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Utilization of Commercial Hydroponics Solution as Low-Cost Medium for Cardava (*Musa Acuminata* × *Balbiciiana* Abb Group) Banana Micropropagation

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Abstract. Cardava banana is a popular cooking banana cultivar in the Philippines, widely processed into chips and other products, making it an important export commodity. Despite its economic value, production is hampered by the limited availability of disease-free and affordable planting materials. This study evaluated the use of commercial hydroponic solutions as cost-effective alternatives to the conventional Murashige and Skoog (MS) medium for cardava micropropagation. Results revealed that the highest survival rate (93.33%) was achieved using General Hydroponics solution alone, while the lowest survival (36.67%) was recorded in the combination of Peter's + General Hydroponics. In terms of shoot production, the Simple Nutrient Addition Program (SNAP) + General Hydroponics produced the highest number of shoots (4.39). The MS medium yielded the longest shoots (47.21 mm), which were statistically similar to most treatments except for Peter's alone (27.33 mm). Root formation occurred in Peter's solution alone (0.33) and in SNAP + Peter's + General Hydroponics (1.5). Remarkably, plantlet production cost was reduced by 97% when using Peter's solution compared to Muashige and Skoog (MS) medium. These findings demonstrate the potential of hydroponic solutions as low-cost micropropagation media, offering a more accessible and economically feasible method for large-scale propagation of cardava bananas.

1. Introduction

Cardava banana (*Musa acuminata* × *balbiciiana* ABB Group) is considered one of the most important fruits in the world due to its contribution to the human diet. Aside from its fruits for staple food, its flesh is being processed for flour, puree, pastelias, blossoms and chips, wine, vinegar, sauce, and ketchup (Shahbandeh, 2022).

The most common propagation method of bananas was the division of sucker from a detached plant to their mother plant, which is widely used as a traditional farming technique. This propagation process was limited due to pests and diseases, and the low multiplication rate of plantlets. Moreover, it is also a way to spread the disease in bananas through suckers that grow together with their mother plant, which is already infected. These problems are the reason for the shortage of production and distribution of bananas in any other country (Tumuhimbise and Talengera 2018). The only possible solution to these problems is the plant tissue culture technique through micropropagation of a disease-indexed banana sucker for rapid mass propagation of clean planting materials.



Micropropagation is the most suitable for the rapid propagation of banana in a short period continuous process. A single explant can be multiplied into several thousand in a relatively short amount of time and space, regardless of the time of year or weather (Akin-Idowu et al., 2009). However, plantlet production is expensive due to the high value of nutrients such as macro, micronutrients, growth hormone, and gelling agents for media preparation (Gamborg & Phillips, 1995). This research was conducted to develop a working protocol for the micropropagation of Cardava (*Musa acuminata* × *balbisiana*) using commercial hydroponics solution (SNAP, General Hydroponics, and Peter's professional solution) as a low-cost nutrient source of the medium.

2. Materials and methods

2.1. Source and Preparation of Commercial Hydroponics Solution

SNAP hydroponics solution, Peter's Professional, and General Hydroponics solutions were obtained from a designated commercial agrivet store/distributor. Stock solutions of Simple Nutrient Addition Program (SNAP), Peter's Professional, and General Hydroponics were diluted to a per-liter volume and used as alternative nutrient sources in Murashige and Skoog (MS) medium (Table 1,2,3 &4). For the SNAP solution, 2.5 mL of Solution A and 2.5 mL of Solution B were measured, giving a total of 5.0 mL of concentrated solutions. These were transferred into a clean 1,000 mL volumetric flask. Distilled water was then added gradually until the final volume reached exactly 1,000 mL. For the General Hydroponics solution, 2.64 mL of Flora Micro, 3.96 mL of Flora Gro, 1.32 mL of Flora Bloom, and 1.0 mL of CaliMAGic were measured accurately using a pipette or measuring cylinder. These concentrated solutions, totaling 8.92 mL, were transferred into a clean 1,000 mL volumetric flask or mixing container. For Peter's solution, 0.3 g of Peter's Blossom Booster, 1.0 g of Peters Yield Booster, 0.4 g of Peters STEM, 1.6 g of Magnesium Sulfate, and 4.0 g of Calcium Nitrate were weighed accurately using an analytical balance. The solid fertilizers were first dissolved in a small volume of distilled water individually to ensure complete solubility before mixing the concentrations. The mixture was then transferred into a clean 1,000 mL volumetric flask. Distilled water was then added gradually until the final volume reached exactly 1,000 mL for each solution.

2.2. Experimental Design and Treatment

All treatments were replicated 3 times with 10 culture vessels arranged in a completely randomized design (CRD): T1 – Control (MS medium), T2 – Snap Solution, T3 – Peter's Solution, T4 – General Hydroponics Solutions, T5 – SNAP + Peter's Solution, T6 – SNAP + General Hydroponics Solution, T7 – Peter's + General Hydroponics Solution, T8 – SNAP + Peter's + General Hydroponics Solution. Data gathered were analyzed statistically using Analysis of Variance (ANOVA) with Statistical Tools for Agricultural Research (STAR) Version 2.0.1 [8]. Tukey's test at a 5% level of confidence was used to separate the treatment means.

2.3. Preparation of Culture Media

Murashige and Skoog (1962) medium was used as the basal medium and supplemented with 3% sugar and 0.6% agar (Pronadisa) as the control. In the experimental treatments, commercial hydroponic solutions at varying concentrations and combinations were incorporated as alternative nutrient sources to the MS medium. All low-cost media were further supplemented with 5.5% sugar. The plant growth regulator benzylaminopurine (BAP) was added at a concentration of 5 mg/L. After mixing all components, the pH was adjusted to 5.8 using either 0.1 N sodium hydroxide or hydrochloric acid. Subsequently, 30 ml of medium was dispensed into 150 ml capped bottles. Sterilization was carried out in a pressure cooker at 15 psi for 20 minutes.

2.4. Preparation of Explant and Sterilization

Field-collected suckers from Brgy. Nonong Butuan City, Agusan del Norte, were initially cleaned and washed in the laboratory using soap and rinsed thoroughly under running tap water. Unwanted leaves, bracts, and other appendages were removed before surface sterilization. The trimmed shoots were sterilized sequentially as follows: immersion 100% Zonrox solution for 1 hour, then rinsed with

sterile water three times. The sterilized shoots were retreated with 50% Zonrox solution for 1 hour, then rinsed with sterile distilled water.

2.5. *Inoculation and Incubation*

Shoot tip excisions were carried out inside a laminar flow chamber using sterile forceps and a scalpel. Tissue segments measuring 1.0 cm were excised and inoculated into 150 ml capacity culture bottles with plastic. Each culture bottle contains 30 ml of freshly prepared culture medium. The cultures were incubated on shelves under white fluorescent light at a room temperature of 21 °C.

Table 1. Chemical Properties of Peter Solution solution per liter of culture medium.

Kind of Fertilizer (% w/v)	Cost per Pack (PHP)	Quantity (g) per L of medium	Cost of solution per L of water (php)	N	P	K	Ca	Mg	B	Mo	Cu	Fe	Mn	Zn	S
Peters Blossom Booster	139/100 g	0.3	0.417	27	135	45	0.3	0.05	0.008	0.01	0.15	0.05	0.008		
Peters Yield Booster	139/100 g	1	1.39	150	100	300	0.7	0.2	0.029	0.036	0.5	0.2	0.025		
Peters STEM	65/100g	0.4	0.065				1.35	0.04	2.3	7.5	8	4.5	13		
Magnesium Sulfate	65/kg	1.6	0.026				64								52
Calcium Nitrate	80/kg	1	0.08	155	190										
Total Cost per Liter of Medium				1.978											

Table 2. Chemical Composition of General Hydroponics Solutions per liter of medium.

Kind of Fertilizer	Cost/ Bottle (946ml)	Quantity (mL) per L of Water	Cost of solution per L of water	N	P	K	Ca	B	Mg	Mo	Cu	Fe	Mn	Zn	S	Co
Flora Micro	1,550	2.64	4.32	5	1	5	0.01	0.0008	0.01	0.1	0.05	0.015	0.0005			
Flora Gro	1,550	3.96	6.49	2	1	6	0.5									
Flora Bloom	1,550	1.32	2.16	5	4	1.5									1	
CaliMAGic	2,550	1	2.70	1	5	1.5				0.1						
Total Cost per Liter of Medium (PHP)				15.67												

Table 3. Nutrient Composition of SNAP (Simple Nutrient Addition Program) Solution per liter of culture medium.

SNAP Solution	Fertilizer Grade (Elemental form)	Concentration (% w/v)	Cost Concentrated Bottle (PhP)	Cost Medium/L
SNAP A	Nitrogen	6.10%	225.00	9.00
	Calcium	4.425%		
	Potassium	3.09%		
SNAP B	Phosphorus	0.376%	225.00	9.00
	Magnesium	0.494%		
	Iron	0.151%		
	Microelements (Boron, Manganese and Molybdenum)	Trace elements		
Total Cost per Liter of Medium			18.00	

Table 4. Nutrient Composition of the Murashige and Skoog Medium (Murashige and Skoog, 1992).

CHEMICAL	AMOUNT (mg/L)	Cost/Bottle (PHP)	Weight/ Bottle(g)	Cost/L (PHP)
<u>Macroelements</u>				
Potassium Nitrate(KNO ₃)	1900	15,000.00	1000	28.5
Ammonium Nitrate (NH ₄ NO ₃)	1650	19,000.00	1000	31.35
Calcium Chloride (CaCl ₂ ·2H ₂ O)	440	2,500.00	1000	1.1
Magnesium Sulfate (MgSO ₄ ·7h ₂ O)	370	4,000.00	1000	1.48
Potassium Phosphate (KH ₂ PO ₄)	170	4,700.00	500	3.2
<u>Microelements</u>				
Manganese sulfate (MnSO ₄ ·H ₂ O)	22.3	2,000.00	1000	0.04
Zinc sulfate (ZNSO ₄ ·7H ₂ O)	8.6	3,500.00	1000	0.03
Boric acid(H ₃ BO ₃)	6.2	1,500.00	500	0.04
Potassium iodide(KI)	0.82	4,000.00	500	0.01
Sodium molybdate (Na ₂ MoO ₄ ·2H ₂ O)	0.25	3,500.00	1000	0.001

Copper sulfate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)	0.025	3,500.00	1000	0.0001
Copper chloride ($\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$)	0.025	2,050.00	500	0.0002
<u>Iron source</u>				
Sodium EDTA	37.3	3,500.00	500	0.52
Ferrous sulfate	27.8	3,100.00	500	0.34
<u>Vitamins</u>				
Glycine	2.0	3500	1000	0.01
Nicotine acid	0.5	3500	500	0.01
Pyridoxine HCl	0.5	3500	1000	0.002
Thiamine HCl	0.1	3500	25	0.56
Myo-inositol	100	15000	500	6
Total Cost MS medium/L			73.19	

3. Results and discussion

3.1. Culture Establishment

Table 5 presents the effects of different hydroponic solutions as alternative nutrient sources on contamination, shoot formation, greening, and browning in tissue culture. Results revealed that the days to contamination were shortest in the General Hydroponics Solution (T4) at 4.67 days, indicating greater susceptibility of this medium to early microbial infection. In contrast, the longest time before contamination occurred was recorded in T5 (SNAP + Peter's Solution) and T8 (SNAP + Peter's + General Hydroponics), both at 40.44 days. This suggests that these combinations were more effective in suppressing early contamination. On the other hand, the earliest days to browning (7 days) were observed in medium with a combination of SNAP, Peter's, and General Hydroponic Solutions, but par with the rest of the treatments except for the control treatment (8.4 days). Days to greening, however, showed significant variation. The longest greening period was observed in T8 (27.16 days), while the shortest was in the T1 control (18.69 days). This indicates that media composition may either enhance or delay chlorophyll development in the explants. For days to shoot emergence, no significant differences were detected among treatments, with values ranging from 67.67 days (T5) to 138.6 days (T1 control). Although not statistically significant, the earlier shoot initiation in T5 may suggest a positive effect of combined nutrient sources. The highest number of shoots (4.39) formed was observed in SNAP and General Hydroponics Solution (T6), while the lowest number of shoot formations was observed in Peter's Solution alone, although comparable with the rest of the treatments. The results indicate that combined nutrient solutions, particularly SNAP with General Hydroponics (T6), were most effective in enhancing shoot multiplication while also delaying contamination and browning. Peter's Solution alone (T3), though capable of producing shoots, showed limited potential due to its lower shoot proliferation rate.

Table 5. Days to contamination, number of shoots, days to shoot, days to greening, and days to browning of shoot tip culture of cardava in response to different hydroponics solutions at 7 months after inoculation.

TREATMENTS	Days to Contamination	Number of Shoots	Days to Shoot	Days to Greening	Days to Browning
T1 - Control	18.67 _b	1.72 _b	138.6	18.69 _c	8.4 _a
T2 - Snap Solution	16.72 _b	1.58 _b	95.67	21.7 _{abc}	7.93 _{ab}
T3 - Peter's Solution	7 _c	0.78 _b	113.56	20.69 _{bc}	7.23 _{ab}
T4 - General Hydroponics Solutions	4.67 _c	1.78 _b	131.44	22.71 _{abc}	7.23 _{ab}
T5 - SNAP + Peter's Solution	40.44 _a	1.83 _b	67.67	23.1 _{abc}	7.47 _{ab}
T6 - SNAP + General Hydroponics Solution	33.06 _{ab}	4.39 _a	109.67	21.88 _{abc}	7.47 _{ab}
T7 - Peter's + General Hydroponics Solution	34.8 _{ab}	1 _b	98.78	24.8 _{ab}	7.23 _{ab}
T8 - SNAP + Peter's + General Hydroponics	40.44 _a	2.05 _{ab}	115.62	27.16 _a	7 _b
Pr(> F)	0.00**	0.0061**	0.8425 ^(ns)	0.0067**	0.0199*

*Means in a column with common letter are not significantly different based on Tukeys's Honest Significant Difference (HSD) Test, 5%, ns- not significant, *- significant, **- highly significant

3.2. Culture Growth

The results in Table 6 show that the different hydroponic solutions used for the shoot tip culture of cardava banana exhibited varied effects on rooting, contamination, survival, and microbial infection seven months after inoculation. Root induction was only observed in Peter's Solution (T3) and the combination of Peter's and General Hydroponics Solution (T8). Among these, T8 produced the highest number of roots (1.5) but required a longer period to initiate rooting (120.56 days), while T3 initiated roots earlier at 65.33 days but with fewer roots (0.33). This indicates that Peter's-based solutions have some potential in stimulating root formation, although the response remains limited. In terms of contamination, the General Hydroponics Solution (T4) recorded the lowest rate at 6.67%, while treatments that included SNAP components (T5–T7) showed relatively higher contamination, with T5 reaching 60%. Correspondingly, survival was highest in T4 (93.33%) and lowest in T7 (36.67%). This suggests that General Hydroponics Solution provided a more favorable medium for plant survival and reduced microbial infection. On the other hand, bacterial and fungal infections were lowest in T4 (3.33% fungus and 3.33% bacteria) and T8 (10% fungus and 6.67% bacteria). In contrast, SNAP-based treatments, particularly T5 and T6, were associated with higher fungal contamination (43.33%). The result indicates that the hydroponics solution could be used as a cheap alternative nutrient source of micropropagation medium for cardava bananas. Plant growth is primarily influenced by the composition of the culture medium, which typically consists of mineral salts, a sugar source for carbon, and water (Gamborg et al., 1968; Gamborg and Phillips, 1995). Hydroponics solutions used in the experiments have enough mineral salts to sustain the growth and

development of the culture. Moreover, the osmolarity of the culture medium, along with culture agitation and aeration, plays a crucial role in regulating cell division (FAO, 2004).

Table 6. Days to roots, number of roots, percent contamination, percent survival, percent bacteria, and percent fungus of shoot tip culture of cardava in response to different hydroponics solution at 7 months after inoculation.

TREATMENT	Days to roots	Number of roots	Percent contamination	Percent survival	Percent bacteria	Percent fungus
T1- (MS medium)	0	0	43.33 _{ab}	56.67 _{ab}	23.33 _{ab}	20.00 _{ab}
T2- Snap Solution	0	0	50.00 _{ab}	50.00 _{ab}	26.67 _a	23.33 _{ab}
T3- Peter's Solution	65.33	0.33	33.33 _{ab}	66.67 _{ab}	6.67 _{ab}	26.67 _{ab}
T4- General Hydroponics Solutions	0	0	6.67 _b	93.33 _a	3.33 _b	3.33 _b
T5- SNAP + Peter's Solution	0	0	60.00 _a	40.00 _b	16.67 _{ab}	43.33 _{ab}
T6- SNAP + General Hydroponics Solution	0	0	56.67 _{ab}	43.33 _{ab}	13.33 _{ab}	43.33 _{ab}
T7- Peter's + General Hydroponics Solution	0	0	63.33 _a	36.67 _b	16.67 _{ab}	46.67 _a
T8- SNAP + Peter's + General Hydroponics	120.56	1.5	16.67 _{ab}	83.33 _{ab}	6.67 _{ab}	10.00 _{ab}
Pr(> F)	0.1075 ^(ns)	0.1445 ^(ns)	0.0123 ^(**)	0.0123 ^(**)	0.0170 ^(**)	0.0182 ^(**)

*Means in a column with common letter are not significantly different based on Tukeys's Honest Significant Difference (HSD) Test, 5%, ns- not significant, *- significant, **- highly significant.

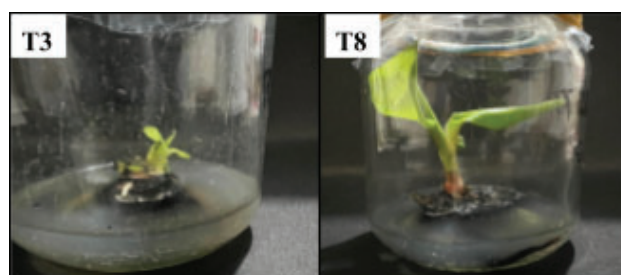


Figure 1. Roots appeared in treatment 3 (100% Peter's Solution) and treatment 8 (33.33% SNAP, Peter's, and General Solutions) in the shoot tip culture of cardava 6 months after inoculation.

3.3. Shoot Length

The shoot length response of cardava cultures in S7 to different hydroponics solutions and combinations as an alternative nutrient source in the micropropagation medium is shown in Figure 2. The results revealed that shoot length was not significantly affected by the different sources of alternative nutrients in the micropropagation until 231 days of culture growth. However, in the 238 days (7 months) of subculture 7, the longest shoot length of shoot tip culture was grown in Control MS medium (T1) with a mean of 47.21mm, although this was comparable to the rest of the treatments except T3 (Peter's Solution alone). The result implies that different hydroponics solutions could be used as an alternative solution in the micropropagation medium. The use of a low-cost

nutrient source (hydroponic solutions) could reduce the cost of analytical grades of macro and micro chemicals used in the conventional medium. This result was corroborated by the result of Toyosumi et al (2021), wherein they reported that the shoot biomass and shoot development of banana plantlets were enhanced when grown under a hydroponics system. Notably, the shoot growth of the hydroponically supplemented medium developed green and erect shoots that are comparable to the control treatment (Figure 2- right). The shoot tip cultures grown in Peter's Solution alone (T3) produced stunted plantlets with yellow-green leaf coloration.

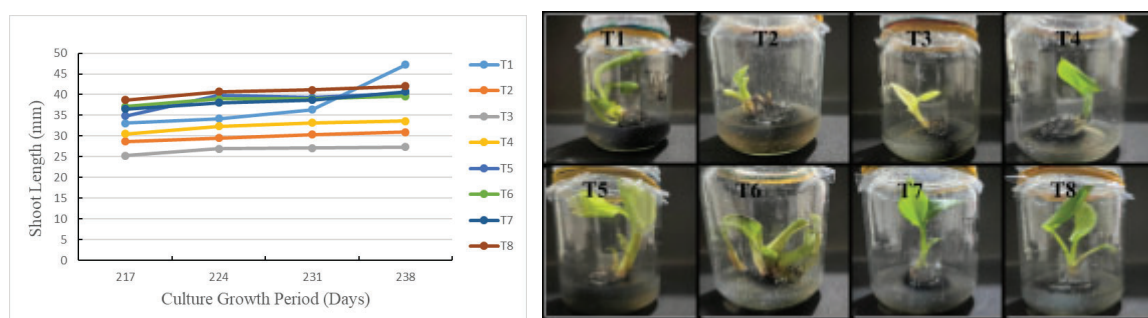


Figure 2. Shootlength (left -graphical presentation, right- actual growth) response of Cardava shoot tip cultures to different hydroponic solutions and combinations at 7 months of micropropagation cycle before planting (**T1**- Control (MS medium), **T2** – Snap Solution (100%), **T3** – Peter's Solution (100%), **T4** – General Hydroponics Solutions, **T5** – 50% SNAP + 50% Peter's Solution, **T6** - 50% SNAP + 50% General Hydroponics Solution, **T7** - 50% Peter's + 50% General Hydroponics Solution and **T8** – 33.33% SNAP + 33.33% Peter's + 33.33% General Hydroponics Solution).

3.3. Cost efficiency

Table 7 shows the comparisons and cost reduction of the modified low-cost medium of cardava shoot tip culture over MS medium. Results show that a significant reduction in the cost of plantlet production of Cardava was achieved regardless of the different sources of alternative nutrients used in the medium. The Highest total cost savings of 97% over conventional medium was observed in Peter's Solution (T3), while the lowest total cost savings was observed in medium SNAP solution alone (T2), having a value of 75.413%. The result of the study greatly reduced the cost of macro and micronutrients needed for the micropropagation medium of the Cardava. In addition, the use of commercially available hydroponics solution could be used as an alternative nutrient source for the micropropagation medium of the cardava.

Table 7. Comparisons and cost reduction of the modified low-cost medium of cardava shoot tip culture over MS medium.

Cost in 1L medium (PHP)								
MS Medium	T1 MS Medium	T2 SNAP	T3 Peter's Solution	T4 General Solution	T5 (SNAP and Peter's)	T6 (SNAP and General Solution)	T7 (Peter's and General Solution)	T8 (SNAP, Peter's and General Solution)
Total Cost per L of Medium	73.1949	18	1.978	15.67	9.99	16.835	8.824	11.8815
% Cost Reduction over MS medium		75.4	97.30	78.597	86.35	76.99	87.94	83.77

4. Conclusions

The use of hydroponic solutions as low-cost nutrient sources in culture media can substantially reduce production expenses. The culture medium supplemented with a combination of SNAP + Peter's and General Hydroponics solution (T8), Simple Nutrient Addition Program (SNAP) with General Solutions (T6), and General Solution alone (T4) medium significantly improved the percent survival, shoot, and root growth development cultures. The highest total cost savings of 97% over conventional medium was recorded in 100% Peter's Solution (T3). These findings suggest that hydroponic solutions have the potential as an alternative low-cost micropropagation medium, making the propagation banana more economically feasible and accessible.

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