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Research Article

Optimization of Organic Mulch Sheet Compositions in Chili (*Capsicum annum* L.) Cultivation: Effect on the Growth and Yield

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Abstract: Climate change causes low production of most vegetables throughout the world by reducing the quality and quantity of yield. Mitigation of the negative impact of climate change on plant productivity must be emphasized in the development of production systems to improve the efficiency of water use, including mulch. Organic mulch sheet (OMS) is an alternative biodegradable mulch made from abundant renewable materials. This study aimed to understand the influence of OMS application on the growth and yield of chili compared to plastic mulch and to optimize the compositions of OMS made from water hyacinth, coconut fiber, and manure for improving the growth and yield of chili. This study was carried out using a simple randomized complete block design with two controls (without mulch (P0) and plastic mulch (P0M)) and five treatments of OMS compositions (the percentage of water hyacinth, coconut coir, and manure) labeled as PO1 (70:20:10), PO2 (60:30:10), PO3 (50:40:10), PO4 (40:50:10) and PO5 (30:60:10). All tested OMS compositions in this study showed insignificantly growth and yield variables of chili compared to the plastic mulch. Optimum OMS composition for yield variables obtained at 59.39% water hyacinth and 0% coconut coir based on response optimizer using response surface analysis. Insignificant different growth and yield produced from OMS and plastic mulch application indicated that all tested OMS compositions, with biodegradable and eco-friendly properties, can be used to substitute for plastic mulch in chili cultivation.

Keywords: Biodegradable mulch, Climate Change, Natural Fiber, Response Surface Methodology

1. INTRODUCTION

Strategies in dealing with climate change and its impacts become one of the objectives of the Sustainable Development Goals (SDGs) with the target of strengthening resilience and adaptive capacity toward climate-related hazards and improving capacity in mitigating, adapting, and reducing the impacts of climate change. Climate change directly impacts the productivity of agricultural products through changes in temperature, climate variability, and extreme weather [1]. Mulch is one of the mitigation strategies to reduce the negative impacts of climate change [2].

Mulch is frequently used in crop cultivation practices, such as chili (*Capsicum annum* L.), to increase water use efficiency, manipulate the microclimate, and improve yields [3-4]. Indonesian chili export is included in the top 20 chili and peppers exporting countries with a quantity reaching 2093 tons in 2017 [5]. Furthermore, the national chili production of Indonesia reached 1045 million tons with 123 thousand ha harvested in 2016 [6], thus the mulch demand is needed in large quantities. The conventional and commercially available mulch used in cultivation is plastic mulch which has limitations associated with its waste handling and sustainability, leading to a potential environmental risk after long-term application [7-8]. Various degradable mulch alternatives were studied because they could reduce global warming potential by 5 % and non-renewable energy use by 14 % compared to the use of polyethylene mulch [9]. The biodegradable film is also widely developed as an alternative mulch material, but it is more expensive and not very durable compared

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with plastic mulch. Paper mulch (organic mulch sheet) is a promising alternative related to abundant material sources and relatively low manufacturing costs [10].

Organic mulch sheets (OMS) are made from natural fibers that can be derived from agricultural waste such as coconut coir and overabundant aquatic weeds such as water hyacinth [11-13]. Biodegradable mulch derived from natural fibers is widely studied, but the optimum composition that satisfies desirable yield as an appropriate substitute for polyethylene mulch still needs further research and improvement. This research aimed to understand the effect of OMS application on the growth and yield of chili compared to plastic mulch and to optimize the composition of OMS made from coconut fiber, water hyacinth, and manure for improving the growth and yield of chili.

2. MATERIALS AND METHODS

The study was conducted in East Java, Indonesia with an altitude of 500 meters asl and rainfall ranging from 1750-2500 mm per year. Materials needed in this study were raw materials for making OMS (water hyacinth petiole, coconut coir, and manure), water, chili seeds, goat manure, inorganic fertilizer, and pesticides. The procedures of making OMS following the method of Iriany *et al*. [14] were conducted.

2.1 Experimental Design

This study was carried out using a simple randomized complete block design (RCBD) with two controls (bare soil(P0) and plastic mulch (P0M)) and five treatments i.e OMS compositions), with three replications. The treatments were various OMS compositions (the percentage of water hyacinth and coconut coir combined with 10 % manure) namely PO1 (70:20:10), PO2 (60:30:10), PO3 (50:40:10), PO4 (40:50:10) and PO5 (30:60:10).

2.2 Measured Variables and Data Analysis

Measured variables were plant growth and plant yield. Plant growth variables were plant height, stem diameter, number of leaves and number of flowers. Plant yield variables were a number of fruits per plant, fruit fresh weight per plant (g), fruit fresh weight per fruit (g), fruits dry weight per plant (g), fruit diameter (mm), and fruit length (cm).

The analysis of variance was performed to understand the effect of the treatment, then HSD (Tukey test) α 5 % was complete to determine the best treatment. Surface response method analysis was also carried out to analyze the optimum OMS compositions based on growth variables and a number of fruits data using Minitab 19.

3. RESULTS AND DISCUSSION

3.1 Effect of OMS Compositions on the Growth of Chili

OMS application produced a similar plant height of chili with plastic mulch (P0M) and higher than produced by bare soil (P0) (Figure 1). Plant height produce from chili grown with various OMS compositions showed an insignificant difference compared to the plastic mulch (P0M) but did significantly higher than without mulch (P0) at the end of observation (7 weeks after planting (WAP)) (Table 1). The PO1 treatment (70 % water hyacinth, 20 % coconut coir, and 10 % manure) showed higher plant height than other OMS compositions although not significantly different.

Various OMS compositions and plastic mulch (P0M) treatments showed a similar number of leaves (Figure 2) yet higher than without mulch (P0). Treatments did not significantly influence the number of leaves at the end of observation (7 weeks after planting) (Table 1). However, OMS made from 50 % water hyacinth, 40 % coconut coir, and 10 % manure (PO3) showed more number of leaves than other OMS compositions even though it was not significantly different.

OMS produced insignificantly different stem diameters compared with control (plastic mulch and without mulch) as shown in Figure 3. The PO2 composition (60 % water hyacinth, 30 % coconut coir, and 10 % manure) showed a higher stem diameter than other OMS compositions although it was not significantly different (Table 1).

OMS composition treatment did not produce more number of flowers compared to the plastic mulch but it was significantly different from

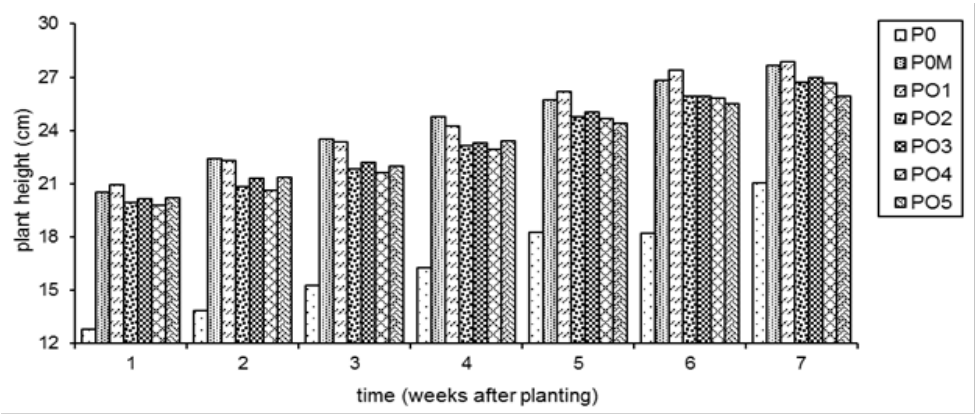

Fig. 1. Plant height of chili grown in various OMS compositions from 1st until 7th WAP. P0; P0M; and PO1, PO2, PO3, PO4, and PO5 represent without mulch, plastic mulch, and various OMS compositions, respectively.

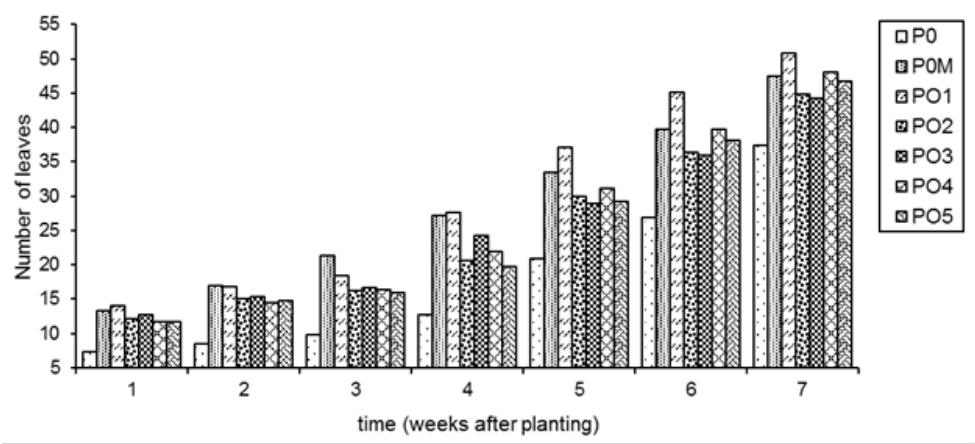

Fig. 2. Number of chili leaves grown in various OMS compositions from 1st until 7th WAP. P0; P0M; and PO1, PO2, PO3, PO4, and PO5 represent without mulch, plastic mulch, and various OMS compositions, respectively.

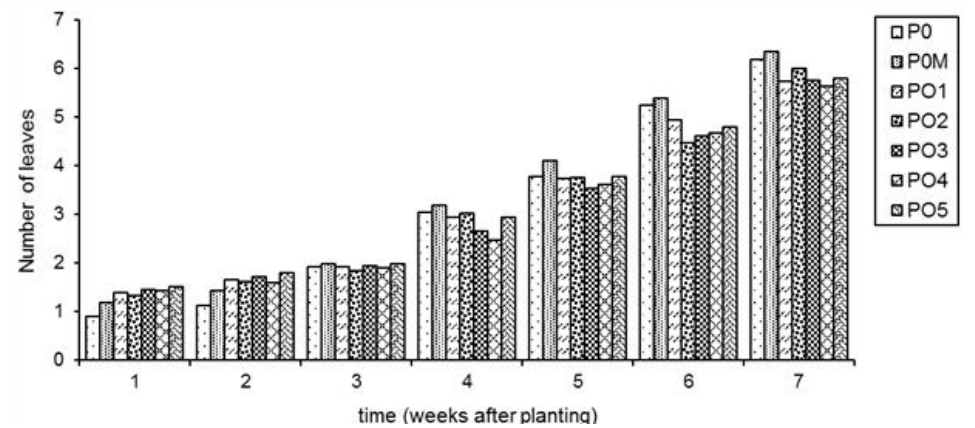

Fig. 3. Stem diameter of chili grown in various OMS compositions from 1st until 7th WAP. P0; P0M; and PO1, PO2, PO3, PO4, and PO5 represent without mulch, plastic mulch, and various OMS compositions, respectively.

without mulch as shown in Figure 4. There was no significant different number of flowers between treatments and control at the end of observation (Table 1). Even though it was not significantly different, PO3 composition (50 % water hyacinth, 40 % coconut coir, and 10 % manure) showed more number of flowers than other OMS compositions.

The influence of OMS composition on the chili growth in this study was consistent with previous studies. The composition ratio of OMS materials did not influence plant growth. Sekara *et al*. [15] stated that tomatoes grown in biodegradable mulch (made from biopolymer of starch) showed an insignificant difference in total biomass, residual biomass, and LAI compared to mulch film (LDPE). Iriany *et al*. [12, 16] assert that the OMS compositions ratio showed an insignificant difference in number of leaves and plant height of shallot and cauliflower compare to the plastic mulch. It can be indicated by the similar microclimatic condition with the application of OMS and plastic mulch. Furthermore, there is an insignificant difference in microclimate factors due to variations in OMS compositions [12].

3.2 Effect of OMS Compositions on the Yield of Chili

Generally, plastic mulch produced higher fruit fresh weight, more number of fruits, and higher fruit dry weight per plant compared to OMS treatments even though it was not significantly different from various OMS compositions (Table 2). Furthermore, plastic mulch and OMS application showed insignificantly different fruit lengths also mulch application did not influence fruit fresh weight and fruit diameter. This finding emphasized that OMS can be applied for the substitution of plastic mulch in chili cultivation which produced similar (not significantly different) crop yields. OMS application increased number of fruit per plant, fruit weight per fruit, and dry fruit weight per plant up to 25 %, 10 %, and 59 %, respectively, compared to the bare soil. OMS compositions influenced the number of fruits per plant significantly with PO5 (30 % water hyacinth, 60 % coconut coir, and 10 % manure) as the highest value. OMS compositions did not affect the fresh fruit weight per plant, fresh fruit weight per fruit, fruit diameter, and fruit length variables significantly, although PO4 (40 % water hyacinth, 50 coconut coir, and 10 % manure) showed higher fresh fruit weight per plant than other OMS compositions.

The earlier research on the application of degradable mulch from various raw materials showed an insignificant effect between the ratio composition of mulch raw material with the marketable yield of several crop species. This present study also has a similar result that crop yield produced from biodegradable mulch (OMS) and plastic mulch was insignificantly different. The difference in OMS compositions (paddy straw, water hyacinth, and tannery waste) shows an insignificant difference compared to the mulch film on the weight and diameter of cauliflower curd and the number of the tuber of shallot variables [12, 16]. Coolong [7] asserts that the difference in paper mulch types did not affect the marketable yield of summer squash significantly compared to plastic mulch. Sekara *et al*. [15] stated that biodegradable mulch and mulch film produced no significant difference in the marketable yield variable and harvest index of tomatoes. Furthermore, there was an insignificant difference in number of fruit, marketable yield, and the total weight of tomatoes grown in biodegradable mulch (made from cornstarch or and cellulose) and mulch film [17, 18].

Application of different commercial degradable mulch product types showed insignificantly yield and an average head weight of lettuce; average curd of broccoli; yield, average fruit weight, and number of fruits of bell pepper; and average fruit weight of watermelon. Mulch type (degradable and non-degradable) also does not influence the marketable yield of cucumber [19-20]. Furthermore, Haapala *et al*. [21] stated that the influence of biodegradable mulch on cucumber yields began to be seen in the second cycle of cultivation. It could be due to the minor effect of weathered buried mulch (starch-based, cellulose-based, and polylactic acid) on the soil quality index (based on the five indicators, namely microbial biomass, and β-glucosidase activity, TOC, EC, and pH) which plays an important role in crop production [22].

3.3 Optimum Compositions of OMS on the Growth and Yield of Chili using RSM

Response surface methodology (RSM) is a multivariate statistic technique for optimizing the

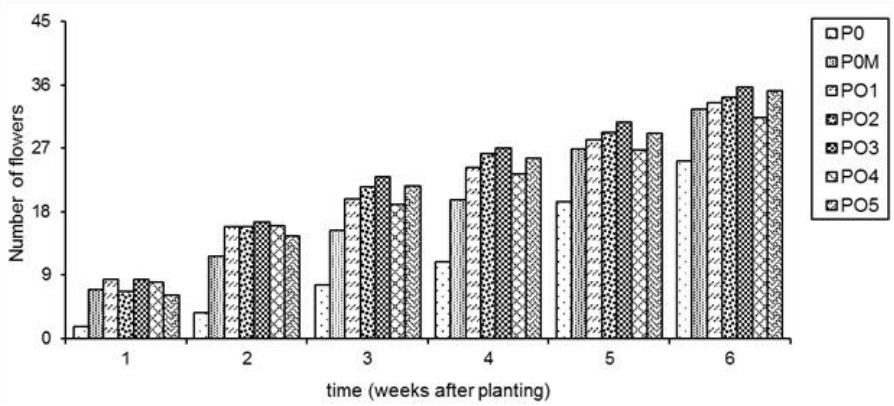

Fig. 4. Number of chili flowers grown in various OMS compositions from 1st until 7th WAP. P0; P0M; and PO1, PO2, PO3, PO4, and PO5 represent without mulch, plastic mulch, and various OMS compositions, respectively.

Table 1. Growth observation variables of chili grown in various OMS compositions on 7 WAP

Treatment	Plant height (cm)	Stem diameter (cm)	Number of leaves	Number of flowers
P0	21.0±3.1 b	6.2±0.3 a	37.3±0.7 a	25.2±1.6 a
P0M	27.7±1.2 a	6.4±0.6 a	50.9±4.3 a	32.6±0.6 a
PO1	27.8±0.9 a	5.7±0.3 a	44.8±4.7 a	33.4±1.7 a
PO2	26.7±1.3 ab	6.0±0.5 a	44.2±3.3 a	34.2±2.4 a
PO3	27.0±1.7 a	5.8±0.9 a	48.1±3.0 a	35.7±1.3 a
PO4	26.6±1.8 ab	5.6±0.2 a	46.8±1.1 a	31.3±1.0 a
PO5	25.9±2.1 ab	5.8±0.3 a	47.4±2.2 a	35.2±5.6 a
HSD 5 %	7.20	2.52	14.18	12.70

Notes: Values were expressed as means ± standard error.
The means followed by the same letter within the same column is insignificantly different based on the HSD test with α 5 %.
Treatments: P0 control (bare soil), P0M (Plastic mulch), PO (OMS compositions i.e the percentage of water hyacinth, coconut coir, and manure namely PO1 (70:20:10), PO2 (60:30:10), PO3 (50:40:10), PO4 (40:50:10) and PO5 (30:60:10).

Table 2. Yield observation variables of chili on various OMS compositions

Treatment	Number of fruits per plant	Fresh fruit weight per plant (g)	Fruit weight per fruit (g)
P0	37.8±0.4 c	326.6±31.2 ab	5.2±1.9 a
P0M	47.4±2.7 a	395.6±1.3 a	5.7±1.7 a
PO1	39.7±1.5 bc	297.0±0.8 b	5.5±1.8 a
PO2	36.8±3.1 c	311.7±3.8 b	5.4±1.8 a
PO3	46.1±1.4 ab	341.5±4.4 ab	5.7±1.7 a
PO4	36.3±1.2 c	347.0±2.7 ab	5.4±1.8 a
PO5	47.1±0.1 a	319.9±20.1 b	5.7±1.7 a
HSD 5 %	7.4	74.4	1.1
	Dry fruit weight per plant (g)	**Fruit diameter (mm)**	**Fruit length (cm)**
P0	27.3±0.8 c	10.1±0.3 a	10.6±0.4 a
P0M	54.8±4.0 a	10.9±0.9 a	9.5±0.4 ab
PO1	38.8±0.7 bc	10.8±1.5 a	8.9±0.4 b
PO2	34.7±0.4 bc	9.9±0.7 a	9.3±0.4 ab
PO3	43.3±5.7 ab	11.3±1.2 a	9.3±0.4 b
PO4	35.6±1.1 bc	10.7±1.3 a	10.2±0.7 ab
PO5	30.9±0.6 bc	11.9±1.2 a	9.4±0.7 ab
HSD 5 %	14.2	2. 26	1.3

Notes: Values were expressed as means ± standard error.
The mean followed by the same letter in the same variable was not significant based on Tukey's test with α 5%.
The means followed by the same letter within the same variable is not significantly different based on the HSD test with α 5%.
Treatments: P0 control (bare soil), P0M (Plastic mulch), PO (OMS compositions i.e the percentage of water hyacinth, coconut coir, and manure namely PO1 (70:20:10), PO2 (60:30:10), PO3 (50:40:10), PO4 (40:50:10) and PO5 (30:60:10)).

levels of independent variables to gain the desired response [23]. RSM can be used to optimize composition and process in biopolymer, bioplastic, biodegraded composite, and biodegradable aliphatic-aromatic polyester film production [24]. In this study, the optimum composition of OMS that supports growth and produces desirable yield was determined using RSM.

Contour and surface plot for the effect of OMS compositions on the growth of chili are shown in Figure 5. The optimum plant height was obtained with OMS made from 70 % water hyacinth and 60% coconut coir as shown in Figure 5a. The optimum composition of OMS to produce a maximum number of leaves was 70 % water hyacinth and 60 % coconut coir (Figure 5b) while the maximum stem diameter was 30 % water hyacinth and 10 % coconut coir (Figure 5c). Related to yield variables, both fruits' weight per plant and fruit length were produced optimally with an OMS composition of about 30 % water hyacinth and 15 % coconut coir (Figure 6a and Figure 6c). Besides, the maximum number of fruits was seen at the OMS composition of 5 % water hyacinth and 60 % of coconut coir (Figure 6b). Based on the response optimizer, the optimum OMS composition for yield variables (fruit length, number of fruits, and fruits weight) was 0 % coconut coir and 59.39 % water hyacinth (Table 3). the composite desirability value (D) that close to one indicated that the composition appeared to achieve favorable outcomes for all responses overall [25].

Table 3. Optimization of OMS compositions for yield variables (fruit length, number of fruits, and fruits weight)

Desirability	**Optimum OMS composition (%)** Water hyacinth: coconut coir 59.39:0
Composite desirability	0.86200
Fruit length	0.82069
Number of fruits	0.94593
Fruit weight	0.82517

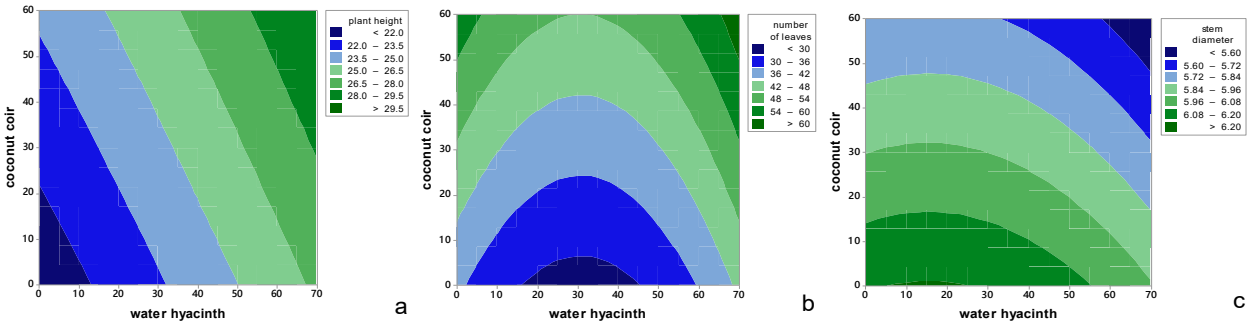

Fig. 5. Contour plot for the effect of OMS composition (the percentage of water hyacinth and coconut coir) on the growth of chili (a. Plant height; b. Number of leaves; and c. Stem diameter).

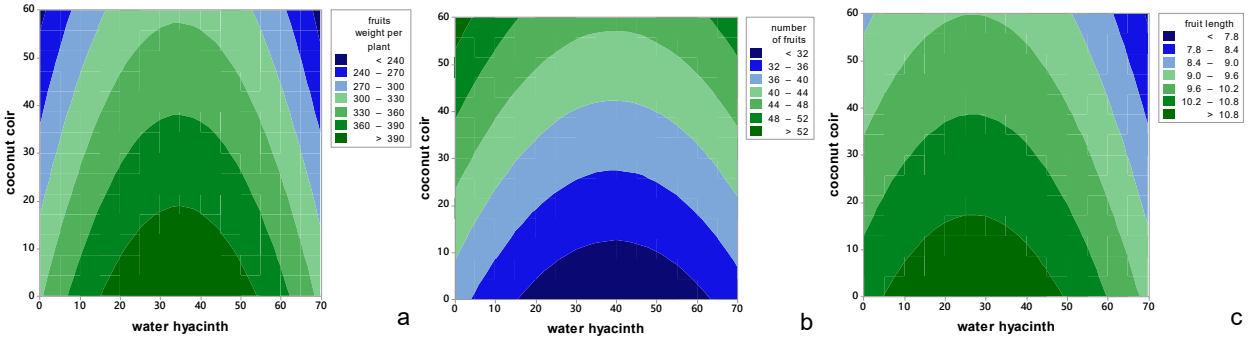

Fig. 6. Contour plot for the effect of OMS composition (the percentage of water hyacinth and coconut coir) on the growth of chili (a. Fruits weight per plant; b. Number of fruits; and c. Fruit length).

Generally, contour and surface plots showed that the optimum composition of OMS for supporting plant growth needs more water hyacinth than coconut coir, but producing a desirable yield needs less water hyacinth than coconut coir. This result was in accordance with the mean value of the observed variables. Although optimum OMS composition has obtained using RSM, all tested OMS compositions showed an insignificant difference in plant growth and crop yield variables based on the HSD test. This study revealed that the use of OMS produced similar growth and yield of chili with plastic mulch. Therefore, OMS composition can be adjusted with the availability of raw materials and made based on the formulation in this research. The significance of this finding is the use of OMS as biodegradable mulch for crop production that supports sustainable agriculture practices so that sustainable development will be achieved.

4. CONCLUSION

All tested OMS compositions in this study showed insignificantly different growth and yield variables of chili compared to the plastic mulch. Optimum OMS composition for yield variables was obtained at 59.39 % water hyacinth and 0 % coconut coir based on RSM analysis. Insignificant different growth and yield produced from OMS and plastic mulch application indicated that all tested OMS compositions, with biodegradable and eco-friendly properties, can be used as a substitute for plastic mulch in chili cultivation.

5. ACKNOWLEDGEMENTS

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6. CONFLICT OF INTEREST

The authors have no conflict of interest.

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