Organic mulch sheet as a mitigation strategy in vegetable cultivation: Its effect on the growth and yield of chili (Capsicum annum L.)

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Abstract. Plastic mulch, mainly used in chili cultivation, is less environmentally friendly due to its non-biodegradable characteristic. An alternative biodegradable mulch is needed to support growth and produce a desirable yield. Organic mulch sheet (OMS) is a promising alternative because it is made from natural fiber which is abundant and renewable organic material. This study aimed to understand the effect of organic mulch sheet (OMS) application on the growth and yield of chili (Capsicum annum L.). This research was carried out using a simple randomized complete block design with one control (black-silver plastic mulch) labeled as M0 and seven treatments (OMS compositions namely percentage of water hyacinth and banana stalk) labeled as M1 (80:20), M2 (70:30), M3 (60:40), M4 (50:50), M5 (40:60), M6 (30:70), and M7 (20:80). Mulch application significantly affected growth (plant height and number of leaves) and yield (fruit weight per fruit and fruit length) variables of chili. Although there was no significant difference in fruit weight per plant between control and OMS compositions, OMS application (M4) increased the yield of chili up to 25% from control. This finding affirmed that OMS is suitable for chili cultivation and can be used as a substitute for black-silver plastic mulch.

1. Introduction
Climate change becomes a threat to food security globally, including most of the vegetables, by reducing its quantity and quality [1]. Moreover, increasing temperature affects water availability, water use efficiency, pest and diseases, plant physiological processes, and enzymatic activities. Shifting and changing in the weather pattern and climate components have threatened crop productivity through the change in temperature and rainfall variability, mainly rainfed agriculture [2,3]. The scenario of representative concentration pathway (RCP) in climate change factors (CC) set at 4.5 and 8.5, equal to 3.4 and 6.0°C higher than the actual weather conditions, decreased yield of hot pepper (Capsicum annum L.) by 21.5% and 89.2%, shortened days to harvest from 5 to 13 days compared to control, and negatively affected fruit qualities [4]. It was asserted by similar work that the mean maximum temperature significantly negatively correlated with chili productivity [5]. Environmental management of the adverse impact of climate change on crop productivity should be done by developing production systems that improved water use efficiency and modifications of microclimate components, including mulching.

Mulch is materials that cover the soil surface, made from organic, inorganic (synthetic), or other specific type materials. Mulch application reduces soil evaporation, conserves and controls soil moisture and temperature, prevents soil erosion, reduces surface runoff, suppresses weed, and importantly...
contributes to the improvement of growth and yield of crops [6,11]. The common commercial mulch used in crop production is made from plastic in which has limitation related to its sustainability and environmental aspects after long-term application [12,13]. Plastic mulch is highly cost in disposal dan waste handling due to its non-degradable properties and poses potential risks if wrongfully handled, e. g burned and piled, which is harmful to human health and degrade soil health [14]. Besides, the mulch demand increases every year as increasing demand for vegetables and agricultural products as well as land cultivation areas.

Chili is one of the important horticultural products from Indonesia in which contains antioxidants, flavonoids, phenolic acids, carotenoids, and vitamins with a distinctive ‘spicy’ flavor [15]. Indonesia, as the top 20 exporting countries of chili and peppers (dry) with harvest area of up to 123 thousand ha in 2016 [16] and export quantity reaching 2,093 tons in 2017 [17], need mulch in large quantities. An alternative biodegradable mulch with good performance is needed to support growth and produce a desirable yield. The degradable film, including bio-, photo-, and thermo-degradable, is also getting interested as an alternative material due to its contribution in reducing global warming and non-renewable energy consumption, but it was not so durable and more expensive than plastic mulch [18,19]. Organic mulch sheet (OMS) is a promising alternative because it is made from natural fiber which is abundant renewable organic material. Research on OMS raw materials, compositions, and applications in crop production still needs further development. This study aimed to understand the effect of organic mulch sheet (OMS) application on the growth and yield of chili (C. annuum L.).

2. Materials and methods

This research was carried out at Mojoagung, Jombang, East Java, Indonesia with an altitude of 500 meters above sea level and rainfall of around 1,750-2,500 mm per year. Materials used in this study were raw materials of OMS (water hyacinth and banana stalk), chili seed (Capsicum annum L.) var Bara, black-silver plastic mulch (BSPM), chicken manure, and organic pesticide. The procedure of making OMS was comprised of cutting and weighing, pulping, molding, and drying [20].

2.1. Experimental design

This study was conducted using a simple randomized complete block design (RCBD) with one control labeled as M0 and seven treatments (OMS composition), repeated three times. The control was a black silver plastic mulch application. The treatments were various OMS compositions (the percentage of water hyacinth and banana stalk) labeled as M1 (80:20), M2 (70:30), M3 (60:40), M4 (50:50), M5 (40:60), M6 (30:70), and M7 (20:80).

2.2. Observed variables and data analysis

The measured variables comprised of growth and yield variables of chili. The observed growth variables were plant height (cm), the number of leaves, and stem diameter (mm) which were observed from 1st until 13th weeks after planting (WAP). Days of first flowering were determined when 50% of the flowers have bloomed on each treatment. The observed yield variables of chili were fruit weight per plant (g), fruit weight per fruit (g), number of fruits, and fruit length (cm). The observed yield variables were an accumulation of measured yield from the first harvest time until 14 weeks after planting. The data were analyzed using the analysis of variance (ANOVA) to determine the effect of the treatments, then by means of HSD (Tukey test) at 5% to find out the best treatment using Minitab v19.

3. Results and discussion

3.1. Growth of chili (Capsicum annum L.) under various organic mulch sheet compositions

The effect of OMS compositions on the plant height began to be seen on 3 WAP until 13 WAP and showed a similar value compared to the BSPM (Figure 1). In brief, the plant height of chili showed a similar response under the application of OMS and BSPM although the M3, M4, and M5 treatments exhibited significantly lower plant height than BSPM (Error! Reference source not found.).
The effects of treatments on the number of chili leaves started to appear in the early growth stage (1st until 3rd WAP) and after entering the generative stage (7th until 13th WAP) of chili (Figure 2). The number of leaves under application of OMS was insignificantly different compared to the BSMP application but the M1 treatment had significantly more leaves than BSMP at the end of observation (Error! Reference source not found.).

The application of OMS did not show a significantly different stem diameter compared to the BSMP from the beginning to the end of the observation (Figure 3, Error! Reference source not found.). These results indicated that all tested OMS composition has a similar diameter of chili stems compared with BSMP. In addition, the difference of days of first flowering under application of OMS and BSMP also
was not seen (Error! Reference source not found.), even the chili flowers bloomed 2 days early than BSPM under application of the M2, M3, and M4 treatment.

Figure 3. Stem diameter of chili on various mulch applications at 1 until 13 weeks after planting. The error bar on the top of the bar is the standard deviation.

In general, the application of OMS did not show significantly different growth variables of chili compared to BSPM although some of OMS compositions showed better or poor performance. This result was in accordance with the previous studies on the use of organic and biodegradable mulch in chili cultivation. It was reported that an application of banana leaves as mulch showed an insignificant number of leaves and branch numbers of chili compared to the plastic mulch [20].

Table 1. Growth variables of chili (C. annum L.) on various mulch application at 13 weeks after planting.

| Treatment | Plant height (cm) | Number of Leaves | Stem diameter (mm) | Days of first flowering (dap) |
|-----------|------------------|------------------|-------------------|-----------------------------|
| M0        | 56.98 ab         | 122.20 b         | 10.83 a           | 42.00 a                     |
| M1        | 55.85 abc        | 133.33 a         | 10.01 a           | 44.33 a                     |
| M2        | 56.59 abc        | 122.67 b         | 10.05 a           | 43.67 a                     |
| M3        | 52.62 d          | 120.73 b         | 9.73 a            | 39.67 a                     |
| M4        | 54.65 cd         | 123.07 ab        | 10.03 a           | 39.67 a                     |
| M5        | 54.90 c          | 121.47 b         | 9.91 a            | 44.33 a                     |
| M6        | 55.05 bc         | 123.53 ab        | 10.59 a           | 44.33 a                     |
| M7        | 57.31 a          | 119.40 b         | 11.05 a           | 42.00 a                     |

Note: The mean value which was followed by the same letter in the same column showed that the difference was not significant based on the HSD test with a 5% significance level. Treatments: M0 (black silver plastic mulch (BSPM)), OMS compositions (the percentage of water hyacinth and banana stalk) labeled as M1 (80:20), M2 (70:30), M3 (60:40), M4 (50:50), M5 (40:60), M6 (30:70), and M7 (20:80).
Biodegradable mulch (starch-based biopolymer with 12 μm thickness) also reported has no significant difference in the leaf area index and total biomass of tomato compare to the low-density polyethylene (LDPE) film [21]. On the other hand, significantly lower plant growth (leaf area index, plant height, and dry weight) were seen on the application of other organic mulch materials, i.e peat moss, sawdust, cocopeat, wheat straw, paddy straw, and soybean straw, in chili and tomato (same family of chili namely Solanaceae) cultivation compared to the plastic mulch [22,23]. Furthermore, the composition of OMS raw materials did not affect the growth of chili. Previous work affirms that the composition of OMS made from water hyacinth, banana stalk, paddy straw, and tannery waste showed no significant difference in plant height and the number of leaves on cauliflower (Brassica oleracea L.) and shallot (Allium ascalonicum L.) [24,25]. An insignificant difference between plastic mulch and OMS, even inter OMS compositions, can be explained by the similar microclimate condition under all of those mulch applications [6,24].

3.2. Yield of chili (Capsicum annum L.) under various organic mulch sheet compositions
The effects of mulch application significantly appeared at fruit weight per fruit and fruit length variables (Figure 4, Figure ). Various applications of mulch did not significantly affect fruit weight per plant and the number of fruits per plant (Figure 4, Error! Reference source not found.). Application of various OMS compositions produced higher fruit weight per plant by 10-25% and more number of fruits of about 3-17% (OMS made from 50-80% water hyacinth and 20-50% banana stalk) and increased fruit weight per fruit and fruit length of about 3-19% and 3-11%, respectively.

Figure 4. Fruit weight per plant and fruit weight per fruit of chili under various mulch applications until 14 weeks after planting. The error bar on the top of the bar is the standard deviation. The same letters on the top of the bar show an insignificant difference at P ≤ 0.05 based on the HSD test.

The relationship between water hyacinth and banana stalk percentage in organic mulch sheet toward fruits weight per plant is shown in Figure 5. The rise of water hyacinth percentage tends to increase fruit weight per plant. On contrary, the rise of banana stalk percentage tends to decrease fruit weight per plant. The maximum water hyacinth and banana stalk percentage values based on the quadratic equation from the scatter plot were 68.77 and 31.13, respectively. it is indicated that a higher water hyacinth percentage than banana stalk in OMS composition is more suitable to improve the yield of chili.
In summary, the application of OMS showed significantly different fruit weight per fruit and fruit length but did not differ significantly on fruit weight and the number of fruits per plant variables compared to BSPM. This result was in accordance with previous studies on the use of organic and biodegradable mulch in chili and other crop cultivation. The yield variables i.e number of fruits per plant, fruit weight, fruit length, dan fruit diameter of chili obtained from the application of rice chaff and paddy straw mulch significantly differ from bare soil [26]. Paddy straw and soybean straw mulch produced no significant difference in fruit yield of chili compare to plastic mulch [23]. On contrary, it was also reported that there was a significantly lower number of fruits, fruit weight, and fruit length under paddy straw application compared to plastic mulch [27]. Prior research on the use of various OMS compositions made from water hyacinth, banana stalk, paddy straw, and tannery waste showed no significant difference in yield variables of cauliflower (B. oleracea L.) and shallot (A. ascalonicum L.) production [24,25].

Furthermore, the application of biodegradable mulch (starch-based polymer) produced insignificantly different marketable yield (productivity, number of fruits, and mean fruit weight) and harvest index of tomato compared to the LDPE film [21]. In addition, commercial biodegradable mulch made from cornstarch and cellulose as well as cornstarch and PE film showed no significant effect on the number of fruit, total weight, and marketable yield variables of tomato [28,29]. The insignificant difference in marketable yield of cucumber and summer squash under application of plastic mulch and degradable mulch, including commercial paper-based mulches, was observed [12, 30,31]. It was also reported that the effect of commercial paper-based biodegradable mulch on cucumber yield started to appear in the second period of cultivation [32]. The insignificant difference between biodegradable mulch compositions can be caused by the minor impacts of weathered buried mulches (starch-based, polylactic acid, and cellulose-based) on soil quality index (based on SMAF model using 5 indicators i.e pH, EC, TOC, microbial biomass C, and β-glucosidase activity) that play important rule on crop production [33].
Figure 5. Relationship between water hyacinth (left) and banana stalk (right) percentage in organic mulch sheet towards fruits weight per plant.

4. Conclusion
Mulch application significantly affected growth (plant height and number of leaves) and yield (fruit weight per fruit and fruit length) variables of chili. Application of various OMS compositions did not show significantly different growth variables of chili compared to BSPM even though some OMS compositions showed better (M1) or poorer (M5) performance than plastic mulch. Although there was no significant difference in fruit weight per plant between BSPM and OMS compositions, OMS application (M4) increased the yield of chili up to 25% from BSPM. This finding affirmed that OMS made from water hyacinth and banana stalk is suitable for chili cultivation and can be used as a substitute for black-silver plastic mulch.

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