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Weed Responses to Crop Residues Management in a Summer Maize Cropland in the North China Plain

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Abstract: Crop residues management has great effects on weeds in croplands. To understand the weed responses to crop residues management and weeds impact on crop yield, a field trial with three crop residues management strategies has been conducted in the North China Plain since 2008. Weed community composition and structure across the species, morphological types, life forms, and community levels were investigated during 2019–2020. The results show that the field with crop residues retention significantly decreased weed density than that in the field with no crop residues retention. Furthermore, total crop residues retention significantly decreased weed density than half crop residues retention. Compared with no crop residues retention, the weed aboveground dry matter in the field with total and half crop residues retention significantly decreased. Meanwhile, the maize grain yield significantly increased, resulting from weeds decreased with crop residues retention on the field. Negative correlations were found between maize grain yield and the density and aboveground dry matter of monocotyledonous weeds. These findings indicate that long term crop residues retention under conventional tillage might be an effective agronomic practice to retard weed growth. However, the mechanism of crop residues retention on weed control is still needed to research.

Keywords: weed density; weed aboveground dry matter; crop residues management

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1. Introduction

Weeds in croplands is one of the main harmful factors influencing crop growth and productivity. High infestation of weeds in croplands has been regarded as the most severe threat to food production [1,2]. It was estimated that the yield potential of major crops losses is as much as 33.92% on an average globally as a result of weeds impacting [3]. To diminish the adverse effects of weeds on crop growth, farmers take various control measures, such as physical, chemical, biological, and ecological weed control ways. However, the extensive use of chemical herbicides has caused environmental pollution, biodiversity reduction, food quality degradation, and human health problems [4,5]. Therefore, environmental-friendly alternative methods should be considered.

Changes in the environment derived from crop rotation, tillage, fertilization, and weed control strategies directly affect weed growth, weed distribution, and competition over crops [6]. Studies showed that fields with corn–oats–hay rotations reduced weed seed density than continuous corn [7]. Similarly, wheat–safflower and wheat–canola rotations can reduce weed species and increase the total revenue compared with continuous wheat [8]. It was reported that tillage had a larger effect on weed density and diversity than crop rotation [9]. Weed species, species richness, and diversity indices were higher under conservation tillage than conventional tillage [10,11]. Fertilization is a vital agronomy practice to ensure food production, but it would affect weed growth. Generally, fertilizer addition, especially nitrogen fertilization, could significantly increase the biomass of the dominant weeds [12]. Other studies found that soil-available P was the primary nutrient regulating weed community composition and construction, followed by N and K [13].

As an agronomic way, crop residues management might be one of the ecological methods to control weeds in cultivated land. It has been considered as a vital means to affect weed emergence and growth [2,14,15]. Crop residues mulching with no-till had similar weed biomass with conventional tillage without crop residues, while no-till without surface residues had nearly double weed biomass [16]. In general, research related to tillage does not include conventional tillage with crop residues retention, so the interactions between conventional tillage and crop residues retention to the weed community are not clear. Researchers reported that the density of barnyard grass, carpetweed, smooth pigweed, and yellow nutsedge are unchanged after adding 2340 kg ha^{-1} of hairy vetch dry matter [17]. However, when adding the biomass of hairy vetch to 6000 kg ha^{-1}, the weed density was significantly reduced [18]. Therefore, the successful weed control strategy by crop residues retention depends on sufficient crop residues [15]. Changes in the weed community triggered by crop residues management are expected to affect agroecosystem function and stability. A better understanding of the weed community changes to crop residues retention with conventional tillage is vital to predicting changes in agroecosystem functions associated with future ecological weed management. Besides, few studies can be found regarding how much crop residues should be left or added to the field to suppress weeds in the winter wheat-summer maize double-cropping system, so a clear understanding of the changes in the weed composition and structure across the species, morphological types, life forms, and community levels under different crop residues management is urgently needed to explain the underlying mechanisms of community dynamics in response to agronomy practices, especially crop residues incorporated into the soil under conventional tillage.

The North China Plain (NCP) is one of the most important areas producing farm products. It covers about 18 million hectares of cultivated land that represent nearly 18.3% of the whole arable land of China [19]. The dominant cropping system in the NCP is winter wheat-summer maize annual double-cropping. Maize is usually sown in June and harvested in October, and the following wheat is often sown after maize harvesting and harvested in early June in the next year. Conventional tillage, ploughed and rotary tillage, incorporated crop residues into the soil, is very popular in this region. Although there were many studies on crop residues retention in the NCP, most of them focused on soil qualities, greenhouse gas emissions, and crop yields [20–23]. Little information about the weed responses to crop residues management in this region is available.

Thus, the objectives of this research were to estimate whether crop residues management affect the weed community in the cultivated land in the NCP; and whether the different weed species have a similar response to crop residues retention.

2. Materials and Methods

2.1. Study Site

The field trial was carried out at Yucheng Comprehensive Experiment Station, Chinese Academy of Sciences, located at Shandong province in the North China Plain. The detailed information of the study site was described in the previous article [24].

2.2. Experimental Design

The trial was designed with a randomized design in 2008, including three treatments with three replicates, i.e., (1) no crop residues retention (NR), (2) half amount of crop residues retention (HR), and (3) total amount of crop residues retention (TR). All treatments were under conventional tillage. Crop residues of wheat straws and maize stalks in TR were about 7000 Kg ha^{-1} yr^{-1} and 7500 Kg ha^{-1} yr^{-1}, respectively. Half wheat straws and maize stalks were removed in HR, and all crop residues were removed in NR. Maize stalks were cut into small pieces (2–5 cm) and incorporated into the soil by conventional tillage after maize harvest in October, and wheat straws were mulched on the ground with no-till in June. Other agronomy practices (sow, fertilization, irrigation, harvest, etc.) were the same for the three treatments since 2008. No herbicides have been used since 2008.

2.3. Weed Community Evaluations

The weed community was investigated in 2019–2020. There were two winter wheat seasons and two summer maize seasons during our observation period. The weed community evaluations were conducted once a year in late July in the summer maize season when most weed species arrived at their maximum growth. At each weed evaluation, four 0.25 m^2 split herbaceous quadrats (0.5 × 0.5 m) were randomly placed in the interior of each plot. All weeds presented in the quadrats were counted, sorted by species, recorded, and oven-dried (70 °C) to measure the aboveground dry matter. In addition, the plant height and grain yield of summer maize were measured and recorded during harvest.

2.4. Statistical Analysis

Weed density was calculated as the total weeds per square meter. To examine the responses of different weed types to crop residues retention, weed species in this study were sorted into one of two weed types by the different morphological types: Monocotyledons and dicotyledons. We also sorted all the weeds into two weed types (i.e., annuals and perennials) according to the weed life cycle. The relative abundance of each weed species was calculated by the ratio between the specific weed abundance and the total abundance of all the weed species. The relative abundances of weed types were summed as the relative abundances of all weed species of each weed type. Weed species richness and the Pielou evenness index were described as the weed community biodiversity. Species richness (S) was evaluated as all weed species presented in the four quadrats per plot. Pielou evenness index (J) was computed as $J = (-\sum P_i \ln P_i)/\ln S$, where P_i is the relative abundance of weed species i and S is weed species richness.

Linear mixed-effects models with repeated measures were used to evaluate the effects of year, crop residues retention, and its interaction on weed density, weed aboveground dry matter, weed types, weed community diversity, plant height and grain yield of summer maize. Variables were log-transformed before analysis to meet homogeneity of variance assumptions when necessary. The differences among the crop residues retention treatments were compared with a Tukey's HSD test at $p < 0.05$ when the effect of treatment was found. Statistical analyses were performed using SPSS (version 20.0), and all figures were drawn with SigmaPlot (version 12.5).

3. Results

3.1. Density and Aboveground Dry Matter of Weeds

Total weed density ranged from 9.67 ± 3.28 individuals m^{-2} in TR to 323.00 ± 34.59 individuals m^{-2} in NR in 2019 and ranged from 13.00 ± 3.21 individuals m^{-2} in TR to 300.33 ± 39.31 individuals m^{-2} in NR in 2020, respectively (Table 1). Total weed density significantly decreased with the increase of the number of crop residues ($p < 0.001$) (Figure 1a, Table S2). The weed density of monocotyledons significantly reduced with crop residues retention ($p < 0.05$), while no differences were found for the dicotyledons density in the treatments ($p > 0.05$) both in 2019 and 2020 (Table 1).

Overall, aboveground dry matter of total weeds and monocotyledonous weeds decreased significantly with crop residues retention ($p < 0.001$) (Figure 1b, Table 2), but were unchanged by the year and the interaction of the year and crop residues retention ($p > 0.05$) (Figure 1b, Table S3). However, the aboveground dry matter of dicotyledonous weeds varied significantly with the year ($p < 0.001$), but was unchanged by crop residues retention and the interaction of the year and crop residues retention ($p > 0.05$) (Table S3).

Table 1. Results of one-way analysis of variance of weed density (individuals m^{-2}) of treatments (NR, no crop residues retention; HR, half crop residues retention; TR, total crop residues retention) during the experiment period.

	NR	HR	TR
2019			
Monocotyledon	311.33 ± 35.71 a (96.39)	47.67 ± 14.86 b (77.30)	6.00 ± 1.00 c (62.07)
Dicotyledon	11.67 ± 1.76 a (3.61)	14.00 ± 6.66 a (22.70)	3.67 ± 2.67 a (37.93)
Total weed	323.00 ± 34.59 a	61.67 ± 9.60 b	9.67 ± 3.28 c
2020			
Monocotyledon	280.33 ± 42.35 a (93.34)	123.67 ± 29.87 b (93.22)	6.33 ± 2.96 c (48.69)
Dicotyledon	20.00 ± 3.79 a (6.66)	9.00 ± 6.03 a (6.78)	6.67 ± 4.67 a (51.31)
Total weed	300.33 ± 39.31 a	132.67 ± 24.83 b	13.00 ± 3.21 c

Values were means ± SE (n = 3), and numbers in parentheses referred to the percentage of the specific weed types. Different letters indicate significant differences at the 0.05 level between the treatments.

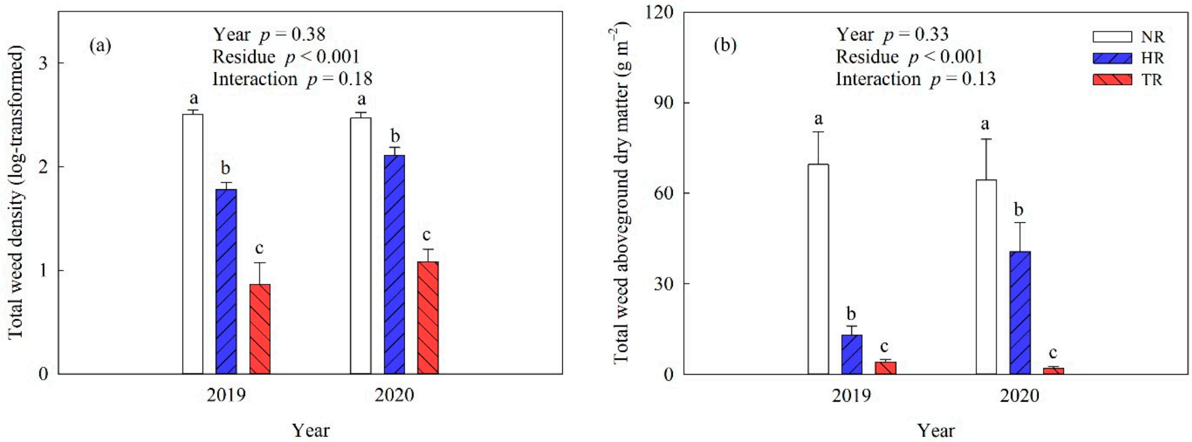

Figure 1. Total density (log-transformed) (**a**) and total aboveground dry matter (**b**) of weeds under treatments (NR, no crop residues retention; HR, half crop residues retention; TR, total crop residues retention) during the observation period. Different letters indicate significant differences at the 0.05 level between treatments. Bars represent means ± SE. Statistical results above the bars show the linear mixed-effects model.

Table 2. Results of one-way analysis of variance of weed aboveground dry matter (g m^{-2}) of treatments (NR, no crop residues retention; HR, half crop residues retention; TR, total crop residues retention) during the study period.

	NR	HR	TR
2019			
Monocotyledon	60.00 ± 11.62 a (86.33)	6.40 ± 2.43 b (48.97)	2.27 ± 0.38 c (55.37)
Dicotyledon	9.50 ± 2.12 a (13.67)	6.67 ± 5.09 a (51.03)	1.83 ± 1.33 a (44.63)
Total weed	69.50 ± 10.85 a	13.07 ± 2.99 b	4.10 ± 0.95 b
2020			
Monocotyledon	61.70 ± 13.29 a (95.85)	39.83 ± 10.32 b (97.96)	1.00 ± 0.50 c (50.76)
Dicotyledon	2.67 ± 0.22 a (4.15)	0.83 ± 0.73 ab (2.04)	0.97 ± 0.28 b (49.24)
Total weed	64.37 ± 13.47 a	40.66 ± 9.60 b	1.97 ± 0.69 b

Values were means ± SE (n = 3), and numbers in parentheses referred to the percentage of the specific weed types. Different letters denote significant differences at the 0.05 level between the treatments.

3.2. Weed Community Biodiversity

The relative abundance of the different morphological types (monocotyledons and dicotyledons) is unchanged by the year, crop residues retention, and their interaction ($p > 0.05$) (Figure 2a, Table S4). TR showed a lower relative abundance of monocotyledons than NR and HR in 2020 ($p < 0.05$). On the contrary, we found that both HR and TR showed a significantly higher relative abundance of dicotyledons than NR in 2019 ($p < 0.05$). Furthermore, the relative abundance of dicotyledons was higher in TR than NR and HR in 2020 ($p < 0.05$).

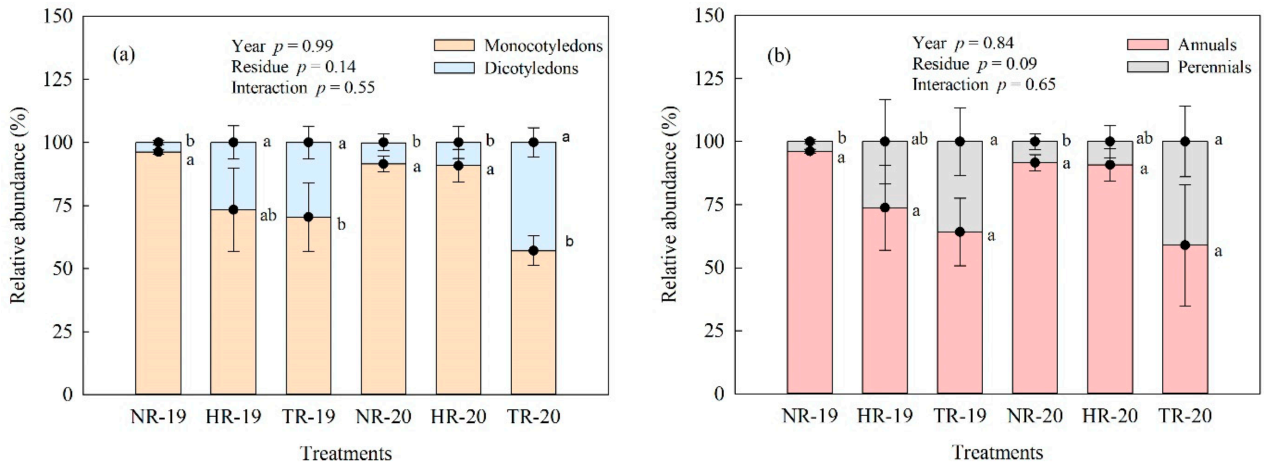

Figure 2. Relative abundance (%) of different morphological types (**a**) and life cycles (**b**) under treatments (NR-19—no crop residues retention in 2019; HR-19—half crop residues retention in 2019; TR-19—total crop residues retention in 2019; NR-20—no crop residues retention in 2020; HR-20—half crop residues retention in 2020) during the observation period. Different letters indicate significant differences at the 0.05 level between the treatments. Bars represent means ± SE. Statistical results above the bars show the linear mixed-effects model.

The relative abundance of the life cycle (annuals and perennials) was similar to the relative abundance of the morphological types. The relative abundance of annual weeds decreased, while the relative abundance of perennial weeds increased with crop residues retention (Figure 2b), but the differences between treatments were not significant ($p > 0.05$) (Table S4).

Weed species richness varied significantly with the year ($p = 0.001$) and crop residues retention ($p < 0.05$) (Figure 3a, Table S5). Pielou evenness index varied significantly with the year ($p < 0.01$) (Figure 3b, Table S5). On average, species richness was higher in NR than in HR and TR during the experimental period, but the difference was not significant in 2020 ($p > 0.05$). TR showed a significantly higher Pielou index than NR in 2020 ($p < 0.05$).

3.3. Impact of Weeds on Crop Growth and Yield

Over the study period, the plant height and grain yield of summer maize varied by the year, crop residues retention, and their interactions ($p < 0.01$), except for the year and crop residues retention interaction on maize yield ($p = 0.94$) (Figure 4a,b, Table S6). The maize yield of this study followed the order: NR < HR < TR. Maize yield in HR and TR increased by 4.38% and 20.12% in 2019, and 3.73% and 9.89% in 2020 compared with NR, respectively.

Negative correlations were shown between maize yield and the density of monocotyledonous weeds both in 2019 ($r^2 = 0.6321$, $p = 0.0104$) and in 2020 ($r^2 = 0.6501$, $p = 0.0087$). Besides, significant negative correlations were found between maize yield and above-ground dry matter of monocotyledonous weeds both in 2019 ($r^2 = 0.4985$, $p = 0.0335$) and in 2020 ($r^2 = 0.6243$, $p = 0.0113$) (Figure 5).

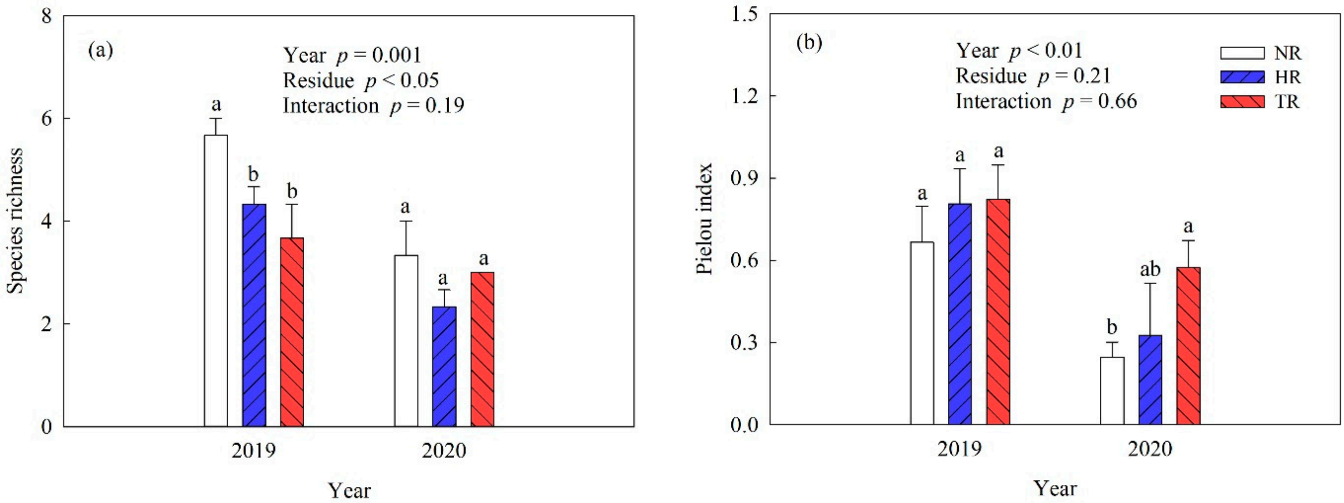

Figure 3. Community-level diversity ((**a**)—species richness, (**b**)—Pielou evenness index) under treatments (NR, no crop residues retention; HR, half crop residues retention; TR, total crop residues retention) during the observation period. Different letters indicate significant differences at the 0.05 level between the treatments. Bars represent means ± SE. Statistical results above the bars show the linear mixed-effects model.

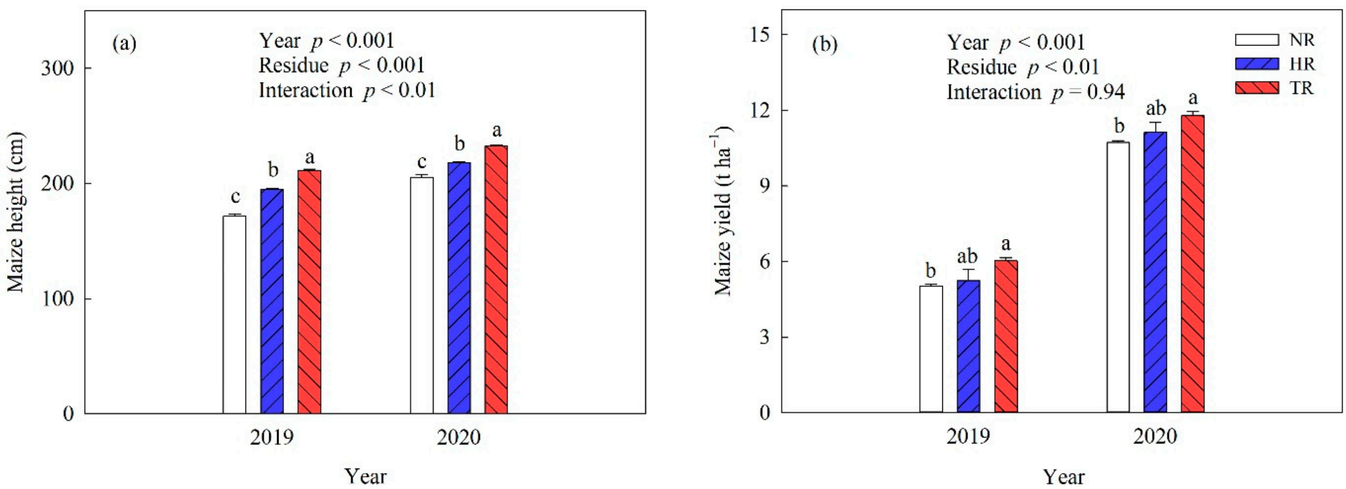

Figure 4. Plant height (**a**) and grain yield (**b**) of maize under treatments (NR, no crop residues retention; HR, half crop residues retention; TR, total crop residues retention) during the study period. Different letters indicate significant differences at the 0.05 level between the treatments. Bars represent means ± SE. Statistical results above the bars show the linear mixed-effects model.

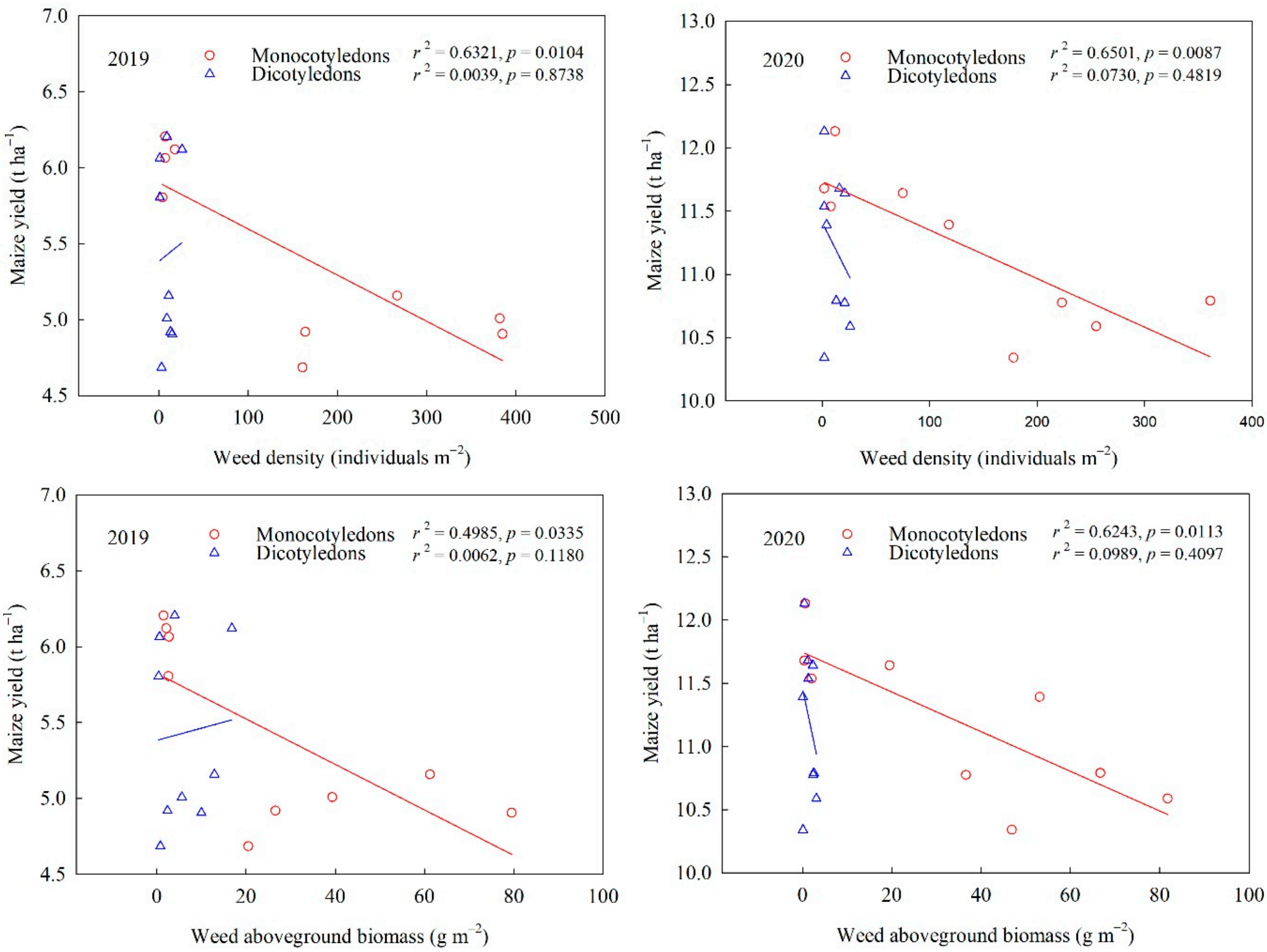

Figure 5. The correlation between maize yield and aboveground dry matter and density of weeds.

4. Discussion

4.1. Effects of Crop Residues Retention on Weed Density and Weed Aboveground Dry Matter

Both total weed density and weed aboveground dry matter was significantly decreased with crop residues retention in the present study (Figure 1, Tables 1 and 2), which is consistent with the findings derived from other croplands [2,11,15,18,25]. The density and aboveground dry matter of monocotyledons were higher in no crop residues retention than in crop residues retention treatments. (Tables 1 and 2). In addition, significant differences in the aboveground dry matter of monocotyledons were found under half crop residues and total crop residues retention treatments (Table 2). This result could be explained by the reason that no crop residues retention treatments do not have a barrier of crop residues that impede the emergence and growth of fertile graminoids [26], so the weed seed bank may be increased after the spread of seed rain, eventually expanding the potential for severe weed infestation originating from seeds. These findings suggest that the effects of crop residues retention on weed emergence and growth vary among different amounts of crop residues [17,18]. Researchers pointed out that successful weed control by crop residues mulches was highly dependent on sufficient aboveground dry matter, so it was necessary to add additional crop residues when insufficient because the number of crop residues fluctuated over the years [15,27]. This study showed that the proportion of dicotyledons increased with the number of crop residues retention (Table 1), which could be attributed to the fact that graminoids with smaller seeds could be impeded to the retention of crop residues. In contrast, the growth of crop and broadleaf weeds with relatively big seeds might be unaffected [28]. The results of the present study showed that half crop residues retention (3500 Kg ha^{-1} wheat straws and 3750 Kg ha^{-1} maize stalks every year) could suppress weeds in the maize fields, so we roughly estimated that 3500 Kg ha^{-1} wheat straws and 3750 Kg ha^{-1} maize stalks retention every year might be sufficient in suppressing weeds in the winter wheat-summer maize annual double-cropping systems.

4.2. Effects of Crop Residues Retention on the Weed Community Diversity

The present study demonstrated that the shift in the composition of weed types with different crop residues management. Total crop residues retention reduced the relative abundance of monocotyledons and elevated dicotyledons for the morphological types in 2020 (Figure 2a). Overall, crop residues retention increased the relative abundance of dicotyledons, indicating that broadleaf dicotyledons may be more adaptive to the residues retention environment than monocotyledons for diverse root systems [29,30]. Previous studies found the broadleaf weeds were species with taproots, whereas the graminoids were the shallower-rooted and fibrous-rooted species [31]. Although both graminoids and broadleaf weeds were suppressed by the crop residues retention (Table 1), the species with shallower or fibrous roots may be more sensitive to the allelochemicals released by the crop residues, leading to the lower relative abundance of graminoids. Meanwhile, the taproot broadleaf weeds can stretch their roots in deep soil layers to utilizing deeper water and nutrients and avoiding being seriously affected by exudates from the crop residues, which facilitates their survival and growth in the crop residues retention conditions [32]. That would, in turn, contribute to increasing the percentage of broadleaf weeds. In addition, many studies found crop residues retention could enhance the soil water content [33]. This study revealed the relative abundance of annual weeds decreased with crop residues retention (Figure 2b), suggesting that soil water content reduction favored annual plant growth [34]. This result could be attributed to the fact that annual weeds may be rapid growth species with a short life span, growing and reproducing faster than perennials when encountering disadvantageous conditions like drought [35]. Overall, the present study found contrasting results of the relative abundance of weed types under different crop residues management, indicating that different weed types may have different adaptation strategies associated with their morphological or physiological traits to adapt to environmental changes [36].

Species richness in the present study showed an apparent decrease with crop residues retention during the observation period (Figure 3a), i.e., crop residues retention significantly decreased species richness of the weed community, consistent with other studies [2,37]. These findings suggest that long term crop residues retention may reduce the weed species richness in the summer maize field. Crop residues could hinder the emergence of seeds by decreasing the light and providing a surviving habitat to pathogens and weed predators [2,26]. Consequently, plots with crop residues could decrease weed species richness. In the present study, no difference in the Pielou evenness index was found under treatments (Figure 3b), implying that crop residues retention might not be the dominant factor affecting the Pielou evenness index. Species richness and Pielou evenness index in this summer maize field varied significantly with the year (Figure 3a,b, Table S4). This could be attributed to the high germination failure rate and seedling mortality rate, due to different annual soil temperatures and precipitations during the observation period (Figures S1 and S2). The present study found an interesting result that the Pielou evenness index in no crop residues retention treatments was slightly lower than that of crop residues retention ones, contrasting with species richness. Although no crop residues retention treatments showed more weed species, the graminoids accounted for more than 90 percent of the total weed density (Table 1), so the Pielou evenness index was lower in no crop residues retention treatments. These findings imply that even small changes in the environment may impact the resistance of the weed community and lead to alternations in weed species composition.

4.3. Effects of Weeds on Maize Growth and Yield

This study showed that the presence of monocotyledons, favoured by no crop residues retention conditions, negatively affected summer maize grain yield (Figure 5). This may be attributed to the fact that crop residues retention could improve soil health status, provide nutrients (C, N fractions, and other elements), and optimize soil conditions [38–40], facilitating maize growth. Moreover, crop residues could impede weed emergence and occurrence by changing the soil conditions [2,11], decreasing the weed competition over crops. Although summer maize grain yield is not dominated by an increase in monocotyledonous weeds solely, it should be noted that monocotyledonous weeds like *Digitaria sanguinalis* (L.) Scop was abundant species in this study, especially in no crop residues retention treatment. Whenever a weed becomes a dominant or troublesome species in a farming field, farmers should alter weed control strategies to mitigate the high infestation of certain weeds [41]. In the present study, the weed management practices of tillage and crop residues retention with no chemical herbicides were used for more than ten years according to the original experiment design, which may benefit certain weeds. The present study showed that crop residues retention caused a significant shift in the weed community, suggesting flexible weed control strategies should be considered in the future according to the weed flora. Previous studies showed that integrated weed management could efficiently control weeds in croplands. Specifically, compared with the chemical approach, mechanical weeding after applied atrazine as a pre-emergence herbicide reduced weed density [42,43]. Integrated weed management in no-till systems may make it possible to reduce herbicides in croplands [44]. Moreover, no-till has been popular in recent decades for many benefits to the cropland environment. Many studies observed that reduced or zero tillage increased weed density and weed aboveground biomass [24,45]. In addition, strip-tillage with crop mulch could decrease the size, but increase the diversity of the soil seed bank when comparing with conventional tillage with no crop mulching [46]. Therefore, further studies with long term observation are needed in the future to determine the mechanisms of integrated weed management related to the soil physicochemical properties, nutrient uptake mechanisms of both crops and weeds, soil microbial community, and soil enzyme activities on the weed community composition and structure.

5. Conclusions

Long term crop residues retention in the field under conventional tillage could change the weed community. Comparing with no crop residues retention from the field, the weed density in the field with total crop residues retention and half crop residues retention were decreased by 96.34% and 68.37%, respectively. The weed aboveground dry matter in the field with total and half crop residues retention decreased by 95.52% and 59.01%, respectively. Furthermore, maize yield was increased by 4.06% and 15.01% in half and total crop residues retention, due to weeds decreased. Negative correlations were found between grain yield and the density and aboveground dry matter of monocotyledonous weeds. Therefore, we suggest that crop residues retention under conventional tillage is an effective agronomic measure to impede weeds and improve crop yield.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/agriculture11080746/s1, Figure S1: Soil temperature in 5 cm depth in 2019 (a) and 2020 (b) under treatments (NR, no crop residues retention; HR, half crop residues retention; TR, total crop residues retention) during the study period, Figure S2, Soil water content in 2019 (a) and 2020 (b) under treatments (NR, no crop residues retention; HR, half crop residues retention; TR, total crop residues retention) during the study period, Table S1: List of weed species and their classification on plant functional groups under different crop residues management (NR, no crop residues retention, HR, half crop residues retention, TR, total crop residues retention) in the summer maize field in NCP during the study period, Table S2: Significance of the impacts of crop residues retention, year, and their interactions on weed density during the period of study, Table S3: Significance of the impacts of crop residues retention, year, and their interactions on aboveground dry matter of weeds during the period of study, Table S4: Significance of the impacts of crop residues retention, year, and their interactions on the relative abundance of weed types during the period of study, Table S5: Significance of the impacts of crop residues retention, year, and their interactions on the weed community-level diversity during the period of study, Table S6: Significance of the impacts of crop residues retention, year, and their interactions on the plant height and crop yield of maize during the period of study. Raw data: The data of this study.

Author Contributions: J.Z.: Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, visualization, and writing-original draft preparation. L.-F.W.: Conceptualization, validation, resources, writing-review and editing, supervision, project administration, and funding acquisition. B.-B.L.: Investigation and data curation. All authors have read and agreed to the published version of the manuscript.

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References

1. San Martin, C.; Long, D.S.; Gourlie, J.A.; Barroso, J. Weed responses to fallow management in Pacific Northwest dryland cropping systems. *PLoS ONE* **2018**, *13*, e0204200. [CrossRef]
2. Yang, M.; Zhao, Y.; Yang, H.; Shen, Y.; Zhang, X. Suppression of weeds and weed seeds in the soil by stubbles and no-tillage in an arid maize-winter wheat-common vetch rotation on the Loess Plateau of China. *J. Arid. Land* **2018**, *10*, 809–820. [CrossRef]
3. Oerke, E.C. Crop losses to pests. *J. Agric. Sci.* **2005**, *144*, 31–43. [CrossRef]
4. Annett, R.; Habibi, H.R.; Hontela, A. Impact of glyphosate and glyphosate-based herbicides on the freshwater environment. *J. Appl. Toxicol.* **2014**, *34*, 458–479. [CrossRef] [PubMed]
5. Gaba, S.; Gabriel, E.; Chadoeuf, J.; Bonneu, F.; Bretagnolle, V. Herbicides do not ensure for higher wheat yield, but eliminate rare plant species. *Sci. Rep.* **2016**, *6*, 30112. [CrossRef]
6. Murphy, C.E.; Lemerle, D. Continuous cropping systems and weed selection. *Euphytica* **2006**, *148*, 61–73. [CrossRef]
7. Cardina, J.; Herms, C.P.; Doohan, D.J. Crop rotation and tillage system effects on weed seedbanks. *Weed Sci.* **2002**, *50*, 448–460. [CrossRef]
8. Sarani, M.; Oveisi, M.; Mashhadi, H.R.; Alizade, H.; Gonzalez-Andujar, J.L. Interactions between the tillage system and crop rotation on the crop yield and weed populations under arid conditions. *Weed Biol. Manag.* **2014**, *14*, 198–208. [CrossRef]
9. Murphy, S.D.; Clements, D.R.; Belaoussoff, S.; Kevan, P.G.; Swanton, C.J. Promotion of weed species diversity and reduction of weed seedbanks with conservation tillage and crop rotation. *Weed Sci.* **2006**, *54*, 69–77. [CrossRef]
10. Dorado, J.; Lopez-Fando, C. The effect of tillage system and use of a paraplow on weed flora in a semiarid soil from central Spain. *Weed Res.* **2006**, *46*, 424–431. [CrossRef]
11. Nandan, R.; Singh, V.; Singh, S.S.; Kumar, V.; Hazra, K.K.; Nath, C.P.; Poonia, S.P.; Malik, R.K. Comparative assessment of the relative proportion of weed morphology, diversity, and growth under new generation tillage and crop establishment techniques in rice-based cropping systems. *Crop Protect.* **2018**, *111*, 23–32. [CrossRef]
12. Mohler, C.L.; Caldwell, B.A.; Marschner, C.A.; Cordeau, S.; Maqsood, Q.; Ryan, M.R.; DiTommaso, A. Weed seedbank and weed biomass dynamics in a long-term organic vegetable cropping systems experiment. *Weed Sci.* **2018**, *66*, 611–626. [CrossRef]
13. Tang, L.; Wan, K.; Cheng, C.; Li, R.; Wang, D.; Pan, J.; Tao, Y.; Xie, J.; Chen, F. Effect of fertilization patterns on the assemblage of weed communities in an upland winter wheat field. *J. Plant Ecol.* **2013**, *7*, 39–50. [CrossRef]
14. Alonso-Ayuso, M.; Gabriel, J.L.; García-González, I.; Del Monte, J.P.; Quemada, M. Weed density and diversity in a long-term cover crop experiment background. *Crop Protect.* **2018**, *112*, 103–111. [CrossRef]
15. Reberg-Horton, S.C.; Grossman, J.M.; Kornecki, T.S.; Meijer, A.D.; Price, A.J.; Place, G.T.; Webster, T.M. Utilizing cover crop mulches to reduce tillage in organic systems in the southeastern USA. *Renew. Agric. Food Syst.* **2011**, *27*, 41–48. [CrossRef]
16. Ngwira, A.R.; Aune, J.B.; Thierfelder, C. On-farm evaluation of the effects of the principles and components of conservation agriculture on maize yield and weed biomass in Malawi. *Exp. Agric.* **2014**, *50*, 591–610. [CrossRef]
17. Koger, C.H.; Reddy, K.N. Effects of hairy vetch (*Vicia villosa*) cover crop and banded herbicides on weeds, grain yield, and economic returns in corn (*Zea mays*). *J. Sustain. Agric.* **2005**, *26*, 107–124. [CrossRef]

18. Mohler, C.L.; Asdale, J.R. Response of weed emergence to rate of *Vicia villosa* Roth and *Secale cereale* L. residue. *Weed Res.* **1993**, *33*, 487–499. [CrossRef]
19. Sun, H.; Zhang, X.; Chen, S.; Pei, D.; Liu, C. Effects of harvest and sowing time on the performance of the rotation of winter wheat–summer maize in the North China Plain. *Ind. Crop. Prod.* **2007**, *25*, 239–247. [CrossRef]
20. Wu, L.-F.; Li, B.-b.; Qin, Y.; Gregorich, E. Soil CO_2 emission and carbon budget of a wheat/maize annual double-cropped system in response to tillage and residue management in the North China Plain. *Int. J. Agric. Sustain.* **2017**, *15*, 253–263. [CrossRef]
21. Mu, X.; Zhao, Y.; Liu, K.; Ji, B.; Guo, H.; Xue, Z.; Li, C. Responses of soil properties, root growth and crop yield to tillage and crop residue management in a wheat–maize cropping system on the North China Plain. *Eur. J. Agron.* **2016**, *78*, 32–43. [CrossRef]
22. Zhang, X.; Pei, D.; Chen, S.; Sun, H.; Yang, Y. Performance of double-cropped winter wheat–summer maize under minimum irrigation in the North China Plain. *Agron. J.* **2006**, *98*, 1620–1626. [CrossRef]
23. Dai, X.; Li, Y.; Ouyang, Z.; Wang, H.; Wilson, G.V. Organic manure as an alternative to crop residues for no-tillage wheat–maize systems in North China Plain. *Field Crop. Res.* **2013**, *149*, 141–148. [CrossRef]
24. Zhang, J.; Wu, L.-F. Impact of tillage and crop residue management on the weed community and wheat yield in a wheat–maize double cropping system. *Agriculture* **2021**, *11*, 265. [CrossRef]
25. Campiglia, E.; Radicetti, E.; Mancinelli, R. Weed control strategies and yield response in a pepper crop (*Capsicum annuum* L.) mulched with hairy vetch (*Vicia villosa* Roth.) and oat (*Avena sativa* L.) residues. *Crop Protect.* **2012**, *33*, 65–73. [CrossRef]
26. Teasdale, J.R.; Mohler, C.L. Light transmittance, soil temperature, and soil moisture under residue of hairy vetch and rye. *Agron. J.* **1993**, *85*, 673–680. [CrossRef]
27. Flower, K.C.; Ward, P.R.; Micin, S.F.; Cordingley, N. Crop rotation can be used to manipulate residue levels under no-tillage in a rainfed Mediterranean-type environment. *Soil Tillage Res.* **2021**, *212*, 105062. [CrossRef]
28. Putnam, A.R.; Defrank, J. Use of phytotoxic plant residues for selective weed control. *Crop Protect.* **1983**, *2*, 173–181. [CrossRef]
29. Mulhouse, J.M.; Hallett, L.M.; Collins, S.L.; Vandvik, V. The influence of seasonal precipitation and grass competition on 20 years of forb dynamics in northern Chihuahuan Desert grassland. *J. Veg. Sci.* **2017**, *28*, 250–259. [CrossRef]
30. Tetetla-Rangel, E.; Dupuy, J.M.; Hernández-Stefanoni, J.L.; Hoekstra, P.H. Patterns and correlates of plant diversity differ between common and rare species in a neotropical dry forest. *Biodivers. Conserv.* **2017**, *26*, 1705–1721. [CrossRef]
31. Jin, Y.; Li, J.; Liu, C.; Liu, Y.; Zhang, Y.; Song, Q.; Sha, L.; Chen, A.; Yang, D.; Li, P. Response of net primary productivity to precipitation exclusion in a savanna ecosystem. *For. Ecol. Manag.* **2018**, *429*, 69–76. [CrossRef]
32. Collins, D.B.G.; Bras, R.L. Plant rooting strategies in water-limited ecosystems. *Water Resour. Res.* **2007**, *43*. [CrossRef]
33. Govaerts, B.; Sayre, K.D.; Goudeseune, B.; De Corte, P.; Lichter, K.; Dendooven, L.; Deckers, J. Conservation agriculture as a sustainable option for the central Mexican highlands. *Soil Tillage Res.* **2009**, *103*, 222–230. [CrossRef]
34. Cleland, E.E.; Collins, S.L.; Dickson, T.L.; Farrer, E.C.; Gross, K.L.; Gherardi, L.A.; Hallett, L.M.; Hobbs, R.J.; Hsu, J.S.; Turnbull, L.; et al. Sensitivity of grassland plant community composition to spatial vs. temporal variation in precipitation. *Ecology* **2013**, *94*, 1687–1696. [CrossRef]
35. Pake, C.E.; Venable, D.L. Is coexistence of Sonoran desert annuals mediated by temporal variability in reproductive success. *Ecology* **1995**, *76*, 246–261. [CrossRef]
36. Jin, Y.; Li, J.; Liu, C.; Liu, Y.; Zhang, Y.; Song, Q.; Sha, L.; Balasubramanian, D.; Chen, A.; Yang, D.; et al. Precipitation reduction alters herbaceous community structure and composition in a savanna. *J. Veg. Sci.* **2019**, *30*, 821–831. [CrossRef]
37. Steponavičienė, V.; Marcinkevičienė, A.; Butkevičienė, L.M.; Skinulienė, L.; Bogužas, V. The effect of different soil tillage systems and crop residues on the composition of weed communities. *Agronomy* **2021**, *11*, 1276. [CrossRef]
38. Turmel, M.-S.; Speratti, A.; Baudron, F.; Verhulst, N.; Govaerts, B. Crop residue management and soil health: A systems analysis. *Agric. Syst.* **2015**, *134*, 6–16. [CrossRef]
39. Dikgwatlhe, S.B.; Chen, Z.-D.; Lal, R.; Zhang, H.-L.; Chen, F. Changes in soil organic carbon and nitrogen as affected by tillage and residue management under wheat–maize cropping system in the North China Plain. *Soil Tillage Res.* **2014**, *144*, 110–118. [CrossRef]
40. Sarkar, S.; Skalicky, M.; Hossain, A.; Brestic, M.; Saha, S.; Garai, S.; Ray, K.; Brahmachari, K. Management of crop residues for improving input use efficiency and agricultural sustainability. *Sustainability* **2020**, *12*, 9808. [CrossRef]
41. Campiglia, E.; Radicetti, E.; Mancinelli, R.; Albrecht, H. Floristic composition and species diversity of weed community after 10 years of different cropping systems and soil tillage in a Mediterranean environment. *Weed Res.* **2018**, *58*, 273–283. [CrossRef]
42. Ghosh, D.; Brahmachari, K.; Skalicky, M.; Hossain, A.; Sarkar, S.; Dinda, N.K.; Das, A.; Pramanick, B.; Moulick, D.; Brestic, M.; et al. Nutrients supplementation through organic manures influence the growth of weeds and maize productivity. *Molecules* **2020**, *25*, 4924. [CrossRef] [PubMed]
43. Ghosh, D.; Brahmachari, K.; Brestic, M.; Ondrisik, P.; Hossain, A.; Skalicky, M.; Sarkar, S.; Moulick, D.; Dinda, N.K.; Das, A.; et al. Integrated weed and nutrient management improve yield, nutrient uptake and economics of maize in the rice-maize cropping system of eastern India. *Agronomy* **2020**, *10*, 1906. [CrossRef]
44. Summers, H.; Karsten, H.D.; Curran, W.; Malcolm, G.M. Integrated weed management with reduced herbicides in a no-till dairy rotation. *Agron. J.* **2021**. [CrossRef]

45. Pratibha, G.; Rao, K.V.; Srinivas, I.; Raju, B.M.K.; Shanker, A.K.; Madhavi, M.; Indoria, A.K.; Rao, M.S.; Murthy, K.; Reddy, K.S.; et al. Weed shift and community diversity in conservation and conventional agriculture systems in pigeonpea- castor systems under rainfed semi-arid tropics. *Soil Tillage Res.* **2021**, *212*, 105075.
46. Hossain, M.M.; Begum, M.; Hashem, A.; Rahman, M.M.; Ahmed, S.; Hassan, M.M.; Javed, T.; Shabbir, R.; Hadifa, A.; Sabagh, A.E.L.; et al. Strip tillage and crop residue retention decrease the size but increase the diversity of the weed seed bank under intensive rice-based crop rotations in Bangladesh. *Agronomy* **2021**, *11*, 1164. [CrossRef]