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Editorial

Sustainable Use of Pesticides

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Pesticides serve as indispensable inputs to ensure the optimal provision of agricultural commodities, thus exerting a significant influence on the quality and yield of food. However, the extensive application of chemical pesticides in agricultural practices has led to an elevation in pest resistance, resulting in a substantial decline in the efficacy of pesticide control. Consequently, the sustainable utilization of pesticides has emerged as a critical area of investigation. The focal point of this Special Issue "Sustainable Use of Pesticides" delves into this subject matter from multiple perspectives, aiming to provide novel insights into the sustainable application of pesticides.

The long-term use of pesticides induces varying degrees of resistance in pests, posing significant challenges to chemical control measures. The mechanisms underlying insect resistance primarily encompass metabolic resistance, gene targeting resistance, epidermal penetration resistance, and symbiotic bacterial resistance. Among these, metabolic resistance stands out as the most crucial pathway. It involves essential components such as cytochrome P450(CYP), detoxification enzymes, uridine diphosphate (UDP) glucosyltransferases (UGTs), and ABC transporters [1]. Li et al. [2] studied the transcriptome-based identification and characterization of genes associated with resistance beta-cypermethrin in *Rhopalosiphum padi* demonstrating that several differentially expressed genes (DEGs) linked to drug resistance were involved in cuticle proteins and detoxification metabolism processes. These DEGs encompass genes associated with cuticle protein, P450, UGT, ABC transporter and trypsin. P450s are present in a variety of organisms and possess the ability to catalyze numerous biochemical reactions. They play a crucial role in the detoxification of exogenous substances in insects and are known to confer metabolic resistance to various insecticides, including pyrethroids [2] and neonicotinoids [3]. The enhanced metabolic activity of P450 enzymes also influences the development of cross-resistance to insecticides. In insects, P450 enzymes are classified into four clans: CYP2, CYP3, CYP4, and mitochondrial CYP. The specific P450 enzymes selected for resistance vary depending on the insect species subjected to the same insecticide stress or when the same insect species face different insecticide pressures. Additionally, it is worth noting that certain P450 enzymes may confer resistance to multiple insecticides. Liang et al. [3] showed that an enhanced expression of cytochrome P450 *CYP4G68* led to the resistance of *Bemisia tabaci* against imidacloprid and thiamethoxam. In order to effectively address P450-mediated resistance and ensure the sustainable use of insecticides, the most encouraging strategy at present is the development of targeted P450 inhibitors utilizing RNAi technology.

To ensure the sustainable use of pesticides, it is crucial to address chemical pesticide resistance and incorporate agricultural production technologies. Mayerova et al. [4] investigated the impact of different herbicide strategies and crop rotations on weed communities in two sites over the past 40 years, discovering that crop species and rotations played a significant role in determining weed community composition. Diverse crop rotations influenced both weed species diversity and the acceptable weed density. By selecting effective

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herbicides based on this information, the repeated use of herbicides containing the same active ingredient can be avoided, promoting efficient herbicide use and minimizing resistance development. In a separate study, Han et al. [5] explored the feasibility of pesticide application for controlling *Spodoptera frugiperda* in fresh corn before transplanting, showing that spraying Chlorantraniliprole or Spinetoram at 25 times the conventional concentration before transplanting effectively controled *S. frugiperda*. Furthermore, when compared to field spraying and seed coating methods, the utilization of insecticide-active ingredients has been reduced, leading to a decrease in overall pesticide usage. To achieve the equivalent effectiveness and optimize the control outcomes, the incorporation of adjuvants has been proven to be highly beneficial in minimizing environmental damage. This positive impact is particularly evident in the realm of plant protection drones, which is of great significance for the field of plant protection unmanned aerial vehicles (UAVs).

The issue of pesticide drift during UAV spraying represents a crucial factor influencing pesticide utilization and the control efficacy. By introducing adjuvants into the spray solution, the droplet atomization spectrum can be modified, resulting in a significant enhancement in the control effectiveness against wheat aphids and rust disease, while also prolonging the duration of pesticide effectiveness [6]. Yan et al. [7] augmented UAV spraying by incorporating an aviation spray adjuvant. This strategic inclusion not only ensured the potent control efficacy of prothioconazole against wheat *Fusarium* head blight and contributed to wheat yield, but also greatly diminished the levels of deoxynivalenol mycotoxin. Consequently, the integration of the aviation spray adjuvant not only upheld the safety of wheat production but also exhibited a favorable impact on the overall quality of the crop.

Currently, there is significant interest in researching the mechanism of pesticide resistance, and numerous studies have shed light on some of these resistance mechanisms. However, the use of RNAi technology to solve the resistance problem is still in the preliminary research stage, requiring extensive exploration before practical implementation. Similarly, the utilization of agricultural technology to ensure sustainable pesticide use is quite limited. Consequently, a viable solution lies in the development of novel pesticides to replace existing ones that are highly resistant or environmentally harmful. Among these alternatives, emamectin benzoate (EMB)stands out as a popular biopesticide due to its potent pest-fighting properties and low toxicity. EMB can significantly disrupt the life cycle of pests like *S. frugiperda* and other lepidoptera species, thereby offering a scientific basis for effectively managing these pests [8]. Adawi et al. [9] studied the effectiveness of low-copper chemicals against olive leaf spot disease, indicating that the utilization of coper complexed with lignosulphonate and gluconate (Disper Cu Max), as well as the self-defense inducer Disper Broton GS, resulted in a noteworthy reduction in olive leaf spot damage and the quantity of copper employed, compared to the conventional use of dodine and copper hydroxide. Alotaibi et al. [10] isolated three entomopathogenic bacteria from entomopathogenic nematodes and investigated their potential for controlling *Ectomyelois ceratoniae*, a pest insect, revealing that both the bacterial cells and filtrates displayed larvicidal activity against *E. ceratoniae. Xenocoumacin* 1 (Xcn1) is a potent antibacterial compound produced by *Xenorhabdus nematophila* CB6. Qing et al. [11] constructed a Δ*PBAD-xcnA* mutant based on *X. nematophila* CB6 and successfully achieved a substantial enhancement in the production of Xcn1 through a promoter replacement strategy. This advancement serves as a basis for the industrial-scale production of Xcn1.

To address the issue of pesticide resistance, one approach involves modifying the specific attributes of plants. By employing natural polysaccharides, it is possible to induce the activation of plant defense responses, bolster plant resistance to diseases and induce plant resistance against viral and fungal plant diseases. This approach mitigates the need for excessive chemical agents and the accumulation of resistance. Sun et al. [12] found that the application of lentinus polysaccharide resulted in a decrease in the malondialdehyde (MDA) content in cotton seeds. Additionally, they noted a significant increase in the activities of various enzymes in leaves. These effects facilitated the growth and development of cotton plants while substantially reducing the occurrence of cotton seedling damping-off disease.

In addition to the aforementioned studies, Yang et al. [13] further demonstrated that the combination of *Ganoderma lucidum* polysaccharide and chemical fungicides, when used as a seed coating chemical compound, proved advantageous in managing soil-borne diseases of wheat and maize. This approach not only prolonged the efficacy of disease control but also reduced the need for excessive application of chemical fungicides. Moreover, the utilization of *G. lucidum* polysaccharides led to an upregulation of resistance genes and induced a plant defense response.

Overall, this Special Issue presents various insights into addressing the challenge of pesticide resistance, aiming to offer a fresh outlook on the sustainable utilization of pesticides.

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