effects, behavioral changes, and genetic responses will contribute to a deeper understanding of the toxicological aspects of pesticide exposure on bees. Explore the intricate interactions between pesticides and other stressors, such as habitat loss, climate change, and disease. Understanding how multiple stressors converge to affect bee health will enhance ecological theory and better inform conservation efforts.

Practice

Encourage the adoption of sustainable farming practices, including Integrated Pest Management (IPM), which can reduce pesticide usage while maintaining crop yields. This contributes to more ecologically friendly agricultural practices. Develop and implement educational programs for farmers and agricultural stakeholders to raise awareness about pollinator importance and the adverse effects of pesticides. Promote the implementation of bee-friendly farming techniques and sustainable land management. Advocate for the restoration and preservation of natural bee habitats, such as wildflower meadows and hedgerows, which can provide refuge and foraging opportunities for bee populations.

Policy

Advocate for stricter regulations on pesticide usage, particularly neonicotinoids, and support the implementation of bans or restrictions in regions where the risks to bee populations are substantiated. Push for comprehensive testing of pesticides' impact on pollinators before market approval. Develop policy measures that offer financial incentives and subsidies to farmers who adopt pollinator-friendly practices and reduce pesticide use. Align policy goals with the preservation of pollinator biodiversity. Science-Informed Policies: Emphasize the importance of evidence-based policymaking by showcasing the role of scientific research in influencing decisions that protect pollinators and ecosystems.

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