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Effectiveness of Liquid Smoke Concentration of Red Fruit Seed Waste As A Bioherbicide on the Physiology and Yield of Moai Upland Rice by Intercropping with Black Soybeans in Jayawijaya District

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Abstract

Bioherbicide from red fruit seed waste and contains phenolic compounds. The objective are: 1) to analyze the effectiveness of red fruit seed waste on the physiology and yield of Moai upland rice; 2) to analyze which concentration of red fruit seed waste liquid smoke is most effective on the physiology and yield of Moai upland rice plants. The design used in this research was a Complete Randomized Block Design with two treatment factors, namely two factors intercropping Moai with black soybeans (T1), Moai rice monoculture (T2), and the second factor is: a) Concentration of 0 ml liquid smoke/l water (S0); b) Concentration of 200 ml liquid smoke/l water (S1); c) Concentration of 250 ml liquid smoke/l water (S2); d) Concentration of 300 ml liquid smoke/1 water (S3). Conclusion: 1) Liquid smoke from red fruit seed waste is effective on the net assimilation rate and growth rate of Moai; number of panicles, dry weight of 100 seeds, number of hollow seeds and number of pithy seeds of Moai; harvest index and chlorophyll content of Moai; 2) The most effective concentration of red fruit seed waste liquid smoke on the physiology and yield of Moai plants is the concentration of red fruit seed waste liquid smoke of 250 ml liquid smoke/l water (S2).

Keywords: *Bioherbicide, Liquid Smoke, Phenolic, Red Fruit, Upland Rice.*

Introduction

Jayawijaya Regency is one of the regions in Papua, Central Highlands, Indonesia which has launched food security for its residents. The agricultural system implemented by local farmers is traditional organic farming (without any input and good management during the cultivation process) carried out in addition to substitute types of food in the area, such as tubers, which are the staple food of the local community. Over time, rice consumption patterns have become popular again due to multiculturalization in the Central Mountains of Papua.

One type of rice variety currently being developed in Jayawijaya Regency is the local Moai variety, which is a type of upland rice or field rice which has accompanied people's consumption patterns rather than having to import rice from outside which is known to require expensive costs due to the high price of imported material supplies and the transportation process only use aeroplanes. Black soybeans are also a commodity that has high potential to be developed intensively. Sitti et al. (2017) said that Papua has great opportunities to develop soybeans because it is supported by potential land spread across several development centres.

Regarding the local wisdom of the community in the agricultural sector so far, it is a cultivation system without utilizing any planting inputs and a planting system that is only monoculture. Therefore, the intercropping system is a method for increasing land productivity and reducing the risk of failure in crop production. An intercropping system with plants with wide leaf morphology, such as legumes, can suppress weed growth. The intercropping system between upland rice and soybeans is also a solution to reduce weed growth for the upland rice monoculture system that local communities have implemented.

Development of innovations in planting and developing upland rice and black soybeans in Jayawijaya Regency through good and correct cultivation technical management in one crop intercropping system. Weeds are plants that can reduce upland rice production, where the growth of weeds can be controlled and reduced in density through an intercropping system between upland rice and soybeans. Weeds are the main cause of crop yield loss through competition for light, water, nutrients, CO2, space, etc. Research results show that late weed control can reduce upland rice yields by up to 35% (Toure et al., 2013). Intercropping

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of rice and soybeans can be applied because these two plants have complementary effects. Rice requires large amounts of N for growth and development, while soybeans can fix large amounts of N in the air through the root nodules that form (Susilo and Parwito, 2013).

One of the organic materials which are thought to be able to be used as a biocontrol is red fruit seed waste, which is pyrolytically converted into liquid smoke, and so far, it is known to play a role in controlling armyworm pests on sweet potato plants, as has been proven through research by Dewi et al., 2021. Results research by Dewi et al. (2021) shows that a phenolic compound content of 4.94% can kill armyworm pests on sweet potato plants.

One of the compounds contained in liquid smoke from red fruit seed waste is phenolic compounds, which are known to be able to eradicate weeds in cropping systems. Phenolic compounds, as one of the secondary metabolites contained in the allelochemicals of pecans, can be of various types in different plant parts and ages and have the potential to inhibit weed germination (Kusuma et al. 2017). Phenolic compounds can cause a decrease in membrane permeability. Furthermore, phenolic compounds in Ageratum conyzoides can inhibit the growth of weeds, which are thought to contain secondary metabolite compounds such as flavonoids, alkaloids, terpenes, chromene, chromone, benzofuran coumarin essential oils, sterols and tannins (Tampubolon et al. 2018). Furthermore, according to research by Jiayu Li et al. (2015), phenolic compounds can control weed activity. Allelopathic shoots of *Sorghum bicolour* (L.), which contain many phenolic compounds, can provide effective and environmentally friendly weed control (Won, 2013)

The aims of this research are: 1) to analyze the effectiveness of red fruit seed waste on the physiology and yield of upland rice; 2) to analyze which concentration of red fruit seed waste liquid smoke is most effective on the physiology and yield of upland rice plants.

Material and Methods

The research location was in Kurulu District, Jayawijaya Regency. The research was carried out in November 2023 – May 2024. The design used in this research was a Complete Randomized Block Design (RAKL) with 2 (two) first treatment factors, namely the first 2 (two) treatment factors, namely a combination of intercropping of Moai upland rice with black soybeans (T1), Moai rice monoculture (T2), and the second factor is the concentration of liquid smoke from red fruit seed waste which includes a) Concentration of 0 ml liquid smoke/l water (S0); b) Concentration of 200 ml liquid smoke/l water (S1); c) Concentration of 250 ml liquid smoke/l water (S2); d) Concentration of 300 ml liquid smoke/1 water (S3).

Results and Discussion

Table 1. Net Assimilation Rate of Moai Rice Plants; Moai Rice Plant Growth Rate

Treatment	Net Assimilation Rate of Moai Rice Plants	Moai Rice Plant Growth Rate
Planting Pattern (T)		
T1	0.013 a	0.0006 a
T2	0.013 a	0.0005 a
Red Fruit Seed Waste Liquid Smoke Concentration (S)		
S0	0.006	0.0002 ab
S1	0.007	0.0002 b
S2	0.003	0.0002 a
S3	0.004	0.0001 b
Interaction T x S		
T1SO	0.019 a	0.0006 a
T1S1	0.017 a	0.0005 ab
T1S2	0.004 bc	0.0007 a
T1S3	0.013 ab	0.0004 b

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T2S0	0.011 abc	0.0005 ab
T2S1	0.020 a	0.0004 b
T2S2	0.013 ab	0.0006 a
T2S3	0.010 abc	0.0004 b

In table 1, it can be seen that the treatment combinations are T1S0 (Moai rice intercropping + soybeans with control), T1S1 (Moai rice intercropping + soybeans with a concentration of liquid smoke from red fruit seed waste of 250 ml liquid smoke/l water) and T2S1 (monoculture of Moai rice with a concentration of liquid smoke from red fruit seed waste of 250 ml liquid smoke/l water) produces a high net assimilation rate and is not significantly different. The high NAR in the three treatment combinations is probably due to the fact that in these treatments, the area of the plant leaves is not too large so that there is no mutual shading between the plant leaves or does not have an impact on reducing the capacity of the leaves to absorb the plant which will ultimately result in the photosynthesis process being hampered. Apart from that, providing a concentration of liquid smoke from red fruit seed waste with its phenolic content will indirectly cause competition with weeds to be controlled so that the plant growth process will not be hampered indirectly.

The plant growth rate (PGR) of Moai rice plants appears significant due to the interaction between planting patterns and the concentration of liquid smoke from red fruit seed waste. In this interaction, it can be seen that the growth rate of Moai rice plants is the lowest at 0.0004 g/m2/week and there is a combination of treatment T2S1 (Moai monoculture with a concentration of liquid smoke from red fruit seed waste of 200 ml liquid smoke/l water) and T2S3 (Moai monoculture by giving a concentration of red fruit seed waste liquid smoke of 300 ml liquid smoke/l water). The low growth rate of this plant is probably due to the fact that in Moai rice monoculture, there is shading between plants, so the photosynthesis process is low. This high level of shading between plants is probably also caused by the concentration of liquid smoke from red fruit seed waste, one of the contents of which is acetic acid, which is a precursor of the hormone auxin. According to Sulthon et al. (2018), the high photosynthesis process influences the increased growth rate. The ability of leaves to utilize sunlight as a source for the photosynthesis process is a major factor in plant growth rate.

Table 2. Number of Panicles Per Clump; Dry Weight 100 Seeds; Number of Empty Seeds; Number of Moai Rice Berries;

Treatment	Number of Panicles Per Clump	Dry Weight 100 Seeds	Number of Empty Seeds	Number of Inpari Rice Berries
Planting Pattern (T)				
T1	3.500 a	4.840 a	193.53 a	0.141 a
T2	3.533 a	4.266 b	247.0 a	0.132 a
Red Fruit Seed Waste Liquid Smoke Concentration (S)				
S0	1.353	1.514 b	107.71 a	0.063
S1	1.380	2.130 a	32.44 b	0.065
S2	1.553	1.822 ab	122.20 a	0.050
S3	1.340	1.818 ab	90.07 ab	0.040
Interaction T x S				
T1SO	3.933 ab	3.766 cd	79.22 de	0.176 ab
T1S1	3.066 bc	5.406 a	85.44 de	0.196 a
T1S2	3.600 abc	4.563 bc	323.67 ab	0.086 bc
T1S3	3.400 abc	5.623 a	285.78 bc	0.106 ab
T2S0	2.833 c	3.803 cd	459.33 a	0.140 ab
T2S1	3.833 abc	5.246 ab	76.78 de	0.130 ab
T2S2	4.166 a	4.550 bc	287.33 bc	0.163 a
T2S3	3.300 abc	3.466 d	164.56 cd	0.096 abc

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In the combination of planting patterns, the highest number of panicles per hill was found in the Moai rice + soybean intercropping pattern (T1), which was 3,533 and was not significantly different if we compared it with the Moai monoculture treatment (T2), which was 3,500. In the intercropping pattern (T1), the light received is sufficient for the growth, provision or formation of panicles, either directly supplying energy for photosynthesis or indirectly through other climate elements. Sunlight influences physiological processes related to seed production since plant vegetative growth, storage organ formation, and seed filling (Dewi et al., 2014). The concentration of liquid smoke from red fruit seed waste of 250 ml liquid smoke/l water (S2) gives a high number of panicles per bush when we compare it with other treatments, namely 1,553. This is thought to be because, at this concentration, acetic acid, which is also contained in liquid smoke from red fruit seed waste, can stimulate and accelerate plant growth without exception to the number of panicles per hill. Research results from Yatagai (2002) and Istiqomah and Kusumawati (2020) show that the contents of liquid smoke (wood vinegar), such as acetic acid and methanol, can accelerate plant growth.

The intercropping pattern of Moai rice + soybeans (T1) produces a high dry weight of 100 seeds, namely 4,840 grams and is significantly different from the monoculture planting pattern of Moai rice (T2), which produces a dry weight of 100 seeds of 4,266 grams. The low dry weight of 100 seeds in a monoculture planting pattern is probably caused by the photosynthesis process in monoculture not being optimal, which will affect assimilation. Dewi et al. (2014) stated that high levels of photosynthesis due to optimum light intensity in crops supported by sufficient water availability produce sufficient assimilate for seed filling, which ultimately contributes to density, 1000 grain weight, and high yields. The concentration of red fruit seed waste liquid smoke of 200 ml liquid smoke/l water (S1) was seen to produce a high dry weight of 100 seeds, namely 2,130 grams and was significantly different from other treatments. It is suspected that at this concentration, one of the compounds contained in liquid smoke from red fruit seed waste, namely acetic acid, can influence and stimulate the growth and production of a plant. Liquid smoke contains acetic acid and methanol, which can stimulate plant growth (Yatagai et al., 2002 *cit* Amiroh, 2022); apart from that, it can also repel and control plant pest organisms (OPT).

The interaction between planting patterns and the concentration of liquid smoke from red fruit seed waste has a significant effect on the parameter number of empty seeds. In this interaction, the T2S0 treatment (Moai rice monoculture with control) produced many empty seeds, namely 459.33. The high number of empty seeds in this treatment was possible because the light intensity received by Moai upland rice was low, coupled with the competition with weeds. Low light intensity will reduce photosynthetic activity so that the allocation of photosynthesis to the reproductive organs is also reduced. Apart from that, this may also be due to the number of tillers that continue to form until just before harvest in Moai rice, thereby increasing the number of empty grains. This is supported by research conducted by Wangiyana et al. (2020), which showed that the formation of tillers after 35 or 45 days after planting is not effective in producing pithy seeds. This is thought to occur due to competition between plant sources and sinks for assimilation and nutrients during seed filling.

The combination of T2S2 treatment (Moai rice monoculture with a red fruit seed waste liquid smoke concentration of 250 ml liquid smoke/l) gave a total of The largest number of Moai rice seeds is 0.163. The high number of pithy seeds in this treatment combination is possible because in this treatment, competition with weeds is low, plus the provision of a concentration of red fruit seed waste liquid smoke of 250 ml liquid smoke/l can increase nutrient uptake in plants. This is in line with the opinion of Murniati et al. (2020), who state that liquid smoke can increase nutrient uptake in plants.

Table 3. Harvest Index and Chlorophyll Content of Moai

Treatment	Harvest Index	Chlorophyll Content of Inpari
Planting Pattern (T)		
T1	0.141 a	0,67 b
T2	0.132 a	0,75 a
Red Fruit Seed Waste Liquid Smoke Concentration (S)		

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S0	0.063	0,23 d
S1	0.065	0,26 c
S2	0.050	0,36 a
S3	0.041	0,29 b
Interaction T x S		
T1SO	0.176 ab	0,52 h
T1S1	0.196 a	0,61 g
T1S2	0.086 cb	0,88 b
T1S3	0.106 ab	0,69 d
T2S0	0.140 ab	0,63 f
T2S1	0.130 ab	0,67 e
T2S2	0.163 ab	0,93 a
T2S3	0.096 abc	0,78 c

The harvest index for Moai rice plants in the intercropping pattern (T1) of 0.141% looks better than the monoculture planting pattern (T2), which is 132%. This is in line with the growth rate of Moai rice plants. There is a relationship between the harvest index and yield. The higher the harvest index value, the greater the seed yield produced, and vice versa. Yuliana, Sumarni, and Fajriani (2013) explained that the harvest index describes the proportion of photosynthate that is translocated into the food reserve storage section. The photosynthate of the Moai rice plant produced by the leaves is translocated to the food reserves in the form of seeds. Although the concentration of liquid smoke from red fruit seed waste did not provide significant results on the harvest index of Moai rice plants, we can see in table 3 that the highest harvest index for Moai rice plants was found when the concentration of liquid smoke from red fruit seed waste was 200 ml of smoke. liquid/l (S1) by producing a Moai rice harvest index of 0.065%. The high harvest index at this concentration may be due to the fact that at this concentration, the compounds contained in liquid smoke from red fruit seed waste are high in acetate compounds, while phenolic compounds are low, which stimulates more plant growth and production.

Chlorophyll is a green pigment in leaves which functions to absorb photosynthetic light energy. The chlorophyll concentration value in the leaves indicates the health status of a plant, and healthy plants will produce more fruit (Kurniawan et al., 2021). In table 3 regarding the chlorophyll content in Moai rice, it can be seen that the planting pattern treatment and the concentration of liquid smoke from red fruit seed waste have a significant effect on the chlorophyll content in Moai rice plants. In the cropping pattern treatment, it can be seen that Moai rice planted in monoculture (T2) produces a high chlorophyll content and is significantly different, namely 0.75 mg/g with the chlorophyll content in Moai rice planted in intercropping with soybeans (T1) which produces chlorophyll of 0.67 mg/g. Treatment with liquid smoke concentration of red fruit seed waste has a significant effect on the chlorophyll content in Moai rice plants. This shows that the ability of Moai rice leaves planted in monoculture (T2) to capture solar radiation energy is higher when compared to Moai rice leaves planted in intercropping with soybeans, so the photosynthesis rate will also be higher indirectly. High chlorophyll content in leaves increases the capacity of plants to carry out photosynthesis. Apart from that, the large chlorophyll content in the monoculture planting pattern is due to the larger leaf surface area in this planting pattern. When observing the leaf area, it can be seen that the leaf area of Moai rice is 22.49 cm2, which means indirect sunlight capture will be optimal. The leaf surface area will also efficiently capture light energy for normal photosynthesis in conditions of low light intensity. The concentration of liquid smoke from red fruit seed waste of 250 ml liquid smoke/l (S2) in table 3 is seen to produce the greatest chlorophyll content, namely 0.36 mg/g when compared with the concentration of liquid smoke from other red fruit seed waste. The high chlorophyll content in treatment S2 (the concentration of liquid smoke from red fruit seed waste was 250 ml liquid smoke/l) may be due to the allelochemical compounds contained in the liquid smoke from red fruit seed waste, in this case, phenol compounds. The phenolic compounds contained will indirectly inhibit the growth of weeds. By inhibiting the growth of weeds indirectly, the growth of the main crop, in this case, the Moai rice plant, will not be hampered, so the chlorophyll content will be high. This is in accordance with Terzi (2008), who states that reduced growth can be caused by allelochemical compounds, which can increase the synthesis of the hormone abscisic acid, where abscisic acid will inhibit growth. Apart from that, the content contained in

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liquid smoke from red fruit seed waste allows it to be used as an alternative bioherbicide, where the dominant compounds in red fruit seed waste liquid smoke are acetic acid and phenol, which are produced from the decomposition of cellulose, hemicellulose and lignin. Thi et al. (2008) stated that allelochemical compounds in the form of phenols, terpenoids and flavonoids are compounds that can inhibit cell division. Sastroutomo (1990) cit Khairunida et al. (2024) stated that phenolic compounds can cause a decrease in cell membrane permeability. A decrease in cell permeability causes delays in the transport and diffusion of the results of the breakdown of food reserves across the cell membrane. This condition results in inhibited cell growth.

Conclusions

1. Red fruit seed waste liquid smoke is effective on the net assimilation rate and growth rate of Moai upland rice; number of panicles, dry weight of 100 seeds, number of hollow seeds and number of pithy seeds of Moai upland rice; harvest index and chlorophyll content of Moai upland rice.

2. The most effective concentration of red fruit seed waste liquid smoke on the physiology and yield of Moai upland rice plants is the concentration of red fruit seed waste liquid smoke of 250 ml liquid smoke/l water (S2).

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