Paddy-fish cultivation within an integrated farming system

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Abstract. This study aimed to determine the growth and production of rice and fish on the integrated paddy-fish farming system known as Minapadi. This research was in form of an experiment based on a two-factor factorial design arranged as randomized group design. The first factor was the planting system consisting of 3 levels: Tegel planting (conventional traditional system), Legowo Tapin (transplanted seedlings), Legowo Tabela (direct seed planting), and the second factor was the population density of Nile Tilapia which consisted of 3 levels, namely: 27, 54, and 80 fish population. The results showed that rice production has the highest average in the legowo tapin planting system (5.05 tons/ha). This system was the best planting system by achieving best results on several other parameters such as plant height at 60 DAT (42.90 cm), the number of productive tillers (13.27), the weight of clumps (39.96 g), the weight of 1000 grains (25.58 g) and the weight of grain per plot (4.81 kg). Whereas the legowo Tabela planting system was the best treatment for the average value of the panicle length growth parameters (22.19 cm), grain weight per clump (38.76 g) and fish weight per plot (12.05 kg). While the Tegel system gave the lowest level of fish mortality (1.42%).

1. Introduction

Integated paddy-fish farming system which is known as Minapadi is system that becomes more popular in Indonesia in addition to regular planting system such as the Legowo planting system. The Mina Padi system is a fish rearing system that is carried out together with rice in paddy fields [1]. The presence of fish in the Minapadi system is thought to have influence the growth and production of rice [2]. Experience of some practices with this system revealed that farmers’ profit increases by inserting fish into the production system. However, it is essential to understand the optimum fish population per land area which will not interrupt the growth and production of rice. Appropriate proportion applied by farmers will result in income increase both from rice and fish.

The Minapadi model is efficient and effective enough to be applied to irrigated rice fields where sufficient water supply is available during the growth of rice and fish [3].

Other beneficial effects of Minapadi farming is that it enables rapid investments return by selling fish and creating opportunities for household savings for farmers [4]. Minapadi farming can reduce pollution and ensure environmental sustainability through reducing the use of pesticides and chemical fertilizers, increasing farmers' rice marketability, and increasing land fertility [5].

Increased rice production in Minapadi farming is considered to be very likely since fish manure can increase soil fertility which in turn has an impact on increasing rice production [6]. Several other advantages of this system such as it is relatively easy to increase land productivity, land management and crop maintenance, reduce the risk of crop failure and rice can be planted twice a year [7].
Efforts to improve rice production by utilization of superior seeds as well as good cultivation practice could not be as effective as expected as some farmers are still practicing conventional traditional farming system-known as Tegel system. This system employs tight planting space of 20 x 20 cm or 25 by 25 cm which according to Sudiarta, Syam’un, & Syamsuddin [8], in general, rice under narrow spacing conditions will experience a decrease in the quality of growth, such as fewer number of tillers and panicles, shorter panicle lengths, and of course the number of grains per panicle is reduced accordingly as opposed to wider spacing conditions.

The common practice of rice planting system is the Tegel system, however, nowadays a new planting system has been developed, namely the Jajar Legowo system. According to Pahrudin & Dida [9], Jajar Legowo was developed from a Tegel system. The principle of the Jajar Legowo planting system is the provision of each row of rice planting to have the effect of outer rows. In general, crops growing in outer row yields higher than plants on the inside rows. These plants also show better growth because crop competition between rows can be reduced.

Legowo planting system is a way of arranging several crop rows to be interspersed with one empty row. Plants whose row was emptied then transferred as inset plants in a row. In this study the system used was 2:1 legowo. It is a way of planting paddy rice which has several rows of plants. In every 2 rows one empty row is interspersing where the spacing of the outer rows is half of the spacing of the plants in the inside rows. Based on the previous research, this sort of planting arrangement was proven to increase rice production by 12-22% [10]. This planting system allows air circulation and utilization of sunlight more optimal for plants. In addition, efforts to tackle weeds and fertilization is possible more easily [11].

2. Methodology
An experiment of two-factor factorial design was arranged as a randomized block design (RBD) of 3 replications. The first factor was planting system which consisted of 3 levels, namely: P1 (Tegel), P2 = (Legowo Tapin (transplanted seedlings) of 2: 1), P3 = (Legowo Tabela (direct seeds planting) of 2: 1). The second factor was the population density of tilapia which consisted of 3 levels, namely: S1 = 27 fishes, S2 = 54 fishes, S3 = 80 fishes.

Furthermore, the research data were analyzed using variance with the linear model as follows:

\[ Y = \mu + (K + \alpha + \epsilon_a) + (\beta + \epsilon_\beta) + \alpha\beta + \epsilon_b \]

Notes:
- K: Effect of grouping
- \( \mu \): Middle Value
- \( \alpha \): population population factor
- \( \beta \): cropping system factors
- \( \alpha\beta \): population and cropping system interactions
- \( \epsilon \): error effect

The main effect of \( \alpha \) (plant population) was investigated through error \( \epsilon_a \) (\( \epsilon_a \)) while the main effect of \( \beta \) (fish population) and interaction of \( \alpha\beta \) (plant population and planting system) was detected through error \( \epsilon_b \) (\( \epsilon_b \)).

2.1. Plants spacing
The planting system employed were Tegel (20 x 20 cm), Legowo Tabela (2: 1), Legowo Tapin (2: 1). The 2:1 refers to way of planting rice where each two rows of plants are interspersed with one empty row. The empty row had planting distance which was twice the spacing between rows. While the spacing of plants within rows was half of the plant spacing between rows. Thus the implemented planting space in the Legowo system (2: 1) is 25 cm (between rows) x 12.5 cm (outer rows) x 50 cm (empty rows) as seen in Figure 1.
2.2. **Fish stocking**

Fish stocking was conducted 20 days after rice planting in the morning. The stocked fishes’ size measuring 2-3 cm with an average weight of 30 grams. Before the fishes were stocked, water from the paddy field was added to the container of the fishes to adjust the water temperature so that the fish adapt and avoid the stress (figure 2). After adjusting for temperature, the fish seeds were released carefully.

![Figure 1. Legowo 2:1 planting under Minapadi system](image1)

![Figure 2. Fish stocking into the Minapadi system](image2)

3. **Results and discussion**

3.1. **Growth variables**

Plant height was one important parameter to identify plant growth including for rice. This study observed the plant height development by recording plant height at three stages namely 20, 40 and 60 DAT-days after transplanting or planting for the direct seeds (Tabela) system. Table 1, 2 and 3 presented the results of observation.
Table 1. Average plant height at 20 DAT (cm)

| Planting system | Fish population | Average | LSD 0.05% |
|-----------------|-----------------|---------|-----------|
|                 | S1              | S2      | S3        |           |
| P1              | 20.60           | 24.35   | 24.58     | 23.18<sup>a</sup> |
| P2              | 23.60           | 30.95   | 29.30     | 27.95<sup>a</sup> |
| P3              | 23.18           | 25.25   | 25.15     | 24.53<sup>b</sup> |
| Average         | 22.46<sup>r</sup> | 26.85<sup>p</sup> | 26.34<sup>p</sup> | 0.49 |

LSD 0.05% 0.49

Notes: The numbers followed by different letters in the column (a, b, c) and lines (p, q, r) indicates significant difference in the LSD test with a confidence level of 0.05.

The results of analysis of variance showed that the treatment of planting systems and fish populations had a very significant effect on plant height 20 DAT, and the interaction between the two had no significant effect.

Table 1 shows that at 20 DAT, the treatment of the Legowo Tapin planting system produced the highest average plant height of 27.95 cm and was significantly different from the treatment of the Tegel (23.18 cm) and the Legowo Tabela planting system (24.53 cm). Whereas the treatment of 54 fish populations had the highest average plant height (26.85 cm) and was significantly different from the population of 80 fish (26.34 cm) and 27 fish (22.46 cm) which had the lowest plant height of 22.46 cm.

Table 2. Average plant height at 40 DAT (cm)

| Planting system | Fish population | Average | LSD 0.05% |
|-----------------|-----------------|---------|-----------|
|                 | S1              | S2      | S3        |           |
| P1              | 36.40           | 37.20   | 38.40     | 37.33<sup>c</sup> |
| P2              | 41.15           | 45.00   | 42.55     | 42.90<sup>a</sup> |
| P3              | 39.55           | 41.25   | 43.78     | 41.53<sup>b</sup> |
| Average         | 39.03<sup>p</sup> | 41.15<sup>p</sup> | 41.58<sup>p</sup> | 0.61 |

LSD 0.05% 0.61

Notes: The numbers followed by different letters in the column (a, b, c) and lines (p, q, r) indicates significant difference in the LSD test with a confidence level of 0.05.

The results showed that the treatment of cropping systems and fish populations had a very significant effect on plant height, while the interaction between the two did not significantly affect.

Table 2 shows that at 60 DAT, Legowo Tapin system produced the highest average plant height of 42.90 cm and was significantly different from the treatment of the Tegel (37.33 cm) and the Legowo Tabela planting system (41.53 cm). While the treatment of 80 fish populations has the highest average plant height (41.58 cm) and was significantly different from the population of 27 fish (39.03 cm) but not significantly different from the treatment of 50 fish (41.15 cm).

Table 3. Average plant height at 60 DAT (cm)

| Planting system | Fish population | Average | LSD 0.05% |
|-----------------|-----------------|---------|-----------|
|                 | S1              | S2      | S3        |           |
| P1              | 51.05           | 53.58   | 54.58     | 53.07<sup>a</sup> |
| P2              | 52.88           | 58.45   | 56.35     | 55.89<sup>a</sup> |
| P3              | 52.23           | 55.05   | 56.08     | 54.45<sup>b</sup> |
| Average         | 52.05<sup>p</sup> | 55.69<sup>p</sup> | 55.67<sup>p</sup> | 0.36 |

LSD 0.05% 0.36

Notes: The numbers followed by different letters in the column (a, b, c) and lines (p, q, r) indicates significant difference in the LSD test with a confidence level of 0.05.

Table 3 shows at 60 DAT the Legowo Tapin system produced the highest average plant height of 55.89 cm and was significantly different from the Tegel plant system (53.07cm) and the Legowo
Tabela system (54.45 cm). Whereas the treatment of 54 fish population had the highest average plant height (55.69 cm) and was not significantly different from the population of 80 fish (55, 67 cm) but it was significantly different from the treatment of 27 fish (52.05 cm).

The legowo Tapin planting system produced the highest average plant height. This is because the Legowo planting system enables adjustment on the spacing between clumps and between rows, resulting in compaction of rice in rows and widening the distance between rows. The high yield obtained in the legowo planting system was due to the fact that all rows of plant clumps became outer rows which usually gives higher yields (side crop effect), there were empty spaces for water regulation and more efficient use of fertilizers [9]. Therefore, application of farming input for both vegetative and productive phases were efficiently usable by the rice plants to the fullest.

### 3.2. Production variables

Observable production variables for the rice are number of productive tillers, grains weight per clump, grains weight per plot and production per hectare.

#### Table 4. Average number of productive tillers (unit)

| Planting system | Fish population | Average | LSD 0.05% |
|-----------------|-----------------|---------|-----------|
|                 | S1              | S2      | S3        |           |
| P1              | 11.93<sup>c</sup> | 12.05<sup>c</sup> | 12.63<sup>d</sup> | 12.20     |
| P2              | 14.13<sup>d</sup> | 13.00<sup>c</sup> | 12.68<sup>d</sup> | 13.27     |
| P3              | 13.18<sup>b</sup> | 13.08<sup>b</sup> | 11.15<sup>f</sup> | 12.47     |
| Average         | 13.08           | 12.71   | 12.15     |           |
| LSD 0.05%       | 0.16            |         |           |           |

Notes: The numbers followed by different letters in the column (a, b, c) indicates significant difference in the LSD test with a confidence level of 0.05.

The results showed that fish population treatment, planting systems and the interactions significantly affected the number of productive tillers. Table 4 shows that the Legowo Tapin planting system produced the highest number of productive tillers which was 14.13 and was not significantly different from the Legowo Tabela (13.18) and was significantly different from the Tegel planting system (12.68).

According to Gigih [12] wider plant spacing will increase the number of productive tillers, because the plants roots did not compete each other in absorbing nutrients, as well as less competition in upper plants’ parts especially the leaves in obtaining sunlight. This is in accordance with research by Masdar, Kasim, Rusman, Hakim, & Helm i [13] that the wider the spacing of the more productive tillers will be produced as opposed to narrower spacing.

#### Table 5. Average grains weight per clump (g)

| Planting system | Fish population | Average | LSD 0.05% |
|-----------------|-----------------|---------|-----------|
|                 | S1              | S2      | S3        |           |
| P1              | 24.55<sup>a</sup> | 31.48<sup>a</sup> | 34.13<sup>a</sup> | 30.05     |
| P2              | 45.30<sup>a</sup> | 43.10<sup>c</sup> | 29.73<sup>d</sup> | 39.38     |
| P3              | 29.65<sup>b</sup> | 36.73<sup>b</sup> | 39.05<sup>f</sup> | 35.14     |
| Average         | 33.17           | 37.10   | 34.30     |           |
| LSD 0.05%       | 0.91            |         |           |           |

Notes: The numbers followed by different letters in the column (a, b, c) and lines (p, q, r) indicates significant difference in the LSD test with a confidence level of 0.05.

The analysis of variance shows that the treatment of planting systems and the fish population had a very significant effect on the weight of grains per clump, while the interaction between the two had no significant effect. Table 5 shows the Legowo Tapin system with 27 fish populations (P2S1) produced wighest grains per clump (45.30g) and was significantly different from the Legowo Tapin with a
population of 54 fish (P2S2) which weighed 43.10g. Whereas the Legowo tapin and 80 fish population (P2S3) was not significantly different from the Legowo Tegel with a population of 27 fish.

Table 6. Average grains weight per plot (1000 g)

| Planting system | Fish population | Average | LSD 0.05% |
|-----------------|-----------------|---------|-----------|
|                 | S1          | S2       | S3       |            |
| P1              | 3.73        | 4.03     | 3.50     | 3.75b      |
| P2              | 5.38        | 4.40     | 4.65     | 4.81a 0.20 |
| P3              | 3.80        | 4.10     | 3.68     | 3.86b      |
| Average         | 4.30        | 4.18     | 3.94     |            |

LSD 0.05% 0.20

Notes: The numbers followed by different letters in the column (a, b, c) indicates significant difference in the LSD test with a confidence level of 0.05.

The results of analysis of variance showed that the planting system significantly affected the grain weight per plot while the fish population and interaction between the two factors had no significant effect. Table 6 shows the Legowo Tapin and population of 27 fish (P2S1) gave the heaviest grains per plot of 5.38 kg and was significantly different from the Legowo Tapin and 80 fish population (P2S3) which was 4.65 kg and Legowo Tapin with population of 54 fish (P2S2) which was 3.86 kg.

The weight of seeds is determined by the size of the grain, The size of the grain determines the yield potential [14]. Large and weighty grain indicates more food content and larger embryo size [15].

Table 7. Average production per hectare (1000 kg)

| Planting system | Fish population | Average | LSD 0.05% |
|-----------------|-----------------|---------|-----------|
|                 | S1          | S2       | S3       |            |
| P1              | 3.50        | 3.75     | 3.25     | 3.50b      |
| P2              | 5.05        | 4.10     | 4.38     | 4.51a 0.18 |
| P3              | 3.55        | 3.85     | 3.25     | 3.55b      |
| Average         | 4.03        | 3.90     | 3.63     |            |

LSD 0.05% 0.18

Notes: The numbers followed by different letters in the column (a, b, c) indicates significant difference in the LSD test with a confidence level of 0.05.

Analysis of variance showed that the planting system significantly affected rice production per hectare while the fish population and interaction between the two factors did not significantly affect the production. Table 6 shows the Legowo Tapin system with 27 fish population of (P2S1) gave the highest production of 5.05 tons/ha and was significantly different from the Legowo Tapin with 80 fish population (P2S3) i.e. 4.38 tons/ha and was also significantly different from Legowo Tapin with 54 fish population (P2S2) i.e. 4.10 tons/ha.

The highest production per hectare was obtained by the Legowo Tapin planting system, This system enabled the realization of edge (outer) crops effects which usually gives a higher yield Ministry of Agriculture [16]. Furthermore Abbas, Riadi, & Ridwan [17] stated that the Legowo planting system of 2: 1 will make all rows of the plant clumps be positioned on the edges which make greater opportunity for higher production compared to those that have no edge (outer) crop effect.

3.3. Fish variables

Observable variables related to fish production were fish weight per plot (kg) and mortality level (%). Table 8 and 9 presented these results.

Table 8. Average fish weight per plot (kg)

| Planting system | Fish population | Average | LSD 0.05% |
|-----------------|-----------------|---------|-----------|
|                 | S1          | S2       | S3       |            |
| P1              | 4.73        | 8.43     | 7.70     | 6.95       |
| P2              | 4.95        | 8.10     | 8.68     | 7.24 0.18  |

Analysis of variance showed that the planting system significantly affected rice production per hectare while the fish population and interaction between the two factors did not significantly affect the production. Table 6 shows the Legowo Tapin system with 27 fish population of (P2S1) gave the highest production of 5.05 tons/ha and was significantly different from the Legowo Tapin with 80 fish population (P2S3) i.e. 4.38 tons/ha and was also significantly different from Legowo Tapin with 54 fish population (P2S2) i.e. 4.10 tons/ha.

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3.3. Fish variables

Observable variables related to fish production were fish weight per plot (kg) and mortality level (%). Table 8 and 9 presented these results.
The results showed that the fish population had a very significant effect on the weight of the fish per plot, while the planting system and the interaction between the two factors did not significantly affect the weight of the fish per plot. Table 8 shows that the 80 fish populations treatment produced the heaviest fish per plot and was not significantly different from the treatment of 54 fish populations. Yet, it was significantly different from the 27 fish population treatment.

| Planting system | Fish population | Average | LSD 0.05% |
|-----------------|-----------------|---------|-----------|
| P3              | 4.80            | 8.45    | 8.68      | 7.31      |
| P3              | 4.80            | 8.45    | 8.68      | 7.31      |
| Average         | 4.83<sup>p</sup> | 8.33<sup>q</sup> | 8.35<sup>r</sup> | 0.18      |
| LSD 0.05%       | 0.18            |         |           |           |

Notes: The numbers followed by different letters in the lines (p, q, r) indicates significant difference in the LSD test with a confidence level of 0.05.

Table 8 shows that the 80 fish populations treatment produced the heaviest fish per plot and was not significantly different from the treatment of 54 fish populations. Yet, it was significantly different from the 27 fish population treatment.

The results showed that the fish population had a very significant effect on fish mortality rate, while the lancing system and the interaction between the two factors had no significant effect on fish mortality rate. Table 9 shows that the 80 fish population had the highest average mortality rate of 3.10% and was significantly different from the 54 fish population which was 2.84% and the 27 fish population which was 2.16%.

Fish population density had a significant influence on the weight of fish per plot. Fish stocking density directly related to competition for feed derived from plants. During the fish rearing period in the study site, there were fish deaths incidence, thereby reducing the number of fish stocked. The mortality of the fish was partially caused by predators such as storks, monitor lizards, and mammals living around the research site. Syamsuddin [18] explained that the culture environment is a trigger factor for the coming of predators in and around the culture site that could prey on fish.

Based on the study, the planting system and fish population had significant effect on the number of productive tillers and grain weight per clump. According to Supriyanto, Jazilah, & Anggoro [19], increased nutrient uptake by plants causes the metabolic process to run smoothly, thereby increasing the production of carbohydrates and starches which are translocated throughout the plant for growth and the rest accumulated in plant tissues. Therefore more carbohydrates and starches accumulated in plant tissues will affect plant growth and production.

### 4. Conclusion

The planting system that provided better rice growth and production was the Legowo Tapin planting system, with best yield per hectar of 5.05 tons. Fish populations that gave the best result for the Minapadi system was the 27 fish populations. There was an interaction between the rice planting system and tilapia fish population on the number of productive tillers of the rice.

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