BRIEF REPORT

REVISED Timing of harvesting reverses the effect of cutting twice with ratoon rice [version 2; peer review: 1 approved, 1 not approved]

Previously titled: Timing of harvesting reverses the effect of twice cutting with ratoon rice

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Abstract

A new ratoon rice cropping method known as the SALIBU system, which uses the lower nodes of the stubble, is gradually spreading throughout the tropical regions. In a previous study, the technology package, 'cutting twice' has a large effect on the number of ratoons (tillers), and interestingly, the effect has a large positive effect under poor management conditions, but a medium negative effect under standard management conditions. The conditions included fertilizing, water management, and growth stage at harvesting; however, which of these conditions has the greatest effect on the effect of 'cutting twice' remains unclear. We performed a pot experiment focusing on fertilizer and timing of harvesting, to clarify which of the level of fertilizer or the delay of harvesting time affects the number of ratoons. The results showed that with a short delay in harvesting there were almost no ratoons, a long delay in harvesting resulted in many ratoons. This indicates the negative effect of cutting twice occur due to earlier harvesting. Generally, the growth of ratoons depends on the carbohydrate reserves of the stubble. Hence, in the case of a single harvest, the ratoons decrease with the delay in harvesting. On the other hand, cutting the stem increases dead buds in the nodes closer to the ground. Namely, the second cut will remove the high node buds and reduce the incidence of ratoons. As for adding fertilizer results in more ratoons steadily. Harvesting earlier (at the physiological maturation stage; 25% green husk) than normal is emphasized in the SALIBU technology package. However, our results show the 'cutting twice' reduces the number of ratoons when harvesting early.

Keywords

Mekong Delta, ratoon rice cropping, SALIBU, triple cropping rice, Harvesting timing.

Open Peer Review

Approval Status

	1	2
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version 1 04 Dec 2020	 view	

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2. **Chenfei Dong**, Jiangsu Vocational College of Agriculture and Forest, Zhenjiang, China

Any reports and responses or comments on the article can be found at the end of the article.

This article is included in the **Agriculture, Food and Nutrition** gateway.

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Author roles: **Oda M:** Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Writing – Original Draft Preparation; **Van Thao H:** Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Writing – Original Draft Preparation; **Nguyen Huu C:** Conceptualization, Formal Analysis, Methodology, Writing – Review & Editing

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REVISED Amendments from Version 1

- 1) The purpose and conclusion of the study were more clearly stated
- 2) The explanation leading to the conclusion was more clearly stated
- 3) Relevant, existing studies were cited
- 4) The perspective of rice variety was added in the conclusion
- 5) The title of Figure 1 was changed

Any further responses from the reviewers can be found at the end of the article

Introduction

The cultivation of rice using ratooning has several advantages over conventional cultivation, including lower costs, lower labor intensity, and lower greenhouse gas emissions (Sacks, 2013; Safruddin, 2017). A new practice for ratooning rice crops using the lower nodes of rice stubble, known as the SALIBU system, is gradually spreading throughout the tropical regions (Fitri et al., 2019; Yamaoka et al., 2017). The practice involves harvesting most of the above-ground portion of the plant but leaves the growing shoots intact. The SALIBU method implements 10 additional management practices to conventional management of rice cultivation in Indonesia. (1) early harvesting, (2) pre-fertilization (at seven days before harvesting), (3) cutting twice (rice was harvested 25 cm above the ground, then cut again at 3–5 cm above ground), (4) late irrigation (irrigation was started on day 14 after harvesting), (5) hand weeding, (6) dividing (dividing hills into two or three tillers and replanting to fill the space), (7) pushing (pushing the rice plants into the soil if the root came up on the soil surface), (8) removing excess plants (to keep original plant density), (9) draining from day 29 to 43 after harvesting, and (10) draining for the above (5) to (9) treatments. However, this new methodology has yet to be well studied. Oda et al. (2019) evaluated the Cohens' *d* effect size (Cohen, 1992) of each practice in the technology package and clarified that the process of cutting twice has a large effect on the number of ratoons. Interestingly, the effect can be reversed depending on the management conditions. The cutting twice has a large positive effect when poor management conditions are used but a medium negative effect when standard management conditions of direct seeding triple-cropping rice in the Mekong Delta are employed. The poor management conditions consisted of not using fertilizer, continuous-flooding water management, and harvesting 10 days late. Obviously, there is an interaction between the management conditions and the practice of cutting twice; however, which of the three conditions was responsible for the interaction has not been clarified. The best harvesting time for good ratooning is when the culms were still greenish because of the growth of ratoon tillers depends on the carbohydrate reserves of the stubble (Fukai, 1988). Hence, the ratoons decrease with the delay in harvesting. The amount of total available carbohydrates in stubble increases with cutting (Fukai, 1988). This means that cutting twice will have the advantage of leaving carbohydrates in longer stems for a period of time. However, after cutting the

main crop, there are more dead buds in the nodes closer to the ground, and lower cutting results in the loss of many hills and reduces tillering (Fukai, 1988). This will be the reason why ratoons decrease with the cutting twice. Due to the balance of the above mechanisms, the effect of cutting twice increase or decrease will be reversed. In contrast, the application of N fertilizer to the main crop results in a steady increase in ratoons (Fukai, 1988).

We assumed that the cause of the reverse effect was the timing of harvesting. Therefore, we examined the relationship between delayed harvesting and the number of ratoons under conditions with and without fertilizer. Consideration of water conditions was omitted to avoid complexity.

Methods

A relationship between delayed harvesting and the number of ratoons was analyzed. We harvested rice plants grown under conditions of both with and without fertilizer. Rice was harvested on the day when 75% of the seeds on the main stems turned yellow (days 0), and after on days 4, 8, and 14. The water management approach we adopted was alternative wet and dry (AWD). Note, SALIBU practices are not used in this experiment except cutting twice. Early harvesting (one of the SALIBU practices) is a conventional practice in the Mekong delta triple cropping.

Treatments

The experiment was conducted in a screen-house at Can Tho University, Can Tho city, Vietnam from October 2019 to February 2020. The climate is classified as tropical savanna (Aw) and the range of the day average temperature of October to February is 26.0 to 27.3°C (Climate-data.org). Containers of size 38 × 58 × 30 cm (l × w × h) were filled with silty clay soil (52% clay, 48% silt, <1% sand, originally collected from a farmer's paddy filed in the Mekong Delta; 10°22' N, 105°58' E) to a depth of 20 cm. To remove excess nutrients, the soil was watered, stirred, and the supernatant water was removed. This procedure was conducted three times. Rice (*Oryza sativa*) seeds of variety ST24 (105 – 110 days provided by Can Tho University) were planted, two seeds per hill, with nine hills per pot (in a 3 × 3 arrangement). ST24 is famous in the Mekong Delta by the high quality and expected to provide high benefit for farmers. The application of fertilizer followed the standards used for direct seeding of triple-cropping rice in the Mekong Delta (An Giang's DARD, 2014; on day seven (27.6 kg ha⁻¹ N, 45.2 kg ha⁻¹ P₂O₅, 3.68 kg ha⁻¹ K₂O), 20 (36.7 kg ha⁻¹ N), and 42 (27.6 kg ha⁻¹ N, 3.68 kg ha⁻¹ K₂O) after seeding), or pots were left unfertilized. The water management approach used was alternative wetting and drying (AWD). When the water level reached –10 cm, water was recharged to +3 from the soil surface. Irrigation was initiated on day 7 after planting and the pots were drained 10 days before harvesting. Rice was harvested on the day when 75% of the seeds on the main stems turned yellow (the conventional practice of the Mekong delta, and as used with the SALIBU method (Yamaoka et al., 2017); days 0), and after

on days 4, 8, and 14 (on day 91, 95, 99, and 105 after seeding). Rice was first harvested at 25 cm aboveground, then cut again at approximately 5 cm aboveground on day 7 after each harvesting. The harvested rice straw was cut into pieces approximately 5-cm long and scattered on the soil. Irrigation (AWD) was started on day 7 after the second cutting. The container locations were randomized with four replications in each, with and without fertilizer (32 pots in total). No fertilizer was applied for the ratoons.

Measurements

We counted the number of panicles and weighed the seeds of whole pots. The maturity of seeds was measured for composite samples of replications by specific gravity (1.06) method. We counted the number of living leaves (being alive was defined as more than half of the leaf being green) at harvesting and the number of ratoons on day 45 after harvesting. The number of fresh leaves is an indicator of carbohydrates stored in the stem.

Analysis

We plotted the relationship between the delay of harvesting and the number of ratoons. We showed statistical significance with a 95% confidence interval in the graph. We used Microsoft Excel 2016 formulas (average, stdev.s, and confidence) for statistical analysis.

Results

Growth of the main crop

The rice yields, maturity, and number of panicles were $0.66 (\pm 0.04) \text{ kg m}^{-2}$, $77.4 (\pm 3.1) \%$, and $67.5 (\pm 3.3) \text{ m}^{-2}$ respectively. Not using fertilizer decreased those properties, but a significant difference was found in the number of panicles ($p=0.047$) only.

Effect of fertilizer

The application of fertilizer to the main crop did not reverse the number of ratoons. There was a consistently greater number of ratoons with fertilizer than without fertilizer (Figure 1a).

Effect of delayed harvesting

The number of ratoons increased significantly with increasing delays in harvesting (Figure 1a). In particular, by day 4, there were almost no ratoons. Conversely, living leaves decreased continuously with delayed harvesting (Figure 1b). Finally, by day 14, there were no living leaves.

Discussion and conclusion

Oda *et al.* (2019) show cutting twice can have a large effect on the number of ratoons, and the effect can be reversed by different management conditions, such as adding fertilizer, delaying harvesting, or changing the type of water management used. We performed a pot experiment to investigate the effects that the level of fertilizer and the delay in harvesting time had on the number of ratoons.

Our results showed that the application of fertilizer to the main crop does not reverse the effect of cutting twice on the number of ratoons. The application of N fertilizer to the main crop results in a steady increase in ratoons and the result is consistent with previous studies (Fukai, 1988). In contrast, the timing of harvesting can reverse the effect of cutting twice on the number of ratoons. Despite the growth of ratoon depends on the carbohydrate storage of the stem, the number of ratoons continuously increased with the decrease of the number of living leaves. Especially, the second cutting conducted on the rice plant harvesting on days 0 resulted in no ratoons. Harvesting increases the number of dead buds on nodes close to the ground (Fukai, 1988). When the harvesting is early, the growth of ratoons is fast, so that growing ratoons are removed and few viable buds remain after the second cutting. However, when the harvesting is late, the growth is slow, so that viable buds remain after the second cutting. On the other hand, cutting twice has the advantage of leaving carbohydrates on the long stem for a period. This increases the number of ratoons for later harvesting.

Harvesting earlier than normal (at the physiological maturing stage) is emphasized in the SALIBU technology package; however, our results showed that the cutting twice decreased

Figure 1. Ratoons and Living leaves. •: fertilized, Δ : unfertilized. Bars represent 95% CI ($n = 4$). Living leaves at the harvesting. Ratoons on day 45 after harvesting. Rice was harvested on the day when 75% of the seeds on the main stem turned yellow (the standard SALIBU method; days 0), and after on days 4, 8, and 14. Rice was harvested at 25 cm aboveground first, then cut again at approximately 5-cm aboveground on day 7 after each harvesting.

ratoons when harvesting at the recommended timing, and that increased ratoons when harvesting late timing. This is a significant finding for the SALIBU practice. The practice of cutting twice originated partially the custom of conventional harvesting of which cutting height is high. That should be distinguished from using lower nodes of stubble. In other words, cutting twice is recognized as an essential practice in SALIBU (Fitri *et al.*, 2019; Yamaoka *et al.*, 2017) but cutting twice is not essential for some varieties when we can cut rice plant stems near the soil surface at harvesting. Previous work also shows that cutting twice reduces the number of ratoons (Shiraki *et al.*, 2020), but if varieties with high ratoon ability are adopted, twice cropping may suppress the growth of weak ratoons from higher nodes and result in higher yields. Cutting twice has a significant effect on ratoon number, but further study is needed because the effect of cutting twice varies among varieties and the timing needs to be adjusted.

Data availability

Underlying data

Figshare: Salibu Effect 2. <https://doi.org/10.6084/m9.figshare.13142720.v2> (Oda *et al.*, 2020)

This project contains the following underlying data:

- SALIBU2.xlsx (Ratoon and living leaves data)

Data are available under the terms of the [Creative Commons Zero "No rights reserved" data waiver](#) (CC0 1.0 Public domain dedication).

Acknowledgements

This work was conducted as a joint research project of JIRCAS and CTU.

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Open Peer Review

Current Peer Review Status:

Version 2

Reviewer Report 25 January 2022

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Chenfei Dong

Jiangsu Vocational College of Agriculture and Forest, Zhenjiang, China

The paper "Timing of harvesting reverses the effect of cutting twice with ratoon rice" only carried out one pot experiment for one year, and only got very few data. In this case, the results need to be certificated for over two or three years in field experiments or larger pot experiments to get more detailed data and reliable replications. The data in this paper with large standard deviation shows its bad replications. In conclusion, my decision is Not Approved.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: My main research areas are rice straw forage utilization and dual-purpose ratoon rice utilizations.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Version 1

Reviewer Report 08 January 2021

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Syarifa Mayly

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This article addresses the relationship between timing of harvesting (delay harvesting 0, 4, 8, 14 days) and level of fertilizer (with and without fertilizer) on the number of ratoons from the rice crop that had cutting twice at 7 days after harvesting. The parameters of this research are (1). number of ratoons, (2) living leaves, (3) yield, (4) maturity, (6) panicle. Parameter (1) was measured 45 days after harvesting (after twice cutting practices). Parameters (2-6) were measured at harvesting main crop (before twice cutting practices).

There are a number of issues/statements that need to be clarified, however. Below are more specific comments by section:

1. Abstract:

- The abstract had contained information about general topics of study, previous study, problem of research addresses, results and conclusions. But the objective of study and analytical methods were not seen clearly. The statement that “the effect changed from positive to negative with changes in the management conditions used to cultivate rice” must be described more specifically and with enough data to justify the statement.
- The statement that “By contrast, the single cutting results in ratoons”, how to justify this statement when there was no single cutting in this research and all of rice get twice cutting.
- And which data in this study can show whether or not there was a reverse effect of twice cutting on number of ratoons from the delay harvesting and level of fertilizer treatment?

2. Introduction:

- The introduction had contained information about salibu method; gap of previous study that is still unclear. But it needs more information about early planting and the factors which influenced the formation of ratoon like variety, etc. Why did you choose harvesting time at 75%, the seeds on the main stems turned yellow (Physiological maturity), why you

do not choose 80% which is also used in some studies of ratoon rice?

- The statement "The results showed that ...", should be written in the results section.

3. Methods:

- Need more information about harvesting time at 75%; obtained on how many days after sowing? And regarding the statement "SALIBU practices are not used in this experiment", it would be clearer to write down which of the 10 additional activities from the Salibu System were not carried out.

4. Treatments:

- The step of treatments was clear, but needs more information about the details of irrigation (AWD) at ratoon crop. Why don't you use the same variety from the previous study that still have many that can be clarified?

5. Measurements and Analysis:

- This is clear.

6. Results:

- - Effect of fertilizer:
Which data can be supported to justify your statement (The application of fertilizer did not reverse the number of ratoons)?
- The title of Figure 1 was considered for change which the living leaves were measured before cutting twice practices. Caption 1 needs to add more information about measured time from number of ratoons and living leaves.

7. Discussion and Conclusion:

- Data showing the reverse effect of twice cutting by timing of harvesting and level of fertilizer are not seen in the results section, so how to justify the statement there was a reverse effect of twice cutting by timing of harvesting?
- The statement "The number of ratoons continuously increased until the rice plants lost all of their living leaves" showed that the growth of ratoons and living leaves occurs simultaneously, but actually living leaves was for main crop not ratoon crop. The large number of ratoons in delay harvesting was most likely because there were sufficient food reserves from stem for the growth of ratoons. Some literature suggests that the ratooning performances was affected by varieties, water and fertilizer management, and number of nodes.
- Conclusions of this study are not written clearly.

8. Data Availability:

- Analysis is clear (Mean, STDEV, CI and t test).
- Why was only the maturity parameter data not displayed in replication form like other parameters' data?

9. Acknowledgement and References:

- This is clear.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Value added product (biochar), waste management, drought stress, climate change, tropical agroecosystem, nutrient management

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 29 Jan 2021

Masato Oda, Japan International Research center for Agricultural Sciences, Tsukuba, Japan

Thank you very much for your valuable comments. We sincerely appreciate it.

Please check the manuscript as we have revised it as follows.

1. Abstract:

"the effect changed from positive to negative with changes in the management conditions used to cultivate rice" must be described more specifically and with enough data to justify the statement.

- *We revised.*

How to justify this statement when there was no single cutting in this research and all of rice get twice cutting.

- *We explained using literature.*

Which data in this study can show whether or not there was a reverse effect of twice cutting on number of ratoons from the delay harvesting and level of fertilizer treatment?

- *We explained.*

2. Introduction:

The gap of previous study that is still unclear.

- *We explained using existing studies.*

It needs more information about early planting.

- *not "early planting" that is conventional in the Mekong delta. We explained it in the "Methods"*

The factors which influenced the formation of ratoon like variety, etc.

- *We explained using existing studies. As for variety, we think that it is a future study so we just mentioned it in the "Discussion and conclusion".*

Why did you choose harvesting time at 75%, the seeds on the main stems turned yellow (Physiological maturity), why you do not choose 80% which is also used in some studies of ratoon rice?

- *That is the conventional of the Mekong Delta triple rice cropping and of the recommendation of SALIBU practices. We described that in the "Methods".*

The statement "The results showed that ...", should be written in the results section.

- *Deleted.*

3. Methods:

More information about harvesting time at 75%; obtained on how many days after sowing?

- *On day 91, 95, 99, and 105. We added.*

"SALIBU practices are not used in this experiment", it would be clearer to write down which of the 10 additional activities from the SALIBU System were not carried out.

- *We added the explanation.*

4. Treatments:

More information about the details of irrigation (AWD) at ratoon crop.

- *We added.*

Why don't you use the same variety from the previous study that still has many that can be clarified?

- *Jasmine rice is photoperiod sensitive so it can use for getting ratoons but not practical.*

6. Results:

Effect of fertilizer: Which data can be supported to justify your statement (The application of fertilizer did not reverse the number of ratoons)?

- *We explained in the "Discussion and conclusion".*

The title of Figure 1 was considered for change which the living leaves were measured before cutting twice practices.

- *We changed to "Ratoons and Living leaves".*

Caption 1 needs to add more information about measured time from the number of ratoons and living leaves.

- *Thank you. We added.*

7. Discussion and Conclusion:

Data showing the reverse effect of twice cutting by timing of harvesting and level of fertilizer are not seen in the results section, so how to justify the statement there was a reverse effect of twice cutting by timing of harvesting?

- *We explained it using existing studies. The previous study provides the data.*

The statement "The number of ratoons continuously increased until the rice plants lost all of their living leaves" showed that the growth of ratoons and living leaves occurs simultaneously, but actually living leaves was for main crop not ratoon crop. The large number of ratoons in delay harvesting was most likely because there were sufficient food reserves from stem for the growth of ratoons. Some literature suggests that the ratooning performances was affected by varieties, water and fertilizer management, and number of nodes.

- *The best harvesting time for good ratooning is when the culms were still greenish because the growth of ratoon tillers depends on the carbohydrate reserves of the stubble (Fukui, 1988). We revised the explanation.*

Conclusions of this study are not written clearly.

- *We revised.*

Competing Interests: No competing interests were disclosed.

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