Volume 24 No. 12
December 2024
SCHOLARLY, PEER REVIEWED
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2024; 24(12): 25329-25354 https://doi.org/10.18697/ajfand.137.24905

Date	Submitted	Accepted	Published
	20th May 2024	15th November 2024	16th December 2024

EFFECTS OF COMPOSTS PRODUCED FROM PINEAPPLE HARVEST AND PROCESSING RESIDUES ON TOMATO (*LYCOPERSICON ESCULENTUM* Mill.) PRODUCTION AND FRUIT QUALITY IN SOUTHERN BENIN

Sossa EL[1], Bouko BDN[1], Agbangba CE[2,3]*, Ayifimi JO[1], Gnonsey GI[1] and GL Amadji[1]

Elvire Line Sossa

*Corresponding author email: elvas2@yahoo.fr

[1]Research Unit in Sustainable Management of Soil Fertility, Laboratory of Soil Sciences, Faculty of Agronomic Sciences, University of Abomey-Calavi, Abomey-Calavi, Benin

[2]Laboratory of Research in Applied Biology, Department of Environmental Engineering, Polytechnic School of Abomey-Calavi, Abomey-Calavi, Benin

[3]Laboratory of Biomathematics and Forest Estimations, Faculty of Agronomic Sciences, University of Abomey-Calavi, Abomey-Calavi, Benin

ABSTRACT

Tomatoes are a vital crop in the market gardening industry, with substantial economic value worldwide. However, the continuous use of chemical fertilizers has degraded soil fertility, limiting the yield, and quality of tomato fruits. To address this issue, a study was conducted to enhance tomato production and quality using composts derived from pineapple harvest and processing residues. The experiment followed a randomized complete block design with four replications. The primary variable was the combination of compost type (C1 = 37.5% Pineapple Crown + 18.75% Pineapple Processing Residues + 18.75% Pineapple Harvest Residues + 25% Poultry Litter; C2 = 75% Pineapple Crown + 25% Poultry Litter; C3 = 75% Pineapple Harvest Residues + 25% Poultry Litter) and application rate (R1 = 10 t/ha; R2 = 20 t/ha; and R3 = 30 t/ha). Additionally, the experiment included a producer's practice (10 t/ha of poultry litter) and a control treatment (C0). Thus, the total treatments tested were C1R1, C1R2, C1R3, C2R1, C2R2, C2R3, C3R1, C3R2, C3R3, PP, and C0. Growth, yield, and quality data were collected from tomato plants and fruits and analyzed using R software. The results showed that composts based on pineapple harvest and processing residues significantly improved tomato production and quality. The application of these composts led to increased plant height, collar diameter, fruit weight, fruit diameter, total sugar content, and shelf-life, with the highest yields recorded under treatments C2R2, C3R3, and C1R2 (38.25, 30.89, and 29 t/ha, respectively). Treatment C3R2 also produced the highest percentage of preserved fruits (31.25%). Based on the findings, it is recommended to apply 20 t/ha of compost made from 75% Pineapple Crown + 25% Poultry Litter or 30 t/ha of compost made from 75% Pineapple Harvest Residues + 25% Poultry Litter for tomato production intended for processing. For tomatoes intended for preservation, 20 t/ha of compost made from 37.5% Pineapple Crown + 18.75% Pineapple Processing Residues + 18.75% Pineapple Harvest Residues + 25% Poultry Litter is ideal. These results have significant implications for sustainable tomato production, enhancing yield, quality, and soil management. Further studies are suggested to evaluate the effects of these composts on other vegetable crops and on the efficiency of nutrient use, particularly nitrogen, phosphorus, and potassium.

Key words: Fertilization, valorization, organic fertilizer, vegetable crops, soil fertility, shelf life, waste, nutrients

INTRODUCTION

In sub-Saharan Africa, fruits and vegetables hold great importance due to their nutritional value and the substantial economic income their production generates [1, 2, 3, 4]. They act as a driving force for agricultural and economic diversification, especially for small farmers who can direct their production towards local, regional, or export markets [3, 5, 6]. In Benin, tomato (*Lycopersicon esculentum* Mill.) is among the most important and widely cultivated fruit vegetables in terms of surface area and production [7, 8, 9]. Its cultivation constitutes a lucrative activity for many producers in rural, urban, and peri-urban areas, and it is used in most dishes consumed by the population [10]. However, tomato production remains well below its potential yield (averaging 7.29 t ha^{-1} in 2019), and does not consistently meet health and environmental quality standards [11, 12]. This low yield is largely due to poor soil fertility [13], stemming from inadequate cultivation practices that deplete soil nutrients and, consequently, affect fruit quality [14, 15]. Low soil fertility can reduce tomato yield by up to 40%, significantly impacting overall productivity [16].

Producers often apply highly variable fertilizer doses, with minimal organic matter additions [11]. In some cases, they use mineral fertilizers at doses exceeding recommended levels [17], leading to soil degradation and pollution. This degradation diminishes the soil's capacity to support healthy plant development and maintain high yields [18, 19, 20]. Additionally, producers face limited access to organic fertilizers necessary for large-scale production [21, 22]. However, in southern Benin, alongside tomato cultivation, there is extensive pineapple production (accounting for around 95% of total production) [23], which generates substantial quantities of harvest residues estimated at 90 to 150 t ha^{-1} [24] and around 5 t of processing waste per day from factories [25]. These residues are challenging to manage, with producers often burning them or discarding them along field edges and factories disposing of them by roadsides, thus causing environmental pollution [26, 27]. Pineapple residues, rich in nutrients, could improve crop yields and soil fertility if returned to the soil [28, 29]. Liu *et al.* [24] reported that fresh pineapple residues contain, on average, 678.6 g kg^{-1} of organic matter, 10.75 g kg^{-1} of total N, 0.83 g kg^{-1} of P_2O_5, and 11.4 g kg^{-1} of K_2O. Studies by Sossa *et al.* [30] demonstrated that burying or mulching pineapple residues in soil, combined with mineral fertilization in pineapple production, increases fruit yield and quality, and enhances the proportion of fruits meeting export standards for the European market or local consumption standards.

Furthermore, farming has considerably expanded in most of the country, which has therefore led to an increase in the amount of poultry waste generated [31]. The most commonly used organic fertilizer in southern Benin is therefore poultry litter [11], which are known to provide adequate nutrients to soil, and accelerate rapid crops

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

vegetative growth [32, 33, 34]. Poor waste management is detrimental to human health and when burned, waste pollutes the environment, thereby increasing climate change impact [35].

For the valorization of large volume waste and reduction of environmental, social and economic impact, composting is an effective method of waste management, and a mean to transform different degradable wastes into products that can be used safely and beneficially as biofertilizers and soil amendments [35, 36, 37, 38]. For Liu *et al.* [24], composting is a good option for valorizing pineapple harvest residues, because it allows a reduction in the apparent density of the soil and increases its organic matter and N, P and K contents.

The use of compost as a fertilizer or soil amendment can significantly improve soil quality by enhancing aeration, water retention, aggregate stability, and erosion resistance [39]. Compost also boosts crop productivity and helps control plant diseases [20, 39, 40, 41]. According to Muscolo *et al.* [42] and Ghimire *et al.* [43], compost enriches the soil with essential macro and micronutrients, promoting healthier plant growth and increasing cation exchange capacity. Numerous studies have shown that organic fertilizers not only help control plant diseases but also raise the levels of secondary metabolites, which can influence the taste of fruits and vegetables [44, 45, 46]. Effective soil management through the use of organic matter can sustainably maintain soil productivity, ensuring long-term food security [47]. However, it is crucial to determine the appropriate dose and type of organic matter for each crop to optimize production [48].

The aim of this research is to determine the types and application rates of compost, produced from pineapple processing and harvest residues, that can enhance the yield and quality of tomato fruits. The findings will support tomato farmers in boosting their income while promoting sustainable soil management, environmental conservation, and the production of higher-quality food.

MATERIALS AND METHODS

Study area

The experiments were carried out in Allada municipality (village of Dagléta) (6º39’ - 4°16’ N, et 2º10’ - 5°9’ E), located in Atlantic department in southern Benin. This area is characterized by high production and processing of pineapple. Average annual rainfall and mean temperature are 1200 mm and 27°C, respectively. The dominant soil type is a low-desaturated lateritic soil, commonly called ‘terre de barre’ [49, 50]. Before setting up the experiment, soil composite samples were taken per block at 0–20 cm depth, for assessment of the initial soil characteristics. The analysis of the soils physicochemical properties indicated that it was a soil of sandy-silty texture, well drained, with an average pH of 5.9, a C/N ratio of 10.7 and

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

exchangeable cations capacity of 10.2 meq/100g. Its carbon, nitrogen, phosphorus and organic matter content were of 0.53; 0.05; 9.6 and 0.92%, respectively.

Plant and organic material

The plant used for this study was the tomato variety "Padma 108-F1", a hybrid tomato variety with better performance [51], and commonly produced in the municipality of Allada. The organic material is made of three types of compost based on available pineapple harvest and processing residues as follows: C1 = 37.5% Pineapple Crown + 18.75% Pineapple Processing residues + 18.75% Pineapple Harvest residues + 25% Poultry litter; C2: 75% Pineapple Crown + 25% Poultry litter; C3: 75% Pineapple Harvest residues + 25% Poultry litter (Table 1).

Composting process

The composts used in this study were produced using the windrow composting method, combining various quantities of pineapple harvest and processing residues with poultry litter. The windrows were installed on elementary plots (1.5 m × 1 m) disposed on slope of 10% in order to avoid water stagnation below. Polyethylene bags were used to cover the soil at the level of each elementary plot. For each compost type, the windrows were arranged in 5 layers each consisting of 300 kg of raw materials. For each layer, the poultry litter were disposed on top of the different pineapple residues used according to the treatment. Poultry litter quantity was uniform in all windrows because it was used as a ferment for composting. A water add of 22 L (02 watering cans of 11 L) was made between two successive layers during windrows installation. Each window was covered with a polyethylene bag to protect it against rainwater and favor the rise of temperature. The windrows were manually turned with a shovel four times at monthly intervals during composting for aeration. The total duration of composting is approximately four months. Any additives or accelerators have not been used to enhance decomposition during the composting process [52].

Experimental design, management and data collection

The experimental design was a randomized complete block design with 4 replications, whose factor was the combination of compost type (at three levels C1, C2 and C3) and application rate (at three levels R1= 10 t ha^{-1}; R2= 20 t $ha^{-1}$and R3 = 30 t ha^{-1}). To these treatments were added the producers practice (PP = 10 t ha^{-1} of poultry litter), and the control (C0). The total tested treatments were then C1R1, C1R2, C1R3, C2R1, C2R2, C2R3, C3R1, C3R2, C3R3, PP and C0. The plants were transplanted onto the experimental units at spacing of 0.8 m between rows and 0.4 m between holes.

After nursery stage which lasted 21 days, the tomato plants were transplanted at spacings of 40 cm x 80 cm, on beds, following soil preparation. The different organic fertilizers (compost and poultry litter) were applied in pockets at ten days after transplanting, in accordance with experiment design. Manual weeding was carried out at intervals of two weeks and the irrigation were done twice a day using two watering can of 14 liters per elementary plot of 8.96 m². The plants staking was carried out 5 weeks after transplanting and the phytosanitary treatment was carried out two and four weeks after transplanting, using neem seed oil of 125 ml/16 water liters for 333 m².

Growth data such as plant height and collar diameter were collected at 2, 4 and 6 weeks after transplanting (WAT), respectively using a measuring tape (cm) and a caliper (mm). The harvest of ripe fruits was done five times at one-week intervals, starting from 8 WAT. At each harvest, the fruits were counted and weighed by elementary plot, which made it possible to calculate the yield.

The quality parameters were evaluated on a sample of ten tomato fruits per elementary plot. For this purpose, weight, diameter, pH and total sugar content (expressed in °Brix) were determined on each fruit, respectively using an electronic balance ((DH2-000050, ±0.0001, Zawiera, Tianjin, China), a caliper (mm), a pH-meter (HI96107, ±0.1 pH, HANNA instruments, Villafranca padovana, Italy) and a refractometer (HI96801, HANNA instruments, Bucharest, Romania). For tomato fruits shelf-life evaluation, twelve fruits were collected per elementary plot and placed at room temperature in the same enclosure. Rotten Fruits were identified per treatment and eliminated every two days.

Statistical analysis

A mixed-effects linear model for longitudinal data was performed on the height and stem diameter of tomato plants. Yield, quality, and fruit dry weight data were subjected to mixed-effects linear models, treating treatment as a fixed factor and replications as random. Full models with random intercepts, random slopes, and both random intercepts and slopes were tested. This analysis was conducted using the 'lmerTest' package [53]. The best model was selected based on Akaike Information Criterion (AIC) scores. Tukey's post-hoc test was used for pairwise comparisons of means between treatments at a significance level of 5%. The marginal and conditional R-squared values of the mixed-effects linear models for yield data were calculated using the 'MuMIn' package function [54], which implements the method developed by [55]. The marginal R-squared gives the variance explained by fixed effects, while the conditional R-squared explains the variance explained by the entire model, including both fixed and random effects. Pearson correlation matrices were established between fruit quality parameters and the percentage of healthy fruits. The cumulative number of rotten fruits was subjected to a mixed-effects Poisson generalized linear model to test the effect of factors on their variation. A mixed-effects negative binomial model was performed

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

on the percentage of healthy fruits to test the effect of treatments, replications, and time on their variation. The analyses and visualizations were carried out in R software version 4.3.0 [56].

RESULTS AND DISCUSSION

Effects of types and rates of pineapple harvest and processing-based composts on tomato growth and yield

Effect on tomato growth

The interaction effect of compost type and rate on plant height and collar diameter over time is presented in Table 2. The analysis reveals that the interaction between compost type, rate, and time significantly influenced tomato plant height ($p<0.05$), while time and the independent effects of compost type and rate significantly affected collar diameter ($p<0.05$) (Table 2). A progressive increase in plant height was observed over time, with the highest value at 6 weeks after transplanting (WAT) under the C3R1 treatment (82.80 ± 13.14 cm), followed by treatments C2R1, C3R2, C2R3, and C1R1 (80.91 ± 12.51, 79.88 ± 12.37, 79.58 ± 13.07, and 79.21 ± 13.44 cm, respectively) (Figure 1A). Similarly, collar diameter increased over time (Figure 1B), with the highest values observed under treatments C1R3, C2R1, and C1R1 (0.92 cm, 0.88 cm, and 0.87 cm, respectively) (Figure 1C). The interaction between compost type, rate, and time alone explained 85.93% of the variance in tomato plant height. However, the inclusion of replication contributed only a small additional amount of explained variance (about 0.7%), resulting in a total of 86.91% explained variance when both factors were considered. For tomato collar diameter, neither the fixed factors (31.74%) nor the random factors (0.24%) contributed significantly to explaining the observed variation.

ajfand Since 2001 AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

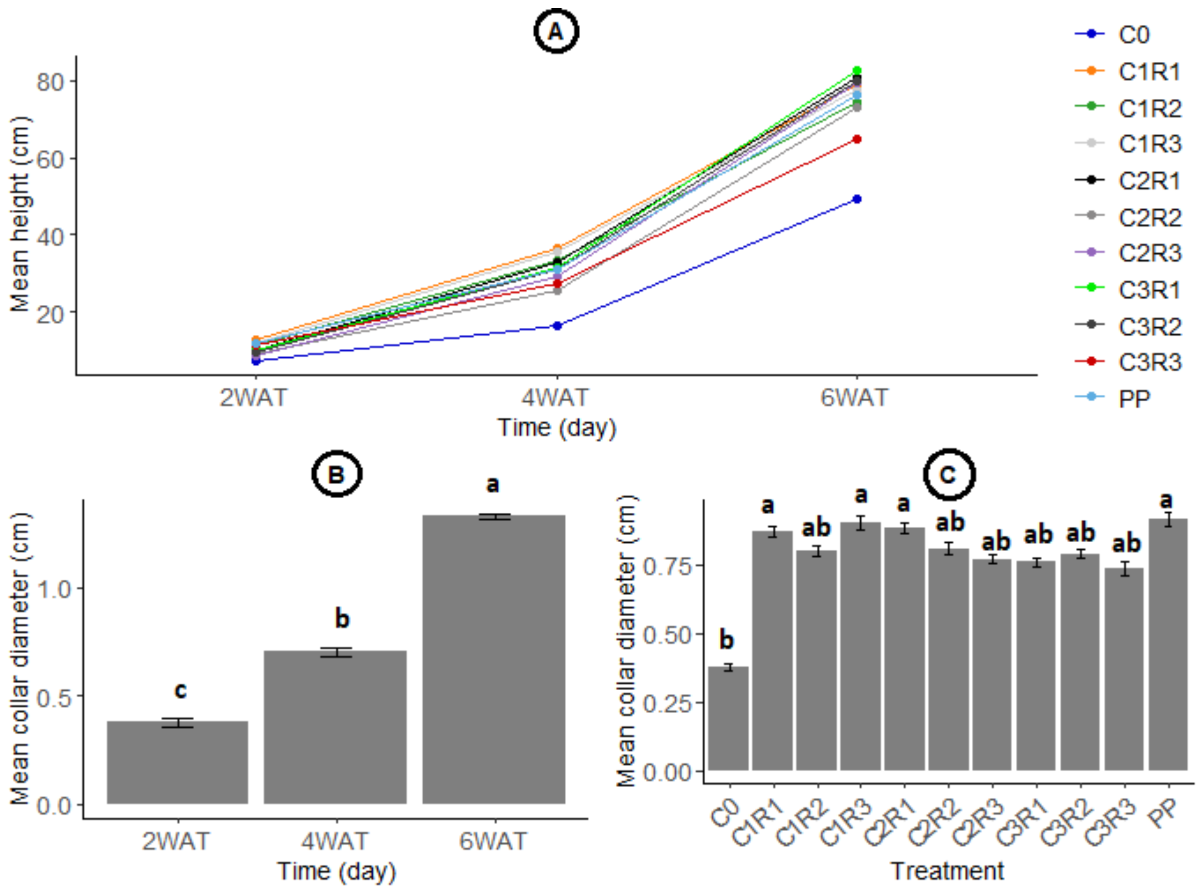

Figure 1: Variation of crop growing mean data in function of time and treatment. A = evolution of mean height over time in function treatment, B = variation of mean collar diameter in function of time and C = variation of mean collar diameter in function of treatment

Effect on tomato yield

Table 3 shows the effect of the interaction between compost type and rate on tomato yield. The table indicates that the interaction between compost type and rate had a significant effect ($p<0.05$) on tomato fruit yield. The highest fruit yields were obtained under treatments C2R2, C3R3, and C1R2 (38.25, 30.89, and 29 t/ha, respectively), while the lowest yield was observed under the control treatment (8.93 t/ha) (Figure 2). The interaction between compost type and rate alone explained 66.09% of the variance in tomato yield. However, the inclusion of replication contributed only a small additional amount of explained variance (about 33.9%), resulting in a total of 99.99% explained variance when both factors were considered.

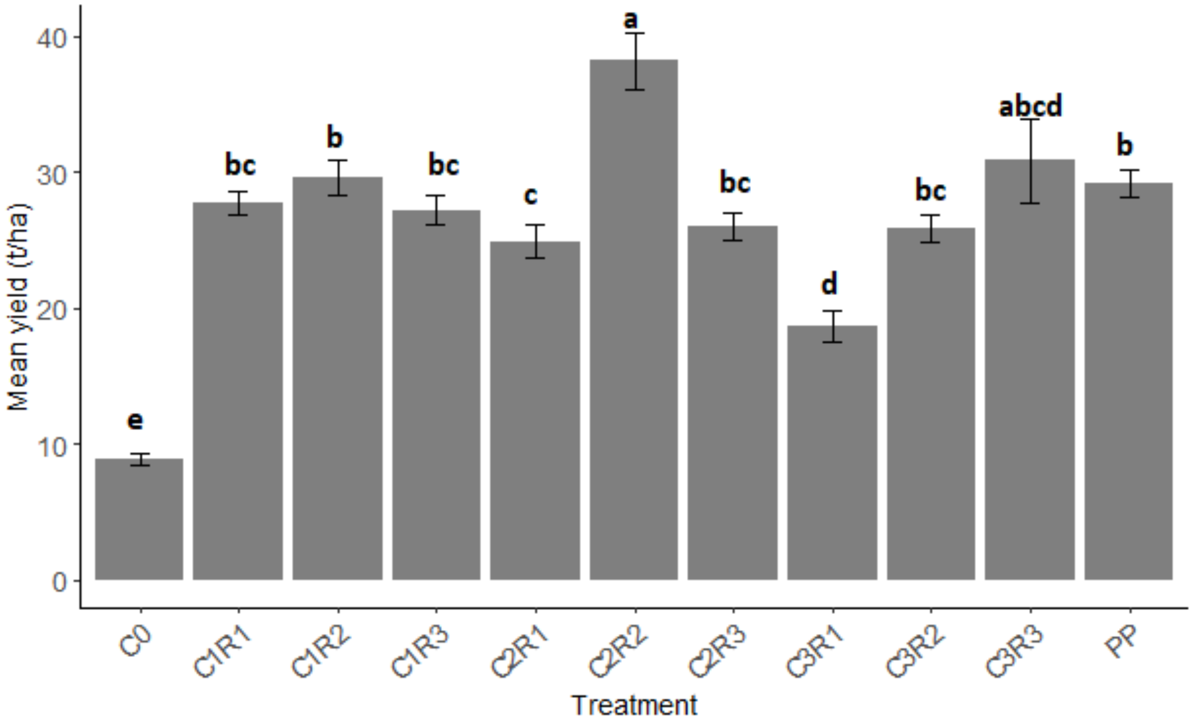

Figure 2: Variation of the mean yield in function of treatment

These observations can be explained by differences in the nutrient content of the applied composts and the release of these elements into the soil during the growing period, which enhanced nutrient absorption by the tomato plants and improved yield [57]. The best growth and yield performances were generally achieved with treatments using composts that had higher nutrient content in P, Ca, Mg, and K compared to poultry litter, and lower C/N ratios (<20), indicating their ability to efficiently release nutrients into the soil. Organic fertilizers contain significant amounts of nutrients and gradually release them over time, providing long-term benefits [58, 59, 60]. In addition, soil amendments with organic fertilizers improve root growth and enhance nutrient and water absorption efficiency [61, 62, 63].

These results align with those of Ddamulira *et al.* [16], who reported that soil amendments increased nutrient availability, doubled the number of fruits per plant, and boosted tomato yield. Furthermore, plant vegetative growth is positively correlated with nutrient absorption, particularly nitrogen, which plays a critical role in photosynthesis and leaf production [64, 65]. Many physiological and metabolic processes in tomatoes are closely linked to nitrogen availability [66]. Cheng *et al.* [66] also concluded that nitrogen uptake significantly affects tomato yield, vitamin C content, sugar/acid ratio, soluble sugars, and total soluble solids. In their study, nitrogen fertilization rates between 236 and 354 kg N ha^{-1} increased tomato yield

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

by 59.9%, and improved vitamin C, sugar/acid ratio, soluble sugars, and total soluble solids (TSS) by 18.8%, 33.5%, 23.5%, and 11.9%, respectively.

Moreover, the increase in fruit weight is closely correlated with the availability of calcium and potassium [67]. These findings are consistent with those of [64, 68, 69, 70], who demonstrated that the application of compost and other organic fertilizers improves plant growth and productivity, especially for fruits and vegetables. Sossa *et al.* [71] found that the addition of 20 t/ha of pineapple processing residue improved both tomato yield and profitability. Similarly, Liu *et al.* [24] noted that adding composted pineapple harvest residues increased soil P and K content, enhanced fruit transverse and longitudinal diameters, and improved fruit weight and yield in pineapples.

Effect of type and rate of pineapple harvest and processing-based composts on tomato fruit quality

Effect on tomato fruit characteristics

The effect of compost type and rate on tomato fruit quality is presented in Table 4. The table shows that fruit weight, diameter, dry matter, and sugar content were significantly affected by the treatments ($p<0.05$), while pH remained unchanged. The variability in tomato fruit characteristics was weakly explained by the interaction between compost type and rate, with 19.79% of the variance in fruit weight, 10.62% in diameter, 7.3% in dry matter, and 9.04% in sugar content being accounted for. Similarly, the random factor contributed only to the variance in fruit weight (17.04%) and sugar content (17.12%).

In particular, the C1R3, C1R2, and C2R1 treatments produced fruits with the highest weight, diameter, and total sugar content, averaging 73.29 g, 4.75 cm, and 6.01° Brix, respectively. However, the highest dry matter content was observed under treatments C0, C2R2, and C3R3 (4.79%, 4.05%, and 4.00%, respectively), while the lowest dry matter content was recorded under the C1R2 treatment (3.05%) (Figure 3).

Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

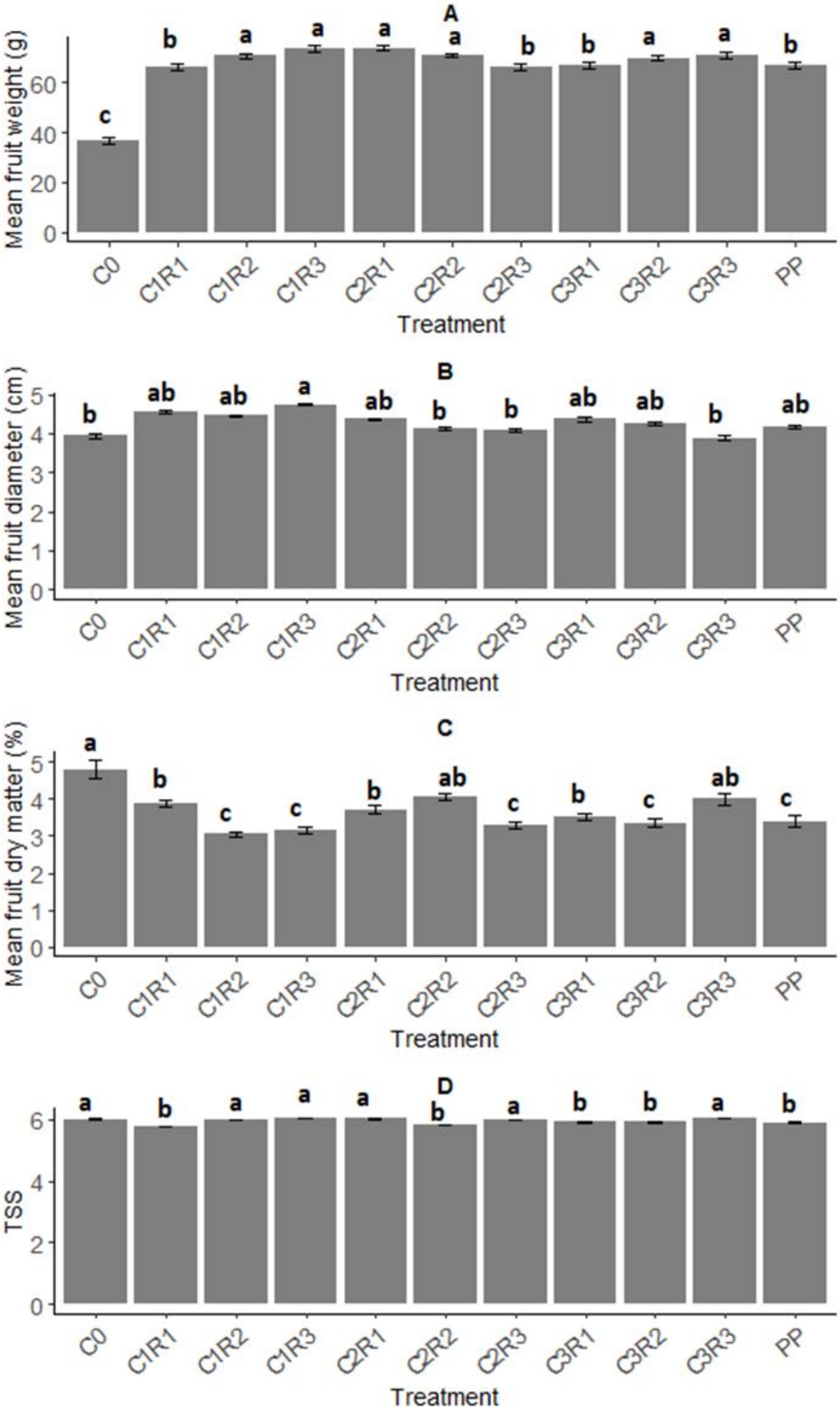

Figure 3: Variation of fruit weight (A), diameter (B), dry matter content (C) and total soluble solids (TSS) (D) following treatments

Since 2001
ajfand
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Effect of type and rate of pineapple harvest and processing-based composts on tomato fruits shelf-life

The interaction between compost type and rate significantly influenced ($p<0.05$) the cumulative number of rotten fruits and the percentage of preserved fruits over time (Table 5). The cumulative number of rotten fruits gradually increased, reaching up to 12 fruits by the 51st day of storage, depending on the treatment. Similarly, the percentage of preserved fruits decreased daily for all treatments until the 54th day. The highest numbers of rotten fruits were recorded under the C0, C2R1, C2R3, and PP treatments, while the C3R2 treatment resulted in the lowest number of rotten fruits. Consequently, the highest percentage of preserved fruits was observed under the C3R2 treatment (31.25%), whereas the lowest percentages were recorded under the C2R1, C2R3, and PP treatments (2.08%) (Figure 4).

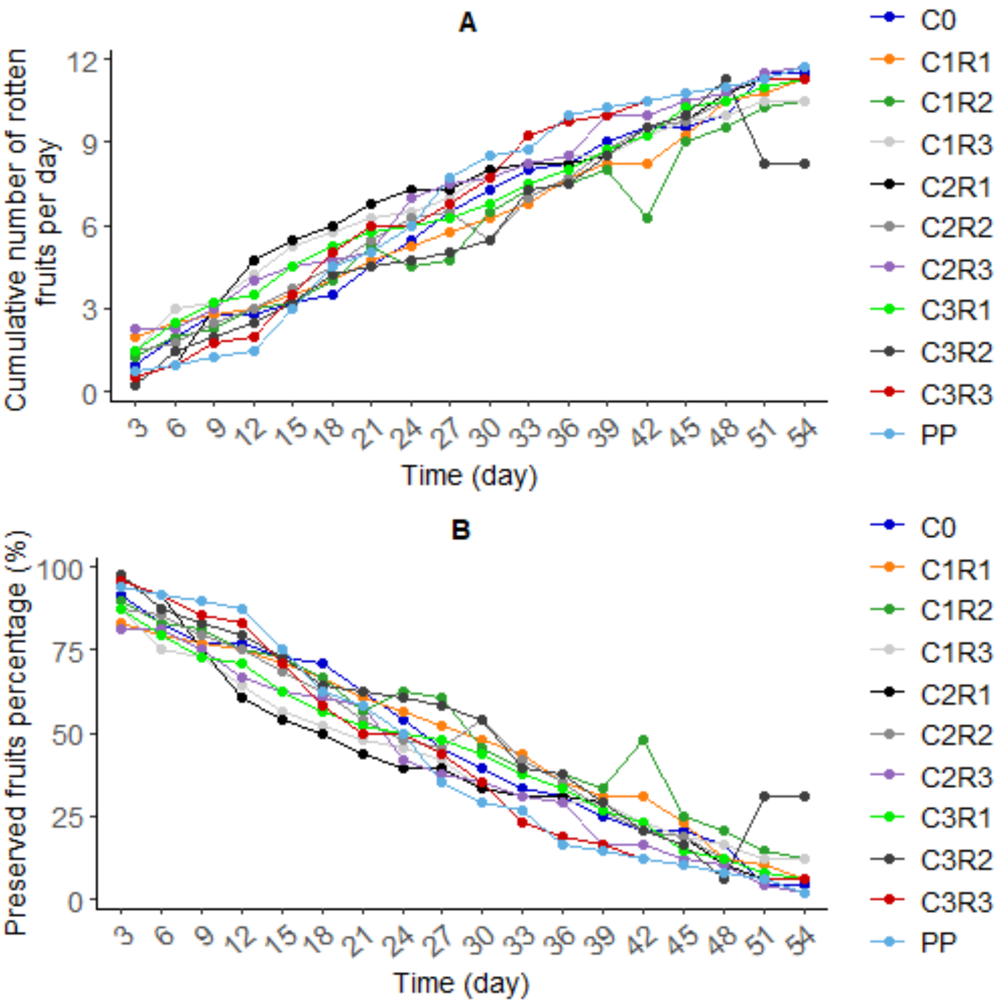

Figure 4: Evolution curves of rotten fruits number (A) and preserved fruits percentage (B) over time for each treatment

Interestingly, the present results suggest that compost made from pineapple harvest and processing residues improved tomato fruit quality more effectively than the current practice of applying poultry litter. While the effects of mineral and/or organic fertilizers on tomato fruit quality attributes have been reported by various authors [72, 73], the impact of composts produced from both pineapple processing and harvest residues on tomato fruit quality had not been explored before. The results show that applying 20 t ha^{-1} of compost C1 (Pineapple Crown + Pineapple Processing residues + Pineapple Harvest residues), 20 t ha^{-1} of compost C2 (Pineapple Crown), or 30 t ha^{-1} of compost C3 (Pineapple Harvest residues) not only leads to good tomato yields but also produces higher-quality fruits with better shelf life. In contrast, fruits grown under the producers' practice (poultry litter application) had a shorter shelf life. This can be attributed to the high nutrient content and availability in the composts, which enhanced tomato plant nutrition [70, 74].

These findings are consistent with those of Sossa *et al.* [30], who demonstrated that incorporating pineapple harvest residues, combined with reduced mineral fertilization, positively influenced the physicochemical and organoleptic characteristics of sugarloaf pineapple fruits (e.g., TSS, pH, fruit weight). This, in turn, increased the percentage of fruits meeting European standards and acceptability criteria for local consumption. Similarly, Liu *et al.* [24] observed a 39.6% increase in the total sugar content of pineapple fruits following the application of composts produced from pineapple harvest residues. Other studies have shown that fruits grown with organic fertilizers contain higher levels of total sugars, vitamin C, and total flavonoids [70, 75].

Notably, the percentage of preserved fruits was higher under the C1R2 treatment (12.50%), followed by the C2R2 (6.25%) and C3R3 (6.25%) treatments, and lower under the producers' practice (2.08%). Additionally, the dry matter content of fruits was higher under the C2R2 and C3R3 treatments. Various authors have noted that the suitability of tomato fruits for preservation and processing is closely linked to a high dry matter content (and consequently low water content) [76].

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

Composts made from pineapple harvest and processing residues significantly enhanced tomato plant growth, yield, and fruit quality compared to current producers' practices. This highlights the potential of these residues, which have long been undervalued and environmentally harmful, to be repurposed as fertilizers for market garden crops, such as tomatoes, with a focus on sustainable soil fertility management to boost both production and product quality.

For this purpose, applying 20 t/ha of compost C1 (Pineapple Crown + Pineapple Processing residues + Pineapple Harvest residues), 20 t/ha of compost C2

(Pineapple Crown), or 30 t/ha of compost C3 (Pineapple Harvest residues) is recommended for tomato production. These treatments not only resulted in the highest tomato yields but also produced fruits of better quality with extended shelf life.

The quality of the composts varied depending on the raw materials used in their production. Therefore, for producing tomatoes intended for processing, applying 20 t/ha of compost C2 (Pineapple Crown) or 30 t/ha of compost C3 (Pineapple Harvest residues) is more appropriate. On the other hand, if the goal is to preserve the fruits for later use, applying 20 t/ha of compost C1 (Pineapple Crown + Pineapple Processing residues + Pineapple Harvest residues) is more suitable. Further studies are recommended to assess the effect of these composts on the efficiency of plant nutrient uptake, particularly nitrogen (N), phosphorus (P), and potassium (K), and their impact on the production of other vegetable crops.

ACKNOWLEDGEMENTS

The authors acknowledge the IFS (International Foundation for Science), for providing funds for the experiment and technical support. They thank also “Jus Tillou”, a pineapple transformation factory located in South of Benin for its collaboration and support.

Authors Contributions

ELS, CEA, conceived the research, edited, revised, and made significant contributions. ELS and JOA planned the work and set up the experiment. BDNB and JOA collected and analyzed the data. ELS drafted the manuscript. BDNB and GLA contributed significantly to manuscript improvement. All authors contributed to the article and approved the submitted version.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

This work was supported by International Foundation for Science.

Data Availability Statement

All data are included in this manuscript.

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 1: Chemical composition of composts and poultry litter

Organic materials	pH_{eau}	C_{org} ($g.kg^{-1}$)	N_{total} ($g.kg^{-1}$)	C/N	P_{total} ($g.kg^{-1}$)	Ca ($g.kg^{-1}$)	Mg ($g.kg^{-1}$)	K ($g.kg^{-1}$)
Compost 1	8.54	113.84	7.51	15.77	77.66	7369.62	1965.31	924.04
Compost 2	8.52	134.83	8.12	16.42	61.75	11164.53	2373.32	361.30
Compost 3	8.38	136.08	9.38	14.57	99.49	9181.79	2800.58	1137.24
Poultry litter	7.71	175.17	14.00	12.51	7.94	364.96	26.52	24.21

Sossa *et al.* [52]

Table 2: Effect of time and the interaction of type and rate of composts on plant height and collar diameter

Variable	Factors	numDF	denDF	F-value	p-value
Height (cm)	(Intercept)	1	1022	620.62	<0.0001***
	Time	2	1022	3351.85	<0.0001***
	Treatment	10	1022	12.97	<0.0001***
	Time:Treatment	20	1022	5.14	<0.0001***
	Marginal R^2			0.8593	
	Conditional R^2			0.8691	
Collar diameter (cm)	(Intercept)	1	1022	908.57	<0.0001***
	Time	2	1022	220.2	<0.0001***
	Treatment	10	1022	2.59	0.0042**
	Time:Treatment	20	1022	1.34	0.1417
	Marginal R^2			0.3174	
	Conditional R^2			0.3198	

*Statistically significant at $0.01 \le p < 0.05$; **Statistically significant at $0.001 \le p < 0.01$; ***Statistically significant at $p < 0.001$; treatment = type*rate of compost

ajfand Since 2001 AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 3: Effect of type and rate of pineapple harvest and processing-based composts on tomato yield

Factor	NumDF	DenDF	F value	Pr(>F)
Treatment	10	9	9784505	<2.2e^{-16}***
Marginal R^2			0.6609	
Conditional R^2			0.9999	

*Statistically significant at 0.01 ≤ p < 0.05; **Statistically significant at 0.001 ≤ p < 0.01; ***Statistically significant at p < 0.001; treatment = type*rate of compost

Table 4: Effect of type and rate of pineapple harvest and processing-based composts on fruit quality parameters

Variable	Factors	NumDF	DenDF	F value	Pr(>F)
Fruit weight (g)	Treatment	10	33	3.1449	0.006277**
	Marginal R^2			0.1979	
	Conditional R^2			0.3683	
Fruit diameter (cm)	Treatment	10	253	3.1245	0.0008826***
	Marginal R^2			0.1062	
	Conditional R^2			0.1062	
Fruit dry matter (%)	Treatment	10	158	1.3767	0.0196*
	Marginal R^2			0.073	
	Conditional R^2			0.2442	
pH	Treatment	10	253	1.7925	0.004878**
	Marginal R^2			0.0672	
	Conditional R^2			0.0672	
TSS	Treatment	10	253	2.6133	0.004878**
	Marginal R^2			0.0904	
	Conditional R^2			0.0904	

*Statistically significant at 0.01 ≤ p < 0.05; **Statistically significant at 0.001 ≤ p < 0.01; ***Statistically significant at p < 0.001; treatment = type*rate of compost; TSS = total soluble solids

ajfand Since 2001
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 12
December 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 5: Effect of type and rate of pineapple harvest and processing-based composts on cumulative number of rotten fruits and preserved fruits percentage

Variable	Factors	Df	Chisq	Pr(>Chisq)
Cumulative number of rotten fruits	Treatment	10	26.314	0.0033**
	Time	1	1093.870	<2e-16***
	Treatment:Time	10	18.909	0.0226
Preserved fruits percentage (%)	Treatment	10	262.01	<2.2e-16***
	Time	1	10711.89	<2.2e-16***
	Treatment:Time	10	355.67	<2.2e-16***

*Statistically significant at $0.01 \leq p < 0.05$; **Statistically significant at $0.001 \leq p < 0.01$; ***Statistically significant at $p < 0.001$; treatment = type*rate of compost

REFERENCES

1. **FAO.** Fruit and Vegetables–Your Dietary Essentials. The International Year of Fruits and Vegetables, 2020.

2. **Martin T, Saidi M, Komlan FA, Simon S, Kasina M, Vidogbéna F, Parrot L, Adegbidi A, Wasilwa LA and S Subramanian** Des Filets Anti Insectes Pour Protéger Les Cultures Maraîchères En Afrique Subsaharienne : Une Technologie Rentable et Adaptée Aux Conditions Climatiques. 2014.

3. **Ngigi PB, Termote C, Pallet D and MJ Amiot** Mainstreaming Traditional Fruits, Vegetables and Pulses for Nutrition, Income, and Sustainability in sub-Saharan Africa: The Case for Kenya and Ethiopia. *Front. Nutr.* 2023; **10:** 1197703. https://doi:10.3389/fnut.2023.1197703

4. **Okuthe G** Valorizing Fruit and Vegetable Waste: The Untapped Potential for Entrepreneurship in sub-Saharan Africa—A Systematic Review. *Recycling*. 2024; **9:** 40. https://doi:10.3390/recycling9030040

5. **Ekesi S, Chabi-Olaye A, Subramanian S and C Borgemeister** Horticultural Pest Management and the African Economy: Successes, Challenges and Opportunities in a Changing Global Environment. 2009; 165–183.

6. **Weinberger K and TA Lumpkin** Diversification into Horticulture and Poverty Reduction: A Research Agenda. *World development.* 2007; **35:** 1464–1480.

7. **Assogba KF, Sikirou R and J Azagba** Comment Réussir La Culture de La Tomate En Toute Saison : Cas Des Régions Urbaines et Périurbaines Du Sud-Bénin. RTE. 2ème édition. INRAB 2013.

8. **Houetohossou SCA, Ratheil HV, Sikirou R and KR Glèlè** Finding Optimum Climatic Parameters for High Tomato Yield in Benin (West Africa) Using Frequent Pattern Growth Algorithm. *PLoS ONE.* 2024; **19:** 0297983. https://doi:10.1371/journal.pone.0297983

9. **Vitouley A, Hounsokou CG, Kouchadé CA, Hounguè GH, N'Gobi GK, Adounkpè J and B Kounouhéwa** Use of a Forced Convection Solar Dryer for the Reduction of Post-Harvest Losses: Case of the 'Akikon' Tomato Variety in Benin (West Africa). *Environ. Res. Commun*. 2024; **6:** 015006. https://doi:10.1088/2515-7620/ad1b66

10. **Wosene G and W Gobie** Value Chain Analysis of Tomato: The Case of Bure, Jabitehinan and North Mecha Districts of Amhara Regional State, Ethiopia. *Journal of Agriculture and Food Research.* 2022; **7:** 100272. https://doi:10.1016/j.jafr.2022.100272

11. **Avadí A, Hodomihou NR, Amadji GL and F Feder** LCA and Nutritional Assessment of Southern Benin Market Vegetable Gardening across the Production Continuum. *Int. J. Life Cycle Assess.* 2021; **26:** 1977–1997. https://doi:10.1007/s11367-021-01977-z

12. **FAOSTAT Crops Production.** Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/#data/QC *Accessed August 2023.*

13. **Saidou A, Kossou D, Acakpo C, Richards P and TW Kuyper** Effects of Farmers' Practices of Fertilizer Application and Land Use Types on Subsequent Maize Yield and Nutrient Uptake in Central Benin. *International Journal of Biological and Chemical Sciences.* 2012; **6:** 365–378.

14. **Biaou D, Yabi J, Yegbemey R and G Biaou** Performances Technique et Économique Des Pratiques Culturales de Gestion et de Conservation de La Fertilité Des Sols En Production Maraîchère Dans La Commune de Malanville, Nord Bénin. *International Journal of Innovation and Scientific Research.* 2016; **21:** 201–211.

15. **Jafari M, Ghasemi-Soloklui AA and M Kordrostami** Enhancing Nutritional Status, Growth, and Fruit Quality of Dried Figs Using Organic Fertilizers in Rain-Fed Orchards: A Case Study in Estahban, Iran. *PLoS ONE.* 2024; 19:0300615. https://doi:10.1371/journal.pone.0300615

16. **Ddamulira G, Malaala A, Otim A, Florence N and M Maphosa** Soil Amendments Improved Tomato Growth, Yield and Soil Properties. *AJPS.* 2022; **13:** 960–971. https://doi:10.4236/ajps.2022.137063

17. **Atidegla S** Metallic Contamination of Vegetables: Causes and Approach of Solutions through Environmental Education. *MOJ Biol. Med.* 2018; **3:** 30–35.

18. **Geethamani R, Soundara B, Kanmani S, Jayanthi V, Subaharini TR, Sowbiyalakshmi V and C Sowmini** Production of Cost Affordable Organic Manure Using Institutional Waste by Rapid Composting Method. Materials Today: *Proceedings*. 2021; **45:** 764–768. https://doi:10.1016/j.matpr.2020.02.803

19. **Jote CA** The Impacts of Using Inorganic Chemical Fertilizers on the Environment and Human Health. *Organ. Med. Chem. Intl. J.* 2023; **13:** 555864.

20. **Lim LY, Lee CT, Bong CPC, Lim JS, Ong PY and JJ Klemes** Selection of Parameters for Soil Quality Following Compost Application: A Ranking Method. *Chemical Engineering Transactions.* 2021; **83:** 505–510. https://doi:10.3303/CET2183085

21. **Bergstrand KJ** Organic Fertilizers in Greenhouse Production Systems–a Review. *Scientia Horticulturae.* 2022; **295:** 110855.

22. **Epule ET, Bryant CR, Akkari C and O Daouda** Can Organic Fertilizers Set the Pace for a Greener Arable Agricultural Revolution in Africa? Analysis, Synthesis and Way Forward**.** *Land Use Policy.* 2015; **47:** 179–187.

23. **Helvetas-Bénin** Appui à La Filière Ananas Biologique et Équitable: Document Du Projet. 2008.

24. **Liu C, Liu Y, Fan C and S Kuang** The Effects of Composted Pineapple Residue Return on Soil Properties and the Growth and Yield of Pineapple. *Journal of Soil Science and Plant Nutrition.* 2013; **13:** 433–444.

25. **COLEAD-PAFO** Fiche d'entreprise-Les Fruits Tillou 2021.

26. **Heard J, Cavers C and G Adrian** Up in Smoke-Nutrient Loss with Straw Burning. Better Crops. 2006; **90:** 10–11.

27. **Sossa EL, Amadji GL, Vissoh PV, Hounsou BM, Agbossou KE and DJ Hounhouigan** Caractérisation Des Systèmes de Culture d'ananas (*Ananas Comosus* (L.) Merrill) Sur Le Plateau d'Allada Au Sud-Bénin. *International Journal of Biological and Chemical Sciences.* 2014; **8:** 1030–1038.

28. **Olufunmi OO, Akintola OA, Okafor M, Dixon UG, Ajoba FB, Adawa AA, Kanu OK, Adeniyi HA, Emmanuel OC, Adebayo AG, Shokalu OO, Akinrinola AO and LO Olajide-Taiwo** Elemental Characterization of Biochar of Some Horticultural Crop Wastes. *Growth*. 2018; **18:** 22nd.

29. **Sossa EL, Agbangba CE, Amadji GL, Agbossou KE and DJ Hounhouigan** Integrated Influence of Soil Tillage, Nitrogen–Potassium Fertiliser and Mulching on Pineapple (*Ananas Comosus* (L.) Merr.) Growth and Yield. *South African Journal of Plant and Soil.* 2019; **36:** 339–345. https://doi:10.1080/02571862.2019.1570568

30. **Sossa EL, Agbangba CE, Accalogoun SGGS, Amadji GL, Agbossou KE and DJ Hounhouigan** Residues Management Practices and Nitrogen-Potassium Fertilization Influence on the Quality of Pineapple (*Ananas Comosus* (L.) Merrill) Sugarloaf Fruit for Exportation and Local Consumption. *Agronomy*. 2017; **7:** 26. https://doi:10.3390/agronomy7020026

31. **Toledo M, Gutiérrez MC, Peña A, Siles JA, MA Martín** Co-Composting of Chicken Manure, Alperujo, Olive Leaves/Pruning and Cereal Straw at Full-Scale: Compost Quality Assessment and Odour Emission. *Process Safety and Environmental Protection.* 2020; **139:** 362–370. https://doi:10.1016/j.psep.2020.04.048

32. **Aiyelaagbe IOO, Abiola IO and MA Sadiku** Growth Response of Juvenile Passion Fruit (Passiflora Edulis, F. Falvicarpa) to Organic and Inorganic Fertilizer in South Western Nigeria. *Nigerian Journal of Horticultural Science.* 2005; **10:** 18–22.

33. **Katung MD, Hussibini IMA and JD Olarewaju** Yield and Storability of Onion (*Allium Cepa* L.) as Influenced by Organic and Inorganic Fertilizers in the Sudan Savanna Region of Nigeria. *Nigerian Journal of Horticultural Science*. 2005; **10:** 82–86.

34. **Rasool A, Ghani A, Nawaz R, Ahmad S, Shahzad K, Rebi A, Ali B, Zhou J, Ahmad MI and MF Tahir** Effects of Poultry Manure on the Growth, Physiology, Yield, and Yield-Related Traits of Maize Varieties. *ACS omega.* 2023; **8:** 25766–25779.

35. **Ayilara MS, Olanrewaju OS, Babalola OO and O Odeyemi** Waste Management through Composting: Challenges and Potentials. *Sustainability*. 2020; **12:** 4456. https://doi:10.3390/su12114456

36. **Bai J, Shen H and S Dong** Study on eco-utilization and treatments of highway greening waste. *Procedia Environmental Sciences.* 2010; **2:** 25-31.

37. **Manea EE, Bumbac C, Dinu LR, Bumbac M and CM Nicolescu** Composting as a Sustainable Solution for Organic Solid Waste Management: Current Practices and Potential Improvements. *Sustainability*. 2024; **16:** 6329. https://doi:10.3390/su16156329

38. **Yu H, Xie B, Khan R and G Shen** The Changes in Carbon, Nitrogen Components and Humic Substances during Organic-Inorganic Aerobic Co-Composting. *Bioresource Technology.* 2019; **271:** 228–235.

39. **Maffia A, Marra F, Battaglia S, Oliva M, Mallamaci C and A Muscolo** Influence of Agro-Industrial Waste Composts on Soil Characteristics, Growth Dynamics, and Yield of Red Cabbage and Broccoli. *Soil Systems.* 2024; **8:** 53. https://doi:10.3390/soilsystems8020053

40. **De Corato U** Agricultural Waste Recycling in Horticultural Intensive Farming Systems by On-Farm Composting and Compost-Based Tea Application Improves Soil Quality and Plant Health: A Review under the Perspective of a Circular Economy. *Science of the Total Environment.* 2020; **738:** 139840. https://doi:10.1016/j.scitotenv.2020.139840

41. **Lopes IG, Braos LB, Cruz MCP and RM Vidotti** Valorization of Animal Waste from Aquaculture through Composting: Nutrient Recovery and Nitrogen Mineralization. *Aquaculture*. 2021; **531:** 735859. https://doi:10.1016/j.aquaculture.2020.735859

42. **Muscolo A, Papalia T, Settineri G, Mallamaci C and A Jeske-Kaczanowska** Are Raw Materials or Composting Conditions and Time That Most Influence the Maturity and/or Quality of Composts? Comparison of Obtained Composts on Soil Properties. *Journal of Cleaner Production*. 2018; **195:** 93–101. https://doi:10.1016/j.jclepro.2018.05.204

43. **Ghimire S, Poudel CB and J Shrestha** Efficacy of Different Organic and Inorganic Nutrient Sources on the Growth and Yield of Bitter Gourd (*Momordica Charantia* L.). Heliyon. 2023; **9:** 22135. https://doi:10.1016/j.heliyon.2023.e22135

44. **Aina OE, Amoo SO, Mugivhisa LL and JO Olowoyo** Effect of Organic and Inorganic Sources of Nutrients on the Bioactive Compounds and Antioxidant Activity of Tomato. *Applied Ecology & Environmental Research.* 2019; **17**.

45. **Dumas Y, Dadomo M, Di Lucca G and P Grolier** Effects of Environmental Factors and Agricultural Techniques on Antioxidantcontent of Tomatoes. *Journal of the Science of Food and Agriculture*. 2003; **83:** 369–382.

46. **Picchi V, Migliori C, Scalzo RL, Campanelli G, Ferrari V and LF Di Cesare** Phytochemical Content in Organic and Conventionally Grown Italian Cauliflower. *Food Chemistry.* 2012; **130:** 501–509.

47. **Shah F and W Wu** Soil and Crop Management Strategies to Ensure Higher Crop Productivity within Sustainable Environments. *Sustainability*. 2019; **11:** 1485. https://doi:10.3390/su11051485

48. **Bot A and J Benites** The Importance of Soil Organic Matter: Key to Drought-Resistant Soil and Sustained Food Production. *Food & Agriculture Org.* 2005; ISBN 92-5-105366-9.

49. **Azonkpin S, Chougourou CD, Aboudou K, Hedible L and MM Soumanou** Evaluation de La Qualité de l'ananas (*Ananas Comosus* (L.) Merr.) de Cinq Itinéraires Techniques de Production Dans La Commune d'Allada Au Bénin. *Revue Internationale des Sciences Appliquées.* 2019; **2:** 48–61.

50. **Sossa EL, Amadji GL, Aholoukpè NSH, Hounsou BM, Agbossou KE and DJ Hounhouigan** Change in a Ferralsol Physico-Chemical Properties under Pineapple Cropping System in Southern of Benin. *J. App. Bioscience.* 2015; **91:** 8559. https://doi:10.4314/jab.v91i1.11

51. **Aisso R, Komlan A, Aissi M, Mensah A and M Soumanou** Cultural Practices and Producers Perception on Sensoral Charact Eristics of Some Tomato Varieties Produced in South Benin. *IJAR.* 2018; **6:** 854–863. https://doi:10.21474/IJAR01/7880

52. **Sossa EL, Agbangba CE, Koura TW, Ayifimi OJ, Houssoukpèvi IA, Bouko NDB, Yalinkpon F and GL Amadji** Dynamics of Co-Composting of Pineapple Harvest and Processing Residues with Poultry Litter and Compost Quality. *Scientific Reports.* 2024; **14:** 17194.

53. **Kuznetsova A, Brockhoff PB and RHB Christensen** ImerTest Package: Tests in Linear Mixed Effects Models. *J. Stat. Soft.* 2017; **82.** https://doi:10.18637/jss.v082.i13

54. **Barton K** MuMIn: Multi-Model Inference. R Package Version 1.15. 6. 2016. https://cran.r-project.org/web/packages/MuMIn/MuMIn.pdf *Accessed February 2024.*

55. **Nakagawa S and H Schielzeth** General and Simple Method for Obtaining R^2 from Generalized Linear Mixed-effects Models. *Methods Ecol Evol.* 2013; **4:** 133–142. https://doi:10.1111/j.2041-210x.2012.00261.x

56. **Core Team R.** A Language and Environment for Statistical Computing. R *Foundation for Statistical Computing*. 2023.

57. **Zhang P, Yang F, Zhang H, Liu L, Liu X, Chen J, Wang X, Wang Y and C Li** Beneficial Effects of Biochar-Based Organic Fertilizer on Nitrogen Assimilation, Antioxidant Capacities, and Photosynthesis of Sugar Beet (*Beta Vulgaris* L.) under Saline-Alkaline Stress. *Agronomy*. 2020; **10:** 1562.

58. **Chang EH, Chung RS and YH Tsai** Effect of Different Application Rates of Organic Fertilizer on Soil Enzyme Activity and Microbial Population. *Soil Science and Plant Nutrition.* 2007; **53:** 132–140.

59. **Muktamar Z, Putri D and N Setyowati** Reduction of Synthetic Fertilizer for Sustainable Agriculture: Influence of Organic and Nitrogen Fertilizer Combination on Growth and Yield of Green Mustard. 2016.

60. **Shaji H, Chandran V and L Mathew** Organic Fertilizers as a Route to Controlled Release of Nutrients. In Controlled Release Fertilizers for Sustainable Agriculture. *Elsevier*. 2021; 231–245.

61. **Huang N, Wang W, Yao Y, Zhu F, Wang W and X Chang** The Influence of Different Concentrations of Bio-Organic Fertilizer on Cucumber Fusarium Wilt and Soil Microflora Alterations. *PLoS One*. 2017; **12:** 0171490.

62. **Ochoa-Velasco CE, Valadez-Blanco R, Salas-Coronado R, Sustaita-Rivera F, Hernández-Carlos B, García-Ortega S and NF Santos-Sánchez** Effect of Nitrogen Fertilization and Bacillus Licheniformis Biofertilizer Addition on the Antioxidants Compounds and Antioxidant Activity of Greenhouse Cultivated Tomato Fruits (*Solanum Lycopersicum* L. Var. Sheva). *Scientia Horticulturae.* 2016; **201:** 338–345. https://doi:10.1016/j.scienta.2016.02.015

63. **Wang J, Zhang B, Wang J, Zhang G, Yue Z, Hu L, Yu J and Z Liu** Effects of Different Agricultural Waste Composts on Cabbage Yield and Rhizosphere Environment. *Agronomy*. 2024; **14:** 413. https://doi:10.3390/agronomy14030413

64. **Alla KT, Bomisso EL, Ouattara G and AE Dick** Effects of Fertilization Using By-Products of Plantain Peel on the Agromorphological Characteristics of the F1 Kalenda Aubergine Variety (*Solanum Melongena*) in the Locality of Bingerville in Côte d'Ivoire. 2018.

65. **Eleiwa ME, Hamed ER and HS Shehata** The Role of Biofertilizers and/or Some Micronutrients on Wheat Plant (*Triticum Aestivum* L.) Growth in Newly Reclaimed Soil. *Journal of Medicinal Plants Research.* 2012; **6:** 3359–3369.

66. **Cheng M, Wang H, Fan J, Xiang Y, Tang Z, Pei S, Zeng H, Zhang C, Dai Y, Li Z, Zou Y and F Zhang** Effects of Nitrogen Supply on Tomato Yield, Water Use Efficiency and Fruit Quality: A Global Meta-Analysis. *Scientia Horticulturae.* 2021; **290:** 110553. https://doi:10.1016/j.scienta.2021.110553

67. **Arah IK, Amaglo H, Kumah EK and H Ofori** Preharvest and Postharvest Factors Affecting the Quality and Shelf Life of Harvested Tomatoes: A Mini Review. *International Journal of Agronomy.* 2015; 478041.

68. **Mazeh M, Almadi L, Paoletti A, Cinosi N, Daher E, Tucci M, Lodolini EM, Rosati A and F Famiani** Use of an Organic Fertilizer Also Having a Biostimulant Action to Promote the Growth of Young Olive Trees. Agriculture. 2021; **11:** 593. https://doi:10.3390/agriculture11070593

69. **Simiele M, Argentino O, Baronti S, Scippa GS, Chiatante D, Terzaghi M and A Montagnoli** Biochar Enhances Plant Growth, Fruit Yield, and Antioxidant Content of Cherry Tomato (*Solanum Lycopersicum* L.) in a Soilless Substrate. *Agriculture*. 2022; **12:** 1135.

70. **Ye S, Peng B and T Liu** Effects of Organic Fertilizers on Growth Characteristics and Fruit Quality in Pear-Jujube in the Loess Plateau. Sci Rep. 2022; **12:** 13372. https://doi:10.1038/s41598-022-17342-5

71. **Sossa EL, Dossou SA, Agbangba CE, Koura T, Ayifimi JO and GL Amadji** Réponse Des Doses et Des Modes d'application de La Drêche Issue de La Transformation d'ananas et de La Fiente de Volaille Sur La Productivité de La Tomate (*Lycopersicum Esculentum* L.) et de l'amarante (*Amaranthus Cruentus* L.) au Sud-Benin. Actes des Journées Scientifiques Internationales de Lomé. 2022.

72. **Acedo Jr AL and MM Benitez** Tomato Fruit Yield, Quality and Shelf-Life Improvement through Organic and Inorganic Fertilization. 2021.

73. **Gao F, Li H, Mu X, Gao H, Zhang Y, Li R and L Ye** Effects of Organic Fertilizer Application on Tomato Yield and Quality: A Meta-Analysis. *Applied Sciences.* 2023; **13:** 2184.

74. **Nabaei SM, Hassandokht MR, Abdossi V and MR Ardakani** Tomato (*Solanum Esculentum* Mill.) Yield and Nutritional Traits Enhancement as Affected by Biochar, Organic and Inorganic Fertilizers. *Acta Scientiarum Polonorum. Hortorum Cultus.* 2021; **20**.

75. **Hallmann E** The Influence of Organic and Conventional Cultivation Systems on the Nutritional Value and Content of Bioactive Compounds in Selected Tomato Types. *Journal of the Science of Food and Agriculture.* 2012; **92:** 2840–2848.

76. **Valverde-Miranda D, Díaz-Pérez M, Gómez-Galán M and Á-J Callejón-Ferre** Total Soluble Solids and Dry Matter of Cucumber as Indicators of Shelf Life. *Postharvest Biology and Technology*. 2021; **180:** 111603. https://doi:10.1016/j.postharvbio.2021.111603