The Effects of A Novel Rice Establishment Method Combined with Wheat Straw Mulch

Yangyang Xu[1,a], Xiangjie Lin [1,2,b], Guangna Zhang [1,c,*], Junxi Chen[1,d], and Xuebing Yang[1,e]

[1] Shandong Provincial Key Laboratory of Water and Soil Conservation and Environmental Protection, College of Agriculture and Forestry Science, Linyi University, Linyi, China;

[2] Philippine Christian University Center for International Education, Manila, Philippines.

[a] 2848201821@qq.com, [b] linxiangjie@lyu.edu.cn, [c] gnzhang@lyu.edu.cn, [d] 2913356593@qq.com, [e] 3122472023@qq.com

Abstract. This experiment compared the effects of a novel rice establishment method with traditional machine-transplanting carpet seedling (MTCS). The new method (RSSR) is a modified direct seeding method, which manually or drone aerial sowed the seeds into the field before wheat harvesting, then cover the seeds with wheat straw after harvesting. Samples were measured to compare the difference of plant height, stem width, and panicle length, straw biomass, effective panicle, spikelets per panicle, panicle weight, 100 grain weight, and grain yield. The results showed that compared with MTCS, RSSR can increase rice growth indicators and yield indicators, but had no significant difference. Only the panicle weight of RSSR was significantly higher than that of MTCS. Furthermore, the management of RSSR was more convenient, which can save water, herbicide and human labor. Thus, this new rice establishment method can be introduced to the wheat-rice and rapeseed-rice rotation area.

Keywords: direct seeding; straw mulch; rice establishment method.

1. Introduction

Rice is the major cereal crop in the world, and feed more than half of the world's population [1, 2]. Due to a lack of water sources and labor shortages, machine-transplanting carpet seedling (MTCS) and direct-seeded rice (DSR) modes are more and more popular than manual puddled transplanted rice (MTR) [3, 4]. However, machine transplanting still cannot avoid the seedling raising process. DSR is a prevalent rice establishment method used before the 1950s [4], which is easier to conduct by sowing dry or pre-germinated seeds into soils [3]. But puddled transplanting became predominant method of rice establishment after the 1950s. However, DSR method has recently been gaining importance due to scarce water resource and labor shortage, and now it is widely practiced in many Asian countries [4].

Straw burning was banned in 2008, so the demand for straw incorporated into the field is increasing. This study introduced a novel rice sowing method that can solve the straw from previous crops and get similar goal of DSR. We name this as rice sowing with straw returning method (RSSR). Straw returning could increase soil organic matter (SOM) contents and available soil nutrients [5], improve soil physical properties [6], and enhance soil enzyme activities [7, 8]. Due to the straw application, RSSR can also reduce the use of water and control weeds.

2. Procedure of the RSSR

2.1 Seed treatment

Firstly, dry the seeds for 1-2 days and make sure to avoid exposure to sunlight; Secondly, mix rice seeds 1-3 days before wheat harvest. Mix 10 kg of seeds with 100 g of silicon fertilizer (1500-2000 mesh), 20 mL of 62.5% fludioxonil suspension, and 150-200 mL of water, shaken evenly. Spread the mixed rice seeds with a thickness of 2-5 cm, and let them air for 1-2 hours.

Two to four hours before the wheat harvest, the treated seeds should be manually or drone aerial sown into the field evenly with 135-150 kg/ha seeds.

2.2 Management

After wheat harvesting, evenly cover the soil surface with wheat straw, make sure the rice seeds are not exposed or covered too much by straw. There is no need to plow (rake) the field. Irrigate once after straw mulch and let it dry naturally (Seeing water draining on the other side of the ground, turn off the water, this is called running horse water). Pour running horse water again after the land dry for 2-3 days. Just irrigate like this and keep the soil moist before the trefoil stage. After trefoil stage, water the field and keep 1-3 cm of the water layer and let it dry naturally. From the jointing and booting stage to the grouting period, keep the field with 3-5 cm water layer and let it dry naturally. If the field water capacity is lower than 80% of the maximum field water capacity, irrigate the field again; Before rice heading, sun the field once and ensure that the soil does not dry and crack.

During the trefoil stage, apply 525-600 kg/ha 20-10-15 compound fertilizer and 20 kg of straw decomposition agent (more than 1 billion/g microbial inoculants). During the booting stage, dressing 150-225 kg of compound fertilizer (19-4-21) to the field. Use conventional methods for controlling diseases and pests.

2.3 Site description and experimental design

The field experiment was conducted on paddy soil at Junan County (118° 46′ E and 35° 20′ N), Shandong Province, Northern China. The region has a typical continental monsoon climate with 60%–80% of the annual precipitation occurs in summer. The study conducted the experiment between MTCS and RSSR: 1) MTCS, machine-transplanting carpet seedling with conventional irrigation, 2) RSSR rice sowing with straw returning method and received the cultivation management methods as 2.2 managements. The MTCS treatment need to prepare seedlings and remove the straw after wheat harvest. Fertilization is the same for both treatments but MTCS treatment need more irrigating water. Three replicates were included and each plot was 20 m × 5 m in size with a 3 m buffer zone between plots.

2.4 Sampling and measurements

Randomly select 3 points per plot and calculate the number of holes per square meter; Select 20 holes in sequence, calculate the number of ears per hole to calculate the effective number of ears, and take 5 holes to investigate the number of grains per ear and seed setting rate. Weigh the stems and the rice ears separately. Measure the plant height, stem width, and panicle length of 5 rice plants, 1000 grain weight. The remaining stems and rice ears are first air dried and then dried at 65 ℃ for 72h to a constant weight. The rice we sampled, natural seed setting rate reached 99% for both treatments.

2.5 Statistical analyses

The differences among treatments were tested by independent-sample t test (p-value < 0.05) using SPSS 16.0 (SPSS Inc., Chicago, Ill., United States).

3. Results

3.1 Management comparasion

Seen from the table 1, MTCS method need 4 times of weed control during the rice growing season. RSSR only need one time of weed control, because the straw mulch on the surface of the ground can also play the same role with herbicide. Thus, through the weed control RSSR can reduce 75 labor per hectare per season than MTCS.

Table 1. Weed control difference between MTCS and RSSR

Treatment	Period	Herbicide application
MTCS	Before transplanting seedlings	Soil sealing treatment with Oxadiazon, butachlor, propachlor, salbutamol, pyrazosulfuron
	After transplanting seedlings	Soil sealing treatment with Oxadiazon, butachlor, propachlor, salbutamol, pyrazosulfuron.
	After turning green	Soil sealing treatment with Butachlor, Propachlor, Benzothiacloprid, Fenpropafenuron, Pyrazosulfuron, Benazosulfuron.
	20 days after transplanting seedlings	Stem and leaf spraying with Pentafluoromethane, Cyanoflufen, Dichloroquinolinic Acid, Oxazolamide, Chlorofluoropyridine Ester, Dimethyltetrachloro, and Methoxasone.
RSSR	2-3 days after pouring the second running horse water	Stem and leaf spraying with 130 mL of 33% dimethoprim emulsifiable concentrate, 150 mL of 90% butachlor emulsifiable concentrate, and 5 g of 60% bensulfuron methyl water dispersible granules.

From table 2, RSSR has more rice field sunning process, the most important requirement is to keep the soil moist, furthermore, the straw in the field can reduce water evaporation and keep soil moist for a longer time. Thus, RSSR need less water than MTCS, which can reduce water usage.

Table 2. Water management difference between MTCS and RSSR

Treatment	Period	Water level
MTCS	Transplanting seedlings	1 – 2 cm
	After transplanting seedlings	2 – 3 cm
	After turning green to a week before harvest	3 – 5 cm, sunning the fields twice
RSSR	Before the trefoil stage	running horse water twice
	trefoil stage	1 – 3 cm
	After trefoil stage to a week before harvest	3 – 5 cm, Water again when the soil moisture content falls below 80% of the maximum field capacity after natural drainage

From the results of table 3, although the plant height, stem width and panicle length data of RSSR are higher than those of MTCS, but no difference were significant. Similarly, dry straw biomass between these two method also showed no clear difference.

Table 3. Differences in rice growth indicators under MTCS and RSSR

Treatment	Height (cm)	Stem width (cm)	Panicle length (cm)	Straw biomass (kg per 1/15hm^2)
MTCS	88.1±0.80a	0.80±0.02a	15.7±0.34a	558±59.8a
RSSR	89.2±1.75a	0.81±0.03a	16.1±0.65a	635±45.4a

Table 4. Differences in rice yield indicators under MTCS and RSSR per 1/15hm^2

Treatment	Effective panicle	Spikelets per panicle	Seed setting rate	panicle weight	100 grain weight	grain yield
	10^4		%	kg	g	kg
MTCS	18.2±1.07a	119±8.62a	90±0.97a	485±23.2b	2.86±0.06a	435±54.6a
RSSR	20.9±1.16a	112±10.3a	90±1.20a	642±30.3a	2.79±0.06a	545±60.1a

The effective panicle, spikelets per panicle, seed setting rate, 100 grain weight, and grain yield all showed no significant difference. Only the panicle weight showed significant difference that panicle weight under RSSR is higher than that of MTCS.

4. Discussion

RSSR can reduce the production costs, which include herbicide, water, human labor and machines. Compared to MTCS, the RSSR use more seeds to make sure adequate seedlings, the fertilizers and pesticides used in this study under two treatments are same. But, the herbicide, water, human labor and machines were used less under RSSR treatment than those used under MTCS treatment. These are supported by previous studies that direct-seeded rice labor saving and less production cost (US$9–125 per hectare) [4, 9]. Under machine transplanting field, rice seedlings must be transplanted into puddled soil, which cost lots of energy [10]. Zero tillage practices combined with straw mulch can increase soil organic matter, reduce water usage, and improve biological activity [11, 12].

RSSR use less herbicide than MTCS technology. Frequent use of herbicide might cause the more resistant weed populations appearance [13]. Straw mulch was reported to suppress the weed as effective as herbicide [14], which was used by RSSR method. Thus RSSR method could control weeds physically, avoid the disadvantage of traditional direct-seeded rice reported by previous study [3].

Through the results of the rice height, stem width, panicle length and straw biomass, no significant differences were found between MTCS and RSSR. Xing et al. (2017) studied the effects of pot seedling mechanical transplanting and MTCS, results showed that pot seedling mechanical transplanting could increase plant height, basal stem while MTCS could not [15]. Thus, pot seedling showed more advantage in seedling quality than carpet seedling. Similarly straw biomass had no significance between the two treatments though RSSR showed more straw biomass. Though straw treatment is a challenge in many areas, rice straws are important resources in Linyi City due to lots of straw weaving home workshop here [16]. Thus more rice straw biomass is very important in this area.

The results showed no significant grain yield between two methods, though RSSR showed more yield. There are contrary results of different rice establishment method, some found no relationship between rice yield and cultivation methods (direct seeding and transplanting) [17], some found direct seeding gain more yield than transplanting method [18]. Rana et al. (2014) also found direct seeding treatment can gain higher number of grains per panicle and 1000 grain weight [18]. Our study showed no difference on most of grain yield indicators but we sure got higher panicle weight under RSSR than that of MTCS treatment. The differences might caused by different rice variety and soil conditions.

5. Summary

Two rice establishment method machine-transplanting carpet seedling (MTCS) and rice sowing with straw returning method (RSSR) were tested in this study. RSSR is a modified method based on direct-seeded method. The study found no significant higher yield under RSSR than that of MTCS though the yield is 25% higher than MTCS treatment. But RSSR can reduce water, heribicide and human labor than MTCS. Promoting RSSR method in wheat-rice and rapeseed-rice area can be a viable alternative to machine-transplanting seedling to rice farmers, which can solve the straw probolem, increase orgainic input soil, reduce water evaporation and conduct weed control in the same time.

References

[1] Ainsworth E. Rice production in a changing climate: a meta-analysis of responses to elevated carbon

dioxide and elevated ozone concentration. Global Change Biology, 2008, 14(7):1642-1650.
[2] Shimono H. Earlier rice phenology as a result of climate change can increase the risk of cold damage during reproductive growth in northern Japan. Agriculture Ecosystems & Environment, 2011, 144(1):201-207.
[3] Bautista A., Mataia A., Austria C., et al. Adoption and Performance of Direct-seeded Rice (DSR) Technology in the Philippines. Philippine Journal of Science, 2023, 152 (1): 459-484.
[4] Chaudhary A., Venkatramanan V., Mishra A., et al. Agronomic and Environmental Determinants of Direct Seeded Rice in South Asia. Circular Economy and Sustainability, 2023, 3:253-290.
[5] Tan C.J., Cao X., Yuan S., et al. Effects of long-term conservation tillage on soil nutrients in sloping fields in regions characterized by water and wind erosion. Scientific Reports, 2015, 5, 17592.
[6] Yao S., Teng X., Zhang B. (Effects of rice straw incorporation and tillage depth on soil puddlability and mechanical properties during rice growth period. Soil & Tillage Research, 2015, 146, 125-132.
[7] Wang X.J., Jia Z.K., Liang L.Y., et al. Changes in soil characteristics and maize yield under straw returning system in dryland farming. Field Crops Research, 2018, 218, 11-17.
[8] Lin X., Zhang G., Wang Z. et al., Phosphatase activities and available nutrients in soil aggregates affected by straw returning to a calcareous soil under the maize–wheat cropping system. Frontiers of Environmental Science & Engineering, 2023, 11:1208323.
[9] Kumar V., Ladha J.K. Direct seeding of rice: recent developments and future research needs. Advances in Agronomy, 2011, 111:297-413.
[10] Matloob A., Khaliq A., Chauhan B.S. Weeds of direct-seeded rice in Asia: problems and opportunities. Advances in Agronomy, 2015, 130:291-336.
[11] Zhang J. Study on the effect of straw mulching on farmland soil water. Journal of Environmental and Public Health. 2022, 2022: 3101880.
[12] Krishnan, P., Ramakrishnan, B., Reddy, K.R., et al. High temperature effects on rice growth, yield, and grain quality. Advances in Agronomy, 2011, 111, 87-206.
[13] de Barreda D., Pardo G., Osca J., et al. An overview of rice cultivation in Spain and the management of herbicide-resistant weeds. Agronomy, 2021, 11, 1095.
[14] Zhu J., Liang W., Yang S., et al. Safety of oilseed rape straw mulch of different lengths to rice and its suppressive effects on weeds. Agronomy, 2020, 10, 201.
[15] Xing Z.P., Wu P., Zhu M., et al. Effect of mechanized planting methods on plant type and lodging resistance of different rice varieties. Transactions of the Chinese Society of Agricultural Engineering, 2017, 33(1): 52-62.
[16] Zhang G., Lin X., Zheng Y. et al. Analysis on the Current Situation and Countermeasures of Straw Utilization in Linyi City. Environmental Protection and Circular Economy, 2017, (6): 20-22.
[17] Yadav S，Evangelista G, Faronilo J, et al. Establishment method effects on crop performance and water productivity of irrigated rice in the tropics[J]. Field Crop Res, 2014, 166: 112-127.
[18] Rana M,Mamun A A, Zahan A, et al. Effect of planting methods on the yield and yield attributes of short duration Aman rice. American Journal of Plant Sciences. 2014, 5(3): 251-255.