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ORIGINAL RESEARCH PAPER

Biodegradable mulch as microclimate modification effort for improving the growth of horenso; *Spinacia oleracea* L.

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ABSTRACT

BACKGROUND AND OBJECTIVES: Increasing global temperature imposes large risks to food security globally and regionally. Besides, adaptation effort on cultivation practices, such as mulching, is urgent to overcome environmental problem due to certain material used, commonly plastic that is not biodegradable. Biodegradable mulch is a mulch that could be degraded by microorganism and made from renewable organic materials. It plays a role in carbon sequestration and will contribute carbon and nutrients to the soil after being degraded. This current research aimed at investigating soil microclimate under various biodegradable mulch compositions and optimizing the compositions of biodegradable mulch that can be used to support the growth of short-cycle crops i.e. horenso (*Spinacia olearecea* L.).

METHODS: This study was carried out using a simple randomized complete block design with one control (without mulch) and five treatments (biodegradable mulch compositions), namely the percentage of water hyacinth (40-80%) and coconut coir (20-60%).

FINDINGS: All tested biodegradable mulch compositions could modify microclimate by decreasing 1-2°C of soil temperature and maintaining the soil moisture within the range of 63-84%. Although there was no significant difference in the growth and yield of horenso among the differing biodegradable mulch compositions, the biodegradable mulch composition treatments resulted in signficantly higher value than the control (without mulch). The biodegradable mulch composition treatments could increase fresh shoot weight around 38-55%, fresh root weight for about 55-94%, and dry shoot weight approximately by 1.6-2.8 times compared to the control (without mulch).

CONCLUSION: This finding has emphasized that all tested biodegradable mulch compositions are potentially used as mulch for horenso *(Spinacia oleracea L.)* cultivation. This study provide information in the formulation of biodegradable mulch to adapt the compositions on other short-cycle crops and other horticulture crops.

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39	7	4

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INTRODUCTION

Human activities have contributed about 1.0°C of rising global temperature over the pre-industrial levels and would reach 1.5°C in the next three decades (IPCC, 2018). Climate change affects food security and nutrition through its impact on food availability, quality, accessibility, and distribution. The rise of global temperatures leads to major risk on global and regional food security, especially in low-latitude areas, as the effects of temperature changes, precipitation, and extreme weather, as well as the increasing CO_2 concentrations (Gornall *et al.*, 2010; Ayinde *et al.*, 2011; Hoegh-Guldberg *et al.*, 2018). A healthy lifestyle is one of the precursors of the initiated habit of consuming fruits and vegetables, including spinach. National spinach consumption increased by 11.25% in 2015-2016, but the increased production, productivity, and harvested area, respectively, were only by 6.77%, 3.53%, and 3.13% (Ministry of Agriculture Republic of Indonesia, 2017). Asia produced most of the world's horenso in 2016-2018, approximately 95%, and the biggest importer was Europe, around 54-58% of world import quantity (FAO, 2020a and 2020b). Horenso *(Spinacia oleracea* L.) is one type of spinach with a higher economic value than other types commonly consumed by local people (Amaranth sp.). Global warming that has caused the evapotranspiration and respiration inflicts an impact on crop yields. An effort to overcome the problem is developing an appropriate technology through modifying the environment to provide a near-optimum growth environment for horenso plants i.e. mulching (Lalljee, 2013; Fagariba *et al.*, 2018). Mulch is commonly used in vegetable crop cultivation practices to manipulate the microclimate, increase water use efficiency, and improve growth and yields (Behzadnejad *et al.*, 2020; Edgar *et al.*, 2016; Henrique, 2020; Lamont, 2017; Sathiyamurthy *et al.*, 2017). Most mulch films are produced from petroleum-based plastics, generally polyethylene, and have caused waste handling problems (Kasirajan and Ngouajio, 2012). Plastics as synthetic polymers are non-biodegradable and the handling of their wastes constitutes the major problem. Furthermore, 8% of total world oil production is consumed in plastics manufacturing, in which 3-4% is used as energy during the production process, and thus indirectly causing CO_2 emissions and global warming (Nkwachukwu *et al.*, 2013). Biodegradable mulch (BDM) is a mulch that could be degraded by microorganism and is made from renewable organic materials. In addition to its environmentally-friendly characteristic, BDM plays a role in carbon sequestration and will contribute carbon and nutrients to the soil after being degraded (Jirapornvaree *et al.*, 2017). Tanveer *et al.* (2019) asserted that mulch can protect the soil from excessive evaporation and increase soil organic matter (SOM) as a result of increasing carbon input and decreasing soil disturbance. It was emphasized that the application of mulch and plant residues has increased soil microbial activity, ameliorated heat stress, provided water storage, and increased soil organic carbon (SOC). Gu *et al.* (2016) reported that the application of mulch above ground level increases SOC contents and its active fractions at the depth of 1-100 cm. Hu *et al.* (2018) affirmed that the combination of green manure and mulching using crop residues in organic crop systems increased C input and SOC contents. Unfortunately, this benefit cannot be obtained from the use of plastic mulch because there is no additional C input nor increasing SOC mineralization (Wang *et al.*, 2016). Biodegradable mulch is a promising solution; therefore, a series of research on raw materials and their compositions has been initiated these past years. Some materials that have been studied are water hyacinth, straw, banana stem, tannery waste, recycled paper, cellulosic fiber, and starch (Iriany *et al.*, 2018; Iriany *et al.*, 2019a and 2019b; Zhang *et al.*, 2019; Henrique, 2020; Marí *et al.*, 2020). In this current research, water hyacinth was used because it is an aquatic weed that has high dry matter yield of approximately 400 kg/ha/week with a high total content of cellulose and hemicellulose (± 43%). In addition, coconut coir was used considering its inexpensive fiber sources from post-harvest coconut with low specific weight so that it has a good tensile strength (Tham, 2012; Sarika *et al.*, 2014; Salleh *et al.*, 2015). The optimum composition of BDM made from the combination of water hyacinth and coconut coir has not been reported yet; accordingly, its application to the crop cultivation, particularly initiated to short-cycle crop e.g. spinach, is required. Furthermore, understanding the role of BDM on microclimate modification is needed to contribute climate change adaptation strategy. The objectives of this current research were to investigate the soil microclimate under various BDM compositions and to optimize the BDM compositions that can be used to support the growth of short-cycle crops, especially horenso. To achieve these objectives, the field experiment was conducted at East Java, Indonesia in 2019.

MATERIALS AND METHODS

This research was conducted at Dau, Malang, East Java, Indonesia with an altitude of 500 meters above sea level, the average daily temperature of 25-32 °C, and the rainfall of around 3600 mm per year. The physical and chemical properties of the soil shown in Table 1. Some materials used in this current research were raw materials of BDM (water hyacinth petiole and coconut coir), horenso seed *(Spinacia oleracea* L), and fertilizer (foliar fertilizer, manure, and green manure (Azolla sp). The procedures of making BDM were cutting and weighing, pulping, molding, and drying as explained by Iriany *et al.* (2018).

Experimental design

This research was carried out using a simple randomized complete block design (RCBD) with one control (without mulch) labeled as MO, and five treatments (BDM compositions), repeated three times. The treatments were various BDM compositions (the percentage of water hyacinth and coconut coir) labeled as MO1 (80:20), MO2 (70:30), MO3 (60:40), MO4 (50:50), and MO5 (40:60).

Measured variables

Measured variables included soil microclimate and plant growth. Microclimate was observed in the morning and at noon (also called as minimum and maximum for soil temperature variables), twice a week, using a digital thermohygrometer during horenso cultivation. Microclimate variables were soil temperature (°C) and soil humidity (%). The plant growth variables were plant height (cm), number of leaves, leaf area (cm^2), and stem diameter (mm), observed once a week from 1st until 5th week after planting (WAP). Marketable yield and dry weight of horenso included fresh shoot and root weight (g) and dry shoot and root weight (g), harvested in the end of observation.

Table 1: Soil physical and chemical properties

Soil properties	Value
Bulk density (g/cm^3)	1.27
Porosity (%)	51.24
Sand (%)	45.09
Silt (%)	41.01
Clay (%)	13.90
Water content at pF 2.5 (cm^3/cm^3)	0.30
Water content at pF 4.2 (cm^3/cm^3)	0.17
Macropores (%)	30.80
Mesopores (%)	12.90
Micropore (%)	8.80
pH	5.96
Soil organic (%)	4.07
N total (%)	0.34
P-available (mg/kg)	41.63
K (mg/100 g soil)	57.69
CEC (cmol(+)/kg)	38.95

Statistical analysis

The data were analyzed using the analysis of variance (ANOVA) to determine the effect of the treatments, then by means of HSD (Tukey test) α 5% to find out the best treatment. Correlation analysis was performed to understand the relationship between plant growth and microclimate (soil temperature and moisture). Response surface method (RSM) analysis was also carried out to analyze the optimum BDM compositions based on fresh shoot weight and plant height data using Minitab v19.

RESULTS AND DISCUSSION

Soil microclimate under various biodegradable mulch compositions

The average of minimum soil temperature under BDM was 25°C and the average of maximum soil temperature was 28°C; while the averages of minimum and maximum soil temperatures in bare soil (control) were 27°C and 28°C respectively. Soil moisture ranged between 75-84% with the average of 80% in the morning and ranged between 63-80% with the average of 73% at noon after the application of various BDM compositions. Soil moisture in bare soil (control) ranged between 60-70% with the average of 66% in the morning and ranged between 51-66% with the average of 57% at noon (Fig. 1). All tested biodegradable mulch compositions in this study could modify microclimate by decreasing 1-2°C of soil temperature and maintaining the soil moisture within the range of 63-84%. This result was in accordance with previous research reported by Iriany *et al.* (2019a) that the soil temperature under BDM made from water hyacinth and banana stalk were lower and more stable compared with without mulch and the soil humidity was within the range of 66.1 - 78.2%.

The optimum temperature of baby leaf spinach cultivation according to Applied Horticultural Research (2016) ranges between 14-24°C with the maximum temperature of 32°C. This condition is even more fulfilled by the use of BDM, with the minimum temperature of 25°C and the maximum temperature of 28°C compared to the control with the minimum and maximum temperatures of 27°C and 28°C respectively. Yamori *et al.* (2005) reported that the optimum temperatures of light-saturated photosynthetic rate of spinach leaves were 27°C, 36°C, and 24°C at the ambient CO_2 concentration of 360 µL/L, 1500 µL/L, and a curve of 50, 100 and 150 µL/L at the high-temperature treatment (day/night i.e. 30/25°C). The use of various BDM compositions could modify the microclimate i.e. decreasing the soil temperature by 1-2°C and maintaining the soil moisture within the range of 63-84%. This result was similiar to a research reported by Chen *et al.* (2015) that there was a reduction of soil temperature under straw mulch application between rows of wheat due to the prevention of direct high solar energy from reaching the furrow soil. Kumar and Dey (2012) explained that the reduction of maximum soil temperature, with application of hay mulch, might be attributed to the higher albedo and the rise in heat transfer diffusion.

Plant growth of horenso (Spinacia oleracea L.) on various biodegradable mulch compositions

The effects of BDM compositions on the plant height of horenso started to appear on 2 and 3 weeks after planting (WAP). On the 4 and 5 WAP, various BDM compositions did not significantly affect the height of horenso although there were significant differences compared to the control (without mulch) (Fig. 2). Based on Spinach Plants, Spinach Leaves, and Bunched Spinach: Shipping Point and Market

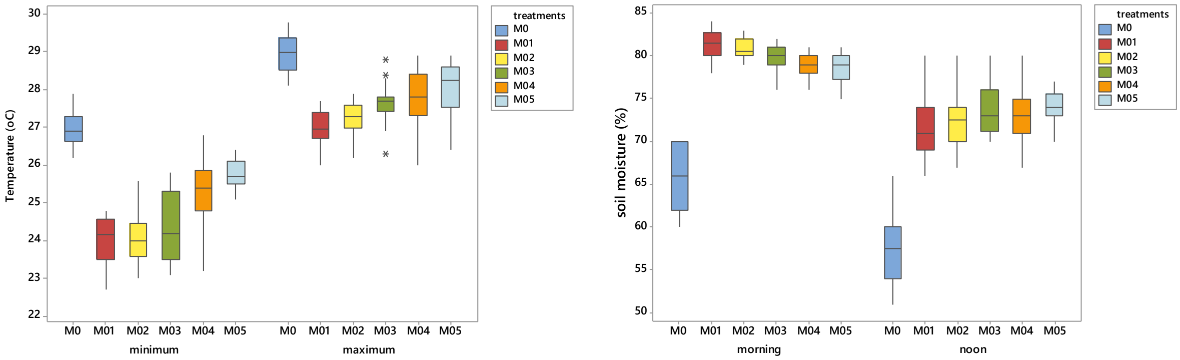

Fig. 1: Minimum and maximum soil temperatures and soil moisture after the application of various BDM compositions

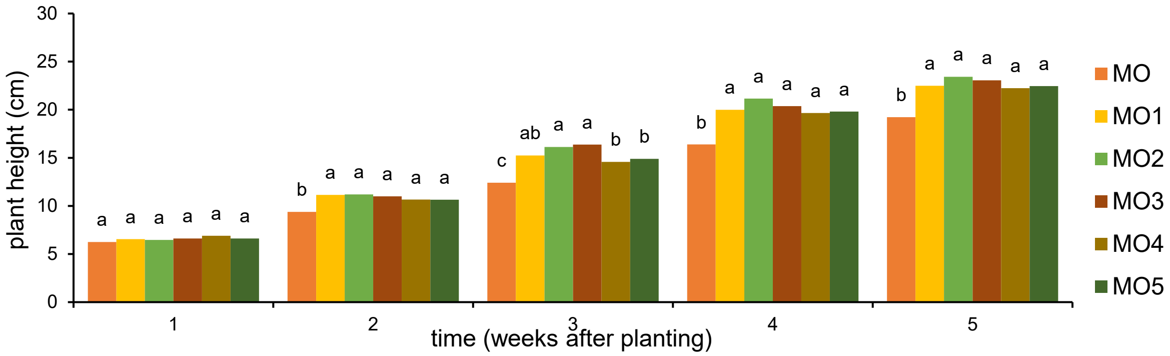

Fig. 2: Plant height of horenso (*Spinacia oleracea* L.) grown in various BDM compositions on 1 until 5 WAP. The same letters on the top of bar in the same WAP show insignificant difference at P≤ 0.05 based on HSD test

Inspection Instructions, plant height at 5 WAP had met spinach medium standard (4-8 inches or 10.16-20.32 cm) to large standard (> 8 inches or 20.32 cm) (USDA, 2006).

The effects of BDM compositions on the number of leaves began to be seen on 2 WAP to 4 WAP and showed higher value than the control (without mulch) (Fig. 3). The BDM composition treatments did not contribute significant effects on the number of leaves at the end of the observation although the BDM composition treatments resulted in more leaves than those of the control.

The effects of treatments on leaf area were seen on the 1st WAP with MO1 treatment showing the highest average of leaf area compared to the other BDM compositions. On 4 and 5 WAP, MO2 treatment showed the highest average leaf area compared to the other BDM compositions and the control (Fig. 4).

The effect on the stem diameter was shown on 2 WAP with MO1 treatment, detecting wider stem diameter than the other BDM compositions. On 3 WAP until the end of the observation, there was no significant difference in stem diameter among differing BDM compositions; however, there were significant differences between the BDM compositions and the control (Fig. 5).

The results of observation on marketable yield and dry weight of horenso (25 days after planting (DAP)) showed that the treatments significantly affected fresh and dry shoot weight as well as fresh root weight variables, but not on the dry root weight (Table 2). The BDM composition treatments could increase fresh shoot weight around 38-55%, fresh root weight for about 55-94%, and dry shoot weight approximately by 1.6-2.8 times compared to the control (without mulch).

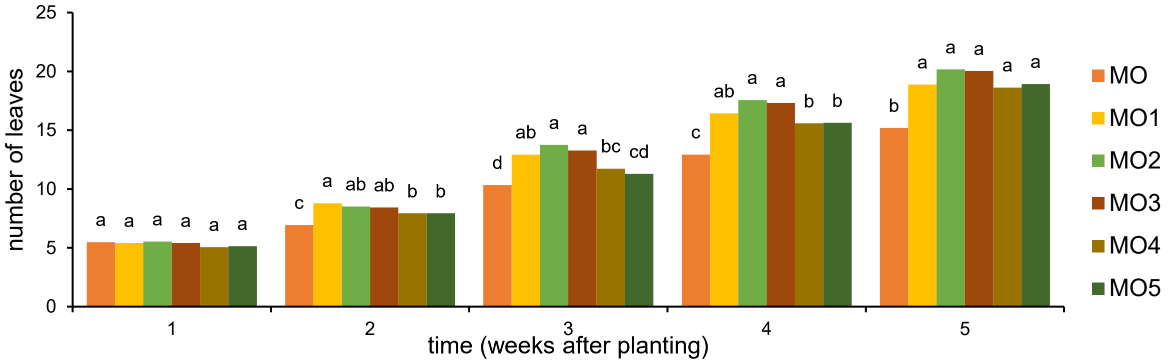

Fig. 3: Number of leaves of horenso (Spinacia oleracea L.) grown in various BDM compositions on 1 until 5 WAP. The same letters on the top of bar in the same WAP show insignificant difference at P≤ 0.05 based on HSD test

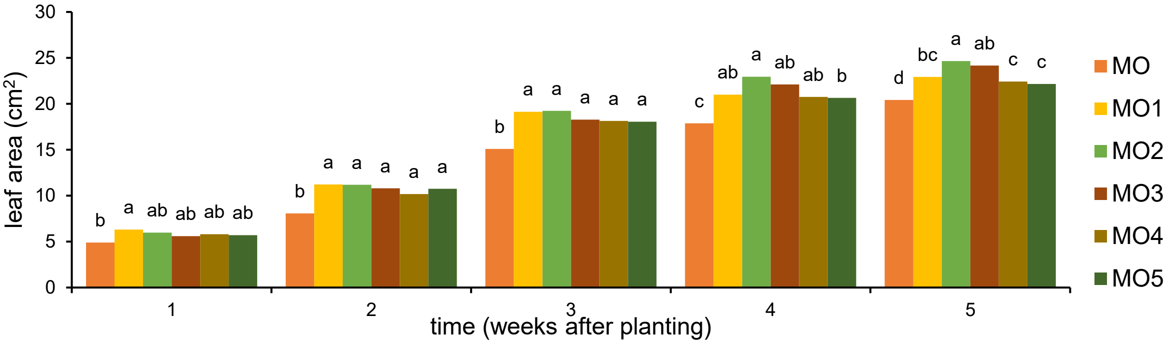

Fig. 4: Leaf area of horenso *(Spinacia oleracea* L.) grown in various BDM compositions on 1 until 5 WAP. The same letters on the top of bar in the same WAP show insignificant difference at P≤ 0.05 based on HSD test

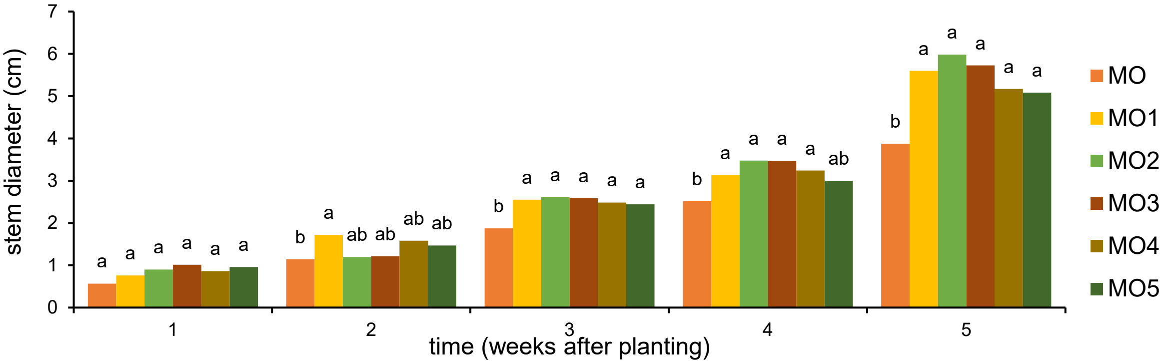

Fig. 5: Stem diameter of horenso (*Spinacia oleracea* L.) grown in various BDM compositions on 1 until 5 WAP. The same letters on the top of bar in the same WAP show insignificant difference at P≤ 0.05 based on HSD test

Table 2: Marketable yield and dry weight of horenso grown in various BDM compositions at 25 days after planting (DAP)

Treatment	Fresh shoot weight (g)	Dry shoot weight (g)	Fresh root weight (g)	Dry root weight (g)
MO	6.88 b	0.73 b	3.27 d	0.53 a
MO1	9.58 a	1.88 ab	5.17 c	0.29 a
MO2	10.63 a	2.17 a	6.32 a	0.61 a
MO3	10.10 a	2.53 a	6.03 ab	0.42 a
MO4	9.45 a	1.91 ab	5.25 bc	0.43 a
MO5	9.54 a	2.76 a	5.07 c	0.48 a

Mean values in same columns followed by the same letter are not significantly different at P≤0.05 significance based on HSD (Tukey test α= 0.05). MO (control/bare soil), BDM compositions (the percentage of water hyacinth and coconut coir) labeled as MO1 (80: 20), MO2 (70:30), MO3 (60:40), MO4 (50:50), and MO5 (40:60).

Table 3: Coefficient correlation (*r*) between microclimate and growth variable

Variable	Leaf area	Stem diameter	Number of leaves	Plant height	Fresh SW	Dry SW	Fresh root weight	Dry root weight
T_{min}	-0.805**	-0.775**	-0.788**	-0.757**	-0.728**	-0.435*	-0.809**	0.212^{ns}
T_{max}	-0.685**	-0.767**	-0.757**	-0.768**	-0.738**	-0.433*	-0.758**	0.266^{ns}
SM_{mor}	0.739**	0.777**	0.889**	0.907**	0.844**	0.658**	0.865**	-0.156^{ns}
SM_{noon}	0.692**	0.751**	0.888**	0.856**	0.793**	0.711**	0.840**	-0.170^{ns}

T= soil temperature; $_{min}$= minimum; $_{max}$= maximum;SM= soil moisture; $_{mor}$= morning; SW= shoot weight
** = *P*-value ≤ 0.01; * = 0.01 < *P*-value ≤ 0.05; ^{ns} = *P*-value > 0.05

Based on the correlation analysis, the temperature component (minimum and maximum) has shown a considerably close relationship with the growth and marketable yield of horenso. In summary, the minimum and maximum temperatures have been connected to the growth and marketable yield variables; while the moisture of the morning and noon soil has shown a positive relationship with the growth and marketable yield variables (Table 3). These results could be explained by the improvement of the growth and marketable yield of horenso after the BDM composition treatments compared to the bare soil.

In general, various BDM compositions did not show significant differences in the growth variables of horenso (plant height, number of leaves, stem diameter, and fresh shoot weight). However, there were significant differences between the BDM composition treatments and the bare soil. The results of this current research were in accordance with the previous BDM-based research on shallot and cauliflower cultivation. BDM application (made from water hyacinth, straw, and tannery waste) on shallot resulted in insignificantly different fresh and dry weight among differing BDM compositions, but significantly different from the control (without mulch) at 40 DAP (Iriany *et al.*, 2019b). In addition, the treatments of various BDM compositions (made from water hyacinth, banana pseudostem, and tannery waste) resulted in insignificant number of leaves on cauliflower (Iriany *et al.*, 2019a). The effects of the use of organic mulch from various sources on *Spinacia oleracea L.* cultivation have been widely reported. The use of organic compost mulch (400 grams per planting basin) increased fresh weight and dry weight of spinach by 8% and 12% respectively, compared to the bare soil (M Manyatsi and Simelane, 2017). In addition, Meena *et al.* (2014) reported that a more suitable microclimate condition, lowering the temperature by 2-6 °C at the depth 0-5 cm, resulted in the increase of fresh weight of spinach around 22-66%. Khan *et al.* (2019) assert that mulching using green tea waste-rice bran compost at the dose of 0.5 kg/m^2 increased dry weight of spinach by 2.5 times compared to the control (without mulch) and increased dry weight of radish by 0.8, 1.7, and 2.0 times compared to the control (without mulch) at the doses of 0.5, 1, and 2 kg/m^2 respectively. Carmichael *et al.* (2012) also confirmed that the use of mulch grass (10 cm thickness) significantly increased plant height and leaf area by 39% and 18% respectively, but it did not significantly increase fresh weight on 5 WAP (only 18%) compared to the bare soil in radish (*Raphanus sativus* L.) cultivation (with 70% soil moisture). The percentage increase in fresh and dry shoot weight of *Spinacia oleracea L.* reported in the previous research is still lower than the results of this current research. Accordingly, BDM made from water hyacinth and coconut fiber is promising to be used in *Spinacia oleracea L.* cultivation. Higher growth, marketable yield, and dry weight in all BDM compositions compared to the control (without mulch) can be specifically explained by microclimates, i.e. lower temperature under BDM compared to the bare soil. It can be caused by Rubisco (μmol/m^2) and cytochrome f per Rubisco content (mol/mol) (balancing between RuBP regeneration and RuBP carboxylation) at lower temperature that were higher compared to the higher temperature treatment (Yamori *et al.*, 2005).

Optimum biodegradable mulch for improving the growth of horenso (Spinacia oleracea L.)

Based on response optimizer, the optimum BDM composition affecting plant height, stem diameter, number of leaves, and fresh shoot weight as the response variables was obtained at 56.42% water hyacinth and 0% coconut coir with the composite desirability (D) value of 0.9620. The D values of the tested BDM compositions from the highest to the lowest were MO2, MO3, MO1, MO4, and MO5 respectively, with the values ranging from 0.8065-0.6211 (Table 4).

The contour plot in Fig. 6 shows that the higher growth variable (plant height) and marketable yield (fresh shoot weight) were obtained with the higher water hyacinth percentage than coconut coir. Based on the overlay contour plot and 3D surface plot, the optimum composition of BDM for the growth and marketable yield was obtained at 40-70% water hyacinth and 0-20% coconut coir (Figs. 6 and 7).

Based on the response surface analysis, the D value of the optimum and tested BDM compositions that is close to 1 imply that compositions appear to accomplish favorable results for all variables as a whole (Minitab Inc., 2014). Generally, regarding individual desirability (D) value from the tested BDM compositions, the effective composition to maximize the number of leaves and stem diameter ranged from 0.60668-0.88254), while the fresh shoot weight and plant height ranged from 0.57272-0.77523. Based on overlay contour plot

Table 4: Response optimizer of BDM compositions on fresh shoot weight, plant height, number of leaves and stem diameter

Treatment (%Water Hyacinth: %Coconut Coir)	Composite desirability (D)	Desirability (d)			
		Fresh shoot weight	Plant height	Number of leaves	Stem diameter
Optimum (56.43:0)	0.962	0.957	0.895	1.000	1.000
MO1 (80:20)	0.750	0.671	0.728	0.757	0.855
MO2 (70:30)	0.807	0.732	0.774	0.846	0.883
MO3 (60:40)	0.804	0.736	0.775	0.861	0.850
MO4 (50:50)	0.742	0.683	0.733	0.800	0.759
MO5 (40:60)	0.621	0.573	0.646	0.663	0.607

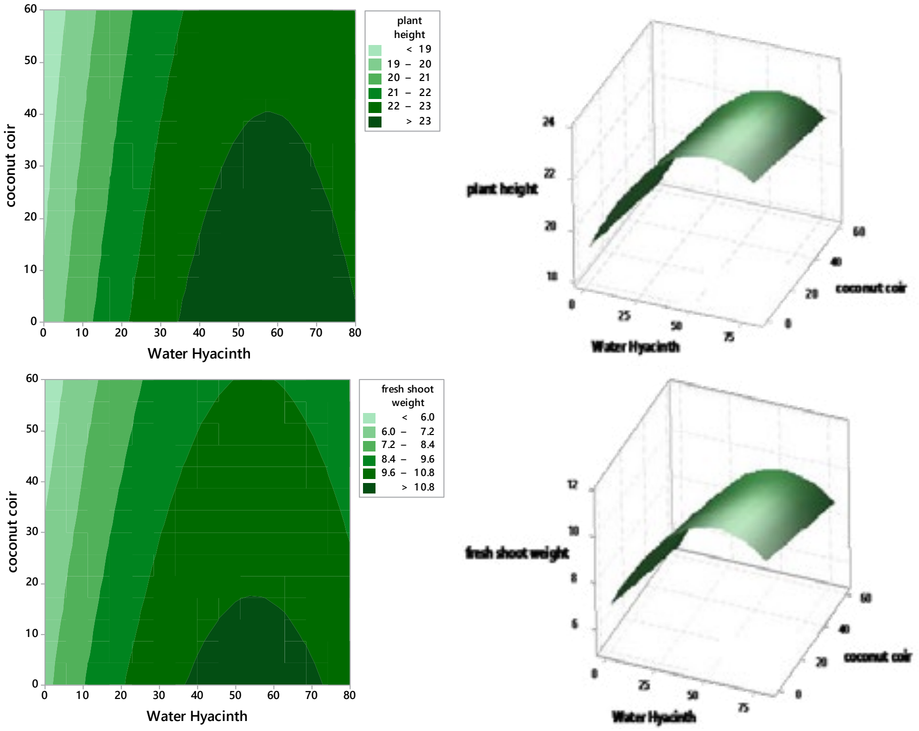

Fig. 6: Contour and surface plots showing the effects of BDM compositions (percentage of water hyacinth and coconut coir) on plant height (top) and fresh shoot weight (bottom) of horenso

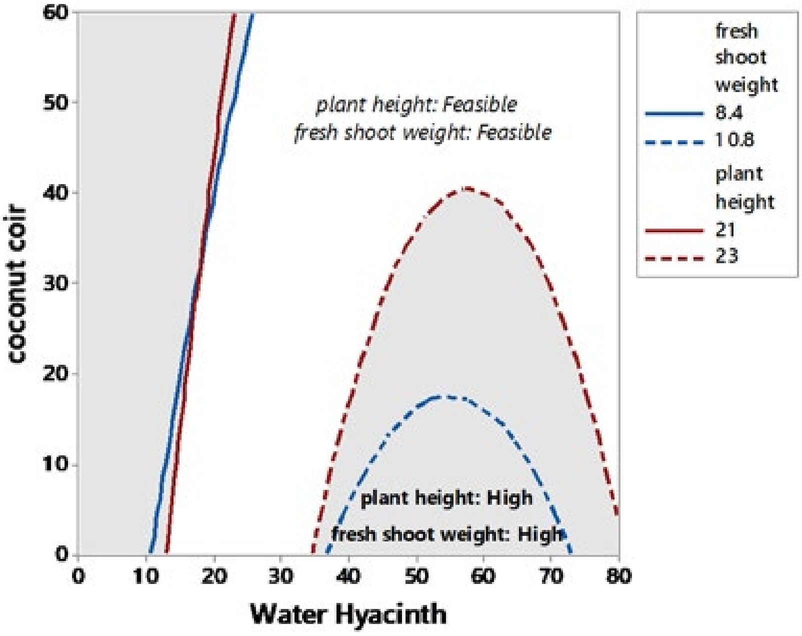

Fig. 7: Overlay countour plot showing the effects of BDM compositions (percentage of water hyacinth and coconut coir) on plant height (top) and fresh shoot weight (bottom) of horenso

and 3D surface plot, the optimum composition of BDM for the growth and marketable yield was obtained at 40-70% water hyacinth and 0-20% coconut coir that was similar to MO2 treatment (70% water hyacinth and 30% coconut coir) with the highest D value compared to the other BDM compositions. Although there was no significant difference in growth and yield of horenso among the differing BDM compositions in general, this optimum composition of BDM can be used as a consideration in the future BDM formulation

CONCLUSION

This study investigated biodegradable mulch composition as microclimate modification effort to combat climate change and to improve the growth and marketable yield of horenso, which may have contributions on other short-cycle crop cultivation. Organic mulch provides a favorable environment for crops and adds nutrients to the soil but its stock is limited due to seasonal and spatial availability and cannot be stored for a long time. On the other hand, plastic mulch is practically easy to use, but less environmentally friendly and expensive disposal cost. Commercial biodegradable plastic mulch is made from expensive raw materials and requires sophisticated production technology. In this study, we attempt to produce biodegradable mulch with abundant and low-cost raw materials using simple technology. The Various tested BDM compositions in this research have contributed a number of modifications on the microclimate by decreasing 1-2°C of soil temperature and maintaining soil moisture within the range of 63-84%. These properties support the adaption effort to combat climate change. High and stable soil humidity indicates the sufficient water availability in the soil for plant growth and development. The optimum composition of the mulch for supporting growth and marketable yield of horenso were obtained with the higher water hyacinth percentage than coconut coir. The optimum composition of BDM for the growth and marketable yield was obtained at 40-70% water hyacinth and 0-20% coconut coir based on the overlay contour plot and 3D surface plot. Referring to the response optimizer analysis with growth and marketable yield as responses, the optimum biodegradable mulch composition was obtained from MO2 treatment (70% water hyacinth and 30% coconut coir) with the highest composite desirability value (D) compared to the other biodegradable mulch compositions. Although there was no significant difference in the growth and yield of horenso among the differing BDM compositions, the BDM composition treatments resulted in significantly higher value than the control (without mulch). The BDM composition treatments could increase fresh shoot weight around 38-55%, fresh root weight for about 55-94%, and dry shoot weight approximately by 1.6-2.8 times compared to the control (without mulch). This finding emphasized that all BDM compositions tested in this current research can be used as mulch in horenso (Spinacia oleracea L.) cultivation. Further research was needed to adapt BDM compositions on other short-cycle crops and other horticulture crops. The long term use of biodegradable mulch in horticulture crops cultivation is not only expected to help crops deal with climate change, but also improve the soil health. Biodegradable mulch is one of the practical aspects to achieve sustainable agriculture that focuses on producing long term crops while having minimal negative impacts on the environment.

AUTHOR CONTRIBUTIONS

A. Iriany contributed in conceptualization, designed methodology, supervision, and writing-original draft. F. Hasanah performed data analysis and interpretation, literature review, and writing-original draft. D. Roeswitawati contributed in supervision. M.F. Bela performed experiments and investigation.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

ABBREVIATIONS

∝	Level of significance
%	Percent
°C	Centigrade or degree Celcius
µL/L	microlitre per litre
$\mu mol/m^2$	micromoles per square metre
ANOVA	Analysis of variance
BDM	Biodegradable mulch
C	Carbon
cm	Centrimetre
cm^2	Square centimetre
CO_2	Carbon dioxide
D	Composite desirability
d	Desirability
DAP	Days after planting
FAO	Food and Agriculture Organization of the United Nations
g	Gram
HSD	Honestly significant difference
kg/ha/week	Kilogram per hectare per week
kg/m^2	Kilogram per square metre
mm	Milimetre
mm per year	Milimetre per year
MO	Control or without mulch (treatment code)
MO1	Biodegradable mulch made of 80% water hyacinth and 20% coconut coir (treatment code)
MO2	Biodegradable mulch made of 70% water hyacinth and 30% coconut coir (treatment code)
MO3	Biodegradable mulch made of 60% water hyacinth and 40% coconut coir (treatment code)
MO4	Biodegradable mulch made of 50% water hyacinth and 50% coconut coir (treatment code)
MO5	Biodegradable mulch made of 40% water hyacinth and 60% coconut coir (treatment code)
mol/mol	mole per mole
P-value	Probability value
r	Pearson correlation coefficient
RCBD	Randomized complete block design
RSM	Response surface method
RuBP	Ribulose 1,5-bisphosphate
SM_{mor}	Soil moisture in the morning
SM_{noon}	Soil moisture in the noon
SOC	Soil organic carbon
SOM	Soil organic matter
T_{max}	Maximum soil temperature
T_{min}	Minimum soil temperature
USDA	United States Department of Agriculture
WAP	Weeks after planting

REFERENCES

Applied Horticultural Research. (2016). Pre-harvest effects on the quality of babyleaf spinach. Sydney (**5 Pages**).

Ayinde, O.E.; Muchie, M.; Olatunji, G.B., (2011). Effect of climate change on agricultural productivity in Nigeria: A co-integration model approach. J. Hum. Ecol., 35(3): 189–194 (**6 Pages**).

Behzadnejad, J.; Tahmasebi-Sarvestani, Z.; Aein, A.; Mokhtassi-Bidgoli, A., (2020). Wheat straw mulching helps improve yield in sesame (*Sesamum indicum* L .) under drought stress. Int. J. Plant Prod. 14, 389–400 (**12 pages**).

Carmichael, P.C.; Shongwe, V.D.; Masarirambi, M.T.; Manyatsi, A.M., (2012). Effect of mulch and irrigation on growth, yield and quality of radish (Raphanus sativus L .) in a semi-arid Sub-tropical environment. Asian J. Agric. Sci. 4(3): 183–187 (**5 Pages**).

Chen, Y.; Liu, T.; Tian, X.; Wang, X.; Li, M.; Wang, S.; Wang, Z., (2015). Effects of plastic film combined with straw mulch on grain yield and water use efficiency of winter wheat in Loess Plateau. F. Crop. Res. 172: 53–58 (**6 Pages**).

Edgar, O.N.; Gweyi-onyango, J.P.; Korir, N.K., (2016). Influence of mulching materials on the growth and yield components of green pepper at Busia County in Kenya. Asian Res. J. Agric. 2, 1–10 (**10 pages**).

Fagariba, C.J.; Song, S.; Baoro, S.K.G.S., (2018). Climate change adaptation strategies and constraints in Northern Ghana: Evidence of farmers in Sissala West District. Sustainability, 10(1484): 1–18 (**18 Pages**).

FAO, (2020a). Import quantity of spinach.

FAO, (2020b). Production quantity of spinach.

Gornall, J.; Betts, R.; Burke, E.; Clark, R.; Camp, J.; Willett, K.; Wiltshire, A., (2010). Implications of climate change for agricultural productivity in the early twenty-first century. Philos Trans R Soc Lond B Biol Sci, 365(1554): 2973–2989 (**17 Pages**).

Gu, C.; Liu, Y.; Mohamed, I.; Zhang, R.; Wang, X.; Nie, X.; Jiang, M.; Brooks, M.; Chen, F.; Li, Z., (2016). Dynamic changes of soil surface organic carbon under different mulching practices in citrus orchards on sloping land. PLoS ONE, 11(12): e0168384 (**15 Pages**).

Henrique, G., (2020). Biodegradable mulch of recycled paper reduces water consumption and crop coefficient of pak choi. Sci. Hortic. 267: 109315 (**8 Pages**).

Hoegh-Guldberg, O.; Jacob, D.; Taylor, M.; Bindi, M.; Brown, S.; Camilloni, I.; Diedhiou, A.; Djalante, R.; Ebi, K.L.; Engelbrecht, F.; Guiot, J.; Hijioka, Y.; Mehrotra, S.; Payne, A.; Seneviratne, S.I.; Thomas, A.; Warren, R.; Zhou, G., (2018). Impacts of 1.5°C of Global Warming on Natural and Human Systems. In Masson-Delmotte, V.; P. Zhai; H.-O. Pörtner; D. Roberts; J. Skea; P.R. Shukla; A. Pirani; W. Moufouma-Okia; C. Péan; R. Pidcock; S. Connors; J.B.R. Matthews; Y. Chen; X. Zhou; M.I. Gomis; E. Lonnoy; T. Maycock; M. Tignor; T. Waterfield (Eds.), Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,. Geneva, Switzerland (**138 Pages**).

Hu, T.; Sørensen, P.; Olesen, J.E., (2018). Soil carbon varies between different organic and conventional management schemes in arable agriculture. Eur. J. Agron. 94: 79–88 (**10 Pages**).

IPCC, (2018). Summary for Policymakers. In Masson-Delmotte, V.; P. Zhai; H.-O. Pörtner; D. Roberts; J. Skea; P.R. Shukla; A. Pirani; W. Moufouma-Okia; C. Péan; R. Pidcock; S. Connors; J.B.R. Matthews; Y. Chen; X. Zhou; M.I. Gomis; E. Lonnoy; T. Maycock; M. Tignor;T. Waterfield (Eds.), Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,. Geneva, Switzerland.

Iriany, A.; Chanan, M.; Djoyowasito, G., (2018). Organic mulch sheet formulation as an effort to help plants adapt to climate change. Int. J. Recycl. Org. Waste Agric. 7(1): 41–47 (**7 Pages**).

Iriany, A.; Hasanah, F.; Hartawati, (2019a). Study of various organic mulch sheet compositions usage towards the growth and yield of cauliflower (Brassica oleracea Var Botrytis, L.). Int. J. Eng. Technol. 8(19): 147–151. (**5 Pages**).

Iriany, A.; Lestari, R.; Chanan, M., (2019b). Examining organic mulch sheet on the growth and yield of shallot (Allium ascalonicum L.). Int. J. Eng. Technol. 8(19): 297–301 (**5 Pages**).

Jirapornvaree, I.; Suppadit, T.; Popan, A., (2017). Use of pineapple waste for production of decomposable pots. Int. J. Recycl. Org. Waste Agric. 6(4): 345–350 (**6 Pages**).

Kasirajan, S.; Ngouajio, M., (2012). Polyethylene and biodegradable mulches for agricultural applications: A review. Agro. Sustain. Dev., 32(2): 501–529 (**29 Pages**).

Khan, M.; Hira, M.; Rahaman, S.; Moni, Z.R.; Hussen, M.; Someya, T.; Ueno, K., (2019). Way of compost application for organic farming. SAARC J Agric, 17(1); 211–217 (**7 Pages**).

Kumar, S.; Dey, P., (2012). Influence of soil hydrothermal environment, irrigation regime, and different mulches on the growth and fruit quality of strawberry (Fragaria × Ananassa L.) plants in a sub-temperate climate. J. Hortic. Sci. Biotechnol., 87(4); 374–380 (**7 Pages**).

Lalljee, B. (2013). Mulching as a mitigation agricultural technology against land degradation in the wake of climate change. Int. soil water Conserv. Res. 1(3): 68–74 (**7 Pages**).

Lamont, W.J., (2017). Plastic Mulches for the Production of Vegetable Crops, in: A Guide to the Manufacture, Performance, and Potential of Plastics in Agriculture. Elsevier Ltd, pp. 45–60 (**16 pages**).

Manyatsi, A.; Simelane, G.R., (2017). The effect of organic mulch on the growth and yield of Spinach (Spinacia oleracea L). Int. J. Environ. Agric. Res. 3(6): 53–56 (**4 Pages**).

Marí, A.I.; Pardo, G.; Aibar, J.; Cirujeda, A., (2020). Purple nutsedge (Cyperus rotundus L .) control with biodegradable mulches and its effect on fresh pepper production. Sci. Hortic. 263: 109111 (**8 Pages**).

Meena, R.K.; Vashisth, A.; Manjaih, K.M., (2014). Study on change in microenvironment under different colour shade nets and its impact on yield of spinach (Spinacia oleracea L.). J. Agrometeorol. 16(1): 104–111 (**8 Pages**).

Ministry of Agriculture Republic of Indonesia. (2017). Agricultural statistics 2017. (A.A. Susanti; B. Waryanto; P.H.A. Muliany; S.N. Sholikhah; R. Widaningsih; T. Heni; R. Suryani, Eds.). Jakarta: Centre for Agricultural Data and Information System, Ministry of Agriculture Republic of Indonesia (**408 Pages**).

Minitab Inc., (2014). Minitab Statistical Software. State College, Pennsylvania.

Nkwachukwu, O.I.; Chima, C.H.; Ikenna, A.O.; Albert, L., (2013). Focus on potential environmental issues on plastic world towards a sustainable plastic recycling in developing countries. Int. J. Ind. Chem. (IJIC), 4(34): 1–13 (**13 Pages**).

Salleh, J.; Mohd Yusoh, M.K.; Ruznan, W.S., (2015). Tensile strength of some natural-fibre composites. Pertanika J. Trop. Agric. Sci. 38(4): 575–582 (**8 Pages**).

Sarika, D.; Singh, J.; Prasad, R.; Vishan, I.; Varma, V.S.; Kalamdhad, A.S., (2014). Study of physico-chemical and biochemical parameters during rotary drum composting of water hyacinth. Int. J. Recycl. Org. Waste Agric., 3(3): 63 (**9 Pages**).

Sathiyamurthy, V.A.; Rajashree, V.; Shanmugasundaram, T.; Arumugam, T., (2017). Effect of different mulching on weed intensity, yield and economics in chilli (*Capsicum annuum* L.). Int. J. Curr. Microbiol. Appl. Sci. 6, 609–617 (**9 pages**).

Tanveer, S.K., Lu, X., Shah, S., Hussain, I., Sohail, M., (2019). Soil Carbon Sequestration through Agronomic Management Practices. In L.A. Frazao; A.M.S. Olaya; J. Cota (Eds.), CO_2 Sequestration. IntechOpen (**17 Pages**).

Tham, H.T., (2012). Water Hyacinth (Eichornia crassipes) – Biomass Production, Ensilability and Feeding Value to Growing Cattle. Swedish University of Agricultural Sciences (**64 Pages**).

USDA, (2006). Spinach Plants, Spinach Leaves, and Bunched Spinach: Shipping Point and Market Inspection Instructions.

Wang, Y.P.; Li, X.G.; Taotao, F.; Wang, L.; Turner, N.C.; Siddique, K.H. M.; Li, F., (2016). Multi-site assessment of the effects of plastic-film mulch on the soil organic carbon balance in semiarid areas of China. Agric. For. Meteorol. 228–229: 42–51 (**10 Pages**).

Yamori, W.; Noguchi, K.; Terashima, I., (2005). Temperature acclimation of photosynthesis in spinach leaves: Analyses of photosynthetic components and temperature dependencies of photosynthetic partial reactions. Plant, Cell Environ. 28(4): 536–547 (**12 Pages**).

Zhang, X.; You, S.; Tian, Y.; Li, J., (2019). Comparison of plastic film, biodegradable paper and bio-based film mulching for summer tomato production: Soil properties, plant growth, fruit yield and fruit quality. Sci. Hortic. 249: 38–48 (**11 Pages**).

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