

THE EFFECT OF DIFFERENT CULTIVATION METHODS ON RICE GROWTH AND DEVELOPMENT

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Abstract. Cultivation is an important part in rice production which could affect rice growth and development significantly. In order to study the effect of different cultivation methods on rice performance, two land preparation ways (plough and rotary) and two rice growing techniques (direct-seed and transplanted rice) were used in present study and four cultivation methods were set as: (PD) the land was puddle twice with plough cultivator and pre-germinated seeds were hill-seeded with direct seeding machine; (RD) the land was puddle twice with rotary cultivator and pre-germinated seeds were hill-seeded with direct seeding machine; (PT) the land was puddle twice with plough cultivator and 15-day-old seedlings were hill-transplanted with transplant machine; (RT) the land was puddle twice with rotary cultivator and 15-day-old seedlings were hill-transplanted with transplant machine. The results showed that the highest yield was recorded in both PT and RT and the lowest yield was recorded in RD. There was no difference among different cultivation methods on net photosynthetic rate but different cultivation affected the transpiration rate and water use efficiency at different stage differently. Furthermore, the highest head rice rate and grain protein and the lowest chalky rice rate was all recorded in PD treatment. Overall, higher yield was recorded in transplanted rice cultivation than direct-seed cultivation and the greatest grain quality was observed under direct seeding rice cultivation and plough tillage conditions.

Keywords: *rice, tillage, cultivation methods, photosynthesis, yield, grain quality*

Introduction

Rice (*Oryza sativa*. L) is one of the main crops in Asia and the rice production system has become the backbone of Chinese food security system for many years (Xing et al., 2019; Wang et al., 2019). In 2017, China's rice planting area was 6.795 billion hectares (Han et al., 2019). However, the availability of arable land has been decreased in recent years and the increasing population has intensified the conflict for land planning between fiber and cereal crops (Fang et al., 2019). Therefore, experts are inevitably striving to find more ways to improve crop productivity.

Normally, land preparation is an important part in rice production because puddling is required to decrease the loss of water and nutrients through excessive percolation and it also is able to reduce weeds and enhance nutrient availability (Hazra et al., 2014; Alam et al., 2018). Previous studies already showed that soil puddling in paddy field benefits rice yield (Datta and Kerim, 1974; Kukal and Aggarwal, 2003). However, the

effect of puddling is still not clear regarding rice growth and development despite the benefits.

Normally, mechanical puddling is performed twice in Chinese paddy field, ploughing and rotary tillage. There also are two rice system which including direct seeding rice and transplanted-flooded rice in China. Those managements all had their own impacts on rice growth and development. For example, the study of Pan et al. (2017) indicated that direct seeding rice could be a more substitutive rice growing technique to transplanted-flooded rice with less production costs, labor and extra efforts for nursery raising, seedling uprooting, and transplanting. SUN (2017) demonstrated that ploughing tillage could help to improve the soil temperature, improve the environment of soil and promote the root activity and improve the production of tobacco leaf. But there was no much report about the effect of different puddling or growing technique on rice growth, development, yield and quality.

Thus, in order to study the effect of different cultivation methods on rice growth and development, present study was conducted in Guangdong Province, China with two mechanical puddling and two rice growing techniques.

Material and Methods

Plant materials and growing conditions

A fragrant rice cultivar, *Meixiangzhan-2*, which having a growth period of 111-114 days and widely planted in South China, was used in the experiment and planted at late season of 2017 in Zengcheng (23°13' N, 113°81' E, altitude 11 m), Guangdong. The experimental site enjoyed a subtropical monsoon climate with mean annual air temperatures of 21.3°C and mean annual precipitation of 2660.9 mm. Before sowing, the seeds were soaked in water for 24 h, germinated in manual climatic boxes for another 12 h and shade-dried. Some of the germinated seeds were sown in polyvinyl chloride trays for nursery raising. The experimental soil in Zengcheng was sandy loam containing organic matter 10.04 g kg⁻¹, total N 0.50 g kg⁻¹, total P 0.26 g kg⁻¹, and total K 15.10 g kg⁻¹.

Treatment description and plant sampling

Two land preparations, ploughing(P) and rotary(R) were adopted with two growing techniques. The treatment description is as below:

- PD: Before planting, the land was puddle twice with plough cultivator. Pre-germinated seeds were hill-seeded with direct seeding machine at a space of 25×15 cm while each hill was planted with 4–6 seeds.
- RD: Before planting, the land was puddle twice with rotary cultivator. Pre-germinated seeds were hill-seeded with direct seeding machine at a space of 25×15 cm while each hill was planted with 4–6 seeds.
- PT: Before planting, the land was puddle twice with plough cultivator. 15-day-old seedlings were hill-transplanted with transplant machine at a space of 25 × 15 cm while each hill was transplanted with 4–6 seedlings.
- RT: Before planting, the land was puddle twice with rotary cultivator. 15-day-old seedlings were hill-transplanted with transplant machine at a space of 25 × 15 cm while each hill was transplanted with 4–6 seedlings.

The treatments were arranged in randomized complete block design (RCBD) in triplicate in each year with net plot size of 120 m². At tillering stage, heading stage and maturity, ten random rice plants were collected from each plot, for estimation of dry matter accumulation.

Photosynthesis

Portable photosynthesis system (CIRAS 2; PP systems, Amesbury, MA, USA) was used to determine net photosynthetic rate and gas exchange attribute i.e., stomatal conductance, intercellular carbon dioxide concentration, transpiration rate, water use efficiency and vapor pressure deficit at 09:00–10:30 a.m.

Grain quality

After sun drying, grains were stored at room temperature for at least a month to determine grain quality components. About 1.0 kg rice grains from each treatment was taken from storage and brown rice rate was estimated using a rice huller (Jiangsu, China) while milled rice and head rice recovery rates were calculated by using a Jingmi testing rice grader (Zhejiang, China). Grains with chalkiness and chalkiness degree were estimated by using an SDE-A light box (Guangzhou, China) while an Infratec-1241 grain analyzer (FOSS-TECATOR) was used to determine the grain amylose and protein contents.

Yield and yield related traits

At maturity stage, the rice grains were harvested from seven-unit sampling area (1 m²) in each plot and then threshed by machine. The harvested grains were sun-dried and weighted in order to determinate the grain yield. Twenty hills of rice from different locations in each plot were sampled for estimate the average effective panicles number per hill. Then, eight hills representative plants were taken for estimation of the yield related traits.

Statistical analysis

Data were analyzed on Statistix 8.1 (Analytical Software, Tallahassee, FL, USA) while differences among means were separated by using least significant difference (LSD) test at 5% probability level. Graphical representation was conducted via Sigma Plot 14.0 (Systat Software Inc., California, USA).

Result

Yield and yield related trails

As shown in *Table 1*, different cultivation methods affected rice yield and its related trails significantly. The highest yield was recorded in both PT and RT while there was no significant difference between RT and PT. The lowest yield was recorded in RD. The difference in rice yield among different cultivation could be explained by the yield related trails. For panicle number, the panicle number per hill in RT and PT was significantly higher than PD and RD; For grains number per panicle, the highest grains number was recorded in PD and grains number in RD and PT was remarkably number

than PD; For seed-setting rate, the highest rate was recorded in PT; For grain weight, the 1000-grain weight in PD was significantly higher than RD, PT and RT.

Table 1. The effect of different cultivation methods on rice yield and its related traits

Treatment	Panicle number per hill	Grains number per panicle	Seed-setting rate (%)	1000-grain weight (g)	Yield (t ha ⁻²)
PD	328.74±2.37b	117.87±4.22a	74.29±1.77b	22.08±0.31a	6.63±0.14b
RD	329.38±1.01b	107.33±4.15b	74.05±4.15b	20.74±0.27b	5.61±0.38c
PT	385.06±4.65a	106.80±6.99b	82.41±6.99a	20.84±0.05b	7.11±0.29ab
RT	395.73±18.51a	111.87±3.25ab	77.77±3.23ab	21.16±0.28b	7.43±0.29a

Values sharing a common letter within a column don't differ significantly at ($P \leq 0.05$) according to least significant difference (LSD) test for both the years. The same as below

Grain quality

As shown in *Table 2*, different cultivation methods affected grain quality significantly. There was no remarkable difference among different cultivation methods in both brown rice rate and milled rice rate. However, the head rice rate in PD and RD was significantly higher than PT and RT. The moisture in PD and RD was significantly higher than PT and RT. The trend of crude protein content was recorded as: PD > RD > RT > PT. The lowest amylose content was recorded in RT while there was no significant difference among PD, RD and PT. Moreover, there was no remarkable difference among Akali and chalkiness whilst the trend of chalky rice rate was recorded as: RT > PT > RD = PD.

Table 2. The effect of different cultivation methods on grain quality

Treatment	Brown rice rate (%)	Milled rice rate (%)	Head rice rate (%)	Moisture (%)	Crude protein content (%)	Amylose content (%)	Akali	Chalky rice rate (%)	Chalkiness (%)
PD	77.12±0.87a	69.86±0.29a	33.39±0.87a	12.90±0.01a	8.87±0.07a	17.63±0.09a	6.37±0.03a	8.33±1.20c	14.17±1.17a
RD	77.50±0.28a	70.33±0.41a	36.45±0.45a	12.67±0.03b	8.50±0.01b	17.80±0.06a	6.47±0.09a	7.33±1.45c	11.33±0.88a
PT	78.20±0.22a	70.38±0.74a	24.21±1.21b	12.97±0.03a	7.87±0.07d	17.73±0.09a	6.30±0.01a	18.00±0.58b	13.00±1.32a
RT	77.50±0.41a	70.19±0.21a	22.60±0.51b	12.77±0.07b	8.10±0.01c	17.17±0.09b	6.37±0.03a	24.67±3.18a	10.67±1.09a

Plant height

As shown in *Figure 1*, the plant height of rice under different cultivation methods increased with the growth until 70 days after the sowing and then it gradually stabilized and remained unchanged. The trend of plant height was recorded as: PT = RT > PD > RD since 42 days after the sowing.

Photosynthesis and gas exchange

As shown in *Figure 2*, there was no remarkable difference in net photosynthetic rate among different cultivation methods at tillering stage, heading stage and maturity. Similar conditions were also observed in both intercellular carbon dioxide concentration and stomatal conductance. However, at tillering stage, the transpiration rate in RT was

significantly higher than PD while the both the lowest vapor pressure deficit and water use efficiency were recorded in RT. Moreover, at maturity, both the highest transpiration rate and the lowest vapor pressure deficit were recorded in RD treatment.

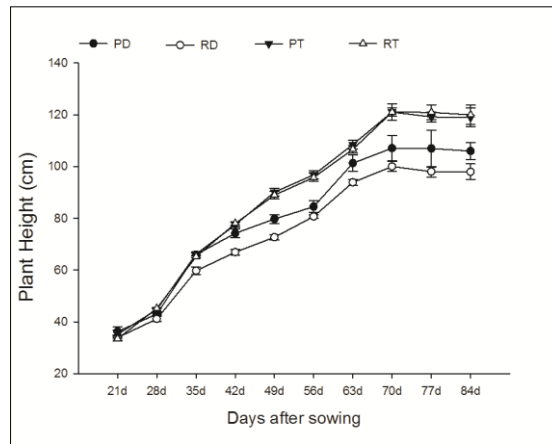


Figure 1. The effect of different cultivation methods on rice plant height

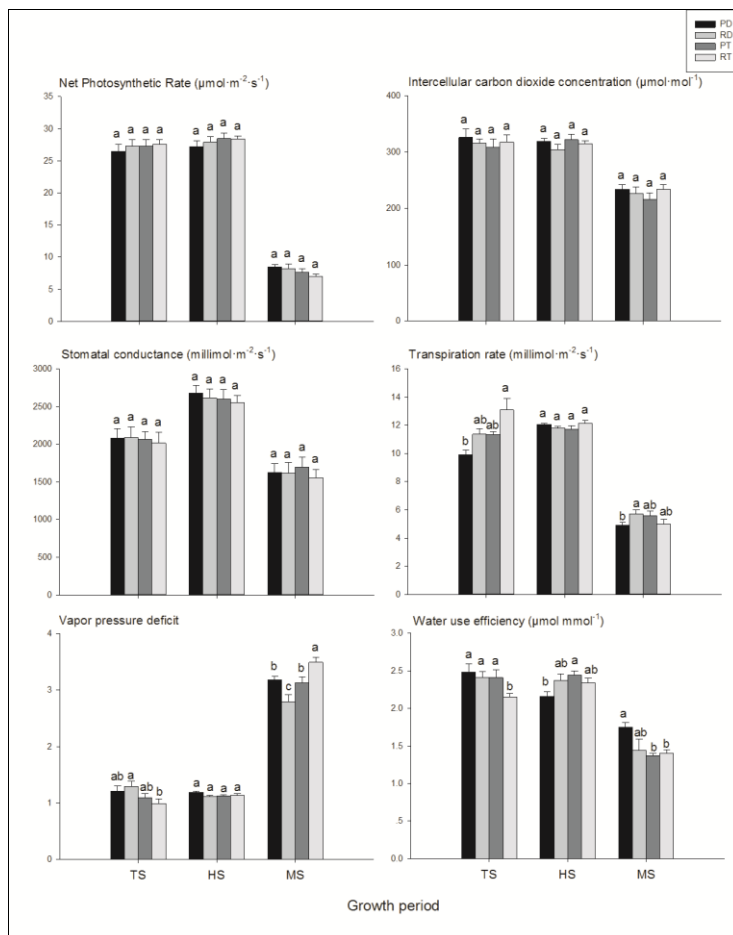


Figure 2. The effect of different cultivation methods on rice photosynthesis and gas exchange. Means sharing a common letter don't differ significantly at ($P \leq 0.05$) according to least significant difference (LSD) test

Dry matter accumulation

Different cultivation methods affected dry matter weight differently (Figure 3). At heading stage, the dry matter weight in PT and RT were significantly higher than PD and RD. At maturity, the trend of dry matter weight was recorded as: PT = RT > PD > RD.

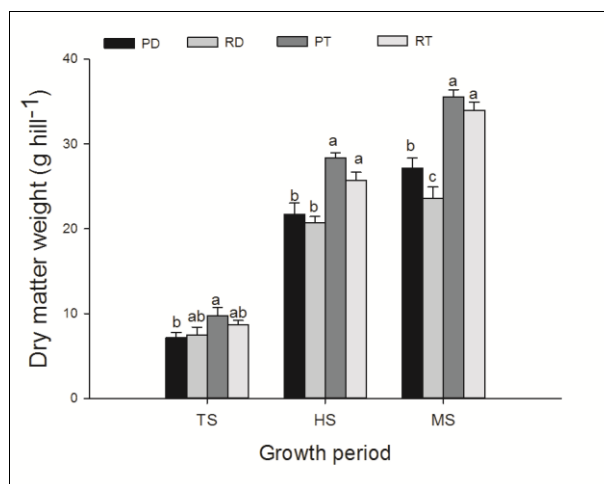


Figure 3. The effect of different cultivation methods on dry matter accumulation of rice

Discussion

Cultivation is a very important part in rice production. Some researchers already investigated the effects of some cultivation methods on rice performance and paddy fields. For example, Zhang et al. (2008) indicated that non-flooded mulching cultivation not only could increase root oxidation activity and photosynthesis, but also enhanced the activities of key enzymes in sucrose-to-starch conversion at filling stage. The study of Bouwman (1991) revealed that different cultivation methods could affect the methane emissions in paddy field by influencing the oxido-reduction capacity of the soil. Moreover, the study of Qin et al. (2006) showed that non-flooded rice cultivation was able to mediate rice growth, decrease the evapotranspiration and increase water use efficiency. In our study, there were also some differences among different cultivation methods in rice yield and yield related traits. The highest yield was recorded in both PT and RT while the rice yield in PT was significantly higher than PD just like RT was higher than RD. This discovery indicated that the transplanted-flooded rice cultivation had higher yield compared to direct seeding rice. The increment of yield in transplanted-flooded rice cultivation could be explained by the higher panicle number and seed-setting rate. The further reason might be the transplanted rice cultivation had the nursery raising part for seedling growth which direct seeding rice cultivation didn't. This result was consistent with previous studies which showed that nursery practice was beneficial to early establishment for rice and could improve the rice yield potential (Sarangi et al., 2015; Zhang et al., 2017). Moreover, there was no significant difference in yield between PT and RT whilst the grain number, grain weight and yield in PD were significantly higher than RD. This discovery might indicate that the land preparation of plough tillage would be more suitable for direct seeding rice system.

Present study also showed that different cultivation methods also affected the grain quality significantly. Compared to PT and RT, PD and RD had higher head rice rates and crude protein contents. The lower chalky rice rates were also recorded in PD and RD than PT and RT. Grain quality is the main factor which depends the rice price in market (Ahmad et al., 2017; Norton et al., 2017). In our study, the result showed that the grain quality in direct seeding rice was higher than transplanted-flooded rice. Moreover, the highest grain protein content was recorded in PD and it might indicate that the environment of direct seeding rice cultivation and plough tillage would be the most suitable for protein content biosynthesis in grains. The reasons could be PD condition enhanced the activity of key enzymes involved in protein biosynthesis or improved the nitrogen absorption, utilization and transportation in rice (TsukaguchiNitta and Matsuno, 2016; Luo et al., 2018; Wang et al., 2018).

In our study, there was no significant difference among different cultivation methods in net photosynthetic rate. But interestingly, we found that different cultivation methods could alter the vapor pressure deficit in paddy field by affecting the transpiration rate of rice. The values of water use efficiency were also different under different cultivation methods. Those differences might be caused by plant-soil systems which were different because of the different land preparations and rice growing techniques (Pan et al., 2017; Wang et al., 2017).

Conclusion

Different cultivation methods affected rice yield and quality differently. Present study showed that the higher yield was recorded in transplanted rice cultivation than direct-seed cultivation and the greatest grain quality was observed under direct seeding rice cultivation and plough tillage conditions. In order to reveal the mechanism of how cultivation affected rice performance, more investigation should be conducted at the field trials or at molecular level before the real application.

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APPENDIX

Photos of the experiment

