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Original article

Growth and yield evaluation of sweetpotato (*Ipomoea batatas* L. (Lam)) stem cuttings stored in different packaging materials

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ABSTRACT

Sweetpotato cuttings are primarily the planting materials used in sweetpotato production which farmers often pack unsuitably during several days of travel and stored inappropriately on delayed planting due to inclement weather. This study was conducted to: evaluate the effects of different packaging materials in storing sweetpotato cuttings on the survival, growth, yield, and yield components of sweetpotato; identify the appropriate packaging materials in storing sweetpotato cuttings that could extend the viability of sweetpotato cuttings without significantly affecting its growth and yield; and determine the cost and return of sweetpotato production using stem cuttings stored in different packaging materials. The different packaging materials significantly affected the percentage survival of stem cuttings, the number of primary lateral vines, the number of marketable roots per plot and per hill, the number and weight of marketable roots per plot and per hectare and the total root yield (t ha-1) of sweetpotato. Cuttings wrapped in a moist newspaper gave the highest survival rating (83.33%) compared to the moist cloth (80.56%). A significantly higher number of primary lateral stems per plant (6.30) was obtained in sweetpotato from cuttings wrapped in moist cloth. The use of moist cloth obtained more marketable roots (9.32 t ha-1) and the highest total root yield (11.93 t ha-1) compared to the plants from cuttings wrapped in moist newspaper (11.57 t ha-1). The highest gross margin (PhP 142,860.00) per hectare was obtained using moist cloth as packaging material while cuttings in perforated polyethylene bags obtained the lowest gross margin (PhP 72,333.00) per hectare.

KEYWORDS: *packaging materials, percentage survival of stem, sweetpotato cuttings, total root yield*

1 INTRODUCTION

Sweetpotato (Ipomoea batatas L. (Lam)) is an herbaceous and perennial vine crop that has white and purple flowers, large nutritious roots, and heart lobed leaves. It is considered an alternative source of carbohydrates and can be grown in temperate, sub-tropical and tropical countries including the Philippines. In fact, the volume of production of sweetpotato in the country as of the second quarter of 2018 was 153.99 thousand metric tons (www.psa.com.ph). Its roots have high nutritive value and fiber, iron and calcium, as well as vitamins C, A and B6. Its leaves have many health benefits as it possesses more dietary fibers and nutrients (www.healthbenefitstimes.com). It is also used as raw materials in the manufacture of alcohol, flour, starch animal feeds, and even beverages (www.PhilRootCrop.com.ph). This can also be processed into different food products like chips with higher economic value than its fresh roots.

During calamities, sweetpotato is an ideal crop. It is considered climate-resilient because of its ability to survive during the dry season (www.fareasternagriculture.com/crops/agriculture). Carpio (2010) reported that it is making a significant contribution to communities prone to typhoons and floods.

In large plantations, scarcity of its planting materials is a problem because of limited sources of stem cuttings. Stem cuttings are procured from faraway places where transport would result in partial wilting of the cuttings and loss of their vigor upon reaching the destination due to long travel time. There are also instances when farmers delay the planting because of unfavorable conditions making the stem cuttings loss their vigor. The National Academy of Science and FAO (2017) found that the deterioration or losses of planting materials can be minimized by careful handling and use of appropriate planting material packaging during transport or storage. Marasigan (1970) also found that when exposed to improper and longer periods of storage, the viability of sweetpotato cuttings reduces decreasing its germination capacity and growth. Such finding was supported by Hall (1985) emphasizing that storing the planting materials more than a week is detrimental to its survival.

On the other hand, cassava cuttings stored for a month reduces its vigor and germination (CIAT, 1985) because the planting material respires with time thereby

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consuming the stored carbohydrates and energy (Leihner, 1984) that is important in germination. Hermoso (1975) also observed that storing cassava cuttings without any packaging for 25 days resulted in low germination due to damage caused by fungal microorganisms.

Generally, since the storage of planting materials for a certain period of time cannot be avoided due to delays in planting and transportation over far distances, appropriate packaging materials and methods are very necessary, most importantly in storing sweetpotato cuttings. Appropriate packaging materials and methods help preserve the vigor of sweetpotato cuttings and maintains their freshness and survival capacity in cases when planting is delayed, hence this study.

2 MATERIALS AND METHODS

The experiment was laid in a Randomized Complete Block Design (RCBD) with three replications. Each replication was divided into five treatment plots with each plot measuring 15m^2 (5m x 3m) in five rows. Alleyways of 1.0m and 1.0m was provided between replications and treatment plots, respectively, to facilitate management and data gathering. The different treatments are designated as follows: T_1 - Unwrapped cuttings; T_2 - Cuttings wrapped in moist newspaper; T_3 - Cuttings wrapped in moist cloth; T_4 - Cuttings wrapped in banana leaves and T_5 - Cuttings placed in perforated polyethylene bags.

Sweetpotato cuttings (NSIC Sp30) about 25cm in length with three (3) leaves and six (6) nodes were collected and stored one day prior to packing using the treatments mentioned above. Newspapers, polyethylene bags (50cm x 50cm) and packaging tapes, moist cloth, and banana leaves were used in packaging the stem cuttings as specified in the treatments. Water was sprinkled just enough to moisten the packaging materials. The wrapped cuttings were placed inside a cartoon box and kept at room temperature for 12 days. After 12 days of storing, the stem cuttings from the different treatments were planted at the same time on specified plots in a vertical position at approximately 25cm apart on the prepared ridges at one cutting per hill. Missing hills were not replanted to quantify the yield loss.

Hand weeding was done to remove the weeds growing close to the plant followed by fertilization at the rate of 40-40-40 kg ha^{-1} of N, P_20_5, and K_2O two (2) weeks after planting. Spot weeding was employed to maintain a weed-free plot until the closure of the plant's canopy.

All plants in the three inner rows in each treatment plot, excluding the two border rows and two end hills in each row were harvested 110 days after planting. Fleshy roots of sweetpotato were dug out using bolo after cutting their vines from the base. Extra care was observed to avoid damaged fleshy roots during harvesting. The fleshy roots with 2.5 cm diameter and 6.5 or greater cm length were considered marketable while those that did not have such measurements were considered non-marketable.

Data Gathered

The following agronomic characteristics of sweetpotato were evaluated: number of lateral vines per plant; length of main vines at harvest (cm); leaf area index (LAI) and fresh herbage yield (t ha^{-1}). For yield and yield components, the following were measured: number of marketable and non-marketable roots per plot; weight of marketable and non-marketable roots (t ha^{-1}); total root yield (t ha^{-1}) and harvest index.

Other Parameters Gathered:

A. Physical Attributes of Stem Cuttings

1. **Degree of wilting and rotting-** the visual quality of the stored cuttings was assessed upon opening after twelve (12) days of storage.

B. Cost and Return Analysis- the gross margin was identified per treatment plot to determine the most promising and economical treatment that will give the highest net return. This was done by subtracting the total variable costs from gross income using the formula:

Net Profit = Gross income – Total variable costs
Where; Gross income = yield that was computed per hectare basis x current price of the crop (P kg^{-1})

3 RESULTS AND DISCUSSIONS

Agronomic Characteristics

Table 2 shows the agronomic characteristics of sweetpotato cuttings as influenced by different packaging materials. Analysis of variance revealed that the number of primary lateral stems per plant and the survival percentage were significantly affected by the different packaging materials.

Table 1. Degree of wilting and rotting of the stem cuttings

Degree of wilting and rotting	Incidence of wilting
0	No wilted and rotted leaves
1	Less than 10% wilted and rotted leaves
2	11-25% wilted and rotted leaves
3	26-50% wilted and rotted leaves
4	51-75% wilted and rotted leaves
5	>75% wilted and rotted leaves

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Table 2. Agronomic characteristics of sweetpotato using stem cuttings stored in different packaging materials

Treatment	Percent Survival (%)	Length of main vines (cm)	No. of primary lateral stem per plant	Leaf Area Index	Fresh herbage weight ($t\ ha^{-1}$)
T_1	67.22 c	321.37	3.93 b	1.09	22.06
T_2	83.33 a	311.20	4.30 b	1.14	28.13
T_3	80.56 ab	387.03	6.30 a	1.51	24.17
T_4	70.00 bc	331.00	4.20 b	1.50	20.55
T_5	66.11 c	342.97	4.03 b	1.02	19.58
Mean	73.45	338.71	4.55	1.25	22.90
CV (%)	9.06	9.15	13.59	26.65	18.78

Means within the same column with the same letter and those without a letter are not significantly different at the 5% level based on Fisher's Least Significant Difference (LSD) test.

Legend

T_1= Unwrapped cuttings
T_2= Cuttings wrapped in moist newspaper
T_3= Cuttings wrapped in a moist cloth
T_4= Cuttings wrapped in banana leaves
T_5= Cuttings placed in perforated polyethylene bags

Table 3. Number and weight (g) of marketable and non-marketable roots per hill of sweetpotato using stem cuttings stored in different packaging materials

Treatment	No. of roots per hill		Wt. (g) of roots per hill	
	Marketable	Non- Marketable	Marketable	Non- Marketable
T_1= Unwrapped cuttings	2.00bc	1.20 a	302.67	97.00
T_2= Cuttings wrapped in moist newspaper	1.83 c	0.77 b	203.33	81.33
T_3= Cuttings wrapped in a moist cloth	2.57 a	0.97 ab	302.67	64.67
T_4= Cuttings wrapped in banana leaves	2.20 b	0.93 b	287.50	85.50
T_5= Cuttings placed in perforated polyethylene bags	1.93 bc	0.90 b	203.17	62.67
Mean	2.11	0.95	259.87	78.23
CV (%)	8.60	13.41	19.97	32.91

Means within the same column with the same letter and those without a letter are not significantly different at the 5% level based on Fisher's Least Significant Difference (LSD) test.

Table 4. Number and weight (kg) of marketable and non-marketable roots per plot of sweetpotato using stem cuttings stored in different packaging materials

Treatment	No. of roots per plot		Weight of roots per plot	
	Marketable	Non- Marketable	Marketable	Non- Marketable
T_1= Unwrapped cuttings	26.33 c	20.00	4.02 b	1.48 b
T_2= Cuttings wrapped in moist newspaper	27.67bc	21.67	3.93 b	3.02 a
T_3= Cuttings wrapped in a moist cloth	37.00 a	19.00	5.59 a	1.17 b
T_4= Cuttings wrapped in banana leaves	30.00 b	21.00	3.98 b	1.79 b
T_5= Cuttings placed in perforated polyethylene bags	27.33bc	16.33	3.44 b	1.20 b
Mean	29.67	19.60	4.19	1.73
CV (%)	4.98	14.75	13.88	25.17

Means within the same column with the same letter and those without a letter are not significantly different at the 5% level based on Fisher's Least Significant Difference (LSD) test.

However, the length of main vines, LAI, and herbage yield were not markedly influenced by the treatments tested. More primary lateral stems per plant were produced in plants from cuttings wrapped in moist cloth.

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Table 5. Root yield (t ha^{-1}) and harvest index of sweetpotato using stem cuttings stored in different packaging materials

Treatment	Root yield (t ha^{-1})			Harvest index
	Marketable	Non- Marketable	Total	
T_1= Unwrapped cuttings	6.71 b	2.47 b	9.18 c	0.48
T_2= Cuttings wrapped in moist newspaper	6.55 b	5.02a	11.57 ab	0.42
T_3= Cuttings wrapped in a moist cloth	9.32 a	1.95b	11.93 a	0.46
T_4= Cuttings wrapped in banana leaves	6.63 b	2.98b	9.61 bc	0.38
T_5= Cuttings placed in perforated polyethylene bags	5.72 b	2.00b	7.72 c	0.46
Mean	6.99	2.88	10.00	0.44
CV (%)	13.90	25.19	11.77	17.69

Means within the same column with the same letter and those without a letter are not significantly different at the 5% level based on Fisher's Least Significant Difference (LSD) test.

Table 6. Physical attributes of stored sweetpotato cuttings as influenced by different packaging materials

Treatment	Degree of wilting	Percent weight loss (%)
T_1= Unwrapped cuttings	2.33 c	26.30 b
T_2= Cuttings wrapped in moist newspaper	2.67 c	36.90 a
T_3= Cuttings wrapped in a moist cloth	3.67 b	24.14 b
T_4= Cuttings wrapped in banana leaves	4.67 a	22.51 b
T_5= Cuttings placed in perforated polyethylene bags	5.00 a	19.04 b
Mean	3.67	25.62
CV (%)	14.08	17.10

Means within the same column with the same letter are not significantly different at the 5% level based on Fisher's Least Significant Difference (LSD) test.

Table 7. Gross margin analysis of sweetpotato using stem cuttings stored in different packaging materials

Treatment	Wt. of marketable root yield (t ha^{-1})	Gross Income * (PhP)	Total Variable Cost (PhP)	Gross margin (PhP)
T_1= Unwrapped cuttings	6.71	134,200.00	41,485.00	92,715.00
T_2= Cuttings wrapped in moist newspaper	6.55	131,000.00	42,915.00	88,085.00
T_3= Cuttings wrapped in a moist cloth	9.32	186,400.00	43,540.00	142,860.00
T_4= Cuttings wrapped in banana leaves	6.63	132,600.00	42,095.00	90,505.00
T_5= Cuttings placed in perforated polyethylene bags	5.72	114,400.00	42,067.00	72,333.00

* Based on the current price of sweetpotato @ PhP 20.00 kg^{-1}

In terms of percentage survival, cuttings wrapped in moist newspapers gave the highest survival rating of 83.33% but were comparable to cuttings wrapped in moist cloth (T_3). This could be attributed to the efficiency of the packaging materials that reduce transpiration and preserve the needed dry matter. Harvested sweetpotato slips are like leafy green vegetables which is 90% water (Acedo and Weinberger, 2007). Because of high water content and the presence of stomata on the leaves, they are extremely vulnerable to high rates of water loss (O'Hare et al., 2001). The cuttings placed in perforated polyethylene bags had the lowest percentage of survival.

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This finding implies that the percentage survival of sweetpotato stem cuttings can be increased by wrapping the cuttings in moist newspaper and moist cloth for twelve (12) days. Furthermore, the result implies that if planting is delayed for 12 days, unwrapped cuttings will have lower percentage of survival than stem cuttings wrapped in moist newspaper and moist cloth.

Yield, Yield Components and Harvest Index

Tables 3-5 present the yield, yield components, and harvest index of sweetpotato cuttings as influenced by different packaging materials. Analysis of variance revealed that the number of marketable and non-marketable roots per hill, the number of marketable roots per plot, the weight (kg) of marketable and non-marketable roots per plot, the marketable and non-marketable root yield (t ha^{-1}), and the total root yield were significantly affected by the packaging materials.

Sweetpotato from cuttings wrapped in moist cloth obtained the highest number of marketable roots per hill, marketable roots per plot, and consequently higher marketable root yield and total root yield (t ha^{-1}).

A. Unwrapped cuttings (T_1)

B. Cuttings wrapped in moist newspaper (T_2)

C. Cuttings wrapped in moist cloth (T_3)

D. Cuttings wrapped in banana leaves (T_4)

E. Cuttings placed in perforated polyethylene bags (T_5)

Figure 1. Sweetpotato cuttings stored for 12 days using different packaging materials

The lowest number of marketable roots per hill was obtained in plants from cuttings wrapped in moist newspaper. The use of moist cloth could have prevented severe water loss from the stem cuttings brought by transpiration that possibly preserved the meristematic parts of stem cuttings like the nodes and shoot tips which are growing points of the planting materials.

Lewthwaite and Triggs (2009) reported that storage root development starts from the adventitious roots that are pre-formed at the nodes. It is possible that formation of adventitious roots prior to transplant could play a role in plant establishment and yield. Thompson et al. (2007) reported that stem cuttings that were held one day before planting had greater total root yield than those held for seven days. It is possible that the cuttings packed in moist cloth were planted at a higher vigor and quality that they simply required very less maintenance energy to allocate for storage root formation. For the weight of marketable roots per plot and weight of marketable roots per hectare, plants from cuttings wrapped in moist cloth (T_3) obtained the highest weight of 5.59 kg and 9.32 t ha^{-1}, respectively. Cuttings wrapped in newspaper, banana leaves, and

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perforated polyethylene bags were comparable in those parameters with the unwrapped cuttings (T_1). A similar trend was observed for the weight of non-marketable roots per plot and per hectare in which plants from stem cuttings wrapped in moist newspaper were heavier.

For to the total root yield, cuttings wrapped in moist clothing obtained the highest yield (11.93 t ha^{-1}); but, this was statistically comparable to the yield of the cuttings wrapped in moist newspaper (T_2) at 11.57 t ha^{-1}. This may be due to the higher percentage of plants that survive in the field. Cuttings wrapped in perforated polybags yielded the lowest which was comparable to those wrapped in banana leaves (T_4) and the unwrapped cuttings (T_1). This can be attributed to fewer plant populations per plot because such treatments obtained the lowest survival percentage. The data implies that plants from cuttings wrapped in moist cloth and newspaper can increase the root yield of sweetpotato.

The number of non-marketable roots per plot, the weight of non-marketable roots per hill and the harvest index were not affected by the different wrapping materials.

Physical Attributes of the Stem Cuttings

Table 6 and Figure 1 show the degree of wilting and rotting and percentage weight of sweetpotato cuttings wrapped in different packaging materials. Results revealed that the degree of wilting and rotting and the weight loss percentage of stem cuttings differed significantly among the different packaging materials used.

Cuttings stored in perforated polyethylene bags (T_5) were severely wilted and rotted compared to the cuttings wrapped in banana leaves (T_4). This was followed by the cuttings wrapped in moist cloth (T_3). Unwrapped cuttings (T_1) and cuttings wrapped in moist newspaper (T_2) recorded the lowest rating. The wilting and rotting of the leaves of stored cuttings could be due to the accumulated moisture by the packaging materials and water loss brought by stomatal transpiration.

One of the major concerns in storing planting materials was the conservation of the water or moisture since any change in its internal water content may influence its viability. The different packaging materials influenced the weight loss of stored sweetpotato cuttings. Cuttings wrapped in moist newspaper obtained the highest weight loss. Those wrapped in moist cloth, banana leaves, and perforated polyethylene bags were comparable to unwrapped cuttings (T_1).

The cost and return analysis of sweetpotato as influenced by different packaging materials of sweetpotato stem cuttings is presented in Table 7. The highest gross margin of PhP 142,860.00 was obtained from cuttings wrapped in moist cloth as it obtained the highest weight of marketable roots in tons per hectare, followed by unwrapped cuttings with PhP 92,715.00 gross margin. Cuttings placed in perforated polyethylene bags obtained the lowest gross margin of PhP 72,333.00. This was due to lower root yield and higher production costs.

4 CONCLUSION

Based on the results, the following conclusions can be drawn: the different packaging materials in storing sweetpotato cuttings significantly affected the percentage survival of stem cuttings, the number of primary lateral vines, the number of marketable roots per plot and per hill, the weight of marketable roots per plot and per hectare, and the total root yield (t ha^{-1}) of sweetpotato; and wrapping sweetpotato cuttings with a moist cloth and moist newspaper extended the viability of sweetpotato stem cuttings stored for twelve (12) days before transplanting. Moreover, using moist newspaper and moist cloth was the appropriate packaging material in storing sweetpotato stem cuttings for twelve (12) days before transplanting. Lastly, plants from cuttings wrapped in moist cloth gave a high gross margin of PhP 142,860.00.

RECOMMENDATION

The result of the study recommends the use of moist cloth and newspaper as packaging materials for sweetpotato cuttings if stored for 12 days because it has extended the viability of the apical stem cuttings. Moreover, moist cloth is recommended for higher production of marketable roots that resulted in a high gross margin among the packaging materials tested for sweetpotato cuttings.

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