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The Effect of Liquid Smoke Concentration of Red Fruit Seed Waste in Controlling Weeds on the Yield of Black Soybean [*Glycine max* (L.) Merrill] Malika Variety by Intercropping with Gogo Rice

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ABSTRACT

Background: Weeds are plants that can reduce black soybean production yields. Biocontrol is an organic red fruit seed waste material containing phenolic compounds, which are known to be able to eradicate weeds in cropping systems.

Methods: The design used in this research was a Complete Randomized Block Design with two treatment factors, namely two factors intercropping Moai upland rice with black soybeans (T1), intercropping INPARI 28 upland rice with black soybeans (T2) and soybean monoculture (T3) and the second factor is the concentration of liquid smoke from red fruit seed waste (S) 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).

Result: The results of the research are: 1) Liquid smoke from red fruit seed waste is effective on the seed weight per plot; the seed weight per plant; the seed weight per hectare; dry weight 100 seeds; root weight and harvest index; 2) The most effective concentration of liquid smoke from red fruit seed waste is a concentration of 250 ml liquid smoke/l water (S2).

Key words: Biocontrol, Black Soybean, Liquid smoke, Red fruit, Upland rice.

INTRODUCTION

Faced with the demands of the times related to the Industrial Revolution 4.0, which is also in line with the need for food independence, the Jayawijaya Regency Government, which is currently by the President's instructions, is activating the "PAJALE" (Paddy-Corn-Soybean) program to meet the carbohydrate needs of the people of the Central Mountains without eliminates the characteristics of local culture and is part of the Ministry of Agriculture's special efforts (upset) for food self-sufficiency (Anonymous, 2017).

The productivity of white soybean plants in Jayawijaya Regency is relatively low, namely 7.50 tonnes/ha (BPS, 2021). White soybean cultivation in Jayawijaya Regency is only found in 3 districts: Walesi, Hubikosi and Musatfak Districts. Sitti *et al*. (2017) said that Papua has excellent opportunities to develop soybeans because it is supported by potential land spread across several development centres. Black soybeans have not yet been developed in the Jayawijaya Regency area. Meanwhile, the development prospects are worth developing to reduce the supply of imported food made from black soybeans. However, soybean farmers in Jayawijaya generally do not know what herbicides are. This is the same as the opinion of Kale *et al*. (2017) which also states that 57.08% of farmers in Vidarbha do not know about the recommended dose for applying herbicides.

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 broad leaf morphology, for example, legume can inhibit weed growth (Eskandari and Kazemi, 2011; Gharineh and Moosavi, 2010; Khan *et al*., 2012). Intercropping rice with soybeans is beneficial because these two crops have complementary effects. Rice requires large amounts of N for growth and development, while soybeans can fix large quantities of N in the air through the root nodules that form (Susilo and Parwito, 2013).

Weeds are plants that can reduce black soybean production yields. Weed control processes that can be

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carried out include the use of allelopathy. Allelopathy is a compound that can inhibit the growth and development of plants next to it (Satiskhumar *et al*., 2020). One of the allelopathic compounds is phenolic compounds. Bioherbicide from liquid smoke from *Pandanus conoideus* Lamk seed waste contains phenolic compounds. One of the compounds contained in liquid smoke from *Pandanus conoideus* Lamk 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).

Furthermore, phenolic compounds in Ageratum conyzoides can suppress weed growth, as these weeds are believed to contain secondary metabolites like flavonoids and alkaloids, terpenes, chromene, chromone, benzofuran coumarin essential oils, sterols and tannins (Tampubolon *et al*., 2018). This was also stated by Einhellig (1995), who suggested that phenolic compounds can inhibit tekian weed germination during the embryo's mitosis process. Furthermore, according to research by Jiayu *et al*. (2015), phenolic compounds can control weed activity. Allelopathic shoots of *Sorghum bicolor* (L.), which contain many phenolic compounds, can provide effective and environmentally friendly weed control (Won, 2013)

The goals of this study are: 1) to analyse the effectiveness of red fruit seed waste on soybean yield; 2) to analyse which concentration of red fruit seed waste liquid smoke is most effective on the yield of the Malika variety of black soybean.

MATERIALS AND METHODS

The research location was in the Kurulu District, Jayawijaya Regency, with an altitude of 1650 m above sea level and at Petra Baliem Wamena College of Agricultural Sciences. The research was conducted in November 2023-May 2024. The research method used in this research is experimental. The design used in this research was a complete randomized block design (RAKL). The first factor is a combination of intercropping of Moai upland rice with black soybeans (T1), a combination of intercropping of INPARI upland rice 28 with black soybeans (T2) and soybean monoculture (T3); the second factor is the concentration of liquid smoke from red fruit seed waste. The concentration treatment given was three replication, which included 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). The region's climatic conditions are tropical.

RESULTS AND DISCUSSION

Number of pods per soybean plant

In Table 1, it can be seen that treatment T1 (intercropping of soybeans+Moai upland rice) produces the lowest number of pods. This is because, in this planting pattern, the population on the plot of land is large, so light is not captured optimally. It indirectly affects the photosynthesis process, which is less than optimal. In the intercropping pattern, the soybean plants' shading becomes greater, indirectly reducing yields and production. Wibowo (2012) added that shade can reduce the yield of pods per plant, the weight of 100 seeds and the harvest index. The application of liquid smoke from red fruit seed waste did not show significant results on the number of soybean pods. It is suspected that the concentration used in this study was still too low, so it could not influence these parameters. The type of raw material determines the quality of liquid smoke, pyrolysis temperature, particle size and moisture content of the raw material (Choi *et al*., 2015; Crespo *et al*., 2017; Oramahi, 2020). The concentration used in this research may be less effective due to one or several factors influencing the quality of liquid smoke. Although the red fruit seed waste liquid smoke herbicide has not had an effect on the number of pods, this herbicide does not have a bad effect on plants. Patel *et al*. (2016) said that applying herbicides did not affect the yield and number of plants.

Number of seeds per soybean pod

The interaction between the concentration of liquid smoke from red fruit seed waste and the combination of planting patterns significantly affects the number of seeds per pod of soybean plants. The combination of T1S3 treatment (soybean intercropping+Moai upland rice with a concentration of red fruit seed waste liquid smoke of 300 ml liquid smoke/l water) produced a high number of seeds per pod, 2.82 compared to other treatments. This may be because weeds can be controlled in this treatment by administering high concentrations of red fruit seed waste liquid smoke.

Number of productive soybean branches

In the Table 1, the highest yield of productive branches was found in the T3S3 treatment (soybean monoculture + red fruit seed waste liquid smoke concentration of 300 ml liquid smoke/l water) of 13.67. The spacing of plants is more spaced, the intensity of sunlight received is more significant and allows plants to grow towards the formation of branches (Agussalim, 2019). The wider the distance between the plants used, the more excellent the opportunity for the plants to form new branches, plus the low growth of weeds due to the provision of liquid smoke from red fruit seed waste as a bioherbicide.

Seed weight per plot

The vegetative needs of plants are met by the nitrogen available in the soil caused by Rhizobium which is able to bind N_2 so that the seed weight per plot in the T1 treatment is high, which will have an impact on increasing plant production (Murtilaksono *et al*., 2021). This means that competition for water, nutrients and light is low so that nutrients, especially nitrogen, will be translocated to the top of the plant, namely the stem and leaves, until pods are

formed on the plant, which are then collected in the pod shell. The closer to the final generative phase, the more nitrogen will be absorbed into the plant. The concentration of liquid smoke from red fruit seed waste produced the lowest seed weight per plot at the S3 concentration, namely 297.176 gr. This may be because, at this concentration, liquid smoke contains chemical components such as acetic acid, methanol and phenol, which do not resist plants and stimulate growth, thereby making soybean plants grow and produce not optimally.

Seed weight per plant

In the Table 2, the interaction between planting patterns and the concentration of liquid smoke from red fruit seed waste was significant in the weight of seeds per plant. In this interaction, the T1S2 treatment (soybean intercropping +Moai upland rice with a concentration of red fruit seed waste liquid smoke of 250 ml liquid smoke/l water) produced the most significant seed weight per plant, namely 13.354 grams. Here, the intercropping of soybeans +Moai upland rice is combined with the provision of liquid smoke from red fruit seed waste, which can control weeds, causing a greater and even distribution of sunlight to the bottom and thereby increasing plant photosynthesis. High photosynthesis results will indirectly increase the yield of a plant, in this case, the weight of seeds per plant. High photosynthetic efficiency underlies high yield potential (Yuan *et al*., 2011).

Dry weight 100 seeds

In Table 2, significant results are seen for the parameter of seed weight per hectare due to the interaction of planting patterns with the concentration of liquid smoke from red fruit seed waste. The T1S0 treatment (soybean intercropping +Moai upland rice with no red fruit seed waste liquid smoke) showed the lowest results. This is possible because, in this treatment, there is competition between the main crop and weeds, so crop production indirectly becomes low. The yield of a crop will be influenced by weed competition with the main crop. According to Sannagaudar *et al*. (2024) said that the level of competition between weeds and plants in fighting for nutrients, light and water determines the results and growth process of a plant.

The dry weight of 100 seeds reflects the size of the soybean seeds; the more significant the seed size, the more diverse the seed sizes in one plant (Adie and Krisnawati, 2013). The combination of planting pattern treatment significantly affected the dry weight of 100 seeds. Here, the T2 treatment (soybean intercropping+Inpari upland rice) showed low results. This is because the narrow spacing in this planting pattern can result in plants competing for nutrients and sunlight, so the photosynthesis process does not occur optimally. According to Nurbaiti *et al*. (2017), stated that apart from genetic factors, environmental factors, especially humidity and temperature around the plant, can influence plant growth and yield. According to

Table 1: Number of pods per soybean plant; number of seeds per soybean pod; number of productive soybean branches.

Treatment	Number of pods per soybean plant	Number of seeds per soybean pod	Number of productive soybean branches
		Planting pattern (T)	
T1	76.56a	2.44a	8.08a
T2	91.86a	2.36a	7.79a
T3	91.58a	2.32a	9.31a
		Red fruit seed waste liquid smoke concentration (S)	
S0	42.51	1.37	4.40
S1	57.89	1.38	5.04
S2	56.24	1.41	4.90
S3	51.36	1.52	5.77
		Interaction T×S	
T1SO	79.11ab	2.42ab	8.11b
T1S1	42.33cd	2.22bc	7.56b
T1S2	110.00ab	2.29bc	9.11b
T1S3	74.78bc	2.82a	7.56b
T2S0	97.11ab	2.49ab	8.11b
T2S1	107.45ab	2.33bc	8.67b
T2S2	88.00abc	2.38b	6.67b
T2S3	74.89bc	2.25bc	7.67b
T3S0	36.33cd	1.96c	5.77b
T3S1	139.67a	2.33bc	9.003b
T3S2	83.22bc	2.49ab	8.78b
T3S3	107.11ab	2.51ab	13.67a

Karamina *et al*. (2017), good soil moisture and temperature provide sufficient pore space so that air circulation in the soil can run well. The high dry weight of 100 seeds in this treatment was due to the concentration of liquid smoke from red fruit seed waste, which could control the weeds on the land so that indirect competition between plants for water, nutrients and light became low. This low competition causes high crop production.

Number of root nodules

The T1S0 treatment (intercropping of soybeans+Moai upland rice with control) in the Table 3, produced the highest number of root nodules compared to other treatments. The root nodules of soybean plants in the T1 planting pattern release N, which is then absorbed by the rice plants so that the N element of the rice plant is sufficient. Irmayanti (2011) stated that the roots of rice plants absorb the N elements released by the root nodules found in soybean plants. The root nodules of soybean plants produce the N needed by rice plants so that the rice plant's nutrients are sufficient to obtain a nutritional supply, such as the number of tillers it gets, thus allowing many productive tillers to be formed during the vegetative phase. Control treatment (S0) or without applying liquid smoke from red fruit seed waste caused many root nodules. This is because phenolic compounds are not present in this treatment. Plant growth activity can be hampered if large amounts of phenolic compounds are administered. Phenolic compounds can limit the supply of oxygen to the seed embryo so that it can inhibit the germination process (Nurfadillah *et al*., 2022).

Root weight

The interaction between the combination of planting patterns and the concentration of liquid smoke from red fruit seed waste gave significant results on the root weight parameters of soybean plants. T3S1 (soybean monoculture +red fruit seed waste liquid smoke concentration of 200 ml liquid smoke/l water) appeared to produce a high soybean root weight of 5.776 grams. The concentration of liquid smoke from red fruit seed waste of 200 ml liquid smoke/l water (S1) is thought to increase plant growth because, in the GCMS (Gas Chromatography Mass Spectrometry) results, there are compounds Benzenemethanol, 3-hydroxy-5-methoxy- which are derivatives of acid. Methanol. Khoshkhara *et al*. (2021) state that acetic acid and methanolic acid help accelerate plant growth.

Harvest index

The harvest index shows the level of plant efficiency in the process of using photosynthesis results. The greater the harvest index, the more efficiently the plant utilises photosynthesis results, which means the higher its economic value. The harvest index is considered a measure of plants' biological success in the assimilation of photosynthate and the formation of yield components (Fitter and Hay, 1991). The combination of planting patterns

Table 2: Seed weight per plot; seed weight per plant; seed weight per hectare; dry weight 100 seeds.

Treatment	Seed weight per plot	Seed weight per plant	Seed weight per hectare	Dry weight 100 seeds
		Planting pattern (T)		
T1	548.767a	11.199a	0.731a	10.82b
T2	490.431a	10.012c	0.653c	10.44c
T3	531.176a	10.839b	0.708b	11.23a
		Red fruit seed waste liquid smoke concentration (S)		
S0	298.602c	6.093c	0.398c	6.358c
S1	329.624b	6.730b	0.439b	6.963a
S2	330.896a	6.752a	0.441a	6.149d
S3	297.176d	6.064d	0.396d	6.527b
		Interaction T×S		
T1S0	452.032l	9.225l	0.603l	11.10e
T1S1	548.658d	11.197d	0.731d	12.74a
T1S2	654.384a	13.354a	0.872a	8.88l
T1S3	539.997f	11.020f	0.719f	10.57g
T2S0	452.741k	9.239k	0.604k	10.52h
T2S1	557.955c	11.402c	0.744c	10.19j
T2S2	472.842i	9.649i	0.630i	10.41i
T2S3	478.186h	9.758h	0.637h	10.65f
T3S0	588.237b	12.004b	0.784b	10.17k
T3S1	541.510e	11.051e	0.722e	11.89b
T3S2	527.258g	10.760g	0.703g	11.46c
T3S3	467.700j	9.544j	0.624j	11.41d

Table 3: Number of root nodules, root weight, harvest index.

Treatment	Number of root nodules	Root weight	Harvest index
		Planting pattern (T)	
T1	9.444a	3.526ab	0.29925b
T2	7.530a	3.417b	0.29975a
T3	7.778a	4.165a	0.2845c
		Red fruit seed waste liquid smoke concentration (S)	
S0	6.200	1.956b	0.193a
S1	4.490	2.666a	0.185b
S2	4.689	2.156ab	0.171c
S3	4.423	2.110ab	0.157d
		Interaction T×S	
T1SO	15.553a	3.110bc	0.332c
T1S1	5.223cd	4.110bc	0.275j
T1S2	6.777bc	3.223bc	0.309d
T1S3	10.223abc	3.663bc	0.281h
T2S0	7.447bc	2.670c	0.356b
T2S1	5.003cd	3.443bc	0.368a
T2S2	12.223ab	4.333b	0.258k
T2S3	5.447cd	3.223bc	0.217l
T3S0	8.000bc	4.000bc	0.277i
T3S1	12.223ab	5.776a	0.283g
T3S2	4.443cd	3.223bc	0.288f
T3S3	6.443bcd	3.663bc	0.290e

and the treatment of liquid smoke from red fruit seed waste gave significant results on harvest index parameters. Table 3 shows that the highest harvest index is in the T2 planting pattern (intercropping of soybeans+Inpari upland rice) and the concentration of liquid smoke from red fruit seed waste is in S0 (control). Intercropping can increase the value of land use seen from the increase in the harvest index when compared to the monoculture harvest index; this is in accordance with the opinion of Machfduz and Huda (2019) that the intercropping cropping pattern produces higher Production than monoculture, this is because in one The land contains more than one type of plant so that the harvest can also increase, apart from that, intercropping is also more efficient, makes maintenance easier, reduces the risk of crop failure, saves on the use of production infrastructure and can increase land use efficiency.

CONCLUSION

Liquid smoke from red fruit seed waste is effective on the seed weight per plot; the seed weight per plant; the seed weight per hectare; dry weight 100 seeds; root weight and harvest index. The most effective concentration of red fruit seed waste by liquid smoke on the yield of black soybean plants of the Malika variety is the concentration of red fruit seed waste liquid smoke of 250 ml liquid smoke/l water (S2).

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Informed consent

All authors read and approved the final manuscript.

Conflict of interest

The authors declare no conflict of interest.

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