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Article

Development of Pineapple Cv. Turiaçu with Aerobic Biofertilizer Applications in Planting with and without Mulching

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RESUMO

A cultura do abacaxi (*Ananas comosus*) tem importância socioeconômica no Maranhão, destacando-se a cultivar regional 'Turiaçu' por suas qualidades sensoriais. Contudo, a produtividade local é inferior à média nacional e a falta de estudos sobre manejo sustentável limita seu potencial. Este trabalho teve como objetivo avaliar o desenvolvimento, a produtividade e a qualidade dos frutos do abacaxizeiro cv. 'Turiaçu' sob aplicação de biofertilizante aeróbico (BA), comparado à adubação mineral, e analisar o efeito de diferentes coberturas de solo (*mulching* plástico e serrapilheira). O experimento foi conduzido em delineamento de blocos casualizados, com oito tratamentos e quatro repetições, totalizando 576 plantas. Os tratamentos incluíram combinações de BA (aplicado a cada 14 dias), *mulching* plástico, serrapilheira, adubação sintética (controle) e testemunha sem tratamento. Avaliaram-se características vegetativas (massa fresca e seca, comprimento e largura da folha D), produtivas (massa e tamanho do fruto, diâmetro basal e apical, floração natural, tombamento) e de qualidade (sólidos solúveis, incidência de fusariose e classificação dos frutos). A serrapilheira como cobertura do solo promoveu maior crescimento da cultivar 'Turiaçu'. Em contraste, a adubação química mostrou-se ineficaz e o *mulching* plástico causou instabilidade das plantas. O uso de BA, embora não tenha superado a serrapilheira em produtividade, demonstrou potencial quando associado a práticas orgânicas. Conclui-se que a serrapilheira é alternativa promissora para o manejo do abacaxizeiro 'Turiaçu', favorecendo o desenvolvimento e a sustentabilidade da produção.
Palavras-chave: *Ananas comosus*; 'Turiaçu'; biofertilizante; *mulching*; serrapilheira; sustentabilidade.

ABSTRACT

The pineapple crop (*Ananas comosus*) is of socio-economic importance in Maranhão, with the regional cultivar 'Turiaçu' standing out for its sensory qualities. However, local productivity is lower than the national average and the lack of studies on sustainable management limits its potential. The aim of this study was to evaluate the development, productivity and fruit quality of the 'Turiaçu' pineapple under application of aerobic biofertilizer (AB), compared to mineral fertilizer, and to analyze the effect of different soil covers (plastic mulch and burlap). The experiment was conducted in a randomized block design, with eight treatments and four replications, totaling 576 plants. The treatments included combinations of AB (applied every 14 days), plastic mulch, leaf litter, synthetic fertilizer (control) and an untreated control. Vegetative (fresh and dry mass, length and width of leaf D), productive (fruit mass and size, basal and apical diameter, natural flowering, toppling) and quality (soluble solids, incidence of fusarium and fruit

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grading) characteristics were evaluated. Mulch as a soil cover promoted greater growth of the 'Turiaçu' cultivar. In contrast, chemical fertilization proved ineffective and plastic mulching caused plant instability. Although the use of AB did not outperform burlap in terms of productivity, it showed potential when associated with organic practices. It can be concluded that litter is a promising alternative for managing the 'Turiaçu' pineapple, favoring the development and sustainability of production.
Keywords: *Ananas comosus*; 'Turiaçu'; biofertilizer; mulching; litter; sustainability.

Introduction

Pineapple (*Ananas comosus*) stands out globally as one of the most economically, nutritionally and commercially important tropical fruits. In 2024, the volume of pineapple exports reached 3.6 million tons, representing a growth of 5.2% over the previous year, with Costa Rica and the Philippines leading the export market. The United States and the European Union are the main importers, accounting for 65% of world purchases, followed by China, which recorded a 7.2% increase in its imports (FAO 2025).

On the national scene, Brazil has established itself as the largest pineapple producer in South America, with the states of Paraíba, Pará and Minas Gerais standing out. National production generated a value of 4,380,071 thousand reais, with an average yield of 26,023 fruits per hectare (IBGE 2024). In addition to its economic value, pineapple is recognized for being rich in vitamins, minerals and bioactive compounds, offering various health benefits and boosting demand in domestic and foreign markets due to its culinary versatility (Mohd Ali et al. 2020). The pineapple production chain generates significant financial turnover and thousands of jobs, especially in tropical and subtropical regions.

Among the cultivars widely exploited in Brazil, 'Pérola', 'Smooth Cayenne' and 'BRS Imperial' stand out, known for their productivity, disease resistance and commercial acceptance.(Ferreira et al. 2016; Oliveira et al. 2024) However, the 'Turiaçu' cultivar, traditionally from Maranhão, has gained regional notoriety for the excellent sensory quality of its fruit, accentuated sweetness, striking aroma and high number of seedlings per plant, desirable characteristics for expanding cultivated areas (Ramos et al. 2020; Reis et al. 2024). Despite its potential, 'Turiaçu' faces significant limitations to its commercial expansion, mainly due to the scarcity of studies on adapted agronomic management, responses to different fertilization systems and soil conservation practices, which restricts its adoption on a large scale (Alves et al. 2024; Reis et al. 2019).

Currently, a large part of pineapple cultivation in Brazil is still based on the intensive use of synthetic mineral fertilizers and chemical pesticides. These practices have been associated with significant environmental impacts, such as nutrient leaching, soil and water contamination, and greenhouse gas emissions (Fu et al. 2025; Gunawardena e Lokupitiya 2024; Liang et al. 2022; Ramos et al. 2020; Reis et al. 2024). This scenario highlights the urgency of developing and implementing more sustainable management strategies, especially for regional cultivars that have great potential.

In this context, the use of biofertilizers and soil covering practices, such as mulching, are emerging as alternatives with less environmental impact. These techniques can reduce water evaporation, stabilize soil temperature, improve nutrient use efficiency and control spontaneous plants, contributing to productivity and fruit quality (Andrade et al. 2021; Lima et al. 2025a; Pacheco et al. 2021). Although positive results have already been reported for various pineapple cultivars, the literature still lacks studies evaluating the effects of these practices on the 'Turiaçu' cultivar, particularly in organic production systems.

In this context, the aim of this study was to evaluate the development, productivity and fruit quality of the 'Turiaçu' pineapple cv. under application of aerobic biofertilizer, compared to conventional mineral fertilization and the use of different soil covers (plastic mulch and burlap), considering that the combination of biofertilizer and organic mulch could provide equal or better performance than conventional management.

Material and Methods

The experiment was conducted between June 2019 and July 2020 at the Fruit Production Educational Unit of the Federal Institute of Education, Science and Technology of Maranhão, São Luís-Maracanã Campus (2°36'26.13"S, 44°16'26.44"O). The soil in the area is classified as Yellow Latosol with a sandy texture, an average annual rainfall of 1800 mm and an average temperature of 27 °C. The experimental area was approximately 200 m^2 in size and had been dormant for more than two years.

'Turiaçu' pineapple seedlings were collected in the municipality of Turiaçu-MA, selected with a minimum length of 40 cm and a mass of over 150 g, discarding those with rot, gum or wilting symptoms. The seedlings underwent a seven-day curing period to heal and reduce pests and diseases and, before planting, they were treated with Bordeaux solution (1% copper sulphate + 1% lime). The plants were planted in single rows with a spacing of 0.30 × 1.00 m, resulting in a density of 33,333 plants ha^{-1}. Each pit received 300 g of tanned bovine manure, corresponding to approximately 10 t ha^{-1}. The area was also limed based on the soil analysis, as recommended by *Comissão Estadual de Fertilidade do Solo* (1989), in order to meet the need for Ca and Mg, according to the results of the soil analysis, so the dose distributed in the area was 1.73 t/ha.

Table 1. Results of the soil analysis at the site where the 'Turiaçu' pineapple experiment was set up.

Depth (cm)	P	K	Na	Al	Ca	Ca+Mg	pH	H+Al	CEC		Saturation	
	-- mg/dm³ --			----- $cmol_c/dm^3$ -----			water	$cmol_c/dm^3$	Total	Effective	Base	Al
									--- $cmol_c/dm^3$ ---		V%	m%
0 - 20	4	17	8	0,78	0,16	0,34	4,78	3,56	3,98	1,20	10,45	65,22
20 - 40	6	14	7	0,81	0,20	0,35	4,70	3,41	3,83	1,22	10,84	66,14

P - phosphorus (mg/dm³); K - potassium (mg/dm³); Na - sodium (mg/dm³); Al - aluminum (cmolc/dm³); Ca - calcium (cmolc/dm³); Ca+Mg - sum of Ca and Mg (cmolc/dm³); pH - in water; H+Al - potential acidity (cmolc/dm³); Total CEC - total cation exchange capacity (cmolc/dm³); Effective CEC - available cation exchange capacity (cmolc/dm³); V% - base saturation; m% - aluminum saturation. Source: by the authors (2025).

The experimental design adopted was a randomized block design, with eight treatments and four replications, totaling 576 plants. Each plot contained 18 plants distributed in three rows, four of which were considered useful. The treatments consisted of: T1 - biofertilizer applied every 14 days associated with plastic mulching and burlap; T2 - biofertilizer + plastic mulching; T3 - biofertilizer + burlap; T4 - biofertilizer only; T5 - plastic mulching + burlap; T6 - burlap only; T7 - chemical control with synthetic fertilizers; and T8 - control without fertilization. The mulching consisted of a black and white double-sided tarpaulin (180 µm) installed at the time of planting, while the leaf litter was collected from an adjacent patch of native vegetation and applied in a volume of 270 L per plot. The aerobic biofertilizer was prepared with bovine manure, poultry manure, babassu mesocarp, ash, raw milk and brown sugar, in aerobic fermentation, according to the methodology adapted from Rivera (2014). Applications were made every two weeks, starting at 60 days after planting, with 100 mL per plant applied to the leaf axils, totaling 16 applications up to 270 days. In the chemical control treatment (T7), the doses of NPK were defined based on the soil analysis and applied according to the recommendations of Carvalho *et al.* (2006).

Table 2. Amount of NPK made available for the Control Treatment (T7) of 'Turiaçu' pineapple, according to plant age.

Nutrients	Top dressing after planting		
	1 to 2 months	5 to 6 months	8 to 9 months
N	2.4 g plant^{-1}	3.3 g plant^{-1}	3.9 g plant^{-1}
P_2O_5	2.4 g plant^{-1}	-	-
K_2O	3.6 g plant^{-1}	4.8 g plant^{-1}	6 g plant^{-1}

N - nitrogen; P_2O_5 - phosphorus; K_2O - potassium; values in g/plant applied as top dressing according to the age of the plants (months). Source: by the authors (2025).

Instrumental

Flower induction was carried out 13 months after planting, when the plants had reached the appropriate stage of development. A calcium carbide solution (6.7 g L^{-1}) was used, applied to the leaf rosette in a volume of 50 mL per plant in the afternoon, following the protocol described by Melo et al. (2013).

The variables evaluated included vegetative characteristics of the "D" leaf (fresh and dry mass, length, basal and central width), measured on four useful plants per plot; and productive and quality characteristics of the fruit, such as fresh mass with and without crown, length, basal and apical diameter, total soluble solids content (°Brix), percentage of natural flowering, fruit set, plant toppling and classification of the fruit according to (CEAGESP 2003b). Evaluations were carried out using a digital scale, tape measure, digital caliper and portable refractometer, according to methodologies already described by (Rodighero et al., 2013).

The data was submitted to analysis of variance, preceded by normality and homogeneity tests. When significance was found, the means were compared using the Tukey test at 5% probability. In cases of heterogeneity, the Factorial Weighted Least Squares method was applied (White 1980) and comparisons of means were made using the non-parametric (Games and Howell 1976). Statistical analyses were carried out using AgroEstat software (Maldonado Jr and Barbosa 2015).

Results And Discussion

The analysis of leaf 'D' of the *Turiaçu* pineapple evaluated fresh mass (FM), dry mass (DM), the FM/DM ratio, length (L), base width (BW), and the width of the central portion of the leaf (CPL). FM showed a significant effect at the 1% probability level for both treatments and blocks, while DM exhibited significant differences among treatments ($p < 0.01$) and blocks ($p < 0.05$). The highest FM values were observed in the treatments that combined biofertilizer every 14 days with mulching, whether plastic or burlap: T1 (biofertilizer + plastic mulch + burlap), T3 (biofertilizer + burlap mulch) and T6 (burlap mulch only), with no statistical differences between them. On the other hand, the lowest MF values were obtained in T4 (biofertilizer alone), in the control with synthetic fertilizer (T7) and in the control (T8), although these treatments did not differ significantly from T1, T2 (biofertilizer + plastic mulch, without leaf litter) and T5 (plastic mulch + leaf litter under plastic). The FM/DM ratio had no significant effect, indicating that the treatments mainly influenced the accumulation of dry matter.

The treatment with only mulch (T6) had the highest dry mass (DM = 5.3 g), followed by the treatment that combined mulch with biofertilizer (T3; DM = 5.2 g), both significantly higher than the control with synthetic fertilizers (T7; DM = 4.1 g). The other treatments showed no significant differences. The fresh mass/dry mass ratio (FM/DM) was not affected by the treatments (F test at 5%), indicating that the effects observed were mainly restricted to the accumulation of dry matter. Similar results were reported by *Sossa et* *al.*(2019) who showed that the use of pineapple waste as a soil cover, alone or in combination with N-K fertilization, promoted a significant increase in leaf biomass and productivity compared to the control without mulching. Although the biofertilizer applied alone did not significantly increase biomass in this study, recent studies have shown that biofertilizers based on phosphorus-solubilizing bacteria can increase the leaf and total biomass of pineapple, especially under stress conditions(Huu et al. 2022), highlighting the potential of these inputs to improve plant growth. These results indicate that the use of mulch, alone or in combination with biofertilizer, is an efficient strategy for increasing biomass production in pineapple trees.

Analysis of leaf length 'D' (LL) revealed significant differences between blocks ($p < 0.05$) and between treatments ($p < 0.01$). The highest FC values were observed in the treatments 'only mulching with burlap' (T6), 'biofertilizer applications every 14 days + mulching with burlap' (T3), 'biofertilizer every 14 days + plastic mulching + burlap under plastic mulching' (T1) and 'plastic mulching + burlap under plastic mulching' (T5), which did not differ statistically from each other. Treatment T6 showed significantly higher LL than the other treatments not mentioned, while treatment T3 was only superior to the control (T7) and control (T8) treatments.

Table 3. Comparison of means* for the Fresh Mass (FM), Dry Mass (DM) and FM/ DM ratio of the 'D' leaves of the Pineapple cv. Turiaçu. "Continued."

Treatments	FM (grams)	DM (grams)	FM/DM**
T1	34,47 a b c	4,85 a b	7,22
T2	30,57 b c	4,27 a b	7,37
T3	39,35 a b	5,22 a	7,57
T4	29,20 c	3,40 a b	7,52
T5	31,07 b c	4,47 a b	7,20
T6	40,57 a	5,27 a	7,75
T7	25,02 c	3,22 b	8,02
T8	26,47 c	3,47 a b	7,82
Average	32,09	4,31	7,56
SD	5,85	0,73	0,01
CV (%)	14,11	23,92	1,02

*Means followed by the same letter in the column do not differ according to the Tukey test at 5% probability; ** means did not differ according to the Tukey test at 5% probability; (T1) biofertilizer applications every 14 days + plastic mulch + burlap under the plastic mulch; (T2) biofertilizer applications every 14 days + plastic mulch, without burlap; (T3) biofertilizer applications every 14 days + burlap mulch; (T4) biofertilizer application every 14 days, without mulch; (T5) plastic mulch + burlap under the plastic mulch, without biofertilizer; (T6) burlap mulch only; (T7) Control: only use of synthetic fertilizers; and, (T8) Witness: no treatment or fertilization. SD: standard deviation. CV: coefficient of variation. Source: by the authors (2025).

The basal and central width of leaf D showed significant variation between treatments, with the treatment with only mulching of leaf litter (T6) and the treatment with biofertilizer every 14 days + mulching of leaf litter (T3) standing out, both with the highest averages in these measurements. These results are consistent with recent research showing that soil management practices and fertilization directly influence the leaf development of the pineapple (Gebisa 2021; 2021; Quoc Khuong et al. 2023).

As for leaf length D (LL), the values obtained in this experiment were lower than those reported by(Man et al. 2021) in commercial cultivars in Malaysia, with averages between 685.50 and 817.75 mm, although studies with mineral and organic fertilization also show that CL is strongly influenced by management and environmental conditions (Lima et al. 2025b; Quoc Khuong et al. 2023).

The central widths observed in T3 and T6, between 4.0 and 4.2 cm, are compatible with the results of experiments with different substrates and fertilizations, such as that of (Gebisa 2021), which recorded widths of up to 4.78 cm in seedlings grown with compost. In studies using mineral and organic fertilization, higher average widths of between 5.80 and 6.16 cm were observed, especially when nutrients were supplemented and irrigation was properly managed (Sk et al. 2020).

The analysis of variance for the weight of 'Turiaçu' pineapple fruit, with and without crown, showed significant differences between treatments ($p<0.01$) and between blocks ($p<0.05$). Comparisons of means showed that treatments 3 and 6 had the highest values, while treatments 4, 7 and 8 had the lowest, being statistically similar to each other for the weight of the fruit with the crown, but different from the other treatments .

Table 4. Comparison of the means* for Leaf Length (LL), Base Width (BW) and Center Width (CW) of 'D' leaves of 'Turiaçu' pineapple.

Treatments	LL (cm)		BW (cm)		CW (cm)	
T1	70,87	a b c	6,92	a b	3,70	b c
T2	66,21	b c	6,55	a b	3,40	c
T3	76,75	a b	7,15	a	4,15	a b
T4	66,37	b c	6,35	a b	3,54	c
T5	68,57	a b c	6,77	a b	3,70	b c
T6	78,92	a	7,12	a	4,20	a
T7	64,80	c	5,60	b	3,52	c
T8	64,90	c	6,12	a b	3,70	b c
Average	69,81		6,57		3,75	
SD	29743		33,12		3,02	
CV (%)	12,70		16,86		17,04	

*Means followed by the same letter in the column do not differ by the Tukey test at 5% probability; (T1) biofertilizer applications every 14 days + plastic mulch + burlap under the plastic mulch; (T2) biofertilizer applications every 14 days + plastic mulch, without burlap; (T3) biofertilizer applications every 14 days + burlap mulching; (T4) biofertilizer application every 14 days, without mulching; (T5) plastic mulching + burlap under the plastic mulching, without biofertilizer; (T6) burlap mulching only; (T7) Control: only use of synthetic fertilizers; and, (T8) Witness: no treatment or fertilization. SD: standard deviation. CV: coefficient of variation. Source: by the authors (2025).

In terms of fruit weight without crown (FWWOC), treatments T1, T2, T3, T5 and T6 did not differ statistically from each other. T2 performed similarly to the control with synthetic fertilizers (T7), which also did not differ from the treatments without soil cover (T4 and T8). It should be noted that T4, T7 and T8 did not receive mulching and, even with chemical fertilizer in T7, there was no increase in fruit weight. No treatment reached the average weight required for class 2; only T6 came close to this standard (1.137 kg), while T4, T7 and T8 had averages below 0.900 kg, i.e. below the minimum for class 1, as shown in Table 6. These results show that soil cover plays a decisive role in pineapple productivity, corroborating studies which show that the combination of biofertilizers and mulching favours fruit weight and quality, especially when associated with fertigation with plastic mulch (Patnaik et al. 2024).

Although Table 6 does not distinguish between varieties, considering the unavailability of a specific reference for the 'Turiaçu' pineapple, it was decided to use it as a basis for classification. The results of the experiment showed that the treatment with the highest average fruit weight (T6 - only mulching with burlap) reached 1,137 g, while the average fruit weight without crown was 1,060 g. Higher values were observed by (Mahmud et al. 2020), who reported 1,734 g for fruit with chemical fertilizer and 1,540 g for fruit with vermicompost, showing that the exclusive use of burlap (T6) provided a significant weight even without the application of chemical fertilizers.

The treatment with the smallest difference between FWWC and FWWOC was the one with biofertilizer applied every 14 days, without mulching, resulting in an average crown weight of 47.50 g. This reflects results similar to those reported in other crops, in which the use of biofertilizer alone has a limited effect on the development of vegetative structures (Syafiuddin et al. 2023). In contrast, the combination of biofertilizer every 14 days with plastic mulch, without burlap, provided the highest crown weight (182.12 g), significantly higher than the other treatments (50 to 78 g), showing the positive effect of mulching on biomass accumulation and productivity.

As for total soluble solids (TSS), the highest values were obtained in T4 (17.47 °Brix), T7 (17.34 °Brix) and T3 (17.09 °Brix), while the lowest occurred in T2 (14.66 °Brix) and T5 (14.23 °Brix). T4 stands out as the treatment with the highest accumulation of TSS and T5 as the lowest. Similar results were also seen in tomatoes and onions, where the use of biofertilizers significantly increased the °Brix of the fruit, showing the influence of management on the final quality of production (Barzee et al. 2019; Verma et al. 2023).

Table 7 shows the comparison of the averages for fruit size with crown (FSC), fruit size without crown (FSWC) and the FSC/FSWC ratio in the different treatments evaluated. It can be seen that the highest values for the FSC/FSWC ratio were recorded in treatments T4 (2.23), T7 (2.31) and T8 (2.10), indicating relatively longer crowns in relation to the total length of the fruit. On the other hand, treatments T2 (1.81) and T5 (1.71) had the lowest values for this ratio, showing fruit with proportionally smaller crowns.

The results highlight the influence of the different managements on crown and fruit development, with the treatment factor determining the variation in the FSC/FSWC ratio.

Table 5. Comparison of means for Fruit Weight With Crown (FWWC), Fruit Weight Without Crown (FWWOC), and Total Soluble Solids (TSS) of Turiaçu pineapple.*

Treatments	FWWC (grams)			FWWOC (grams)				TSS (°Brix)		
T1	957,88	a		895,25	a			15,72	a	b
T2	994,99	a		812,88	a	b		14,66		b
T3	1002,10	a		933,31	a			17,09	a	
T4	461,88		b	414,38			c	17,47	a	
T5	984,44	a		925,44	a			14,23		b
T6	1137,90	a		1060,9	a			15,85	a	b
T7	562,88		b	494,31		b	c	17,34	a	
T8	475,31		b	424,50			c	15,50	a	b
Average	816,67			745,12				15,96		
SD	3,73			7,60				0,15		
CV (%)	8,26			11,59				2,82		

*Means followed by the same letter in the column do not differ by the Tukey test at 5% probability; (T1) biofertilizer applications every 14 days + plastic mulch + burlap under the plastic mulch; (T2) biofertilizer applications every 14 days + plastic mulch, without burlap; (T3) biofertilizer applications every 14 days + burlap mulching; (T4) biofertilizer application every 14 days, without mulching; (T5) plastic mulching + burlap under the plastic mulching, without biofertilizer; (T6) burlap mulching only; (T7) Control: only use of synthetic fertilizers; and, (T8) Witness: no treatment or fertilization. SD: standard deviation. CV: coefficient of variation. Source: by the authors (2025).

Table 6. Pineapple fruit classification table, in terms of weight, for yellow-fleshed fruit, according to *Companhia de Entrepostos e Armazéns Gerais de São Paulo* -(CEAGESP 2003a)

Class	Infructescence weight (kg)
1	Greater than or equal to 0.900 to 1.200
2	Greater than 1,200 up to 1,500
3	Greater than 1,500 to 1,800
4	Greater than 1,800 to 2,100
5	Greater than 2,100 to 2,400
6	Greater than 2,400

*Means followed by the same letter in the column do not differ by the Tukey test at 5% probability; (T1) biofertilizer applications every 14 days + plastic mulch + burlap under the plastic mulch; (T2) biofertilizer applications every 14 days + plastic mulch, without burlap; (T3) biofertilizer applications every 14 days + burlap mulching; (T4) biofertilizer application every 14 days, without mulching; (T5) plastic mulching + burlap under the plastic mulching, without biofertilizer; (T6) burlap mulching only; (T7) Control: only use of synthetic fertilizers; and, (T8) Witness: no treatment or fertilization. SD: standard deviation. CV: coefficient of variation. Source: by the authors (2025).

Table 7. Comparison of means* for Fruit Size With Crown (FSC), Fruit Size Without Crown (FSWC) and FSC/FSWC ratio.

Treatments	FSC (cm)	FSWC (cm)	FSC/FSWC
T1	30,37 a b	16,06 a	1,87 b c
T2	29,31 a b	16,09 a	1,81 c
T3	30,56 a b	16,50 a	1,85 b c
T4	24,13 b	10,81 b	2,23 a
T5	28,28 a b	16,53 a	1,71 c
T6	32,47 a	16,84 a	1,93 b c
T7	27,19 a b	11,75 b	2,31 a
T8	23,87 b	11,34 b	2,10 a b
Average	28,27	14,49	1,98
SD	448,59	0,76	0,13
CV (%)	16,38	8,82	12,76

*Means followed by the same letter in the column do not differ by the Tukey test at 5% probability; (T1) biofertilizer applications every 14 days + plastic mulch + burlap under the plastic mulch; (T2) biofertilizer applications every 14 days + plastic mulch, without burlap; (T3) biofertilizer applications every 14 days + burlap mulching; (T4) biofertilizer application every 14 days, without mulching; (T5) plastic mulching + burlap under the plastic mulching, without biofertilizer; (T6) burlap mulching only; (T7) Control: only use of synthetic fertilizers; and, (T8) Witness: no treatment or fertilization. SD: standard deviation. CV: coefficient of variation. Source: by the authors (2025).

The size of the pineapple fruit varied considerably between the treatments, with a difference of up to 8.5 cm between the largest and smallest values, observed between the mulching of leaf litter and the control without fertilization or mulching. The use of mulching, especially plastic or organic, increased fruit length and weight by up to 42% and 54% respectively (Imo; Ijagem, 2020; Kelbore et al., 2024; Krishi Vigyan Kendra (AAU), Karbi Anglong, Assam; Kalita, 2022). Mulching with burlap showed an average fruit size with a crown that was statistically superior to biofertilizer without mulching and the control, while the other treatments did not differ from each other.

With regard to the TFCC/TFSC ratio, treatments T7 (control with synthetic fertilizers), T4 (biofertilizer every 14 days, without mulching) and T8 (control without treatment or fertilization) showed the highest values, with no statistical difference between them. In this relationship, the higher the value obtained, the larger the crown size. Consequently, treatments T4, T7 and T8 had longer crowns than the infructescences, possibly due to the lower development of the plants in these treatments at the time of flower induction.

The diameter of the 'Turiaçu' pineapple fruit showed significant variation at 1% probability both at the base (DB) and at the apex (DA). The highest DB values were recorded in T2 (10.20 cm) and T6 (10.12 cm), while T4 (8.04 cm), T7 (8.58 cm) and T8 (8.54 cm) had the lowest. As for DA, the highest values occurred in T6 (9.08 cm) and T3 (8.99 cm), and the lowest in T4 (7.67 cm). These results indicate that the management adopted directly influenced the size and shape of the fruit:

Table 8. Comparison of the means* of the Base Diameter (BD) and Apical Diameter (AD) of the 'Turiaçu' pineapple fruit.

Treatment	BD (cm)				AD (cm)			
T1	9,83	a			8,97	a		
T2	10,20	a			8,68	a	b	
T3	9,96	a			8,99	a		
T4	8,04			c	7,67			c
T5	9,80	a	b		8,81	a	b	
T6	10,12	a			9,08	a		
T7	8,58			c	8,41	a	b	c
T8	8,54		b	c	8,07		b	c
Average	9,35				8,58			
SD	43,55				25,35			
CV (%)	14,51				11,83			

*Means followed by the same letter in the column do not differ by the Tukey test at 5% probability; (T1) biofertilizer applications every 14 days + plastic mulch + burlap under the plastic mulch; (T2) biofertilizer applications every 14 days + plastic mulch, without burlap; (T3) biofertilizer applications every 14 days + burlap mulching; (T4) biofertilizer application every 14 days, without mulching; (T5) plastic mulching + burlap under the plastic mulching, without biofertilizer; (T6) burlap mulching only; (T7) Control: only use of synthetic fertilizers; and, (T8) Witness: no treatment or fertilization. SD: standard deviation. CV: coefficient of variation. Source: by the authors (2025).

The fruit diameter values, especially the basal diameter (DB), showed that the treatment with biofertilizer applications every 14 days associated with plastic mulch, without burlap (T2), had the highest averages, followed by the treatments with only burlap mulch (T6) and biofertilizer every 14 days combined with burlap mulch (T3). On the other hand, the treatment with biofertilizer every 14 days, without mulching (T4), had the lowest averages for both DB and apical diameter (AD). Statistical analysis showed significant differences at 1% probability for DB and AD between treatments, indicating that integrated management, especially the use of mulching and biofertilizer, positively influences the size and shape of fruits. These findings are corroborated by recent studies, which show that the combination of mulching, whether plastic or organic, with biofertilizers contributes to an increase in fruit diameter, weight and quality (Freire et al. 2014; Fikry et al. 2022; Gitea et al. 2024; Hussien e M. Radhi 2024; Kumar et al. 2024).

Natural flowering (NF), plant toppling (PT), the incidence of fusarium wilt, the occurrence of cracks and fasciation in the fruit, and the grading of the fruit by weight were evaluated. It was observed that natural flowering of the 'Turiaçu' pineapple can occur as early as 10 months after planting, depending on the size of the seedling and the development conditions. In the experiment, spontaneous flowering occurred at 11 months, a period when flower induction is normally carried out. Quantitatively, treatments T1, T2 and T5 had the highest proportion of spontaneously flowering plants, with the use of plastic mulch standing out as a common factor. Table 9 shows a comparison of the averages for NF, fruiting at 550 days after planting (Frut.) and plant toppling (PT) between the treatments.

Table 9. Comparison of the means* of the number of plants that showed Natural Flowering (NF), Fruiting (Frut.) at 550 Days After Planting (DAP) and Plant Toppling (PT) of 'Turiaçu' pineapple.

Treatment	NF (%)	Fruiting (%)			PT (%)		
T1	0,7144	0,7241	a		0,7217	a	
T2	0,7156	0,7187	a	b	0,7168	a	b
T3	0,7099	0,7205	a	b	0,7074		b
T4	0,7071	0,7175	a	b	0,7071		b
T5	0,7144	0,7193	a	b	0,7172	a	b
T6	0,7105	0,7217	a	b	0,7080		b
T7	0,7074	0,7135		b	0,7071		b
T8	0,7071	0,7190	a	b	0,7074		b
Average	0,7107	0,7193			0,7114		
SD	0,0120	0,0035			0,0088		
CV (%)	2,0621	14,319			1,5233		

*Means followed by the same letter in the column do not differ by the Tukey test at 5% probability; (T1) biofertilizer applications every 14 days + plastic mulch + burlap under the plastic mulch; (T2) biofertilizer applications every 14 days + plastic mulch, without burlap; (T3) biofertilizer applications every 14 days + burlap mulching; (T4) biofertilizer application every 14 days, without mulching; (T5) plastic mulching + burlap under the plastic mulching, without biofertilizer; (T6) burlap mulching only; (T7) Control: only use of synthetic fertilizers; and, (T8) Witness: no treatment or fertilization. SD: standard deviation. CV: coefficient of variation. Source: by the authors (2025).

Treatments T4 and T8 showed no natural flowering, while control T7 recorded a low proportion of flowering plants, highlighting the importance of ground cover. Treatment T1 (biofertilizer every 14 days + plastic mulch + burlap) had the highest number of fruits, differing only from the control, and the other treatments did not differ statistically. As for toppling, T1, T2 and T5 recorded the highest averages, affecting the entire plant and indicating a limitation of the root system, especially in treatments with plastic mulch. No cases of fusariosis, cracking or fasciation were observed on the fruit, and despite the lack of protection against sunburn, there was no visible damage. These results highlight that integrated management with mulching and biofertilizer positively influences flowering, fruiting and plant stability, increasing productivity and improving fruit quality (Altobaishi et al. 2023; Kaimuddin et al. 2020; Lasmini et al. 2023; Negi et al. 2021).

Conclusions

The agro-ecological cultivation of the 'Turiaçu' pineapple proved to be viable, with emphasis on the use of burlap as a soil cover, which favored the vegetative development and productivity of the crop. Management with chemical fertilizer was inferior, while biofertilizer, in the formulation and application evaluated, did not result in significant increases. The use of leaf litter is therefore a promising alternative for sustainable production systems.

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