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Soil temperature conditions in Samhong King plant cultivation land (*Brassica rapa* var*. chinensis* L.) due to the application of embedded biochar

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Abstract. Climate change is characterized by increasing greenhouse gases that change temperature conditions and weather patterns that result in increasing earth temperatures and trigger various natural disasters such as droughts, floods, increased temperatures, and heat waves. This condition causes many losses in various sectors, especially in the agricultural sector. To overcome this problem, the application of biochar as an effort to mitigate climate change was very efficient in reducing extreme temperatures in plant cultivation. The application of biochar can create microclimate conditions that were more suitable for the growth of Samhong King plant. The studied aim to learn the effect of embedded biochar treatment on soil temperature in Samhong King cultivation. The study was conducted at the Biochar Research Station, Universitas Syiah Kuala. This study used a non-factorial randomized block design with 10 treatments and 3 replications. The factors observed were soil temperature with a depth of 0 and 10 cm. The results showed that embedded biochar had a significant effect on soil temperature at 0 cm but not significant effect on soil temperature at a depth of 10 cm. The best treatment with the lowest temperature was the coconut fiber embedded biochar treatment of 10 tonnes ha^{-1}.

1. Introduction

The phenomenon of global warming and climate change that has occurred is not only a problem of a country but has become a global problem including Indonesia [1]. Climate change is caused by the phenomenon of greenhouse gases, so that this situation results in an increase in earth's temperature and natural disasters, such as drought, erratic rainfall instability, increased

temperature, humidity, and many other widespread impacts resulting in damage and failure in various production sectors, especially in the agricultural sector, which is highly dependent on stable climatic conditions [2]. The monthly average surface air temperature in the Indonesian region from January to December 2024 is predicted to experience anomalies between +0.23 °C to +0.36 °C (with an average of 0.3 °C) warmer than the 1991-2020 period [3]. The occurrence of climate change will greatly affect the agricultural sector arising from its impact on the life cycle of plants ranging from growth, development, and crop yields, all of which are very sensitive and dependent on weather and climate conditions.

Based on the data obtained, it shows that climate conditions in Indonesia are increasingly worrying. If this situation continues, it will have a significant impact on agricultural production in Indonesia. Climate change and increasing temperatures can cause drought, changes in rainfall patterns, and the emergence of pests and diseases, all of which have the potential to reduce the productivity of agricultural products. Therefore, it was important to make efforts to respond to climate change, especially in the agricultural sector [4].

One of the steps of applying biochar to soil is as a simple and effective mitigation effort to deal with climate change and protect the environment. Biochar can increase carbon sequestration (capture and storage process) that can remediate and conserve soil so that agricultural yields will increase [5]. The effectiveness of biochar has been tested and was very effective in improving soil conditions, both acidic and alkaline [6]. The capacity of biochar to bind carbon stably was a very potential solution in addressing climate change such as reducing the rate of carbon emissions, especially in the face of increasing frequency and intensity of extreme weather [7].

Samhong King mustard (*Brassica rapa* var. *chinensis* L.) is one type of plant that is well adapted. Samhong King mustard is very suitable and easy to cultivate in the highlands with sufficient sunlight intensity. Optimal growth of Samhong King mustard requires a low to warm temperature range of 22 - 33°C, and soil temperature around 7 - 28°C. Optimization of microclimate modification settings is a crucial factor for optimal growth of Samhong King plants in order to get maximum yields [8]. So that one way of giving biochar in the cultivation of this plant is very effective to neutralize soil temperature and can submerge extreme temperatures, which we know that the earth's temperature continues to increase every year.

The application of biochar to soil has the potential to increase soil organic carbon levels, water retention and nutrient availability. The carbon contained in biochar is stable and can be stored in the soil for thousands of years [9]. Biochar provides long-term benefits to the soil by increasing the availability of plenty of water and more nutrients for plants. Therefore, the application of biochar as a climate mitigation strategy plays an important role in reducing extreme temperatures [10]. Based on the description of various studied that had been conducted, the aim of this experiment was to determine the effect of biochar treatments in soil temperature at Samhong King cultivation.

2. Materials and methods

The research was conducted at the Biochar Research Station of Universitas Syiah Kuala, Banda Aceh, Aceh. This research was conducted from July to October 2024. The tools and materials used were soil tester, infrared thermometer, lux meter, humidity meter, rain gauge, Samhong King seeds, coconut fiber biochar, Inceptisol soil, label paper, tissue, polybag, hoe, scales, paddle, sprayer, ruler, stationery, inorganic fertilizer (urea 75 kg ha^{-1}, KCl 50 kg ha^{-1}, SP36 50 kg ha^{-1}), cow manure 10 tonnes ha^{-1}, incubated biochar. The raw material of biochar was coconut fiber.

This study used a non-factorial group randomized design with 10 treatments (Table 1) and 3 replications, these observations were measured for 5 weeks. There were 30 experimental units.

Each experimental unit consisted of 4 samples. The observation parameters was the microclimate around plant roots (soil temperature at a depth of 0 and 10 cm). The research data were analysed using ANOVA. Significant data were analysed by Duncan New Multiple Range Test (DNMRT).

This study began with Samhong King seeds sown in a tray for 14 days. After 14 day after sowing, the seedlings were transferred to polybags with a size of 13 cm x 15 cm. The nursery media was a mixture of soil and cow manure in a ratio of 2:1. Then the preparation of planting media used was Inceptisol soil from Barbate, Krueng Raya, Aceh Besar District. The soil was dried and sieved using a 2 mm sieve. The sieved soil was put into 2 kg per polybag and given treatment (Table 1). After that, the application of biochar, embedded biochar, and cow manure was mixed in polybag according to the treatment and incubated for 7 days. Samhong King plants were planted after 28 day after sowing. Soil temperature measurements were taken at a depth of 0 and 10 cm from the soil surface after planting, measuring soil temperature at a depth of 0 cm using an infrared thermometer, while at a depth of 10 cm using a soil tester. Measurements were made three times a day, namely in the morning at 07.00-08.00 WIB (western Indonesia time), in the afternoon at 12.00-13.00 WIB, and in the afternoon at 17.00-18.00 WIB (Figure 1).

Table 1. Application treatment of the effect of using embedded biochar

Symbol	Treatments
CF_0	Control
CF_1	Cow manure 10 tonnes ha^{-1}
CF_2	Coconut fiber biochar 10 tonnes ha^{-1}
CF_3	Coconut fiber biochar 20 tonnes ha^{-1}
CF_4	Coconut fiber biochar 10 tonnes ha^{-1} + cow manure 10 tonnes ha^{-1}
CF_5	Coconut fiber biochar 20 tonnes ha^{-1} + cow manure 10 tonnes ha^{-1}
CF_6	Coconut fiber embedded biochar 10 tonnes ha^{-1}
CF_7	Coconut fiber embedded biochar 20 tonnes ha^{-1}
CF_8	Coconut fiber embedded biochar 10 tonnes ha^{-1} + cow manure 10 tonnes ha^{-1}
CF_9	Coconut fiber embedded biochar 20 tonnes ha^{-1} + cow manure 10 tonnes ha^{-1}

Figure 1. Soil temperature measurement

3. Results and discussion

3.1 Effect of embedded biochar at a depth of 0 cm on soil temperature

The results of the analysis of variation (ANOVA) test showed that application of biochar to the soil had a significant effect on soil temperature in the 4th week observation. However, observations of the 1st to 4th weeks and the 5th week of biochar application on the soil did not have a significant effect on soil temperature. The data obtained during measurement can change. The difference in temperature obtained based on the measurement time was also due to fluctuations in soil surface temperature (0 cm depth) which was influenced by changes in atmospheric temperature above the soil surface [11]. In the 4th week of observation, there was a change in soil temperature between morning and evening (Table 2). This was due to the influence of the biochar application given. Other factors that affect the high and low soil temperature at different times were solar radiation and vegetation [12].

Based on Table 2, the soil temperature at a depth of 0 cm in the afternoon showed a significant effect in the 4th week with the treatment of coconut fiber embedded biochar 10 tonnes ha^{-1} had the lowest temperature of 29.03 °C which was not significantly different from the treatment of coconut fiber biochar 10 tonnes ha^{-1}. This showed that the addition of biochar can reduce soil temperature, as a result of increased water holding capacity in the soil [13]. The treatment of coconut fiber biochar 10 tonnes ha^{-1} + cow manure 10 tonnes ha^{-1} had the highest temperature of 30.14°C. While for the treatment of coconut fiber biochar 20 tonnes ha^{-1} and coconut fiber embedded biochar 10 tonnes ha^{-1} + cow manure 10 tonnes ha^{-1} had the same average temperature of 29.50°C, and for the morning and afternoon showed not significant difference in soil temperature. From the observation of the effect of the application of embedded biochar on soil temperature at a depth of 0 cm was still very fluctuating. The difference in temperature in the morning, afternoon and evening can occur because the soil temperature will be influenced by the amount of absorption of solar radiation by the soil surface [14]. Biochar which has large pore characteristics and a large surface area can store large amounts of water and nutrients and also as a place for microbial life in large quantities. Storage of large amounts of water will affect soil temperature so that it becomes ideal for Samhong King plant temperature [15].

Table 2. Average 0 cm depth of soil temperature

Time (WIB)	Treatments	Average weekly soil temperature (°C)					Weekly average (°C)
		1	2	3	4	5	
07.00-08.00	CF_0	25.34	25.98	25.79	26.40	26.59	26.02
	CF_1	24.99	26.20	25.65	26.34	26.89	26.01
	CF_2	25.83	26.84	25.63	26.40	26.65	26.27
	CF_3	24.75	26.52	25.75	26.46	26.33	25.96
	CF_4	25.09	26.40	25.93	26.81	27.06	26.26
	CF_5	25.37	26.86	25.98	26.42	26.24	26.18
	CF_6	24.92	26.37	25.96	26.42	26.95	26.12
	CF_7	26.45	26.14	25.76	26.18	26.43	26.19
	CF_8	25.44	25.97	22.78	26.37	26.85	25.48
	CF_9	24.82	26.12	25.67	26.62	26.95	26.04
12.00-13.00	CF_0	36.81	36.41	39.87	36.73	36.54	37.27
	CF_1	37.51	37.17	40.37	37.08	36.73	37.77
	CF_2	37.51	36.76	40.52	37.01	37.44	37.85
	CF_3	39.79	36.21	39.99	37.54	38.88	38.48
	CF_4	38.92	38.29	40.40	37.38	37.53	38.50
	CF_5	37.52	37.71	40.06	37.64	36.60	37.91
	CF_6	36.13	36.18	40.02	36.63	36.28	37.05
	CF_7	40.50	36.04	40.12	35.59	36.14	37.68
	CF_8	36.03	35.52	40.19	36.89	37.06	37.14
	CF_9	38.06	37.17	40.53	37.87	37.93	38.31
17.00-18.00	CF_0	29.48	29.01	30.25	29.21^{bc}	27.44	29.08
	CF_1	29.65	28.59	30.68	29.28^{cde}	27.25	29.09
	CF_2	28.98	28.16	30.55	29.17^{b}	27.20	28.81
	CF_3	28.95	28.31	30.34	29.50^{f}	27.78	28.98
	CF_4	29.37	29.19	31.62	30.14^{g}	27.85	29.63
	CF_5	29.28	29.39	30.82	29.49^{f}	27.89	29.37
	CF_6	28.73	28.44	30.08	29.03^{a}	26.99	28.66
	CF_7	29.35	28.51	31.29	29.26^{bcd}	27.09	29.10
	CF_8	28.82	28.66	30.71	29.50^{f}	27.63	29.06
	CF_9	29.08	28.67	31.31	29.31^{cde}	28.06	29.29

3.2 Effect of embedded biochar at 10 cm depth on soil temperature

The embedded biochar treatment had not significant effect on soil temperature at a depth of 10 cm for 5 weeks of observation. The weekly average data showed that the soil temperature tends to be better (had a lower temperature) in the morning at the treatment of coconut fiber biochar 20 tonnes ha^{-1} + cow manure 10 tonnes ha^{-1} (25.75°C), in the afternoon at the treatment of coconut fiber embedded biochar 10 tonnes ha^{-1} at 33.23°C, and in the afternoon at the treatment of coconut fiber biochar 20 tonnes ha^{-1} + cow manure 10 tonnes ha^{-1} at 29.82°C (Table 3). The temperature difference from the three measurement times was not significant different. The difference in

temperature increase and decrease can occur because the characteristics and performance of biochar vary widely and largely depend on the raw materials (particle size and type) and pyrolysis conditions (pyrolysis temperature, heating rate, residence time, and gas loading) [16].

Table 3. Average 10 cm depth of soil temperature

Time (WIB)	Treatments	Soil temperature average (°C)					Weekly average (°C)
		1	2	3	4	5	
07.00-08.00	CF_0	26.28	25.67	25.78	26.05	25.73	25.90
	CF_1	26.06	25.72	25.72	26.22	25.80	25.91
	CF_2	26.06	25.72	25.72	25.89	25.80	25.84
	CF_3	26.28	25.89	25.67	26.05	25.53	25.88
	CF_4	26.55	26.28	26.06	26.33	26.00	26.24
	CF_5	25.94	25.61	25.83	26.05	25.33	25.75
	CF_6	26.11	25.72	25.72	26.11	25.53	25.84
	CF_7	25.89	25.78	25.78	26.17	25.80	25.88
	CF_8	25.89	25.72	25.78	25.89	25.67	25.79
	CF_9	25.89	25.56	25.78	26.00	26.33	25.91
12.00-13.00	CF_0	34.33	32.48	34.78	32.33	33.11	33.41
	CF_1	34.87	32.33	34.72	33.11	32.89	33.58
	CF_2	34.47	32.24	34.78	32.61	32.78	33.37
	CF_3	34.47	32.34	34.72	32.67	33.78	33.59
	CF_4	34.33	32.29	34.56	32.50	33.72	33.48
	CF_5	34.53	32.62	34.78	32.56	33.06	33.51
	CF_6	34.80	32.38	34.72	32.83	31.39	33.23
	CF_7	34.27	32.10	34.83	32.56	32.95	33.34
	CF_8	34.60	32.29	34.61	32.28	33.28	33.41
	CF_9	34.53	32.48	34.61	32.89	33.83	33.67
17.00-18.00	CF_0	29.73	30.14	31.28	29.72	30.08	30.19
	CF_1	30.47	30.05	31.89	30.00	29.00	30.28
	CF_2	29.93	29.90	31.83	29.86	29.17	30.14
	CF_3	30.00	30.00	31.06	29.95	28.67	29.94
	CF_4	29.47	30.24	31.50	29.86	29.33	30.08
	CF_5	29.87	29.90	31.50	29.43	28.42	29.82
	CF_6	29.73	29.86	31.56	29.95	29.00	30.02
	CF_7	29.80	29.95	31.56	29.95	29.08	30.07
	CF_8	29.33	30.19	31.50	29.57	29.25	29.97
	CF_9	29.67	30.43	31.56	29.90	29.42	30.19

Based on the Table 3, it can be concluded that the effect of biochar application did not significantly effect on soil temperature at a depth of 10 cm. This was because although there was an increase in temperature, the temperature difference was not statistically significant. Soil temperature with treatment of biochar and without biochar at a depth of 10 cm showed a similar

graph with daily fluctuations that were not significantly affected by biochar application (Figure 2). In addition, biochar also tends to stabilize soil temperature, but the effect was more pronounced at greater depths or under certain conditions. Biochar as amendment soil can reduce soil temperature fluctuations on a daily and seasonal scale. Biochar can moderate daily or seasonal fluctuations in soil temperature, so it can lower the temperature when soil temperature was high and raise it when soil temperature was low [17]. Several studies had shown that biochar can improve the physical and chemical conditions of soils with salinity, alkalinity and nutrient deficiency problems. However, it was necessary to determine the right raw materials, manufacturing methods and dosage of biochar for each specific soil condition, which can affect in significant changes in soil temperature at a depth of 10 cm [18].

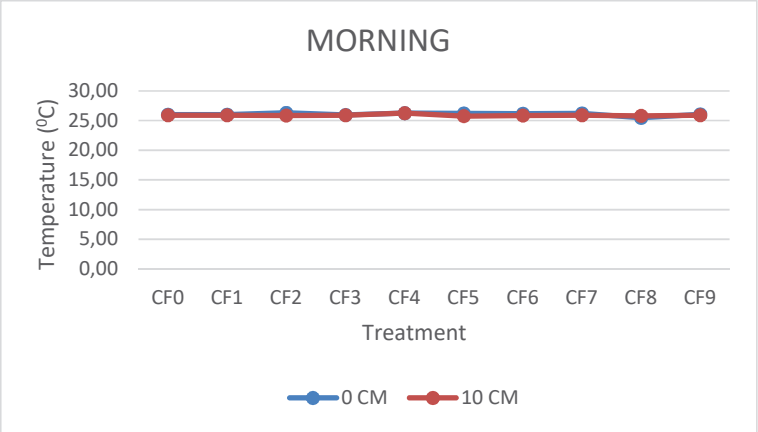

Figure 2. Soil temperature in the morning at depths of 0 and 10 cm.

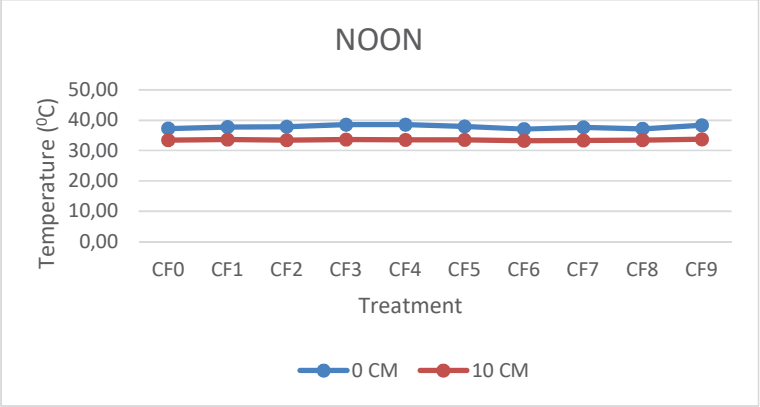

Figure 3. Soil temperature during the noon at depths of 0 and 10 cm.

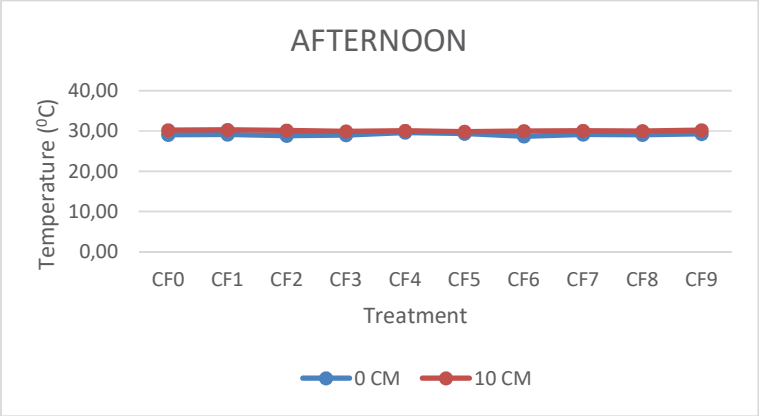

Figure 4. Soil temperature in the afternoon at depths of 0 and 10 cm.

The effect of biochar application on the microclimate in Samhong King cultivation at 0 cm and 10 cm soil temperature showed a difference in temperature every time it was measured (Figure 2, 3 and 4). This was caused by external factors, internal factors, and topographic factors. There were several factors that make the soil temperature high and low, namely solar radiation, clouds, rainfall, wind speed and air humidity, causing temperature changes every week. As for factors in the soil that include soil structure, soil moisture content, organic matter content, soil pH and soil color also cause changes in temperature every week. The higher the soil temperature, the faster the maturation process in plants [19]. These weekly air temperature fluctuations and measurement times were the dominant factors that affect microclimate conditions with changes in air temperature during that period. These temperature changes greatly affect the environmental conditions around the plants. This was especially evident in the distribution of heat on the surface and underground around the plants [20].

3.3 The climate supporting data

Weather conditions during the experiment (5 weeks of observation) showed hot weather conditions with high air temperature, humidity and rainfall (Table 4 and 5). Plant growth and yield were determined by three main factors, namely soil, climate or weather, and plant species. Climate was one of the elements that affect plant growth and productivity. Some of the climatic factors that greatly affect plant growth include rainfall, maximum and minimum temperatures, air humidity, and radiation. By understanding these weather factors, we can simulate plant growth as well as photosynthesis and respiration rates that evolve dynamically according to plant needs. Microclimate refers to local climatic conditions that directly impact the physical characteristics of an environment [21].

The addition of organic matter such as biochar and manure were not only beneficial for improving soil fertility, but also plays an important role in maintaining soil temperature stability. This suggests that good soil management can help crops survive extreme climatic conditions.

Table 4. Average of air temperature and air humidity

Time (WIB)	Average weekly air temperature (°C)	Average weekly air humidity (%)
07.00 – 08.00	28.03	75.07
12.00 – 13.00	32.65	67.03
17.00 – 18.00	31.04	66.87

Table 5. Average of weekly rainfall

Variable	Weekly rainfall					Weekly average (mm)
	1	2	3	4	5	
Rainfall	26.97	4.25	13.56	3.30	7.26	11.068

4. Conclusion

The application of embedded biochar significantly difference on the microclimate at Samhong King cultivation at a soil depth of 0 cm. The best treatment obtained at a depth of 0 cm was coconut fiber embedded biochar 10 tonnes ha^{-1}. While at a depth of 10 cm, the application of embedded biochar had not significant effect on soil temperature.

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