Application of effective growing season patterns for the cultivation of rice and tiger shrimp on brackish water intruded land.

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**Abstract**

The study aims to test more productive growing season patterns for rice and tiger shrimp cultivation. The research was conducted in Oring Hamlet, Lawallu Village, Barru Regency, South Sulawesi. The implementation of rice and tiger shrimp cultivation is carried out in ponds disturbed by brackish water, which have been reconstructed into rice fields and trenches. The rice varieties planted, INPARI 34 (saline tolerant rice seeds), from the Rice Seed Centre of the Ministry of Agriculture, Sukamandi West Java Indonesia, while post-larvae of PL-25 tiger shrimp are obtained from the Tiger Shrimp Hatchery Installation, which has previously been adapted with a decrease in salinity under the conditions of the cultivation site. The treatment tested, namely: a) the cultivation of rice-tiger shrimp at the beginning of the rainy season; b) the cultivation of rice-tiger shrimp at the beginning of the dry season. Preparation of rice cultivation land is carried out by tillage, fertilizing, seed sowing, and seeding for 25 days. Furthermore, rice planting is carried out to move to the rice fields with the legowo planting system, followed by the maintenance of rice plants for 105 days. The distribution of post-larvae PL-25 tiger shrimp in trenches when rice plants aged 14 days after planting moved. The process of maintaining rice plants and tiger shrimp by controlling growth and sampling every 14 days. The results showed that rice production in the first growing season (the beginning of the rainy season) was 1027 kg, compared to the second growing season (the beginning of the dry season) of 350 kg. The survival rate (SR) and daily growth rate (DGR) of tiger shrimp obtained in the first growing season were 20.16% and 0.18, while the Survival Rate and Daily Growth Rate of tiger shrimp in the second growing season (the beginning of the dry season) were 18.45% and 0.17. The production value of rice cultivation and tiger shrimp is higher in planting season I (early rainy season).

Keywords: Rice; Shrimp; Season pattern; Brackish water; Intruded Land

## Introduction

The rapid increase in the world's population has its impact on survival, such as security and lack of food, limited land, and water resources for agricultural production, and declining environmental quality, which is increasingly felt today (Bashir et al., 2020). Meeting food needs for the world's growing population is indispensable (Jin et al., 2020; Nayak et al., 2018), and efforts are needed to cultivate agricultural commodities and fisheries in an integrated manner (Wang et al., 2019).

Integrated rice and fish cultivation systems have been widely applied to rice fields with irrigation channels for rice cultivation and fish co-culture systems (Jin et al., 2020; Khoshnevisan et al., 2021; Li et al., 2019). Co-culture system (Bashir et al., 2020; Liu et al., 2019; Yaobin et al., 2019) is a technology that has long been practised in the freshwater world, but there has not been much cultivation of rice and tiger shrimp in brackish water-stricken areas with agricultural production systems that are more tolerant to salinity such as rice-shrimp and permanent shrimp alternately (Braun et al., 2019).

Rice is maintained in rice fields with freshwater irrigation systems or rain-fed rice fields, With this system it is expected that rice crop production will increase so that it can increase production to meet the needs of the community (Mullick & Das, 2021). Integrated cultivation of rice fish has been widely practised because it is considered capable of controlling the environmental impact caused by intensive cultivation (Leigh et al., 2020). Trials have been conducted with rice-fish cultivation in yellow catfish ponds (*Pelteobagrus fulvidraco*) and freshwater shrimp (*Macrobrachium Nipponese*) using new high-stalk rice varieties (Yaobin et al., 2019).

Fish or other fishery commodities are kept in trenches that have been integrated with rice fields. On brackish water-induced land, of course, the factor of freshwater supply in rice fields is indispensable for the cultivation process, and this will depend on the pattern of the growing season (western and eastern seasons) usually carried out by the cultivation group. This study aims to examine the pattern of a more productive growing season in the cultivation of rice-tiger shrimp in brackish water-intruded land.

## Materials and Method

**Research Preparation**

The research was carried out in Oring Hamlet, Lawallu Village, Soppengriaja District, Barru Regency, South Sulawesi Province, Indonesia. The land used is selected from land owned by members of the farmer group in the region. The land is a rice field bordering the overhaul, so it gets influenced by brackish water intrusion. The land is reconstructed into rice fields and trenches made around it, with a ratio of 70:30 (rice field court: trench). Trenches are made with a depth of 50-100 cm, There is an intermediate barrier that limits each trench and there is also the main barrier that surrounds the outermost court and trench (Khan et al., 2023). Soil excavations derived from trenches as well as used as new barriers, the size of the limiting made lower width of 3 meters and the upper width is 1.5 meters with a height of about 1.0 - 1.2 meters from the court, the barrier is an intermediate barrier bordering with other maps that are the same there are caren excavations. Meanwhile, the manufacture of barriers adjacent to other productive rice fields is made smaller in size because they are not dug under it, namely, the width of the bottom is 1.2 meters, and the height of 0.5-0.8 meters.

**Preparation of rice fields, seeding, and planting of moved rice seeds.**

Rice seed nursery land used covers an area of 5 m x 10 m, preparation begins with the processing and defection of the soil, and the provision of organic fertilizers for the nutritional needs of the soil. Along with the preparation of nursery land, rice seed immersion is also carried out for 24 hours, namely the saline tolerant variety INPARI 34, then squeezed in a damp place for 24 hours until germinating.

The sowing of rice seeds is carried out in the morning or evening to avoid the scorching heat of the sun. The period of grain preservation lasts for 25 days. Furthermore, planting is carried out to move rice seeds to rice fields with a Legowo alignment planting system, followed by the maintenance of rice plants for 105 days.

**Trench preparation and tiger shrimp post-larvae**

The preparation of trenches for shrimp cultivation is carried out in conjunction with rice field preparations, namely: drying, lime application, tillage, fertilizing, water filling, and distribution of tiger shrimp post larvae. Postlarvae tiger shrimp (PL-25) obtained from tiger shrimp hatchery installation. Before stockings, the adjustment/decrease in salinity follows the salinity of the levels at the cultivation site. The growth of natural feed is stimulated by using organic fertilizers that are put into the trenches before spreading windu shrimp larvae. Re-fertilization is carried out on the 30th day after fertilization of tiger shrimp larvae.



**Figure 1.** Preparation for the spread of post-larvae of PL-25 tiger shrimp in trenches

In the trenches/caren that has been prepared, namely, drying, calcification, water replenishment, and natural feed growth. The distribution of tiger shrimp post-larvae PL 25 in the trench is carried out when the rice plant is 14 days after planting. Post windu shrimp larvae that were stocked previously carried out a gradual decrease in salinity in the holding media from 30 ppt to < 10 ppt, this is done to adjust the physiological conditions of shrimp with the cultivation media in the trenches with salinity between 5-7 ppt.

**Research Design**

The land that has been reconstructed into rice fields and caren fields is divided into 4 plots, each planted with INPARI-34 saline-tolerant variety rice in the yard and stocked with PL-25 tiger shrimp in the trench section. The treatments tested were:

cultivation of tiger shrimp rice at the beginning of the rainy season; (salinity dynamics are rather low) and cultivation of tiger shrimp rice at the beginning of the dry season (higher salinity dynamics)

**Parameters measurement**

Measurement of the growth of rice and tiger shrimp is carried out once every 14 days, as well as measurements of water quality parameters (temperature, salinity, pH, and oxygen demand). At the end of the study, rice production, survival rate (SR), daily growth rate (DGR), and tiger shrimp production were calculated.

**Data analysis**

The data obtained is analyzed with SPSS. The T-test is performed to compare the production of the two treatments, then discussed descriptively. Meanwhile, water quality parameter data were analyzed descriptively and presented in table form.

**Result**

**Growth and harvest of rice crops**

Measurements of rice plant growth per sampling are seen in Figure 2. The height of rice, when planting moved, was 35-40.7 cm, in the first sampling there was a growth of rice to 55 cm (treatment A) and 55 cm in treatment B, as well as in the next sampling there was an increase of 64, 73, 85 96 and 104 cm respectively (treatment A) while treatment B with a high start when planting moved 35 cm higher during sampling I to the end, respectively, namely 41, 52, 67, 79, 86 and 92 cm. Growth was better in treatment A than in the growth of rice plants in treatment B.



120

112

98

100

85

80

73

64

86

92

60

55

79

40.7

67

40

56

48

40.7

20

A

treat…

0

25 days 40 days 54 days 67 days 81 days 95 days 105 days

Rice age (days)

rice height (cm)

**Figure 2**. Growth of rice plants during observation

**Figure 3.** Grain production at both beginnings of the growing season tested in the study.

1200

1027

1000

800

600

400

350

200

0

A.Treatment I (rainy season)

B.Treatment II (dry season)

Grain roduction (kg)

The harvest of rice crops from both treatments is seen in Figure 3. In the early growing season of the rainy season (treatment I) obtained grain as much as 1027 kg while in the early growing season, the dry season only gets 350 kg of grain. In treatment I, rice plants in their infancy get an adequate freshwater supply due to high rainfall, land conditions do not experience high salinity checks (highest salinity value of 7,05 ppt) and can still be tolerated by rice seeds of the INPARI-34 variety.

**Growth and harvest of tiger shrimp**

The data on the growth of tiger shrimp in each treatment can be seen in Figure 6 below. The initial weight of tiger shrimp larvae is 0.3 grams/ind., At the first sampling, the weight becomes 4.1 gram/ind., In treatment I, in treatment II the weight increases to 3.85 grams/ind. In the 4th sampling when the shrimp aged 60 days the weight reached 9.75 grams/ind. (Treatment I) and 8.61 grams/ind. in treatment II, so that the final weight of tiger shrimp in treatment I is higher than in treatment II.



12.00

Treatment I

Treatment II

10.00

8.00

6.00

4.00

2.00

0.00

sampling I

sampling II

sampling III

sampling IV

sampling periods

shrimp weight (gram)

**Figure 4.** Growth of tiger shrimp in the treatment of growing season I and planting season II

The growth parameters of tiger shrimp are seen in Table 1, the density of tiger shrimp in caren is 3-4 ind./m2, including the traditional cultivation system plus, with the initial weight of postlarvae stocked 0.3 grams/ind., which is maintained for 65 days so that the weight finally reaches 11 grams/ind. and 10 grams/ind. The daily growth rate is 0.18 (A) and 0,17 (B), and the survival rate of tiger shrimp in treatment I is 20.18% and 18.45% in treatment II. Growth parameters show that treatment A is better than treatment B.

**Table 1.** Biological parameters of tiger shrimp during the research period

|  |  |  |
| --- | --- | --- |
| Biological Parameter | Treatment A | Treatment B |
| Density (ind./m2) Early weight (gram) Final weight (gram) Cultivation time (days) Daily growth rate Survival rate (%) | 3-4  0,3  11  65  0,18  20,16 | 3-4  0,3  10  65  0,17  18,45 |

The daily growth rate of tiger shrimp in treatment A is 0.18 and in treatment, B is 0.17. The survival value of tiger shrimp is 20.16% and 18.45%. From the results of calculations of biological variables, tiger shrimp showed that treatment A (early rainy season) gave better results than treatment B (early growing season of the dry season).

**Water quality parameters**

The quality parameters observed during the study are listed in Table 2. Salinity values differ greatly between the two treatments.

**Table 2.** Water quality parameter value during the research period

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | Range value | |
| Number | Water quality parameters | Treatment I | Treatment II |
| 1. | Salinity (ppt) | 0,17-7,05 | 7-15 |
| 2. | Temperature (oC) | 25,1-33,4 | 29-35 |
| 3. | Degree of acidity (pH) | 7,87-8,11 | 8,4-9,3 |
| 4. | Dissolved oxygen (ppt) | 3,32-7-68 | 3,52-6,4 |

In treatment II the range of salinity values is 0.17 ppt – 7.05 ppt, when there is high rainfall the salinity value is close to 1 or even lower (close to freshwater conditions), at the time of low rainfall the salinity value becomes brackish due to the influence of rising tides. Other rated water quality parameter values are; temperature with values of 25.1oC – 33.4oC (treatment I) and 29oC – 35oC (treatment II), pH values of 7.87 – 8.11 (treatment I) and 8.4 – 9.3 (treatment II), as well as dissolved oxygen values of 3.32 – 7.68 ppt (treatment I) and 3.52 – 6.4 ppt (treatment II).

**Discussion**

Better growth of rice crops is planted at the beginning of the rainy season. The yield of rice planted at the beginning of the rainy season is also higher (Nayak et al., 2018) due to the land conditions corresponding to the rice crop supported by high rainfall, as is the case in India of millions of ha of rice planting land suitable for the adoption of an integrated rice-fish production system, especially in rain-fed, low-lying waterlogged fields (Nayak et al., 2018; Saikia & Das, 2008). This has been reported (Berg & Tam, 2018; Hendrajat et al., 2020; Islam et al., 2021; Leigh et al., 2020) when the rainy season occurs, commodity growth conditions will be better because environmental parameters are somewhat stable, especially water salinity conditions with sufficient fresh water available with high rainfall.

Salinity concentration in treatment II ranges from 7-15 ppt, the condition is very extreme for rice plant varieties INPARI 34, this has also been tested so that it is found that rice plants are not able to tolerate land conditions with high salinity checks (Hendrajat et al., 2020; Islam et al., 2021)in areas disturbed by brackish water environmental conditions are quite dynamic because of the influence of brackish water inspection that always occurs.

The practice of cultivating rice integrated with shrimp has been practised by (Leigh et al., 2020) by planting rice during the rainy season, and during the dry season with high salinity dynamics, rice planting is not carried out, such management avoids the risk of crop failure.

The growth of tiger shrimp at the beginning of the rainy season seems to be higher than at the beginning of the dry season, this is related to the conditions of the aquatic environment such as temperature, salinity, and oxygen content as well as many other factors that affect the environment of aquaculture commodities (Guo et al., 2020; Leigh et al., 2020; Panda et al., 2021). The concentration value is higher on distribution at the beginning of the rainy season, this condition is in line with (Leigh et al., 2020) which has been tested in the growing season of sea shrimp Penaeus monodon for a full year in the Mekong Delta, Vietnam, until the rainy season when the water is fresh. Rice and shrimp growth conditions are influenced by seasonal conditions and many other aquatic environmental factors (Bashir et al., 2020; Jin et al., 2020; Yaobin et al., 2019). The survival value (30-41%) and total biomass area (350- 531 kg ha-1) of shrimp are limited to poor water quality conditions, with water temperature, salinity, and dissolved oxygen concentrations outside the optimal range recorded for a few weeks (Leigh et al., 2020; Suwoyo & Hendrajat, 2021; Yaobin et al., 2019). There is an intrusion of brackish water in the Mekong River Delta of Vietnam so it is emotional to the surrounding environment including aquaculture land.

The water parameters are still within the range that can be tolerated by rice commodities and tiger shrimp, water quality parameters greatly affect the growth of cultivated commodities (Mustafa et al., 2022). Seeing the growth in rice and tiger shrimp cultivation by connecting the conditions of the growing season, it is considered important to make changes in aquaculture management practices, by choosing the beginning of the growing season at the beginning of the rainy season because it can increase sustainable growth and productivity, where the overall condition of the aquatic ecosystem is important to support the growth of aquaculture commodities (Leigh et al., 2020; Mustafa et al., 2022)The growth of tiger shrimp is better in conditions of an aquatic environment that does not experience too extreme dynamics, poor water quality, with water temperature, salinity, and dissolved oxygen concentration far beyond the optimal range will decrease and the growth rate of shrimp. Overall, our findings suggest that shrimp survival, conditions, and growth in the extensive rice shrimp tem ecosystem will be constrained when poor water quality and high and low salinity alternately negatively impact the physiology, growth, and composition of natural aquatic biota (Leigh et al., 2020; Yaobin et al., 2019)

**Conclusion**

The value of rice production in the first growing season (the beginning of the rainy season) is higher compared to the second growing season (the beginning of the dry season). The survival rate (SR) and daily growth rate (DGR) of windu shrimp obtained in the first growing season are also higher than in the second growing season. The production value of rice and windu shrimp cultivation is higher in the first growing season (the beginning of the rainy season). The implementation of the cultivation of the windu rice-shrimp brackish water rice-shrimp system is pursued at the beginning of the rainy season to get higher productivity.

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**Author Contributions**

SS and HSS planned, coordinated the research, collected data, and prepared and made up the articles. SS, ES, EAH, AS and MF collected data, statistically analyzed the data and made illustrations.

**Conflicts of Interest**

All authors declare no conflict of interest in writing articles, financing, or personal beliefs. Data Availability All research data is available and can be requested from the corresponding authors.

**Ethics Approval**

This study was conducted in full accordance with ethical principles. All experimental protocols were carried out according to the relevant guidelines and regulations.

**References**

Bashir, M. A., Liu, J., Geng, Y., Wang, H., Pan, J., Zhang, D., Rehim, A., Aon, M., & Liu, H. (2020). Co-culture of rice and aquatic animals: An integrated system to achieve production and environmental sustainability. *Journal of Cleaner Production*, *249*, 119310. https://doi.org/10.1016/j.jclepro.2019.119310

Berg, H., & Tam, N. T. (2018). Decreased use of pesticides for increased yields of rice and fish options for sustainable food production in the Mekong Delta. *Science of the Total Environment*, *619*–*620*, 319–327. https://doi.org/10.1016/j.scitotenv.2017.11.062

Braun, G., Braun, M., Kruse, J., Amelung, W., Renaud, F. G., Khoi, C. M., Duong, M. V., & Sebesvari, Z. (2019). Pesticides and antibiotics in permanent rice, alternating rice-shrimp and permanent shrimp systems of the coastal Mekong Delta, Vietnam. *Environment International*, *127*(April), 442–451. https://doi.org/10.1016/j.envint.2019.03.038

Guo, H., Qi, M., Hu, Z., & Liu, Q. (2020). Optimization of the rice-fish coculture in Qingtian, China: 1. Effects of rice spacing on the growth of the paddy fish and the chemical composition of both rice and fish. *Aquaculture*, *522*(November 2019), 735106. https://doi.org/10.1016/j.aquaculture.2020.735106

Hendrajat, E. A., Sahabuddin, & Nafisah. (2020). Tiger shrimp farming in the rice-fish farming system using salinity-tolerant rice lines. *AACL Bioflux*, *13*(6).

Islam, M. A., Lobry de Bruyn, L., Warwick, N. W. M., & Koech, R. (2021). Salinity-affected threshold yield loss: A signal of adaptation tipping points for salinity management of dry season rice cultivation in the coastal areas of Bangladesh. *Journal of Environmental Management*, *288*(February), 112413. https://doi.org/10.1016/j.jenvman.2021.112413

Jin, T., Ge, C., Gao, H., Zhang, H., & Sun, X. (2020). Evaluation and screening of co-culture farming models in rice field based on food productivity. *Sustainability (Switzerland)*, *12*(6). https://doi.org/10.3390/su12062173

Khan, M. I. R., Kumari, S., Nazir, F., Khanna, R. R., Gupta, R., & Chhillar, H. (2023). Defensive Role of Plant Hormones in Advancing Abiotic Stress-Resistant Rice Plants. *Rice Science*, *30*(1), 15–35. https://doi.org/10.1016/j.rsci.2022.08.002

Khoshnevisan, B., Amjad, M., Sun, Q., Pan, J., Wang, H., Xu, Y., Duan, N., & Liu, H. (2021). Optimal rice-crab co-culture system as a new paradigm to air-water-food nexus sustainability. *Journal of Cleaner Production*, *291*, 125936. https://doi.org/10.1016/j.jclepro.2021.125936

Leigh, C., Stewart-Koster, B., Sang, N. Van, Truc, L. Van, Hiep, L. H., Xoan, V. B., Tinh, N. T. N., An, L. T., Sammut, J., & Burford, M. A. (2020). Rice-shrimp ecosystems in the Mekong Delta: Linking water quality, shrimp and their natural food sources. *Science of the Total Environment*, *739*(May 2017), 139931. https://doi.org/10.1016/j.scitotenv.2020.139931

Li, F., Feng, J., Zhou, X., Xu, C., Haissam Jijakli, M., Zhang, W., & Fang, F. (2019). Impact of rice-fish/shrimp co-culture on the N2O emission and NH3 volatilization in intensive aquaculture ponds. *Science of the Total Environment*, *655*, 284–291. https://doi.org/10.1016/j.scitotenv.2018.10.440

Liu, G., Huang, H., & Zhou, J. (2019). Energy analysis and economic assessment of a rice-turtle-fish co-culture system. *Agroecology and Sustainable Food Systems*, *43*(3), 299–309. https://doi.org/10.1080/21683565.2018.1510870

Mullick, M. R. A., & Das, N. (2021). Estimation of the spatial and temporal water footprint of rice production in Bangladesh. *Sustainable Production and Consumption*, *25*, 511–524. https://doi.org/10.1016/j.spc.2020.12.002

Mustafa, A., Paena, M., Athirah, A., Ratnawati, E., Asaf, R., Suwoyo, H. S., Sahabuddin, S., Hendrajat, E. A., Kamaruddin, K., Septiningsih, E., Sahrijanna, A., Marzuki, I., & Nisaa, K. (2022). Temporal and Spatial Analysis of Coastal Water Quality to Support Application of Whiteleg Shrimp Litopenaeus vannamei Intensive Pond Technology. *Sustainability (Switzerland)*, *14*(5). https://doi.org/10.3390/su14052659

Nayak, P. K., Nayak, A. K., Panda, B. B., Lal, B., Gautam, P., Poonam, A., Shahid, M., Tripathi, R., Kumar, U., Mohapatra, S. D., & Jambhulkar, N. N. (2018). Ecological mechanism and diversity in the rice-based integrated farming system. *Ecological Indicators*, *91*(April), 359–375. https://doi.org/10.1016/j.ecolind.2018.04.025

Panda, D., Mishra, S. S., & Behera, P. K. (2021). Drought Tolerance in Rice: Focus on Recent Mechanisms and Approaches. *Rice Science*, *28*(2), 119–132. https://doi.org/10.1016/j.rsci.2021.01.002

Saikia, S. K., & Das, D. N. (2008). Rice-Fish Culture and its Potential in Rural Development: A Lesson from Apatani Farmers, Arunachal Pradesh, India. *J Agric Rural Dev*, *6*(2), 125–131. http://www.banglajol.info/index.php/jard

Suwoyo, H. S., & Hendrajat, E. A. (2021). High-density aquaculture of white shrimp (Litopenaeus vannamei) in controlled tank. *IOP Conference Series: Earth and Environmental Science*, *777*(1), 0–10. https://doi.org/10.1088/1755-1315/777/1/012022

Wang, A., Ma, X., Xu, J., & Lu, W. (2019). Methane and nitrous oxide emissions in rice-crab culture systems of northeast China. *Aquaculture and Fisheries*, *4*(4), 134–141. https://doi.org/10.1016/j.aaf.2018.12.006

Yaobin, L., Lin, Q., Fengbo, L., Xiyue, Z., Chunchun, X., Long, J., Zhongdu, C., Jinfei, F., & Fuping, F. (2019). Impact of Rice-Catfish/Shrimp Co-culture on Nutrients Fluxes Across Sediment-Water Interface in Intensive Aquaculture Ponds. *Rice Science*, *26*(6), 416–424. https://doi.org/10.1016/j.rsci.2019.06.001