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EFFECTS OF SUBSTRATES ON GROWTH, YIELD AND TUBER QUALITY OF SWEET POTATO CULTIVATED USING SOILLESS CULTURE SYSTEM

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ABSTRACT

The soilless culture system effectively promotes plant growth by facilitating water and nutrient uptake by plant roots. To increase sweet potato (*Ipomoea batatas*) production, we developed containerized planting in which tuberous roots were grown in solid substrates in the polybags supplied with a nutrient solution through an irrigation system. Five combinations of growth substrates were evaluated: 100% coir dust; 100% burnt paddy husks; 70% coir dust + 30% burnt paddy husks; 30% coir dust + 70% burnt paddy husks; and 50% coir dust + 50% burnt paddy husks. The sweet potato plants were harvested 90 days after planting. Plants grown in 100% coir dust gave the best yield compared to the other treatments. They produced the highest tuber yield (2788 g) compared to the plants grown in 100% burnt paddy husk which produced the lowest tuber yield (1174 g). Tubers obtained from 100% coir dust showed the highest Total Soluble Solid (TSS) value (12.1° Brix) and moisture content (76.73%) compared to other treatments. These results showed that sweet potato cultivated in coir dust substrates increased the tubers yield by 2.3 times compared to those grown in burnt paddy husks. Studies revealed that planting sweet potato in 100% or high coir dust substrates increased the plant growth, tuber yield and enhanced tuber quality compared to substrates containing high burnt paddy husk.

Keywords: *Sweet potato, soilless culture system, coir dust, burnt paddy husk, tuber.*

INTRODUCTION

Sweet potato (*Ipomoea batatas* L. Lam.) belongs to the family Convolvulaceae that produces nutritious tuberous roots. The main problem in cultivating sweet potato in Malaysia is that the current average tuber yield grown using the conventional method is still low at 9 mt/ha compared to 20-30 mt/ha targeted. Self Sufficiency

Rate (SSR), which has not yet reached 100% for sweet potatoes (75.1%), has forced Malaysia to import with an Import Dependence Rate (IDR) for sweet potatoes reaching 26.3% (Mohd Yusrizal, 2021). Vast open market opportunities and high domestic demand for this commodity require a more sustainable and high yielding system of cultivation. There is potential to increase the growth and yield of sweet potato using soilless system based on significant increase in yields of ginger, chilies, rockmelons, tomatoes, and other leafy and fruity vegetables grown on various substrates (Yaseer Suhaimi *et al*., 2011). Many types of substrates such as rockwool, perlite, vermiculite and peat can be used to grow many kinds of crops in soilless culture system (Böhme 1995; *Komada et al*., 1997). Soilless substrates such as rockwool, perlite and vermiculite are expensive because they have to be imported. Hence, alternative substrates that are cheaper and locally available such as coir dust and burnt paddy husks should be used as alternative media. One of the most important factors influencing plant fertility in soilless culture system, besides water and nutrient content, is oxygen availability or level of aeration in the substrates (Wall and Heiskenen, 2003; Humara *et al*., 2002). Substrates need to provide adequate storage of water and nutrients for the plant, while maintaining good aeration. There are number of crops had been tested in coir dust and burnt paddy husk as substrates. For instance, Raviv *et al*. (2001) revealed rose plants grown using coir dust as substrates gave 19% higher number of flowers. Previous studies found faster root development of tomatoes and consequently better yield (Islam *et al*., 2002). Ginger able to grow and produce rhizomes when cultivated using burnt paddy husk (Suhaimi *et al*., 2012). Therefore, cultivating sweet potato using soilless culture system could be an alternative method to plant sweet potato that can give a higher yield than the conventional method. Thus, this study was conducted to determine the effects of soilless substrates such as coir dust and burnt paddy husks on the growth and yield of sweet potato. The main objective was to determine the optimum growth substrate for sweet potato cultivation using soilless culture system.

MATERIALS AND METHODS

Sweet potato var. Lembayung was used in this study. Stem cuttings were used as plant material for the cultivation of sweet potato. 30 cm long stem cuttings with 5-7 leaves were taken from a 2.5-month-old sweet potato plant. The stem cuttings were treated with Benomyl and copper solution before planting. Cuttings were planted 5 cm deep horizontally in substrates. A side-netted rain shelter of 30 m long x 10 m wide x 4.5 m high located in MARDI Serdang, Selangor, Malaysia was used in the study. The treatments were arranged in a randomised complete block design (RCBD) with five levels of treatment,three replicates and 30 plants per treatment. The treatments were as follows: T1 = 100% coir dust; T2 = 70% coir dust and 30% burnt paddy husks; T3 = 50% coir dust and 50% burnt paddy husks; T4 = 30% coir dust and 70% burnt paddy husks; and T5 = 100% burnt paddy husks. Each mixture was thoroughly mixed in a 10-liter bucket before filling into 60 cm x 60 cm black polythene bags. Planting materials were planted into the media according to the

treatments. Each polyethylene bag was placed randomly on four irrigation lines under the side-netted rain shelter and individually irrigated with a nutrient solution via a dripper on the surface of the substrates.
The fertiliser was formulated by MARDI based on the needs of the plant tubers. The irrigation solutions were prepared in a 1,500-litre tank. Stock A and stock B were added into the tank at a 1:1 ratio until the needed electricity conductivity (EC) was achieved. The EC of the fertigation solution was between 1800 µS/cm and 2600 µS/cm. The irrigation duration was 3 minutes and an identical amount of fertiliser solution was applied to all polyethylene bags. The irrigation scheduling was automatically implemented by a digital timer, three times per day in the first three weeks (07:00 h, 10:00 h and 17:00 h) and six times per day after four weeks (07:00 h, 08:00 h, 10:00 h, 11:00 h, 12:00 h and 17:00 h) until the end of cultivation periods. The daily irrigation volumes per plant were 675 ml in the first three weeks and 1,350 ml after four weeks until the end of the cultivation periods. If necessary, routine horticultural practices for pest, disease, and weed control were performed using biopesticides. The growth of the sweet potato plants was measured by measuring the main stem length, stem diameter, number of lateral shoots, vegetative biomass and SPAD value. The sweet potato plants were randomly selected and the tubers were harvested after three months of planting to determine the yield and growth of tubers. The weight was measured immediately after harvest to prevent desiccation and water loss from the tubers. The container moisture capacity (CMC) is the amount of water present after the substrates have been saturated and allowed to drain. The CMC of the five different substrates mixtures was taken at two different time intervals and calculated using the formula: (saturated mass – dry mass)/dry volume. The measurement was taken by weighing the container at one hour and five hours after watering one month after planting. Air-filled porosity (AFP) or air capacity can be defined as the proportion of the volume that contains air after it has been saturated with water and allowed to drain. Data obtained were subjected to statistical analysis using analysis of variance (ANOVA) procedures to test the significant effect of all the variables investigated using SAS version 9.1. Means were separated using the Duncan Multiple Range Test (DMRT) as the significance test at $p \leq 0.05$.

RESULTS AND DISCUSSION

There were significant differences in the AFP and CMC values between each treatment (Table 1). The 100% coir dust treatment had the highest porosity after one hour and five hours of irrigation. T5 or 100% burnt paddy husks (initial: 6.6% / final: 8.7%) had the lowest initial and final porosity at both times after irrigation. The AFP value from 100% coir dust and mixture with higher coir dust increased compared to 100% burnt paddy husks and combination with higher burnt paddy husk. Mixtures with high content of burnt paddy husks had lower AFP values due to their compaction and high-water retention properties. The CMC values decreased five hours after irrigation (Table 1). The highest initial and final CMC values were obtained from 100% burnt paddy husks. The differences in CMC values between 100% burnt paddy husks and 100% coir dust were 27.5% and 29.7%, respectively, both times after irrigation. The availability of air, air retention and moisture in the substrate is an essential factor affecting the success of growing plants in containers (Aendekerk, 1994). The water content of substrates and AFP gives the estimation of oxygen availability or level of aeration in the substrates (Wall and Heiskenen 2003).

Table 1. Physical properties of five growing substrates at two different times after irrigation

Treatment	**Air-filled porosity (%)**		**Container moisture capacity (%)**	
	1 h	**5 h**	**1 h**	**5 h**
T1	10.4 [a*]	14.5 [a]	40.5 [e]	35.0 [e]
T2	9.0 [b]	10.9 [b]	49.7 [d]	46.0 [d]
T3	8.4 [c]	10.0 [c]	53.9 [c]	51.0 [c]
T4	7.4 [d]	9.0 [d]	65.0 [b]	60.0 [b]
T5	6.6 [e]	8.7 [e]	68.0 [a]	64.7 [a]

*Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

There were significant differences in plant growth between treatments (Table 2). The longest main stem was produced by plants cultivated in 100% coir dust with an average length of 398 cm and the shortest were those grown in 100% burnt paddy husks (average length 236 cm). Treatment containing 100% coir dust produced plant with the thickest stem diameter, the highest number of lateral shoots, vegetative biomass and SPAD value compared to other substrates. The highest vegetative biomass was recorded from plants cultivated in 100% coir dust with an average weight of 3850 g. The lowest biomass was obtained from plants grown in 100% burnt paddy husks. According to Humara *et al*. (2002), the high water content in the growing substrates can reduce both AFP and aeration, which can lead to logging and hypoxia which are detrimental to most plant species. This explains the lower plant growth in the 100% burnt paddy husks compared to other substrates mixtures. In extreme waterlogging conditions, sweet potato plants fail to develop storage roots (Sakamoto *et al*., 2018).

Table 2. Effects of substrates on plant growth after three months of cultivation

Treatment	**Main stem length (cm)**	**Stem diameter (cm)**	**Number of lateral shoots**	**Vegetative biomass (g)**	**SPAD value**
T1	398 [a*]	2.08 [a]	13.30 [a]	3850 [a]	51.45 [a]
T2	385 [b]	1.69 [b]	9.13 [b]	3270 [b]	49.9 [b]
T3	262 [c]	1.29 [c]	7.97 [c]	2700 [c]	49.6 [b]
T4	263 [c]	1.24 [c]	7.98 [c]	2450 [d]	48.9 [c]
T5	236 [d]	1.01 [d]	8.10 [c]	1860 [e]	47.6 [c]

*Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

There were significant differences in tuber yield between treatments after 90 days of cultivation (Table 3). The highest average fresh tuber yield was obtained from plants cultivated in 100% coir dust. These results showed that sweet potato cultivated in a higher amount of coir dust substrates increased the tubers yield by 2.3 times compared to those grown in substrates containing a higher amount of burnt paddy husks. Plant cultivated in a higher amount of coir dust substrates gave more tubers than those grown in substrates containing a higher amount of burnt paddy husks. Tuber yield per plant is positively correlated to the number of tubers as the higher the tuber yield per plant gave rise to high tubers number per plant. The average weight per tuber obtained from 100% coir dust also was higher compared to other treatments. These results were similar to the study done by Hayden *et al*. (2004) found that the growth of rhizomes is dependent on the type of medium. Substrates containing more than 50% of coir dust showed 0.72 harvest index indicating biomass partitioning of storage roots and shoots accordingly (Hermans *et al*., 2006). Substrates that ensure proper root aeration such as coir dust were suitable for the soilless culture cultivation of sweet potato (Kitaya *et al*., 2008).

Table 3. Effects of substrates on tuber yield after three months of cultivation

Treatment	**Tuber yield per plant (g)**	**Number of tubers per plant**	**Average weight per tuber**	**Harvest index**
T1	2788 [a*]	7.1 [a]	374.39 [a]	0.72 a
T2	2350 [b]	6.06 [b]	368.17 [b]	0.72 a
T3	1858 [c]	5.10 [c]	349.30 [c]	0.69 b
T4	1528 [d]	5.09 [c]	287.26 [d]	0.62 c
T5	1174 [e]	4.9 [d]	275.89 [e]	0.63 c

*Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

The selection of substrates is critically important to obtain high sweet potato tuber yield in the soilless culture system. High oxygen availability in the coir dust substrates supports the underground tuber requirement for high oxygen for growth. It is crucial for crops grown in containers to consider the tendency of most root systems to grow gravitropically to form a dense layer at the bottom of the containers (Raviv *et al*., 2011). Coir dust has a strong capillarity that provides more uniform moisture conditions for roots. These conditions can increase aeration in the base mix and reduce surface drying by lifting the moisture higher up in the polyethylene bags. This redistribution of moisture is perhaps one of the reasons for plants grown in pure coir dust to have higher tuber yield. Aeration in the growing substrates is positively related to AFP and negatively to water content (Raviv and Lieth, 2008).

Table 4. Effects of substrates on tuber quality after three months of cultivation

Treatment	**Total Soluble Solid (Brix value)**	**Tuber dry matter content (%) (1 g)**	**Tuber flesh pH**	**Tuber diameter (mm)**			**Tuber length (cm)**
				Upper part	**Middle part**	**Lower part**	
T1	12.1 [a*]	76.73 [a]	5.9 [b]	32.14 [a]	36.67 [a]	29.34 [c]	18.50 [a]
T2	12 [a]	74.11 [b]	5.84 [b]	27.44 [c]	37.82 [a]	31.10 [a]	18.80 [a]
T3	11.7 [b]	63.43 [d]	6.08 [a]	30.07 [b]	37.10 [a]	27.61 [d]	15.92 [b]
T4	10.3 [d]	67.09 [c]	5.85 [b]	23.93 [e]	28.15 [c]	19.41 [e]	14.79 [c]
T5	11.2 [c]	68.06 [c]	5.89 [b]	25.01 [d]	32.91 [b]	30.27 [b]	14.70 [c]

*Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

There were significant substrate effects on tuber quality between treatments (Table 4). Tubers obtained from a high content of coir dust gave higher Total Soluble Solid (TSS) or Brix value, tuber dry matter content and tuber length compared to tuber grown in high burnt paddy husk substrates. Most of the dry matter in sweet potatoes consists of carbohydrates, primarily starch and sugars and to a lesser extent pectins, cellulose and hemicellulose (Truong *et al*., 2018). Tuber flesh pH in all treatments ranging between 5.85 – 6.08, indicated that the flesh is slightly acidic. The shape of the tuber is tapered at the top and bottom with the middle part is expanded. All treatments produced similar tuber shapes with T2 giving the longest tuber length. However, there were no significant differences between T1 and T2, with substrates containing high coir dust giving high tuber length compared to substrates containing high burnt paddy husk. Good quality sweet potatoes should be smooth and firm, with uniform shape and size (Cantwell and Suslow, 2002). Planting sweet potato in high coir dust substrates increased the tuber quality compared to substrates containing high burnt paddy husk.

CONCLUSION

Data revealed that planting sweet potato in high coir dust substrates increased the plant growth, tuber yield and enhanced tuber quality compared to substrates containing high burnt paddy husk. It can be concluded that 100% coir dust is the best substrate for growing sweet potato in a soilless culture system. However, studies on burnt paddy husks in combination with other agricultural wastes like sago waste, industrial by-products like polystyrene beads, or any other cheaper substrates such as coarse sand should be continued to increase the use of burnt paddy husks as a growing substrate for growing sweet potato or any suitable crop in soilless culture production system.

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