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Comparative Performance of Three Methods for Producing Suckers of Smooth Cayenne Pineapple (*Ananas comosus* L.) in the Municipality of Zè, Southern Benin

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Abstract

Fruit heterogeneity in pineapple production limits access to export markets for Beninese producers. This study compared three methods for producing Smooth Cayenne pineapple suckers: apical meristem destruction (gouging), castration following Flowering Induction Treatment (FIT), and macropropagation. A dispersed block design with six replications of 30 plants per method was implemented in the Municipality of Zè, Southern Benin. Data were analyzed using mixed-effects linear models and Poisson generalized linear models with R software version 4.3.0. Results demonstrated that castration achieved a 100% success rate, compared to 90% for gouging and 60% for macropropagation. Castration produced significantly more suckers per plant (3 ± 1) and yielded both observed sucker types (aerial slips and hapas). Suckers from castration and gouging exhibited superior morphological characteristics, with greater heights (aerial slips: 34.15 ± 2.2 cm and 35.3 ± 1.5 cm respectively; hapas: 24.5 ± 3.8 cm and 25.01 ± 2.1 cm) and larger basal circumferences (aerial slips: 12.54 ± 1.01 cm and 11.9 ± 1.5 cm; hapas: 9.1 ± 1.6 cm and 8.3 ± 1.4 cm) than those from macropropagation. Regarding weight, suckers from castration (449.01 ± 13.78 g) and gouging (450.14 ± 34.34 g) were comparable and heavier than those from macropropagation (434.47 ± 7.17 g). Castration following FIT therefore represents the optimal method for producing homogeneous, vigorous, and high-quality suckers that meet export market requirements.

Keywords

Ananas comosus, Vegetative Propagation, Castration, Gouging, Macropropagation, Fruit Uniformity

1. Introduction

Pineapple (*Ananas comosus* L.) is a perennial herbaceous plant belonging to the Bromeliaceae family, native to South America and extensively cultivated in tropical and subtropical regions worldwide [1]. In West Africa, pineapple represents a strategic crop for the economies of several countries. Benin ranks as the third-largest African producer after Côte d'Ivoire and Ghana, with national production estimated at 400,000 tons in 2019 [2]. According to the Agricultural Statistics Directorate (DSA) report, pineapple contributes approximately 1.2% to the national GDP and 4.3% to the agricultural Gross Domestic Product (GDP), ranking second behind cotton [3]. This sector therefore represents a significant lever for diversifying Benin's agricultural economy and reducing cotton dependency.

The edaphic and climatic conditions of Southern and Central Benin are particularly favorable for pineapple cultivation and confer recognized organoleptic qualities in national and international markets [4]. The main production zones are concentrated in five municipalities of the Atlantique Department: Abomey-Calavi, Allada, Toffo, Tori-Bossito, and Zè, which account for 97% of national production [3]. The Municipality of Zè, in particular, constitutes one of the most important pineapple production areas in Benin, with a cultivated area of 2,500 ha and annual production of 112,500 tons in 2019 [3]. Two varieties are primarily cultivated: Smooth Cayenne and Sugar Loaf. Average yields in the Atlantique department are 36.41 t/ha for Sugar Loaf variety and 45.59 t/ha for Smooth Cayenne variety [5]. Pineapple is valued for its fruit consumed fresh, processed into juice or canned, or used as an ingredient in various culinary preparations. It also presents significant nutritional and therapeutic benefits due to its richness in vitamins (vitamin C), minerals, and enzymes such as bromelain [6].

Despite this considerable potential, the pineapple sector in Benin faces several major constraints that limit its development and competitiveness in international markets [7]. These constraints include: 1) insufficient supply and procurement difficulties for quality suckers, and 2) fruit heterogeneity that compromises quality standards required by international markets. These problems significantly affect profitability, quality, and marketing of pineapple-based products. They drastically reduce export opportunities to the European Union, which represents only 2% of Beninese exports despite strong demand in this market [8].

Traditional pineapple propagation, although ancestral and widespread, presents several major disadvantages: process slowness (the number of suckers per plant being naturally limited to 3 - 5 suckers), heterogeneity of produced plant material, and high cost of sucker transportation, which are heavy and bulky [9]. Depending on the type of sucker used for planting, different results are obtained in terms of vegetative cycle duration, plant growth, and fruit quality, thus generating significant harvest heterogeneity [10]. For example, crowns require 18 to 24 months to produce fruit, while slips and hapas require only 12 to 16 months [11]. This cycle difference causes harvest desynchronization and caliber heterogeneity that severely penalize marketing.

To address these constraints, several alternative vegetative multiplication methods have been developed and tested in different geographical contexts. These methods include stem apical meristem destruction (gouging), which involves eliminating the terminal bud to stimulate development of latent axillary buds [12]; plant material fragmentation (macropropagation), which multiplies suckers from stem fragments [9] [13]; castration of flowering plants after flowering induction treatment, which redirects plant resources toward sucker production instead of fruiting [14] [15]; and *in vitro* multiplication through tissue culture, a more sophisticated technique enabling massive production of genetically homogeneous plants [16].

However, these methods yield variable results in terms of success rates, number of suckers produced, types of suckers obtained, and plant material quality, depending on pedoclimatic conditions, cultural practices, and varieties used [15]. *In vitro* multiplication, although highly effective, remains costly and poorly accessible to small producers in developing countries [16]. It therefore appears necessary to identify and validate the most efficient and accessible methods in the specific context of Benin, where producers' technical and financial resources are limited. This study primarily aims to evaluate the comparative performance of three specific vegetative multiplication methods for pineapple: plant apical meristem destruction (gouging), plant castration after Flowering Induction Treatment (FIT), and sucker macropropagation, under the pedoclimatic and agronomic conditions of the Municipality of Zè in Southern Benin. It will identify the optimal method for massively producing quality suckers and obtaining more homogeneous fruits, thereby contributing to improving the competitiveness of the Beninese pineapple sector in export markets.

2. Materials and Methods

2.1. Study Area

The study was conducted in the Municipality of Zè in the Atlantique Department of Southern Benin. It encompasses six districts: Zè Centre, Dodji-Bata, Adjan, Dawè, Hèkanmè, and Koundokpoé (**Figure 1**). The climate is subtropical with two rainy seasons and two dry seasons. Average annual temperature is 27˚C and average rainfall is 1200 mm [17]. Sandy-clay soils provide favorable conditions for pineapple cultivation.

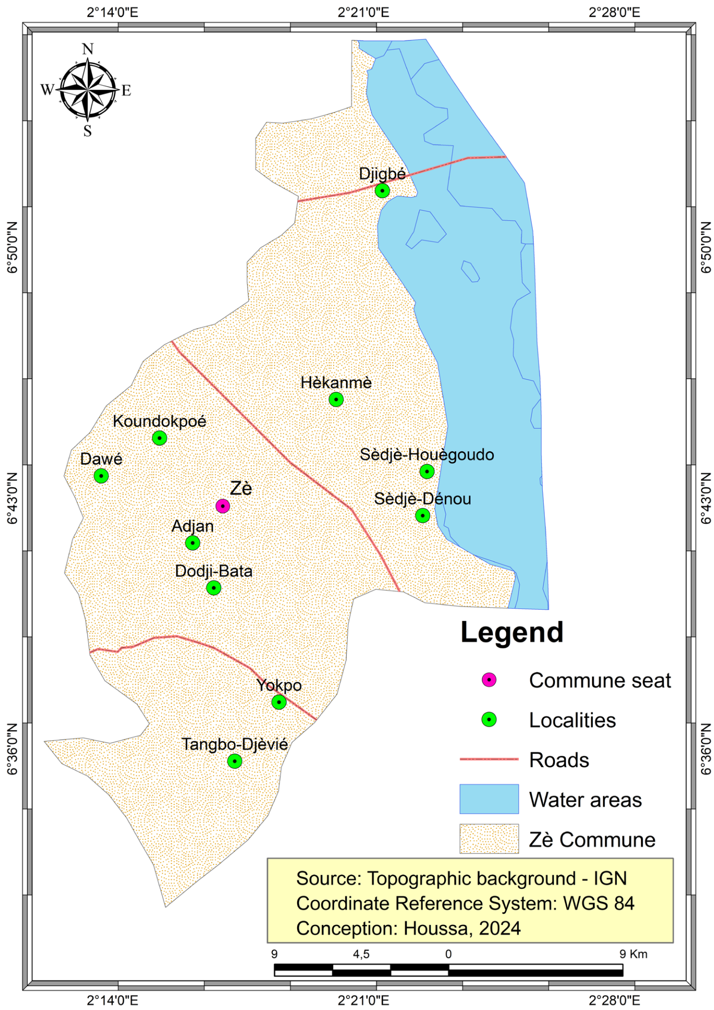

Figure 1. Map of experimental zones showing the six districts.

2.2. Plant Material

The plant material consisted of the Smooth Cayenne variety, the most cultivated in Benin. This variety was selected for its appealing organoleptic quality and very large fruit caliber (over 2 kg) according to farmers and traders. Slips calibrated at 300 - 350 g from producers in the Districts of Zè Centre, Dodji-Bata, Adjan, Dawè, Hèkanmè, and Koundokpoé were used.

2.3. Experimental Design

A dispersed complete randomized block design with 6 replications was established. Each replication was set up at a different producer's location, with the three methods tested simultaneously (Figure 2). For methods A (gouging) and B (castration), an area of 2.5 m^2 composed of three rows of 10 plants each was defined, with 30 cm spacing between plants. Method C (macropropagation) was implemented over 3 m^2.

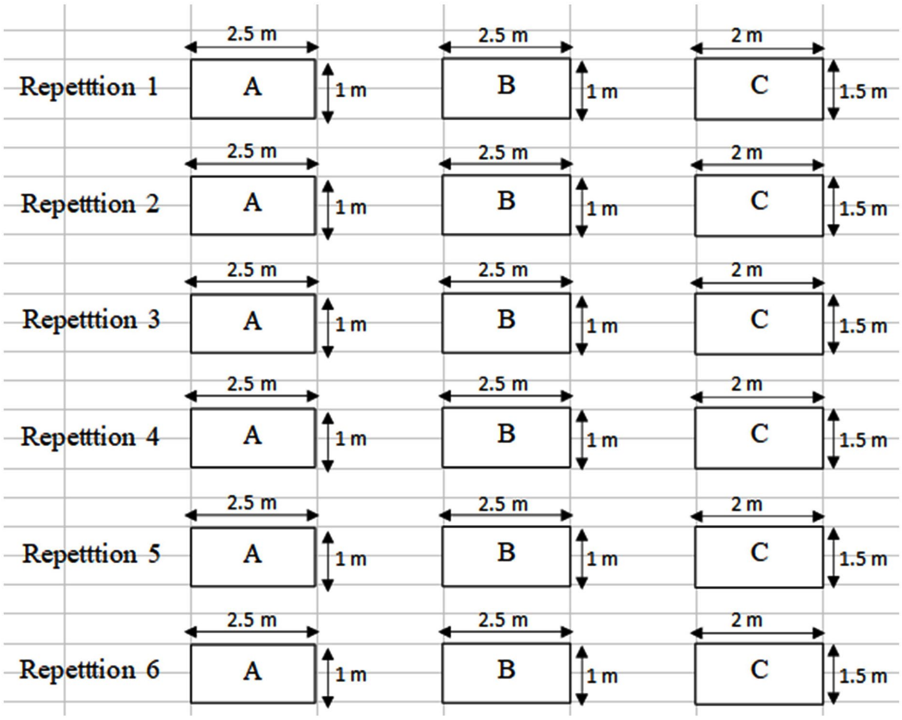

Figure 2. Diagram of experimental design installed at one producer's location.

2.4. Description of Multiplication Methods

2.4.1. Apical Meristem Destruction (Gouging)

The meristem destruction or gouging technique involves mechanically destroying the apical meristem of the pineapple plant to stimulate development of latent axillary buds. Complete destruction of all meristematic tissues at the stem apex is essential to prevent apex regrowth [11]. This technique requires expertise to avoid excessive plant damage and ensure successful sucker development.

Detailed procedure:

1) Plant selection: Fifteen healthy and vigorous pineapple plants were selected per replication. Plants had to be free from diseases, pests, and fungal infections. Data were collected on 10 plants that successfully underwent the operation.

2) Intervention period: The operation was performed 8 months after planting, when plants had reached sufficient vegetative maturity.

3) Tool preparation: A sharp knife was sterilized before each use to minimize infection risks.

4) Meristem destruction: Using the sterilized knife, the apical meristem tip (active growth zone located at the upper extremity of the main stem) was cut. The cut had to be deep enough to completely eliminate the meristem without excessively damaging the rest of the plant (**Figure 3**).

5) Post-operation maintenance: No special treatment was applied after gouging, except standard cultural care, including fertilizer application at a rate of 10 g NPK (15-15-15), 5 g urea, and 5 g KCl per plant, as well as regular manual weeding, in accordance with local good agricultural practices.

Figure 3. Meristem destruction technique. (a) Gouging; (b) Removed meristem; (c) Sucker emergence.

2.4.2. Castration following Flowering Induction Treatment (FIT)

The castration technique involves cutting flowers or floral buds that form on the plant after floral induction to redirect plant resources toward sucker production rather than fruiting.

Detailed procedure:

1) Flowering Induction Treatment (FIT): FIT was performed 12 months after planting, depending on plant vigor and growth conditions. This treatment consists of Ethrel application to induce flowering. To carry out the treatment, 1 kg of calcium carbide was dissolved in 200 L of fresh water and 50 ml of the resulting solution was poured into the center of the plant.

2) Castration timing selection: Castration was performed 60 days after FIT, corresponding to the beginning of flower or floral bud formation.

3) Tool preparation: A sharp garden knife was sterilized. Tools were cleaned and disinfected between each plant to minimize disease spread risk.

4) Flower cutting: Flowers were cut at the base, cleanly and close to the main stem of the pineapple plant, using the knife. Special care was taken not to damage the rest of the plant during the process (Figure 4).

5) Removal of cut flowers: After cutting, flowers were carefully removed and evacuated from the plot to prevent disease development.

6) Post-castration maintenance: After castration, standard cultural care was maintained, including fertilizer application at a rate of 10 g NPK (15-15-15), 5 g urea, and 5 g KCl per plant, as well as weed control, in accordance with local good agricultural practices.

Figure 4. Plant castration technique. (a) Bud castration; (b) Cut bud; (c) Castrated plants.

2.4.3. Sucker Macropropagation

Macropropagation enables rapid sucker multiplication through plant material fragmentation while entirely preserving the genetic characteristics of the mother plant. This technique uses stems that have already produced fruits.

Detailed procedure:

1) Mother plant identification: Pineapple fields bearing fruits at complete physiological maturity and not treated with ethylene for ripening were identified.

2) Mass selection: Five vigorous and healthy mother plants were selected per trial and marked for identification.

3) Plant extraction: Previously marked stumps were completely extracted using a hoe.

4) Stump preparation: All leaves and roots were removed to obtain clean stems called "carrots" ready to be cut.

5) Bed construction: Germination beds were prepared in a shaded and protected location.

6) Bed disinfection: Beds were disinfected with wood ash to limit fungal attacks.

7) Sowing line tracing: Regular lines were traced on beds to organize seeding.

8) Carrot cutting: Carrots were first cut into transverse slices approximately 2-3 cm thick.

9) Fragmentation into seedlings: Each slice was then cut into small fragments (seedlings) of homogeneous size.

10) Seedling disinfection: Fragments were soaked in a wood ash solution for 5 minutes to prevent infections.

11) Drying: Disinfected seedlings were dried in the shade on banana leaves for 15 minutes to allow cut surface healing.

12) Seeding: Shallow trenches were opened in prepared beds. Seedlings were deposited in these trenches, then lightly covered with potting soil.

13) Mulching: Seeded beds were covered with palm leaves to maintain moisture and protect seedlings from direct sunlight (Figure 5).

14) Watering: Beds were watered moderately in each morning and evening to maintain constant moisture without excess.

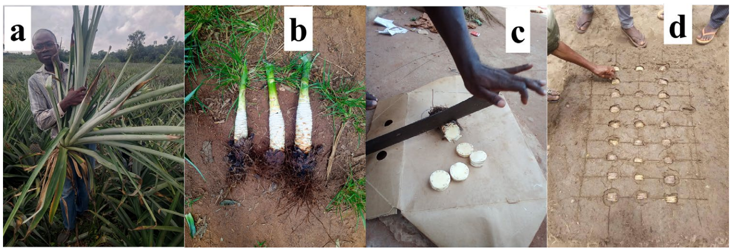

Figure 5. Macropropagation technique. (a) Plant extraction; (b) Stump preparation (carrots); (c) Carrot cutting; (d) Seedling planting.

2.5. Measured Parameters

Observations were conducted according to a specific schedule for each method, from March 2022 to November 2023.

2.5.1. Success Rate of Multiplication Methods

The success rate was calculated for each method as the ratio between the number of plants or seedlings that effectively produced suckers and the total number of plants or treated seedlings, multiplied by 100. For gouging and castration methods, data were collected on 10 plants that successfully underwent the operation per replication, enabling standardized comparison.

2.5.2. Number and Types of Suckers Produced per Plant

The total number of suckers per plant was determined by manual counting of all visible and sufficiently developed suckers (exceeding 5 cm height). Suckers were classified according to their emergence position: aerial slips (developed on the main stem, above ground level) and hapas (developed at the plant base, at or below ground level). This distinction is crucial due to their agronomic differences, particularly vegetative cycle duration and fruit quality.

2.5.3. Morphological Characteristics of Suckers

To evaluate sucker vigor and growth potential, the following parameters were measured:

- Number of leaves: Manually counted on each sucker.
- Leaf color: Visually noted as "dark green" or "light green", an indicator of physiological state and chlorophyll content.
- Sucker height (cm): Measured using a graduated ruler, from the base to the tip of the longest leaf.
- Basal circumference (cm): Measured using a measuring tape at plant collar level.

2.5.4. Fresh Weight of Suckers

Sucker weight was measured individually using a precision balance (±0.01 g) immediately after harvest. Before weighing, roots and dead or damaged leaves were removed to standardize measurements. This variable enabled evaluation of weight quality and reserves of produced plant material.

2.6. Statistical Analyses

Data were analyzed with R software version 4.3.0. Continuous quantitative data (height, basal circumference, and sucker weight) were subjected to a mixed-effects linear model, and count data to a mixed-effects Poisson generalized linear model. The multiplication method was considered as a fixed factor and replication as a random factor. Pairwise mean comparisons were performed using Tukey's test at the 5% threshold. Leaf color was subjected to a chi-square test.

3. Results

3.1. Effect of Multiplication Methods on Success Rate following Operations

Table 1 reveals that multiplication methods had a highly significant effect ($p = 7.881e^{-07}$) on success rate at the 5% threshold. Castration displayed the best performance with 100% success, followed by gouging (90%) and macropropagation (60%).

Table 1. Effect of multiplication methods on plant success rate following operations.

Multiplication methods	Number of successful plants
Castration	10 ± 0 a
Gouging	9 ± 1 b
Macropropagation	6 ± 2 c
Prob (>chi-sq)	**$7.881e^{-07}$**

abcValues bearing different letters in the same column are significant at the 5% threshold.

3.2. Effect of Multiplication Methods on Number of Suckers per Plant and Types of Suckers Produced

Table 2 shows that multiplication methods had a significant effect ($p = 0.04607$) on the number of suckers produced per plant at the 5% threshold. Castration produced significantly more suckers (3 ± 1 suckers) than gouging (2 ± 1 suckers) and macropropagation (2 ± 1 suckers). Multiplication methods significantly influenced ($p < 0.05$) the types of suckers produced. Two sucker types were recorded: aerial slips and hapas. Castration produced more aerial slips (2 ± 1) and hapas (1 ± 0) than gouging and macropropagation, which yielded respectively 1 ± 1 aerial slips and 1 ± 1 hapas.

Table 2. Effect of multiplication methods on number of suckers per plant and types of suckers produced.

Multiplication methods	Average number of suckers grown per plant	Average number of suckers by type	
		Aerial slips	Hapas
Castration	3 ± 1 a	2 ± 1 a	1 ± 0 a
Gouging	2 ± 1 b	1 ± 1 b	1 ± 0 a
Macropropagation	2 ± 2 b	1 ± 1 b	1 ± 1 a
Prob (>chi-sq)	**0.04607**	**0.0482**	**0.966**

abcValues bearing different letters in the same column are significant at the 5% threshold.

3.3. Effect of Multiplication Methods on Number and Color of Leaves by Sucker Type

Analysis of foliar parameters reveals a significant influence of multiplication methods on sucker morphology and physiology (Table 3). Regarding leaf number, a statistically significant difference was observed for both sucker types (Aerial slips: $p = 0.0386$; Hapas: $p = 0.0492$). Castration (14 ± 1 leaves) and gouging (13 ± 2 leaves) methods produced significantly leafier aerial slips than macropropagation (10 ± 2 leaves). A similar trend was recorded for hapa suckers, where castration and gouging induced a higher leaf number (11 ± 1 and 10 ± 1 respectively) compared to macropropagation (8 ± 2).

Leaf color, a key indicator of physiological state and chlorophyll content, was also significantly affected by cultural practices. For aerial slips, the proportion of suckers displaying dark green color, characteristic of high chlorophyll concentration and good nutritional status, was significantly higher (p = 0.0292) with castration (85.71%) and gouging (76.92%) than with macropropagation (70%). Conversely, for hapa suckers, macropropagation produced the highest proportion of light green suckers (50%, p = 0.0418), a shade often associated with more juvenile tissues or lower chlorophyll accumulation.

Table 3. Effect of multiplication methods on number and color of leaves by sucker type.

Multiplication methods	**Number of leaves by sucker type**		**Color of leaves by sucker type**			
			Aerial slips		**Hapas**	
	Aerial slips	**Hapas**	Dark green	Light green	Dark green	Light green
Castration	14 ± 1 a	11 ± 1 a	85.71% (12)	14.29% (2)	36.36% (4)	63.44% (7)
Gouging	13 ± 2 a	10 ± 1 a	76.92% (10)	23.08% (3)	40% (4)	60% (6)
Macropropagation	10 ± 2 b	8 ± 2 b	70% (7)	30% (3)	50% (4)	50% (4)
Prob (>chi-sq)	**0.0386**	**0.0492**	**0.0292**	**0.8371**	**0.793**	**0.0418**

[abc]Values bearing different letters in the same column are significant at the 5% threshold.

3.4. Effect of Multiplication Methods on Sucker Height and Basal Circumference

Multiplication methods exert a highly significant effect on dimensional parameters of suckers (Table 4). Height analysis shows that suckers from castration and gouging are significantly taller (Aerial slips: ~34 - 35 cm; Hapas: ~24 - 25 cm) than those produced by macropropagation (Aerial slips: 30.41 cm, p = 0.0261; Hapas: 18.9 cm, p = 0.00574). The same trend is observed for basal circumference, a crucial parameter linked to nutritional reserves and root development potential. Aerial slips from castration and gouging presented significantly greater circumference (~12 cm and ~11.9 cm) than those from macropropagation (8.81 cm, p = 0.0494). Similarly, hapas from traditional methods had superior circumference (~9.1 cm and 8.3 cm) to those from macropropagation (5.95 cm, p = 0.0366).

Table 4. Effect of multiplication methods on sucker height and basal circumference.

Multiplication method	**Sucker height (cm)**		**Basal circumference of suckers (cm)**	
	Aerial slips	**Hapas**	**Aerial slips**	**Hapas**
Castration	34.15 ± 2.2 a	24.5 ± 3.8 a	12.54 ± 1.01 a	9.1 ± 1.6 a
Gouging	35.3 ± 1.5 a	25.01 ± 2.1 a	11.9 ± 1.5 a	8.3 ± 1.4 a
Macropropagation	30.41 ± 2.70 b	18.9 ± 3.31 b	8.81 ± 2.05 b	5.95 ± 1.23 b
Prob (>F)	**0.0261**	**0.00574**	**0.0494**	**0.0366**

[abc]Values bearing different letters in the same column are significant at the 5% threshold.

3.5. Effect of Multiplication Methods on Sucker Weight

The effect of multiplication methods on fresh sucker weight proved highly significant ($p = 3.43e^{-08}$ for aerial slips; $p = 0.00281$ for hapas), confirming the major impact of the technique used on biomass accumulation (**Table 5**). Gouging (450.14 ± 34.34 g) and castration (449.01 ± 13.78 g) methods produced the heaviest aerial slip suckers, with no significant difference between them, but significantly heavier than those from macropropagation (434.47 ± 1.92 g). The same hierarchy was observed for hapa suckers, where gouging and castration again generated the heaviest suckers.

Table 5. Effect of multiplication methods on sucker weight.

Multiplication method	Sucker weight	
	Aerial slips	Hapas
Castration	449.01 ± 1.51 a	356.18 ± 2.73 a
Gouging	450.14 ± 1.2 a	357.05 ± 3.54 a
Macropropagation	434.47 ± 1.92 b	340.25 ± 3.44 b
Prob (>F)	**$3.43e^{-08}$**	**0.00281**

[abc]Values bearing different letters in the same column are significant at the 5% threshold.

4. Discussion

This study demonstrates that castration following FIT is the most effective method for producing Smooth Cayenne pineapple suckers, followed by gouging and macropropagation. The 100% success rate obtained with castration confirms its effectiveness in redirecting plant resources toward sucker production after inflorescence removal. This result is superior to that of gouging (90%) and markedly higher than that of macropropagation (60%). Floral bud removal strongly releases axillary bud inhibition, as also observed by Souleymane *et al.* [14] and Fassinou Hotegni *et al.* [15]. Gouging, although effective, involves mechanical injury that can increase failure risks, while macropropagation, through stem fragmentation, faces rooting challenges and pathogen sensitivity [9] [13]. The macropropagation success rate, observed at 60%, raises concerns about its reliability. Several causes could explain these results, including contamination by pathogens, inappropriate environmental conditions, or suboptimal cultivation practices. To improve this success rate, several technical approaches could be considered. Use of Fungicide Soaks: Applying fungicide treatments before planting can reduce the risk of contamination, thereby promoting better seedling adaptation. Control of Environmental Conditions: Optimizing parameters such as humidity, temperature, and lighting can promote more uniform growth and reduce plant stress. Selection of High-Quality Plant Material: Using strains and explants with better vigor can also improve propagation success.

Regarding the number of suckers per plant, castration generated an average of 3 suckers, significantly more than the two other methods (2 suckers). This performance is explained by complete release of apical dominance induced by inflorescence removal, favoring development of a greater number of lateral buds. Gouging, by destroying the apical meristem, also stimulates sucker growth, but less systematically. Macropropagation may be limited by competition between buds on the same stem fragment.

All three multiplication methods produced two types of suckers: aerial slips and hapas. This sucker diversity represents a major asset for plantation homogenization, as using specific sucker types enables better synchronization of cultural cycles and standardization of fruit caliber, an essential criterion for exportation [11].

Finally, the weight of suckers from castration and gouging was significantly higher than that of suckers from macropropagation. This indicates better biomass accumulation and reserves in suckers produced by the first two methods, which is favorable for good establishment and vigorous growth after planting. Castration and gouging appear to promote more efficient resource allocation toward developing suckers. Macropropagation, conversely, could limit this accumulation due to stress experienced by stem fragments and competition between buds.

The main advantages of this method of castration lie in the significant improvement in the quality, vigor, and uniformity of the suckers. These factors are fundamental to ensuring better plant survival and growth, thus offering long-term benefits for the crop.

The results of this study highlight the effectiveness of castration in producing more uniform suckers, an essential factor in the context of growing export market demands. Indeed, standardizing fruit size and synchronizing ripeness are crucial criteria for meeting the expectations of international consumers and distributors. The production of more uniform suckers, promoted by castration, ensures that fruits reach a similar size, which facilitates their packaging and presentation in the marketplace. Uniform fruit not only increases visual appeal for consumers, but also optimizes logistics costs and improves supply chain efficiency. In addition, the synchronization of fruit ripeness, achieved through greater uniformity of suckers, meets a key demand of export markets. Fruits that ripen simultaneously can be harvested and shipped within optimal time windows, reducing losses due to uneven ripening. This is particularly important for perishable products, where good timing can mean the difference between a quality product and an unsellable one.

In this study, it is essential to consider the economic trade-offs associated with each propagation method. Although castration shows promising results in terms of the quality and uniformity of suckers, an analysis of labor and material costs is necessary in order to make practical recommendations to producers. Regarding labor costs: The castration technique may require a higher initial investment in skilled labor to ensure accurate and efficient execution. On the other hand, traditional methods, while potentially less labor-intensive, may require additional interventions to manage suckering variability, which may lead to additional costs in the long term. For Material Costs: Castration may also involve higher material costs due to the use of specialized equipment and plant protection products. However, improving the quality and vigor of suckers can lead to higher yields and shorter maturation times, potentially offsetting these initial costs. On the other hand, traditional methods may seem less expensive at first glance, but they could result in greater losses due to less uniform growth and staggered harvesting. In short, while it is necessary to consider the direct costs.

It is important to note that this study was conducted in a single municipality. Therefore, although the results are promising, they may not be generalizable to other regions, where agroecological conditions can vary considerably. Factors such as climate, soil quality, and local agricultural practices could influence the effectiveness of castration and, consequently, impact the scope of these results.

5. Conclusions

This study aimed to identify the most effective multiplication method for producing homogeneous Smooth Cayenne pineapple suckers. Results clearly demonstrated the superiority of plant castration following flowering induction treatment. This method achieved a 100% success rate, produced significantly more suckers per plant (3 ± 1), and yielded two sucker types (aerial slips and hapas). Moreover, suckers produced by castration and gouging were heavier and morphologically more vigorous than those from macropropagation.

Castration following FIT therefore presents itself as the most promising solution to address insufficient quality suckers and reduce fruit heterogeneity that penalizes the Beninese pineapple sector. Its adoption by producers could significantly improve export competitiveness. Complementary studies evaluating the impact of these methods on final fruit quality (caliber, organoleptic quality) are recommended to confirm this technique's potential at large scale.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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