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EFFECT OF PLASTIC MULCHING AND PESTICIDE APPLICATION ON ACTIVE AND STABLE CARBON IN VOLCANIC SOILS, WEST SUMATRA

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ABSTRACT

Agricultural intensification plays an important role in sustaining productivity. Plastic mulching and the application of pesticides in crop cultivation have become inevitable to achieve high yield production. This study was aimed to determine the effect of plastic mulching and pesticide applications on carbon (C) fractions. The field experiment was designed using a completely randomized design with two factors consisting of plastic mulching and the application of pesticide at two levels (with and without) at each treatment. All the treatments were prepared for three replications. The soil carbon fractions data collected includes active C and humic acid as stable C fractions. The findings of this research showed that both active and stable C fractions were not significantly influenced by plastic mulching and pesticide applications. The active and stable C fractions were ranging from 1.40 to 1.42 g/kg and from 193.3 to 220 g/kg, respectively. These results might be attributed to the period of the study. The duration of this study might be not sufficient to capture any potential long-term changes in soil C fractions induced by the treatments. Thus, further research should consider extending the experiment duration to assess the long-term effects of the agricultural practices to C fractions.

Keyword: *Andosols, labile C, conventional farming, humic substance*

ABSTRAK

[PENGARUH MULSA PLASTIK DAN APLIKASI PESTISIDA TERHADAP KARBON AKTIF DAN STABIL PADA TANAH VULKANIS, SUMATRA BARAT]. Intensifikasi pertanian memainkan peran penting dalam menjaga produktivitas. Penggunaan mulsa plastik dan penerapan pestisida dalam budidaya tanaman menjadi hal yang tidak terhindarkan untuk mencapai produksi yang lebih tinggi. Penelitian ini bertujuan untuk menentukan efek penggunaan mulsa plastik dan penerapan pestisida terhadap fraksi karbon (C). Percobaan lapangan dirancang menggunakan rancangan acak lengkap dengan dua faktor, yaitu penggunaan mulsa plastik dan penerapan pestisida dengan dua tingkat (dengan dan tanpa) pada setiap perlakuan. Semua perlakuan disiapkan dalam tiga ulangan. Data fraksi C tanah yang dikumpulkan meliputi C aktif dan asam humat sebagai fraksi C yang stabil. Hasil penelitian ini menunjukkan bahwa baik fraksi C aktif maupun stabil tidak dipengaruhi oleh penggunaan mulsa plastik dan penerapan pestisida. Fraksi C aktif dan stabil berkisar antara 1,40 hingga 1,42 g/kg dan antara 193,3 hingga 220 g/kg, masing-masing. Hasil ini mungkin dapat dikaitkan dengan durasi percobaan. Durasi percobaan mungkin tidak cukup panjang untuk menunjukkan perubahan jangka panjang dalam fraksi C tanah yang disebabkan oleh perlakuan. Oleh itu, penelitian lebih lanjut diperlukan dengan mempertimbangkan durasi percobaan yang lebih panjang untuk mengevaluasi efek jangka panjang dari praktik pertanian terhadap fraksi C.

Kata kunci: *Andosols, labil C, pertanian konvensional, asam humat*

INTRODUCTION

Andosols, according to the World Reference Base (WRB) for Soil Resources (IUSS Working Group WRB, 2015) are soils derived from volcanic ash. Andosols are distributed widely in active volcanic regions such as Japan and Indonesia (Takashi & Shoji, 2002). Being the highest carbon (C) storage in the mineral soils (Eswaran *et al*., 1993), Andosols has become an important natural resource for climate mitigation. Andosols can accumulate high soil organic matter (OM), which is related to the interaction of OM with short-range order minerals such as allophane and imogolite in allophanic Andosols and Al-humus complexes in non-allophanic Andosols (Shoji *et al*., 1993). Andosols are utilized for various agricultural productions including vegetables, tea, and coffee plantations in Indonesia (Fiantis *et al*., 2005; Abe *et al*., 2018; Abe *et al*., 2020). While promoting C sequestration which is now becoming more crucial (Tan *et al*., 2023), understanding OM stabilization in volcanic soils is necessary for climate mitigation and adaptation.

The utilization of plastic mulching has been recognized for its positive effects on plants, including maintaining soil moisture and suppressing weed growth (Abouziena *et al*., 2008) thereby creating favorable conditions for plant growth. Similarly, pesticide plays an important role in protecting plant productivity by controlling pests and diseases (Ibarra -Jimenez *et al*., 2011). Despite the positive impacts from these agricultural intensification components, the specific impact of mulching and pesticide application to C fractions in soil remains scarce.

The presence of OM in soil is closely connected to its organic C content. Lal (2016) indicates that approximately 45-60% of the mass of soil OM is composed of organic C. Capturing and storing soil organic C have been identified as effective strategies for mitigating climate change and are associated with the retention of C within the soil (Chan *et al*., 2008; Lal, 2009). Enhancing C sequestration can improve soil quality as it impacts physical, chemical, and biological aspects. An active C fraction exhibits rapid responses to variations in organic C inputs into the soil (Bolinder *et al*., 1999). Changes of active C fraction can serve as early indicators of soil degradation or improvement from certain management practices (Weil *et al*., 2003). Whilst the stable C fraction that consists of humic compounds is the end product of biogeochemical transformation of organic C. The presence of humic compounds (humic acid) in the soil can indicate the amount of C sequestered in the soil as they are more stable and a long turn over period. The stable C fraction is important in maintaining cation exchange capacity (CEC) and the accumulation of OM by complexing with metals ion (Takashi & Shoji, 2002).

In the same study, our findings also suggest that intercropping with Welsh onion can also reduce yield losses in chili pepper (Kamil *et al*., 2022). Our previous study at the same location revealed that the use of plastic mulching can significantly increase soil pH, total Nitrogen (N) and exchangeable Magnesium (Mg) while the application of pesticide showed a significant lower of organic C (Kamil *et al*., 2020). This finding suggests potential alterations in soil C dynamics. The increase of nutrient availability and higher pH can influence microbial activity and thus affect soil C sequestration. Furthermore, a concern is raised on how the stability and persistence of C pools is affected by plastic mulching and pesticide application. The potential interactive effects between these factors on soil active and stable C pools in volcanic soils need further investigation. The objective of this study was to determine the effect of plastic mulching and pesticide applications on soil organic C fractions (i.e. soil active and stable C) in tropical volcanic soils of West Sumatra, Indonesia.

MATERIALS AND METHODS

Site description

This study was conducted at the foot of Mount Marapi (1000 meters above sea level), an active volcano in West Sumatra, Indonesia. Located in the intensive farming area, it provides vegetables for several provinces in Sumatra. This region has a tropical rain forest climate (Köppen and Geiger classification: *Af*) while the soil is classified as Andosols (Abe *et al*., 2020). Farmers in this area normally use a high number of agrochemicals and short fallow periods. The use of organic input such as organic manure is also common (Abe *et al*., 2020; Kamil *et al*., 2022). These management practices are categorized as agricultural intensification (Ickowitz *et al*., 2019).

Experimental design

An experimental plot was conducted for a period of six months (December 2019 to June 2020) on a 600 m^2 intensive agricultural land owned by a farmer. This experimental land had a pH of 5.5, 4.52% organic C content, 0.27% total N content, 0.75 mg/kg available phosphorus (P), exchangeable potassium (K) of 0.03 $cmol_c(+)/kg$ and 42.07 $cmol_c(+)/kg$ CEC. While active and stable C were 1.42 g/kg and 210 g/kg, respectively. Each treatment (plot) consisted of two sub-plots (2 m x 1 m), with a distance of 50 cm between sub-plots and 1 m between different treatments. In all plots, chili pepper (*Capsicum annuum*) and Welsh onion (*Allium fistulosum*) seedlings were transplanted, and pak choi (*Brassica rapa* chinensis) seeds were directly sow into the planting holes. The detail of planting design is presented in Figure 1.

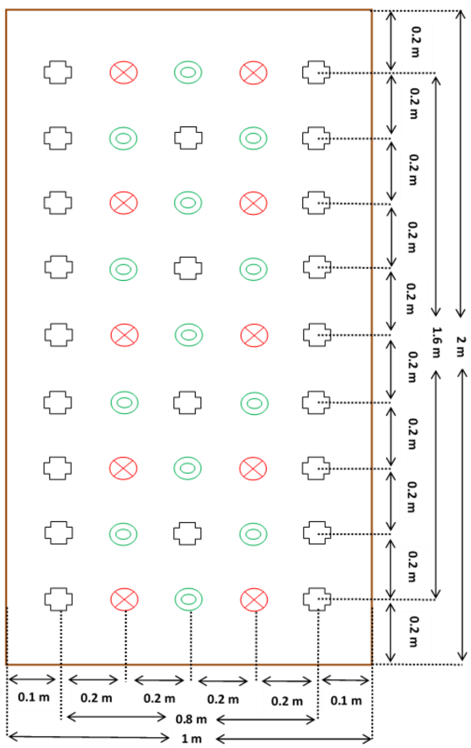

Figure 1. Design of planting system

Chili Pepper; Pak choi; Welsh Onion

The crops were cultivated using polyculture system following farmers' practices. Fertilization was based on the nutrient requirements of red chili pepper, the main commodity, and referred to the recommended fertilization guidelines by ICHORD (2015). The average nutrient usage by farmers were 370 kg/ha N, 160 kg/ha P_2O_5, and 120 kg/ha K_2O. Basal fertilization was evenly broadcasted onto the planting beds, while subsequent fertilization was done using the pocket method.

The experiment was conducted using a completely randomized design (CRD) with three replications, involving two factors. The first factor comprised plots without plastic mulching (P_0) and with plastic mulching (P_1), while the second factor consisted of plots without pesticide application (C_0) and with pesticide application (C_1). The plastic mulching used was black and silver polyethylene with a thickness of 0.03 mm and commonly used by farmers. This plastic mulching was installed before planting and remained until the end of the study. The pesticides used included Dupont Prevathon insecticide (active ingredient: Chlorantraniliprole 50 g/L), Callicron insecticide (active ingredient: Profenofos 500 g/L), and Dithane fungicide (active ingredient: Mancozeb 80%). Pesticide application was carried out once a week using a hand sprayer (or twice if pest or disease infestation increased) on each experimental plot treated with pesticides.

Soil sampling and laboratory analyses

Soil samples were collected after the cultivation period ended. The samples were collected from 0-20 cm considering the depth of soil on the ridge. Both core and bulk soil samples were collected. The core samples were projected to bulk density and total pore space while the bulk samples were air dried and sieved (2 mm mesh) to be prepared for laboratory analysis. Soil active C fraction was analyzed using permanganate oxidation described by Weil *et al.* (2003) and the stable C was analyzed using humic acid determination described by Tan (2010). The other soil properties have been reported by Kamil *et al.* (2020).

Data analysis

The analysis of variance (ANOVA) was computed to determine the single and interactive effects of plastic mulching and pesticide application on active and stable C factions. All statistical analyses were performed using SPSS software (version 23.0.0, IBM Corp, Armonk, New Work, USA).

RESULTS AND DISCUSSION

Other soil properties at the study site have been reported elsewhere by Kamil *et al.* (2020). The effects of plastic mulching and pesticide application on organic C, total N, bulk density and soil pH are shown in Table 1 and 2, respectively. In summary, the use of plastic mulching can significantly increase soil pH and total N. Plastic mulching was able to protect the soil by reducing the potential loss of exchangeable cations such as Mg, K and calcium, and other nutrients like N through leaching process especially during raining day. Due to this protection, the soil exchangeable bases can be sustained and consequently the soil can maintain high pH.

An increase in temperature which is modified by plastic mulching can accelerate N mineralization and thus increase the N content in the soil. Moreover, the reduction in organic C can be attributed to the elevated temperatures created by the plastic mulching, which enhances microbial activity and accelerates the decomposition process.

Table 1. Effect of plastic mulching on selected soil properties

Parameters	Unit	P_0			P_1		
pH (H_2O)	-	5.42b	±	0.08	5.62a	±	0.21
Organic C	%	4.76	±	0.44	4.37	±	0.34
Bulk Density	g/cm^3	0.73	±	0.06	0.67	±	0.03
Total N	%	0.25b	±	0.08	0.36a	±	0.04

Note : P_0 = without plastic mulching and P_1 = with plastic mulching. Different letters indicate a significant difference at $p<0.05$

Table 2. Effect of pesticide application on selected soil properties

Parameters	Unit	C_0			C_1		
pH (H_2O)	-	5.55	±	0.26	5.48	±	0.08
Organic C	%	4.79a	±	0.43	4.34b	±	0.31
Bulk Density	g/cm^3	0.71	±	0.81	0.69	±	0.03
Total N	%	0.31	±	0.06	0.31	±	0.10

Note : C_0 = without pesticide application and C_1 = with pesticide application. Different letters indicate a significant difference at *p<0.05.*

These high microbial and decomposition activities may also be able to reduce the soil bulk density. Similar results also found in Ma *et al*. (2018), a decreased of soil organic C by plastic mulching in the first 10 cm of soil layer but significantly increase N (NO_3^-) content. In recent study, Chen *et al*. (2023) shown that plastic mulching could results to higher N uptake for corn and lower N (N_2O and NH_3) emission compared to no plastic mulching treatment. Regardless, N (NO_3^-) leaching was much higher by the mulching treatments due to the limited gas transport in the soil surface under mulching. Moreover, the plastic mulching also can be able to protect the soil from direct rainfall and reduce the potential breakdown of soil aggregates. The application of pesticide can significantly reduce organic C but not showing any significant impact to other properties. The lower organic C probably due to a lower microorganism abundance as affected by pesticide. According to Karas *et al*. (2018) findings, that showed application of chlorpyrifos and tebuconazole can significantly reduce microorganism abundance.

Soil active C

The results indicate no significant effect between plastic mulching and pesticide application on the soil active C (Table 3). The active C contents are relatively close to the initial soil values. This is because the soil active C is a dynamic component that can easily change over time and it can form relatively fast. Active C commonly consists of the residue of plants, animals, and microorganisms. Loss of OM due to soil processing mainly occurs in the light fraction, which is the labile fraction present in macroaggregates (Gijsman, 1996). However, the presence of active C plays a role in regulating the availability of N in the soil and reducing N loss through leaching. This is in line with the findings by Kaye *et al.* (2002), who stated that active C in the soil regulates the availability of N and reduces N loss through leaching, as active C serves as a substrate for heterotrophic metabolism and N immobilization.

The content of active C obtained is probably influenced by continuous addition of organic fertilizers such as organic manure throughout the year. Thus, the changes in active C pools might be limited in the short period of time. This finding is aligned with the research by Lewis *et al*. (2011), which showed that active C is higher in soils with minimal management compared to intensive tillage, indicating an intensive soil disturbance can affect soil C pools. On the other hand, OM also affects active C in the soil. The application of OM without well mixing with soils can protect active C within microaggregates from microbial attack, thus reducing the loss of active C through microbial respiration. According to Gijsman (1996), the mixing process of OM through soil processing leads to the destruction of microaggregates sized 50-250 µm, making the active C protected within those microaggregates more vulnerable to microbial attack. This indicates that the active fraction is highly susceptible to soil processing.

Table 3. Effect of plastic mulching and pesticide application on active C

Pesticide	Plastic Mulching	
	P_0 (g/kg)	P_1 (g/kg)
C_0	1.42 ± 0.00	1.41 ± 0.01
C_1	1.40 ± 0.00	1.41 ± 0.01

Note : P_0 = without plastic mulching; P_1 = with plastic mulching; C_0 = without pesticide application and C_1 = with pesticide application. Different letters indicate a significant difference at *p<0.05*.

Soil stable C

The analysis indicates no significant effect between plastic mulching and pesticide application on the stable C soil content (Table 4).

Table 4. Effect of plastic mulching and pesticide applica-

Pesticide	Plastic Mulching	
	P_0 (g/kg)	P_1 (g/kg)
C_0	193.3 ± 41.63	220 ± 62.44
C_1	210.0 ± 20.00	220 ± 10.00

Note : P_0 = without plastic mulching; P_1 = with plastic mulching; C_0 = without pesticide application and C_1 = with pesticide application. Different letters indicate a significant difference at *p<0.05*.

Although application of plastic mulching did not significantly impact the soil stable C content, the values are comparable. The use of plastic mulching tends to have higher values compared to the treatment without plastic mulching. The same applies to the treatment with and without pesticide application, which also did not have a significant effect on the stable C values. This is because stable C has a stable nature and takes a very long time to form. According to Esmaeilzadeh (2011), the amount of stable C is not significantly affected by treatments and management practices. Stable C consists of materials that form from a long process and has a long period of turnover time. This group of organic materials is also referred to as passive OM or humus. This group is also considered as recalcitrant, which is resilient to decomposition (Esmaeilzadeh, 2011). The amount of stable OM is not greatly influenced by current management practices and tends to increase. However, management practices such as residue disposal, burning, soil processing, and cover cropping can have long-term effects on the relative and absolute amounts of stable OM (Esmaeilzadeh & Ahangar, 2014).

CONCLUSION

The study indicates that there is no significant interaction between plastic mulching and pesticide application in relation to the content and fraction of soil OM. These findings emphasize the importance of considering the potential effects of plastic mulching and pesticide application on soil properties and nutrient dynamics in intensive farming in volcanic soils. Further research and sustainable management practices are necessary to optimize soil OM and nutrient management in such agricultural systems.

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