agriculture

MDPI

Article

# Plastic Mulching Effects on Cotton Seedling and Wilt Disease, Lint Yields, and Yield Components

Xingmei You [1], Jingru Zhang [1], Yannan Xue [2], Ruikai Zhang [1], Siwen Zhang [1], Chuanwang Li [1] and Xiaoming Xia [1,*]

[1] College of Plant Protection, Shandong Agricultural University, Tai'an 271018, China; 15194103776@163.com (X.Y.); m15153876185@163.com (J.Z.); 18606461290@163.com (R.Z.); zhangsiwen3291@163.com (S.Z.); 19860936395@163.com (C.L.)
[2] College of Resources and Environment, Shandong Agricultural University, Tai'an 271018, China; xyn81926@163.com
* Correspondence: xxm@sdau.edu.cn; Tel./Fax: +86-0538-8242341

**Abstract:** Plastic mulching is a widely used intensive planting system for cotton production in China. For the present study, the effects of three plastic mulching treatments (i.e., NDNM: normal sowing date with no plastic mulching as a positive control, NDM: normal sowing date with plastic mulching, and LDM: sowing 7 days late with plastic mulching) were studied in the field on seedling disease, Verticillium wilt, and Fusarium wilt as well as on the lint yield in cotton from 2019 to 2020. The treatment effects were evaluated based on the disease incidence (DI) and disease severity index (DSI), seedling fresh weights, lint yields, and yield components. For all cultivars (SCRC28, SCRC21, and Jimian11), both the DIs and DSIs of the seedling disease were lower in the LDM treatment than in the NDNM and NDM treatments. The DIs and DSIs of Fusarium wilt for all the cultivars were higher in the NDNM treatment than in the NDM and LDM treatments. However, the DIs and DSIs for Verticillium wilt were lower in the NDNM treatment. Moreover, the seedling fresh weights, average lint yields, and boll numbers per square meter were all highest in the NDM treatment and lowest in the NDNM treatment. The results of this study demonstrated that the use of plastic mulching with a suitable seed sowing date would be an appropriate cultural practice for enhancing cotton production and reducing the severity of cotton seedling and Fusarium wilt disease.

**Keywords:** plastic mulching; seedling disease; wilt disease; yield; cotton

check for updates

**Citation:** You, X.; Zhang, J.; Xue, Y.; Zhang, R.; Zhang, S.; Li, C.; Xia, X. Plastic Mulching Effects on Cotton Seedling and Wilt Disease, Lint Yields, and Yield Components. *Agriculture* **2024**, *14*, 401. https://doi.org/10.3390/agriculture14030401

Academic Editors: Aocheng Cao, Dongdong Yan and Wensheng Fang

Received: 26 January 2024
Revised: 23 February 2024
Accepted: 28 February 2024
Published: 1 March 2024



## 1. Introduction

Cotton (*Gossypium hirsutum* L.) is one of the most important cash crops in China. It is mainly distributed throughout the following three regions: the Yellow River valley, the Yangtze River valley, and the northwest [1]. The Yellow River valley is an important cotton-growing region in China and includes Shandong province, which normally ranks among the top in cotton planting area, total yield, and fiber quality [2]. Cotton is sown in the spring and harvested during the fall in this region, which implies limitations relating to cold springs and summer rains. Therefore, fungal diseases are important factors that limit cotton yield and quality under certain local environmental conditions.

Cotton seedling diseases are mainly caused by *Rhizoctonia solani* Kühn and *Fusarium moniliforme* Sheld [3]. The diseases are influenced by the soil temperature, soil moisture, and cultural practices at planting [4,5] and occur widely throughout Shandong province. The severity of these diseases can determine the necessity for total or partial cotton re-sowing under a high soil moisture and low soil temperature. Despite the effectiveness of fungicides, their widespread use has not eliminated cotton seedling diseases that are caused by *R. solani* and other cotton seedling pathogens [5]. Verticillium wilt caused by *Verticillium dahliae* and Fusarium wilt caused by *Fusarium oxysporum* are also the most serious diseases that affect cotton production in this region in China due to the rainy summers [6,7].

At present, cultivar choices and cultural practices are still the most significant measures available for controlling these diseases [8]. In China, cotton disease-resistant breeding was initiated in the 1950s, by which time a series of cotton cultivars that were highly resistant to Fusarium wilt had been bred. However, because of a lack of resistant cotton sources, it is difficult to breed cotton cultivars that are highly resistant to Verticillium wilt, particularly the defoliating strains that emerged in the 1990s [9]. Crop rotation has a good effect on the prevention and control of cotton wilt, but it is not practical because of the concentration and continuous cropping of cotton planting areas in China. Although the use of chemical fungicides to control cotton diseases is the most practical control method, long-term large-scale use will cause the problem of environmental pollution [10]. Therefore, it is necessary to develop new cultural practices to manage these cotton diseases.

Plastic mulching is a common practice that has been used in different countries and crops for many years. Since the 1980s, it has become the most popular technique for cotton production in China [11]. The biggest benefits of plastic mulching are increased soil temperature, water conservation, weed control, early planting readiness, and improvements in the crop production yield and quality [12]. The temperature-increasing and yield-enhancing effects of plastic mulching on cotton fields has been confirmed in China [13]. Another important benefit of plastic mulching is an associated decrease in pathogenic fungi [14] or a reduction in disease severity [15]. Choosing a suitable sowing date can also reduce plant disease severity [16].

However, the influence of plastic mulching in combination with different sowing dates on cotton seedling and wilt diseases is not clearly understood. This work was therefore undertaken to study the effects of plastic mulching in concert with a normal or late sowing date on the severity of cotton seedling and wilt diseases, cotton lint yields, and field yield components.

## 2. Materials and Methods

### 2.1. Experimental Site and Cultivars

Field experiments were conducted during consecutive years (2019, 2020) at the Experimental Station of the Shandong Cotton Research Center (SCRC), Linqing County (115°42′ E, 36°61′ N), Shandong province, in the Yellow River Delta of China. The soil is a fertile sandy loam with 0.98% organic matter, 580 mg/kg total N, 12 mg/kg of available P, and 80 mg/kg of available K. Cotton is usually planted in mid-April and harvested at the end of October and the rainfall is variable, with greater distribution in July and August [17]. The site has been successively planted with cotton for many years and has a large reservoir of cotton seedling and wilt diseases.

Two commercial Bt transgenic cotton (*Gossypium hirsutum* L.) cultivars, i.e., SCRC28 and SCRC21, were highly resistant to Fusarium wilt and tolerant to Verticillium wilt. One non-Bt cotton cultivar, Jimian11, was included because of its susceptibility to all cotton diseases. Acid-delinted seeds (with a germination percentage of ≥80%) from each cultivar were treated with imidacloprid (Gaucho FS600, Bayer CropScience, Monheim, Germany) by the Lumian Cottonseed Company Ltd., Jinan, China.

### 2.2. Field Experimental Design and Management

The experiment was established during both years in a randomized block design made up of three plastic mulching treatments. Blocks were arranged to account for a previously observed gradient in cotton disease symptoms. Plastic mulching treatments were replicated three times and were randomly assigned to whole plots, and three cultivars were randomly assigned to each whole plot. Thus, nine treatments (three mulch treatments × three cultivars) with three replicate plots per treatment were established (nine replicate plots per block). The three plastic mulching treatments were designed and carried out as follows: (1) a normal sowing date (mid-April) with plastic mulching (NDM), (2) sowing seeds 7 days late with plastic mulching (LDM), and (3) a normal sowing date with no mulching (bare ground) (NDNM). The three cotton cultivars under evaluation included two Bt cotton

(SCRC28 and SCRC21) and one non-Bt cotton (Jimian11). For both experiments, each plot was 4.5 m wide and 20 m long and contained 6 rows of cotton with row spacing of 0.75 m and a plant density of 4.5 plants/$m^2$.

For all experiments, cotton was planted on 28 April 2019 and 24 April 2020. The field was fertilized with 15 t of chicken manure and 300 kg of commercial compound fertilizer containing (by weight) 20% N, 13% P, and 33% K per hectare and was plowed, harrowed, and irrigated 15 days before planting. The furrows (3.5 cm deep and 5 cm wide) were prepared by passing an animal-drawn plow over the soil at a row distance of 75 cm, and then four or five seeds per hill were hand-planted into the prepared furrows. The seeds were covered with moist soil and then mulched with transparent plastic film (6 μm thick and 80 cm wide) along the rows. After emergence, seedlings were freed from the mulch by cutting the film that appeared above the hills. When most seedlings reached the 2-true-leave stage, all plots were thinned to a plant density of 4.5 plants/$m^2$. The plastic film was not removed at all during the growing season.

Weeds were controlled with applications of trifluralin (48% EC, Shandong Binnong Technology Co., Ltd., Binzhou, China), which was mixed with the soil before planting. A top dressing of 100 kg/ha of urea was applied at first flowering for each plot (approximately 90 days after planting). Irrigation was scheduled for every two weeks or when needed during the rainy period. The plastic was removed after each season. Other cotton management was conducted according to local agronomic practices unless otherwise indicated.

### *2.3. Data Collection*

Data were collected to gauge the disease incidence (DI) and disease severity index (DSI) for seedling disease, Verticillium and Fusarium wilt, and seedling fresh weights, as well as lint yields and yield components, including boll numbers per square meter, boll weights, and lint percentage for all experiments.

Seedling disease was assessed using the DIs and DSIs at about two weeks after seedling emergence. One hundred cotton seedling plants were randomly selected from each plot and carefully removed from the field, washed thoroughly with tap water, and weighed. Seedling symptom severity was assessed on a 0 to 4 rating scale based on the percentage of discolored roots (0 = 0%, 1 = 1 to 25%, 2 = 26 to 50%, 3 = 51 to 100%, 4 = dead plant) [9]. Total fresh weights per 100 seedlings were also recorded in 2019 and 2020. The DIs and DSIs of each replication were calculated as follows:

$$\text{DIs} = ((B + C + D + E)/T) \times 100$$

$$\text{DSIs} = \sum((0A + 1B + 2C + 3D + 4E)/4T) \times 100$$

where A, B, C, D, and E are the number of plants corresponding to the grades 0, 1, 2, 3, and 4, respectively, and T is equal to the total number of plants (T = A + B + C + D + E). The averages are presented in this paper.

To determine the severity of wilt disease, 100 cotton plants were randomly selected from each replication and evaluated for foliar symptoms in late June for Fusarium wilt and late August for Verticillium wilt (according to the peak of disease). Individual plants were rated for disease severity based on a 0 to 4 scale according to the percentage of foliage that was affected by chlorate or foliage that was necrotic or defoliated (0 = no symptoms, 1 = 1 to 25% leaves with symptoms, 2 = 26 to 50% leaves with symptoms, 3 = 51 to 100% leaves with symptoms, 4 = dead plant) [9]. Disease severity was expressed in terms of DIs and DSIs for each plot according to the equation above.

Cotton plants from each plot were manually harvested three times by hand within two years. Lint yields were determined after each harvest and expressed in kilograms per hectare (kg/ha). The yield components included the total boll numbers per square meter, boll weights, and lint percentages (lint/seed cotton W/W), which were determined from 50 mature plants that were randomly selected from each plot. Lint percentages were determined using hand ginning in the laboratory [18].

### 2.4. Data Analysis

Two years of data were analyzed using Statistical Product and Service Solutions (V.16.0 for windows, SPSS Inc., Chicago, IL, USA). The effects of the plastic mulching treatments, cultivars, and their interaction on the measured parameters were evaluated by univariate ANOVA using the general linear model (GLM). There were significant year × treatment and year × cultivar interactions on the DIs and a significant year × cultivar interaction on the DSIs for Verticillium wilt ($p < 0.05$). Therefore, the Verticillium wilt data from each of the two years were analyzed separately. Otherwise, the data from both years were pooled. To determine the significant differences in each measured parameter in combination with plastic mulching treatments, data were analyzed by one-way ANOVA for each cotton cultivar. In all of the analyses, when the *F*-values were significant at $p \leq 0.05$, the significance of differences was determined according to the Student–Newman–Keuls significant difference test at $p = 0.05$. Figures were drawn using Sigma Plot Software (V.10.0 for Windows, Systat Software Inc., Point Richmond, CA, USA).

## 3. Results

### 3.1. Effects of Plastic Mulching on Seedling Disease

Seedling disease was investigated on 21 May 2019 and 16 May 2020, when the most serious seedling disease symptoms appeared. The DSIs of seedling disease in 2019 were less than those in 2020 ($p = 0.039$), though no significant differences in the DIs were observed between the two years ($p = 0.644$).

Significant differences in the DIs of seedling disease were observed among plastic mulching treatments ($p < 0.001$) but not among the cultivars ($p = 0.945$), and the cultivar × treatment interaction was not significant ($p = 0.843$) (Table 1). Significant differences were also observed among the three plastic mulching treatments in each cotton cultivar. The LDM treatment for all cultivars generally provided a lower DI of seedling disease relative to the NDNM and NDM treatments, and the difference between the NDNM and NDM treatments was not significant (Figure 1A).

There were no significant differences in the DSIs of seedling disease among the cultivars ($p = 0.328$) or the cultivar × treatment interaction ($p = 0.190$), but a significant difference was found among the plastic mulching treatments ($p < 0.001$) (Table 1). The DSIs of seedling disease for all cultivars was generally higher in the NDNM treatment than in the NDM and LDM treatments. For the Jimian11 and SCRC21 cultivars, the DSIs of seedling disease were highest for the NDNM treatment, higher for the NDM treatment, and lowest for the LDM treatment. However, there were no significant differences between the NDM and LDM treatments for Jimian11, and no significant difference between the NDNM and NDM treatments for SCRC21. Moreover, significant differences were not observed among the three plastic mulching treatments for SCRC28 (Figure 1B).

**Table 1.** Statistical analysis of variance (ANOVA) of disease incidence (DI) and disease severity index (DSI) of seedling disease, and seedling fresh weights (SFWs) in cotton with different plastic mulching treatments and cultivars [y].

| Model Effect | DI [z] | | | DSI [z] | | | SFW [z] | | |
|---|---|---|---|---|---|---|---|---|---|
| | ***F*** | **df** | ***p*** | ***F*** | **df** | ***p*** | ***F*** | **df** | ***p*** |
| Plastic mulching (PM) | 29.94 | 2.45 | <0.001 | 20.19 | 2.45 | <0.001 | 34.18 | 2.45 | <0.001 |
| Cultivar (Cv) | 0.06 | 2.45 | 0.945 | 1.14 | 2.45 | 0.328 | 16.2 | 2.45 | <0.001 |
| PM × Cv | 0.35 | 4.45 | 0.843 | 1.6 | 4.45 | 0.19 | 1.07 | 4.45 | 0.381 |

[y] Data were collected on 21 May 2019 and 16 May 2020. Data pooled from two years were analyzed by Univariate GLM ANOVA. [z] *F* test of fixed effects; df = degrees of freedom (numerator, denominator); *p* value.

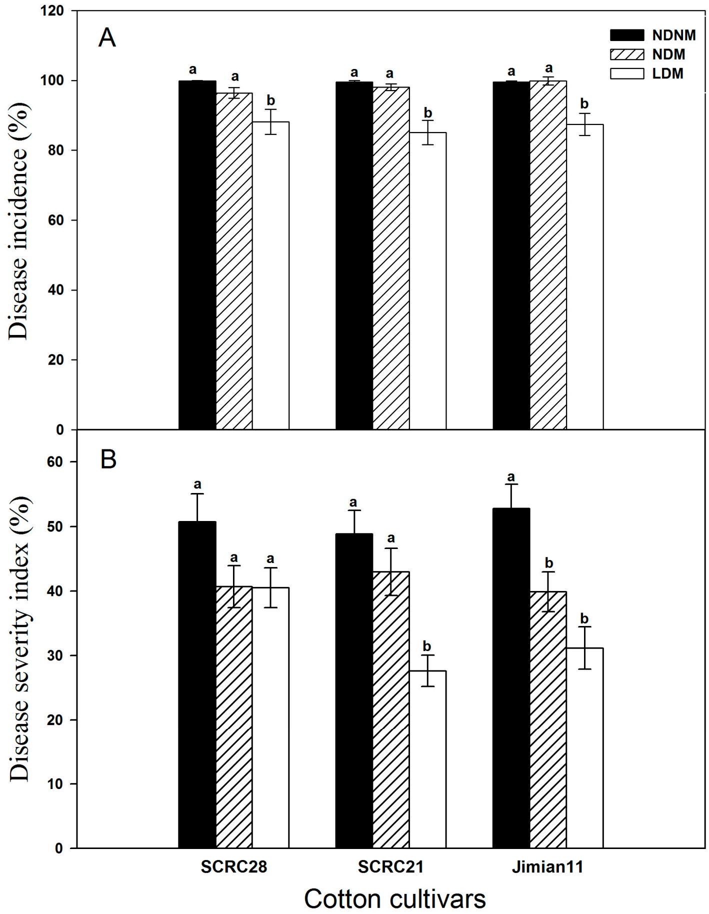


**Figure 1.** Mean (±SE) disease incidence (**A**) and disease severity index (**B**) of seedling disease in cotton for plastic mulching treatments. Cotton cultivars SCRC28, SCRC21, and Jimian11 were evaluated for their response to three plastic mulching treatments (NDM, normal sowing date with plastic mulching; LDM, sowing 7 days late with plastic mulching; NDNM, normal sowing date with no mulching). Two years of pooled data were analyzed by one-way ANOVA, and the bars represent the average of six replications (plots) for each cultivar. Means with the same lowercase letter among treatments within each cultivar were not significantly different, according to the Student–Newman–Keuls test at $p \leq 0.05$.

### *3.2. Effect of Plastic Mulching on Seedling Fresh Weights*

Significant differences in the seedling fresh weights were observed in the data from the plastic mulching treatments and cultivars ($p < 0.001$), and the cultivar × treatment interaction was not significant ($p = 0.381$) (Table 1). The plastic mulching treatments considerably affected the seedling fresh weights per 100 plants from each cotton cultivar. In all the cotton cultivars, the seedling fresh weights were highest for the NDM treatment, intermediate for the LDM treatment, and lowest for the NDNM treatment (Figure 2).

The average seedling fresh weight per 100 plants of the NDM treatment was increased by 56.17 g, 46.71 g, and 67.61 g in comparison to the NDNM treatment for SCRC28, SCRC21, and Jimian11, respectively. However, there were no significant differences between the LDM and NDNM treatments for all the cotton cultivars.

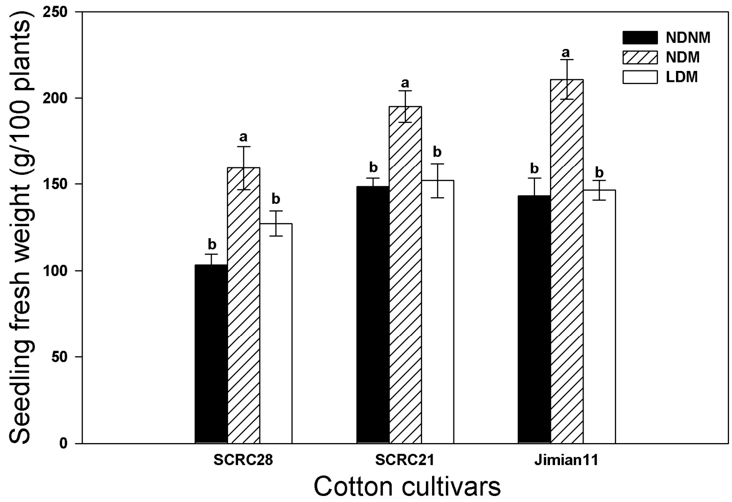


**Figure 2.** Mean seedling fresh weights (±SE) in cotton for plastic mulching treatments. The cotton cultivars SCRC28, SCRC21, and Jimian11 were evaluated for three plastic mulching treatments (NDM, normal sowing date with plastic mulching; LDM, sowing 7 days late with plastic mulching; NDNM, normal sowing date with no mulching). Data pooled from two years were analyzed by one-way ANOVA, and the bars represent the average of six replications (plots) for each cultivar. Means with the same lowercase letter among treatments within each cultivar were not significantly different, according to the Student–Newman–Keuls test at $p \leq 0.05$.

### *3.3. Effects of Plastic Mulching on Fusarium Wilt*

Fusarium wilt symptoms were investigated on 26 June 2019 and 23 June 2020. Although the disease was more serious in 2019 than in 2020, the severity was not serious during either year, and no significant differences in the DIs or the DSIs of Fusarium wilt were observed over the two years.

There were no significant differences in the DIs of Fusarium wilt among cultivars ($p = 0.473$) or the cultivar × treatment interaction ($p = 0.634$), but there were significant differences among the plastic mulching treatments ($p < 0.001$). The significant differences in the DSIs for Fusarium wilt were observed among the plastic mulching treatments and cultivars ($p < 0.001$), but the cultivar × treatment interaction was not significant ($p = 0.122$) (Table 2).

**Table 2.** Statistical analysis of variance (ANOVA) of disease incidence (DI) and disease severity index (DSI) of Fusarium wilt in cotton with different plastic mulching treatments and cultivars [y].

| **Model Effect** | **DI** [z] | | | **DSI** [z] | | |
|---|---|---|---|---|---|---|
| | ***F*** | **df** | ***p*** | ***F*** | **df** | ***p*** |
| Plastic mulching (PM) | 23.89 | 2.45 | <0.001 | 27.66 | 2.45 | <0.001 |
| Cultivar (Cv) | 0.76 | 2.45 | 0.473 | 20.92 | 2.45 | <0.001 |
| PM × Cv | 0.64 | 4.45 | 0.634 | 1.93 | 4.45 | 0.122 |

[y] Data were collected on 26 June 2019 and 23 June 2020. Data pooled from two years were analyzed by Univariate GLM ANOVA. [z] *F* test of fixed effects; df = degrees of freedom (numerator, denominator); *p* value.

The DIs and DSIs of Fusarium wilt for all cultivars were generally higher in the NDNM treatment than in the NDM and LDM treatments, but no significant differences were observed between the LDM and NDM treatments (Figure 3).

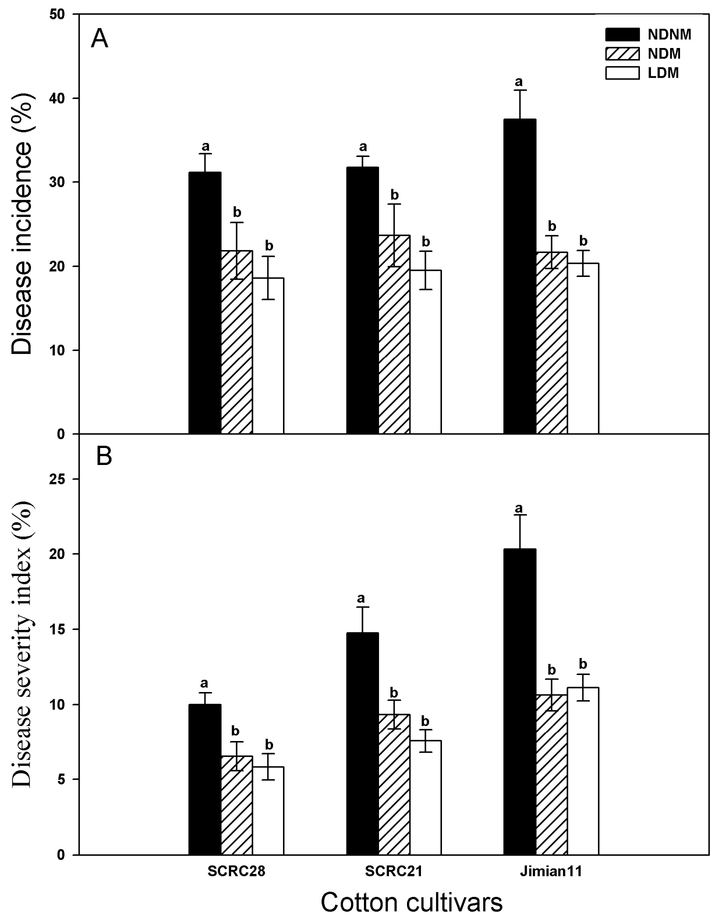


**Figure 3.** Mean (±SE) disease incidence (**A**) and disease severity index (**B**) of Fusarium wilt in cotton for plastic mulching treatments. The cotton cultivars SCRC28, SCRC21, and Jimian11 were evaluated for three plastic mulching treatments (NDM, normal sowing date with plastic mulching; LDM, sowing 7 days late with plastic mulching; NDNM, normal sowing date with no mulching). Data pooled from two years were analyzed by one-way ANOVA, and the bars represent the average of six replications (plots) for each cultivar. Means with the same lowercase letter among treatments within each cultivar were not significantly different according to the Student–Newman–Keuls test at $p \leq 0.05$.

### *3.4. Effects of Plastic Mulching on Verticillium Wilt*

The symptoms of Verticillium wilt were investigated on 25 August 2019 and 24 August 2020, when the most serious symptoms appeared. The severity of Verticillium wilt was more serious in 2019 than in 2020 ($p < 0.05$).

The DIs of Verticillium wilt indicated significant effects from the plastic mulching treatments ($p = 0.002$) and cultivars ($p < 0.001$) in 2019, as well as significant effects during 2020 ($p < 0.001$). The DSIs of Verticillium wilt were also significantly affected by the plastic mulching treatments and cultivars ($p < 0.001$). However, no significant cultivar × treatment interaction of the DIs or DSIs was observed for Verticillium wilt during both years (Table 3).

There were no significant differences in the DIs of Verticillium wilt for the three plastic mulching treatments in each cotton cultivar during 2019, but there was a significant difference in 2020 ($p < 0.05$; Figure 4(1A,2A)). In 2020, the DIs of Verticillium wilt were highest for the NDM treatment, higher for the LDM treatment, and lowest for the NDNM treatment in each cotton cultivar.

**Table 3.** Statistical analysis of variance (ANOVA) of disease incidence (DI) and disease severity index (DSI) of Verticillium wilt in cotton with different plastic mulching treatments and cultivars [y].

| Year | Model Effect | DI [z] | | | DSI [z] | | |
|---|---|---|---|---|---|---|---|
| | | *F* | df | *p* | *F* | df | *p* |
| 2019 | Plastic mulching (PM) | 9.09 | 2.18 | 0.002 | 39.77 | 2.18 | <0.001 |
| | Cultivar (Cv) | 14.28 | 2.18 | <0.001 | 194.74 | 2.18 | <0.001 |
| | PM × Cv | 2.23 | 4.18 | 0.107 | 0.33 | 4.18 | 0.854 |
| 2020 | Plastic mulching (PM) | 22.17 | 2.18 | <0.001 | 21.99 | 2.18 | <0.001 |
| | Cultivar (Cv) | 10.65 | 2.18 | 0.001 | 16.68 | 2.18 | <0.001 |
| | PM × Cv | 0.68 | 4.18 | 0.617 | 0.65 | 4.18 | 0.633 |

[y] Data were collected on 25 August 2019 and 24 August 2020. Data from two years were separately analyzed by Univariate GLM ANOVA. [z] *F* test of fixed effects; df = degrees of freedom (numerator, denominator); *p* value.

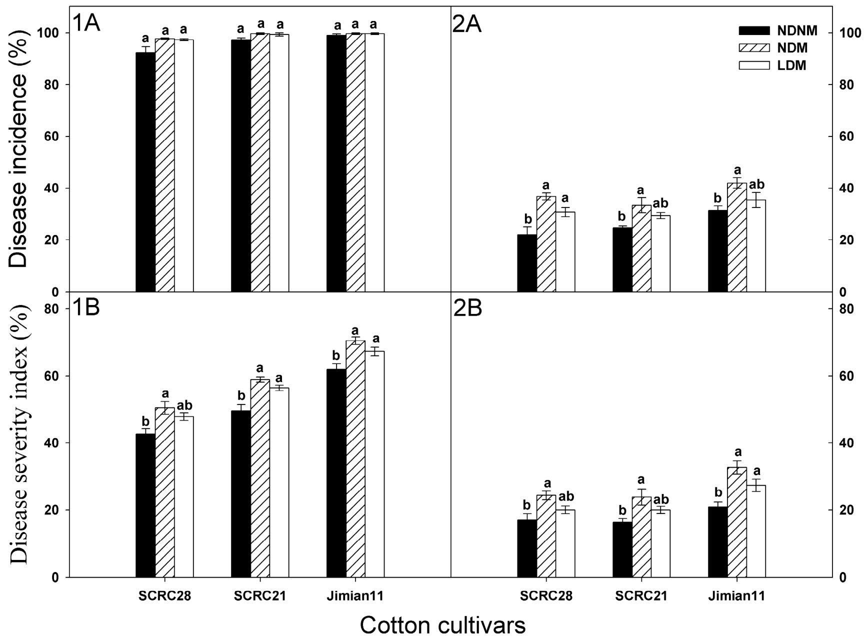


**Figure 4.** Mean (±SE) disease incidence (**1A**,**2A**) and disease severity index (**1B**,**2B**) of Verticillium wilt in cotton for plastic mulching treatments in 2019 (**A**) and 2020 (**B**). The cotton cultivars SCRC28, SCRC21, and Jimian11 were evaluated for three plastic mulching treatments (NDM, normal sowing date with plastic mulching; LDM, sowing 7 days late with plastic mulching; NDNM, normal sowing date with no mulching). Data were separately analyzed by one-way ANOVA for each year, and the bars represent the average of three replications (plots) for each cultivar. Means with the same lowercase letter among treatments within each cultivar were not significantly different according to the Student–Newman–Keuls test at $p \leq 0.05$.

Significant differences were also observed for the DSIs of Verticillium wilt among the three plastic mulching treatments in each cotton cultivar during both years ($p < 0.05$; Figure 4(1B,2B)). For all of the cultivars, the DSIs of Verticillium wilt were highest for the NDM treatment, higher for the LDM treatment, and lowest for the NDNM treatment.

### *3.5. Effects of Plastic Mulching on Cotton Lint Yields and Yield Components*

The average lint yields and boll numbers per square meter were significantly affected by the plastic mulching treatments and cultivars ($p < 0.001$), but no significant cultivar × treatment interaction was observed. Moreover, no significant differences in the average boll weights or lint percentages were observed among the plastic mulching treatments, cultivars, or cultivar × treatment interaction (Table 4).

**Table 4.** Statistical analysis of variance (ANOVA) of lint yields (LY), boll numbers (BN), boll weights (BW), and lint percentages (LP) in cotton with different plastic mulching treatments and cultivars [y].

| Model Effect | LY [z] | | | BN [z] | | | BW [z] | | | LP [z] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *F* | df | *p* | *F* | df | *p* | *F* | df | *p* | *F* | df | *p* |
| Plastic mulching (PM) | 29.6 | 2.45 | <0.001 | 27.5 | 2.45 | <0.001 | 2.06 | 2.45 | 0.139 | 0.75 | 2.45 | 0.48 |
| Cultivar (Cv) | 64.2 | 2.45 | <0.001 | 60.2 | 2.45 | <0.001 | 1.34 | 2.45 | 0.273 | 1.54 | 2.45 | 0.23 |
| PM × Cv | 0.25 | 4.45 | 0.905 | 0.49 | 4.45 | 0.745 | 0.66 | 4.45 | 0.625 | 0.3 | 4.45 | 0.88 |

[y] Data pooled from two years were analyzed by Univariate GLM ANOVA. [z] *F* test of fixed effects; df = degrees of freedom (numerator, denominator); *p* value.

Significant differences in the average lint yields and boll numbers per square meter were also observed among the three plastic mulching treatments in each cotton cultivar ($p < 0.05$). In all cultivars, the average lint yields and boll numbers per square meter were highest for the NDM treatment, intermediate for the LDM treatment, and lowest for the NDNM treatment (Figure 5A,B).

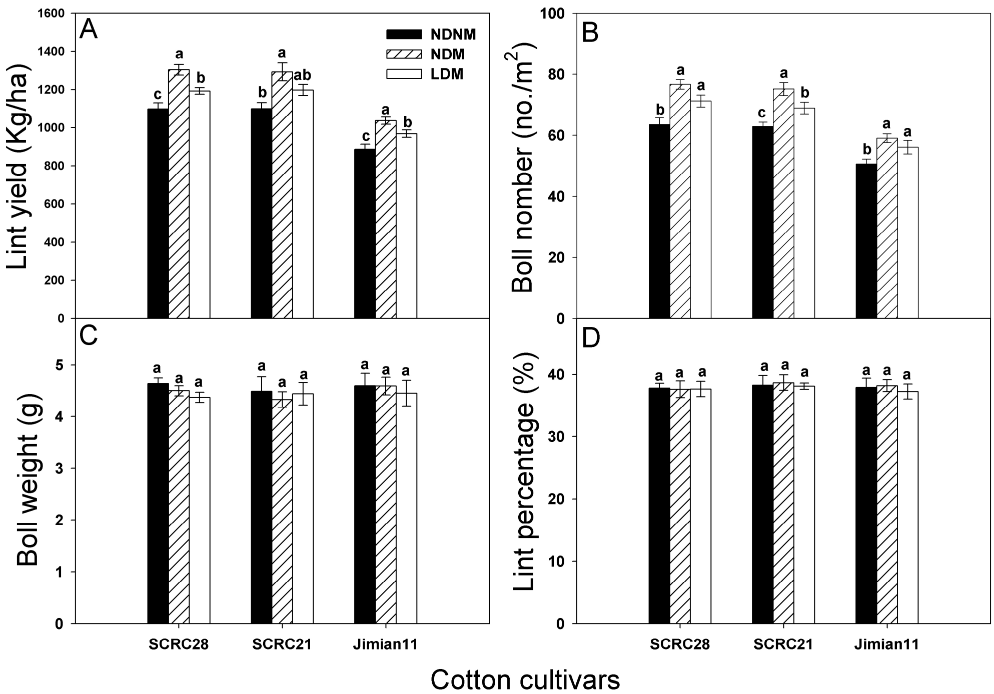


**Figure 5.** The mean (±SE) lint yield (**A**), boll number (**B**), boll weight (**C**), and lint percentage (**D**) in cotton for plastic mulching treatments. The cotton cultivars SCRC28, SCRC21, and Jimian11 were evaluated for three plastic mulching treatments (NDM, normal sowing date with plastic mulching; LDM, sowing 7 days late with plastic mulching; NDNM, normal sowing date with no mulching). Data that were pooled from two years were analyzed by one-way ANOVA and the bars represent the average of six replications (plots) for each cultivar. Means with the same lowercase letter among treatments within each cultivar were not significantly different according to the Student–Newman–Keuls test at $p \leq 0.05$.

The average lint yields for the NDM treatment were increased by 18.52%, 17.56%, and 17.00%, and samples from the LDM treatment increased by 8.51%, 8.97%, and 9.25% in relation to the NDNM treatment in SCRC28, SCRC21, and Jimian11, respectively. The boll numbers per square meter in the NDM treatment were increased by 20.70%, 19.58%, and 16.85%, and those in the LDM treatment increased by 12.18%, 9.69%, and 10.96%, compared with the NDNM treatment for SCRC28, SCRC21, and Jimian11, respectively.

However, there were no significant differences in the average boll weights and lint percentages among the three plastic mulching treatments for all the cotton cultivars (Figure 5C,D).

## 4. Discussion

Plastic mulching has been used widely to control many soil-borne diseases and pests by soil heating since the early 1960s [14]. One of the main benefits of plastic mulching is its ability to increase the root zone temperature (RZT) [19], thereby reducing the population of soil-borne pathogens at the soil surface. Plastic mulching may also weaken soil-borne pathogens [20], thus reducing the incidence and severity of plant disease [21]. Successful control of the plant disease caused by *R. solani* with plastic mulching has been reported in preliminary studies [22].

This study showed significant reductions in the average DSIs of cotton seedling disease for three cotton cultivars in all the NDM and LDM treatment plots (normal sowing or sowing 7 days late with plastic mulching) relative to those in the NDNM treatment plots (given a normal sowing date with no mulching) in the field. However, the average DI reductions in seedling disease were only observed in the LDM treatment, and there were no differences between the NDM and NDNM treatments.

In fact, the DI at a given period does not actually represent the total number of diseased plants because some plants that contracted the disease early may have died and disappeared [23]. Therefore, these results also emphasize that the LDM treatment was more effective in reducing the average DIs and DSIs of cotton seedling disease when compared with the NDM treatment. Similar results were reported by Colyer (1991) [24], who found that the DI values were higher for early planting and lower in later planting. This phenomenon may be a result of reductions in the severity of seedling disease that were aided by later sowing when the soil temperatures had increased [25]. A delay in planting for the sake of favorable growth conditions (i.e., warmer soil temperature) often allows the host to escape or reduce infection [18]. In addition, although no data were available for the RZT of cotton in this study, previous research has shown that plastic mulching significantly increased soil temperatures within 30 days after planting in this region [11]. Similar results were reported by Ji Qingyuan. At the cotton seedling stage, the highest temperature of each treatment in the film was 36.5 °C, while that outside the film was 33.4 °C, and the soil temperature inside the film was higher than that outside the film. The highest temperature of each treatment in the cotton bud stage was 31.8 °C, and the highest temperature of each treatment outside the film was 31.6 °C. At the flowering and bolling stage, the highest temperature of each treatment in the cotton flower film was 33.1 °C, and the highest temperature of each treatment outside the film was 31.6 °C. The highest temperature of each treatment in the cotton boll opening period during the batting period was 27.4 °C, and the highest temperature of each treatment outside the film was 27.7 °C [26]. Soil temperature is a critical factor for the development of Verticillium wilt, Fusarium wilt, and fungal growth. Noviello et al. determined that Fusarium wilt is a warm-weather disease, and the optimal temperature for fungal growth is 26 °C [27]. In China, Xu et al. determined that the optimal growth temperature for V. dahliae isolates of the D and ND pathotype was 25 °C [28]. In Calderón, R et al., the most favorable soil temperature for Verticillium wilt development caused by the V. dahliae D pathotype was 24 °C. At 16 and 20 °C soil temperatures, high values of final disease incidence and severity were also observed, although they were lower than those reached at 24 °C. At 28 and 32 °C, the final disease incidence and severity decreased dramatically, reaching the lowest values at 32 °C [29]. Covering with plastic film for 2–4 weeks at an average temperature of >25 °C can eliminate many soil-borne pathogens, such as *Fusarium oxysporum*, *Fusarium solani*, and *Verticillium dahliae* [30].

Another beneficial effect of plastic mulching is to advance cotton seed emergence and the early growth attributed to the higher soil temperature and water content [31,32]. Yang et al. [33] showed that plastic film mulching can increase the surface soil temperature, especially in the early and middle stages of cotton growth. In the early growth stage (sowing-emergence), the daily average surface soil temperature of the covered plots was 2.5–3.2 °C higher than that of the control group, which may be due to the fact that the plastic film mulching reduced soil moisture evaporation and latent heat flux, thus increasing the soil temperature [34]. The increase in the ground temperature is beneficial to the vegetative growth of cotton and ultimately promotes cotton growth [35]. Our results also showed that plastic mulching with a normal sowing date (NDM) greatly enhanced cotton growth in terms of the seedling fresh weights for all three cotton cultivars. However, the increased seedling fresh weights were not obvious in the LDM treatment when compared with the NDNM treatment for all the cotton cultivars. Although the LDM treatment more effectively reduced the severity of the seedling disease than the NDM treatment, which had a higher seedling fresh weight, cotton seedling growth was consistently enhanced regardless of the seedling disease severity over the course of this study. The improved early cotton growth in the NDM treatment may be a consequence of the combination of early planting and higher soil temperature; this may happen because cotton plants can recover from even the most severe stem damage caused by *R. solani* when growing under optimal conditions [36].

Although the severity of Fusarium wilt varied considerably over the two-year study period, the effects of the three plastic mulching treatments were quite similar, possibly due to differences in seasonal weather [37]. The DIs and DSIs of Fusarium wilt were greatly reduced in the NDM and LDM treatments compared with the NDNM treatment for the three cotton cultivars, while no differences were found between the NDM and LDM treatments. This finding is consistent with a previous study showing that plastic mulching significantly decreased the DSIs of Fusarium wilt in the middle or later period of cotton development (after 20 June) as a result of the reduction in the pathogen population in the soil of China [38]. A decreased incidence of cotton wilt and a decreasing population of *F. oxysporum* caused by heating the soil with transparent polyethylene (PE) has also been previously reported [39]. The chlamydospores of *F. oxysporum* were reduced by 58% under a single PE sheet after only 31 days of treatment following its application on 10 June [40]. In our study, the symptoms data for Fusarium wilt were recorded approximately two months (26 June 2019, and 23 June 2020, respectively) after planting without removing the plastic film. In addition, similar results were also found in China in which plastic mulching reduced Fusarium wilt severity from 10 June to 20 July, which was attributed to a higher soil temperature [23]. While a severity reduction in Fusarium wilt symptoms was also positively correlated with increasing soil temperatures resulting from the use of plastic mulch [41].

As observed with Fusarium wilt, the severity of Verticillium wilt also varied considerably, with more serious symptoms in 2019 than in 2020. However, during any given year, the changing effects were similar in all three treatments for the three cultivars. Although several reports have demonstrated that pathogen populations or symptomatic defoliation by Verticillium wilt were significantly reduced by soil heating with PE [42,43], a previous study has shown that the symptoms of Verticillium wilt appeared sooner and with more severity in a plastic mulched cotton field than on bare ground [44]. Similarly, we found that the plastic mulching treatments (NDM and LDM) had earlier (not listed here) and more severe symptoms of Verticillium wilt than when there was no mulching (NDNM) in relation to the DIs and DSIs for all three cotton cultivars. The effects of earlier and more severe Verticillium wilt symptoms grown with black plastic mulching were also demonstrated [45].

In our study, Verticillium wilt was investigated in late August (at a stage when the plants were fully grown), when the cotton was blooming at the boll opening in this region. During this period, the cotton leaf area was significantly enhanced because of the advancement in cotton growth development at an earlier growth stage after using plastic mulching, and the air and soil temperatures were thus decreased because of a reduction in the solar energy entering the lower layer of the cotton colony [15]. In addition, some plastic films were broken; thus, the warming and heat preservation effects of film mulching were greatly reduced [26]. Cool air and soil temperatures favor Verticillium wilt in cotton [29], so the more severe symptoms of Verticillium wilt may be a consequence of optimal soil and air temperatures.

In addition, Verticillium wilt symptoms strike around the time of anthesis and fruit set [46]. Flowering may also affect host defense [45] and can lead plants to develop Verticillium wilt symptoms sooner [42]. Another possible factor in the development of more severe Verticillium wilt symptoms is the earliness of flowering, plastic mulching enhanced the earliness of flowering and produced more flowers [47].

The phenomenon of improved cotton yields under plastic mulching has been recognized by many researchers [13]. Although Verticillium wilt can greatly suppress eggplant yields [48], plastic mulching treatments (NDM and LDM) significantly increased cotton lint yields in spite of the more severe symptoms of Verticillium wilt that were observed within this study.

In fact, cotton yields were enhanced by plastic mulching mostly by increasing the soil temperature and preserving the soil moisture because the cotton yields in this region are limited by lower soil temperatures during the early and late growing season [49]. In addition, an increased soil temperature can also enhance the earliness of flowering and produce more flowers, which increases the boll numbers because the flowers that form after late August cannot develop into harvestable bolls in this region [13]. We also found that the boll numbers per square meter were significantly increased by the plastic mulching treatments (NDM and LDM) for the three cultivars, but no significant differences in the average boll weights or lint percentages were observed among the three treatments for all the cotton cultivars. Therefore, the increased lint yields may be mainly related to the increased boll numbers per square meter in this study.

A previous study found that early sowing also gave significantly higher yields for cotton [31]. The cotton produced more flowers and bolls, resulting in 20% higher yields by plastic mulching, particularly in combination with early sowing [31]. In the present study, similar positive effects were obtained for the NDM treatment on the cotton lint yields. As a result, the relation of NDM to LDM significantly increased the average lint yields as well as the boll numbers per square meter for all three cultivars.

## 5. Conclusions

In summary, our results demonstrated that two plastic mulching treatments with normal or late sowing (by 7 days) can reduce the severity of overall symptoms on cotton seedling and Fusarium wilt diseases in spite of the cotton cultivars in the field. The overall symptoms and severity of Fusarium wilt of cotton seedlings and field cotton varieties treated without a normal sowing date with no plastic mulching (NDNM) are higher than those treated with two kinds of normal or late sowing (7 days) plastic mulching treatments. The severity of Verticillium wilt was significantly increased by plastic mulching with normal or late sowing for the three cultivars. While the severity of Verticillium wilt was lower when there was a normal sowing date with no plastic mulching (NDNM). Significantly increased cotton lint yields were also observed in two plastic mulching treatments with normal or late sowing for all the cultivars, as well as a significant increase in the seedling fresh weights and boll numbers. The fresh weight of seedlings, cotton wool yield, and the number of cotton bolls were the lowest in the treatment without a normal sowing date with no plastic mulching (NDNM). Of the two plastic mulching treatments, plastic mulching with sowing 7 days late (LDM) may be more efficient for Fusarium wilt and seedling disease; however, plastic mulching with a normal sowing date (NDM) would be more attractive for early cotton growth and yield. Overall, plastic mulching with a suitable sowing date would be an appropriate and economical cultural practice for cotton production in this region. The optimal plastic types and combination of plastic mulching and sowing dates with the goal of maximizing cotton yields and minimizing the severity of cotton diseases will require additional investigation.

**Author Contributions:** Conceptualization, X.Y., J.Z. and Y.X.; Data curation, X.Y., C.L., R.Z. and S.Z.; Formal analysis, X.Y. and Y.X.; Funding acquisition, X.X.; Investigation, X.Y., J.Z., C.L., R.Z. and S.Z.; Methodology, X.Y.; Project administration, X.X.; Resources, J.Z., C.L., R.Z. and S.Z.; Software, Y.X. and J.Z.; Supervision, X.Y. and X.X.; Visualization, X.X.; Writing—original draft., X.Y. and X.X.; Writing—review and editing, X.Y. and X.X. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the National Natural Science Foundation of China (No. 32072459).

**Institutional Review Board Statement:** Not applicable.

**Data Availability Statement:** No new data were created or analyzed in this study. Data sharing is not applicable to this article.

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

## References

1. Wang, X.G.; Xia, S.B.; Zhang, J.H.; Qin, H.D.; Feng, C.H.; Zhang, Y.C.; Bie, S. Present Situation and Prospect of Developing Machine Picked Cotton in the Yangtze River Basin. *J. Agric.* **2023**, *13*, 89–94. (In Chinese) [CrossRef]
2. Guo, Y.R.; Wang, R.R.; Chang, H.H. Research on the Industrial Competitiveness of Chinas Cotton Production Area Based on the Perspective of Regional Competitiveness. *Cotton Sci.* **2021**, *43*, 32–40. (In Chinese)
3. Mayinur, M.; Zu, M.N.; Sajida, A.; Guo, Q.Y. Species and distribution of cotton root and stem diseases in eastern Xinjiang based on molecular detection. *Xinjiang Agric. Sci.* **2017**, *54*, 2046–2053. [CrossRef]
4. Rothrock, C.S.; Winters, S.A.; Miller, P.K.; Gbur, E.; Verhalen, L.M.; Greenhagen, B.E.; Isakeit, T.S.; Batson, W.E., Jr.; Bourland, F.M.; Colyer, P.D.; et al. Importance of fungicide seed treatment and environment on seedling diseases of cotton. *Plant Dis.* **2012**, *96*, 1805–1817. [CrossRef]
5. Zhang, G.Y.; Ma, Z.Y.; Zhao, H.B.; Wang, X.F.; Wu, L.Q.; Li, X.H. Genetic improvement on resistance and yield components of Chinese cottons with Fusarium and Verticillium wilts resistance. *Chin. Agric. Sci. Bull.* **2005**, *21*, 264–267. (In Chinese) [CrossRef]
6. Gallego-Clemente, E.; Moreno-González, V.; Ibáñez, A.; Calvo-Peña, C.; Ghoreshizadeh, S.; Radišek, S.; Coque, J.J.R. Changes in the microbial composition of the rhizosphere of hop plants affected by verticillium wilt caused by verticillium nonalfalfae. *Microorganisms* **2023**, *11*, 1819. [CrossRef]
7. Zhang, J.; Zhu, Y.; Wheeler, T.; Dever, J.; Hake, K.; Bissonnette, K. Targeted development of diagnostic SNP markers for resistance to fusarium wilt race 4 in upland cotton (*Gossypium hirsutum*). *Mol. Genet. Genom.* **2023**, *298*, 895–903. [CrossRef]
8. Dong, H.Z.; Li, W.J.; Zhang, D.M.; Tang, W. Differential expression of induced resistance by an aqueous extract of killed *Penicillium chrysogenum* against Verticillium wilt of cotton. *Crop Prot.* **2003**, *22*, 129–134. [CrossRef]
9. Zhao, M.; Xia, X.M.; Ma, H.; Zhou, Y.; Wang, H.Y. Occurrence and control measures of primary cotton disease in 2008 in Shandong province. *Shandong Agric. Sci.* **2009**, *3*, 99–102. (In Chinese) [CrossRef]
10. Zheng, D.Y. Control of Cotton Fusarium Wilt Synergistically by Plant Growth Regulator and Fungicide and Its Mechanism. Master's Thesis, Xinjiang Aqricultural University, Urumqi, China, November 2022. (In Chinese). [CrossRef]
11. Dong, H.Z.; Li, W.J.; Tang, W.; Zhang, D.M. Furrow Seeding with Plastic Mulching Increases Stand Establishment and Lint Yield of Cotton in a Saline Field. *Field Crops Res.* **2015**, *111*, 269–275. [CrossRef]
12. Ding, F.; Lu, J.; Liu, Q.; Guo, Y.; He, W.J.; Wang, L.; Yan, C.R. Changes in the main cotton producing areas and plastic film residue pollution in China. *South China Agric. Univ.* **2021**, *40*, 60–67. (In Chinese) [CrossRef]
13. Liu, H.J.; Lin, T.; Wang, X.C.; Wang, D.; Zhang, H.; Wang, Y.F.; Chen, M.G. Effect of different mulching films on yield benefit and residual film recovery rate of machine-picked cotton in southern Xinjiang. *J. Agric. Resour. Environ.* **2024**, *41*, 187–196. (In Chinese) [CrossRef]
14. Sun, D.B.; Li, H.G.; Wang, E.L. An overview of the use of plastic film mulching in China to increase crop yield and water use efficiency. *Natl. Sci. Rev.* **2020**, *7*, 1523–1526. [CrossRef]
15. Elmer, W.H. Comparison of Plastic Mulch and Nitrogen Form on the Incidence of Verticillium Wilt of Eggplant. *Plant Dis.* **2000**, *84*, 1231–1234. [CrossRef]
16. Barbetti, M.J.; Khan, T.N.; Pritchard, I.; Lamichhane, J.R.; Aubertot, J.N.; Corrales, D.C.; Pei, Y.M. Challenges with Managing Disease Complexes during Application of Different Measures Against Foliar Diseases of Field Pea. *Plant Dis.* **2021**, *105*, 616–627. [CrossRef]
17. Dong, H.Z.; Li, W.J.; Tang, W.; Li, Z.H.; Zhang, D.M.; Niu, Y.H. Yield, quality and leaf senescence of cotton grown at varying planting dates and plant densities in the Yellow River Valley of China. *Field Crops Res.* **2006**, *98*, 106–115. [CrossRef]
18. Yao, Y.; Yao, Y.G.; Liu, J.; Wang, M.; Cui, J.D.; Yang, X.L. Integrated technology research on the mechanized planting model of grass-cotton double cropping in the Yellow River Delta. *Chin. Cotton* **2020**, *47*, 34–37. (In Chinese) [CrossRef]
19. Yin, W.; Chai, Q.; Guo, Y.; Fan, H.; Fan, Z.L.; Hu, F.L.; Zhao, C.; Yu, A.Z.; Jeffrey, A.C. No tillage with plastic re-mulching maintains high maize productivity via regulating hydrothermale effects in an Arid Region. *Front. Plant Sci.* **2021**, *12*, 649684. [CrossRef] [PubMed]

20. Indhumathi, K.; Shanmugam, P.S.; Sangeetha, M. Analytical Study of Plastic Mulching in Tuberose and Melons in Dharmapuri District of Tamilnadu. *Asian J. Agric. Ext. Econ. Sociol.* **2020**, *38*, 78–86. [CrossRef]
21. Lin, Y.C.; Wei, K.S.; Gao, W.C.; Chen, Y.; Lin, Y.C.; Chen, W.; Li, H.X.; Pan, W.J. Effects of plastic mulching film-induced leaf burning on seedling growth in tobacco cultivation: Different findings beyond conservation view. *J. Integr. Agric.* **2018**, *17*, 1327–1337. [CrossRef]
22. Liu, Y.H.; Wang, W.Q. Occurrence of Diseases and Insects on One-cropping Potatoes in Hebei Province and Their Integrated Managements. *Chin. Potato J.* **2010**, *03*, 159–164. (In Chinese) [CrossRef]
23. Yi, H.Y.; Liu, Z.; Gao, F.; Ren, Y.Z.; Ma, J.F.; Li, G.Y. The relationships between Occurrence of Cotton Mulched with Plastic Film Fusarium wilt and Meteorological Factors. *Xinjiang Agric. Sci.* **2008**, *45*, 797–800. (In Chinese)
24. Colyer, P.D.; Micinski, S.; Nguyen, K.T. Effect of planting date on the efficacy of an in-furrow pesticide and the development of cotton seedling disease. *Plant Dis.* **1991**, *75*, 739–742. [CrossRef]
25. Huang, M.S.; Xiang, Z.J.; Jin, L.R.; Kong, L.J. The causes and control measures of cotton Fusarium and verticillium wilt outbreak in Hubei Province. *Hubei Agric. Sci.* **2007**, *5*, 0754-03. (In Chinese)
26. Ji, Q.Y. *Effects of Soil Matrix Potential Regulated Irrigation on Cotton Growth and Soil Water, Heat and Salt Distribution in Northern Xinjiang*; Northwest A&F University: Xianyang, China, 2022; (In Chinese). [CrossRef]
27. Noviello, C.; Snyder, W.C. Fusarium wilt of hemp. *Phytopathology* **1962**, *52*, 1315–1317. [CrossRef]
28. Xu, F.; Yang, L.; Zhang, J.; Guo, X.P.; Zhang, X.L.; Li, G.Q. Effect of temperature on conidial germination, mycelial growth and aggressiveness of the defoliating and nondefoliating pathotypes of Verticillium dahliae from cotton in China. *Phytoparasitica* **2012**, *40*, 319–327. [CrossRef]
29. Calderón, R.; Lucena, C.; Trapero-Casas, J.; Zarco-Tejada, P.; Navas-Cortés, J.A. Soil temperature determines the reaction of olive cultivars to verticillium dahliae pathotypes. *PLoS ONE* **2014**, *9*, e110664. [CrossRef]
30. Shrestha, U.; Ownley, B.H.; Bruce, A.; Rosskopf, E.N.; Butler, D.M. Anaerobic soil disinfestation efficacy against *Fusarium oxysporum* is affected by soil temperature, amendment type, rate, and C: N ratio. *Phytopathology* **2021**, *111*, 1380–1392. [CrossRef]
31. Dong, H.Z.; Li, W.J.; Li, Z.H.; Tang, W.; Zhang, D.M. Increased yield and revenue with a seedling transplanting system for hybrid seed production in Bt cotton. *J. Agron. Crop Sci.* **2005**, *191*, 116–124. [CrossRef]
32. Wang, R.T.; Wang, Y.N.; Dong, X.R. Effects of plastic film covering on dropping ground temperature at the full-growing stages of cotton, maize and soybean. *Sheng Tai Xue Bao* **2003**, *23*, 1667–1672. (In Chinese) [CrossRef]
33. Yang, B.; Lu, F.; Li, X.; Yang, G.; Ma, Y.; Li, Y. Effects of plastic film mulching on the spatiotemporal distribution of soil water, temperature, and photosynthetic active radiation in a cotton field. *PeerJ* **2022**, *10*, e13894. [CrossRef] [PubMed]
34. Li, R.F.; Ma, J.J.; Sun, X.H.; Guo, X.H.; Zheng, L.J. Simulation of soil water and heat flow under plastic mulching and different ridge patterns. *Agriculture* **2021**, *11*, 1099. [CrossRef]
35. Zong, R.; Wang, Z.H.; Wu, Q.; Guo, L.; Lin, H. Characteristics ofcarbon emissions in cotton fields under mulched drip irrigation. *Agric. Water Manag.* **2020**, *231*, 105992. [CrossRef]
36. Davis, R.M.; Nunez, J.J.; Subbarao, K.V. Benefits of cotton seed treatments for the control of seedling diseases in relation to inoculum densities of *Pythium* species and *Rhizoctonia solani*. *Plant Dis.* **1997**, *81*, 766–768. [CrossRef] [PubMed]
37. Fender, W.F. Effect of autumn planting date and stand age on severity of stem rust in seed crops of perennial ryegrass. *Plant Dis.* **2004**, *88*, 1017–1020. [CrossRef] [PubMed]
38. He, Z.X.; Liu, G.Z.; Deng, X.M. Effect of plastic film mulching on cotton Fusarium wilt. *J. Northwest A&F Univ.* **1994**, *5*, 419–421. (In Chinese)
39. Bennett, R.S.; Spurgeon, D.W.; DeTar, W.R.; Gerik, J.S.; Hutmacher, R.B.; Hanson, B.D. Efficacy of four soil treatments against *Fusarium oxysporum* f. sp. *Vasinfectum* race 4 on cotton. *Plant Dis.* **2011**, *95*, 967–976. [CrossRef]
40. Ben-Yephet, Y.; Stapleton, J.J.; Wakeman, R.J.; DeVay, J.E. Comparative effects of soil solarization with single and double layers of polyethylene film on survival of *Fusarium oxysporum* f. sp. *vasinfectum*. *Phytoparasitica* **1987**, *15*, 181–185. [CrossRef]
41. Jiang, P. Causes and control measures of premature senescence of plastic film watermelon in low heatareas of south china. *Tillage Cultiv.* **2002**, *6*, 33–38. (In Chinese) [CrossRef]
42. Goud, J.C.; Termorshuizen, A.J.; Blok, W.J.; Bruggen, A.H.C. Long-Term Effect of Biological Soil Disinfestation on Verticillium Wilt. *Plant Dis.* **2004**, *88*, 688–694. [CrossRef]
43. Zhang, C.S.; Kong, F.Y.; Wang, F.L.; Li, L.Y. Soil disinfection technology instead of methyl bromide. *Shangdong Sci.* **2005**, *1*, 24–29. (In Chinese) [CrossRef]
44. Jiang, Y.Y.; Lu, Y.H.; Li, J.; Liu, J.; Zeng, J.; Liu, J. Analysis on evolution dynamics and influence factors of cotton diseases and pests in Xinjiang. *China Plant Prot.* **2015**, *35*, 19–28. (In Chinese) [CrossRef]
45. Chai, Z.L.; Qin, Y.C.; Hua, X.Q.; Wang, Z.J.; Wang, Q. Research progress on flowering causes of bamboo. *J. Zhejiang For. Sci. Technol.* **2006**, *2*, 53–57. (In Chinese) [CrossRef]
46. Terry, A.W.; James, P.B.; Wayne, K. The effectiveness of crop rotation on management of Verticillium wilt over time. *Crop Prot.* **2019**, *121*, 157–162. [CrossRef]
47. Liu, H.J.; Zhang, H.; Wang, Y.F.; Chen, M.G.; Wu, F.J.; Lin, T.; Tang, Q.X. Effects of different mulching materials and irrigation rates on the formation of machine-picked cotton yield and the production efficiency of effective accumulated temperature. *Xinjiang Agric. Sci.* **2023**, *60*, 2091–2100. (In Chinese) [CrossRef]

48. Ogundeji, A.O.; Li, Y.; Liu, X.J.; Meng, L.B.; Sang, P.; Mu, Y.; Wu, H.L.; Ma, Z.N.; Hou, J.; Li, S.M. Eggplant by grafting enhanced with biochar recruits specific microbes for disease suppression of Verticillium wilt. *Appl. Soil Ecol.* **2021**, *163*, 103912. [CrossRef]
49. Dong, H.Z.; Zhang, D.M.; Tang, W.; Li, W.J.; Li, Z.H.A. Effects of planting system, plant density and flower removal on yield and quality of hybrid seed in cotton. *Field Crops Res.* **2005**, *93*, 74–84. [CrossRef]