applied sciences

MDPI

Article

Effects of Varying Planting Patterns on Wheat Aphids' Occurrence and the Control Effect of Pesticide Reduction Spraying Process by Unmanned Aerial Vehicle

Haifeng Gao [1,2,†], Yuyang Shen [2,†], Li Chen [2], Hanlin Lai [2], Hong Yang [2], Guangkuo Li [2,*], Sifeng Zhao [1,*] and Feng Ge [3,*]

1 Xinjiang Production and Construction Corps Key Laboratory of Special Fruits and Vegetables Cultivation Physiology and Germplasm Resources Utilization, Agriculture College, Shihezi University, Shihezi 832000, China; ghf20044666@163.com
2 Institute of Plant Protection, Xinjiang Academy of Agricultural Sciences/Key Laboratory of Integrated Pest Management on Crop in Northwestern Oasis, Ministry of Agriculture and Rural Affairs, Urumqi 830091, China; sansirosoul@163.com (Y.S.)
3 State Key Laboratory of Integrated Management of Pest and Rodents, Institute of Zoology, Chinese Academy of Sciences, Beijing 100101, China
* Correspondence: lgk0808@163.com (G.L.); zhsf_agr@shzu.edu.cn (S.Z.); get@ioz.ac.cn (F.G.)
† These authors contributed equally to this work.

check for updates

Citation: Gao, H.; Shen, Y.; Chen, L.; Lai, H.; Yang, H.; Li, G.; Zhao, S.; Ge, F. Effects of Varying Planting Patterns on Wheat Aphids' Occurrence and the Control Effect of Pesticide Reduction Spraying Process by Unmanned Aerial Vehicle. *Appl. Sci.* **2023**, *13*, 11916. https://doi.org/10.3390/app132111916

Academic Editors: Xin Yang and Ran Wang

Received: 12 September 2023
Revised: 28 October 2023
Accepted: 30 October 2023
Published: 31 October 2023

Abstract: A walnut–wheat intercropping pattern is practiced widely in southern Xinjiang to alleviate the contradiction between the lack of cultivated land resources and to increase economic value. Previous studies have confirmed that an alley cropping pattern could change the microclimate by supplying additional ecological functions such as windbreak, light interception, water conservation, etc. Cereal aphids (including *Sitobion avenae*, *Rhopalosiphum padi*, *Metopolophium dirhodum*, etc.) are commonly spread pests that harm wheat plants. But, the difference in population numbers between local patterns is still unknown. Pesticide reduction is the national strategy in China to alleviate the contraction between the demand of grain yield and environment protection. Plant protection-unmanned aerial vehicles (UAV) spraying pesticides are the most efficient method to control pests. However, compared to traditional artificial spraying method, how the UAV spraying method affect the control effect of reduced concentration pesticide is unclear. In order to address this problem, we conducted field investigations at Zepu county in southern Xinjiang to test the difference between walnut–wheat intercropping and wheat monocropping patterns for three consecutive years. And, we employed the field experiments to ensure the effectiveness of the reduced concentration common pesticides through the UAV spraying method. In conclusion, we conducted a comparison of the control effects of two spraying methods under conditions of reduced pesticide usage. Our findings revealed that the population of cereal aphids was larger in the intercropping pattern compared to the monocropping pattern. Although the control effect of the reduced treatment was lower than the regular dosage, some treatments still demonstrated sufficient capability to eliminate aphids, particularly when considering the effect within major varieties. Additionally, the use of the UAV spraying method exhibited a satisfactory effect when compared to the traditional artificial spraying method.

Keywords: alley cropping; wheat; aphid; UAV; pesticide reduction

1. Introduction

Crop yields have dropped over the last few years owing to the scarcity of cultivated land, lack of irrigation water, climate change, and the low utilization of soil nutrition [1]. However, in the region of southern Xinjiang, which is located in northwest China, farmers have extensively practiced the alley cropping system not only to alleviate the contradiction between the relatively low income of grain monocropping and the increasing requirement of grain yield, but also to maximize the advantages of light, temperature, water, and other essential production factors utilized under the 'cash tree–grain crop' system [2–4].

In the agroforestry system, previous studies had focused on the interaction of subterranean organs as well as on the competition of nutrient utilization between both component plants. For instance, Duan et al. (2019) identified that the yield of the aerial part, and the parameters to evaluate subterranean roots such as LER or RD of both species, had decreased significantly under the alley cropping system. On the contrary, the alley cropping pattern increased the root length [5]. Under drought conditions, Rivest et al. (2013) reported the biomass, yield, and number of grains per spike higher than monocropping [6]. But, Swieter et al. (2019) had found no substantial differences between the narrow crop alley, wide crop alley, and traditional patterns [7].

As a remarkable agroforestry practice, alley cropping enhances the capability of soil nutrients, the abundance of soil microbial communities, the presence of landscape species, as well as reduces carbon emissions to a significant level [8–11]. More specifically, walnut trees bring many important ecological functions, such as light interception and windbreak [12–14]. But, some reversed conclusions were also drawn by other researchers. They discovered that tree/wheat mixture shows a low photosynthetically active radiation and are affected significantly by the tree age [3,15,16]. All these alterations induced varying degrees of impact to the microclimate factors (temperature, humidity, light intensity, wind strength, etc.) on the participant plants in the system. It differs significantly as compared to the monocropping system.

Cereal aphids (including *Sitobion avenae*, *Rhopalosiphum padi*, *Metopolophium dirhodum*, etc.) are commonly observed wheat pests which reside in major ecological niches under both patterns at locality, and harm wheat production in China [17–19]. The insects generally suck phloem sap through their mouthparts from wheat stems, leaves, and ears [20]. During the process of sap sucking and saliva injection, the transmission of barley yellow dwarf virus (BYDV) and other plant viruses occurs. The infection has huge negative impacts on wheat production. In pandemic years, virus infestations can cause yield losses of up to 40% of total wheat production [21].

With the concept development of integrated pest control, reasonable agricultural method application has received much attention from researchers. The alley cropping pattern can attenuate pest harm by decreasing entomic immigration, survival rate, and fecundity and build a temporary shelter for predators to maintain the population before the crop pests' outbreak [22–24]. Some researchers have explored relationships between pest dynamics and the intercropping patterns of several horticultural crops and cash trees. In this regard, the intercropping system of pear orchards and aromatic plants is beneficial for orchard intercropping systems [25]. Similarly, when cultivating rosemary (*Rosmarinus officinalis*) and sweet pepper (*Capsicum annum*) simultaneously in the same field (intercropping), the densities of the sampled *Frankliniella intonsa*, *Myzus persicae*, and *Bemisia tabaci* in this system are significantly lower than that observed in a monoculture field of sweet pepper [26].

Although much effective research has been carried out in the field of agricultural prevention method, it is undeniable that chemical control is still occupying the main status in cereal aphid control methods [27–30]. Pesticides sprayed by unmanned aerial vehicles (UAV) for plant protection are characterized by the high efficiency and high utilization rate of the pesticide [31–33] and has now commonly been conducted in southern Xinjiang. But, the relative research to investigate the relationship between the occurrence of cereal aphids and the walnut–wheat intercropping system as well as the wheat monocropping pattern is rarely seen. This study, therefore, has targeted such relations to address the deficiency in this regard. For this purpose, the researchers of this study collected field data on cereal aphid dynamics as exhibited in two cropping systems for three consecutive years. This survey made us recognize the difference in the pest prevention period to control wheat aphids between two cropping patterns. Then, we conducted an UAV foliar spraying experiment to testify to the control efficiency difference in cereal aphids between aerial/artificial methods using two major wheat varieties under an intercropping pattern in the desert oasis district of northwestern China.

2. Materials and Methods

2.1. Wheat Aphids Occurrence Survey

A survey was conducted every five days after incidence of cereal aphids on wheat plants until harvesting. The wheat aphid species was confirmed through morphological observation. However, if the extreme meteorological conditions such as sandstorms or rainstorms did not match the investigation requirement, we would postpone the date to the seventh day from the last investigation. Hence, in 2017, the researchers investigated the data seven times, while the same was performed ten times in 2018, and nine times in 2019.

Under the intercropping system, the variety of walnut trees is Wen185. Walnut trees were transplanted at the experimental locality in 2007. The wheat variety for both intercropping and monocropping is Xindong 20 (XD20). The sowing times for the wheat were 5 October, 2 October, and 7 October and the harvest time was about 10 June every year. The survey time points were during the filling stage and maturity stage. All agricultural operations and management measures of investigation plots were the same.

During this research, four different townships Aktamu, Kuibag, Yima, and Gulebag in Zepu County, Kashgar, Xinjiang Uygur Autonomous Region of China were selected randomly. At each township, eight fixed intercropping fields were randomly chosen. The area of each field was 667 m^2. In the fields we had chosen already, a five-point sampling method was employed to set the investigating plot. Five plots were selected with an area of 1 m^2. All plots were surrounded with nylon ropes to locate quickly and 20 fixed wheat plants were chosen from each plot to investigate the total number of aphids that fed under the walnut–wheat intercropping system. Each of the 20 plants was marked by tying 'Red knitting' wool under the ears of every wheat plant. Meanwhile, the same survey method was employed to investigate four wheat monocropping fields at a depilation yard in Yima Township. The area of each monocropping field was 0.5 hectares, but the investigating plot area was the same as the intercropping plots. In the meantime, the number of all apterous adult aphids per block was also recorded. It was found that *Sitobion avenae* (Fabricius) was among the predominant species in both intercropping and monocropping experimental fields. On the other hand, *Metopolophium dirhodum* (Walker) and *Rhopalosiphum padi* (L.) appeared sporadically until the selected wheat crop was ready to harvest. Therefore, the number of these two aphid species was not calculated.

2.2. UAV Spraying Pesticides to Control Wheat Aphids Experiment

We conducted an UAV pesticide application experiment in the wheat monocropping field at the depilation yard to evaluate the control effects of six different pesticides and the corresponding 30% reduced application treatments on wheat aphids, which were fed on two major local varieties named Xindong No. 20 (XD20) and Xindong No.60 (XD60).

The experimental model of UAV is Dji T16. During the whole pesticide spraying process, the operating altitude, speed, and spray amplitude were controlled at 1.5 m, 4.0 m/s, and 4.5 m, respectively. The liquid volume was 12 L/hm^2.

All pesticides were sprayed on the morning of 12 May 2020. The wheat was in the early filling stage. Before aviation, the cardinality of wheat aphids in each plot was investigated. The second dilution method was carried out during this experiment. The experiment design is shown in Table 1, where wheat plants are in the filling stage. During the spraying process, every treatment had three plots as the replicates, and the area of each replicate was 400 m^2 (4 m $\times$ 100 m). A 1 m wide protection row was set between all plots. Plot positions were arranged randomly in the order of 1 d (13 May), 3 d (15 May), and 7 d (19 May) after pesticide spraying (we abbreviated them in the following text as 1 DAS, 3 DAS, and 7 DAS, respectively); the same method was repeated three times for investigation purposes.

Table 1. Experimental pesticides and application dosage in 2020.

Treatments	Pesticides	Dosage (g/hm^2)	Percentage Reduction of Recommanded Concentration (%)
1	Thiamethoxam 70 WG	21.00	0.00
2	Thiamethoxam 70 WG	14.70	−30.00
3	Sulfoxaflor 22 SC	33.00	0.00
4	Sulfoxaflor 22 SC	23.10	−30.00
5	Imidacloprid 70 WG	31.50	0.00
6	Imidacloprid 70 WG	22.05	−30.00
7	Pymetrozine 50 WG	112.50	0.00
8	Pymetrozine 50 WG	78.75	−30.00
9	Acetamiprid 20 WP	9.00	0.00
10	Acetamiprid 20 WP	6.30	−30.00
11	Thiamethoxam-Cyhalothrin 22 SC	33.00	0.00
12	Thiamethoxam-Cyhalothrin 20 SC	23.10	−30.00
CK	Water	-	-

2.3. UAV Spraying and Artificial Spraying Comparison Experiment

According to the results of the experiment mentioned in 2.2, we chose sulfoxaflor 22 SC and acetamiprid 20 WP (which performed the best control effect and the worst control effect in 2020) to conduct a supplementary experiment on 15 May 2021, to confirm differences in the control effects on wheat aphids of these two extreme pesticides by using UAV and artificial spraying (manual backpack electric sprayer (MBES)) methods. In this test, we kept concentrations, test plots, UAV model, and spraying parameters as the same compared to 2020. The specific pesticide concentrations and application methods are shown in Table 2. The liquid volume was set to 650 L/hm^2.

Table 2. Experimental pesticides and application dosage in 2021.

Treatments	Pesticides	Dosage (g/hm^2)	Pesticide Spraying Method
P3	Sulfoxaflor 22 SC	33.00	UAV
P4	Sulfoxaflor 22 SC	23.10	UAV
P9	Acetamiprid 20 WP	9.00	UAV
P10	Acetamiprid 20 WP	6.30	UAV
P3M	Sulfoxaflor 22 SC	33.00	MBES
P4M	Sulfoxaflor 22 SC	23.10	MBES
P9M	Acetamiprid 20 WP	9.00	MBES
P10M	Acetamiprid 20 WP	6.30	MBES
CK	Water	-	-

The experimental backpack electric sprayer model is the Weifeng 3 (WBD-20) manual backpack electric sprayer (MBES), which is manufactured by Taizhou Guangfeng Plastic Industry Co., Ltd. at Taizhou, Zhejiang Province, China. The sprayer was purchased from manufacturer's online store in 2019. The equipment's basic parameters are introduced in Table 3.

Table 3. Experimental MBES performance parameters.

Parameters	Values
Operating Pressure	2–3 kg
Liquid Injection Volume	1.5–1.9 L/min
Impeller Speed	3200 r/min
Effective Range	≤4.5 m

2.4. Statistical Analysis

During the survey of wheat aphid occurrence, the collected data fail to pass the normality test (Shapiro) and heteroscedasticity test (ncv). In cases of less than 60% proportion of zero value to the total data volume and the existence of over-dispersion, a general linear model (GLM) (negative binomial error structure logit link function) was run to detect the fixed effect of cropping mode, year, and their interaction (if it exists) on the number of wheat aphids. A Likehood Ratio Chi-Square was used to determine whether the differences between groups were significant. Once the statistical differences were detected (p value < 0.05), TukeyHSD was used to make a pairwise contrast between levels in treatments.

In the pesticide reduction spraying process by UAV and MBES, a Shapiro test was employed to evaluate the normality of the data, and Levene-test was run to evaluate the homogeneity of variance. One-way ANOVA was used to verify the impact of treatments on the control effects of wheat aphids. F-test was run to determine whether the statistical difference existed. If the p value was <0.05, Duncan's new multiple range test was run to make multiple comparisons.

All data analysis and mapping processes were performed using R software (Version 4.2.1). The car package was used to run GLM and one-way ANOVA, the multicomp and agricolae packages were used to make pairwise contrast, and the ggplot2 package was used for mapping images.

3. Results

3.1. Wheat Aphids Occurrence

Based on the investigated data, the results show that, both the cropping pattern (χ^2 =183.47, df = 1, $p < 0.001$), and the year (χ^2 = 70.53, df = 2, $p < 0.001$) have a significant influence on the number of wheat aphids. Meanwhile, the interactions between cropping method and year are also significant with (χ^2 = 167.11, df = 2, $p < 0.001$).

The results of the year-wise study on the link between the wheat aphids and cropping modes indicate that the number of wheat aphids while practicing a walnut–wheat intercropping system is higher than that recorded via a monocropping system of wheat production: the year 2017 (z = 2.38, p = 0.02), the year 2018 (z = 10.01, $p < 0.001$), the year 2019 (z = 18.19, $p < 0.001$) (Figure 1). Further results demonstrate that the walnut–wheat intercropping system records a lower number of wheat aphids in 2017 than the number tabled in 2018 ($z = -10.30$, $p < 0.001$) and in 2019 ($z = -6.85$, $p < 0.001$). Concurrently, the mean number of wheat aphids in 2019 is significantly lower than 2018 ($z = -3.38$, p = 0.002).

Contrary to the results of this study regarding the linkage between the wheat aphids and the cropping systems as discussed in the preceding paragraph, the figures for such a link are different in the wheat monocropping system. For example, the number of wheat aphids in 2019 is significantly lower than the number in 2017 ($z = -11.73$, $p < 0.001$) and 2018 ($z = -10.41$, $p < 0.001$). However, there is a slight statistical difference in this number between the years 2017 and 2018.

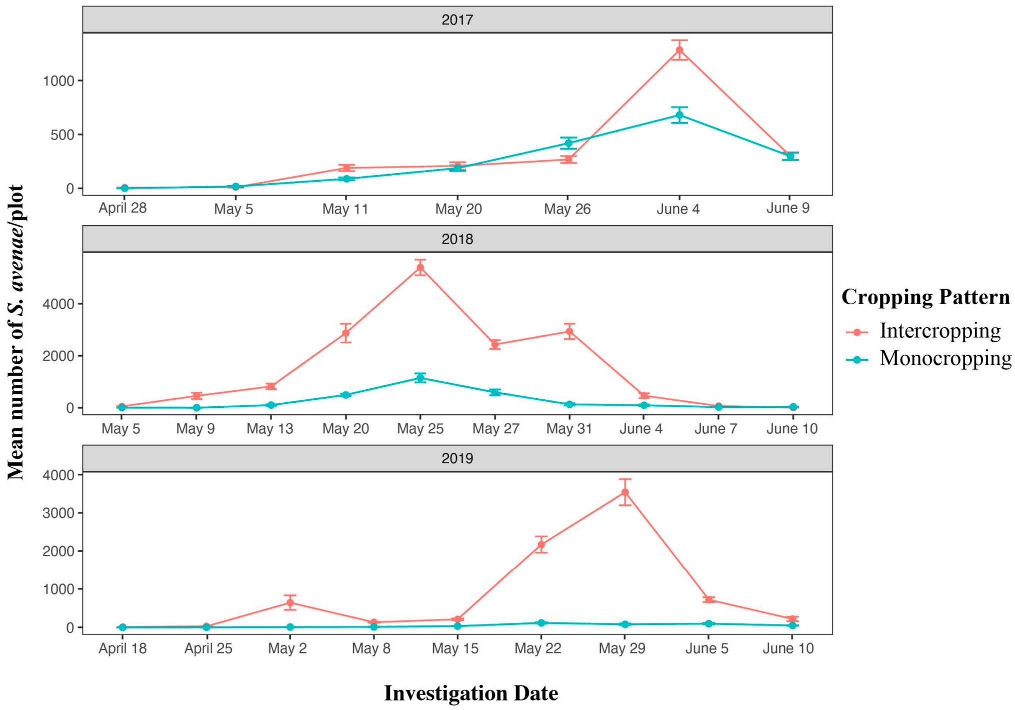

Figure 1. The effect of cropping pattern on wheat aphid population density.

3.2. UAV Spraying Pesticides to Control Wheat Aphids

The results of XD20 on 1 DAS of pesticides show that the control effects of regular dosages on wheat aphids are 54.19–84.52%. Subsequently, thiamethoxam 70 WG reveals the best control effect of 84.52%, while sulfoxaflor 22 SC stands second with a value of 68.92%. Meanwhile, the control effect of 30% reduction treatments ranges from 39.22% to 73.90%. And, except for thiamethoxam 70 WG, the control effects of the other 30% reduction application treatments remain below 60% (Figure 2a).

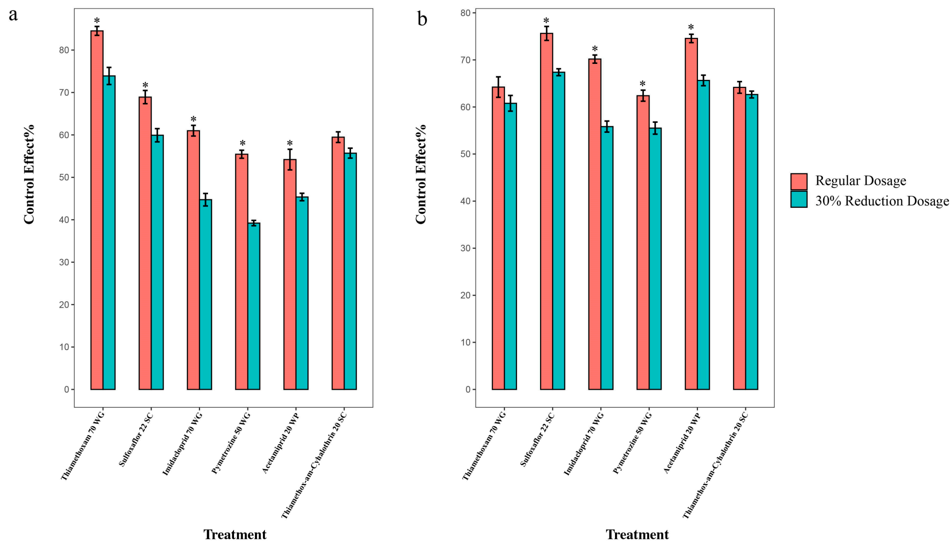

Figure 2. 1 DAS control effect of pesticides on wheat aphids fed on XD20 (**a**) and XD60 (**b**). Note: * represents the significant difference between regular dosage treatment and reduction dosage treatment.

In the continuation of presenting the values of the control effects, the control effects of common practice treatments of XD60 range from 62.40% to 75.63%. Comparatively, sulfoxaflor 22 SC shows the best efficiency of 75.63%; Acetamiprid 20 WP and imidacloprid 70 WG also perform good control effects of 74.56% and 70.17% (Figure 2b).

For the 3 DAS of pesticides to the target population, the control effects of regular dosage treatments in XD20 fields transposed from 44.67% to 81.39%. This verifies that sulfoxaflor 22 SC has the highest control effect of 81.39%, and thiamethoxam 70 WG has the second highest value of 78.60%. At the same time, sulfoxaflor 22 and thiamethoxam 70 WG show the highest efficiency of 30% reduction; the control effect of these two treatments is 69.44% and 67.34%, respectively (Figure 3a).

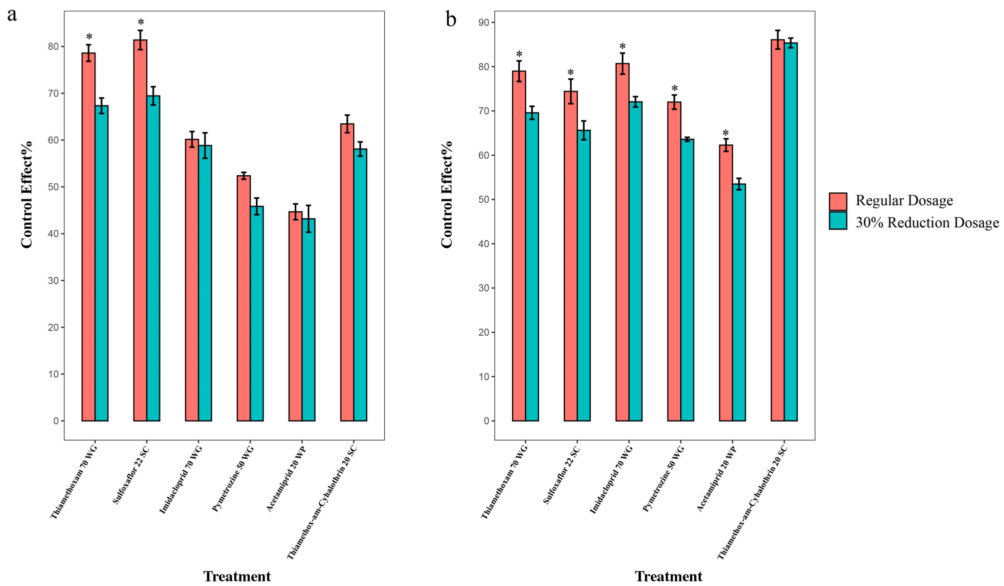

Figure 3. 3 DAS control effect of pesticides on wheat aphids fed on XD20 (**a**) and XD60 (**b**). Note: * represents the significant difference between regular dosage treatment and reduction dosage treatment.

The results compiled after investigating XD60 show that the figures, noted three days after the application of pesticides, for the effectiveness of conventional dosage treatments range from 62.27% to 86.08%. More specifically, the value of the control effect of imidacloprid 70 WG and thiamethoxam-cyhalothrin 22 SC is relatively higher (80%), followed by thiamethoxam 70 WG, sulfoxaflor 22 SC, and pymetrozine 50 WG, which stay at higher than 72%. The efficacy of 30% reduction treatments ranges from 53.48% to 85.36%, among which thiamethoxam-cyhalothrin 20 SC has the best control effect with 85.36%, followed by imidacloprid 70 WG with a value of 72.05% (Figure 3b).

According to the results recorded seven days after the spraying process, the control effects of regular dosage treatments for XD20 species range from 46.73% to 85.55%, where sulfoxaflor 22 SC has the best efficiency of 85.55%, while thiamethoxam 70 WG shows a value of 73.15%. The control effects of 30% reduction dosage treatments range from 45.25% to 68.27%. The results also show that sulfoxaflor 22 SC and thiamethoxam 70 WG have relatively better efficacy with 68.27% and 63.42%, respectively, whereas the figures for the rest of the treatments are below 60%. The control effect of regular dosage treatments is higher than the control effect of the corresponding 30% reduction treatments, though there is no significant difference between them. However, the control effect of sulfoxaflor 22 SC regular dosage treatment is significantly higher than that of the 30% reduction dosage treatment (Figure 4a).

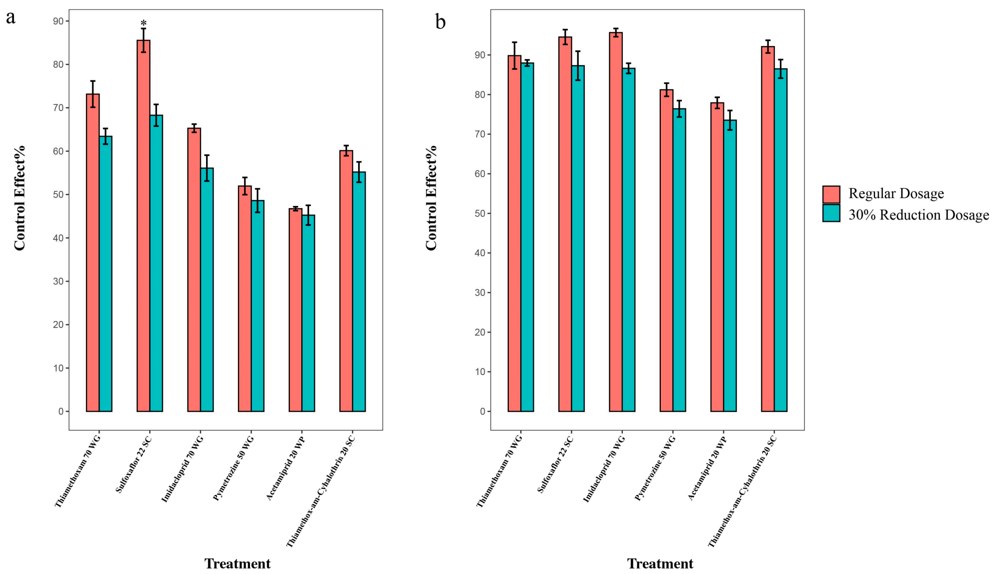

Figure 4. The 7 DAS control effect of pesticides on wheat aphids fed on XD20 (**a**) and XD60 (**b**). Note: * represents the significant difference between regular dosage treatment and reduction dosage treatment.

In the study of the XD60 field, the efficacy of regular dosage treatments ranges from 77.90% to 95.64%, as calculated on 7 DAS. The results, in this context, indicate that the efficacy of sulfoxaflor 22 SC and imidacloprid 70 WG is relatively high, with 94.53% and 95.64%, respectively, followed by the effectiveness of sulfoxaflor 22 SC and thiamethoxam-cyhalothrin 22 SC, with the values of 89.82% and 92.10%, respectively. The efficacy value of 30% reduction dosage treatments ranges from 73.52% to 87.97%, where the efficacy of thiamethoxam 70 WG, sulfoxaflor 22 SC, imidacloprid 70 WG, and pymetrozine 50 WG (with the control effect of 86%) was relatively better than the rest of the treatments. In brief, the study finds no significant difference between the control effects of conventional dosage treatments and the corresponding 30% reduction treatments (Figure 4b).

3.3. UAV Spraying and Artificial Spraying Pesticides to Control Wheat Aphids

In the XD20 fields, one day after the spraying of pesticides, the control effect of sulfoxaflor recommend dosage and its 30% reduction dosage applied by MBES were 71.94% and 61.10%, respectively. The corresponding UAV treatments showed 67.47% and 58.80%, respectively. No significant difference was tested between P3 and P3M, as were P4 and P4M. Similarly, acetamiprid treatments P9 (55.94%) versus P9M (55.70%) and P10 (46.64%) versus P10M (48.99%) also performed with few differences (Table 4).

Table 4. The control effects on wheat aphids of sulfoxaflor and acetamiprid with different method.

Treatments	Fields	1 DAS Control Effects (%)	3 DAS Control Effects (%)	7 DAS Control Effects (%)
P3	XD20	67.47% ± 3.63% ^{a}	77.54% ± 2.86% ^{a}	84.59% ± 2.05% ^{a}
P3M		71.94% ± 3.69% ^{a}	79.68% ± 2.94% ^{ab}	87.01% ± 2.14% ^{a}
P4		58.80% ± 2.10% ^{b}	67.80% ± 2.15% ^{b}	75.92% ± 1.94% ^{b}
P4M		61.10% ± 2.15% ^{b}	73.62% ± 2.37% ^{c}	76.11% ± 2.22% ^{b}
P9		55.94% ± 1.91% ^{a}	48.59% ± 2.49% ^{ab}	50.74% ± 2.93% ^{b}
P9M		55.70% ± 3.25% ^{a}	52.81% ± 3.29% ^{a}	76.12% ± 2.22% ^{a}
P10		46.64% ± 1.94% ^{b}	43.61% ± 3.76% ^{b}	43.37% ± 2.56% ^{c}
P10M		48.99% ± 2.03% ^{b}	46.84% ± 1.11% ^{b}	55.10% ± 5.02% ^{b}

Table 4. *Cont.*

Treatments	Fields	1 DAS Control Effects (%)	3 DAS Control Effects (%)	7 DAS Control Effects (%)
P3	XD60	75.16% ± 0.91% [a]	73.80% ± 3.70% [a]	92.06% ± 1.49% [a]
P3M		82.79% ± 3.41% [b]	80.14% ± 2.74% [b]	92.62% ± 3.45% [a]
P4		66.03% ± 1.79% [c]	63.53% ± 3.06% [c]	84.29% ± 2.87% [b]
P4M		69.75% ± 3.92% [c]	66.47% ± 3.03% [c]	86.01% ± 4.03% [b]
P9		73.80% ± 1.61% [a]	61.76% ± 2.77% [c]	75.72% ± 1.33% [a]
P9M		74.36% ± 3.90% [a]	73.50% ± 3.51% [a]	74.36% ± 3.90% [a]
P10		62.44% ± 1.75% [b]	53.54% ± 3.32% [d]	71.20% ± 2.31% [a]
P10M		65.13% ± 2.36% [b]	67.48% ± 1.92% [b]	65.13% ± 2.36% [b]

Note: The same letter represents no significant difference between different concentrations and application methods of the same chemical agent. Numbers in first column correspond exactly to the serial numbers in Table 1.

After three days, the control effect of P4M was 73.62%, which was significantly higher than UAV treatment P4. The regular dosage P3 and P3M performed with no such difference. But, the control effects of all sulfoxaflor treatments were higher than 80%. On the other hand, all acetamiprid treatments showed lower control effects compared to the sulfoxaflor treatments, but still stayed with no differences between the UAV method and MBES method of regular dosage treatments (P9 and P9M) and 30% reduction dosage treatments (P10 and P10M). Their control effects were 48.59% (P9), 52.81% (P9M), 43.61% (P10), and 46.84% (P10M), respectively (Table 4).

The survey after seven days showed a similar result compared to one day after pesticide applications. The control effect of regular dosage of sulfoxaflor sprayed by MBES could reach 87.01%. That number of UAV sprayers could also gain a relative high value of 84.59%. By the way, two 30% reduction dosage treatments, P4 and P4M treatments, showed no significantly different control effects, but these two treatments both were significantly lower than P3 and P3M. During this time, acetamiprid treatments performed dissimilarly. The control effect of P9M (76.12%) was significantly better than its corresponding UAV treatment (50.74%). The 30% reduction dosage treatment also showed a significantly higher value (55.11%) than P10 (43.37%) (Table 4).

Similarly, after three days, the control effect of P3M (80.14%) was significantly higher than P3 (73.79%), but P4 (66.47%) performed with no such difference compared to P4 (63.53%). P9M (73.50%) and P10M (67.48%) both had capabilities to show significantly higher control effects compared with their corresponding UAV treatments P9 (61.76%) and P10 (53.54%) (Table 4).

But, after seven days, the results of sulfoxaflor treatments and acetamiprid treatments had reversed entirely. The P3M/P3 group and P4M/P4 group both performed with no obvious difference in the control effects. Surprisingly, two concentration treatments of acetamiprid showed a significantly better control effect by aerial method. The artificial sprayer gained the worst value (Table 4).

4. Discussion

This research reveals the dynamics of the cereal aphid population fed on wheat plants under two different cultivation modes in desert–oasis areas. Most studies show that pest outbreak issues have always combined with ecological habitat exacerbation, particularly when monoculture application grossly oversimplifies the variety of the arthropod community [34,35]. In supplying this deficiency, intercropping wheat with other crops and fruit trees has been conducted by lowering the densities of pest insects [36]. Liu et al. (2017) found significant differences in the populations of immigrating winged aphids and their natural enemies among different wheat coverage rates, and the reduction in wheat planting proportion showed a negative trend of wheat aphids. The wheat monoculture system was found to have the most wheat aphids [37]. Wang et al. (2011) also observed wheat monoculture's maximum aphid densities compared to the intercropping pattern [38].

The distribution of wheat aphids under walnut–wheat intercropping in southern Xinjiang differed from the studies stated above in other ecological zones. Our result showed that a higher amount of apterous adult aphids exists under a walnut–wheat intercropping pattern for three consecutive years. This could be due to the inevitable decrease in some growth indicators such as root length density, leaf area index, and light use efficiency of wheat plants resulting from the intense belowground and aboveground competition for resources [39–44]. These indicators could characterize the capability of photosynthesis and nutrition status of wheat plants, leading to a severe yield depression of intercropped wheat crops [45].

Some previous studies showed that host plant quality affects herbivorous insect fertility at the individual and population levels [46]. Poor food quality could lead to a higher survival rate, a shorter development period of *Drosophila melanogaster* [47], a smaller body size of *Aphis glycines* [48], and the maximum aphid abundance of *M. dirhodum* [49]. The poor nitrogen condition of the host plant can increase the population of *Schizaphis graminum* by shorting the reproductive period [50]. The male sycamore aphid, *Drepanosiphum platanoidis*, fed on poor-quality host plants, takes longer to appear than it would under ideal nutritional conditions. The female bias in sex ratio and competition alleviation is proven due to the host's poor quality [51,52]. Therefore, some nutrition depression in insects may be advantageous to reduce intraspecific competition pressure, although this needs to be confirmed in the future.

At the population level, the cereal aphid growth rate is mainly affected by the field microclimate [53]. Several meteorological factors could exert direct influences on aphids in the monoculture system. Rodriguez-del-Bosque et al. (2020) found that rainfall caused a significant reduction in the survival rate of the aphid, *Melanaphis sacchari*, on sugarcane. A substantial reduction in the aphid population was observed because of stimulating rainfall [54]. A previous study reported a 30–80% reduction in the population density of the lower-instar nymph of *S. avenae* due to rain [55]. In southern Xinjiang, a 15-year pattern revealed that the gale season typically lasts from April through July [56]. This period perfectly coincides with the occurrence period of *S.avenae* on wheat. It may partly explain the relatively higher aphid population under the walnut–wheat intercropping pattern within the ecological function of windbreak working and the lower population in the wheat monoculture fields.

The excessive application of pesticides has aggravated pesticide residues, intensified environmental pollution, and enhanced the pesticide resistance of aphids [57,58]. Therefore, the Ministry of Agriculture and Rural Affairs of PRC formulated a plan named the course of action for zero growth of agricultural chemicals consumption by 2020. The goal of reducing pesticide consumption and improving pesticide utilization rate has been defined. Compared with a traditional artificial knapsack sprayer, an unmanned aerial vehicle (UAV), as the newly emerging plant protection machinery in China, has a higher operational efficiency, a faster spraying speed, and a better feature to control time-sensitive target organisms [59–62]. Considering our study results, regular dosage treatments could give better efficiency in both major wheat varieties XD20 and XD60 than their corresponding 30% dosage reduction treatments for all three surveys. Sulfoxaflor and thiamethoxam, two out of six experimental pesticides, were the only ones to exhibit reasonably effective control effects higher than 60% on the aphids fed by XD20. On the other side, the control effect of all reduction dosage treatments was shown to be more than 70% on the *S. avenae* that infested XD60. Among them, the control effect of imidacloprid, sulfoxaflor, thiamethoxam, and thiamethoxam-cyhalothrin even exceeded 86%. Some studies demonstrated that different features among varieties, such as height, canopy density, leaf area index, and leaf inclination angle, could affect the utilization efficiency of specific pesticides by changing the pesticide's deposition [63,64]. The inherent variations in the physical and physiological structure of XD20 and XD60 may account for the variations in control effect performances observed in the current study.

5. Conclusions

Based on our research, we have determined that cereal aphid populations in the walnut–wheat intercropping pattern were higher in southern Xinjiang during the years 2017, 2018, and 2019, compared to wheat monoculture fields. We found that the peak occurrence of *S. avenae* in the walnut–wheat intercropping system in South Xinjiang was observed in middle and late May, with the optimal period for prevention being in mid-May. Our study also revealed that the effectiveness of general pesticides in controlling *S. avenae* varied depending on the spraying method used in XD20 and XD60 fields. After seven days of pesticide spraying, we observed that tested pesticides displayed better control effects on *S. avenae* in wheat fields. Among the tested agents, 22% Sulfoxaflor SC and 20% acetamiprid WP exhibited the highest and lowest control efficacy, respectively. No evidence showed that the control effect has a special relationship with both varieties and spraying methods. However, no significantly high values were observed between different spraying methods. Additionally, there were no notable differences in the control effects between regular dosages and a 30% reduction dosage of all tested agents during the pesticide persistent period.

Author Contributions: Conceptualization, H.G.; methodology, H.G.; formal analysis, Y.S.; investigation H.G., L.C., H.L. and H.Y.; writing—original draft preparation, Y.S.; writing—review and editing, G.L., S.Z. and F.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Key Research and Development Program of Xinjiang Uygur Autonomous Region (2021B02002-1), the Biotechnology in Plant Protection of Ministry of Agriculture and Rural Affairs and Zhejiang Province, Xinjiang Agriculture Research System (XJARS-01), Open Fund for Key Laboratory of Integrated Pest Management on Crop in Northwestern Oasis, Ministry of Agriculture and Rural Affairs, PRC (KFJJ202002), The Earmarked Fund for CARS (CARS-03-88) and Project of Fund for Stable Support to Agricultural Sci-Tech Renovation (xjnkywdzc-2022004).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Most of the recorded data are available in all Tables and Images in the manuscript.

Acknowledgments: The authors sincerely thank the selfless help and convenience provided by Wheat Breeder Base of Zepu, Xinjiang and Agricultural Technology Center of Zepu County.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Arenas-Corraliza, M.G.; Rolo, V.; López-Díaz, M.L.; Moreno, G. Wheat and barley can increase grain yield in shade through acclimation of physiological and morphological traits in Mediterranean conditions. *Sci. Rep.* **2019**, *9*, 9547. [CrossRef] [PubMed]
2. Du, Y.D.; Cao, H.X.; Liu, S.Q.; Gu, X.B.; Gao, Y.X. Response of yield, quality, water and nitrogen use efficiency of tomato to different levels of water and nitrogen under drip irrigation in northwestern China. *J. Integr. Agric.* **2017**, *16*, 1153–1161. [CrossRef]
3. Zhang, W.; Wang, B.J.; Gan, Y.W.; Duan, Z.P.; Hao, X.D.; Xu, W.L.; Li, L.H. Different tree age affects light competition and yield in wheat grown as a companion crop in jujube-wheat agroforestry. *Agrofor. Syst.* **2017**, *93*, 653–664. [CrossRef]
4. Zhang, D.; Zhang, L.; Liu, J.; Han, S.; Wang, Q.; Evers, J.; Liu, J.; Van der Werf, W.; Li, L. Plant density affects light interception and yield in cotton grown as companion crop in young jujube plantations. *Field Crops Res.* **2014**, *169*, 132–139. [CrossRef]
5. Duan, Z.P.; Gan, Y.W.; Wang, B.J.; Hao, X.D.; Xu, W.L.; Zhang, W.; Li, L.H. Interspecific interaction alters root morphology in young walnut/wheat agroforestry systems in northwest China. *Agrofor. Syst.* **2019**, *93*, 419–434. [CrossRef]
6. Rivest, D.; Lorente, M.; Olivier, A.; Messier, C. Soil biochemical properties and microbial resilience in agroforestry systems: Effects on wheat growth under controlled drought and flooding conditions. *Sci. Total Environ.* **2013**, *463*, 51–60. [CrossRef] [PubMed]
7. Swieter, A.; Langhof, M.; Lamerre, J.; Greef, J.M. Long-term yields of oilseed rape and winter wheat in a short rotation alley cropping agroforestry system. *Agrofor. Syst.* **2019**, *93*, 1853–1864. [CrossRef]
8. Quinkenstein, A.; Woellecke, J.; Böhm, C.; Grünewald, H.; Freese, D.; Schneider, B.U.; Hüttl, R.F. Ecological benefits of the alley cropping agroforestry system in sensitive regions of Europe. *Environ. Sci. Policy* **2009**, *12*, 1112–1121. [CrossRef]
9. Pardon, P.; Reubens, B.; Reheul, D.; Mertens, J.; De Frenne, P.; Coussement, T.; Janssens, P.; Verheyen, K. Trees Increase Soil Organic Carbon and Nutrient Availability in Temperate Agroforestry Systems. *Agric. Ecosyst. Environ.* **2017**, *247*, 98–111. [CrossRef]

10. Udawatta, R.P.; Rankoth, L.; Jose, S. Agroforestry and Biodiversity. *Sustainability* **2019**, *11*, 2879. [CrossRef]
11. Baker, T.P.; Moroni, M.T.; Mendham, D.S.; Smith, R.; Hunt, M.A. Impacts of windbreak shelter on crop and livestock production. *Crop Pasture Sci.* **2018**, *69*, 785–796. [CrossRef]
12. Dupraz, C.; Blitz-Frayret, C.; Lecomte, I.; Molto, Q.; Reyes, F.; Gosme, M. Influence of latitude on the light availability for intercrops in an agroforestry alley-cropping system. *Agrofor. Syst.* **2018**, *92*, 1019–1033. [CrossRef]
13. Reyes, F.; Gosme, M.; Wolz, K.J.; Lecomte, I.; Dupraz, C. Alley cropping mitigates the impacts of climate change on a wheat crop in a Mediterranean environment: A biophysical model-based assessment. *Agriculture* **2021**, *11*, 356. [CrossRef]
14. Böhm, C.; Kanzler, M.; Freese, D. Wind speed reductions as influenced by woody hedgerows grown for biomass in short rotation alley cropping systems in Germany. *Agrofor. Syst.* **2014**, *88*, 579–591. [CrossRef]
15. Nuberg, I.K.; Mylius, S.J. Effect of shelter on the yield and water use of wheat. *Aust. J. Exp. Agric.* **2002**, *42*, 773–780. [CrossRef]
16. Li, F.D.; Meng, P.; Fu, D.L.; Wang, B.P. Light distribution, photosynthetic rate and yield in a paulownia-wheat intercropping system in China. *Agrofor. Syst.* **2008**, *74*, 163–172. [CrossRef]
17. Friday, J.B.; Fownes, J.H. Competition for light between hedgerows and maize in an alley cropping system in Hawaii, USA. *Agrofor. Syst.* **2002**, *55*, 125–137. [CrossRef]
18. Li, H.Q.; Pan, H.S.; Wang, D.M.; Liu, B.; Liu, J.; Zhang, J.P.; Lu, Y.H. Intercropping with fruit trees increases population abundance and alters species composition of spider mites on cotton. *Environ. Entomol.* **2018**, *47*, 781–787. [CrossRef]
19. Hu, X.S.; Liu, X.F.; Thieme, T.; Zhang, G.S.; Liu, T.X.; Zhao, H.Y. Testing the fecundity advantage hypothesis with Sitobion avenae, *Rhopalosiphum padi* and *Schizaphis graminum* (Hemiptera: Aphididae) feeding on ten wheat accessions. *Sci. Rep.* **2015**, *5*, 18549. [CrossRef]
20. Hu, X.S.; Keller, M.A.; Liu, X.F.; Hu, Z.Q.; Zhao, H.Y.; Liu, X.T. The resistance and correlation analysis to three species of cereal aphids (Hemiptera: Aphididae) on 10 wheat varieties or lines. *J. Econ. Entomol.* **2013**, *106*, 1894–1901. [CrossRef]
21. Liu, F.H.; Kang, Z.W.; Tan, X.L.; Fan, Y.L.; Tian, H.G.; Liu, T.X. Physiology and defense responses of wheat to the infestation of different cereal aphids. *J. Integr. Agric.* **2020**, *18*, 2–12. [CrossRef]
22. Xu, Z.H.; Chen, J.L.; Cheng, D.F.; Sun, J.R.; Liu, Y.; Francis, F. Discovery of English Grain Aphid (Hemiptera: Aphididae) Biotypes in China. *J. Econ. Entomol.* **2011**, *104*, 1080–1086. [CrossRef] [PubMed]
23. Macfadyen, S.; Gibson, R.; Raso, L.; Sint, D.; Traugott, M.; Memmott, J. Parasitoid control of aphids in organic and conventional farming systems. *Agric. Ecosyst. Environ.* **2009**, *133*, 14–18. [CrossRef]
24. Gold, C.S.; Altleri, M.A.; Bellotti, A.C. Effects of intercropping and varietal mixtures on the cassava hornworm, *Erinnyis ello* L. (Lepidoptera: Sphingidae), and the stemborer, *Chilomima clarkei* (Amsel) (Lepidoptera: Pyralidae), in Colombia. *Pans. Pest. Art. News Summ.* **1990**, *36*, 362–367.
25. Lys, J.A.; Nentwig, W. Augmentation of beneficial arthropods by strip-management. *Oecologia* **1992**, *92*, 373–382. [CrossRef] [PubMed]
26. Song, B.Z.; Zhang, J.; Hu, J.H.; Wu, H.Y.; Kong, Y.; Yao, Y.C. Temporal dynamics of the arthropod community in pear orchards intercropped with aromatic plants. *Pest Manag. Sci.* **2011**, *67*, 1107–1114.
27. Li, X.W.; Lu, X.X.; Zhang, Z.J.; Huang, J.; Zhang, J.M.; Wang, L.K.; Hafeez, M.; Fernández-Grandon, G.M.; Lu, Y.B. Intercropping rosemary (*Rosmarinus officinalis*) with sweet pepper (*Capsicum annum*) reduces major pest population densities without impacting natural enemy populations. *Insects* **2021**, *12*, 74. [CrossRef]
28. Shi, X.Y.; Li, H.B.; Wang, H.G.; Wang, F.T.; Cao, S.Q. Progresses of pesticide reduction techniques in wheat production and the synergistic effects on the prevention and control of wheat pests. *J. China. Agric. Univ.* **2022**, *27*, 53–62.
29. Wei, N.; Lin, L.L.; He, X.F.; Zhong, Y.Z.; Zhang, G.L.; Xie, M.H.; Su, W.H.; Chen, H.L. Laboratory bioassay and field efficiency test of eight pesticides on wheat aphids. *Agrochemicals* **2020**, *59*, 918–920+924.
30. Chen, B.C.; Zhang, Y.N.; Liu, T.J.; Yin, X.; Zhu, Q.S.; Jiang, H.Y.; Ma, H. Relationships between the control effect on aphid populations and the residue decline dynamics of thiamethoxam in wheat fields. *Plant. Protect.* **2019**, *45*, 98–103.
31. Dong, W.Y.; Zhang, H.H.; Chen, A.Q.; Yan, J.H.; Wei, Y.H.; Ma, K.S.; Pu, L.M.; Cao, S.Q.; Shi, X.Y. Resistance levels to five insecticides of wheat aphid field populations from some regions of Gansu and Qinghai province of China. *Agrochemicals* **2020**, *59*, 532–536.
32. Xue, X.Y.; Tu, K.; Qin, W.C.; Lan, Y.B.; Zhang, H.H. Drift and deposition of ultra-low altitude and low volume application in paddy field. *Int. J. Agric. Biol. Eng.* **2014**, *7*, 23–28.
33. Chen, S.D.; Lan, Y.B.; Li, J.Y.; Zhou, Z.Y.; Liu, A.M.; Xu, X.J. Comparison of the pesticide effects of aerial and artificial spray applications for rice. *J. South China Agric. Univ.* **2017**, *38*, 103–109.
34. Zhou, H.B.; Chen, L.; Chen, J.L.; Francis, F.; Haubruge, E.; Liu, Y.; Bragard, C.; Cheng, D.F. Adaptation of wheat-pea intercropping pattern in China to reduce *Sitobion avenae* (Hemiptera: Aphididae) occurrence by promoting natural enemies. *Agroecol. Sustain. Food* **2013**, *37*, 1001–1016. [CrossRef]
35. Altieri, M.A.; Letourneau, D.K. Vegetation management and biological control in agroecosystems. *Crop Prot.* **1982**, *1*, 405–430. [CrossRef]
36. Xie, H.C.; Chen, J.L.; Cheng, D.F.; Zhou, H.B.; Sun, J.R.; Liu, Y.; Francis, F. Impact of wheat-mung bean intercropping on English grain aphid (Hemiptera: Aphididae) populations and its natural enemy. *J. Econ. Entomol.* **2012**, *105*, 854–859. [CrossRef]

37. Liu, J.H.; Yan, Y.; Ali, A.; Wang, N.T.; Yu, M.F. Effects of wheat-maize intercropping on population dynamics of wheat aphids and their natural enemies. *Sustainability* **2017**, *9*, 1390. [CrossRef]
38. Wang, G.; Cui, L.L.; Dong, J.; Francis, F.; Liu, Y.; Tooker, J. Combining intercropping with semiochemical releases: Optimization of alternative control of Sitobion avenae in wheat crops in China. *Entomol. Exp. Appl.* **2011**, *140*, 189–195. [CrossRef]
39. Zhang, K.; Pan, Q.; Yu, D.Y.; Wang, L.M.; Liu, Z.Z.; Li, X.; Liu, X.Y. Systemically modeling the relationship between climate change and wheat aphid abundance. *Sci. Total Environ.* **2019**, *674*, 392–400. [CrossRef]
40. Zhang, W.; Ahanbieke, P.; Wang, B.J.; Gan, Y.W.; Li, L.H.; Christie, P.; Li, L. Temporal and spatial distribution of roots as affected by interspecific interactions in a young walnut/wheat alley cropping system in northwest China. *Agrofor. Syst.* **2015**, *89*, 327–343. [CrossRef]
41. Wang, B.J.; Zhang, W.; Ahanbieke, P.; Gan, Y.W.; Xu, W.L.; Li, L.H.; Christie, P.; Li, L. Interspecific interactions alter root length density, root diameter and specific root length in jujube/wheat agroforestry systems. *Agrofor. Syst.* **2014**, *88*, 835–850. [CrossRef]
42. Zhang, W.; Ahanbieke, P.; Wang, B.J.; Xu, W.L.; Li, L.H.; Christie, P.; Li, L. Root distribution and interactions in jujube tree/wheat agroforestry system. *Agrofor. Syst.* **2013**, *87*, 929–939. [CrossRef]
43. Cao, F.L.; Kimmins, J.P.; Wang, J.R. Competitive interactions in Ginkgo and crop species mixed agroforestry systems in Jiangsu, China. *Agrofor. Syst.* **2012**, *84*, 401–415. [CrossRef]
44. Livesley, S.J.; Gregory, P.J.; Buresh, R.J. Root distribution and properties of a young alley-cropping system: Effects on soil carbon storage and microbial activity. *Plant Soil* **2022**, *482*, 601–625.
45. Swieter, A.; Maren, L.; Justine, L. Competition, stress and benefits: Trees and crops in the transition zone of a temperate short rotation alley cropping agroforestry system. *J. Agron. Crop Sci.* **2022**, *208*, 209–224. [CrossRef]
46. Awmack, C.S.; Leather, S.R. Host plant quality and fecundity in herbivorous insects. *Annu. Rev. Entomol.* **2002**, *47*, 817–844. [CrossRef]
47. Ali, M.Y.; Naseem, T.; Arshad, M.; Ashraf, I.; Rizwan, M.; Tahir, M.; Rizwan, M.; Sayed, S.; Ullah, M.I.; Khan, R.R.; et al. Host-Plant Variations Affect the Biotic Potential, Survival, and Population Projection of *Myzus persicae* (Hemiptera: Aphididae). *Insects* **2021**, *12*, 375. [CrossRef] [PubMed]
48. Rostami, M.; Zamani, A.A.; Goldastech, S.; Shoushtari, R.V.; Kheradmand, K. Influence of nitrogen fertilization on biology of Aphis gossypii. *J. Plant Prot. Res.* **2016**, *52*, 118–121.
49. Ríos Martínez, A.F.; Costamagna, A.C. Effects of crowding and host plant quality on morph determination in the soybean aphid, *Aphis glycines*. *Entomol. Exp. Appl.* **2018**, *166*, 53–62. [CrossRef]
50. Zarasvand, A.A.; Allahyari, H.; Fattah-Hosseini, S. Effect of nitrogen fertilisation on biology, life table parameters and population abundance of greenbug; *Schizaphis graminum* (Rondani) (Hemiptera: Aphididae). *Arch. Phytopathol. Plant Prot.* **2013**, *46*, 882–889. [CrossRef]
51. Vijendravarma, R.K.; Narasimha, S.; Kawecki, T.J. Adaptation to abundant low quality food improves the ability to compete for limited rich food in *Drosophila melanogaster*. *PLoS ONE* **2012**, *7*, e30650. [CrossRef] [PubMed]
52. Leather, S.R.; Wade, F.A.; Godfray, H.C.J. Plant quality, progeny sequence, and the sex ratio of the sycamore aphid, *Drepanosiphum platanoidis*. *Entomol. Exp. Appl.* **2005**, *115*, 311–321. [CrossRef]
53. Honěk, A. Effect of plant quality and microclimate on population growth and maximum abundances of cereal aphids, *Metopolophium dirhodum* (Walker) and *Sitobion avenae* (F.) (Hom., Aphididae). *J. Appl. Entomol.* **1987**, *104*, 304–313. [CrossRef]
54. Rodríguez-Del-Bosque, L.A.; Silva-Serna, M.M.; Aranda-Lara, U. Effect of Natural and Simulated Rainfall and Wind on *Melanaphis sacchari* on Sorghum. *Southwest. Entomol.* **2020**, *45*, 357–364. [CrossRef]
55. Soares, J.R.S.; Silva Paes, J.; Araújo, V.C.R. Spatiotemporal dynamics and natural mortality factors of *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) in bell pepper crops. *Neotrop. Entomol.* **2020**, *49*, 445–455. [CrossRef] [PubMed]
56. Wang, Y.Z.; Yan, H.W.; Wang, X.P.; He, Y. Spatio-temporal analysis of gale concentration in Xinjiang. *Arid Land Geogr.* **2020**, *43*, 623–632.
57. Heckel, D.G. Insecticide resistance after Silent spring. *Science* **2012**, *337*, 1612–1614. [CrossRef] [PubMed]
58. Kankam, F. Causes and management of pesticides contamination in agriculture: A review. *Ghana J. Sci. Technol. Dev.* **2021**, *7*, 103–118. [CrossRef]
59. Qin, W.C.; Xue, X.Y.; Zhang, S.M.; Gu, W.; Wang, B.K. Droplet deposition and efficiency of fungicides sprayed with small UAV against wheat powdery mildew. *Int. J. Agric. Biol. Eng.* **2018**, *11*, 27–32. [CrossRef]
60. Lou, Z.X.; Xin, F.; Han, X.Q.; Lan, Y.B.; Duan, T.Z.; Fu, W. Effect of unmanned aerial vehicle flight height on droplet distribution, drift and control of cotton aphids and spider mites. *Agronomy* **2018**, *8*, 187. [CrossRef]
61. Wang, G.B.; Lan, Y.B.; Yuan, H.Z. Comparison of spray deposition, control efficacy on wheat aphids and working efficiency in the wheat field of the unmanned aerial vehicle with boom sprayer and two conventional knapsack sprayers. *Appl. Sci.* **2019**, *9*, 218. [CrossRef]
62. Wang, G.B.; Lan, Y.B.; Qi, H.X.; Chen, P.C.; Hewitt, A.J.; Han, Y.X. Field evaluation of an unmanned aerial vehicle (UAV) sprayer: Effect of spray volume on deposition and the control of pests and disease in wheat. *Pest Manag. Sci.* **2019**, *75*, 1546–1555. [CrossRef]

63. Li, X.; Giles, D.K.; Niederholzer, F.J.; Andaloro, J.T.; Lang, E.B.; Watson, L.J. Evaluation of an unmanned aerial vehicle as a new method of pesticide application for almond crop protection. *Pest Manag. Sci.* **2020**, *77*, 527–537. [CrossRef]
64. Meng, Y.H.; Lan, Y.B.; Mei, G.Y.; Guo, Y.W.; Song, J.L.; Wang, Z.G. Effect of aerial spray adjuvant applying on the efficiency of small unmanned aerial vehicle for wheat aphids control. *Int. J. Agric. Biol. Eng.* **2018**, *11*, 46–53. [CrossRef]