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RICE (*Oryza sativa* L.) GROWTH AND PRODUCTION IN MAIN SQUARE SYSTEM TREATMENT WITH LIQUID ORGANIC FERTILIZER OF GOLD SNAILS (*Pomacea caniculata* L.) AND CITRONELLA OIL (*Cymbopogon nardus* (L.) Rendle)

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Abstract. *The use of artificial chemicals as fertilizers and pesticides can endanger the health of the environment and consumers, so the potential utilization of natural materials as fertilizers and pesticides needs to be increased from local sources such as golden snails and citronella. The experiment aims to get the best interaction between golden snail Liquid Organic Fertilizer (LOF) and citronella oil for rice growth and production. The experiment was carried out in the paddy fields of Jorong Paraman Ampalu, Gunung Tuleh District, West Pasaman Regency from September 2020 to January 2021 using an RBD of 2 factors with 3 replications. The first factor was the golden snail LOF concentration, namely: 0, 100, 200, and 300 ml/L. The second factor was the citronella oil concentration, namely: 0, 10, 20, and 30 ml/L. Data were analyzed with ANOVA and DNMRT at 5% and 1%. The experimental results showed that the interaction between golden snail LOF and citronella oil concentration accelerated flowering, increased panicle length, grain weight, and dry grain production per hectare, while the golden snail LOF concentration factor increased plant height, maximum number of tillers and productive tillers, panicle length, number of grains per panicle, and 1000 grain weight. The highest grain production was obtained at concentrations of golden snails LOF of 200 ml/L and citronella oils 20 ml/L, namely 9.18 t/ha. The frequency of attacks by ground beetles and golden snails decreased at a concentration of 30 ml/L citronella oil, while stink bug infestation frequency was reduced at a concentration of 10 ml/L.*

Keywords: *citronella oil; LOF gold snails; main square system*

1. Introduction

Planted areas and rice production are still different. The harvested area was 10.66 million ha in 2020, went down 20 thousand ha (0.19%) from 10.68 million ha in 2019, but production increased slightly. Rice production in 2020 was 54.65 million tons of dry milled grain (DMG), while in 2019, it was 54.6 million tons DMG, 50 thousand tons more than in 2019 (BPS, 2021). This increase in production cannot be separated from the strengthening measures carried out so far, such as the improvement of varieties and the use of innovations in the cultivation of rice. One of today's lesser-known innovations in high-yield agricultural technology is the Main Square System or SBSU (Utama, 2019). This system was developed from the System of Rice Intensification (SRI) method and a cropping pattern that alternates between two or more (usually two or four) rows of rice plants and one empty row (Jajar-Legowo method) and is modified with different planting points. This system adjusts the planting distance in clumps (four planting points) with other clumps, known as a one-one cropping system (Sunadi *et al.*, 2019; Sunadi *et al.*, 2020;

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Sunadi *et al*., 2021). The SBSU system also regulates the age of seed planted and the use of soil amendments made from organic materials such as cow manure, chicken manure, compost, and irrigation systems to control golden slug pests and weeds (Utama, 2019). In addition, we found higher grain production in his SBSU system than in the conventional system (Sunadi *et al*., 2021; Utama *et al*., 2019).

Success in increasing rice production is always followed by an increase in the need for both inorganic and organic fertilizers. The use of chemical fertilizers and artificial chemical pesticides can have adverse effects on the environment, such as aquatic microcosms (Henry *et al*., 2013) and consumers, while organic fertilizers are important ingredients in building soil fertility physically, chemically, and biologically. The results showed an increase in soil bacterial biomass, rice growth, and nitrogen cycle activity (Kai *et al*., 2020). Therefore, the use of organic fertilizers should be increased using readily available, cheap, and high-quality resources, such as the use of golden snails.

Golden snails can be used as an organic fertilizer because they contain enough chitin and other elements to fertilize the soil, increase soil quality, and act as a source of beneficial microorganisms. Liquid Organic Fertilizer (LOF) Golden Snail contains the essential amino acids histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, and valine (Madusari *et al*., 2021). Golden snail LOF increases melon growth and yield (Andriani, 2019), and increases shoot number, panicle length, number of mature seeds, and seed weight in rice (Sulfianti *et al*., 2018). Golden snails have the potential to be used as fertilizer in environmentally friendly rice plantations (Siregar *et al*., 2017). Japanese snail residue increases plant height and corn leaf length (Abello *et al*., 2021). Golden apple snail residues can provide soil amendments to increase pH and prevent soil degradation, enrich nutrients, and increase soil exocellular enzyme activity (Wang *et al*., 2020a; Wang *et al*., 2020b).

The threat to plants from plant-pest organisms (PPO) continues to increase which forces farmers to use chemical pesticides massively which has a very bad impact on the health of the environment and consumers. Therefore, PPO control using natural pesticides is the most appropriate, inexpensive, and safe alternative for the environment. Botanical pesticides are easily decomposed into harmless materials, making them an alternative in pest control that is environmentally friendly. A mixture of cumin, orange peel, and wintergreen oils as botanical pesticides can control desert locusts and locusts (Abdelatti & Hartbauer, 2020). The potential of essential oils and their fractions from the leaves and rhizomes of wild ginger as botanical fungicides has also been discovered (Nurmansyah *et al*., 2021). Various essential oils as additives in the formulation of botanical pesticides *Piper aduncum* essential oil positively affected increasing antifungal activity (Nurmansyah *et al*., 2022). Citronella is a type of plant that has the potential to be developed as an organic insecticide (Salaki & Montong, 2019) because citronella oil contains many types of compounds that are pesticides (Baker *et al*., 2008). The results of the enriched consortium bacteria and golden snail analysis showed that the highest concentration was citronella (35.97%), nerol (17.28%), citronellol (10.03%), geranyl acetate (4.44%), elemole (4.38%), limonene (3, 98%), and citronellol acetate (3.51%) (Setiawati *et al*., 2011). The results of other studies showed that citronella oil is effective in controlling populations of fruit-bearing insects (Papulwar *et al*., 2020). Citronella oil is also effective in controlling brown planthoppers (Himawan *et al*., 2021) and its use is safe against non-target organisms and the environment (Bajpai, 2019; Chaubey, 2019). Gold snail flour can increase the toxicity of *Bacillus thuringiensis* against pests of *Spodoptera litura* (Pujiastuti *et al*., 2018). Previous research focused on studying the effect of a single factor from golden snail liquid organic fertilizer and citronella oil but this study aimed to obtain the best interaction between golden snail liquid organic fertilizer and citronella oil in increasing the growth and production of rice with the main square system and its effectiveness in controlling important pests in rice cultivation.

2. Methods

The experiment was conducted from September 2020 to January 2021 in Jorong Paraman Ampalu, Nagari Rabi Jonggor, Gunung Tuleh District, West Pasaman Regency, West Sumatra, with an altitude of 500-700 m above sea level, on rice fields with soil type of alluvial, pH 5-7, rainfall ±3500 mm/year, and average temperature 26-30^{o}C. The experiment used golden snail LOF, citronella leaf extract, IR-64 rice seeds, and the main fertilizer of Urea, NPK, SP-36, and KCl. The experiment used a two-factor randomized block design (RBD) with three replications. The first factor was the LOF concentration of the golden snail, which had 4 levels, namely: 0, 100, 200, and 300 ml/L. The second factor was the concentration of citronella oil at four levels, namely: 0, 10, 20, and 30 ml/L.

The rice fields were first plowed with a hand tractor, then flooded with water and 48 plots of 1.85 m x 1.85 m were made. Seedlings were planted 14 days after sowing (DAS) using the SBSU Type 4 system, with row spacing of 40 cm, and row spacing of 25 cm, and seedling spacing in subgroups was 7.5 cm. The production of golden snail LOF is through a fermentation process that starts with 5 kg of golden snail which has been crushed by pounding, 5 L of coconut water, 5 kg of rice bran, 15 L of well water into a plastic bucket then added by EM-4 300 ml and molasses 450 ml then stir well and close tightly. The bucket cover is perforated as a place for the end of the hose and the other end of the hose is connected to a bucket filled with water which functions to maintain air pressure. After 15 days, the fermented product can be harvested with a characteristic of yellow-brown color, then squeezed using a cloth, and subsequently stored in a plastic bottle. The citronella oil used comes from steam distillation of citronella leaves at a farmer's refinery in Jorong Bandar, Gunung Tuleh District, West Pasaman Regency, West Sumatra.

LOF golden snail and citronella oil were applied to plants 1 week after planting (WAP) and repeated weekly until rice plants reached the reproductive stage. Citronella oil was dissolved in a litre of water in a concentration corresponding to each treatment and then sprayed on the plants in the form of a mist with a nozzle. Plant growth components were observed from five sample plant clusters per plot from each experimental unit, then the observation results were averaged. The variables observed in this study were: plant height, total number of tillers, number of productive tillers, flowering age, panicle length, number of grains per panicle, weight of 1000 grains, dry grain weight per clump, and dry grain production per hectare. The total number of tillers was calculated at the time the panicles emerge, namely by counting the number of plant stems that emerge from the base of the clump and have at least 2 full leaves (one *phytomer*). The number of productive tillers per clump was calculated from all the tillers that produced panicles in each clump of each experimental unit at the time of harvest. Harvest age was calculated from the number of days from sowing to harvest at physiological maturity. The length of the panicle was measured from the base of the panicle, namely where the branching node of the panicle stems to the tip of the spike at the time of harvest. The number of grains per panicle was calculated from all grains formed on all panicles per clump and then divided by the total number of panicles per clump on the sample plants from each experimental unit. The weight of 1000 grains were weighed from the results of the rice grains in each experimental unit plot which were taken randomly. The dry grain yield weight (MDG) per clump was obtained by weighing the grain yield from the five sample plants for each experimental unit plot and then averaging it, while the grain production per hectare was obtained from the conversion of grain production per plot using the following Formula (1).

$$\text{Production of MDG} = \frac{10.000\ \text{m}^2}{\text{Area Per Plot (m}^2\text{)}} \times \text{Production of MDG Per Plot (kg)} \qquad (1)$$

Then, the grain yield is converted into 14% of water moister content (MC) in the following Formula (2).

$$\text{Grain Yield (at 14\% MC)} = \frac{100 - \text{MC}}{(100-14)} \times \text{Grain Yield (g)} \qquad (2)$$

As an additional variable, the frequency of attack of three main rice pests was also observed, namely: ground bed bugs, golden snails, and stink bugs. Observations were made during the vegetative and generative growth phases by calculating the frequency of each pest attacking the plants in each experimental unit plot using the Formula (3).

$$F = \frac{S}{R} \times 100\% \quad (3)$$

Information :
F: Frequency of pest attacks
S: Number of plants attacked
R: Total number of plants

Data were analyzed using Analysis of variance and Duncan's New Multiple Range Test (DNMRT) tests at 5% and 1% significance levels.

3. Results and Discussion

3.1. Plant Height, Maximum Number of Tillers, Number of Productive Tillers, and Flowering Age of Paddy Rice.

Plant height, maximum number of tillers, number of productive tillers, and flowering age of paddy rice were affected by golden snails LOF concentration. The application of golden snail liquid organic fertilizer significantly increased the paddy's growth as represented by the parameters of plant height, number of tillers, and productive tillers. However, increasing the dose from 100 to 200 and 300 mL L^{-1} did not have a significant effect on the growth, especially the number of tillers and productive tillers (Table 1). Some of the previous studies are likely to be the cause of this increase in growth, namely, according to Nugroho *et al.* (2020) and Setiawan *et al.* (2016) that the golden snail LOF is a suitable growing medium for both the consortium of soil bacteria. According to Sulfianti *et al.* (2018) that the addition of golden snail meat to liquid organic fertilizer increases N, P and K levels of the liquid fertilizer.

Table 1. Plant height, the maximum number of tillers, and the number of productive tillers of lowland rice plants treated with LOF concentration of golden snails.

The Concentration of Golden Snail LOF (ml/L)	Plant Height (cm)	Number of Tillers (stem/clump)	Number of Productive Tillers (stem/clump)
0	79.48 ab	28.00 b	20.50 b
100	83.33 a	38.08 a	32.08 a
200	76.54 b	35.25 a	30.50 a
300	77.46 b	34.83 a	31.58 a
CV	4.41 %	12.93 %	15.35 %

Column numbers followed by the same letters are not different according to the DNMRT 1%
LOF = liquid organic fertilizer

The increased number of rice was due to LOF nutrients from the golden snail. The nutritional content of this golden snail shell and LOF meat is 4.85% N. 0.77% P; 2.47% K (Sulfianti *et al.*, 2018). As the number of N nutrients in the soil increases, the number of N nutrients, especially chlorophyll in the leaves increases. The role of the element N is very important in the growth process of some rodents (Azalika *et al.*, 2018). The nutrient N is required by plants in larger numbers than other nutrients because N plays a very important role in photosynthetic activity, thereby affecting plant growth and yield (Ambarita, 2017).

The treatment without LOF of golden snails accelerated flowering by increasing the concentration of citronella oil to 30 ml/l and this acceleration reached 2 days, but the use of LOF gold snails 100 ml/L and the use of 20 ml/L citronella oil slowed the flowering ages. Increasing the LOF concentration of gold snails to 200 ml/L and 300 ml/L with the application of citronella oil at concentrations of 0 - 30 ml/L did not produce different flowering ages (Table 2). However, these results are different from those found in Ciherang rice, in which the use of golden snail plus bacterial consortium can accelerate flowering (Setiawan *et al.*, 2016).

Table 2. Age of flowering of paddy rice plants treated with golden snail LOF concentration and citronella oil.

The Concentration of Golden Snail LOF (ml/L)	Concentration of Citronella Oil (ml/L)			
	0	10	20	30
	……........................... DAP…..…………............……			
0	67.00 Bb	67.00 Bb	67.00 Bb	65.00 Aa
100	65.00 Aa	65.33 Aab	66.00 Bab	65.33 Aa
200	65.00 Aa	65.33 Aa	65.00 Aa	65.00 Aa
300	65.00 Aa	65.00 Aa	65.00 Aa	65.00 Aa
KK = 0.38 %				

Numbers in one row followed by capital letters and in one column followed by the same lowercase letter are the same according to the DNMRT 1%; LOF = liquid organic fertilizer; DAP = days after planting

3.2. Panicle Length, Grains Number Per Panicle, and Weight of 1000 Grains

Golden snail LOF concentration and its interaction with citronella oil affected panicle length, but the number of grains per panicle and 1000-grain weight were only affected by golden snail LOF concentration. The panicle length increased when the citronella oil concentration increased to 30 ml/L in the concentration of golden snails LOF with 0 ml/L, but the panicle length did not change when given golden snail LOF 100 – 300 ml/L with all concentration levels of citronella oil. In general, the longest panicles were obtained at a golden snail LOF concentration of 100 ml/l for all citronella oil concentration levels (Table 3).

Table 3. Panicle length of paddy rice that received LOF concentration treatment of golden snail and citronella oil.

The Concentration of Golden Snail LOF (ml/L)	Concentration of Citronella Oil (ml/L)			
	0	10	20	30
	……………..........................cm...........…………........…			
0	22.63 Bb	21.90 Bb	26.27 Aa	26.37 Aa
100	24.77 Aa	25.20 Aa	24.77 Aa	26.07 Aa
200	25.77 Aa	25.37 Aa	25.93 Aa	25.87 Aa
300	25.37 Aa	25.83 Aa	26.07 Aa	25.47 Aa
CV = 0.38 %				

Numbers in one row followed by capital letters and in one column followed by the same lowercase letter are the same according to the DNMRT 1%; LOF = liquid organic fertilizer

The number of grains per panicle increased with an increase in the dose of LOF of golden snails to 300 ml / L, which reached 153.08 grains per panicle. While the weight of 1000 grains increased until the concentration of 100 ml / L, but the weight of 1000 grains did not increase with the addition of LOF concentrations of golden snails 200 - 300 ml / L (Table 4).

Table 4. The grains number per panicle and weight of 1000 grains of paddy rice treated with golden snail LOF concentration.

The Concentration of Golden Snail LOF (ml/L)	Total Grain (ear/panicle)	Weight 1000 Grain (g)
0	131.67 b	25.17 b
100	147.42 ab	29.33 a
200	147.00 ab	27.67 ab
300	153.08 a	28.00 ab
CV	12.33 %	7.30 %

Column numbers followed by the same letters are not different according to the DNMRT test 1%; LOF = liquid organic fertilizer

3.3. Dry Grain Weight and Grain Production

Dry grain weight per clump and dry grain production were affected by the interaction of the concentration of golden snail LOF and citronella oil. The dry grain weight per clump increased with increasing concentrations of citronella oil at all levels of golden snail LOF concentration. In general, the highest yield of dry grain weight was obtained when the LOF concentration of the golden snail increased in the concentration of citronella oil increased (Table 5).

Table 5. Dry grain weight per clump of paddy rice main square system treated with LOF golden snail and citronella oil concentrations.

The Concentration of Golden Snail LOF (ml/L)	Concentration of Citronella Oil (ml/L)			
	0	10	20	30
	……..………………..........	g/clump	....…........………..............	
0	115.67Cb	121.67Bb	118.00BCb	131.33Aa
100	121.33Ba	125.00ABab	130.33Aa	126.00ABb
200	121.67ABa	117.33Bb	125.67Aab	125.33Ab
300	119.67Cab	128.00Aa	124.67ABab	123.67ABb
CV = 3.98 %				

Numbers in one row followed by capital letters and in one column followed by the same lowercase letter are the same according to the DNMRT 1%; LOF = liquid organic fertilizer

Grain yield increased when LOF was given at high concentrations (200–300 mL/L) with increasing citronella oil concentration, but at 100 mL/L, grain yield did not increase with increasing citronella oil concentration. Grain yield did not increase with golden snail LOF up to 300 ml/L when citronella oil concentrations of 0 and 30 ml/L were used, and grain yield was reduced at 10 ml/L, but at the use of 200 ml/L, there was an increase in grain production by giving citronella oil snail 20 ml/L (Table 6). This increase in grain yields can occur because it is supported by sufficient nutrients from the golden snail LOF and protected from pest attacks by using citronella oil insecticides so that the yield of grain per clump will increase. Furthermore, the grain production will be higher. As a comparison, the highest yield of milled dry unhusked rice was obtained from the golden snail LOF treatment with a concentration of 42 ml/L, which was 6.39 ± 0.50 t/ha (Nugroho *et al*., 2020).

Table 6. Production of dry unhulled paddy rice in the main square system treated with golden snail LOF concentration and citronella oil.

The Concentration of Golden Snail LOF (ml/L)	Concentration of Citronella Oil (ml/L)			
	0	10	20	30
	……………................. t MDG/ha ......………………....			
0	7.62Ba	8.00Aa	7.92Bb	7.67Ba
100	6.36Aa	6.98Ab	7.19Ab	6.60Aa
200	7.16BCa	6.27Cb	9.18Aa	7.97ABa
300	7.66Ba	7.40Bab	8.45Aab	6.74Ba
CV = 13.21 %				

Numbers in one row followed by capital letters and in one column followed by the same lowercase letter are the same according to the DNMRT 5%; LOF = liquid organic fertilizer; MDG = milled dry grain

Element N is the building block of amino acids, an integral part of chlorophyll, and plays a very important role in the process of photosynthesis, the result of which is stored in grains (Ritonga *et al*., 2019). The higher the N, P, and K content of a given LOF, the higher the grain weight. LOF provides sufficient nutrients to meet rice growth and yield requirements, so as to maximize the filling and weight of rice grain (Sulfianti *et al*., 2018).

3.4. Frequency of Pest Attack

The frequency of attacks by three insect pests (ground bed bugs, golden snails, and stink bugs) was not affected by golden slug LOF, but was affected by the addition of citronella oil. A citronella oil concentration of 30ml/L was able to reduce the frequency of attacks by ground bugs and golden snails, while a concentration of 10ml/L significantly reduced stink bug pests. Compared to the control of ground bed bugs pest, frequency was significantly reduced from 38.33% to 24%, golden snail pests from 46.67% to 21.67% at a concentration of 30 ml/L, and stink bugs has decreased. It increased significantly from 50% to 26.0% at a concentration of 10 ml/L (Table 7). Lemongrass as a close cousin of the citronella plant also produces essential oils that can affect the locomotion of *L. oratorius* insects, and the higher the concentration, the faster the insecticide kills the insects (Salaki & Montong, 2019). Citronella oil can function as an anti-eating and repellent insecticide (Papulwar *et al*., 2020), how it functions by interfering with the insect octopaminergic nervous system (Bajpai, 2019). Citronella contains biotoxic compounds such as citric acid, citronella, geraniol, nerol, farnesol, methylheptenone, and dipentene. Farnesol is a sesquiterpene compound that is toxic and allergenic and may repel various pests (Koul *et al*., 2008).

Table 7. Frequency of attacks of ground bed bugs, golden snails, and stink bugs on paddy rice crops treated with citronella oil.

Types of Pests	Concentration of Citronella Oil (ml/L)			
	0	10	20	30
	……................... Frequency (%) …………………….			
Ground bed bugs	38.33B	26.67AB	25.00AB	24.17A
Golden snail	46.67B	26.67B	30.00B	21.67A
Stink bug	50.00B	26.67A	26.67A	25.83A

Inline numbers followed by the same capital letters are not different according to the DNMRT 1%.

The mechanism of action of citronellal contact poison is to inhibit the enzyme acetylcholinesterase, causing phosphorylation of the amino acid serine in the stellate center of the enzyme in question. Pest poisoning results from the accumulation of acetylcholine, which causes central nervous system damage, seizures, respiratory paralysis, and death (Rohimatun & Laba, 2013). The content of citronella oil can suppress the invasion of pests into rice, thus making the flowering process more optimal. Citronella oil and citronella ingredients are repellents and insecticides. Furthermore, since citronella oil is effective in controlling brown planthopper pests (Himawan *et al*., 2021), its effectiveness, especially against rice worms and bed bugs, may arise due to the similarity of these two pests to brown planthopper.

4. Conclusion

The interaction of gold snail liquid organic fertilizer with citronella oil can accelerate flowering time and increase panicle length and dry grain weight. The highest dry grain production, namely 9.18 tons of DMG/ha, was obtained at a LOF concentration of gold snail LOF 200ml/L and citronella oil 20ml/L, but to reduce the frequency of attacks by bedbugs and golden snails, citronella oil with a concentration of 30 ml/L can be used, while for stink bugs, using a concentration of 10ml/L is sufficient.

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