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Strip Tillage Improves Productivity of Direct-Seeded Oilseed Rape (*Brassica napus*) in Rice–Oilseed Rape Rotation Systems

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Abstract: Oilseed rape (*Brassica napus*) is a crucial global oil crop. It is generally cultivated in rotation with rice in southern China's Yangtze River Basin, where the wet soil and residue retention after rice harvest significantly hinder its seedling establishment. Hence, this study developed a strip-tillage seeder for oilseed rape seeding following rice harvest. Additionally, seedling establishment, soil infiltration and evaporation post-seeding, soil moisture change, oilseed yield, and weed occurrence under strip tillage (ST) were compared with conventional shallow rotary-tillage (SR) and deep rotary-tillage (DR) seeding practices. Compared to SR and DR, the results demonstrated that ST had a higher seeding efficiency and 53.8% and 80.2% lower energy consumption, respectively. ST also enhanced seedling growth and oilseed yield formation more effectively than the competitor tillage treatments, with an oilseed yield increase exceeding 6%. Additionally, ST improved water infiltration and reduced soil water evaporation, resulting in higher topsoil (0–20 cm) moisture during the critical growth stages. Furthermore, ST reduced soil disturbance, significantly decreasing the density of the dominant weed, *Polypogon fugax*. Overall, ST seeding technology has the potential to improve the productivity of oilseed rape in rice–oilseed rape rotation systems, and its yield superiority is mainly due to seedling establishment improvement and soil moisture adjustment.

Keywords: strip tillage; oilseed rape; seedling establishment; yield; soil moisture; weed density

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1. Introduction

Oilseed rape (*Brassica napus*) is a vital global oil crop and the largest in China, cultivated on 7.5 million hectares, representing nearly one-fifth of global cultivation and production [1,2]. Despite this, China's significant consumption creates a supply–demand imbalance [1,3]. To address this, the Chinese government has implemented policies to boost domestic production. Nevertheless, mechanization, particularly in sowing and harvesting, remains low, discouraging farmers from planting oilseed rape [4]. Currently, in the Yangtze River Basin, the main cultivation area of oilseed rape in southern China, primary production relies on labor-intensive and inefficient artificial seedling transplanting [2]. Although direct seeding for oilseed rape, compared to traditional manual transplanting, saves labor and cost, the high soil moisture after rice harvest, continuous autumn rainfall, and significant residue retention often result in poor establishment of direct-seeded oilseed rape in this region [5].

Several studies have aimed to improve the establishment of mechanically direct-seeded oilseed rape in high-soil-moisture conditions [6–8]. The main procedure involves soil disturbance and straw mixing, followed by mechanical seeding and fertilization. These steps can be performed separately or simultaneously using a combine seeder. Large clods may be created if the topsoil is too wet when tilled, resulting in high soil roughness affecting subsequent mechanical seeding operations [9]. High moisture levels or excessive straw return can also block mechanical seeding structures, adversely impacting seeding practice and seedling establishment [6,8]. Additionally, in wet clay soils, severe soil disturbance can exacerbate waterlogging for subsequent dryland crops in rice-based systems [5,10].

When exploring alternatives, strip tillage, where rotary tillage occurs only in a narrow strip to facilitate the seeding of the next crop, reduces soil disturbance and straw blockage and adapts well to fields with high soil moisture and residue mulching, particularly for wheat seeding [11]. The tilled soil in the strips contributes to water infiltration and crop root development [12,13]. Removing the residues from tilled strips has a positive effect on mitigating soil temperature changes [14,15]. Moreover, retaining crop residues between tilled strips reduces soil evaporation, allowing increasing moisture storage in the soil profile used by crop roots [14]. In most cases, strip tillage minimizes soil compaction and optimizes the seedbed environments for seed germination and crop seedling growth [16,17]. However, strip tillage adoption is regionally specific, and its positive effect on crop yield depends on multiple factors, such as tillage strip width, soil properties, and climatic conditions [13]. Nevertheless, there is evidence that strip tillage may benefit multiple-cropping production with *graminaceous* crops [13]. Most of the existing strip-tillage practices for oilseed rape production have been conducted in dryland systems, and the yield response varies according to different experimental conditions [18–20]. In contrast, strip tillage under complex conditions with high soil moisture and full residue retention has rarely been reported. Moreover, plowing or rotary tillage has been used as an effective way to control weeds, and strip tillage may increase weed occurrence and thus affect crop yields [21,22]. Therefore, this paper developed a strip-tillage seeder for oilseed rape seeding and conducted a field comparison with conventional shallow and deep rotary-tillage practices. This study aimed to (1) evaluate the seedling establishment of oilseed rape with a strip-tillage seeder; (2) determine the impact of strip tillage on oilseed rape growth and yield; and (3) estimate the effects of strip tillage on soil moisture change and weed occurrence.

2. Materials and Methods

2.1. The Machine Structure and Working Principle of the Strip-Tillage Oilseed Rape Seeder

A design diagram of the innovative strip-tillage oilseed rape seeder is shown in Figure 1. It comprises the following key components: a frame, strip rotary blades, a seed and fertilizer box, a seeding regulation system, a fertilizer distribution system, and a ground wheel. The seeder accommodates 6 or 8 seeding rows, corresponding to 6 or 8 blade groups on the rotary axis. Each group contains 4 blades for preparing the seedbed.

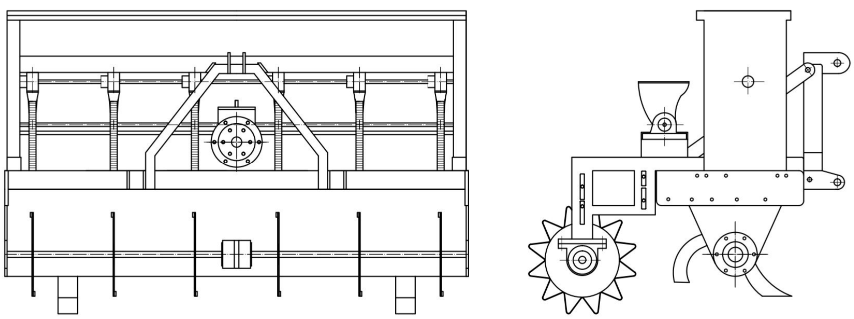

Figure 1. Main view (**left**) and side view (**right**) of the strip-tillage oilseed rape seeder.

The seeder uses a three-wire suspension system connected to the tractor, with the sowing and fertilizer devices driven by the ground wheel behind the seeder. The tractor's movement drives the rotation of the ground wheels, which in turn drive the seeding and fertilizing shafts via a chain. As the blades rotate, the fertilizer dropped in front of them is mixed effectively with soil and straw. Since the seeding tube's pipe mouth is directly opposite the corresponding blade group, the rape seeds fall onto the rotary-tillage belt after the strip rotary-tillage operation. No-tillage soil is maintained between seeding rows to minimize straw blockage. When the tractor stops or the seeder is raised to turn, the ground wheels cease operation, halting seeding and fertilizing automatically. To reduce mud and straw adhesion, the ground wheels behind the seeder are not traditional rollers but two narrow, serrated wheels. This design prevents slippage and minimizes mud accumulation. A picture of the field operation is shown in Figure 2.

Figure 2. Field operation of the strip-tillage oilseed rape seeder.

2.2. Comparison of Different Oilseed Rape Seeding Regimes

2.2.1. Field Trial Design

After developing the above machine, a comparative experiment was conducted under field conditions using conventional rotary-tillage seeding techniques. The experiment took place in Guanghan City, Sichuan Province, located in southwest China during the 2021/2022 and 2022/2023 growing seasons. In 2021/2022, the topsoil (0–20 cm) was sandy loam, while in 2022/2023 it was closer to silty loam. The topsoil moisture before tillage was 52.5% and 45.5% in 2021 and 2022, respectively. The previous crop, rice, was harvested in late September. In 2021, a semi-feed combine harvester was used, leaving straw chopped and dispersed on the soil surface. In 2022, a full-feed combine harvester was employed, and the straw was additionally crushed by a straw crusher before land preparation. The current local rice yield is approximately 10,000 kg ha^{-1} (14% grain moisture content), and the residue amount returned to the field is close to 9000 kg ha^{-1} each year. The seeding dates were 9 October 2021 and 7 October 2022, respectively. In the 2021/2022 season, the experiment included two seeding methods: the innovative seeding practice with the above strip-tillage seeder (ST) and conventional shallow rotary tillage (SR). Each treatment had three replications and was randomly arranged. In the 2022/2023 season, a deep rotary-tillage (DR) seeding practice was added, and three seeding practices were implemented. Each plot covered an area of 120 m^2.

For the ST seeding practice, an 8-row seeder was used in 2021 and a lighter 6-row seeder was used in 2022 under no-tillage and residue-retention conditions. For the SR seeding treatment, an integrated seeding machine performed rotary tillage for land preparation, sowing, and fertilization in one pass under no-tillage conditions, with a till depth of 7–8 cm. The DR seeding practice employed a traditional deep rotary tiller for tillage at a depth of 18–20 cm before seeding, and seeds were sown using the same seeder as in the SR seeding practice.

In the 2021/2022 season, the variety Chuanyou 81 was sown at a rate of 2.9 kg ha^{-1}. In the 2022/2023 season, the variety Chuanyou 83 was used, with seeding rates of 2.6, 2.7, and 2.7 kg ha^{-1} for the ST, SR, and DR treatments, respectively. Throughout the growth period, each treatment received 150 kg nitrogen (N) ha^{-1}, with 60% applied as compound fertilizer

(N-P-K, 15-15-15) during sowing and the remainder as urea at bolting. No irrigation was applied, and diseases and pests were well controlled according to technical requirements. During the 2021/2022 season, given the requirement to investigate the occurrence of weeds, chemical weeding was not conducted during the entire growth stage, while in the 2022/2023 season, chemical weeding was performed. Table 1 reports the temperature and rainfall during the period in which the experiment was conducted.

Table 1. Temperature and rainfall during the experiment.

Year	Factor	October	November	December	January	February	March	April
2021/2022	Mean temperature (°C)	17.3	11.3	8.3	7.7	7.4	17.0	18.3
	Rainfall (mm)	114.8	3.2	1.7	3.1	24.2	18.2	70.7
2022/2023	Mean temperature (°C)	18.3	15.2	7.2	6.6	10.0	14.0	18.9
	Rainfall (mm)	27.6	1.8	0.5	0.1	6.3	21.4	32.3

2.2.2. Sowing Efficiency and Energy Consumption

In the 2022/2023 growing season, the time and fuel consumption for each operation during land preparation and seeding were recorded, including tillage, seeding, fertilization, etc.

2.2.3. Topsoil Disturbance

After seeding in 2022/2023, two representative quadrats were selected in each plot. Each quadrat covered one row and was 35 cm in length. The soil clods in the quadrats were categorized into four groups based on diameter (>20 cm, 10–20 cm, 2–10 cm, and <2 cm). The number of clods and the averaged maximum diameters of the first three groups were measured.

2.2.4. Soil Infiltration and Topsoil Evaporation after Seeding

In 2022/2023, the double-ring method was used to measure soil infiltration after seeding [23]. The rings had a height of 25 cm and diameters of 50 cm (outer) and 25 cm (inner). For the ST treatment, the center of the inner and outer rings was on the midline of the rotary-tilled strip, and for the SR and DR treatments, the topsoil was fully tilled, and the center of the rings was close to the location of the seeds. They were inserted 20 cm into the soil and filled with water using two Mariotte bottles. The water level dropped rapidly in the first 30 min, then the rate slowed down, and data were recorded every 30 min after the slowdown. The water level was consistently maintained at 3 cm in both rings throughout the experiment. A consistent infiltration rate was assumed after three successive measurements showed identical values. The cutting-ring method was used to measure soil evaporation [24]. After seeding, topsoil was excavated using a cutting ring, with a height of 5 cm and a volume of 100 m^2. The ring was sealed with plastic film, and the total weight (soil and cutting ring) was recorded and returned to the sampling position. The cutting rings were removed and weighed after three days to calculate soil evaporation per unit area.

2.2.5. Seedling Emergence

Following seedling emergence, the number of emerged seedlings was assessed. In 2021/2022, six sample sites per plot were randomly investigated. Each site included two rows 2 m in length. In 2022/2023, three quadrats containing three rows 3 m in length were randomly selected to investigate the number of emerged seedlings. The coefficient of variation for the number of seedlings for each plot was also calculated.

2.2.6. Agronomic Characters Measurement at Seedling Stage

At 30 days post-seeding, fifteen representative seedlings were selected from each plot to measure the stem base diameter and the number of green leaves per plant. Then, all seedlings sampled in each plot were mixed and oven-dried at 105 °C for 20 min and then at 75 °C to a constant weight to determine the aboveground dry mass per seedling and the dry mass per m^2. Dry mass per m^2 was the product of dry mass per seedling and the number of seedlings per m^2.

2.2.7. Yield and Yield Components Investigation

Before harvesting at maturity, five and nine representative plants were taken from each plot in the 2021/2022 and 2022/2023 seasons, respectively, and these plants were used to investigate the number of siliques per plant, the number of seeds per silique, and 1000-seed dry weights [25]. At maturity, surviving plants in the center of the plot, undamaged by sampling, were harvested to evaluate the yield. In 2021/2022, the harvested area was 8 m^2 per plot. In 2022/2023, the harvested area encompassed three locations, each with two rows measuring 3 m in length. The number of surviving plants in each quadrat was investigated before harvest. After sun-drying and manual threshing, the seeds were weighed and moisture contents were measured. Seed yield was calculated based on 8% seed moisture.

2.2.8. Weed Occurrence Survey

Weed occurrence was assessed at 90 days post-seeding in the 2021/2022 season. Two quadrats, each 1 m^2, were examined in each plot. The species and stem numbers of weeds in each quadrat were recorded, and weed density per m^2 was calculated.

2.2.9. Soil Moisture Change

In the 2022/2023 season, every 30 days after seeding, soil from the 0–40 cm depth was sampled at three plot locations and divided into layers of 0–10, 10–20, 20–30, and 30–40 cm. The soil from each layer was mixed evenly, and its moisture content was determined by the oven-drying method, where samples were dried at 105 °C to a constant weight.

2.3. Data Analysis

Data were processed using Microsoft Excel 2013. Analysis was conducted using IBM SPSS 22.0 software, and the data were presented as averages. The significant differences among treatments were analyzed using ANOVA, the independent two-sample *t*-test was used to determine the difference between the two treatments in the 2021/2022 season, and Duncan's multiple range test was used to identify the differences among the three treatments in the 2022/2023 season.

3. Results

3.1. Variance Analysis of Seed Yield and Yield Components

The variance analysis revealed that oilseed yield was mainly affected by the seeding practice rather than the year (Table 2). The difference in emerged seedlings per m^2 between the years was noticeable, affecting surviving plant number per m^2. Moreover, the seeding practice mainly affected the number of siliques per plant, while the number of seeds per silique and 1000-grain weights were significantly affected by the year.

Table 2. Variance analysis of oilseed yield, yield components, and benefits under the two experimental years and the different seeding practices.

Factor	Oilseed Yield	Seedling Number per m^2	Surviving Plants per m^2	Number of Siliques per Plant	Number of Seeds per Silique	1000-Seed Dry Weight
Year (Y)	3.1	191.4 **	90.4 **	0.3	42.6 **	10.0 *
Seeding practice (S)	14.9 **	5.5 *	18.0 **	9.7 **	2.0	0.4
Y × S	4.3	7.4 *	26.8 **	0.2	0.002	2.1

The data presented in the table are *F* values. "*" means significantly different ($p < 0.05$); "**" means extremely significantly different ($p < 0.01$).

3.2. Yield and Yield Components

Consistent trends in oilseed yield among seeding treatments were observed across both years, with the ST practice consistently outperforming the other practices (Table 3). In 2021/2022, the ST treatment yielded 6.9% more than SR, though the difference was not significant. In 2022/2023, ST yielded 48.9% and 107.2% more than SR and DR, respectively, and a significant difference was observed among the treatments. The seed yield increase of ST was mainly due to the substantial increase in the number of siliques per plant.

Table 3. Effect of different oilseed rape seeding practices on oilseed yield and yield components.

Year	Seeding Practice	Oilseed Yield (kg ha^{-1})	Surviving Plants per m^2	Number of Siliques per Plant	Number of Seeds per Silique	1000-Seed Dry Weight (g)
2021/2022	ST	2838 ± 168 a	28.9 ± 1.1 b	284.5 ± 27.7 a	13.6 ± 1.6 a	4.22 ± 0.10 a
	SR	2655 ± 496 a	41.1 ± 3.6 a	196.9 ± 69.1 a	12.3 ± 1.0 a	4.13 ± 0.07 a
2022/2023	ST	2899 ± 385 a	24.0 ± 1.1 b	286.6 ± 8.9 a	17.8 ± 0.8 a	3.82 ± 0.09 a
	SR	1947 ± 218 b	24.5 ± 1.0 b	225.0 ± 36.2 ab	16.5 ± 1.1 a	3.99 ± 0.27 a
	DR	1399 ± 211 b	27.2 ± 1.5 a	138.0 ± 67.1 b	17.3 ± 0.7 a	3.84 ± 0.12 a

ST, strip-tillage seeding; SR, shallow rotary-tillage seeding; DR, deep rotary-tillage seeding. Data are presented as means with standard deviations (means ± SDs), and data in the same column from the same year followed by different lowercase letters are significantly different ($p < 0.05$).

3.3. Seeding Efficiency, Energy Consumption, and Soil Disturbance

The efficiency and energy consumption of different seeding methods varied due to differing pre-seeding operations and soil disturbance intensity (Table 4). ST increased seeding efficiency by 28.6% and 62.5% and reduced energy consumption by 53.8% and 80.2% compared to the SR and DR treatments, respectively. Different tillage practices created varied soil clod distributions (Table 4). Clods with extra-large (>20 cm) and large (10–20 cm) diameters dominated in the DR and SR treatments, while the ST treatment mainly produced clods with medium diameters.

Table 4. Effects of different oilseed rape seeding practices on seeding efficiency, energy consumption, and soil clod distributions during the 2022/2023 season.

Seeding Practice	Seeding Efficiency (h ha^{-1})	Fuel Consumption (L ha^{-1})	NCED	ACDED (cm)	NCLD	ACDLD (cm)	NCMD	ACDMD (cm)
ST	3.0	18.7	0 b	-	0 c	-	71.5 ± 8.9 a	5.6 ± 0.5 b
SR	4.2	40.5	1.9 ± 3.3 b	26.2 ± 0.5 a	22.9 ± 5.7 a	15.1 ± 1.8 a	19.0 ± 8.7 b	5.5 ± 1.1 b
DR	8.0	94.5	9.5 ± 3.3 a	27.1 ± 4.5 a	15.2 ± 3.3 b	16.2 ± 2.0 a	3.8 ± 6.6 b	7.5 ± 0.7 a

ST, strip-tillage seeding; SR, shallow rotary-tillage seeding; DR, deep rotary-tillage seeding; NCED, number of clods with extra-large diameters (>20 cm) per m^2; ACDED, average clod diameter for extra-large diameters; NCLD, number of clods with large diameters (10–20 cm) per m^2; ACDLD, average clod diameter for large diameters; NCMD, number of clods with medium diameters (2–10 cm) per m^2; ACDMDA, average clod diameter for medium diameters. Data for soil clods are presented as means with standard deviations (means ± SDs), and data in the same column followed by different lowercase letters are significantly different ($p < 0.05$).

3.4. Seedling Establishments

With nearly the same seeding rates, the difference in seedling number emerged per m^2 between treatments did not reach a significant level in the two experimental years (Table 5). However, the ST treatment exhibited better field distribution uniformity in the 2021/2022 growing season.

Table 5. Effect of different oilseed rape seeding practices on seedling establishments.

Year	Seeding Practice	Seedling Number per m^2	CVSD (%)
2021/2022	ST	47.0 ± 3.0 a	11.1 ± 1.7 b
	SR	56.6 ± 4.0 a	27.0 ± 8.3 a
2022/2023	ST	27.0 ± 2.8 a	11.0 ± 2.0 a
	SR	26.8 ± 2.8 a	11.5 ± 5.8 a
	DR	31.5 ± 2.7 a	10.2 ± 4.9 a

ST, strip-tillage seeding; SR, shallow rotary-tillage seeding; DR, deep rotary-tillage seeding; CVSD, coefficient of variation of seedling distribution. Data are presented as means with standard deviations (means ± SDs), and data in the same column in the same year followed by different lowercase letters are significantly different ($p < 0.05$).

3.5. Agronomic Characters at Seedling Stage

Most agronomic character values for oilseed rape seedlings decreased with the increase in tillage intensity at 30 days post-seeding (Table 6). In 2021/2022, significant differences existed in the main individual parameters between the two seeding practices, while dry mass per m^2 values remained similar. However, in 2022/2023, all tested agronomic parameters were significantly higher under ST compared to SR and DR, and dry mass per m^2 increased by 65.3% and 95.1%, respectively.

Table 6. Effects of different oilseed rape seeding practices on agronomic characters at seedling stage (30 days post-seeding).

Year	Seeding Practice	Diameter of Stem Base (cm)	Number of Green Leaves per Plant	Dry Mass per Plant (g)	Dry Mass per m^2 (g)
2021/2022	ST	4.55 ± 0.12 a	5.93 ± 0.29 a	1.27 ± 0.19 a	60.3 ± 13.1 a
	SR	3.73 ± 0.26 b	5.36 ± 0.23 b	0.88 ± 0.10 b	50.4 ± 8.4 a
2022/2023	ST	4.75 ± 0.36 a	4.92 ± 0.20 a	1.50 ± 0.22 a	40.2 ± 2.4 a
	SR	3.63 ± 0.27 b	4.19 ± 0.20 b	0.92 ± 0.16 b	24.3 ± 3.2 b
	DR	3.45 ± 0.20 b	4.00 ± 0.02 b	0.65 ± 0.08 b	20.6 ± 3.9 b

ST, strip-tillage seeding; SR, shallow rotary-tillage seeding; DR, deep rotary-tillage seeding. Data are presented as means with standard deviations (means ± SDs), and data in the same column in the same year followed by different lowercase letters are significantly different ($p < 0.05$).

3.6. Weed Occurrence

Seeding methods significantly influenced weed occurrence in the field (Table 7). In this study, the dominant weed was *Polypogon fugax*. At 90 days post-seeding with ST, the *Polypogon fuga* densities decreased by 85.2% and 83.7% compared to the SR and DR treatments, respectively.

Table 7. Effects of different oilseed rape seeding practices on field weed density at 90 days post-seeding in the 2021/2022 season.

Seeding Practice	Total Weed Density (Seedlings m^{-2})	*Polypogon Fugax* Density (Seedlings m^{-2})
ST	529 ± 18 b	525 ± 18 b
SR	3560 ± 966 a	3553 ± 967 a
DR	3235 ± 1342 a	3224 ± 1334 a

ST, strip-tillage seeding; SR, shallow rotary-tillage seeding; DR, deep rotary-tillage seeding. Data are presented as means with standard deviations (means ± SDs), and data in the same column followed by different lowercase letters are significantly different ($p < 0.05$).

3.7. Soil Infiltration and Evaporation Post-Seeding

Soil infiltration and evaporation measurements post-seeding showed that the stable infiltration rate in the ST treatment was significantly higher than in the other two treatments, while evaporation was lower (Figure 3). Over three days post-seeding, topsoil evaporation in the ST treatment decreased by 35.1% and 32.7% compared to the SR and DR treatments, respectively.

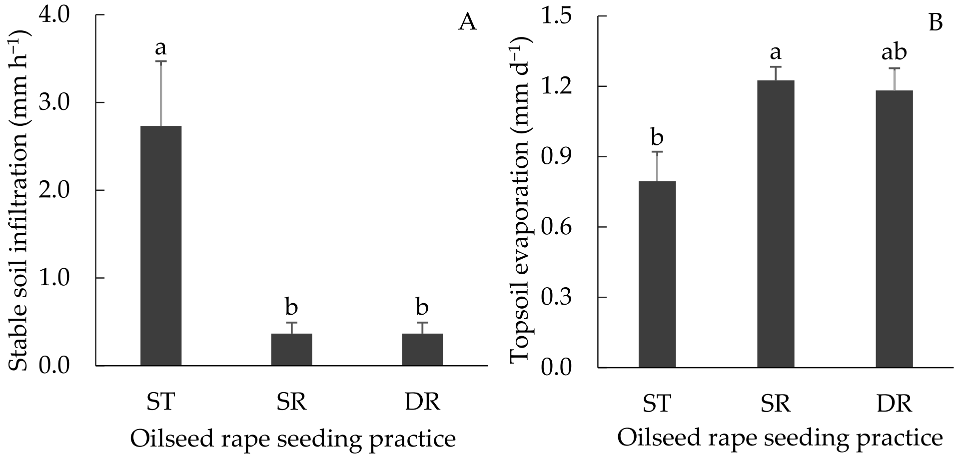

Figure 3. Effects of different oilseed rape seeding practices on stable soil infiltration (**A**) and topsoil evaporation (**B**) post-seeding in the 2022/2023 season. ST, strip-tillage seeding; SR, shallow rotary-tillage seeding; DR, deep rotary-tillage seeding. Bar graphs show the means, and the error bars represent standard deviations. On the bar chart, different lowercase letters indicate significant differences between different oilseed rape seeding practices for each parameter ($p < 0.05$).

3.8. Soil Moisture Change during Oilseed Rape Growth

The ST treatment maintained higher topsoil moisture (0–20 cm) throughout the oilseed rape growth period (Figure 4). The average soil moisture during the whole growth stages at depths of 0–10 cm and 10–20 cm in the ST treatment increased by 11.6% and 24.6% and by 8.0% and 16.6%, respectively, compared to the SR and DR treatments. However, soil moisture differences in deep soil (20–40 cm) between the treatments were reduced.

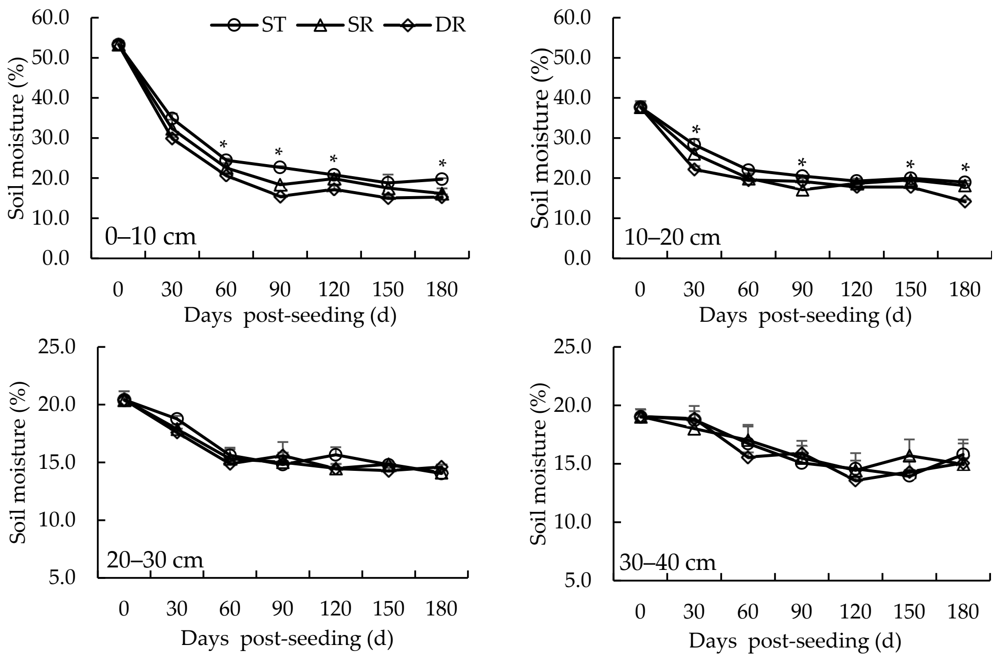

Figure 4. Effects of different oilseed rape seeding practices on soil moisture change during the 2022/2023 season. The moisture data in the figure show the means and the error bars represent standard deviations. ST, strip-tillage seeding; SR, shallow rotary-tillage seeding; DR, deep rotary-tillage seeding. "*" indicates a significant difference in soil moisture among the three treatments at a specific sampling time.

4. Discussion

The low quality of mechanized direct seeding is an important factor limiting oilseed rape yield improvement in rice–oilseed rape rotation systems in southern China [5,6]. This study reveals that, compared with conventional rotary tillage, strip-tillage practices can improve the seedling establishment and yield of oilseed rape. Many studies have confirmed that tillage systems have a pronounced impact on crop yield [26,27]. Strip tillage combines the advantages of no tillage and full tillage and thus positively affects crop yields in most regions, especially increasing dryland system production in cooler temperate areas [13]. This study confirmed that strip tillage positively affects oilseed rape production in subtropical–humid regions.

The positive effects of strip tillage on crop growth and yield are related to improvements in temperature and moisture conditions in seedbeds [12–15]. Some studies have proved that strip tillage in cooler areas can increase seedbed temperature, promoting crop emergence and growth [14,15]. However, the average temperature exceeds 15 °C when oilseed rape is seeded in southern China, and temperature may be not a limiting factor for oilseed rape establishment in this region. In contrast, in this study, the enhancement of seedling establishment and oilseed yield with strip tillage may have been caused by improved seedbed moisture conditions. High soil moisture after rice harvest and continuous rainfall make fields prone to waterlogging [5]. In this study, the soil water infiltration rate with strip tillage was higher than that in the shallow- and deep-tillage systems, which reduced the adverse effects of excessive soil moisture on seed germination and seedling growth. Other studies also supported this result, indicating that reduced tillage preserves soil capillary structure and increases water infiltration [28,29]. In addition, increasing soil surface roughness after intensive tillage leads to rapid topsoil moisture loss, thus affecting water absorption by seeds and seedlings [9]. This study also found that strip tillage with less soil disturbance led to fewer large soil clods and less soil water evaporation, resulting in a relatively ideal soil moisture state in the seedbeds, which positively affected oilseed rape growth. Compared with other conventional tillage practices, the oilseed yield increase with strip tillage in 2021/2022 was lower than that in 2022/2023. The rainfall in the former season was much higher than in the latter, especially in winter and spring, which further confirmed the positive effect of soil moisture retention with strip tillage on oilseed rape yield improvement. Due to the improvement in soil moisture conditions, most agronomic parameters with strip tillage at the oilseed rape seedling stage were superior to those of the competitor tillage regimes, and the number of siliques per plant at maturity was significantly improved. In conclusion, the positive effects of strip tillage on oilseed rape production in southern China are mainly due to soil moisture adjustment, which promotes surface water infiltration to alleviate waterlogging and reduces water evaporation to improve crop drought resistance.

Weeds significantly impact crop growth and yield, yet there is no consensus regarding their occurrence under conservation tillage conditions [30]. This study identified *Polypogon fugax* as the dominant weed species in oilseed rape fields, and its density and total weed density were lower in the strip-tillage treatment than in the other traditional tillage treatments. The occurrence of weeds in the field is influenced by factors including the number and spatial distribution of weed seeds in the soil and the tillage method used for previous crops [31]. In China's Yangtze River Basin, rotary tillage is typically employed before rice transplanting to accommodate transplanting, resulting in most weed seeds being buried deep in the soil. Once the topsoil is disturbed, the weeds rapidly germinate when air and water conditions around the seeds are favorable. In this study, *Polypogon fugax* was primarily found in rotary-tillage belts (Figure 5), contrasting with the relatively uniform distribution of weeds in fully rotary-tilled fields. Therefore, in rice–dryland crop rotation systems, ST seeding practices may potentially reduce weed occurrence during dryland crop growth seasons. In addition, strip tillage reduces fuel consumption in seeding operations by more than 50% (Table 4); thus, coupled with other innovative nutrient managements [32], it will be an option for future oilseed rape sustainable production in rice–oilseed rotation systems.

Figure 5. Weeds mainly occurred in tilled rows under the strip-tillage seeding practice in the oilseed rape fields.

5. Conclusions

Mechanical direct seeding for oilseed rape in rice–oilseed rape rotation systems in southern China faces great challenges due to high soil moisture and residue retention. In this study, the innovative oilseed rape strip-tillage (ST) seeding practice minimized soil disturbance, facilitated efficient seedling establishment, and enhanced seedling growth and seed yield, which was confirmed to benefit oilseed rape production. The seed yield improvement is attributable to the preservation of soil moisture and the suppression of weed germination. ST technology for oilseed rape seeding needs to be evaluated in multiple environments to further improve its adaptability to complex environments following rice harvest.

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