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Research Article

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Effect of Propagulr and Planting Pattern on Growth and Yield of Pineapple

Oloso KK*, Akanbi WB and Onarinde CR

Department of Crop Production and Soil Science Faculty of Agricultural science, Ladoke Akintola University of Technology, Nigeria

***Corresponding author**
Oloso KK, Department of Crop Production and Soil Science Faculty of Agricultural science, Ladoke Akintola University of Technology, Nigeria.

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ABSTRACT

Pineapple (Ananas comosus L.) is an economically important tropical fruit crop valued for its nutritional, medicinal, and industrial uses. It contributes significantly to income generation and food security in many tropical regions, including Nigeria. However, productivity is often constrained by inappropriate selection of planting propagules and planting pattern. This study determines the effects of propagule type and planting pattern on vegetative growth, reproductive performance, and fruit yield of pineapple under the agro-ecological conditions of Ogidi Village, Orire Local Government Area, Ogbomoso, Nigeria.

The experiment consisted of a factorial combination of three propagule types (suckers, slips, and crowns) and two planting patterns (single-row and double-row). Data were collected on plant height, D-leaf length, number of leaves, days to flowering, days to fruiting, fruit length, fruit diameter, mean fruit weight, crown weight, and fruit yield.

Propagule type significantly ($P \leq 0.05$) influenced all measured vegetative and reproductive parameters. Sucker-derived plants consistently exhibited superior vegetative growth, attaining the greatest plant height (118.83 cm), D-leaf length (41.57 cm), D-leaf width (10.90 cm), and leaf number (37.23 leaves) at 14 months after planting. Suckers also produced significantly higher fruit length (19.71 cm), fruit diameter (36.86 cm), mean fruit weight (1.779 kg), and crown weight (327.20 g) compared with slips and crowns. Planting pattern significantly affected most growth and yield traits, with single-row planting generally enhancing plant height and fruit weight, while double-row planting improved certain fruit dimensions. Significant interaction effects indicated that the influence of planting pattern on growth and yield was dependent on propagule type.

Fruit yield ranged from 22.36 to 84.71 t ha^{-1} and was highly significant ($P \leq 0.01$) among treatments. The highest yield was obtained from sucker-based treatments under favorable planting configuration. The findings demonstrate that the use of sucker propagules combined with single row planting optimizes vegetative development, fruit characteristics were recommended for improved pineapple production under the agro-ecological conditions of Ogbomoso, Nigeria.

Keywords: Pineapple, Ananas Comosus, Propagule Type, Planting Pattern, Fruit Yield, Ogbomoso

Introduction

Pineapple (Ananas comosus L. Merr.) is a major tropical fruit crop belonging to the family Bromeliaceae and is widely cultivated in humid and sub-humid regions of the world. Globally, pineapple ranks among the most important fruit crops in international trade, contributing substantially to the economies of tropical countries through fresh fruit export and processed products such as juice, canned slices, concentrates, and dried fruit. Leading producers include countries in Latin America, Southeast Asia, and Africa, with global production steadily increasing due to rising consumer demand and improvements in agronomic practices [1]. In addition to its economic value, pineapple is nutritionally important, being rich in vitamin C, dietary fibre, potassium, and bioactive compounds such as bromelain, which contribute to antioxidant and anti-inflammatory properties.

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Pineapple is propagated vegetatively because commercial cultivars produce few viable seeds and seed propagation leads to genetic variability. The principal planting materials are crowns, slips, and suckers, each differing in physiological age, size, dry matter content, and carbohydrate reserves. These differences significantly influence early establishment, vegetative vigor, and subsequent reproductive performance. Suckers, which arise from axillary buds near the base of the mother plant, are generally larger and more physiologically mature than slips and crowns, enabling them to establish faster, accumulate biomass more rapidly, and initiate flowering earlier. Slips, produced on the peduncle below the fruit, are intermediate in size and performance, whereas crowns are typically smaller and slower to establish due to lower initial reserves [2]. Studies have demonstrated that heavier or larger planting materials often result in improved vegetative growth, earlier floral induction, and higher fruit weight, emphasizing the importance of propagule quality in maximizing yield potential [3,4].

Planting pattern are also critical determinants of pineapple productivity. Spatial arrangement influences canopy structure, light interception, nutrient uptake efficiency, and microclimatic conditions within the crop stand. High-density planting systems, including double-row arrangements, are widely adopted in commercial production to maximize yield per unit area. Although increased plant density often enhances total fruit yield per hectare, excessive competition may reduce individual fruit size and quality due to limitations in assimilate availability [5]. Conversely, wider spacing may favor larger fruit development but reduce overall yield per hectare. Therefore, optimizing planting pattern involves balancing individual plant performance with total field productivity.

Recent research has highlighted the interactive influence of planting material characteristics and crop management practices on pineapple growth dynamics and yield formation. The response of pineapple to planting density may vary depending on propagule type, as differences in initial vigor and growth rate can alter competitive ability under crowded conditions. For instance, more vigorous propagules such as suckers may better tolerate higher plant densities compared with smaller crowns. However, comprehensive studies evaluating the combined effects of propagule type and planting arrangement remain limited, particularly under specific tropical agroecological conditions where soil fertility, rainfall distribution, and temperature regimes vary.

Given the increasing demand for improved pineapple productivity and resource-use efficiency, it is essential to generate location-specific recommendations that integrate propagation material selection with optimal spatial arrangement. Therefore, this study was designed to investigate the interactive effects of propagule type and planting pattern on vegetative growth, reproductive development, and fruit yield of pineapple under tropical production conditions.

Materials and Methods

Experimental Site

The experiment was conducted at Ogidi Village, Orire Local Government Area, Ogbomoso, and Oyo State, Nigeria. The study area lies within the derived savannah agro-ecological zone of southwestern Nigeria and is characterized by a tropical climate with distinct wet and dry seasons. The area experiences a mean annual rainfall of approximately 1100–1300 mm, with rainfall distribution occurring mainly between April and October. The average temperature ranges between 25 and 32°C, and relative humidity is generally high during the rainy season. The soil of the experimental site is predominantly sandy loam, typical of the derived savannah zone.

Experimental Design and Treatments

The experiment was laid out in a factorial arrangement consisting of:

Factor A: Propagules type
P1 ------- crown
P2--------Slip
P3------ Sucker
Factor B: Planting pattern
PP1---- single-row
PP2 ------- double-row

The treatments were arranged in a Randomized Complete Block Design (RCBD) with three replications. Each replicate contained all treatment combinations, giving a total of six treatment combinations per block replicated 4 times

Land Preparation and Planting

The experimental field was cleared, ploughed, and harrowed to obtain a fine tilth. Beds were prepared according to the specified planting patterns. Planting was carried out by inserting the propagules into the soil at an appropriate depth to ensure proper anchorage and root establishment.

Crop Management

Healthy and uniform planting materials were selected. Suckers, slips, and crowns were trimmed and air-dried prior to planting to reduce infection risk and ensure uniform establishment. Weed control was carried out manually as required. Fertilizer application and other management practices were implemented uniformly to avoid confounding treatment effects. Spraying of cypermethrine (40m/15L) was done as the need arises.

Data Collection

Growth Parameters: growth data were collected at 4, 6, 8, 10, 12, and 14 months after planting (MAP). The parameters measured included:

- Plant height (cm): measured from the base of the plant to the tip of the longest leaf.
- D-leaf length (cm): measured from the base to the tip of the longest leaf (D-leaf).
- D-leaf width (cm): measured at the widest portion of the D-leaf.
- Number of leaves: total fully expanded leaves per plant.

Reproductive Parameters

Reproductive data recorded included:

- Days to flowering
- Days to fruiting
- Fruit length (cm)
- Fruit diameter (cm)
- Mean fruit weight (kg)
- Crown weight (g) and
- Fruit yield (t ha)

Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA). Treatment means were separated using Duncan's Multiple Range Test (DMRT) at 5% probability level. Significance levels were determined at where applicable. Statistical analysis was performed using appropriate statistical software.

Result

Effects of Propagule Type and Planting Pattern on Plant Height

Plant height was significantly influenced by propagule type at all sampling periods (4–14 MAP). Suckers consistently produced the tallest plants throughout the growth period, recording significantly higher values than slips and crowns ($P < 0.05$). At 14 MAPS, plants established from suckers attained the greatest height (118.83 cm), followed by slips (85.40 cm) and crowns (82.80 cm). The superior performance of suckers may be attributed to their larger initial size and greater stored assimilates, which enhanced early vigor and sustained vegetative growth as shown in Table 1.

Table 1: Main effects of Propagules and planting Patterns and their interaction on the plant height of Pineapple leaves

Treatments	MONTH AFTER PLANTING					
	4	6	8	10	12	14
Propagation propagules (PP)						
Crown	24.87c	32.50c	41.9c	62.93c	75.17c	82.80c
Slip	26.13b	34,73b	44.53b	66.83b	78.03b	85.40b
Suckers	27.60a	37.60a	57.77a	77.00a	95.30a	118.83a
Prob. F (0.05)	**	**	*	**	**	**
Planting Pattern (PP)						
Single Row	27.53a	36.04a	48.24a	72.80a	84.40a	96.02a
Double Row	24.87b	33.84b	47.89a	65.04b	81.27b	95.33a
Prob. F (0.05)	**	**	Ns	**	**	Ns
Interactions						
PM x PP	**	**	*	**	**	**

Means for each factor with the same superscripts along the column are not significantly different at $P < 0.05$ using Duncan's Multiple Range Test (DMRT)

Planting pattern also significantly affected plant height at most growth stages. Single-row planting produced taller plants than double-row planting at 4, 6, 10, and 12 MAP ($P < 0.05$), although differences were not significant at 8 and 14 MAP as shown in table 1. The significant interaction between propagule type and planting pattern across most sampling periods indicates that the response of pineapple height to planting density depended on the propagule used as shown in Figure 1.

Effects of Propagule Type and Planting Pattern on D-leaf length

D-leaf length was significantly affected by propagule type from 6 to 14 MAP. Suckers consistently produced longer D-leaves compared with slips and crowns, particularly at later growth stages. At 14 MAPS, suckers recorded the highest D-leaf length (41.57 cm), indicating enhanced vegetative development and potential assimilatory capacity as shown in Table 2.

Planting pattern significantly influenced D-leaf length from 6 MAP onwards, with single-row planting generally producing longer leaves than double-row planting. The significant propagule and planting pattern interaction suggests that optimum leaf elongation depended on the combination of planting material and spatial arrangement as shown in Table 3.

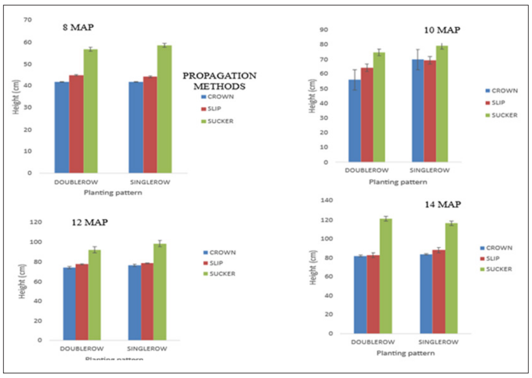

Figure 1: Interactive Effect of Planting Pattern and Propagation method on plant Height of pineapple

Table 2: Main effects of Propagules and planting Patterns and their interaction on the D length of Pineapple leaves

Months after Planting						
Treatment	4	6	8	10	12	14
Propagation propagules (PM)						
Crown	19.50a	20.67b	23.97c	28.70b	33.23b	36.40c
Slip	15.60a	20.03c	25.96b	29.10b	34.00b	37.70b
Suckers	20.33a	24.23a	29.97a	33.80a	37.83a	41.57a
Prob. F (0.05)	**ns**	**	**	**	**	**
Planting Pattern (PP)						
Single row	22.24a	22.73a	27.80a	31.27a	36.33a	39.73
Double row	14.71a	20.56b	25.47b	29.80b	33.71b	37.38
Prob. F (0.05)	**ns**	**	**	**	**	**
Interactions						
PM x PP	**ns**	**	**	**	**	**

Means for each factor with the same superscripts along the column are not significantly different at $P < 0.05$ using Duncan's Multiple Range Test (DMRT)

Table 3: Effects of Propagules and Planting Patterns and their interaction on the D -length leaves of Pineapple leaves

Months After Planting						
Treatment	4	6	8	10	12	14
Propagation propagules (PM)						
Crown	40.47a	2.50b	4.20a	5.87a	7.17b	8.10c
Slip	36.78b	2.60b	4.17a	5.77a	6.97b	9.13b
Suckers	36.57b	3.17a	4.27a	5.97a	8.10a	10.90a
Prob. F (0.05)	**	**	**ns**	**ns**	**Ns**	**

Planting Pattern (PP)						
Single row	39.53a	2.67b	4.44a	6.07a	7.56a	9.18b
Double row	36.33b	2.84a	3.98b	5.67b	7.27a	9.58a
Prob. F (0.05)	**	*	**	*	ns	**
Interactions						
PM x PP	**	*	ns	*	**	Ns

Means for each factor with the same superscripts along the column are not significantly different at P < 0.05 using Duncan's Multiple Range Test (DMRT)

Effects of Propagule Type and Planting Pattern on Number of Leaves

The number of leaves was significantly influenced by propagule type at all sampling periods (P < 0.01). Suckers consistently produced the highest leaf numbers throughout the experiment. At 14 MAPS, suckers recorded 37.23 leaves, significantly higher than slips (31.87 leaves) and crowns (31.67 leaves) as shown in Table 4.

Table 4: Interactive effects of propagules and Planting Patterns on the D-leaf length of Pineapple at 4 to 14 MAPS

Planting Pattern	Propagation propagules		
	Crown	Slip	Sucker
		4MAP	
Double row	3.633b	3.57b	3.69b
Single row	4. 46a	3.78b	3.62b
		6MAP	
Double row	2.33d	2.67c	2.67c
Single row	2.67c	2.53cd	2.53cd
		8MAP	
Double row	3.87b	3.87b	4.20ab
Single row	4.53a	4.47a	4.33a
		10MAP	
Double row	5.53c	5.87bc	5.60c
Single row	6.20ab	5.67c	6.33a
		12MAP	
Double row	6.73d	6.73d	8.33a
Single row	7.60bc	7.20cd	7.87ab
		14MAP	
Double row	8.20d	9.47b	11.07a
Single row	8.00d	8.80c	10.73a

Means with the same letters within the same month are not significantly different at P <0.05 using Duncan's Multiple Range Test (DMRT). MAP = Months after planting

Planting pattern effects were less consistent. Double-row planting produced significantly more leaves at 4, 10, and 14 MAP, whereas differences were not significant at 6, 8, and 12 MAP. This suggests that higher plant population density may stimulate leaf production at certain growth stages as shown in table 4. The interaction effect showed that sucker propagules under double-row planting produced the highest leaf number at 14 MAP (39.73 leaves), indicating that the combination of vigorous planting material and higher plant density enhanced canopy development as shown in Table 5.

Table 5: Effects of Propagules and Planting Patterns, and their interaction on the Number of leaves of Pineapple

Months After Planting						
Treatment	4	6	8	10	12	14
Propagation propagules (PM)						
Crown	7.67c	11.17c	13.13c	21.03c	29.33b	31.67b
Slip	8.70b	11.90b	19.17b	22.20b	29.60b	31.87b
Suckers	10.13a	13.90a	20.40a	25.53a	31.40a	37.23a
Prob. F (0.05)	**	**	**	**	**	**
Planting Pattern (PP)						
Single row	8.62a	12.36a	17.29a	21.93b	29.96a	32.47b
Double row	9.04b	12.29a	17.84a	23.91a	30.27a	34.711a
Prob. F (0.05)	*	ns	ns	**	Ns	**
Interactions:						
PM x PP	**	ns	ns	**	Ns	**

Means for each factor with the same superscripts along the column are not significantly different at P < 0.05 using Duncan's Multiple Range Test (DMRT)

Effect of Propagules and Planting Pattern and their Interactions on Reproductive Parameters of Pineapple

Propagation material significantly (P ≤ 0.05) influenced all measured reproductive and fruit parameters. Plants established from suckers produced superior fruit characteristics compared to slips and crowns. Suckers recorded the highest fruit length (19.71 cm), fruit diameter (36.86 cm), mean fruit weight (1.779 kg), and crown weight (327.20 g). Although suckers had slightly higher days to flowering (51.43 days), crowns flowered earliest (50.67 days) but produced significantly smaller fruits (10.57 cm length; 27.50 cm diameter) and the lowest fruit weight (0.631 kg). Similarly, crowns recorded the highest number of days to fruiting (82.48 days), indicating delayed fruit development compared to slips and suckers as shown in Table 6

Table 6: Interactive effects of propagules and Planting Patterns on Number of leaves of Pineapples at 4 to 14 Months after Planting (MAP)

Planting Pattern	Propagation propagules		
	Crown	Slip	Sucker
		4MAP	
Double row	7.53d	8.73c	10.87a
Single row	7.80d	8.67c	9.40b
		6MAP	
Double row	11.13d	11.87bc	13.87a
Single row	11.20cd	11.93b	13.93a
		8MAP	
Double row	13.53c	18.93b	21.07a
Single row	12.73c	19.40b	19.73ab

		10MAP	
Double row	21.87c	22.27c	27.60a
Single row	20.20d	22.13c	23.47b
		12MAP	
Double row	29.53bc	29.20c	32.07a
Single row	29.13c	30.00bc	30.73b
		14MAP	
Double row	32.07c	31.60c	39.73a
Single row	31.27c	32.13c	34.73b

Means with the same letters within the same month are not significantly different at P <0.05 using Duncan's Multiple Range Test (DMRT).
MAP = Months after planting

These results suggest that suckers, due to their physiological maturity and greater carbohydrate reserves, enhanced fruit development and yield performance relative to slips and crowns.

Planting pattern also significantly (P ≤ 0.05) affected all reproductive and fruit parameters. Single-row planting resulted in slightly higher days to flowering (51.34 days) and fruiting (81.81 days) compared to double-row planting. However, double-row planting produced significantly longer fruits (14.30 cm) and larger fruit diameter (33.47 cm) as shown in Table 7. Despite this, single-row planting recorded significantly higher mean fruit weight (1.211 kg) and crown weight (277.50 g) compared to double-row planting (1.147 kg and 261.80 g, respectively). This indicates that while double-row planting slightly improved certain fruit dimensions, single-row planting enhanced overall fruit mass and crown development as shown in table 6. The interaction between propagation material and planting pattern was significant (P ≤ 0.05) for all parameters measured. This indicates that the effect of planting pattern on reproductive and fruit characteristics depended on the type of propagules used. Suckers consistently produced superior fruit yield attributes, confirming their suitability for enhanced pineapple productivity as shown in Table 7

Fruit yield was significantly influenced by the treatment factor, as indicated by the highly significant effect (P ≤ 0.01). Mean fruit yield ranged from 22.36 to 84.71 t/ ha, demonstrating substantial variability among treatments. The highest fruit yield (84.71 t/ ha) was significantly superior to all other treatments, as evidenced by its distinct superscript letter. This was followed by 60.89 t/ ha and 35.63 t / ha which were also significantly different from one another. Moderate yield was recorded at 30.71 t/ ha while the lowest yield (22.36 t /ha) was significantly inferior to all other treatments. As shown in Table 7.

Table 7: Main effects of Propagules, Planting Patterns and their interaction on the Reproductive and fruit parameters of Pineapple

Treatment	No Days to Flowering	No Days to Fruiting	Fruit length (cm)	Fruit diameter (cm)	Mean Fruit weight (kg)	Crown weight (g)	Fruit yield (t/ha)
Propagation propagules (PM)							
Crown	50.67b	82.48a	10.57c	27.50c	0.631c	210.82c	30.71e
Slip	51.33a	80.86b	15.36b	35.14b	1.129b	270.93b	60.89c
Suckers	51.43a	81.10b	19.71a	36.86a	1.779a	327.20a	84.71a
Prob. F (0.05)	**	**	**	**	**	**	**
Planting Pattern (PP)							
Single row	51.34a	81.81a	14.13b	32.87b	1.211.a	277.50a	22.36f
Double row	50.94b	81.16b	14.30a	33.47a	1.147b	261.80b	35.63d
Prob. F (0.05)	**	**	*	**	**	**	**
Interactions							
PM x PP	**	**	**	*	**	**	**

Means for each factor with the same superscripts along the column are not significantly different at P < 0.05 using Duncan's Multiple Range Test (DMRT)

Table 8: Interactive Effects of propagules and Planting Patterns on the Reproductive of Pineapple

Propagation propagules	Planting patterns	No Days to Flowering	No Days to Fruiting	Fruit length (cm)	Total Fruit weight (kg)
Crown	Doublerow	50.30d	82.27ab	10.68e	633.2e
Slip	Doublerow	51.47ab	80.00d	15.93c	1255.5c
Sucker	Doublerow	51.07bc	81.20c	16.29b	1746.6b
Crown	Singlerow	51.03c	82.70a	10.45e	629.9f
Slip	Singlerow	51.20bc	81.73bc	14.80d	1003.6d
Sucker	Singlerow	51.80a	81.00c	17.13a	1812.5a

Means for each factor with the same superscripts along the column are not significantly different at P < 0.05 using Duncan's Multiple Range Test (DMRT

Discussion

The results of this study demonstrate that propagule type and planting pattern significantly influenced vegetative growth and reproductive of pineapple, with strong interaction effects across most parameters measured. Sucker-derived plants consistently exhibited superior vegetative performance, including greater plant height, D-leaf length and leaf number throughout the growth period (4–14 MAP). This enhanced growth can be attributed to the greater physiological maturity, larger biomass, and higher carbohydrate reserves of suckers at planting. Vigorous early establishment likely improved canopy expansion and photosynthetic capacity, which translated into sustained vegetative growth. Previous studies have similarly reported that sucker propagules promote stronger vegetative vigor and improved assimilate accumulation compared with slips and crowns [6,7]. Since D-leaf size is strongly associated with plant nutritional status and yield potential, the superior D-leaf traits observed in suckers indicate enhanced assimilatory capacity and future reproductive advantage.

Planting pattern significantly affected several vegetative traits. Single-row planting generally promoted taller plants and longer leaves, likely due to reduced intra-specific competition for light and nutrients. Conversely, double-row planting occasionally enhanced leaf number and leaf width, suggesting that moderate competition may stimulate canopy expansion in vigorous propagules. These findings align with reports that planting density modifies canopy architecture and light interception efficiency in pineapple production systems [8]. The significant interaction between propagule type and planting pattern indicates that vegetative response to spatial arrangement is propagule-dependent. Suckers demonstrated strong adaptability under both planting systems, maintaining superior growth performance even under relatively higher plant density. This plasticity suggests that sucker propagules are better suited for intensified production systems.

Propagation material significantly influenced reproductive and fruit characteristics. Suckers produced longer fruits, larger fruit diameters, higher fruit weight, and greater crown weight than slips and crowns. Although crowns flowered slightly earlier, they exhibited delayed fruiting and inferior fruit size, indicating weaker assimilate partitioning capacity. Early flowering in less vigorous propagules may reflect stress-induced reproductive transition rather than optimal physiological readiness, as previously observed in pineapple production studies [9].

Planting pattern also affected reproductive parameters. While double-row planting improved fruit length and diameter, single-row planting resulted in higher mean fruit weight and crown weight. This suggests that reduced competition under single-row spacing enhanced assimilate translocation to fruit biomass rather than dimensional elongation alone. The significant interaction further confirms that fruit development is determined by the combined effects of propagule vigor and spatial arrangement. Fruit yield showed highly significant variation ($P \leq 0.01$), ranging from 22.36 to 84.71 t ha^{-1}. The highest yield was associated with treatments combining vigorous propagules and favorable planting arrangement, demonstrating that yield formation in pineapple is closely linked to vegetative vigor, canopy development, and fruit mass accumulation. The complete separation of treatment means indicates distinct physiological responses to management practices. Similar yield responses to propagule vigor and planting density have been documented in recent pineapple production systems [6,7]. Overall, the findings emphasize that optimal pineapple productivity requires strategic selection of propagation material in combination with appropriate planting configuration [10-14]. Sucker propagules, due to their superior vegetative growth and assimilate partitioning efficiency, are recommended for enhanced yield performance under tropical production conditions [15-17].

Conclusion

This study clearly demonstrates that both propagules type and planting patterns significantly influence the vegetative growth, reproductive performance, and yield of pineapple. Strong interaction effects observed across most parameters confirm that pineapple growth and productivity are not determined by a single factor but by the combined influence of planting material and spatial arrangement.

Sucker plants consistently exhibited superior vegetative growth, including greater plant height, longer D-leaf length, and higher leaf number throughout the growth period (4–14 MAP). Their enhanced performance can be attributed to higher physiological maturity, larger initial biomass, and greater carbohydrate reserves at planting.

Planting pattern significantly modified growth and reproductive responses. Single-row planting generally favored plant height and mean fruit weight, likely due to reduced intra-specific competition for light and nutrients. In contrast, double-row planting improved certain dimensional fruit traits such as fruit length and diameter. However, the interaction analysis revealed that sucker propagules maintained strong adaptability under both planting systems, confirming their suitability for varying production intensities.

Reproductive and yield parameters were strongly influenced by propagule vigor. Suckers produced larger fruits, higher fruit and crown weights, and achieved superior overall yield performance. Although crowns flowered earlier, their delayed fruiting and reduced fruit size suggest weaker assimilate partitioning efficiency. The wide yield range observed (22.36–84.71 t ha^{-1}) highlights the substantial impact of management decisions on pineapple productivity. Treatments combining vigorous propagules with appropriate planting configuration achieved the highest yields, demonstrating that vegetative vigor and canopy development are fundamental determinants of fruit mass accumulation.

Recommendations

The establishment of pineapple using suckers in a double row planting system is recommended in the study area.

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