Influence of the Improved System of Rice Intensification (SRI) on Rice Yield, Yield Components and Tillering Characteristics under Different Rice Establishment Methods

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Abstract: The impacts of the system of rice intensification (SRI) and conventional management (CM) on grain yield, yield components and tillering capacity were examined under 4 rice establishment methods transplanting (TP), seedling casting (SC), mechanical transplanting (MT) and direct seeding (DS). SRI produced significantly higher grain yield than CM under TP and MT but not under DS or SC. DS and SC produced much higher seedling quality than TP or MT, suggesting that robust seedlings with vigorous roots weaken the positive effect of SRI on rice yield. SRI produced a higher tillering rate than CM, but did not affect ear-bearing tiller rate significantly. Moreover, the net photosynthetic rate of the recent fully expanded leaf at mid-tillering stage was significantly higher in SRI than in CM under MT and TP. The obtained results also indicated that SRI increased biomass accumulation before heading and improved utilization of photosynthates in the grain-filling stage.

Key words: Rice establishment method, Rice yield, SRI, Tillering traits.

Rice is the major food grain for more than one third of the world’s population (Prasertsak and Fukai, 1997). About 75% of the world’s rice supply comes from 79 million hectares of irrigated rice production in Asia (Cabangon et al., 2002). China is the world’s largest producer of rice, with 31.7 million hectares of rice. Of this total, about 92.7% is irrigated to some extent, producing about 35% of the world’s total rice (FAO, 2001). In China, the traditional rice establishment method is transplanting with rice seedlings, which involves replanting of rice seedlings grown in nurseries to puddled soils (Chen et al., 2007). However, rising labor costs and the need to intensify rice production through double and triple cropping provide economic incentives for a switch to alternative establishment methods (De Datta, 1986), such as direct sowing, mechanism transplanting, seedling broadcasting or a combination of methods. Simultaneously, the availability of high-yielding, short-duration varieties and chemical weed control methods have made such a switch technically viable (Pandey and Velasco, 2002).

Changes in crop establishment have important implications for farm operations, including primary tillage, seedbed preparation, planting, weeding, and water management (Ergiuza et al., 1990), that have a considerable impact on rice growth, especially seedling development and rice canopy structure establishment (Saha and Bharti, 2010). In the transplanting system, including manual transplanting and mechanical transplanting, rice seedling development is generally delayed due to injuries to the root caused by uprooting and replanting (Salam et al., 2001). Furthermore, the balance between water and transpiration in seedlings also changes, causing the leaves to wilt or partly die (Sasakawa and Yamamoto, 1978). Therefore, the growth and development of the seedlings become stagnant temporarily; this is the so-called “transplanting shock” (Sasakawa and Yamamoto, 1978; Salam et al., 2001). In the seeding broadcasting system, seedlings are grown in a nursery or plate, and at 15 – 20 days old, they are broadcast manually to the puddled field. The seedlings take root and begin to grow upright 2 – 3 days later. Their root growth into the soil is shallow and as a result the young plants are distributed randomly throughout the field (Zhang et al., 1998; Dai et al., 2001). Accordingly, most of the seedling roots are concentrated in the upper layer soil and are supposed to be sensitive to chemical fertilizer (Dai et al., 2001; Zhang et al., 2008). However, due to the lower level of injuries during replanting, the revival time of rice seedlings that have been
broadcast is shorter than that of transplanted seedlings, and tillers appear rapidly with vigorous roots (Zhang et al., 2008). These traits were also partly found in direct seeded (DS) rice, which has been reported to have a shorter time from seeding to mid tillering/heading stage (Pandey and Velasco, 2002), shallow but vigorous root activity and greater biomass production at its early stage (Naklang et al., 1996). Changes in rice establishment generally result in marked differences in seedling/tillering characteristics at the vegetative stage which will ultimately affect the grain yield as well as the efficiency of utilization of resources, such as fertilizer, water and/or solar energy (Zhang et al., 2008; Chandrapala et al., 2010; Saha and Bharti, 2010).

Rice establishment is also sensitive to agronomic practices such as planting density, water and fertilizer management, weed control alone or in combination. The system of rice intensification (SRI), a widely used but controversial rice cultivation method developed in Madagascar during the early 1980s (Dobermann, 2004; Sheehy et al., 2004; Stoop et al., 2009; Uphoff et al., 2009; Kassam et al., 2011), has generated considerable global debate. According to Stoop et al. (2002), SRI is not a fixed technological package, but rather a set of principles for raising the productivity of all of the factors involved in rice production, including land, labor, capital, seed and water. These principles include (1) careful transplanting of young seedlings at wide spacing on a precise grid with only one seedling per hill; (2) water management that keeps the soil moist but not continuously flooded; (3) frequent (i.e., three to four times during the growth period) manual or mechanical weeding before canopy closure; and (4) reliance on high rates of organic compost for fertilizer. The purpose of using young seedlings, wide spacing and a single seedling per hill was to provide enough resources for stronger individual plants in the rice group (Shao-hua, 2002; Uphoff, 2009), which attracted the interest of Chinese agronomists. In traditional agronomic practice, a large crop population is achieved through heavy planting density of the landrace variety (Zhu et al., 2011). The use of organic fertilizer and intermittent irrigation also results in high grain yield and high resource utilization (Yuan, 2001; Lin et al., 2005; Zhu et al., 2011).

The effect of SRI has been well documented, as well as the scientific elements of the principle (Makarim et al., 2002; Dobermann, 2004; Chen et al., 2006; Uphoff, 2009). It was developed to be used in a transplanting system; use of SRI in other establishment systems seems to be unsuitable, especially the direct seeding system. However, there have been a few cases in which specific farms referred to a certain management practice in direct seeding as “SRI” (Zhu et al., 2007; Ginigaddara, 2009), and some farmers actually utilize “direct seeded SRI” in the field. How the principles of ordinal SRI in transplanting system could be applied to the direct seeding system should be investigated. In this study, we utilized both conventional and alternative management methods in direct seeding. The latter was named SRI (for direct seeding) because its agronomic practices were set based on the key components of SRI, such as the reduced amount of broadcasting seeds compared with conventional management, the use of organic fertilizer and intermittent irrigation. We examined whether the principles of SRI could be applied to other establishment systems and examined the response of rice yield and tillering characteristics to different agronomic management methods with different seeding establishment by field experiments carried out in two years. We examined the effect of SRI on rice yield, components and seedling/tillering characteristics using four rice establishment methods: rice direct sowing (DS), rice seedling broadcasting (SC), manual transplanting (TP), mechanical transplanting (MT), and the conventional management/farmer’s agronomic practice (CM) as control. The study of rice production and tillering physiological response to SRI was thought to lead to a better understanding of the mechanism of the effect of SRI on rice seeding establishment.

### Materials and Methods

1. Site description

Field experiments were conducted at the experimental farm of Jiaxing Agriculture Research Institute, China (30°17′N, 120°45′E, 6 m altitude) in 2010 and 2011. The soil of the experimental site before planting was alluvial sandy clay loam, with pH 6.8, organic C 30.3 g kg⁻¹, total N 2.4 g kg⁻¹, available P 32.5 mg kg⁻¹ and available K 58.6 mg kg⁻¹. Soil sampling and properties were determined according to the Laboratory Manual for Agriculture and Soil Analysis (Pao, 2005).

2. Experimental design

The rice (*Oryza sativa* L.) variety used was Xiushui 09, a Japonica variety released by Jiaxing Crop Research Institute. The field experiment utilized a split-plot randomized complete block design in triplicate. Main plot treatments were two cultivation systems: CM and SRI. Split-plot treatments were four rice establishment methods: manual transplanting (TP), direct seeding (DS), seedling broadcasting (SC) and mechanical transplanting (MT). The size of each sub-plot was 5.5 m × 4.5 m, and there were three replications for each treatment. All plots were surrounded by consolidated ridges with plastic sheets installed to a depth of 0.3 m to prevent seepage between plots.

3. Experimental Treatment

For TP, seeds were sown on the nurse bed in mid-May, and rice seedlings with three fully expanded leaves were transplanted into the puddle field (about 25 − 30 days...
after sowing). For DS, rice seeds were manually broadcast on the plowed wet paddy field in early June. The sowing date was about 10 days later than that in TP in order to keep the dates of the heading stage similar. The amount of seeds in CM was chosen according to the local farmer’s practice: about 60 kg dry seeds per ha, but only 30 kg dry seeds per ha for SRI. The predicted seedling densities in the field were 60 − 70 and 120 − 140 plants per m$^2$ for SRI and CM, respectively. For SC, rice seeds were sown on the nurse plate (375 holes per plate) at the rate of 60 g seeds per plate in late May, and density of rice seedlings was controlled by manually broadcasting on a different number of plates (750 and 1000 plates per ha in SRI and CM, respectively). For MT, the seedling nursery was similar to that of SC, and the seedlings were transplanted by rice transplanter (Yanji 2ZT-9356B, JLKA, China). The major differences in agronomic practice between SRI and CM are shown in Table 1. The protocol of CM was provided by previous investigation (Wang et al., 2010), and the levels of agronomic treatment were decided taking into consideration comments from local experts. In the SRI system, the levels of hill space and/or seed rate were decided according to the conjunction of the principles of SRI and the requirements for obtaining high yields (Rice Expert Group of China Minstry of Agriculture, 2010), and the same seedlings stage was used as in CM.

For fertilizer management, total amounts of 180 kg ha$^{-1}$ nitrogen and 135 kg ha$^{-1}$ potassium were applied in both CM and SRI. Different from CM, 60 kg ha$^{-1}$ nitrogen was applied in the form of organic fertilizer (rapeseeds) in SRI. About 50% nitrogen fertilizer (including all the organic fertilizer) was incorporated as basal fertilizer one day before transplanting, about 600 kg ha$^{-1}$ compound fertilizer (N : P$_2$O$_5$ : K$_2$O = 15 : 15 : 15) in CM and 1200 kg ha$^{-1}$ rapeseeds (5% nitrogen content) combined with 200 kg ha$^{-1}$ compound fertilizer (N : P$_2$O$_5$ : K$_2$O = 15 : 15 : 15) in SRI. The remaining N fertilizer was broadcast, as urea, at the tillering and booting stages of the rice, 25% in each application. A total amount of 135 kg ha$^{-1}$ of potassium was applied to each plot, with 50% being basal dressing in the form of compound fertilizer, and 50% in the form of potassium chloride as topdressing at panicle initiation. Phosphorus was not supplied because of its sufficient level in the soil. Weeds, insects and diseases were controlled as required to avoid yield loss.

### 4. Sampling and Measurement

In both years, plants were sampled from a 0.48 m$^2$ area in each plot at maturity. Plants were hand-threshed for measurement of the number of filled and unfilled spikelets. The filled spikelets were separated by submerging the hand-threshed spikelets in a NaCl solution with a specific gravity (g cm$^{-3}$) of 1.06. The filled spikelets were then hulled and oven-dried at 105°C to a constant weight to determine the dry weight of the grain. A survey of yield was carried out as follows: hills were collected from the center part of each plot of 5 m$^2$. Unhulled (rough) rice grain was obtained after reaping, threshing and wind selection. The weight of rough rice grain was adjusted to a moisture content of 14%.

In 2010, plants in a 0.64 m$^2$ area in each plot were marked to count the tillers (including main stem) starting at 15 days after DS sowing at 5-day intervals until the number diminished. Tilling duration was defined as the number of days from sowing to final tilling. Tilling rate was calculated as: tilling rate = the number of final tillers per area/tilling duration. The net photosynthetic rate was determined with a portable photosynthesis system (LI-
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6400, Li-Cor, Lincoln, NE, USA) at 0900-1030. It was measured at a light intensity of 1200 μmol m⁻² s⁻¹, a leaf temperature of 30ºC, a constant CO₂ concentration of 380 ± 5 μmol mol⁻¹, and a relative humidity of 75 ± 5% in the sample chamber.

5. Data Analysis

All data were subjected to analysis of variance (ANOVA) using SAS 8.0 statistical software (2003). The data of grain yield and yield components were subjected to SAS 8.0 and analyzed by mixed model with year (Y) being used as a random effect parameter testing all possible interactions of cultivation system (C) and rice establishment method (E). One-way ANOVA was used to compare the effect of the cultivation method (SRI and CM) on grain yield and yield components in each seedling establishment method in 2010 and 2011 separately. The effect of SRI on tiller traits in each rice establishment method was tested by one-way ANOVA. Means of values were subjected to the Tukey’s HSD at the 0.05 probability level.

Results and Discussion

1. Yield and its components

In both years, grain yields were significantly higher than those using CM, with average yields that were 10.5% higher for MT and 25.1% higher for TP. However, no significant differences were found in the yields between the SC and DS plots in either year (Tables 2, 3, and 4). The greatest yield of 10.93 t ha⁻¹ was found in TP under SRI in 2010. In addition, there was a significant difference in grain yield between years, with 2010 greater than 2011 (Tables 2, 3, and 4). Yearly variation of grain yield was also found among rice establishment methods. TP produced the greatest average yield followed by SC, MT and DS in 2010, while SC produced the greatest average yield followed by DS, TP and MT in 2011.

There was no significant difference in panicle number per m² between SRI and CM in each seedling establishment at p < 0.05 by Tukey test. *p < 0.05; **p < 0.01; ns, not significant.

Table 2. ANOVA parameters using mixed model.

| Year (Y) | Rice yield | Panicle number per m² | Grain number per panicle | Grain filling percentage | Grain weight |
|----------|------------|-----------------------|--------------------------|--------------------------|-------------|
|          | **         | **                    | **                       | **                       | **          |
| Cultivation system (C) | *          | *                     | *                        | ns                       | ns          |
| Rice establishment method (E) | **        | **                    | **                       | ns                       | ns          |
| Y × C   | ns         | *                     | *                        | ns                       | ns          |
| Y × E   | **         | ns                    | ns                       | ns                       | ns          |
| Y × C × E | **      | **                    | *                        | ns                       | ns          |

*p < 0.05; **p < 0.01; ns, not significant.

Table 3. Grain yield and yield components of Japonica Xiushui 09 grown under conventional management (CM) and system of rice intensive cultivation (SRI) with different rice establishment methods in Jiaxing, Zhejiang Province, China in 2010.

| Rice establishment method | Cultivation system | Panicle number per m² | Grain number per panicle | Grain number per m² | Grain filling percentage (%) | Grain weight (mg) | Rice yield (t ha⁻¹) |
|---------------------------|--------------------|-----------------------|--------------------------|---------------------|-------------------------------|-------------------|---------------------|
| MT | SRI | 336 a | 130 a | 43458 a | 86.3 a | 28.2 a | 9.66 a |
| CM | 299 b | 125 a | 37380 b | 86.6 a | 28.5 a | 9.07 b |
| SC | 344 a | 106 a | 36412 a | 88.1 a | 28.3 a | 9.64 a |
| CM | 358 a | 107 a | 38354 a | 87.3 a | 28.4 a | 9.82 a |
| DS | 372 a | 94 a | 34931 a | 86.0 a | 27.9 a | 9.01 a |
| CM | 371 a | 97 a | 35974 a | 84.4 a | 28.2 a | 8.85 a |
| TP | 343 a | 127 a | 43386 a | 85.3 a | 28.1 a | 10.93 a |
| CM | 336 a | 95 b | 31938 b | 85.8 a | 28.6 a | 8.70 b |

ANOVA

| Rice establishment method (E) | Cultivation system | Panicle number per m² | Grain number per panicle | Grain number per m² | Grain filling percentage (%) | Grain weight (mg) | Rice yield (t ha⁻¹) |
|-------------------------------|--------------------|-----------------------|--------------------------|---------------------|-------------------------------|-------------------|---------------------|
| E × C | *          | ns                    | ns                       | ns                  | ns                        | ns                | ns                  |

Means with different small letter was significantly different between SRI and CM in each seedling establishment at p < 0.05 by Tukey test. *p < 0.05; **p < 0.01; ns, not significant.
CM was found in DS and SC. On the other hand, “transplanting shock” played an important role in later plant population development as well as the final yield production. Sim et al. (2008) state that rice plants with early emergence produced a higher yield. Pasuquin et al. (2008) also found that promoting early tiller emergence as a response to transplanting young seedlings increased grain yield. This might partly explain the yield increase in SRI treatment in the TP and MT systems. However, the yield difference between SRI and CM in DS plants that grew up without “transplanting shock” and SC plants with weak “transplant shock” is not significant. Direct seeded rice and broadcast rice have been reported to have an advantage in rapid seedling establishment and root vigor at the early stage (Zhang et al., 1998; Makarim et al., 2002; Zhang et al., 2008). Therefore, we speculate that the SRI effect might be altered by the seedling status, and that strong seedlings with vigorous root growth at the early stage might weaken the SRI effect on rice yield.

2. Tillering characteristics

In order to evaluate the effect of SRI on the tiller characteristics under different seedling establishment methods, we determined tillering traits such as the maximum tiller number per m$^2$, the panicle bearing tiller rate and the tillering rate. With the MT method, the maximum tiller number per m$^2$ in SRI plants was 8.3% lower than that in CM plants, while there was no significant difference in the productive tiller percentage between CM and SRI plants. The effects of cultivation system and rice establishment method on grain filling percentage and grain weight were not significant in either year (Tables 3 and 4).

Table 4. Grain yield and yield components of Japonica Xiushui 09 grown under conventional management (CM) and system of rice intensive cultivation (SRI) with different rice establishment methods in Jiaxing, Zhejiang Province, China in 2011.

| Rice establishment method | Cultivation system | Panicle number per m$^2$ | Grain number per panicle | Grain number per m$^2$ | Grain filling percentage (%) | Grain weight (mg) | Rice yield (t ha$^{-1}$) |
|---------------------------|--------------------|--------------------------|--------------------------|------------------------|----------------------------|------------------|-------------------------|
| MT                        | SRI                | 245 a                    | 200 a                    | 49089 a                | 80.9 a                    | 27.1 a          | 8.69 a                  |
| MT                        | CM                 | 259 a                    | 171 b                    | 45453 b                | 79.2 a                    | 26.8 a          | 7.59 b                  |
| SC                        | SRI                | 254 a                    | 177 a                    | 44813 a                | 82.8 a                    | 28.3 a          | 8.56 a                  |
| SC                        | CM                 | 261 a                    | 178 a                    | 46563 a                | 82.6 a                    | 27.3 a          | 8.46 a                  |
| DS                        | SRI                | 282 a                    | 165 a                    | 46334 a                | 80.6 a                    | 26.8 a          | 8.23 a                  |
| DS                        | CM                 | 283 a                    | 168 a                    | 47487 a                | 81.1 a                    | 27.1 a          | 8.12 a                  |
| TP                        | SRI                | 252 a                    | 197 a                    | 49773 a                | 79.9 a                    | 27.0 a          | 8.99 a                  |
| TP                        | CM                 | 249 a                    | 166 b                    | 41342 b                | 80.4 a                    | 27.5 a          | 7.22 b                  |

ANOVA

| Rice establishment method (E) | ns | ** | ** | ** | ns | ns |
| Cultivation system (C) | * | ns | * | ns | ns | ** |
| E × C | ns | ns | ns | ns | ns | ns |

Means with different small letter were significantly different between SRI and CM in each seedling establishment at $p < 0.05$ by Tukey test.

$p < 0.05$; **$p < 0.01$; ns, not significant.

The positive effect of SRI on TP rice has been well documented (Stoop et al., 2002; Lin et al., 2005; Kassam et al., 2011; Zhu et al., 2011). In the current study, similar results were found in the TP and MT systems. However, the effects of SRI on SC and DS rice were limited. The response of yield components to SRI also indicated that the increased grain yield using the SRI system with TP and MT methods might be attributed to the improved sink size. There has been a great deal of controversy about the SRI effect on yield component, panicle number per area and grain number per panicle (Tao and Ma, 2003; Chen et al., 2006; Zhang et al., 2008; Zhu et al., 2011). Chen et al. (2006) attributed the rice yield improvement in SRI to the increased panicles per area. However, Tao and Ma (2003) found that heavy panicles might be the key to the high yield performance in SRI, which was in agreement with the hypothesis that SRI rice plants had an advantage in individual tillers (Kassam et al., 2011; Zhu et al., 2011).

Our results indicate that SRI might play an important role in single panicle development in MT and TP, which provided evidence for the importance of a strong individual tiller. However, little difference between SRI and CM was found in DS and SC. On the other hand, “transplanting shock” played an important role in later plant population development as well as the final yield production. Sim et al. (2008) state that rice plants with early emergence produced a higher yield. Pasuquin et al. (2008) also found that promoting early tiller emergence as a response to transplanting young seedlings increased grain yield. This might partly explain the yield increase in SRI treatment in the TP and MT systems. However, the yield difference between SRI and CM in DS plants that grew up without “transplanting shock” and SC plants with weak “transplant shock” is not significant. Direct seeded rice and broadcast rice have been reported to have an advantage in rapid seedling establishment and root vigor at the early stage (Zhang et al., 1998; Makarim et al., 2002; Zhang et al., 2008). Therefore, we speculate that the SRI effect might be altered by the seedling status, and that strong seedlings with vigorous root growth at the early stage might weaken the SRI effect on rice yield.
SRI and CM. This suggests that the greater amount of panicles per m$^2$ in CM plants resulted from the increased number of tillers per m$^2$ rather than an increased rate of panicle bearing tillers. Furthermore, the number of tillers per m$^2$ was determined by the number of tillers per hill and the number of hills per m$^2$. In the present study, the number of tillers per hill for MT, SC and TP was greater in SRI than in CM by 26.0%, 48.1% and 26.1%, respectively, but there was no significant difference in the number of tillers per hill in DS plants between SRI and CM (Table 5). Therefore, the greater number of tillers per m$^2$ in CM was owing to the greater number of hills per m$^2$, or so-called planting spacing. In the current study, the panicle-bearing tiller rate was slightly improved in SRI (though the difference was not statistically significant), and the number of tillers per hill was greater in SRI than in CM. These results differ from those of other studies. Zhu et al. (2010) stated that percentage of productive panicle was generally improved by SRI because SRI facilitates the efficient use of resources such as nutrients, solar radiation and water in the vegetative stage (Ashraf et al., 1999; Nuruzzaman et al., 2000) as unproductive tillers compete for light and nutrients with productive tillers. Jiang et al. (1994) reported that reducing unproductive tillers in the middle growth stage promoted the development of heavy panicles and improved canopy structure and photosynthetic efficiency in the late growth stage (Jiang et al., 1994).

The number of tillers per hill could be regarded as the time integration of the tillering rate. That is to say, the number of tillers per hill could be increased by accelerating the tillering rate or prolonging tillering duration or both. In the present study, the tillering rate was also affected by the number of seedlings per hill due to different rice establishment method. Seedling number per hill was investigated at transplanting (broadcasting, manually and mechanical transplanting), and seedling number per hill for DS rice was considered as 1. We found no difference in the tillering duration between SRI and CM, regardless of rice establishment method (Tables 5 and 6). MT had the highest number of seedlings per hill among rice establishment methods, followed by SC, TP and DS. Furthermore, the tillering rate was significantly higher in SRI than in CM plants in MT and TP, while no significant differences between SRI and CM were found in SC and DS (Table 5). The higher tillering rate indicated greater biomass accumulation in plants, which was partly explained by the results of the net photosynthetic rate of the fully expanded leaves at mid-tillering stage; the net photosynthetic rate was greater in SRI plants than in CM in TP and MT (Fig. 1). These results indicated that carbon fixation in CM plants was not as great as in SRI plants at the tillering stage, which was consistent with the smaller

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**Table 5.** Tillering characteristics of Japonica Xiushui 09 grown under conventional management (CM) and system of rice intensive cultivation (SRI) with different rice establishment methods in Jiaxing, Zhejiang Province, China in 2011.

| Cultivation system | Maximum tiller per m$^2$ | Maximum tillers per hill | Panicle-bearing tiller rate (%) | Tilling duration (d) | Hills per m$^2$ | Seedlings per hill | Tillering rate (tillers hill$^{-1}$ d$^{-1}$) |
|--------------------|-------------------------|--------------------------|--------------------------------|---------------------|----------------|------------------|----------------------------------|
| MT CM SRI          | 568 a 524 b             | 18.7 b 23.6 a            | 45.6 a 46.8 a                  | 57 57               | 30 a 22 b     | 4.6 a 4.8 a       | 0.07 b 0.09 a                    |
| SC CM SRI          | 485 a 458 b             | 13.9 b 16.4 a            | 53.9 a 55.5 a                  | 57 57               | 35 a 28 b     | 2.3 a 2.7 a        | 0.11 a 0.11 a                    |
| DS CM SRI          | 686 a 615 b             | 7.1 a 7.1 a              | 41.3 a 45.8 a                  | 53 53               | 96 a 86 b     | 1.0 a 1.0 a        | 0.13 a 0.13 a                    |
| TP CM SRI          | 495 a 484 a             | 17.7 b 24.2 a            | 50.4 a 52.2 a                  | 63 63               | 28 a 20 b     | 2.2 a 2.4 a        | 0.13 b 0.16 a                    |

Means with different small letter were significantly different between SRI and CM in each seedling establishment at p < 0.05 by Tukey test.

**Table 6.** The date of major growth period of rice at Jiaxing in 2010.

| Cultivation system | Seeding | Seedling broadcasting | Transplanting | Panicle initiation | Heading | Mature |
|--------------------|---------|-----------------------|---------------|-------------------|---------|--------|
| MT SRI             | 26 May  | –                     | –             | 22 July           | 2 September | 1 November |
| CM                 | 26 May  | –                     | 11 June       | 22 July           | 2 September | 1 November |
| SC SRI             | 26 May  | 13 June               | –             | 22 July           | 1 September | 1 November |
| CM                 | 26 May  | 13 June               | 22 July       | 1 September       | 1 November |
| DS SRI             | 2 June  | –                     | –             | 25 July           | 6 September | 1 November |
| CM                 | 2 June  | –                     | 25 July       | 6 September       | 1 November |
| TP SRI             | 20 May  | –                     | 20 June       | 22 July           | 3 September | 1 November |
| CM                 | 20 May  | –                     | 20 June       | 22 July           | 3 September | 1 November |
The effect of SRI practice on grain yield varied depending on the seedling establishment method. Significant differences between SRI and CM were found in the TP and MT systems, but little difference was found in the DS and SC systems. A similar result was also found in sink size parameter (grain number per m²). We speculate that the effect of SRI might depend on the seedling status: strong seedlings and vigorous roots at an early stage might weaken the effect of SRI on rice yield. Furthermore, examination of the traits of tiller development showed that the tillering rate was enhanced by SRI, but the bearing tillering rate did not show a significant difference between SRI and CM. We also found that the net photosynthetic rate at mid-tillering was increased by MT and TP in SRI. These results indicated that the utilization of dry-matter accumulated before heading might have a more positive effect when used in the SRI system.

Conclusion
The effect of SRI practice on grain yield varied depending on the seedling establishment method. Significant differences between SRI and CM were found in the TP and MT systems, but little difference was found in the DS and SC systems. A similar result was also found in sink size parameter (grain number per m²). We speculate that the effect of SRI might depend on the seedling status: strong seedlings and vigorous roots at an early stage might weaken the effect of SRI on rice yield. Furthermore, examination of the traits of tiller development showed that the tillering rate was enhanced by SRI, but the bearing tillering rate did not show a significant difference between SRI and CM. We also found that the net photosynthetic rate at mid-tillering was increased by MT and TP in SRI. These results indicated that the utilization of dry-matter accumulated before heading might have a more positive effect when used in the SRI system.

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