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ENHANCEMENT OF THE CULTURE OF GAC *(Momordica cochinchinensis* [Lour.] Spreng) FOR COMMERCIALIZATION AND SUSTAINABLE UTILIZATION

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Abstract

Propagation and cultural techniques were developed to enhance the domestication and culture of the wild indigenous vegetable, *Momordica cochinchinensis* (Lour.) Spreng. The vegetative propagation techniques include using two-node vine cuttings of female plants and dipping them for five hours in a commercial liquid rooting hormone or honey solution. These propagation techniques enhanced the survival and growth of propagules. The cultural techniques include planting propagules grown from two-node vine cuttings, applying 1.5kg organic fertilizer (OF) plant^{-1}, and rejuvenating by pruning annually at 0.5m height from the soil line after the fruiting season. Plants grown following the above cultural techniques gave the highest yield, net income, and the lowest break-even price.

The developed techniques on propagation, field establishment, fertilization, and rejuvenation could be integrated into a package of technology that will enhance the transformation of this species from subsistence to commercial level and its sustainable utilization for food, nutrition, and health.

Keywords: indigenous vegetable, Momordica cochinchinensis, production technology, propagation

Introduction

Momordica cochinchinensis (Lour.) Spreng, Family Cucurbitaceae*,* is a dioecious, viny indigenous vegetable (IV) possessing food, nutrition, and health benefits. This plant is commonly called gac or spiny bittergourd (Engl.), (balbas-bakiro (Tag.), tabog-uak (Bik.), or libas, sugod-sugod and parog-parog (Ilk.) (Plate 1). In East and Southeast Asian countries, it has long been used in cuisine and traditional medicine (Kubola & Siriamornpun, 2011). In the Philippines, the fruits and young shoots are prepared into various dishes (Antonio et al., 2011). The seed aril (seed membrane) is used as a colorant in food recipes such as sticky rice, sweets, and beverages (Bootprom et al., 2015). The aril contains high amounts of lycopene and beta-carotene (Aoki et al., 2002; Kubola & Siriamornpun, 2011), which are beneficial in reducing the risk of various diseases such as prostate cancer, colon cancer, stomach cancer, and cerebral thrombosis (Ishida et al., 2004; Voung et al.,

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2006). Thus, this crop, particularly the aril, could be utilized as a natural food colorant, food additive, and functional food product because of its high carotenoid content.

Despite these potentials, *M. cochinchinensis* remains underutilized worldwide because of unsustainable supply and a lack of awareness of its potential value (Sanwal et al., 2011; Vuong & King, 2003). There is an unsustainable fruit supply because it is generally wild, seasonally available, difficult to grow from seeds due to dormancy, and of unpredictable occurrence of unproductive male plants, among others. It is cultivated on a small scale in a few Southeast Asian countries but remains a wild species in the Philippines, particularly in the Ilocos provinces, where it is an important IV. Initial efforts have been made on its domestication at the botanical garden of the Mariano Marcos State University (MMSU) in the City of Batac, Ilocos Norte. It is now being grown as a perennial crop bearing fruits year-round but peaks during May to August. Those growing in the wild die off during the dry months of January to May and become revived during the rainy months of June to October, during which sufficient moisture is available for plant growth and development.

Thus, this research was conducted to develop a package of technology (POT) to enhance the domestication and culture of the plant, transforming it from a wild plant to a cash crop. As a result, this will aid in creating a market niche and promoting the sustainable utilization and genetic conservation of this IV species.

Methodology

The project consisted of two components: first, the development of propagation techniques conducted in the Plant Genetic Resources nursery, and second, the development of cultural techniques done at the Experimental Farm of MMSU. The site of the field experiments was in a rainfed lowland ecosystem in the City of Batac, Ilocos Norte. In the Modified Corona's Climate Classification based on rainfall distribution, the climate in the site is classified as Type I, which is characterized by two pronounced seasons: dry from November

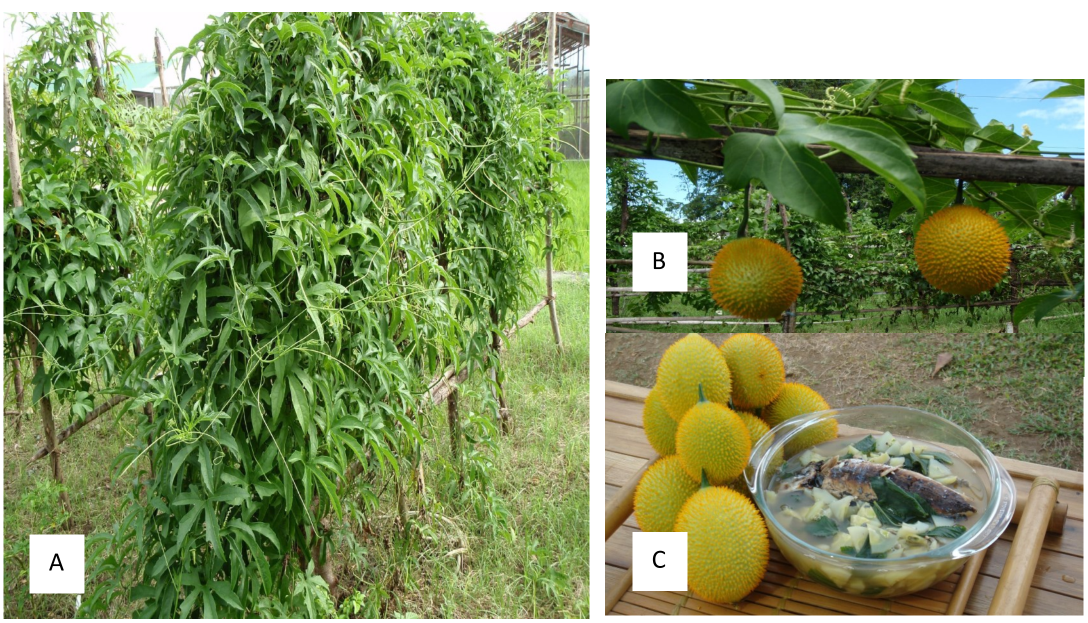

Plate 1. *M. cochinchinensis* in its viny habit (A), fruiting habit (B), and use as Iluko dish called "dinengdeng" (C).

to April and wet during the rest of the year (https://www.pagasa.dost.gov.ph).

Propagation techniques, which include vegetative propagation of vine cuttings and supplementation with rooting solutions, were evaluated. Meanwhile, cultural management techniques for crop production were likewise assessed, such as using seed- and cutting-derived planting materials, organic fertilizer (OF) application, and plant rejuvenation by pruning.

Development of Propagation Techniques

Seeds are an easy source of planting material for *M. cochinchinensis*. However, the plant is dioecious, and domestication trials done at the MMSU Botanical Garden proved the unpredictable occurrence of unproductive male individuals. Thus, vegetative propagation using vine cuttings of female parent plants is a potential alternative method to eliminate male plants.

Experimental Treatments and Design

Different lengths of vine cuttings and presoaking in various rooting solution types and concentrations were evaluated in succession.

Length of vine cuttings. Measured in terms of number of nodes, four vine lengths (one-, two-, three- and four-nodes) were cut (approximately 7 to 10mm in diameter) from healthy and mature female plants. MMSUGB Accn.60, an *M. cochinchinensis* accession collected from Cocson's farm in Paoay, Ilocos Norte, was used in the propagation trials.

Type of rooting solution*.* Presoaking the proximal end of the vine cuttings in a rooting solution was done to enhance the survival and growth of the propagules. One indigenous (honey) and two commercial liquid rooting hormones (CLRH), A and B, were evaluated. Manufacturers' recommendations on the dosage and soaking time in the CLRH were followed.

Honey has already been used as an alternative rooting stimulant in cuttings. It contains many kinds of sugars, amino acids, minerals, antioxidants, and gluconic acid, thus giving some benefits in plant propagation (Firth & Trask, 2017). Meanwhile, CLRH A and B contain synthetic auxin, a plant hormone that aids root formation and cutting quality (Tien et al., 2020). Specifically, CLRH A contains thiamine (Vitamin B1) (0.05%) and NAA (0.10%); almost all of them are inert materials (99.85%) and have no Indole butyric acid (IBA). Meanwhile, CLRH B is a vitamin hormone that prevents transplant shock and promotes root and plant growth. It contains 0.25% thiamine, 0.24% NAA, and 0.013% IBA. NAA and IBA are auxins commonly used in horticultural crops as rooting stimulants and are essential in plant propagation using cuttings (Tien et al., 2020).

Concentration of rooting solution. Vine cuttings were presoaked in different concentrations (0, 5, 10, and 15ml gal^{-1} water) of the best rooting solution identified above.

The above trials were laid out in a Completely Randomized Design (CRD) with three replications. Exactly 25 plants were used in each replication. Survival and growth data were scored at 60 days after planting (DAP) except for days to shoot formation, which was scored when the sprouts had attained about 1cm length.

Propagule Management

Cuttings were planted in polyethylene bags (PEB) (10cm x 15cm) filled with potting media composed of equal parts of ordinary garden soil, OF, and decomposed rice hull. Pots were kept in the shade and covered with transparent plastic for two weeks or until sprouts formed. Watering was done once a week or as needed.

Development of Cultural Techniques

For crop production, two sets of field evaluations were done: a comparison of two types of planting material applied with different levels of OF and pruning of old stands to varying heights from the soil line.

Experimental Treatments and Design

Type of planting material and level of organic fertilizer. The growth and yield performance of vine cutting- and seed-derived propagules applied with different levels of OF were evaluated in a field trial. The experiment was laid out in a 2x4 factorial in a Randomized Complete Block Design (RCBD) in three replicates. The experimental treatments were the following

Factor A (Type of planting material)

A1- two-node vine cutting
A2 - seedling

Factor B (Level of OF, kg plant^{-1})

B1- 0 (Control)
B2- 0.5
B3- 1.0
B4- 1.5

The experimental site has 2.16% organic matter (O.M.), 0.11% nitrogen (N), 0.02% (227.5 ppm) phosphorus (P), and 0.003% (28.61 ppm) potassium (K). The soil classification based on O.M. is moderate (Taye & Simane, 2007). So, to augment the low O.M. content of the experimental site, an OF supplement was applied. The OF contains 77% O.M., 1.47% N, 6.15% P, and 1.20% K.

Three OF levels were evaluated to determine the optimum OF level for gac production. The OF was given in split application: 50% at transplanting and the remaining 50% three months after transplanting (MAT).

Pruning of old stands at different heights. The plants senesce as they approach the dry season. Thus, the old stands were pruned in November to rejuvenate and increase productive branches for the next fruiting season and eradicate pests harboring in them.

Pruning of old stands was evaluated in both vine cutting- and seed-derived plants following three pruning heights (0.50m, 1.0m, 1.5m). The experiment was laid out in a 2x3 factorial in RCBD in three replicates with the following treatments:

Factor A (Type of planting material)

A1- Two-node cutting-derived
A2 – Seed-derived

Factor B (Pruning height, m from soil line)

B1 – 0.5
B2 – 1.0
B3 – 1.5

Field Management

Before crop establishment, the field was plowed and harrowed thoroughly. A planting distance of 1m between hills and 2m between rows was followed. Plants were transplanted in 30cm x 30cm holes in June (start of the rainy season).

Irrigation was done weekly on the first month of establishment. The plants were provided a trellis using bamboo poles lined with tie wire #16 as lateral support. Fruits were harvested at market maturity, about 55 days from anthesis (DFA).

After pruning, plants were cultivated at the stem base, applied with 1.5kg OF plant^{-1}, and irrigated. Plants were irrigated bi-weekly during the dry months (March to May) and weeded as needed.

Conceptual Framework

The availability of planting materials is primary for the domestication and cultivation of wild species such as *M. cochinchinensis.* Seeds of *M. cochinchinensis* could be grown, but the occurrence of male plants limits this. So, asexual propagation was explored using vine cuttings of female plants. Length of vine cuttings and type and concentration of rooting solution were evaluated in terms of propagule survival and root and shoot parameters. To enhance crop production, comparisons were made on seed- *vs.* cutting-derived planting materials, OF levels, and pruning heights in terms of the plant's growth, yield performance, and production economics. The developed component techniques constitute the POT for *M. cochinchinensis.* The POT aims to ensure sustainable supply and enhance crop commercialization (Fig 1).

Results and Discussion

Development of Propagation Techniques

M. cochinchinensis can be propagated by seed, vine, or root cutting. Mass propagation can be achieved using seeds, as each fruit contains as many as 36 seeds (Antonio et al., 2016). However, such propagation method allows the occurrence of unproductive male plants. Meanwhile, propagation of root cuttings is destructive to the source plant. Tissue culture and grafting *of M. cochinchinensis* were also reported (Debnath et al., 2013; Tran et al., 2020). Despite the rapid propagation benefits offered by the tissue culture technique, this is not highly adoptable by local farmers due to the intricacies of the aseptic *in vitro* growing protocol. On the other hand, grafting is a skill that a propagator needs to master. Propagation using vine cuttings is by far the easiest method to employ. Cuttings obtained from rejuvenation activities can be used for planting material.

Length of Vine Cuttings

Vine length significantly affected days to shoot formation ($p \leq 0.01$) and the number of roots formed ($p \leq 0.05$), as shown in Table 1. The two-node vine cuttings produced shoots earliest (10 days) and most roots (four

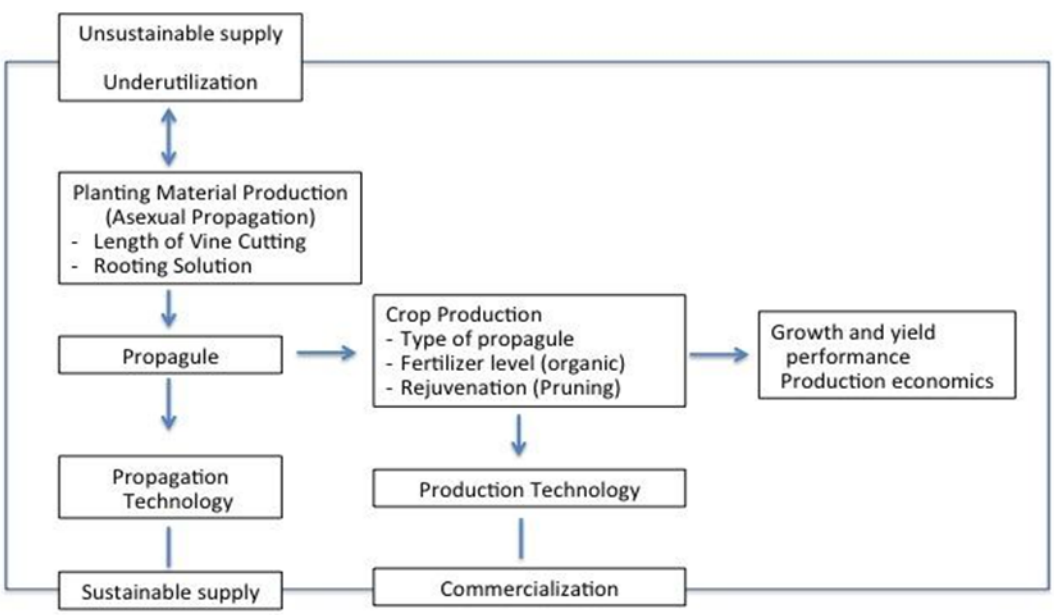

Fig 1. Different component techniques evaluated in the nursery and on-field constitute the POT for *M. cochinchinensis.*

Table 1. Survival and growth of *M. cochinchinensis* derived from different lengths of vine cuttings.

Vine length	Survival (%)	Shoot			Root	
		Formation (days)	Number	Length (cm)	Number	Length (cm)
	ns	**	ns	ns	*	ns
One-node	71	12b	2	15.16	3b	8.89
Two-node	63	10a	2	18.26	4a	10.00
Three-node	57	13c	2	17.65	3b	7.55
Four-node	64	16d	2	12.61	3b	6.67
CV (%)	36.7	5.7	29.2	17.9	7.4	16.1

Means in a column followed by a common letter are not significantly different at 5% level by DMRT.
**- significant 1% level *- significant at 5% level ns- not significant

roots/plant). The four-node cuttings produced shoots last (16 days). All the vine lengths except two-node had a comparable number of roots formed. Meanwhile, percent survival, shoot number and length, and root length were similar regardless of vine length at 60 DAP.

In the two-node cuttings, the proximal node, which is in contact with the soil, usually becomes the point of root origin and formation, while the distal node (aerial node) becomes the point of shoot origin and formation. The early appearance of shoots and many developed roots in the two-node cuttings could lead to progressive complementation for propagule recovery and subsequent plant development. With early shoot formation, leaves appear earlier for light interception; hence, photosynthetic activity is earlier. Meanwhile, the production of more roots could be associated with more effective water and nutrient uptake to support the growth of developing new shoots and leaves.

While there is no significant difference in percent survival of different lengths of *M. cochinchinensis* cuttings, the authors of the current study recommend the use of two-node cuttings because of the significant difference in days to shoot formation (10 days in two-nodes versus 12 days in one-node) and number of roots formed. The faster shoot and more robust root formation in the two-node cuttings would positively contribute to faster recovery and subsequent plant vegetative and reproductive development. Some propagators would probably support that percent survival is an important parameter in plant propagation and that one-node cuttings can be employed to maximize the number of propagules that can be produced. This is a valid point, and using one-node cuttings is most appropriate in cases of and for areas with limited vines for propagation.

Using two-node cuttings in other species corroborates the result observed on two-node cuttings of *M. cochinchinensis*. In a study done on *Camellia sinensis* (tea), two-node cuttings had superior performance over single-node cuttings in most parameters measured (Mwangi, 2014). The use of two-node cuttings also significantly increased the production of planting materials in the ornamental foliage plant *Aglaonema* (Siar et al., 2002). The two-node cutting technique was further enhanced by splitting the stem longitudinally, producing well-rooted normal plants later. Although the species compared are woody shrubs and herbs, respectively, the two-node cutting technique had similar good results in the above species.

Compared with longer cuttings, using two-node cuttings is more beneficial, such as that used in vine tea plants with three to four nodes per cutting (patent application CN 01131513). The former enhanced greater seedling vigor due to faster shoot emergence and more roots formed, corroborating the results obtained in *M. cochinchinensis*. Longer cuttings were supposed to provide more stored assimilates to supply and sustain the developing roots and shoots during establishment. However, slower shoot and root growth were observed in this study, possibly due to higher evapotranspiration in the longer cuttings.

Supplementation With Rooting Solution

The rooting solution used in the propagation affected all growth parameters except shoot length. Cuttings dipped separately in CLRH B, and honey performed best, resulting in 67% and 63% survival, producing two shoots per propagule in 11 and 12 days and roots measuring 11.1cm and 9.8cm, respectively (Table 2). Cuttings dipped in CLRH A performed similarly to those in the former treatments in terms of percent survival (63%) and root length (8.8 cm) only. CLRH A and honey dip had similar effects on shoot formation and the number of roots. Cuttings dipped in plain water had the poorest growth except in shoot length, like the treated and untreated cuttings.

The excellent performance of CRLH B as a rooting and growth hormone could be attributed to its thiamine hydrochloride (Vitamin B1) (0.25%), NAA (0.24%), and IBA (0.013%) contents. CRLH A also contains thiamine and NAA, but the levels are lower than in CLRH B, and it has no IBA. Hence, CLRH A proved less effective than CLRH B in stimulating rooting and growth. Although the concentration of CLRH used was 30 ml gal^{-1} water, this concentration is still insufficient to match the effect of CLRH B at 10 ml gal^{-1} water.

The honey dip had similar effects as the CLRH B dip in many parameters. Several gardening tips recommend using honey as a rooting solution for cuttings. It can be used as a dip or pre-soak, smear on shears or knife, or fertilizer mix. Honey provides a few benefits in propagation (Firth & Trask, 2017), *i.e.,* as an enzyme to stimulate new root growth, an antibacterial and antifungal agent to prevent rotting, a nutrient source through its natural sugar content, and has a hygroscopic nature which minimizes dehydration of the cut end.

Concentration of Rooting Solution

Different concentrations were tested to attain the best level for enhancing root and shoot formation in *M. cochinchinensis* cuttings. The CLRH B was used as a representative plant hormone because it performed well in the preceding propagation study. All parameters except the number of shoots were affected by the rooting concentrations used. Cuttings dipped in 10ml CLRH B gal^{-1} of water had the highest survival of 86.67% ($p \leq 0.01$). This was followed by cuttings dipped in 15ml CLRH gal^{-1} of water (73%), comparable to those dipped in 5ml CLRH gal^{-1} of water (68%). The lowest survival was attained in cuttings dipped in water (58%), comparable to those in 5ml CLRH B gal^{-1} of water.

Shoot formation was earliest (9 days) ($p \leq 0.01$), and shoots were longest (44 cm) ($p \leq 0.05$) in 10ml CLRH gal^{-1} of water. Four roots measuring 9.6 cm were formed from 10ml CLRH gal^{-1} of water. Root length, however, was similar to 5ml CLRH gal^{-1} water (8.8cm) and 15ml CLRH gal^{-1} water (7.3cm). Propagules dipped in water had the poorest shoot and root growth.

Table 2. Survival and growth of *M. cochinchinensis* vine cuttings pre-soaked in different rooting solutions.

Rooting solution (per gal water)	Survival (%)	Shoot			Root	
		Formation (days)	Number	Length (cm)	Number	Length (cm)
	*	**	*	ns	*	*
CLRH A (30ml)	63a	13.33b	1b	12.42	3b	8.78ab
CLRH B (10ml)	67a	10.66a	2a	15.40	4a	11.11a
Honey (30ml)	63a	12.33ab	2a	13.68	3b	9.77a
No R.S.	34b	16.66c	1b	11.94	2b	4.56b
CV (%)	18.1	7.0	17.9	19.4	12.1	25.7

CLRH – commercial liquid rooting hormone

Means in a column followed by a common letter are not significantly different at 5% level by DMRT.

**- significant 1% level *- significant at 5% level ns- not significant

Table 3. Survival and growth of *M. cochinchinensis* vine cuttings pre-soaked in different levels of CLRH B.

Concentration (ml gal^{-1} water)	Survival (%)	Shoot			Root	
		Formation (days)	Number	Length (cm)	Number	Length (cm)
	**	**	ns	*	*	*
5	68.33bc	12.33a	2.18	34.75b	2.45b	8.78a
10	86.67a	8.66c	2.63	44.05a	4.00a	9.55a
15	73.33b	10.66b	2.85	35.18b	2.55b	7.33a
Plain Water	58.33c	12.66a	1.70	25.00c	1.55c	4.45b
CV (%)	9.23	7.0	28.1	14.1	11.4	16.7

Means in a column followed by a common letter are not significantly different at 5% level by DMRT.

**- significant at 1% level *- significant at 5% level ns- not significant

Several studies reported the use of somewhat complex combinations for rooting. For the rooting of Cucurbits, soaking the proximal end of the cutting in chitosan solution or dust coating with chitosan-containing powder and treating with auxin improved the rooting rate, survival rate, and vegetative growth after implantation (patent application number J.P. 2003116338A) (https://patents.google.com/patent/ JP2003116338A/en). A *Momordica* species, *Momordica grosvenori,* is propagated by dipping the proximal end of the cutting in a root inducer and spraying with root growth-promoting nutrient agent while in the seedbed (patent application CN102668854A) (https://patents.google.com/patent/ CN102668854A/en). Brassinolide and heteroauxin were used as root inducers, while *Bacillus subtilis* fertilizer and nucleotide were used as root growth-promoting nutrient agents. Meanwhile, a patent-applied quick dipping-rooting agent for woody plants increases the rooting and survival rate of cuttings (patent application CN1802922A) (https://patents.google. com/patent/ CN1802922A/en). The agent is a hormone + nutrition complex formula mainly comprised of indoxylic butanoic acid, 1-NAA, 2,4-Dichlorophenoxyacetic acid, boracic acid, bee honey, and monobasic potassium phosphate. The rooting agent also included bee honey, but the specifics were not disclosed.

The above methods were shown to enhance rooting and vegetative growth. However, concerns have been raised about the chemicals and raw materials used. The chemicals are expensive, not readily nor locally available, and not popular among local growers, and there is a question on the stability of the formulations with respect to temperature effect and viability of the chemicals and formulation after a certain duration. Thus, using CLRH B or honey, as shown in this study, remains more practical and accessible.

The developed propagation techniques provide an easy method of producing female plants of *M. cochinchinensis.* It is easy to follow, inexpensive, and uses readily- and locally-available materials. The complete propagation protocol includes the following details: 1) use two-node vine cuttings (7-10 cm diam.) of female plants, 2) dip the proximal end of the cuttings in CLRH B (10ml gal^{-1} water) or honey solution (30ml gal^{-1} water) for 5 hours, 3) plant the cuttings in 10cm x 15cm polyethylene bags filled with soil media consisting of 1:1:1 ordinary garden soil-OF-decomposed rice hull, 4) keep the pots in shade and cover them with transparent plastic for two weeks to minimize evapotranspiration, and 5) water the pots weekly until the growing propagules reached desired height.

Recommending propagation of female plants of *M. cochinchinensis* using vine cuttings is supported by the report of Parks et al. (2013). The latter recommends a mass production protocol for *M. cochinchinensis* by first growing the plants from seed, then vegetatively increasing the number of productive female plants by cuttings. They, however, recommend dipping the cuttings in IBA rooting hormone powder or gel instead of the IBA+NAA+thiamin-containing hormone used in the present study. Vegetative propagation by cuttings offers several advantages: true-to-type plants are produced, plants are quick to produce flowers and fruits, the rate of propagation is high, and there is a short time to get the seedlings (Tien et al., 2020).

Tran et al. (2020) also reported grafting female scions onto seedling rootstock as a potential propagation method for the plant. But propagation by cuttings is an easier technique than grafting. Additionally, grafting gave only about 53% survival, which is lower than the 57% to 71% survival obtained in the propagation by cuttings in this study. Nonetheless, grafting efficiency can be increased to 85% using young rootstock (4 and 8 week-old) (Tran et al., 2020).

Development of Cultural Techniques

Types of Planting Material Applied with Different Levels of Organic Fertilizer

There was no interaction effect of the type of planting material and level of OF on the growth of the plants (Table 4). However, the two types of planting materials varied in the number of branches produced, days to flowering, and days to first harvest, but not on vine length at different observation periods. Plants derived from seeds produced more branches (seven/plant). However, plants derived from vine cuttings flowered and harvested at 186 days and 248 days, respectively, 26 days earlier than plants grown from seeds. The quicker flowering and fruiting observed in this study corroborates the report of Tien et al. (2020), who reported it as an advantage of vegetative propagation by cuttings. Such result is more advantageous to growers and farmers as it will give them an earlier income. The level of OF had varied effects on vine length at 45 DAT and 135 DAT but not at 90 DAT. Plants applied with 0.5kg OF plant^{-1} produced longer vines (1.11m) at 45 DAT but were surpassed by plants applied with 1.5kg OF plant^{-1} at 135 DAT. The first dose of fertilizer was applied before transplanting, and the remaining dose was applied at 90 DAT. It is hypothesized that at 90 DAT, the nutrient derived from the first dose might have been depleted, resulting in a similar effect of the varied OF levels.

Meanwhile, there was no effect of OF level on the number of branches and days of flowering. It took 196 to 219 DAT for the *M. cochinchinensis* plants to flower under the different OF levels (Table 4).

Days to first harvest varied with OF level ($p \geq 0.01$). Harvesting was earliest in applying 1.5kg OF plant^{-1} and 1.0kg OF plant^{-1} (242 and 247 DAT, respectively). Plants applied with 0.5kg OF plant$^{-1,}$ and the control plants took longer to harvest (273 and 281 DAT, respectively) (Table 4). The result implies that the initial application of higher doses of OF (1 to 1.5kg plant^{-1}) boosted the flowering and fruit development of *M. cochinchinensis*. It took 29 to 37 days longer for fruit development when a lower dose of OF is applied or not applied at all.

In terms of fruit characters and yield, there was no interaction effect between the type of planting material and the level of OF (Table 5). Similarly, the type of planting materials did not influence fruit characters and yield, which ranged from 677 to 721kg/1000 m^2 (1.35 to 1.44 kg plant^{-1}). However, the level of OF had marked effect on fruit size ($p \geq 0.05$) and yield per plant and per 1000m^2 ($p \geq 0.05$). Plants responded to OF applications such that they responded most to higher OF levels in terms of yield. Plants

Table 4. Agronomic performance of *M. cochinchinensis* vine cuttings and seedlings applied with organic fertilizer.

Factors	Vine length (m)			Vine number	50% flowering (day)	First harvest (day)
	45 DAT	90 DAT	135 DAT			
Type of planting material (A)	ns	ns	ns	*	**	**
Two-node vine cutting	0.85	2.01	2.89	6.00b	186a	248a
Seedling	0.96	2.02	2.96	7.43a	222b	274b
Level of OF (kg plant^{-1}) (B)	*	ns	**	ns	ns	**
0 (Control)	0.82b	1.973	2.40d	6	219	281b
0.5	1.11a	1.893	2.88c	7	199	273b
1.0	0.81b	2.102	3.09b	7	204	247a
1.5	0.87b	2.075	3.33a	7	196	242a
A X B	ns	ns	ns	ns	ns	ns
CV (%)	17.9	14.1	5.3	19.7	8.2	5.9

In a column, means followed by a common letter are not significantly different at 5% level by DMRT. Day was counted from transplanting.
*- significant at 5 % level **-significant at 1% level ns- not significant
OF- organic fertilizer

applied with 1.5kg OF plant^{-1} outyielded those applied with lower levels. The high yield (919kg/1000m^2), which was obtained from the 1.5kg OF plant^{-1} treatment, was contributed by bigger and heavier fruits (105.8g fruit^{-1} or 1.84kg plant^{-1}) and more fruits per plant (17 fruits). Yield and yield components were in descending order as the OF level decreased.

Male plants will likely arise in a plot planted to 'true' seedlings. However, the fruit yield per 1000m^2 in Tables 5 and 6 was the area's potential yield, which was computed assuming all the hills were productive female plants. It was computed using the formula yield per plant x 500 plants. The planting density in 1000m^2 was 500, at a planting distance of 1m between hills and 2m between rows.

Dioecious plants have pollination limitations because they are unable to self-pollinate, and thus become the main factor limiting fruit and seed set (Ohaya et al., 2017). The fruit set of flowers and seed production per fruit of dioecious trees were reduced when the density of reproductive males was low, while the fruit set increased in females when males occurred in nearby sites (Ohaya et al., 2017). The growth of at least one male plant growing in a plot of *M. cochinchinensis* is needed for the flowering female plants to be pollinated, thus improving fruit and seed set. *M. cochinchinensis* plants grown from seed give an unpredictable ratio of male to female plants (Parks et al., 2013).

Cost and return analysis indicated the highest net income of PhP 15,757.40/1000 m^2 from using two-node vine cuttings applied with 1.5kg OF plant^{-1} (Table 6). The highest production cost (PhP 13,742.50/1000 m^2), which was contributed by OF cost, was incurred in this treatment. However, the high yield (983.33kg/1000 m^2) compensated for the high production cost. Thus, only PhP13.97 was spent producing one kilogram of fruits (break-even price, BEP). BEP was lowest in plants propagated from two-node vine cuttings and supplied with 1.5kg OF plan^{-1}.

In all OF levels, net income was generally higher in plants grown from vine

Table 5. Fruit yield of *M. cochinchinensis* grown from vine cutting and seedling applied with MMSU organic fertilizer.

Factor	Size (g)	Diameter (cm)		Fruit/plant		Fruit/ 1,000m^2 (kg)
		Polar	Equatorial	Number	Weight (kg)	
Type of planting material (A)	ns	ns	ns	ns	ns	ns
Two-node vine cutting	99.01	6.98	5.83	14	1.44	720.83
Seedling	96.64	6.66	5.35	14	1.35	676.67
Level of OF (kg plant^{-1}) (B)	*	ns	ns	**	**	**
0 (Control)	92.40c	6.64	5.31	11d	1.00c	500.00d
0.5	89.73c	6.87	5.69	13c	1.17c	585.83c
1.0	103.44b	6.82	5.67	15b	1.58b	790.00b
1.5	105.76a	6.95	5.76	17a	1.84a	919.17a
A X B	ns	ns	ns	ns	ns	ns
CV (%)	7.02	7.87	5.43	5.66	9.31	9.25

**- significant at 1% level ns- not significant OF- organic fertilizer

In a column, means followed by a common letter are not significantly different at 5% level by DMRT.

cuttings than their counterpart plants grown from seedlings. This could be attributed to the higher yield obtained from the former, which could be due to the earlier flowering and fruiting of said plants.

M. cochinchinensis could be an alternative crop to grow. At a selling price of PhP30kg^{-1} of fruits, a net income of PhP5,000 to PhP16,000 could be earned per 1,000m^2 area. About PhP14 to PhP19 is incurred in producing a kilogram of fruits regardless of the type of planting material and OF level applied.

Rejuvenation of Old Stand

There was no significant interaction effect of the type of planting material and pruning height on the agronomic performance of rejuvenated *M. cochinchinensis.* There was also no significant effect of the type of planting material on all parameters except days to the first harvest (Table 7). Fruits were harvested earlier (178 days) in plants derived from vine cuttings than in plants derived from seedlings (181 days).

On the other hand, pruning height had a significant effect on all parameters except vine length at 3 MAP. Plants pruned at 0.5 to 1.0m from the soil line consistently gave longer vines at 6 MAP (7.5 to 7.7m), more branches (8.7 to 9.3/plant), and flowered (139 to 140 days) and harvested earlier (174 to 177 days). The result implies that rejuvenating *M. cochinchinensis* by pruning at 0.50m to 1.0m from the soil line enhanced vine growth and induced earlier flowering and fruiting.

In terms of yield (Table 8), pruned plants derived from cutting had more and bigger fruits per plant (16.94 and 53.16cm diameter) than those pruned plants grown from seed. Likewise, pruning at 0.5 to 1.0m from the soil line gave higher yields of 1.83 and 1.66kg plant^{-1} and 831 to 914kg per 1,000 m^2, respectively. The pruning height did not influence the other yield parameters. The higher yield obtained could be attributed to the longer and more vines where flowers and fruits developed, and most likely more priming owing to the earlier start of fruiting (Table 7).

Pruning of cutting-derived plants at 0.5 m height was most beneficial, giving the highest net income of PhP18,005.10/1000m^2

Table 6. Cost and return analysis for *M. cochinchinensis* grown from two-node vine cuttings and seedlings and applied with organic fertilizer. Computation was based on a 1,000m^2 area and PhP30 kg^{-1} fruit.

Factor	Yield (kg)	Production Cost	Income (PhP)		BEP (PhP/kg)
			Gross	Net	
Two-node vine cutting					
Without OF	521.67	9,200.00	15,650.10	6450.10	17.63
0.50kg OF/plant	580.00	10,637.50	17,400.00	6,762.50	18.34
1.0kg OF /plant	798.33	12,075.00	23,949.90	11,874.90	15.12
1.50kg OF /plant	983.33	13,742.50	29,499.90	15,757.40	13.97
Seedling					
Without OF	478.33	9,200.00	14,349.90	5,149.90	19.23
0.50kg OF /plant	591.67	10,637.50	17,750.10	7,112.60	17.98
1.0kg OF/plant	781.67	12,075.00	23,450.10	11,375.10	15.45
1.50kg OF/plant	855.00	13,742.50	25,650.00	11,907.50	16.07

OF- organic fertilizer BEP-break-even price and the lowest BEP (PhP11.18 kg^{-1} fruit) (Table 9). The high net income is attributed to the high fruit yield (956.67kg/ 1000 m^2).

The above-mentioned cultural techniques developed in the current research include: a) use of planting materials propagated from two-node vine cuttings, b) application of 1.5kg OF $plant^{-1}$, and c) annual pruning at 0.5m height from the soil line. The developed technology is intended for tropical regions and does not require much input, unlike the propagation and protected cultivation techniques developed for *M.*

Table 7. Agronomic performance of rejuvenated *M. cochinchinensis*.

Factor	Vine length (m)		Branches	50% Flowering (day)	First harvest (day)
	3 MAP	6 MAP			
Type of planting material	ns	ns	ns	ns	*
Two-node vine cutting	4.04	7.22	8.27	144.59	177.75a
Seedling	3.65	7.12	8.65	145.17	181.42b
Pruning height (m)	ns	*	*	**	**
0 (Control)	3.64	6.44c	7.54c	151.67b	184.00b
0.5	3.99	7.71a	8.71ab	138.83a	173.67a
1.0	4.16	7.52a	9.33a	140.33a	177.17a
1.5	3.59	7.01b	8.25bc	148.67b	183.50b
A X B	ns	ns	ns	ns	ns
CV (%)	13.53	4.18	7.35	2.4	1.98

* - significant at 5% level **- significant at 1% level ns- not significant

Table 8. Fruit yield of rejuvenated *M. cochinchinensis* grown from vine cuttings and seeds.

Factor	Size (g)	Diameter (cm)		Fruit/plant		Fruit/ 1000/m^2
		Polar	Equatorial	Number	Weight (kg)	
Type of planting material	ns	ns	*	*	ns	ns
Two-node vine cutting	95.76	62.80	53.16a	16.94a	1.61	805.83
Seedling	98.77	60.47	50.02b	14.56b	1.43	717.08
Pruning height (m)	ns	ns	ns	ns	**	**
0 (Control)	88.04	60.43	49.88	14.29	1.25c	623.33b
0.5	105.03	62.47	52.50	17.67	1.83a	914.17a
1.0	102.07	64.25	52.45	16.50	1.66ab	831.67a
1.5	99.92	59.38	51.53	14.54	1.35bc	676.67b
A X B	ns	ns	ns	ns	ns	ns
CV (%)	13.88	6.42	5.62	14.60	15.06	15.08

* - significant at 5% level **- significant at 1% level ns- not significant

cochinchinensis in temperate regions. The cultivation techniques in temperate regions include a climate-controlled greenhouse where the first crop is grown from seeds in warm and humid conditions, plants are grown hydroponically, and pistillate plants are mass-produced vegetatively by cuttings (Parks et al., 2013). The propagation of cuttings was also enhanced by dipping them in IBA rooting hormone powder or gel (Parks et al., 2013).

Conclusions and Recommendations

Propagation using two-node vine cuttings dipped in CLRH B at 10ml gal^{-1} water or honey solution at 30ml gal^{-1} water enhanced the survival and growth of M. *cochinchinensis* propagules. The propagation technology is described as follows: 1) use two -node vine cuttings (7-10cm diam.) of female plants, 2) dip the proximal end of the cuttings in CLRH B (10ml gal^{-1} water) or honey solution (30ml gal^{-1} water) for 5 hours, 3) plant the cuttings in 10cm x 15cm polyethylene bags filled with soil media consisting of 1:1:1 ordinary garden soil-OF-decomposed rice hull, 4) keep the pots in shade and cover them with transparent plastic for two weeks to minimize evapotranspiration, and 5) water the pots weekly until the growing propagules reached desired height.

When establishing in the field, grow plants derived from two-node cuttings and apply 1.5kg OF $plant^{-1}$. Plants grown from two-node vine cuttings flowered and bore fruits earlier than those grown from seeds. Cutting-derived plants applied with 1.5kg OF $plant^{-1}$ gave the highest yield (983kg/1,000 m^2) and net income (PhP15,757/1,000 m^2) and lowest BEP (PhP13.97). Rejuvenate old stands by pruning at 0.50m from the soil line. This enhanced the plants' horticultural traits and gave the highest yield, net income, and lowest BEP.

The above propagation and cultural techniques are recommended to constitute the POT for *M. cochinchinensis* domestication and cultivation. The POT will aid plans and targets of putting this species in the mainstream for commercial production to

Table 9. Comparative cost and return analysis per 1,000 m^2 area of *M. cochinchinensis* grown from vine cutting and seedling and pruned at different cutting heights.

Planting Material/ Pruning Height	Yield (kg/1000 m^2)	Gross Income (PhP)	Production Cost Per 1,000 m^2 (PhP)	Net Income (PhP)	BEP (PhP kg^{-1})
Two-node Vine Cutting					
0 (Control)	673.33	20,199.90	10,465.00	9,734.90	15.54
0.50 m	956.67	28,700.10	10,695.00	18,005.10	11.18
1.0 m	880.00	26,400.00	10,695.00	15,705.00	12.15
1.50 m	713.33	21,399.90	10,465.00	10,934.90	14.67
Seedling					
0 (Control)	573.33	17,199.90	10,465.00	6,734.90	18.25
0.50 m	871.67	26,150.10	10,695.00	15,455.10	12.27
1.0 m	783.33	23,499.90	10,695.00	12,804.90	13.65
1.50 m	640.00	19,200.00	10,465.00	8,735.00	16.35

PhP 30.00- price/kg of *M. cochinchinensis*

support its potential for food, nutrition, health, and as a commercial crop for additional income.

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