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Implications of Pesticide Usage on Pollinators and Agricultural Sustainability

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In the context of developing nations, agriculture stands as the cornerstone of their economies. However, the augmented presence of pests has gravely imperiled crop cultivation. In response, an assortment of pesticides has been employed to safeguard these vital crops. Regrettably, this defensive strategy has exhibited inadvertent repercussions on non-target, advantageous organisms, and notably, on pollinators. Pollinators, crucial for sustaining agriculture, contribute significantly to production and yield augmentation through pollination, a service pivotal for 84% of global crop varieties. Notably, bees, prominent pollinators, face substantial jeopardy during pollination endeavors, further exacerbating the decline in their populations. As the prevalence of pesticides surges, the dwindling pollinator populations precipitate a distressing diminution in a gricultural productivity. Consequently, this reduced food supply cascade effect propels an escalated demand for sustenance resources. This comprehensive overview elucidates the indispensable role of pollinators, the intricate landscape of pesticide application, and the intricate interplay that imperils these vital species, ultimately posing challenges to sustainable agriculture.

Keywords: Pollinators, Agriculture, Pesticides, Pesticide consumption, Bees

INTRODUCTION

Pesticides, engineered to target specific organisms like pest insects, inadvertently impose collateral damage on non-target pollinators, precipitating a global decline in food crop productivity by approximately 35% (Badawy et al., 2015). The intricate choreography of pollinators underpins the transfer of pollen among flowers, pivotal for the successful seed and fruit production of nearly 88% of flowering plants designated as pollinator-dependent. Prominent amongst these are bees, exhibiting prowess in pollen transport and rendering indispensable pollination services to both cultivated and wild flora (Sponsler et al., 2019). Cross-pollinating and incompatible plants, crucial for biodiversity conservation, rely on pollination for the propagation of seeds. Bees, in their quest for nectar, inadvertently participate in pollination by ferrying pollen grains via specialized body hairs, thereby fostering inter-floral pollination (Martin, 2015). In the grand tapestry of global agriculture, around 300 commercially cultivated crops owe their existence to insect-mediated pollination, with a staggering 84% being reliant on this process (Stanley et al., 2016).Among these, bumblebees and honey bees, possessing eusocial attributes, emerge as principal pollinators, lending their services to crucial crops like tomatoes, vegetables, and fruits (Berenbaum, 2007). The escalating demand for crop-pollinating bees parallels the rise in insect-mediated pollination-dependent crop production globally (Isaacs et al., 2017). These intricate interactions are facilitated by a multitude of flower signals, encompassing color, odor, texture, taste, and shape, collectively forming pollination syndromes that guide insects towards rewarding blossoms (Frankie et al., 2009).This comprehensive review navigates the intricate web of pesticides, pollinators, and agricultural dynamics, shedding light on their interdependence, vulnerabilities, and the urgent need for sustainable practices to safeguard global food security and ecological equilibrium.

Importance of Pollinators

The pivotal role of pollinators in agriculture is underscored by their substantial global worth, amounting to €153 billion (217 billion US dollars), constituting 9.5% of the value of agricultural products used for human consumption in 2005 (Irshad et al., 2014). In the context of the United States, insect-pollinated crops hold a value of $4.5 billion (Pimentel et al., 1993). Remarkably, vegetables and fruits emerge as the most economically valuable crop categories, contributing to a staggering worth of over €50 billion, followed by edible oil crops, stimulants, nuts, and spices (Gallai-Salles et al., 2009). This profound economic association is also reflected in specific regions, exemplified by the valuation of insect pollinators at 954.59 million US dollars in Pakistan's Himalayan region (Irshad et al., 2013), and the impressive export of eight Brazilian agricultural commodities valued at €7 billion, along with significant contributions in East Africa, Uganda, and the Netherlands (Irshad et al., 2014).

A comprehensive analysis of global crop diversity has revealed that more than 75% of the 115 studied crops, which rely on identified pollen vectors, exhibit a degree of dependency on animal pollination. Among these, thirteen crops exhibit complete reliance on pollinators, while 30 and 27 crops are classified as highly dependent and moderately reliant, respectively. A subset of crops is entirely contingent on pollinators for their reproductive processes, necessitating manual pollination in their absence. Noteworthy examples include cocoa, a cornerstone cash crop in tropical nations, as well as kiwifruit, passion fruit, annona and sapodilla fruits, vanilla, various squashes and pumpkins, cantaloupes, watermelons, and Brazil- and macadamia nuts. The indispensable contribution of animal pollination is exemplified by the substantial yield enhancement ranging from 5% to 50% across most crops (primarily facilitated by bees) (Gallai-Vaissiere, 2009).

Pesticides Toxicity to Pollinators

The global market's reliance on honey, a product of the industrious honey bee, stands as a testament to their pivotal role as essential pollinators and contributors to the economy (Hashimi et al., 2020). The Food and Agriculture Organization (FAO) reported substantial figures for beeswax (65k tons) and honey (1.6 million tons) production in 2013, emphasizing their economic importance (Rortais et al., 2017). An intricate ecological interplay emerges where the proliferation of pollinator insect populations is bolstered by plant biodiversity, while herbicide application inadvertently diminishes plant communities (Hashimi et al., 2020).

However, the thriving existence of these invaluable pollinators is severely threatened by the application of diverse chemicals to plants. Honey bees, reliant on plant nectar for honey production, bear the brunt of chemical toxicity, significantly compromising their functionality (Hashimi et al., 2020). This susceptibility results in a weakened immune system, compounding their vulnerability (Martin, 2015). Notably, certain insecticides such as organophosphates, neonicotinoids, carbamates, phenyl pyrazoles, and pyrethroids, frequently employed, serve as toxic agents for bees. These chemicals disrupt the bees' nervous system, leading to a cascade of effects including loss of coordination, paralysis, and eventual fatality (Hashimi et al., 2020).

Exposure to pesticides occurs through direct contact, where droplets from spraying land on bees, or indirectly, where wind carries pesticide particles from treated fields. The concentrated chemical presence in both scenarios is often lethal to bees. Moreover, bees face significant risks when caught in the trajectory of spray drift, and residues of agrochemicals have been identified in honey, water, pollen, larvae, feed, and hives. Additionally, bees are imperiled by exposure to combs treated with acaricides, collectively heightening their susceptibility (Sanchez-Bayo et al., 2016).

The pivotal challenge confronting pollinators stems from the pervasive utilization of agrochemicals. In the wake of their application in crop fields, a nuanced disruption of diverse pollinator communities emerges. This pre- and post-application destabilization, compounded by low and unpredictable pollinator presence, cascades into discernible consequences on pollination dynamics. This disruption culminates in the incurrence of pollen-limited seed and fruit production, inevitably precipitating a decline in crop yields (Garibaldi et al., 2011; Klein et al., 2009). In the intricate web of ecological interplay, numerous species populations are subject to the pervasive influence of biotic environmental pressures, including pests, predators, and parasites. The multifaceted nature of this issue is underscored by a confluence of interacting factors, categorized as lethal and sublethal stressors, contributing to the predicament. The safeguarding of crops against a broad spectrum of pests necessitates the application of insecticides. However, the intended target, pests, shares an unfortunate overlap with non-target organisms, ultimately affecting an estimated 35% of global food crops (Velthuis et al., 2006). The alarming repercussions reverberate through cultivated ecosystems, as the deleterious impact of broad-spectrum insecticides reverberates far beyond their intended target. This resonance of impact is a significant contributor to the precipitous decline in pollinators, a phenomenon welldocumented within cultivated domains (Badawy et al., 2015). Beyond the loss of life among non-target organisms, the broader ramifications encapsulate the instigation of aberrant behaviors and physiological dysfunctions, amplifying the complexity of the challenge.

CONCLUSION

The use of pesticides on the one hand can alleviate plants from vector-borne diseases but on the other hand impact severely on non-target or beneficial organisms. Proper guidance and usage of agrochemicals should be considered during the time of application. Effective pesticides should be produced that are specific for target organisms and produce minimum side effects for other non-target and beneficial organisms like pollinators (honeybees) that ultimately help in sustaining non-target organism.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

AK presents the idea, RU, RS and BA have supervised and wrote the manuscript, SWA, KAS, MU and AW did the experiment. SU, SR and IU reviewed and reform the manuscript. All authors read and approved the final version.

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