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Editorial

Agricultural Environment and Intelligent Plant Protection Equipment

Xiongkui He [1,*], Fuzeng Yang [2] and Baijing Qiu [3]

[1] College of Science, China Agricultural University, Beijing 100193, China
[2] College of Mechanical and Electronic Engineering, Northwest A&F University, Xianyang 712100, China; yfz0701@163.com
[3] Key Laboratory of Plant Protection Engineering, Ministry of Agriculture and Rural Affairs, Jiangsu University, Zhenjiang 212013, China; qbj@ujs.edu.cn
* Correspondence: xiongkui@cau.edu.cn; Tel.: +86-6273-1446

Intelligent plant protection equipment utilizes advanced sensor technology and data analysis algorithms to achieve real-time monitoring and precise management of crop growth status, pest and disease situations, and environmental parameters. By employing sensors for data collection, image recognition technology, and automated operations, intelligent plant protection equipment can accurately identify pests and diseases, locate infected areas, and achieve precise pesticide spraying during operations, thereby minimizing pesticide usage and enhancing crop yield and quality. Additionally, through remote monitoring and management functions, users can oversee equipment remotely and schedule its operations, thereby improving agricultural production efficiency, reducing labor costs, and mitigating environmental impact.

Pesticide spraying remains the primary method for pest and disease control in orchards. Orchard spraying technology and equipment, as vital components of orchard pest and disease management, play a crucial role in reducing pesticide usage, improving pesticide efficiency, and minimizing pesticide pollution to the environment. Li et al. [1] conducted a study on the effects of airflow distribution patterns on the droplet deposition coverage and penetration efficiency of multi-unit air-assisted orchard sprayers. Their experimental results indicated that increasing airflow velocity can enhance the droplet deposition coverage on the backside of pear and cherry tree leaves, though it does not significantly affect spray penetration. The article also investigated the relationship between airflow velocity, direction, and droplet deposition indicators through Partial Least Squares (PLS) analysis. The study revealed that enhancing airflow velocity in the forward and horizontal directions can significantly improve the droplet deposition coverage on the outer side of pear trees; however, airflow indicators did not significantly affect droplet deposition coverage on cherry trees. Determining the orchard spraying deposition rate is crucial for optimizing application performance and pesticide efficiency. However, the large canopy and dense foliage of orchard trees, coupled with mutual shading, pose challenges for quantitatively assessing spraying efficiency. Wang et al. [2] examined spraying deposition quantity and distribution in different heights and layers of the fruit tree canopy using orchard sprayers. Their experimental findings showed that when using a trailed orchard sprayer, the upper and lower layers of leaves in the canopy have larger leaves, while the top and bottom have smaller leaves. When using a fixed orchard sprayer, the deposition quantity of spray liquid decreases with increasing canopy height. Additionally, within the canopy, the deposition quantity of spray liquid is lower, whereas it is higher in external areas. Sun et al. [3] employed an analysis method based on CFD orthogonal experiments to study the effects of four key structural parameters—shrinkage pipe attenuation angle, diffusion pipe divergence angle, venturi diameter, and venturi length—on an online pesticide mixing device and the pesticide dissolution and mixing performance. This study provides theoretical references for the production of prototype online pesticide mixing devices based on pipeline spraying.

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Citation: He, X.; Yang, F.; Qiu, B. Agricultural Environment and Intelligent Plant Protection Equipment. *Agronomy* **2024**, *14*, 937. https://doi.org/10.3390/agronomy14050937

Received: 8 April 2024
Accepted: 25 April 2024
Published: 30 April 2024

To meet the demand for precise monitoring of field pest and disease information in modern agriculture, Wang et al. [4] proposed an intelligent plant protection monitoring system. This system comprises wireless cameras, temperature and humidity sensors, smart information terminals, and probes, facilitating the collection of plant images and meteorological information. Additionally, the system features positioning and communication functions, enabling the real-time recording of field environmental information and wireless data transmission to the monitoring center. In order to enhance the path-tracking control accuracy and driving stability of orchard trailed spraying robots, Ren et al. [5] proposed a navigation path-tracking control algorithm based on Double Deep Q Network (Double DQN). Through simulation tests, this method demonstrated high accuracy and stability in both straight and "U"-shaped path-tracking scenarios. To tackle the issue of pesticide depletion during field spraying tasks when the spraying robot is incomplete, Qin et al. [6] developed a spraying–dosing robot group and proposed a collaborative navigation system based on an orchard map. Firstly, a three-dimensional orchard point cloud map was constructed, and navigation path points were set on the projected map. Secondly, a master–slave command-based collaborative navigation strategy was developed, where the spraying robot acts as the master and the dosing robot as the slave. Finally, the spraying robot and the dosing robot performed collaborative navigation on the constructed map using the pure pursuit algorithm and the D-A control algorithm, respectively. To verify the collaborative navigation system, field tests were conducted on individual communication and navigation controls. The communication experiment results showed a packet loss rate of less than 5%, meeting the communication requirements. The navigation control experiment results indicated that the maximum absolute lateral error for the spraying robot was 24.9 cm, and for the dosing robot it was 29.7 cm.

Unmanned Aerial Vehicles (UAVs) for low-altitude, low-volume and ultra-volume crop protection operations offer several advantages, including the separation of humans and machinery and of personnel and chemicals; good adaptability to terrain; flexible maneuverability; efficient labor, water, and pesticide saving; as well as a high level of automation. Gradually, they have become significant equipment in agricultural crop protection operations. Dengeru et al. [7] conducted research on the application of insecticides sprayed by UAVs agricultural sprayers on nutmeg crops, investigating the spray deposition and drift characteristics. They found a potential method to effectively enhance insect control. This research opens up new possibilities for agricultural production and demonstrates the broad prospects of UAV technology in agriculture. Thomson et al. [8] studied the spray deposition and off-target drift characteristics of plant protection materials sprayed by UAVs to enhance spraying effectiveness and reduce off-target losses. They found that wind speed is the most important weather factor affecting the local off-target drift of pesticides. In drift of very fine droplets sampling experiments, accurately describing wind speed and direction at sampling positions is challenging due to natural variations in spray movement during the sampling target approach. Although accurately tracking wind direction to the target is difficult or even impossible, analyzing spray drift using statistical models with a large amount of field experiment data obtained by varying the wind speed and the tracking method can yield many conclusions. Comparing wind tunnel experiments with other technologies, Wang et al. [9] evaluated the spray drift of an octocopter Unmanned Aerial Spraying System (UASS). Compared to ground sprayers, UASS sprays more fine droplets at higher operating heights and faster travel speeds, hence posing higher drift risks. Li et al. [10] discussed the effectiveness and distribution of pesticide spraying using UAVs and ground sprayers. Their research revealed that cooperative spraying by UAVs and ground sprayers can improve the all-round coverage of pesticides in fruit tree canopies, especially in the upper and inner layers. By adjusting the spraying parameters, pesticide utilization and operational efficiency can be enhanced. Moreover, increasing the application proportion of ground equipment can improve the uniformity of deposits in the vertical direction of the canopy. In summary, this joint spraying strategy can reduce pesticide usage while ensuring the effective use of insecticides and protective fungicides. Mu et al. [11]

investigated the complex wheat field classification problem based on multi-scale feature fusion. They conducted ground target classification research using UAV multispectral remote sensing images in diverse wheat field scenes with various varieties. Compared to satellite remote sensing, UAVs provide high-spatial-resolution remote sensing images with rich details at low altitudes. However, different wheat varieties exhibit different characteristics, which may lead to category misjudgments during semantic segmentation, reducing the classification accuracy and affecting the classification effectiveness of ground targets.

The interaction between soil erosion and farmland vegetation restoration and its impact on soil enzyme activity and microbial nutrient limitations in the loess hilly region of China is a significant research area. Tang et al. [12] investigated these interactive effects by analyzing soil macroaggregate carbon (C), nitrogen (N), and phosphorus (P) contents, alongside microbial biomass and enzyme activity. The study revealed that soil properties such as composition, organic carbon content, and microbial biomass strongly influence soil enzyme activity and microbial nutrient limitations. Furthermore, different land use types (forest, grassland, and farmland) also display variations in their effects on soil enzyme activity and microbial nutrient limitations. Given the importance of timely disease detection to mitigate crop yield reduction due to pathogen infections, Wan et al. [13] explored the potential of hyperspectral imaging as a rapid, non-destructive sensing technology for disease identification. By analyzing spectral changes, they investigated the feasibility of using hyperspectral imaging to detect plant diseases in their early stages. In addition, Zhang et al. [14] examined the light and heat environment gradients and crop growth within open-air agriculture photovoltaic systems (OAVSs) in the eastern region of China. They measured solar radiation intensity, air temperature, and soil temperature during both summer and winter seasons. Utilizing Autodesk Ecotect Analysis 2011 software, they conducted light environment analysis, energy consumption analysis, and sunlight shading analysis to assess the effects of building structural parameters, material parameters, and environmental parameters on agricultural building environments. While the research findings offer valuable insights for standardizing agricultural production and the photovoltaic agriculture industries, there are limitations to consider. The study primarily focused on the effects of continuously laid photovoltaic panels on the light and heat environment within the OAVSs at specific spans and heights. Future research should expand to explore OAVSs with different photovoltaic panel layout densities, span lengths, and heights. Moreover, there is a need for further investigation into the response mechanisms of agricultural production to environmental factors, integrating environmental analysis and agricultural production to better understand the effects of light and heat environments on crop growth.

Author Contributions: All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: We thank the authors and reviewers for their valuable contributions on this topic.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

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