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The Effect of Mulching and Planting Materials on the Growth and Yield of Sweet Potato (*Ipomoea batatas* L.) Sari Variety

Paramyta Nila Permanasari*, Rakha Alfyanda Putra, Karuniawan Puji Wicaksono and Bambang Guritno

Departement of Agronomy, Faculty of Agriculture, Brawijaya University, Veteran St., Malang 65145 East Java, Indonesia
*Correspondent: paramytanp@ub.ac.id

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Abstract— *The production of sweet potatoes (Ipomoea batatas L.) in Indonesia is still considered low compared to the national needs, which is approximately 2 million tons per year. Sweet potato yields can be improved by influencing both internal and external factors of the cultivation practices. The use of mulch has the potential to stabilize plants environment and growing condition. The use of different planting materials that has different characteristics and hormone contents will also influence the growth and yield of sweet potatoes. The aim of this study is to determine the interaction between the use of mulch and planting materials on sweet potatoes. The hypothesis of this research is that there will be an interaction between the two treatments, which could enhance yield. This research was conducted from February to May 2024 in Sidodadi Village, Garum Subdistrict, Blitar Regency. This study is a factorial experiment arranged based on a Randomized Block Design (RBD) consisting of 2 factors. The first factor is mulch with 3 levels: M0 (no mulch), M1 (silver-black plastic mulch) and M2 (rice straw mulch). The second factor is planting materials with 3 levels: T1 (upper shoot cuttings), T2 (middle shoot cuttings) and T3 (lower shoot cuttings). The results showed that the application of silver-black plastic mulch provided the best yield when applied together with upper shoot cuttings (28.40 tons ha^{-1}), middle shoot cuttings (28.05 tons ha-^{1}), and lower shoot cuttings (27.86 tons ha^{-1}). The rice straw mulch treatment provided the best yield when applied together with upper shoot cuttings (22.53 tons ha^{-1}) and middle shoot cuttings (21.68 tons ha^{-1}). The treatment without mulch provided the best yield when applied together with upper shoot cuttings (25.79 tons ha^{-1}). The choice of planting material can vary according to availability (upper, middle or lower of the shoot cutting) if using black silver plastic mulch.*

Keywords— ***Mulch, Planting Material, Sweet Potato***

I. INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is a type of tuber plant that is widely cultivated in Indonesia. Sweet potato is a vining plant that is the fourth largest source of carbohydrates after rice, maize, and cassava. In addition to carbohydrates content, sweet potatoes have other nutritional content such as 0.26-1.42% fat, 3.71-6.74% protein, 91.42-93.45% carbohydrates, vitamin B1 (0.08 mg), vitamin B2 (0.05 mg), vitamin A (7100 IU) vitamin C (20 mg), and vitamin B3 (0.9 mg) (Pratiwi *et al*., 2020). Sweet potatoes can grow at ideal temperatures between 21-27°C and an altitude of 500-1,000 meters above sea level with optimal rainfall ranging from 750-1500 mm year^{-1} (Yoandari, 2017).

National sweet potato production in 2021 reached up to 1,604,184 tons and in 2022 decreased to 1,511,041 tons (Indonesian Directorate General of Food Crops, 2023). On the other hand, the need for sweet potatoes for

national consumption in Indonesia is around 2 million tons per year and continues to increase along with the increasing population (Paturohman and Sumarno, 2015). Sweet potatoes are plants with vining growth that will form adventitious roots on each stem segment that contacts with the soil surface. Adventitious roots require a lot of photosynthetic assimilates to support their growth, which causes inhibition of tuber formation due to a shift in the priority of assimilates distribution (Rohmadani and Wijaya, 2022).

The attempt to avoid the sweet potato stem node interactions with soil (growing medium) could be done by covering the soil surface with mulch. Commonly used mulches in the field are organic mulch (straw) and inorganic mulch (black and silver plastic). In addition to cover the soil surface, mulch is physically able to maintain soil moisture, temperature, water availability, and also prevent the growth of weeds due to its ability in limiting the sun light radiation exposure directly to the soil surface (Annisa *et al*., 2014).

The source of the planting material will also affect the growth and yield of sweet potato plants because each planting material has its own characteristics. According to Mardi *et al*. (2016), cuttings on the top shoot of the plant that have relatively young tissue and a lot of auxin accumulation can accelerate the growth process of sweet potatoes plant. In addition, cuttings of the stem of sweet potatoes that have epidermal tissue with stomata and chlorophyll cortex tissue will accelerate the growth of leaf shoots and roots faster due to photosynthesis activity (Rismanto, 2019).

II. MATERIALS AND METHOS

The research was conducted from February to May 2024 on Sidodadi St., Sidodadi Village, Garum District, Blitar Regency, East Java with an altitude of approximately 156 meters above sea level, average rainfall of 3585 mm year^{-1}, average temperature of 22 – 29 °C and humidity of 71-85%. The tools used include silver-black plastic mulch (1.2 m x 1 m per ridge), straw mulch, cultivation tools, ovens, digital scales, camera, and stationery. The materials used are sweet potato seedlings of the Sari variety with planting material source in the form of upper shoot cuttings; middle shoot cuttings; and lower shoot cuttings, goat manure, and NPK fertilizer. The research was arranged using a Factorial Randomized Block Design (FRBD) consisting of 2 factors. The first factor is mulch with 3 levels in the form of M0 (without mulch), M1 (silver-black plastic mulch) and M2 (rice straw mulch). The second factor is planting material consisting of 3 levels, which are T1 (upper shoot cuttings), T2 (middle shoot cuttings) and T3 (lower shoot cuttings). Growth variables consist of plant length (cm), number of leaves, number of vine, leaf area (cm^2), fresh weight (g) and biomass weight (g). Yield variables consist of number of tubers per plant, tuber diameter (cm), tuber weight per plant (g), yield per hectare (ton ha^{-1}) and root/shoot ratio. Microclimate variables consist of minimum and maximum soil temperature (^{o}C). The data obtained were analyzed using analysis of variance (ANOVA) and continued with the Tukey Test at the 5% level if there is a significant effect.

III. RESULT AND DISCUSSION

A. Growth Variables

Length of Sweet Potato Plants

Based on the research, it was found that in each treatment experiments showed a significant effect on both factors (i.e the type of mulch and planting material) to the length of sweet potato plants. Both factors showed an effect on length of the plant at all observation intervals except for the observation at 84 DAP (Table 1).

Based on the observations (Table 1), it shows that the highest length of plant value was found in the silver-black plastic mulch treatment at the 42 and 63 DAP. This is in accordance with the opinion of Panjaitan *et al*. (2019) where sweet potato plants need hot and humid air for its optimal life cycle needs. This is also in line with the function of silver-black plastic mulch which is able to maintain soil temperature to be more stable and maintain the soil humidity around plant roots (Annisa *et al*., 2014). High air temperature (which will affect the soil temperature as well) can increase plant length because high temperature stimulates the activity of the gibberellin hormone (GA) in plants which stimulates the growth of the length of sweet potato plant branches (Hayati *et al*., 2016).

The highest plant length was reached by upper shoot cuttings at 21, 42 and 63 DAP. Rismanto (2019) mentioned that the result can happen because upper shoot cuttings came from plant's organs that are relatively young with huge proportions of epidermal tissue containing stomata and companion cells as well as cortex tissue that has chlorenchyma cells containing chlorophyll. So that they are able to stimuli photosynthesize activity to grow roots when it is planted in a humid conditions. The impact of early root development can increase the speed of plants to grow new shoots and will continue to develop into new plants (organism) that are able to produce and adapt to the environment in which they grow.

Table 1. Length of Sweet Potato Plants Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Length of Plant (cm) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	37.56	65.49 a	103.24 b	132.93
Silver-Black Plastic Mulch	34.41	77.86 b	105.14 b	142.24
Rice Straw Mulch	38.83	62.72 a	90.53 a	135.70
Tukey Test 5%	ns	8.33	8.59	ns
Source of Planting Materials:				
Upper Shoot Cuttings	46.22 c	76.13 b	105.82 b	143.11
Middle Shoot Cuttings	34.80 b	65.29 a	97.15 a	129.82
Lower Shoot Cuttings	29.79 a	64.64 a	95.94 a	137.94
Tukey Test 5%	4.86	8.33	8.59	ns
CV (%)	10.90	10.05	7.14	7.96

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

Number of Leaf

The results of the analysis of variance showed that there was no significant interaction ($F_{count}<F_{table0.05}$) between the different use of mulch type and source of planting materials at all observation intervals. Each treatment showed a significant effect on both the different type of mulch and source of planting materials on the number of sweet potato leaves in observation interval age of 42 and 63 DAP but both treatments had no significant effect on 21 and 84 DAP (Table 2).

Table 2. Number of Leaf of Sweet Potato Plants Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Number of Leaf (unit) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	29.48	53.24 a	73.13 ab	86.67
Silver-Black Plastic Mulch	34.07	60.61 b	74.89 b	91.20
Rice Straw Mulch	26.50	52.59 a	69.17 a	84.78
Tukey Test 5%	ns	5.58	5.52	ns
Source of Planting Materials:				
Upper Shoot Cuttings	30.80	60.59 b	75.83 b	89.07
Middle Shoot Cuttings	30.69	53.07 a	69.57 a	86.54
Lower Shoot Cuttings	28.57	52.78 a	71.78 ab	87.04
Tukey Test 5%	ns	5.58	5.52	ns
CV (%)	22.01	10.02	6.32	6.20

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

The number of leaf variable observations show that the silver-black mulch treatment resulting to the highest leaf number value at 42 and 63 DAP. However, at 63 DAP it was not significantly different from the treatment without mulching. This is related to the ability of silver-black mulch to reflect the direct sunlight exposure

towards the soil surface. Based on the opinion of Soplanit *et al*. (2021) silver-black mulch can increase the number of sweet potato leaves by reflecting light back to certain degree of the light source. In addition, silver-black mulch also able to increase the efficiency in converting light radiation energy, especially not only in the upper leaves but also in the lower leaves which will increase the rate of photosynthesis activity and the number of leaves from the meristematic tissue. On the other hand, upper shoot cuttings also showed the highest value number of leaves at 42 and 63 DAP. This is in accordance with the results of research by Idoko *et al*. (2017) with the use of the upper shoot as a cutting source of sweet potato planting materials which can produce a great number of leaves because the upper shoot contains apical meristem tissue which is responsible for the growth of new leaves. Increasing the time of leaf shoot initiation in sweet potato cultivation will potentially increase the potential for increasing the number of leaves as well, which generally occurs when planting using planting material originating from upper shoot cuttings (Lencha *et al*., 2016).

Number of Vine

The results of the analysis of variance showed that there was no significant interaction ($F_{count}<F_{table0.05}$) between the use of different mulch and source of planting materials at all observation intervals. The treatment of different planting materials source was able to provide a significant effect on the number of sweet potato vines. Conversely, different mulch treatment did not show any significant effect on the number of sweet potato vines at 21, 42, 63, and 84 DAP (Table 3).

Table 3. Number of Vine of Sweet Potato Plants Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Number of Vine (unit) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	2.48	5.07	7.94	9.91
Silver-Black Plastic Mulch	2.30	4.48	7.02	9.56
Rice Straw Mulch	2.41	4.72	7.76	9.61
Tukey Test 5%	ns	ns	ns	ns
Source of Planting Materials:				
Upper Shoot Cuttings	2.00 a	4.28 a	6.96 a	9.02 a
Middle Shoot Cuttings	2.41 b	4.98 b	7.63 ab	9.83 ab
Lower Shoot Cuttings	2.78 c	5.02 b	8.02 b	10.22 b
Tukey Test 5%	0.27	0.64	1.01	1.14
CV (%)	9.34	11.21	11.08	9.76

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

Based on Table 3, the treatment of different planting material sources has a significant effect on the number of vines of sweet potato plants. The treatment of different planting material sources shows that lower shoot cuttings have the best effect on the average number of vines and are not significantly different from middle shoot cuttings. This is because lower and middle shoot cuttings have a relatively larger diameter when compared to shoot cuttings. As stated by Bararyenya *et al*. (2020), that stem cuttings have pericycle tissue that plays a role in secondary stem growth including the stimulation of vines formation at stem nodes and triggering adventitious root formation. Meanwhile, the mulching treatment did not show any effect on the number of sweet potato vines at all observation intervals. According to Wijewardana *et al*. (2018), sweet potato vine growth are mostly influenced by natural factors such as the intensity and duration of sunlight radiation exposure. 12 hours of sunlight radiation can provide optimal conditions for sweet potatoes to form new branches/vines. In addition, optimal water availability can also affect the formation of sweet potato vines. Conditions of water shortage/drought will cause the photosynthesis rate of plants to decrease and the branch/vines formation process will be obstructed (Solis *et al*., 2014).

Leaf Area

The results from the analysis of variance showed that there was no significant interaction ($F_{count}<F_{table0.05}$)

between the use of different mulch and source of planting materials at all observation intervals. Each treatment showed a significant effect on both the use of different mulch and source of planting materials on the leaf area of sweet potato plants at 21, 42, 63, and 84 DAP (Table 4).

Table 4. Leaf Area of Sweet Potato Plants Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Leaf Area (cm^2) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	710.82 ab	1282.20 a	1763.77 b	2088.80 a
Silver-Black Plastic Mulch	841.37 b	1495.43 b	1845.63 b	2248.01 b
Rice Straw Mulch	606.48 a	1208.07 a	1587.30 a	1945.00 a
Tukey Test 5%	181.21	159.28	135.14	155.85
Source of Planting Materials:				
Upper Shoot Cuttings	747.78	1466.45 b	1829.80 b	2152.53 b
Middle Shoot Cuttings	707.27	1224.06 a	1602.90 a	1994.29 a
Lower Shoot Cuttings	703.63	1295.18 a	1764.00 b	2134.98 ab
Tukey Test 5%	ns	159.28	135.14	155.85
CV (%)	20.87	9.94	6.47	6.17

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

The leaf area variable observations (Table 4) shows that different mulch treatments had a significant effect on all of the observation intervals with the highest leaf area value in silver-black plastic mulch. This is in accordance with the research of Muslim and Soelistyono (2017) where silver-black plastic mulch treatment had the highest effect on leaf area parameters caused by the silver color of the mulch surface which can reflect most of the sunlight radiation received. The amount of reflected sunlight radiation can increase the absorption of light used in the photosynthesis activity. The treatment of different planting material sources showed that shoot cuttings were able to produce the highest leaf area values at 42, 63, and 84 DAP but in the 63 and 84 DAP it was not significantly different from the lower shoot cuttings. This is in accordance with the opinion of Lencha *et al*. (2016), that upper shoot cuttings were able to provide the highest leaf area values when compared to stem cuttings (middle and/or lower). This is also related to the opinion of Rosnina *et al*. (2022) where the number of leaves is directly proportional to the leaf area so that the more leaves formed, the more sunlight will be absorbed so and the leaves will grow wider. Lower shoot cuttings were not significantly different from upper shoot cuttings at 63 and 84 DAP because in addition to leaf area being correlated with the number of leaves, lower shoot cuttings have a larger diameter of stem and tend to be able to support wider size of leaf (Suwitono *et al*., 2024).

Fresh Weight of Shoot

The results from the analysis of variance showed a significant interaction ($F_{count}>F_{table0.05}$) between the use of different mulch and source of planting materials to the fresh weight of plant's shoot. There was a significant effect on silver-black plastic mulch treatment on planting material treatment. Meanwhile, the treatment of planting material sourced from the upper and lower shoot cuttings also showed a significant effect on different types of mulch treatment (Table 5).

The fresh weight values of the plant's shoot (Table 5) observation variable show a significant interaction between the use of different mulching application and source of planting materials. The highest value was obtained in the interaction between silver-black plastic mulch treatment with the use of upper shoot cuttings as planting material. Based on the opinion of Soplanit and Rumbarar (2020), silver-black plastic mulch can increase photosynthetic activity by reflecting light and being intercepted by the plant leaf so that the amount of photosynthate assimilation produced can be increased and distributed to the shoots and roots/tubers. In addition, Amare and Desta (2021) stated that silver-black plastic mulch can increase water availability in the soil by

minimizing evapotranspiration so that the amount of water will be optimal for the implementation in the plant's photosynthesis process. Meanwhile, upper shoot cuttings have the highest fresh weight value compared to middle shoot cuttings and lower shoot cuttings. This is in accordance with the opinion of Netsai *et al*. (2019), which is the fresh weight of the plant's shoot is directly proportional to the length of the plant and the number of leaves, so the longer the plant, and the higher number of leaves, the higher the fresh weight value will be. Meanwhile, in the middle and lower shoot cuttings, the number of branches is indeed higher than the upper shoot cuttings. However, the average length of the plants shoot in the middle and lower shoot cuttings treatment is lower than the upper shoot cuttings, so it's resulting to the fresh weight value of the upper shoot cuttings treatment to be lower.

Table 5. Fresh Weight of Plant's Shoot of Sweet Potato Affected by Several Type of Mulches and Source of Planting Materials

Type of Mulches	Fresh Weight of Plant's Shoot (g)		
	Planting Material Sources		
	Upper Shoot Cuttings	Middle Shoot Cuttings	Lower Shoot Cuttings
Without Mulch	778.43 a A	813.47 a A	858.53 a A
Silver-Black Plastic Mulch	1423.95 b C	985.86 a A	1081.00 a B
Rice Straw Mulch	1110.68 a B	955.58 a A	947.58 a AB
Tukey Test 5%	211.75		
CV (%)	10.18		

Annotations: Numbers accompanied by the same lower case letters in the same row or the same upper case letters in the same column show no significant difference based on the Tukey test at the 5% level. CV=Coefficient of Variance. DAP = Day After Planting.

Table 6. Dry Weight of Plant's Shoot of Sweet Potato Affected by Several Type of Mulches and Source of Planting Materials

Type of Mulches	Dry Weight of Plant's Shoot (g)		
	Planting Material Sources		
	Upper Shoot Cuttings	Middle Shoot Cuttings	Lower Shoot Cuttings
Without Mulch	226.66 a A	253.7 a A	232.96 a A
Silver-Black Plastic Mulch	370.49 b B	264.66 a A	310.46 a B
Rice Straw Mulch	330.18 b B	235.28 a A	253.52 a A
Tukey Test 5%	54.62		
CV (%)	9.49		

Annotations: Numbers accompanied by the same lower case letters in the same row or the same upper case letters in the same column show no significant difference based on the Tukey test at the 5% level. CV=Coefficient of Variance. DAP = Day After Planting.

Dry Weight of Shoot

The results of the analysis of variance showed a significant interaction ($F_{count}>F_{table0.05}$) between the use of different mulch and source of planting materials to the dry weight of plant's shoot. There was a significant effect on mulch treatment on planting material treatment, such as on the treatment of silver-black plastic mulch and rice straw mulch. Meanwhile, the treatment of different source of

planting materials also showed a significant effect on the mulching treatment on the treatment of upper shoot cuttings and lower shoot cuttings (Table 6).

The dry weight variable of the plant's shoots also showed a significant interaction between mulching treatment and several source of planting material treatment. The high plant's shoot dry weight value was found in the interaction between silver-black or rice straw mulch and upper shoot cuttings. Plant's shoot dry weight is the result of carbohydrate accumulation in plant tissue as a product of photosynthesis. The total dry weight value indicates the plant's ability to store photosynthesis results into its tissue (Soplanit *et al*., 2021). Upper shoot cuttings are young organs that have apical meristem tissue that can stimulate branch length growth and leaf formation while silver-black plastic mulch acts as a reflector that reflects sunlight so that it can be captured by the plant shoot which can increase photosynthetic activity. In addition, the use of plastic mulch is also able to maintain the availability of water in the soil by minimizing evaporation so that it can provide water for plants to carry out photosynthesis optimally (Indawan *et al*.. 2020). Rice straw mulch in the other hand, has a similar function to be able to prevent weed growth and minimize competition for nutrients and water. According to Monica *et al*. (2020), rice straw mulch can also minimize evapotranspiration by lowering soil temperature, thereby reducing water loss on the soil surface.

B. Yield Variables

Weight of Tuber

The results from the analysis of variance showed a significant interaction ($F_{count}>F_{table0.05}$) between the use of different mulch and source of planting materials to the on the weight of sweet potato tubers. There was a significant effect of mulch treatments on the source of planting material treatments, namely in the treatment without mulch and rice straw mulch. Meanwhile, the treatments of planting material sources also showed a significant effect on mulch treatments in all treatments starting from upper shoot cuttings, middle shoot cuttings and lower shoot cuttings (Table 7).

Table 7. Weight of Sweet Potatoes Tuber Affected by Several Type of Mulches and Source of Planting Materials

Type of Mulches	Dry Weight of Sweet Potatoes Tuber (g plant^{-1})		
	Planting Material Sources		
	Upper Shoot Cuttings	Middle Shoot Cuttings	Lower Shoot Cuttings
Without Mulch	596.61 b AB	406.32 a A	398.61 a A
Silver-Black Plastic Mulch	656.95 a B	648.87 a B	644.54 a B
Rice Straw Mulch	521.29 b A	501.45 ab A	404.79 a A
Tukey Test 5%		112.05	
CV (%)		10.10	

Annotations: Numbers accompanied by the same lower case letters in the same row or the same upper case letters in the same column show no significant difference based on the Tukey test at the 5% level. CV=Coefficient of Variance. DAP = Day After Planting.

The results of tuber weight (Table 7) show that there is a significant interaction between mulching treatments and different source of planting materials. The highest value of plant's tuber weight was found in the interaction between silver-black plastic mulch treatment and any kinds of shoot cuttings. The silver-black plastic mulch treatment shows a value that is not significantly different in all cutting source treatments, indicating that the use of silver-black plastic mulch is suitable for application together with all different sources of planting material treatments. Based on the opinion of Soplanit *et al*. (2021), that in addition to its function as a sunlight reflector to increase the photosynthesis process, the black color of silver-black mulch also acts as an inhibitor of weed growth and limits the movement of weeds to sprout in the field. Treatment without mulching with upper shoot cuttings has an effect that is not significantly different from silver-black plastic mulch because treatment without mulch can also provide enough sunlight exposure, creating an optimal environment for the growth of sweet potato.

The treatment of planting material on the tuber weight variable shows that upper shoot cuttings produce the highest tuber weight value in all mulch treatments compared to middle shoot cuttings and lower shoot cuttings. This is in accordance with the results of Netsai *et al*. (2019) research where upper shoot cuttings were able to produce tuber with the weight of 29.53 tons ha^{-1}. Theoretically it is due to the ability of upper shoot cuttings to produce new and active cells that support the roots in providing auxin hormone supply from the plant's growing point. The early root formation encourages, will increases tuber growth and weight. Silver-black plastic mulch were able to suppress weed growth so that there is no competition for nutrients and also could act as a reflector. On the other hand, upper shoot cuttings play a role in supplying growth hormone (auxin) from the plant's growing point to stimulates root growth and accelerates tuber filling rapidly so that tuber weight can increase.

Number of Tuber

The results of the analysis of variance showed that there was no significant interaction ($F_{count}<F_{table0.05}$) between the use of different mulch and source of planting materials. The treatment of planting materials showed a significant effect on the number of tubers. While the mulch treatments did not show any significant effect on the number of tubers (Table 8).

Table 8. Number of Sweet Potatoes Tuber Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Number of sweet potatoes tuber (unit $plant^{-1}$)
Type of Mulches:	
Without Mulching	3.54
Silver-Black Plastic Mulch	3.89
Rice Straw Mulch	3.72
Tukey Test 5%	ns
Source of Planting Materials:	
Upper Shoot Cuttings	4.15 b
Middle Shoot Cuttings	3.52 a
Lower Shoot Cuttings	3.48 a
Tukey Test 5%	0.59
CV (%)	13.26

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

The observation variable of the number of tubers showed a significant effect on the treatment of different sources of planting material, but did not show a significant effect on the treatment of different types of mulch. The highest average value of the number of tubers in the treatment of different sources of planting material was in the treatment of upper shoot cuttings. The factor of the formation of the number of tubers is highly dominated by genetic influences compared to environmental factors (Armaini, 2017). Good physical soil conditions could support plant growth optimally, starting from the vegetative to generative phases including the formation of adventitious roots and branch growth affecting the number of sweet potato tubers (Etica and Husaini, 2019). The number of tubers produced in the upper shoot cuttings is greater than in the middle shoot cuttings and lower shoot cuttings because the amount of carbohydrates in the upper shoot tissue tends to be greater than the amount of lignin. In the stem cuttings, some of the pores contain lignin which can inhibit root growth. From that reasoning, it is thought to cause fewer tuber formation in the stem (middle to lower shoot) cuttings compared to the upper shoot cuttings (Mardi *et al*., 2016).

Diameter of Tuber

The results of the analysis of variance showed that there was no significant interaction ($F_{count}<F_{table0.05}$) between the use of different mulch and source of planting materials. The treatment of different planting material sources showed a significant effect on tuber diameter. While type of mulch treatment did not show any significant effect on tuber diameter (Table 9).

Table 9. Diameter of Sweet Potatoes Tuber Affected by Several Type of Mulches and Source of Planting Materials

Treatments	Diameter of sweet potatoes tuber (cm)
Type of Mulches:	
Without Mulching	5.76
Silver-Black Plastic Mulch	6.41
Rice Straw Mulch	6.03
Tukey Test 5%	ns
Source of Planting Materials:	
Upper Shoot Cuttings	6.60 b
Middle Shoot Cuttings	5.79 a
Lower Shoot Cuttings	5.81 a
Tukey Test 5%	0.74
CV (%)	10.15

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

The diameter of sweet potatoes tuber variable observation also showed something similar to the value of number of tubers where the planting material sources treatment had a significant effect on the result. The highest average tuber diameter value was found in the upper shoot cuttings treatment with a value of 6.60 cm. The shoot cuttings likely lengthen the sweet potatoes adventitious roots first before filling the tubers (Nedunchezhiyan *et al*., 2012). The size of the adventitious roots achieved determines the size of the tubers produced by the plants. Tuber filling begins with the accumulation of carbohydrates at the bottom of the root and continues to the top. This is supported by the opinion of Netsai *et al*. (2019), that the amount of carbohydrates contained in the upper shoot cuttings tends to be greater than lignin produced, where these carbohydrates are stored at the bottom of the root and continue to fill the top of the root. Therefore, the shoot part that contains more carbohydrates than the other, it will be the main substrate for filling tubers which is carbohydrates. It can be said that cuttings in the shoot can produce larger tuber sizes in terms of carbohydrate accumulation in the shoot and also photosynthate products from photosynthesis activity.

Table 10. Yield of Sweet Potatoes Tuber per Hectare Affected by Several Type of Mulches and Source of Planting Materials

Type of Mulches	Tuber Yield of Sweet Potatoes (ton ha^{-1})		
	Planting Material Sources		
	Upper Shoot Cuttings	Middle Shoot Cuttings	Lower Shoot Cuttings
Without Mulch	25.79 b AB	17.56 a A	17.23 a A
Silver-Black Plastic Mulch	28.40 a B	28.05 a B	27.86 a B
Rice Straw Mulch	22.53 b A	21.68 ab A	17.50 a A
Tukey Test 5%		4.84	
CV (%)		10.10	

Annotations: Numbers accompanied by the same lower case letters in the same row or the same upper case letters in the same column show no significant difference based on the Tukey test at the 5% level. CV=Coefficient of Variance. DAP = Day After Planting.

Tuber Yield per Hectare

The results of the analysis of variance showed a significant interaction ($F_{count}>F_{table0.05}$) between the use of different mulch and source of planting materials to the on the weight of sweet potato tubers on the yield per hectare. There was a significant effect of mulching treatment on planting material source treatment especially on the treatment without mulch and rice straw mulch. In addition, the treatment of several planting material source also showed a significant effect on all mulching treatments, on upper shoot cuttings, middle shoot cuttings, and lower shoot cuttings (Table 10).

Based on Table 10, the yield per hectare variable observation has a similar trend with tuber weight result. The highest yield value is found in the interaction between the silver-black plastic mulch with any kinds of shoot cuttings. The yield is the ability or carrying capacity of agricultural land in the yield of certain crops, in this case tubers (carbohydrate storage) (Nurmala *et al*., 2012). This is in accordance with the opinion of Kharolina *et al*. (2023) where the yield is proportional to the weight of the tubers produced by plants, so that if the weight of the tubers produced is high, it will also produce a high yield. The value of tuber weight and yield value is greatly influenced by the initial growth factor of plant, especially in the vegetative phase. Therefore, to get a high yield, it must start from good plant maintenance during the initial vegetative period. Whereas if the plant has entered the generative phase, the vegetative process that takes place will be reduced (Azmi *et al*., 2011).

Root Shoot Ratio (RSR)

The results of the analysis of variance showed that there was a significant interaction ($F_{count}>Ft_{able0.05}$) between the use of different mulch and source of planting materials. Mulch treatments showed a significant effect on the RSR value. Likewise, the treatment of planting materials had a significant effect on the RSR value as well (Table 11).

Table 11. Root Shoot Ratio of Sweet Potatoes Affected by Several Type of Mulches and Source of Planting Materials

Type of Mulches	Root Shoot Ratio		
	Planting Material Sources		
	Upper Shoot Cuttings	Middle Shoot Cuttings	Lower Shoot Cuttings
Without Mulch	0.70 b B	0.43 a A	0.39 a A
Silver-Black Plastic Mulch	0.50 a A	0.59 a A	0.52 a A
Rice Straw Mulch	0.45 a A	0.47 a A	0.41 a A
Tukey Test 5%		0.18	
CV (%)		17.70	

Annotations: Numbers accompanied by the same lower case letters in the same row or the same upper case letters in the same column show no significant difference based on the Tukey test at the 5% level. CV=Coefficient of Variance. DAP = Day After Planting.

The RSR observation variable shows the interaction between 2 factors. Root Shoot Ratio (RSR) is the ratio between the fresh weight of the lower part of the plant (roots and tubers) and the fresh weight of the upper part of the plant (shoots) (Anjani *et al*., 2021). The root shoot ratio value is used to determine the allocation of translocated photosynthate to the shoot and tubers. In addition (Mubarok *et al*., 2024). RSR is generally observed at certain intervals to determine the growth phase of a plant starting from the beginning of the initial vegetative growth. The beginning of the formation of storage roots, tuber filling, until the maximum size of tuber. According to Alynad *et al*. (2023) the RSR value can indicate the allocation of plant photosynthate at a certain time such as when facing a lack of elements or sunlight (stress condition). The growth of the plant when facing a non optimum planting environment will be disturb and the photosynthate products will be allocated for survival needs.

C. Microclimate Observations

Minimum and Maximum Soil Temperature

The results from the analysis of variance showed that there was no significant interaction ($F_{count}<F_{table0.05}$)

between the use of different mulch and source of planting materials. Mulching treatment showed a significant effect on the minimum and maximum soil temperatures. While the treatment of several sources of planting materials did not show any significant effect on the minimum soil temperature (Table 12 and 13).

Table 12. Minimum Soil Temperature Affected by Several Type of Mulches and Source of Planting Materials

Treatment	Minimum Soil Temperature (°C) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	25.79 ab	25.30 a	24.14 a	24.24
Silver-Black Plastic Mulch	26.47 b	26.02 b	24.84 b	24.17
Rice Straw Mulch	25.21 a	24.77 a	23.88 a	23.83
Tukey Test 5%	0.99	1.03	0.82	ns
Source of Planting Materials:				
Upper Shoot Cuttings	25.93	25.21	24.23	23.87
Middle Shoot Cuttings	25.83	25.56	24.18	24.16
Lower Shoot Cuttings	25.71	25.32	24.46	24.21
Tukey Test 5%	ns	ns	ns	ns
CV (%)	3.19	3.37	2.80	2.19

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

Table 13. Maximum Soil Temperature Affected by Several Type of Mulches and Source of Planting Materials

Treatment	Minimum Soil Temperature (°C) in the age observation of (DAP)			
	21	42	63	84
Type of Mulches:				
Without Mulching	32.55 ab	32.23 a	30.63 a	29.48
Silver-Black Plastic Mulch	33.45 b	32.87 b	31.77 b	29.07
Rice Straw Mulch	32.14 a	31.33 a	30.53 a	28.68
Tukey Test 5%	1.22	1.28	1.12	ns
Source of Planting Materials:				
Upper Shoot Cuttings	32.74	31.73	30.86	28.92
Middle Shoot Cuttings	32.47	32.32	31.11	29.29
Lower Shoot Cuttings	32.93	32.38	30.97	29.01
Tukey Test 5%	ns	ns	ns	ns
CV (%)	3.10	3.29	3.00	3.15

Annotations: Numbers followed by the same letter in the same column showed no significant difference based on the Tukey Test at the 5% level. CV=Coefficient of Variance. ns = not significant. DAP = Day After Planting.

Based from the observation (Table 12 and 13), it can be seen that mulching treatment statistically effecting the minimum and maximum soil temperatures. The highest minimum and maximum temperatures were found in the silver-black plastic mulch treatment. Silver-black plastic mulch has the colors that can transmit heat from the sun to the soil and store it in the soil to stabilize the soil temperature. Sweet potatoes can grow well at relatively high temperatures, because high temperatures will stimulate the formation of adventitious roots and the

activity of gibberellins (GA) which play a role in plants growth. The minimum temperature has a very important role because the process of photosynthate translocation from the shoots to the roots is carried out in the nighttime until morning when the air temperature is at its lowest. A high minimum temperature value will be able to increase the stimulation of the photosynthate translocation process due to the high gibberellins (GA) activity (Wijewardana *et al*., 2018).

Sweet potatoes are plants that are sensitive to low temperatures. Based on the opinion of Dumbuya *et* al. (2021), low soil temperatures (<25°C) will inhibit the process of shoots growth in plant. In addition, Gajayanake *et al*. (2014) revealed that there was an increase in percentage of 6-7% plant growth for every 1°C of soil temperature increased. Meanwhile, according to Ramadhani (2010) the optimal soil temperature range for tuber formation is between 25-35°C. In addition, Hayati *et al*. (2016) stated that high temperatures in general can initiate the activity of gibberellin hormone (GA) which is very important for the early growth of sweet potatoes because it plays a role in activating the auxin hormone which can stimulate branch and root elongation. The results of the study by Setyorini and Ariffin (2023) revealed that the regression results showed that if the temperature increased by 1°C, it would increase production by 3 tons ha^{-1} in the lowlands and 2.5 tons ha^{-1} in the highlands.

IV. CONCLUSSION

1. The observation results show that there is a significant interaction between mulch treatment and source of planting materials. Application of silver-black plastic mulch gives the best results compared to no mulch and rice straw mulch treatment. Silver-black plastic mulch gives the same results on all types of planting material sources including upper shoot cuttings (28.40 tons ha^{-1}), middle shoot cuttings (28.05 tons ha^{-1}), and lower shoot cuttings (27.86 tons ha^{-1}). Rice straw mulch treatment gave the best results when applied together with upper shoot cuttings (22.53 tons ha^{-1}) and middle shoot cuttings (21.68 tons ha^{-1}). Treatment without mulching gave the best results when applied together with the use of planting materials in the form of upper shoot cuttings (25.79 tons ha^{-1}).
2. The use of upper shoot cuttings gave the best results with the use of no mulch and silver-black plastic mulch. While the use of middle shoot cuttings and lower shoot cuttings only gives the best results with the use of silver-black plastic mulch.
3. Application of silver-black plastic mulch was able to provide the best value on growth variables, namely leaf area (2248.01 cm^2 $plant^{-1}$), and microclimate variables, namely minimum soil temperature (26.47°C) and maximum soil temperature (33.45°C). Treatment without mulch was able to provide the best value on growth variables, namely the number of leaves (73.13 unit $plant^{-1}$).
4. Treatment of upper shoot cuttings was able to provide the best value on yield variables, namely the number of tubers (4.15 tubers $plant^{-1}$) and tuber diameter (6.60 cm $plant^{-1}$). Meanwhile, middle shoot cuttings were able to provide the best value on growth variables, namely the number of vines (9.83 unit $plant^{-1}$).

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