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Comprehensive Study on the Effects of Peanut Leaf Characteristics and Tank-Mix Adjuvant on Droplet-Spreading Behavior

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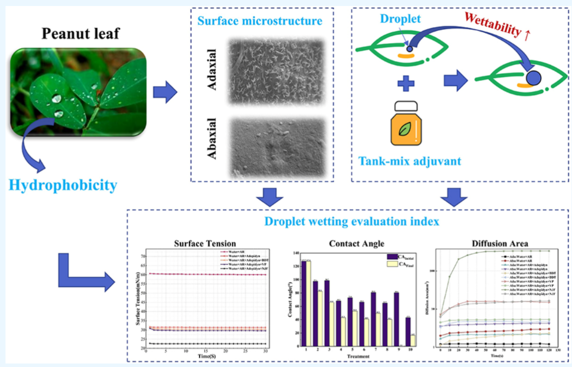

ABSTRACT: In agricultural production, the application of pesticides via spraying is an effective approach to controlling pests and diseases. However, the pesticide utilization efficiency in peanut fields is generally low, owing to factors such as crop-specific characteristics and the nonoptimal use of adjuvants. To enhance the spreading performance of droplets on the surface of peanut leaves and increasing pesticide utilization efficiency, in this study, the effects of leaf surface characteristics and three different types of tank-mixed adjuvants on the droplet-spreading characteristics of peanut leaves were comprehensively analyzed. The results indicate that structural differences exist between the adaxial and abaxial surfaces of peanut leaves, leading to varying degrees of hydrophobicity. The adaxial surface is covered with a uniform, erect, waxy crystal structure, which increases the surface roughness and consequently enhances hydrophobicity. On the Adaxial of peanut leaves have higher CA and lower SA. While tank-mix adjuvants can improve the wetting and spreading performance of droplets on peanut leaves, the efficacy of the methylated plant oil adjuvant Beidatong (BDT) and the mineral oil adjuvant VELEZIA PRO (VP) is limited. In contrast, organosilicon adjuvant Nongjianfei (NJF) effectively improved the wettability of peanut leaf surfaces. Specifically, the addition of NJF can significantly reduce the surface tension of the spray solution, dissolve the waxy structure on the surface of peanut leaves, and greatly enhance the spreading performance of droplets on those leaves. On the adaxial leaf surface, the contact angle (CA) of the droplet rapidly reached 0°, and the droplet-spreading area (SA) increased by 150 times. On the abaxial leaf surface, the effect of NJF was relatively weaker, where the CA was 16.5° and the SA increased by 3.8 times. Therefore, in peanut field applications, incorporating the tank-mix adjuvant NJF can greatly enhance the spreading and retention of pesticides on peanut leaf surfaces, thereby improving pesticide utilization efficiency.

1. INTRODUCTION

Peanut (*Arachis hypogaea* L.) is a vital crop with substantial economic and nutritional significance, serving as an essential source of oil, food, and feed.[1] However, the intricate field environment and the inherent characteristics of peanut leaves render them highly susceptible to pathogen infections, significantly compromising the yield and quality of peanut crops.[2]

To mitigate the invasion of pests and diseases, researchers commonly apply pesticides on peanut plants, thereby ensuring the yield and quality of the crop.[3] However, due to the superhydrophobicity of peanut leaves, droplets often rebound or slide off the peanut leaves upon contact.[4] This phenomenon results in a significant portion of the pesticide droplets failing to adhere effectively to the leaves, reducing pesticide utilization efficiency and significantly weakening pest and disease control efficacy.[5] Additionally, the droplets that fall off infiltrate the soil,[6] not only wasting pesticide resources but also potentially causing severe environmental pollution to the soil and groundwater, further threatening the balance of the ecosystem.[7]

Currently, methods to enhance the distribution of pesticide droplets in the field include improving pesticide formulations, optimizing spraying technologies,[8] adjusting droplet sizes,[9] and utilizing pesticide adjuvants.[10] Tank-mix adjuvants are effective enhancers of pesticides and have been extensively utilized in agricultural production. Currently, researchers have conducted comprehensive evaluations of these auxiliaries, identifying the most suitable options for various crop types. Jing et al.

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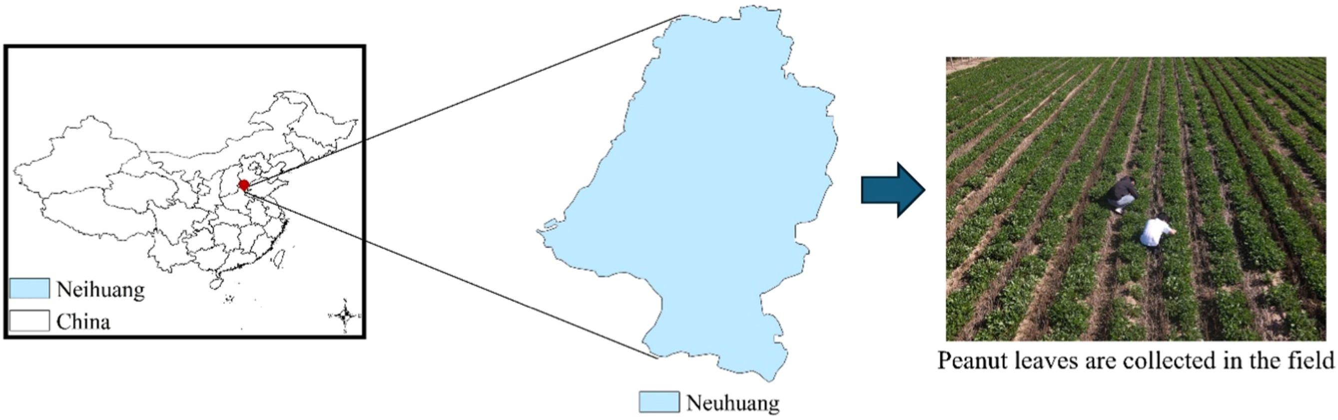

Figure 1. Location of the experimental field experimental.

demonstrated that the tank-mixed plant oil adjuvant can disrupt the cuticle wax on the leaf surface of rice, thereby reducing the hydrophobicity of rice leaves and facilitating the wetting, spreading, and penetration of pesticides on rice foliage.[11] Zheng et al. examined the wetting behavior of two pesticide formulations prepared with oil-based solvents on rice leaves by analyzing parameters such as surface free energy, dynamic surface tension (DST), contact angle (CA), adhesion tension, and work of adhesion.[12] Song et al. investigated the effects of three adjuvants on the wetting and deposition properties of pesticides on wheat leaves.[13] They examined parameters such as DST, CA, and field deposition, providing practical guidance for the use of adjuvants in wheat fields.

Although the use of adjuvants to improve droplet deposition performance has been widely studied, current research mainly focuses on crops such as rice,[14] wheat,[15] and corn.[16] There is relatively little research on the effects of adjuvants on the wetting and spreading of pesticide droplets on peanut leaves. Additionally, in actual production, droplets falling through the air are influenced by environmental factors, crop canopies, and application equipment, inevitably leading to their deposition on different surfaces of peanut leaves. Particularly when using UAVs, the wind generated by the rotors can cause leaves to flip, resulting in a significant accumulation of droplets on the abaxial (Aba) surface of the leaves. However, the existing studies primarily examine droplet deposition characteristics on the Ada side of leaves, with less attention given to the abaxial (Aba) side,[4,17] leading to an incomplete understanding of droplet deposition on leaf surfaces. Thus, studying the deposition characteristics of droplets on the Ada and Aba surfaces of peanut leaves is crucial for understanding the realistic deposition of droplets in the field and for selecting suitable types of tank-mix adjuvants.

To enhance the deposition of pesticide droplets in peanut fields and improve both pesticide utilization efficiency and the effectiveness of disease and pest control, this study targeted different surfaces of peanut leaves and examined the effects of three commonly used adjuvants (methylated vegetable oil, mineral oil, and surfactant) on the deposition performance of pesticide droplets on peanut leaves. The experiment measured the CA, dynamic surface tension (DST), and spreading area (SA) of various solutions on both sides of peanut leaves for the effect of the tank-mix adjuvant on droplet deposition. Furthermore, to better understand the reasons for the poor spreading performance of pesticide droplets in peanut fields, we observed the microstructure of the Ada and Aba surfaces of peanut leaves was observed. Through a comprehensive analysis of the effects of peanut leaf surface structure and adjuvants on droplet wettability, practical guidance was provided for selecting suitable adjuvants for subsequent peanut field applications.

2. MATERIAL AND METHODS

2.1. Peanut Field and Location. In this experiment, peanut leaf samples were collected from a peanut experimental field in Neihuang County, Zhumadian City, Henan Province (32°56′N, 114°24′E). The variety tested was Yuhua No.7. At the time of sampling, the peanuts were in the flowering stage, with an average plant height of 35 cm and a row spacing of 25 cm (Figure 1 and Table 1).

Table 1. Details of Peanut Plants Used In The Experiment

field location	cultivar	planting date	plant height (cm)	row space (cm)
Neihuang	Yuhua 7#	15 May 2023	35	25

2.2. Fungicide, Droplet Tracer, and Tank-Mix Adjuvant. The commonly used peanut foliar fungicide, Adepidyn (75g/L pydiflumetofen and 125g/L difenoconazole SC; Syngenta Nantong Crop Protection Co. Ltd., China), was selected for the spraying practice. Allura Red (AR) (Shanghai Dyestuffs, China) was used as a droplet tracer to make droplets visible on the peanut leaves.

This research focused on three types of commonly used tank-mixed adjuvants for hydrophobic crops: Nongjianfei (NJF) (Organosilicon, Guilin Jiqi Biological Technology Co. Ltd. China), VELEZIA PRO (VP) (Mineral oil, TotalEnergies Fluid company, France) and BeiDaTong (BDT) (Methylated plant oil, Hebei Mingshun Agricultural Co., Ltd., China). These adjuvants are primarily utilized to improve the deposition performance of spray solutions and to enhance the efficiency of pesticide utilization.

Five different treatment solutions were prepared for comparative evaluation, with AR employed as a tracer. Table 2 provides detailed information about the five mixed solutions configured for this experiment.

2.3. Experimental Design. *2.3.1. Observation of the Surface Microstructure of Peanut Leaves.* Fresh peanut leaves were collected from the test field and cut into appropriately sized pieces. The preliminary preparation of leaf samples

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Table 2. Experimental Configuration of the Mixed Solution

adjuvant type	treatment
	Water+3% AR
	Water+3% AR+2.7% Adepidyn
methylated plant oil	Water+3% AR+2.7% Adepidyn+1.5% BDT
mineral oil	Water+3% AR+2.7% Adepidyn+3% VP
organosilicon	Water+3% AR+2.7% Adepidyn+5‰ NJF

involved steps such as Soaking (2.5% glutaraldehyde solution), cleaning (deionized water), and drying.

After the sample was prepared, it was initially freeze-cured using a low-temperature curing agent. Second, the samples were lyophilized in a vacuum and coated with metal by evaporating platinum. Finally, the Ada and Aba surface of leaf samples were examined with a solid-state freeze scanning electron microscope (SEM), model Su3500 (Hitachi (China) Co. Ltd.), at an accelerating voltage of 10 KV (Figure 2).

The surface microstructure images of the trichomes, the stomata, and wax layer on both sides of the peanut leaves were obtained at different magnifications. The experiment was conducted under controlled conditions of a relative humidity of 57% and a room temperature of 20 ± 0.2 °C.

2.3.2. DST and CA Measurement. The DST of five mixed solutions and the CA of mixed solution droplets on the Ada and Aba of peanut leaves were measured. The experiment was conducted under controlled conditions of relative humidity of 57% and room temperature of 20 ± 0.2 °C.

In this study, the CA were carried out using the sessile drop method[18] to determine the size of the CA of each solution on the Ada and Aba sides of peanut leaves. The procedure comprises the following specific steps. First, flat peanut leaves were affixed onto slides (76 mm × 25 mm) using double-sided adhesive tape. Second, each treatment solution was aspirated separately using a microsyringe, and the volume of the resulting droplets was set to be 4 μL, which were dropped on the Ada and Aba sides of the peanut leaves, respectively. Finally, the CA meter of the DSA100 (Krüss GmbH, Hamburg, Germany) was employed to measure both the advancing and retreating contact angles of droplets on peanut leaves. The two contact angles were then averaged to obtain the final contact angles of the droplets on the leaf. Measurements were taken at 5 frames per second, and the numerical change of CA was recorded from 0 to 120 s. Three replicates were determined for each treatment.

Another hand, the maximum bubble pressure method[19] was used to measure the DST of five solutions with a BP50 (Krüss GmbH, Hamburg, Germany) DST meter. The instrument was capable of performing single DST measurements within a range of 15−5000 ms, using a capillary with a diameter of 0.898 mm. During the test, measurements were taken at 1000 ms intervals over a total duration of 30 s. Each solution was measured three times to ensure accuracy.

2.3.3. Spread Area Measurement. To estimate the SA of each solution on the leaf surfaces, the leaves were placed on A4 white paper and a 25 mm coin was used as a reference. We pipetted a 2 μL droplet of each solution on the Ada and Aba surfaces and vertically photographed them with a mobile phone at a 21 cm distance above the leaf every 10 s in 120 s. The image acquisition platform is shown in Figure 3. The experiment was conducted under controlled conditions of relative humidity of 57% and room temperature of 20 ± 0.2 °C. After data collection, Adobe Photoshop 2021 was used to outline the contours of droplets on the surface of peanut leaves, employing the measurement tool to calculate their area.

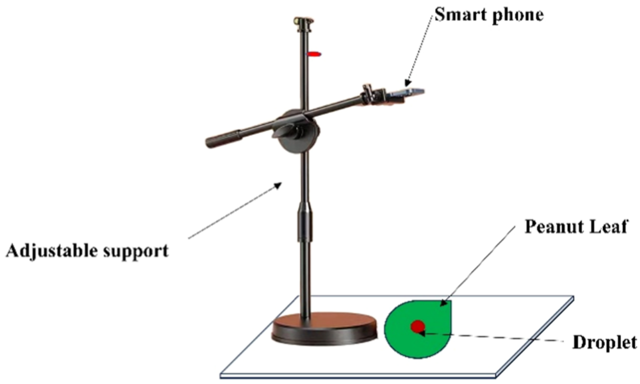

Figure 3. Spreading behaviors image acquisition platform.

2.4. Data Processing. After data collection was completed, OriginLab 2021 software was used to perform statistical analysis and plotting of the collected data, resulting in curves that illustrate the changes in ST, CAs on different surfaces of peanut leaves, and the SA of the solutions being measured over time. Significant differences between treatments were determined using Tukey's test at a significance level of 95%.

3. RESULTS AND DISCUSSION

3.1. Surface Microstructure of Peanut Leaves. The leaf served as the primary medium for the deposition, spreading, and absorption of pesticide droplets, and the structural features

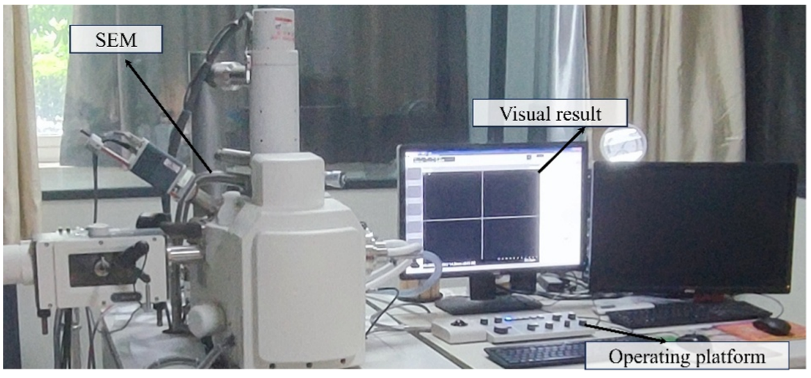

Figure 2. SEM working platform.

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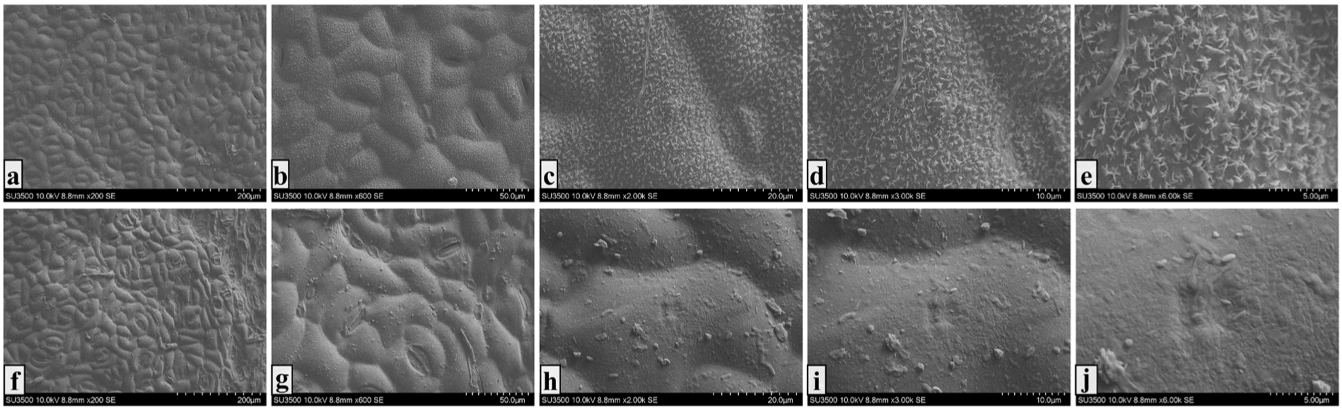

Figure 4. Surface microstructure of peanut leaves. (a) SEM image of peanut leaf Ada surface at 200×; (b) SEM image of peanut leaf Ada surface at 600×; (c) SEM image of peanut leaf Ada surface at 2000×; (d) SEM image of peanut leaf Ada surface at 3000×; (e) SEM image of peanut leaf Ada surface at 6000×; (f) SEM image of peanut leaf Aba surface at 200×; (g) SEM image of peanut leaf Aba surface at 600×; (h) SEM image of peanut leaf Aba surface at 2000×; (i) SEM image of peanut leaf Aba surface at 3000×; (j) SEM image of peanut leaf Aba surface at 6000×; Note: The text in the black box below the image represents the SEM model, voltage, working distance, magnification, and measuring scale;.

of the leaf surface were crucial in dictating the efficiency of pesticide application and utilization.[20] For typical hydrophobic crops, a comprehensive understanding of the microstructural features on the peanut leaf surface was crucial to optimize the efficiency of pesticide utilization. Figure 4 presents the microstructural characteristics of different surfaces on peanut leaves.

In general, leaves characterized by high surface roughness and an abundance of hydrophobic wax or trichomes tend to exhibit greater hydrophobicity. As seen from the low-magnification SEM images, the surface of peanut leaves was composed of numerous stomata and hill-like protrusions (Figure 4(a, b), (f, g)). Notably, the Ada surface was uniformly covered with fluff-like structures, while the Aba surface appeared relatively smooth, indicating that the adaxial surface exhibited higher roughness and hydrophobicity.

The high-magnification SEM images clearly showed that the fluff-like structure on the Ada surface of peanut leaves was composed of a dense array of vertically oriented wax platelets. These wax sheets partitioned the leaf surface into distinct regions and were the primary reason for the superhydrophobicity of the Ada surface (Figure 4(c−e)). In contrast, the Aba surface of peanut leaves exhibited a relatively smooth morphology (Figure 4(h−j)).

3.2. DST of Sprayed Solutions. The deposition and spreading of droplets on leaves were influenced by the physicochemical properties of the sprays.[21] As an important index of droplet wetting and spreading performance, the DST of the spray solution had important guidance to study the distribution of droplet deposition. The DST of the spray solution is a crucial indicator for assessing the wettability and spreading performance of droplets; generally, a lower ST indicates that the solution more readily spreads on solid surfaces.

Figure 5 illustrates the change in ST over time for five tested solutions over a duration of 120 s. The results showed that the ST values of the five tested solutions remained constant throughout the measurement process. Among the five solutions, Water + AR exhibited the highest DST, approximately 60 mN/m. Upon the addition of the fungicide Adepidyn, the DST of the solution Water + AR + Adepidyn was measured at 31.5 mN/m, which was slightly above the critical ST of peanut leaves. Consequently, when only the fungicide solution was applied, it was unable to spread effectively on the surface of the peanut leaves.

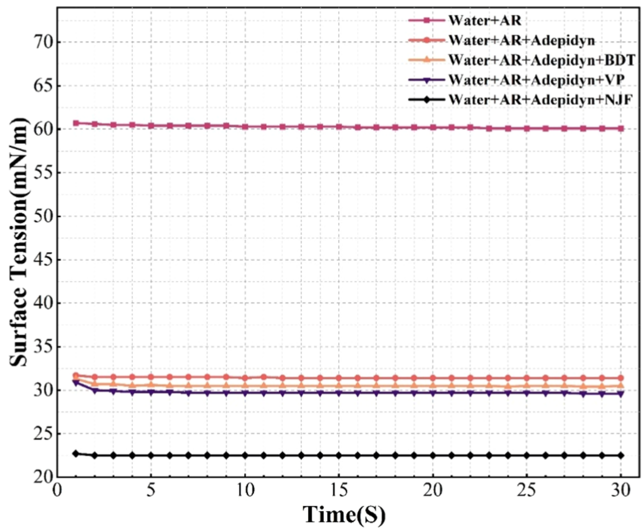

Figure 5. Dynamic ST of different solutions.

Further analysis indicates that the DST can be further reduced by incorporating tank-mix adjuvants. Specifically, the addition of BDT and VP reduces the DST to 30.5 mN/m (Water+ AR+ Adepidyn+ BDT) and 29.7 mN/m (Water+ AR + Adepidyn+ VP), respectively. These two adjuvants have a modest effect on reducing the DST. In contrast, adding NJF significantly lowers the DST, reaching 22.5 mN/m (Water+ AR+ Adepidyn+ NJF).

3.3. CA of Sprayed Solution. The CA was the angle between a liquid and a solid surface, which is used to measure the wettability of the liquid on the material's surface.[22] On the leaves of hydrophilic plants, the CA of water droplets was less than 90°, indicating that the droplets spread easily, which increased the contact area and thereby improved water use efficiency. In contrast, on the leaves of hydrophobic plants, the CA of water droplets exceeded 90°, making it difficult for the droplets to spread. As a result, the droplets tended to take on a spherical shape, leading to a smaller contact area.[23]

Figure 6 illustrates the dynamic changes in CAs of five different treatment solutions on various surfaces of peanut

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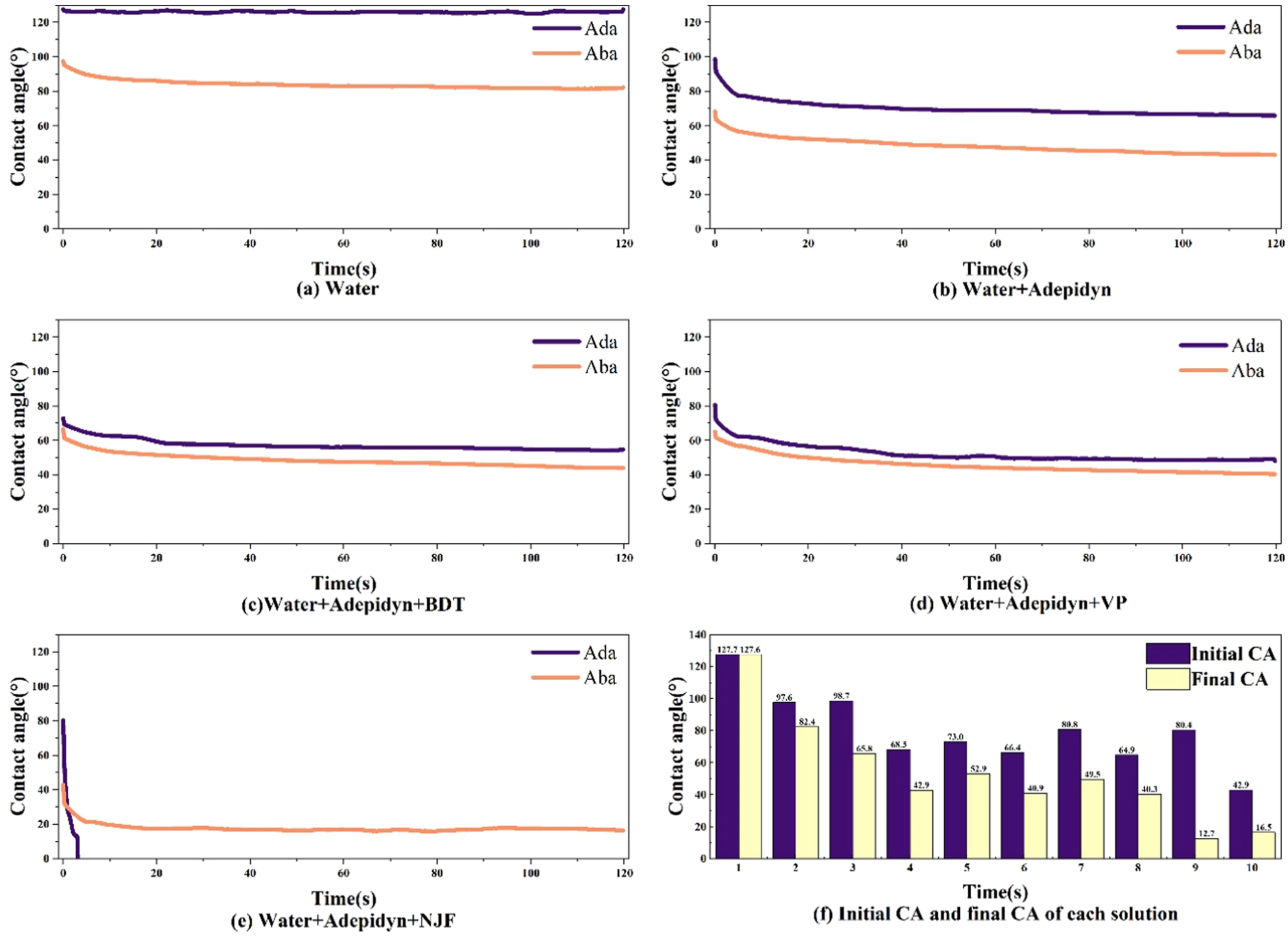

Figure 6. Changes in CA of five solutions on both sides of peanut leaves: (a) Water; (b) Water+ Adepidyn; (c) Water+ Adepidyn+ BDT; (d) Water+ Adepidyn+ VP; (e) Water+ Adepidyn+ NJF; (f) Initial CA and final CA of each solution Note: Treatments 1−10 in this figure represent the initial and final contact angles of each treatment liquid in (a)−(e) on the Ada and Aba of the leaf surface, respectively.

leaves over time. For the water, the initial CA of droplets on the Ada surface of peanut leaves was 127.7°, remaining stable for 120 s. On the Aba surface, the CA decreased from 97.6° to below 90° within 5 s, eventually stabilizing at 82.4° (Figure 6(a)). After adding Adepidyn, the CA of the mixed solution (water + Adepidyn) on both the Ada and Aba surfaces of peanut leaves decreased. On the Ada surface, the CA slowly decreased from 98.7 to 65.8°. On the Aba surface, the initial CA value was 68.3°, which dropped to 42.9° by the end of the 120 s observation period (Figure 6(b)).

This research further compared the effects of various tank-mix adjuvants on the CA of the fungicide solution (water + Adepidyn). The results demonstrated that the addition of tank-mix adjuvants significantly reduced the CA of the fungicide solution, indicating that the inclusion of adjuvants effectively lowers the ST of the solution and enhances its ability to spread on leaf surfaces.

Among them, BDT and VP had a smaller impact on the CA. The CA of the mixed solutions showed a similar decreasing trend as the solution without adjuvants. The initial CA of droplets with BDT on the Ada surface of peanut leaves was 73.0°, which decreased to 52.9° within 120 s. On the Aba surface, the CA slowly decreases from 66.4 to 40.9° within 120 s (Figure 6(c)). Compared to BDT, droplets with VP added exhibited a higher initial CA on the Ada surface (Figure 6(d)). However, the CA of these droplets gradually decreased over time, eventually reaching 40.9°, which is slightly lower than the final CA with BDT added. On the Aba surface, the CAs of droplets with both BDT and VP were essentially the same, with the CA of droplets with VP added being slightly lower.

It is worth noting that after the addition of NJF, the CAs of droplets on both surfaces decreased significantly, but the trend was different from that of field VP and BDT. After the addition of the organosilicon adjuvant NJF, the CA of the solution on the surface of peanut leaves significantly decreased. Specifically, on the Ada surface of the peanut leaves, the CA rapidly dropped from 80.4° to 0° within 3 s, resulting in the complete spreading of the droplets. In contrast, on the Aba surface, the initial CA was 42.9°, but the decrease was limited, dropping to 16.5° within 120 s (Figure 6(e)).

These results indicated that NJF exhibited superior effectiveness in reducing the CA of the fungicide solution on the peanut leaves, significantly lowering the solution's CA and demonstrating the best effect among the three adjuvants.

3.4. Spread Area of Sprayed Solution. The SA of droplets on the target surface intuitively reflects the coverage and spread of pesticide droplets on plant leaves and serves as the most direct indicator of droplet wettability. The size of the SA determines the uniformity and extent of the pesticide distribution on the leaf surface, which, in turn, affects the

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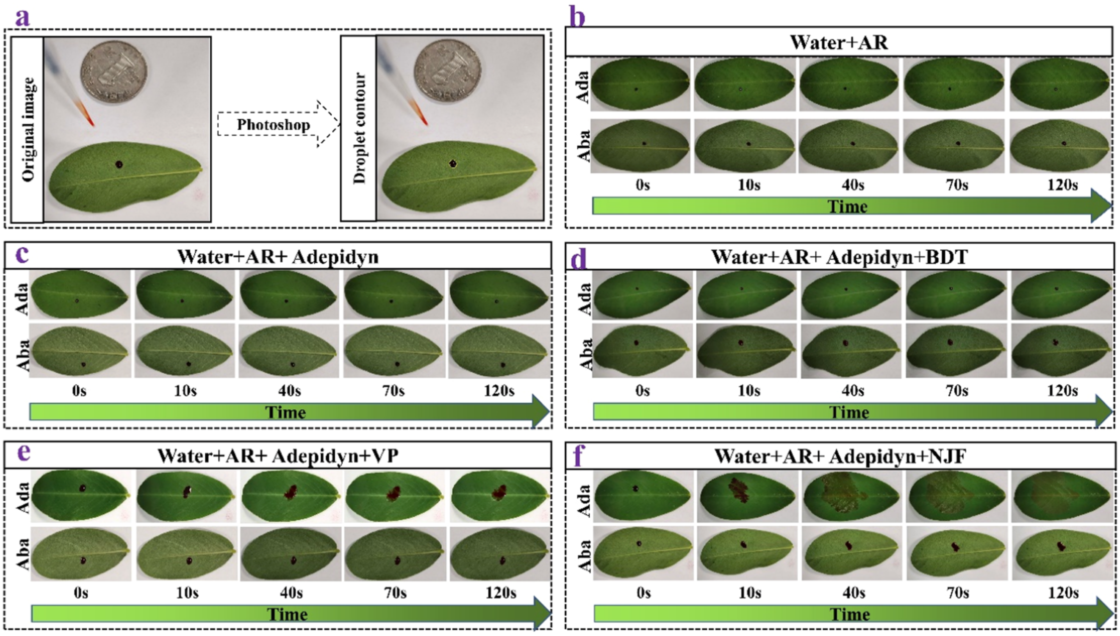

Figure 7. Spreading of droplets on the Ada and Aba surfaces of peanut leaves: (a) A comparison of peanut leaf images before and after processing; (b) Water + AR; (c) Water + AR+ Adepidyn; (d) Water + AR+ Adepidyn + BDT; (e) Water + AR+ Adepidyn + VP; (f) Water + AR+ Adepidyn + NJF.

efficacy of the pesticide. A larger SA indicates that the pesticide can distribute more thoroughly across the leaf surface, thereby increasing its contact area with pathogens or pests and enhancing its control effectiveness.

Figure 7 illustrates the spreading of droplets on the Ada and Aba surfaces of peanut leaves when exposed to different solutions. The results indicated that the spreading rates and areas of different solution droplets on the Ada and Aba surfaces of peanut leaves varied. Prior to the addition of the tank-mix adjuvant, the shape, size, and SA of the droplets in the mixed solution groups of water + AR and water + AR + Adepidyn on the surface of peanut leaves did not change significantly within 120 s. The droplets could not effectively diffuse on the peanut leaves.

The spreading behavior of droplets on the surface of peanut leaves was significantly altered with the addition of tank-mix adjuvants. When VP and NJF were applied to the Ada surface of the leaves, noticeable changes in the size and morphology of the droplets were observed. Over time, the droplets gradually diffused across the leaf surface. After the addition of the NJF, the spreading performance of droplets on both the Ada surface and the Ada surface of the peanut leaves was significantly enhanced. Notably, on the Ada surface, the fungicide solution with the NJF spread rapidly across the leaf surface and achieved complete wetting (Figure 7(f)). On the Ada side of the leaves, a noticeable spreading of the droplets occurred during the observation period, with changes in droplet size and morphology, demonstrating the best performance among the three adjuvants.

The results of the SA changes indicated that when only the fungicide solution was applied, the SA of droplets on the Ada surface of the peanut leaves was only 2.2 mm^2. In contrast, on the Ada side, the SA of droplets increased to 4.3 mm^2, which was twice that of the Ada surface of the leaves. This phenomenon demonstrates that the contact area between the droplet and leaf is low when only the fungicide solution is used (Figure 8).

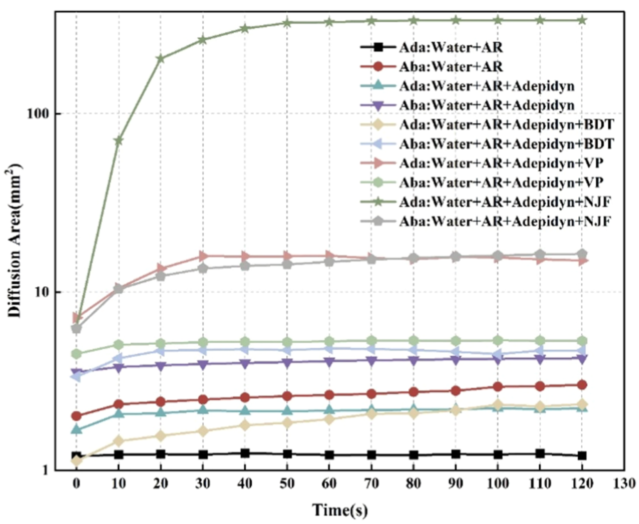

Figure 8. Relationship between SA of the droplet on the peanut leaf surface and time Note: The vertical axis data represent the actual diffusion area of the droplet on the surface of the peanut leaf in Figure 7.

After the addition of the plant oil adjuvant BDT, the Da of droplets on peanut leaves showed no significant change compared to before the addition, remaining at 2.3 mm^2 on Ada and 4.7 mm^2 on the Aba. However, after adding the mineral oil adjuvant VP, the spreading speed and area of the droplets on the Ada of the peanut leaves significantly improved, with the SA increasing to 15.2 mm^2, which was seven times larger than prior to the addition. On the Aba of the peanut leaves, the enhancement effect of the adjuvant was relatively weak, resulting in a SA of 5.3 mm^2, which was slightly better than the effect observed with BDT.

Following the addition of the NJF, droplets rapidly spread across the entire Ada surface of the peanut leaves, achieving a SA of 335.3 mm^2, which is 150 times greater than the SA of

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droplets before the addition of the adjuvant. On the Aba of the peanut leaves, the SA of the droplets also increased to 16.35 mm^2, which is 3.8 times larger than the SA of droplets prior to the addition of the adjuvant.

3.5. Analysis of the Differences in Droplet-Spreading Behavior. Droplet spreading was enhanced by optimizing pesticide formulations and selecting appropriate adjuvants, which modified the microstructure of plant surfaces to improve the wettability and increase the efficiency of spray solutions. Experimental results indicated significant differences in CAs, spreading behavior, and SAs of the same solution on different surfaces of peanut leaves. Specifically, prior to the addition of any adjuvant, the CA of the fungicide solution on the Ada surface was consistently higher than that on the Aba surface, with a correspondingly smaller SA. This phenomenon was attributed to the waxy, lamellar structure on the Ada surface, which contributed to greater surface roughness and hydrophobicity, thereby limiting droplet spreading.

After the addition of tank-mix adjuvants, the spreading performance of the fungicide solution improved. This enhancement was primarily due to a reduction in the ST, which facilitated droplet spreading. However, the effects of BDT and VP on ST reduction were limited, resulting in insufficient improvement in droplet spreading on peanut crops.

The addition of the NJF adjuvant resulted in significant changes in both the contact angle and the SA of droplets on peanut leaves. Initially, the CA on the Ada surface was higher than that on the Aba surface due to the waxy structure impeding droplet spreading. Over time, the CA on the Ada surface rapidly decreased to 0°, while the angle on the Aba surface gradually decreased and stabilized at 16.5°, remaining higher than that on the Ada surface. This trend was the opposite of that observed without the adjuvant. This behavior was primarily attributed to the unique chemical properties of the silicone adjuvant, which effectively broke down the waxy layer on the leaf surface. As droplets came into contact with the surface, the waxy structure gradually dissolved. Additionally, NJF significantly reduced the ST of the solution, further promoting complete droplet spreading on the adaxial surface.

4. CONCLUSIONS

Enhancing the spreading properties of droplets on the leaf surface is crucial for improving the pesticide utilization efficiency in peanut fields. To investigate the underlying causes of low pesticide utilization efficiency in peanut fields and to propose effective improvement measures. This study investigated the microstructure of the peanut leaf surface and discussed the factors contributing to difficulties in droplet spreading. By comparing the effects of various types of tank-mix adjuvants on droplet-spreading performance on the leaf surface, we identified suitable adjuvants for peanut fields were identified. Based on the results analysis, the following conclusions could be drawn:

(1) The peanut leaf surface is comprised of stomata and hill-like protrusions, which collectively contribute to its high roughness and significant hydrophobicity. However, the Ada and Aba of peanut leaves had different surface structures. The Ada leaf surface equipped with many special wax flakes, increasing surface roughness, resulting in a higher hydrophobicity than the Aba surface. On the Ada of peanut leaves, the droplets have higher CA and lower SA.

(2) Different types of barrel-mixed adjuvants were able to reduce the DST of the fungicide solution to varying degrees. After the addition of the adjuvants, the DSTs of the fungicide solutions were measured as follows: 30.5 mN/m for BDT, 29.7 mN/m for VP, and 22.5 mN/m for NJF.

(3) By altering the physical and chemical properties of the solution, the tank-mix adjuvant reduces ST and CA, thereby enhancing the spreading ability of droplets on the target. Among the three tank-mix adjuvants used in this study, the methylated plant oil adjuvant BDT and mineral oil VP had limited effects on improving the spreading performance of droplets on the surface of peanut leaves. In contrast, the DST of the solution was reduced by the tank-mix adjuvant NJF, resulting in a significant decrease in the CA of droplets on the peanut leaf, which greatly enhanced the spreading of the solution on the peanut leaf surface. On the Ada and Aba surfaces of the leaf surface, the tank-mix adjuvant NJF increased the droplet SA by 150 and 3.8 times, respectively.

In general, NJF is an effective tank-mix adjuvant that significantly enhances the wetting and spreading properties of droplets on peanut leaf surfaces, thereby improving the pesticide utilization efficiency during field spraying. These findings provide a scientific basis for optimizing the application of adjuvants in peanut cultivation and enhancing pesticide utilization efficiency in the field.

■ ASSOCIATED CONTENT

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Y.M. contributed to writing−original draft, funding acquisition, investigation, methodology, validation, writing−review and

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editing. X.L. contributed to writing−original draft, methodology, data curation, visualization. Q.W. contributed to writing−review and editing, methodology, validation. Wh.C., X.D., and Y.Z. contributed to formal analysis and validation. W.C. contributed to writing−review and editing and validation. Y.H. contributed to funding acquisition, validation, supervision, project administration, and writing−review and editing. All of the authors read and approved the manuscript.

Notes

The authors declare no competing financial interest.

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