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EFFECT OF ORGANIC FERTILIZERS ON PHYSICAL AND CHEMICAL QUALITY OF SUGAR LOAF PINEAPPLE (*ANANAS COMOSUS L)* GROWN IN TWO ECOLOGICAL SITES IN GHANA

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ABSTRACT

Pineapple has a large demand for plant nutrients and for this reason; fertilization is almost mandatory where the fruit is destined for sale. As consumer demand for organic food grows, organic production and certification is seen as a valuable alternative for smallholder farmers in developing countries. This study sought to investigate the effects of different organic fertilizers on the physical and chemical quality of pineapple (*Ananas comosus L.)* cultivated in two different ecological zones in Ghana. Organic fertilizers treatments were POME (Palm oil meal effluent), Phos-K (PH), Yara (Y) and combination of Phos-K and POME (PH+P) and Yara + POME (Y+P) in the ratio of 1:1. Soil without fertilizer was control. A farmer field demonstration and an on-station experimental trial were conducted parallel at Nsakyi and at the Biotechnology and Nuclear Agriculture Research Institute (BNARI) research farm, respectively. The experiment was laid out in the Randomised Completely Block Randomized Design (RCBD) with five fertilizer treatments and four replications. Sugar loaf pineapples were harvested at 17 months upon maturity, washed, peeled, and juice extracted for analyzing vitamin C, Total Soluble Solids, pH, Titratable acidity, juice yield and colour. Fruits were weighed with Sartorius scale and percentage weight loss estimated over 15 days. The weight loss of pineapples treated with POME (25.56 ± 0.62 %) from BNARI farm was significantly ($p<0.05$) higher than all the other pineapple treaments. pH of all pineapple samples significantly ($P<0.05$) differed for all the different fertilizer treatments for both farms. Phos-K significantly ($p<0.05$) enhanced the vitamin C content of pineapples from both ecological sites Lightness (L*) and yellowness (b*) for juice of pineapple treated with Phos-K from BNARI farm was significantly ($p<0.05$) higher, than samples from Nsakyi farms indicating desirable visual appeal for sugar loaf pineapples. Organic fertilizers significantly ($p<0.05$) influenced the pH, vitamin C and juice yield of pineapples grown in the two different ecological zones. Irrespective of the ecological differences in Nsakyi and BNARI farm sites, the application of Phos-K to pineapple significantly ($p<0.05$) increased the juice yield which is a desirable quality of pineapple. Thus the application of Phos-K organic fertilizer, better improved the physical and chemical quality attributes of pineapple. However, there is the need to conduct further work on application rate and utilization efficiency of organic fertilizers that will produce maximum pineapple quality and yield.

Key words: Organic fertilizers, Juice, weight loss

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INTRODUCTION

Pineapple is the third most important tropical fruit in world production after banana and citrus. It is cultivated in all tropical and subtropical countries. World production of pineapple in 2010 was estimated at more than 19.42 million tons per year [1]. A major part of world production is processed as canned products and juices, and about 25% goes to the fresh fruit market. Pineapple production in Ghana was 70,000 MT in 2008 and 35,601MT was exported, making up 4% of world exports to the European Union [2].

Pineapple can grow well in low soil fertility areas, but the best production is obtained with high fertile soils. High soil organic matter is also desirable. Pineapple has high requirement for nitrogen (N), potassium (K) and iron (Fe) and relatively low requirement for phosphorus (P) and calcium (Ca) [3, 4] and high soil organic matter and potassium status is also desirable. Nitrogen is required second after potassium and is important in determining the growth and productivity of the plant. The absence of Nitrogen in either organic or inorganic form, always results in compromised development and/or productivity of the plant, with the appearance of typical symptoms of nitrogen deficiency. Increase in nitrogen rates increased yield, fruit size [4, 5, 6] and juice content [7, 8] and decreased Total soluble solids (TSS), Titratable Acidity (TA) and vitamin C [3, 5]. Similarly, an increase in potassium rates increased pineapple yield, fruit size, TSS, TA and vitamin C content [3, 4, 7]. Potassium is important in water conservation as well as in enhancing flowering, fruit maturity and yield when applied in adequate quantities [9]. Experimental studies have shown that increasing the amount of K increases the acidity of the pulp and/or sugar content and improves aroma. Teisson *et al*. [5] ascribed increase in ascorbic acid in the fruit pulp to increasing amounts of K, in consequence contributing to a reduction of internal fruit darkening. Pineapple requires less fertilizer in the first 5 months after planting and Spironello *et al.* [3] observed that late application of N had a positive effect on fruit yield but decreased TSS. Phosphorus and Calcium are usually banded in the plant line during bed preparation while potassium is usually applied to the soil before planting and later by side dressing. Deficiency in K can be balanced out by the use of wood ash (combined with compost). Most farmers for a long time have been using inorganic fertilizers to grow pineapple, but in spite of the effect on size, yield and quality of pineapple, the requirement by international regulations to practice environmentally sound, sustainable agriculture is forcing many farmers to shift from conventional farming to organic farming. The world market for fresh pineapple has been growing rapidly during the past years. Like other tropical fruit, pineapple is grown predominantly in developing countries, where two thirds of rural people live on small scale farms of less than two hectares [10]. As consumer demand for organic food grows, organic certification is increasingly promoted in many developing countries. Studies have recently found that certified organic agriculture is more profitable than conventional agriculture in developing countries, due to the higher price farmers receive for their product [11, 12].

Yield of inorganically grown fruits are similar or slightly higher than those from organic agriculture according to USDA report on organic farming; Knorr *et al.* [13, 14]. While there is no agreement about difference in quality [15], organic products earn a premium price on the market compared to conventional varieties. Though some research work on

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the effect of conventional fertilizers on growth, yield, fruit quality, soil fertility and nutrition of pineapple has been done [16], there is limited information on the responses of pineapple to organic fertilizers and their influence on yield and fruit quality. This study investigated the effects of organic fertilizers on physical and chemical quality of pineapple (*Ananas comosus L.*) cultivated in two different ecological sites in Ghana.

MATERIALS AND METHOD

Study Site and Environment:

A farmer field demonstration and an on-station experimental trial were conducted at Nsakyi and the Biotechnology and Nuclear Agriculture Research Institute (BNARI) research farm, respectively. Nsakyi is located in between Pokuase and Aburi in the Transitional Zone of the Eastern Region of Ghana with annual precipitation of 1500 mm per annum and a mean annual temperature of 28-34ºC. Nsakyi is typically known for the production of pineapple and most pineapple farms in the eastern region are situated here because of the conducive weather and soil characteristics for the production of pineapple. BNARI is in the Coastal Savannah Zone of Ghana on approximately 76 m above sea level with annual precipitation of 800 mm per annum, mean annual temperature 23-34ºC and the soils are classified as ferric acrisol [17] according to FAO [18]. This soil is loamy and not typically used for the cultivation of pineapple; however, with the application of appropriate nutrients, soil fertility can be improved for the cultivation of pineapple.

Plant Materials

Uniform suckers of sugar loaf pineapple variety were planted in February and July 2011 on Nsakyi and BNARI farms, respectively. Pineapples were harvested 17 months after planting.

Fertilizer Treatments and Application

Three organic fertilizers: Phos-K (PH), POME (Palm oil meal effluent) and Yara (Y) were combined in 6 Treatments-PH only, Y only , PH+P in ratio 1:1, Y+P in a ratio 1:1 and soil only (without fertilizer) was used as control.

PH and Y were each applied at 300 kg per ha with palm oil meal effluent (POME) at 166 m3/ha or without PH or P and replicated four times. Phos-K contains 17% P_2O_5 + 13% K_2O + 5% S, Yara fertilizer contains 0% N + 17% P_2O_5 + 13% K_2O + 29% CaO + 7.5 S and 2.5 MgO, POME (rich in nitrogen).

Experimental Design

Randomized Complete Block Design (RCBD) was used. Each treatment plot was 3.4m by 3.4m and was replicated four times. There were 28 plants per treatment in the block.

Sample preparation

Sugar loaf pineapple samples were harvested upon17 months maturity and transported to the laboratory. Samples were washed, peeled, and juice extracted for physical and chemical analysis.

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Physical Analysis

Weight of fruit

Fruits were weighed using a top loading balance (Salterand Model, Japan).

Juice yield

Pineapple samples were peeled with a slicer and the flesh scooped and passed through a fruit juice extractor to collect the juice. The volume of juice was measured using a measuring cylinder.

Weight Loss (%)

This is defined as weight loss due to natural water loss. The initial change in weight with storage was measured using Sartoruis scale model 9100. The percentage weight loss was calculated by differences between initial weight and final weight divided by initial weight after 15 days of storage at ambient room conditions (28±2^{0}C).

$$Percent\ weight\ loss\ (\%) = \frac{IW - FW}{IW} \times 100$$

Where IW = Initial weight of fruits FW = Final weight of fruits.

Chemical Analysis

Vitamin C was determined by the Dichloroindophenol method as outlined in 967.21 of Association of Official Analytical Chemists [19]. pH of the pineapple juices was evaluated using an electronic TOA pH meter (HM 305 Model, Japan) according to AOAC [19]. Titratable acidity (TA) was assessed by adding three drops of 1% to phenolphthalein to 10mls extracted pineapple juice and titrated with 0.1N NaOH solution as outlined in 942.15 of AOAC [19]. Titratable acidity was analyzed in triplicate and expressed as citric acid equivalent. Acidity was computed and expressed as percent citric acid

$$\%\ Acid = \frac{Titre\ value \times Normality \times M.eq.wt\ of\ Acid \times 100}{Volume\ of\ sample} \times 100$$

Milli-equivalent weight of citric acid is =0.06404

Total Soluble Solids (TSS) was determined by placing a drop of pineapple juice on the reading lens of Abbe refractometer and the probe adjusted to read the corresponding value. Readings were taken in triplicates after the refractometer was calibrated. A hunters lab chromameter was used for the colour analysis with the L*a*b* colour space used as physical parameters to measure the lightness (L), redness (a) and yellowness (b) of the samples. A standard white calibration curve plate was used to calibrate the calorimeter before taking the measurement in triplicates.

Data Analysis

The data obtained was statistically analyzed using Stats graphics plus, version 3.0 (Statistical graphics Corporation, STSC INC, U.S.A). Analysis of variance was done using multiple range test and LSD was used to assess differences between the varieties at 95% confidence level.

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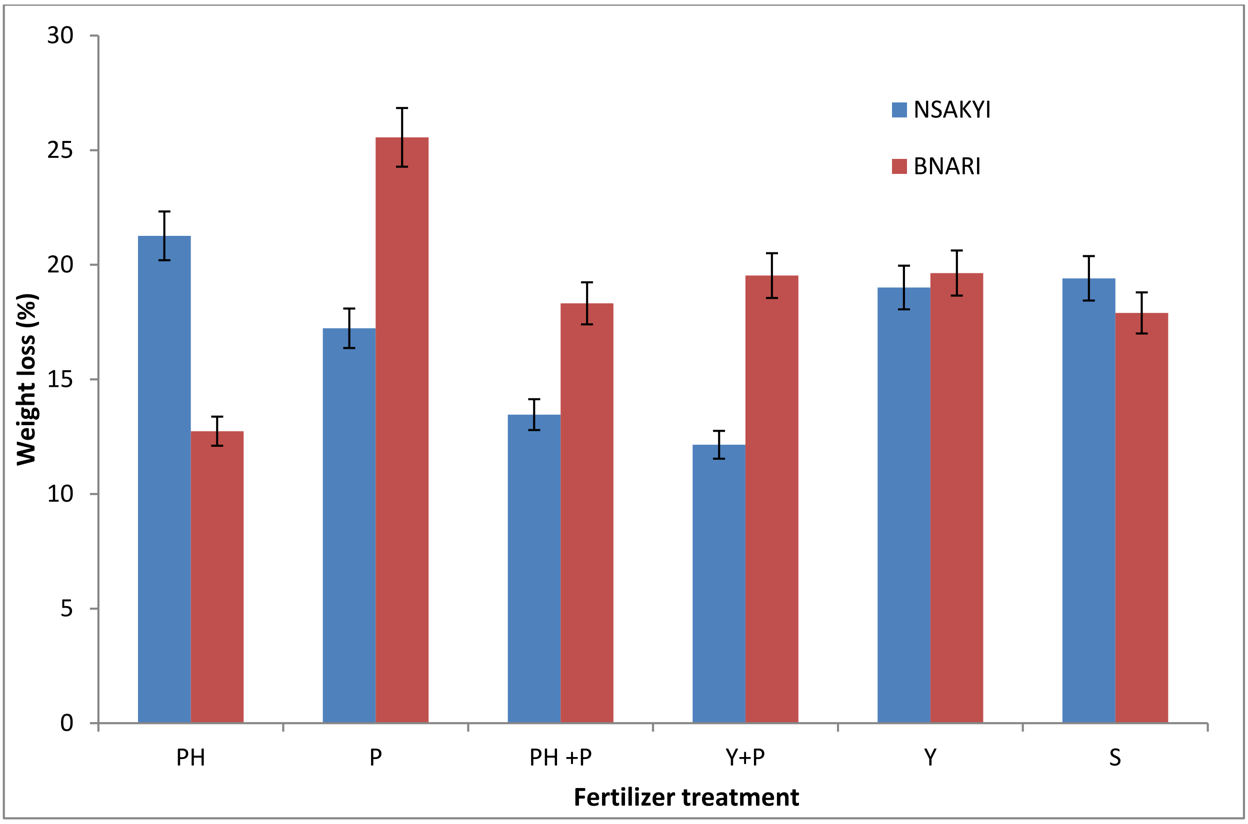
RESULTS

Physical Quality Analysis of Pineapple



Yara (Y), Phos-K, (PH), POME-(P), Yara+POME (Y+P), Phos-K+ POME (PH+P), Soil alone

Figure 1: Effect of organic fertilizers on weight loss (%) of Pineapples harvested from BNARI and Nsakyi farm

Pineapples sampled from Nsakyi farm recorded the highest weight loss (23.25±0.52%) for samples treated with NPK + AS and samples treated with Yara+ POME recorded the least weight loss of 17.23±0.39% (Figure 1).

Results of this study show that weight loss ranged between 12.74 ± 0.31 - 25.56 ± 0.62 % in over 15 days of storage for pineapples from BNARI farm (Figure 2). The highest weight loss was recorded in samples treated with POME (25.56 ± 0.62 %) and least weight loss for samples treated with Phos-K (Figure 2).

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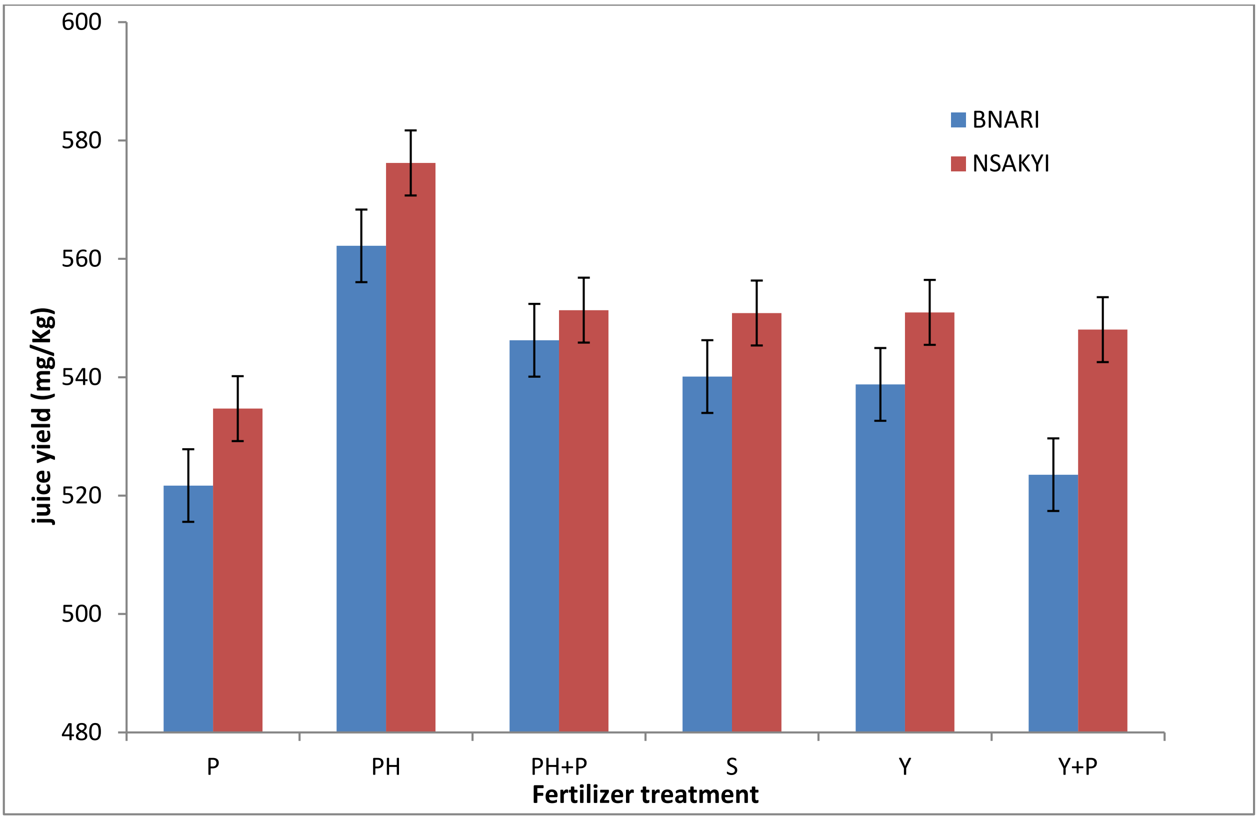

Yara (Y), Phos-K, (PH), POME-(P), Yara+POME (Y+P), Phos-K+ POME (PH+P), Soil alone

Figure 2: Effect of organic fertilizers on Juice yield (ml/Kg) of Pineapples harvested from BNARI and Nsakyi

The juice yield ranged from 534.70±2.42 - 576.20±2.91ml/kg and 521.7±2.42 - 562.20±2.91 for pineapples samples cultivated on Nsakyi and BNARI farm respectively (Figure 3). Juice yield was significantly higher in pineapples treated with Phos-K on both farm sites. Pineapple samples treated with POME on BNARI site recorded the least juice yield (534.70 ±2.42 ml/kg).

Chemical Analysis of pineapple

Table 1 shows chemical characteristics of pineapple from Nsakyi and BNARI farms. The pH of Pineapples from Nsakyi farm ranged from 3.90±0.01 - 4.22±0. Yara + POME recorded the lowest pH of 3.90 and control samples (soil only) recorded the highest pH of 4.22. pH ranged between 3.42±0.02 - 3.74±0.02 for Yara+Pome and Yara respectively for pineapples on BNARI farm. pH of pineapples in all the fertilizer treatments on Nsakyi farm were higher than treatments on BNARI farm

Titratable acidity for samples from the BNARI site ranged from 0.54±0.30-0.66±0.01 for Yara + POME and soil, respectively. TA for Nsakyi pineapples ranged between 0.49±0.08 – 0.66±0.33% for POME and soil respectively. The highest acidity (0.66) was recorded for both POME from Nsakyi farm and for control (soil only) from BNARI farm. Control samples without any fertilizer application (soil only) from Nsakyi farm site recorded the lowest acidity (0.49±0.08).

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Total soluble solids (17.1 ±0.11) was highest for Yara treated pineapples on BNARI farm. Samples treated with POME recorded the second highest TSS of 16.20% on Nsakyi farm.

Samples treated with Yara (17.1±0.11) recorded the highest TSS with Yara + POME treated pineapples recording the least (14.54±0.11).

The highest vitamin C (52.04±0.02mg/100g) was recorded for pineapples treated with Phos-K on Nsakyi farm.

Vitamin C was highest for Phos-K+Pome (51.24 ±0.02mg/100ml) for pineapples cultivated on BNARI farm. Vitamin C was significantly ($p<0.05$) different in all the fertilizer treatments for each farm. The highest vitamin C (52.04±0.02mg/100ml) was recorded for pineapples treated with Phos-K on BNARI farm.

Table 2 shows the L* a* b* colour values of pineapples from both BNARI and Nsakyi. Phos-K treated pineapples from BNARI farm which recorded the highest L* value of 47.16±2.63.

DISCUSSION

The weight loss signifies the loss of moisture from the pineapple over the storage time. Weight loss of 25.56 % was significantly higher ($p< 0.05$) for POME from BNARI farm compared to the other treatments. This general loss in weight reduces the juice content of the POME treated pineapples over the storage. The juice yield of samples treated with POME and Phos-K were significantly different ($p<0.05$) from samples treated with Phos-K+POME, Soil (control), Yara and Yara + Pome on BNARI farm. Generally juice yield for each fertilizer treatment at Nsakyi farm was higher than that of BNARI farm. Pineapple is more preferred for its juice than flesh and thus the volume of juice extractible/yield is of significant importance. Juice yield for samples treated with Phos-K from the two ecological sites were significantly higher than that of the other fertilizer treatments. This implies that irrespective of ecological differences in Nsakyi and BNARI farm sites, the application of Phos-K to pineapple at both sites significantly increased ($p<0.05$) the juice yield of pineapple. In a study by Spironello *et al.* [3], increases in nitrogen fertilizer application rates increased juice content of pineapple and an increase in potassium rates also increased pineapple yield and fruit size. In this study however, the application of POME did not significantly increase ($p>0.05$) juice yield. Pineapple treated with Phos-K, which is mainly composed of potassium recorded the highest juice yield for pineapples grown on both BNARI and Nsakyi farms. Potassium, the nutrient that accumulates in the largest amount in the plant, also influences productivity and development, although to a lesser extent than N. The application of POME which mainly contains nitrogen did not significantly increase ($p>0.05$) juice yield compared to all the other fertilizer treatment on both farm sites. The least juice yield was recorded for pineapples treated with POME than Phos-K which contains predominantly K. Since K increases fruit size, this also increases the fruit juice extracted from the fruits. In this study K form Phos-K significantly ($p < 0.05$) influenced the juice yield than N from POME. Juice yield from all the fertilizer treatments were generally higher than that of

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BNARI farm site. This could be due to the conducive climatic conditions for the cultivation of pineapples at the Nsakyi site (predominantly a pineapple producing area).

The pH values of pineapple to a significant extent reflect the microbial stability of the pineapple. The lower the acidity, the more susceptible the fruit is to microbial spoilage [6]. Fruit acidity decreases with fruit maturity and the higher the acidity, the higher the astringency and the longer the storage shelf life. Experimental studies have shown that increasing the amount of K increases the acidity [6]. pH of samples were significantly ($p<0.05$) different for the different fertilizer treatments. The pH for control samples was significantly ($p<0.05$) higher than the pH of all the other samples on Nsakyi. The different fertilizers applied to the pineapples significantly ($p<0.05$) affected the pH of pineapples on both Nsakyi and BNARI samples. The difference in ecological sites significantly ($p<0.05$) influenced the pH of the pineapples, and the pH of pineapples from Nsakyi were significantly ($p<0.05$) higher than that of BNARI farm. Citric acid recorded in samples treated with organic fertilizers were significantly ($p<0.05$) higher than samples without any treatment (soil only) at Nsakyi; it also recorded the lowest citric acid content.

Significantly high ($p<0.05$) vitamin C content was recorded for pineapples treated with Phos-K and Phos K+POME, than the other fertilizer treatments on BNARI farm and significantly high ($p<0.05$) vitamin C for Phos-K and Yara on Nsakyi farm. Teisson *et al*. [5] ascribed the benefit of increasing amounts of K to an increase in ascorbic acid in the fruit pulp and, in consequence contributing to a reduction of internal fruit darkening.

Significant ($p< 0.05$) differences in TSS were recorded for samples treated with organic fertilizers in both ecological sites and with the exception of pineapples treated with Phos-K +POME, the ecological sites significantly affected the TSS of pineapples. TSS is used as an indicator of fruit maturity and quality [20] and for pineapple it ranges between 10.8-17.5% [21] with very little variations between varieties. Soluble solids impact sweetness index than total sugars [22]. Increasing levels of nitrogen can result either in a reduction of the brix value or no significant ($p< 0.05$) changes in fruit sugar content [23], this is similar to results obtained from pineapple samples treated solely with POME (14.67 ± 0.23) and Yara +POME (14.54 ± 0.11) from the BNARI farm recorded significant ($p<0.05$) decreases in brix. Treatment with Yara, Yara + Pome, Phos-K + Pome and POME did not significantly ($p>0.05$) affect L* values of pineapple on BNARI farm. Lightness (L*) and yellowness (b*) for pineapple juice treated with Phos-K was significantly ($p<0.05$) higher than the other fertilizer treatments, indicating good visual appeal for sugar loaf pineapples. The lower the lightness L*value the higher the darkening of the internal pulp of the fruit and the lesser it's visual appeal and quality to consumers. L* values recorded for samples from BNARI farm were generally higher than that from Nsakyi farm.

CONCLUSION

Phos-K, in this study proved to be the best organic fertilizer for cultivating pineapple, because its utilization results in high juice yield high vitamin c and moderate acidity. Pome should not be used alone because it application caused significant weight loss and

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lower juice yield but in companion with other fertilizers like Phos-K or Yara because the combination of these two with POME produced pineapples with better quality in relations to TA, TSS and juice yield and Tristimulus colour L*. As per these findings farmers should be encouraged in adopting the use of organic fertilizers such as Phos-K or in combination with POME so as to cut down on the use of imported inorganic fertilizers because of the potential benefits of these fertilizers improving the quantity and quality of pineapple. There is the need for further studies on the application rates of Phos-K +POME for maximum yield and quality of pineapple.

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Table 1: Chemical quality analysis of pineapples treated with organic fertilizers from Nsakyi and BNARI farm

Fertilizer treatment	pH		TA		TSS		Vitamin C	
	Nsakyi	BNARI	Nsakyi	BNARI	Nsakyi	BNARI	Nsakyi	BNARI
P	3.92^{Ae} ±0.01	3.44^{Be}±0.02	0.66^{Aa}±0.03	0.64^{Ab}±0.01	16.2^{Aa}±0.00	14.7^{Bcd}±0.23	47.33^{Ab}±0.01	45.34^{Ac}±0.01
PH	4.10^{Ab} ±0.01	3.67^{Bb}±0.01	0.51^{Be}±0.03	0.59^{Ad}±0.12	15.3^{Bc}±0.12	16.2^{Ab}±0.15	52.04^{Aa}±0.02	49.98^{Aab}±0.01
PH+P	3.97^{Ad}±0.01	3.53^{Bc}±0.01	0.63^{Ac}±0.03	0.61^{Ac}±0.12	14.8^{Ad}±0.00	14.9^{Ac}±0.12	46.7^{Bc}±0.01	51.24^{Aa}±0.02
S	4.22^{Aa} ± 0.01	3.48^{Bd}±0.01	0.49^{Bf} ±0.08	0.66^{Aa}±0.06	15.8^{Bb}±0.00	16.0^{Ab}±0.12	42.67^{Ad}±0.01	45.37^{Ac}±0.03
Y	3.99^{Ac} ± 0.01	3.74^{Ba}±0.02	0.64^{Ab}±0.03	0.54^{Be}±0.30	15.7^{Bb}±0.12	17.1^{Aa}±0.11	51.67^{Aa}±0.01	42.67^{Bd}±0.01
Y+P	3.90^{Af} ± 0.01	3.42^{Be}±0.02	0.57^{Ad}±0.03	0.64^{Ab}±0.01	15.0^{Ad}±0.00	14.5^{Bd}±0.11	38.9^{Be}±0.01	48.61^{Ab}±0.01

PH, Titratable, Acidity (%) TA, Vitamin C (mg/100ml), Total Soluble Solids (%)-TSS indices of pineapples from BNARI and Nsakyi farms. The results are means of triplicates with a standard deviation for each response variable

-Mean values within a column for fertilizer treatment for each farm with same superscript (abcdef) are not significantly different (p>0.05) from each other

-Mean values across a row for each treatment between farms with same superscript (AB) are not significantly different (p>0.05) from each other

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Table 2: Tristimulus colour of pineapples treated with organic fertilizers from Nsakyi and BNARI farm

Fertilizer Treatment	L*		a*		b*	
	Nsakyi	BNARI	Nsakyi	BNARI	Nsakyi	BNARI
P	43.55^{Abc}±1.42	44.25^{Ac}±0.18	-1.82^{Bab}±0.40	-3.84^{Ab}±0.07	2.99^{Bcd}±0.80	8.22^{Ab}±0.15
PH	44.95^{Bab}±1.31	47.16^{Aa}±2.63	-2.13^{Bbc}±0.25	-4.32^{Aa}±0.36	3.79^{Ba}±0.44	11.16^{Aa}±1.14
PH+P	42.68^{Ac}±0.42	43.79^{Ac}±0.47	-1.72^{Ba}±0.16	-3.77^{Ac}±0.23	2.57^{Bd}±0.01	7.82^{Abc}±0.74
S	45.71^{Aa}±1.12	46.86^{Aab}±1.86	-1.93^{Babc}±1.11	-3.79^{Abc}±0.59	3.47^{Bab}±0.26	8.87^{Ab}±1.27
Y	42.95^{Bc}±0.58	44.69^{Abc}±0.28	-1.68^{Ba}±0.14	-4.38^{Aa}±0.29	2.54^{Bd}±0.28	10.62^{Aa}±0.21
Y+P	42.53^{Ac}±0.79	43.58^{Ac}±0.50	-1.89^{Babc}±0.10	-3.24^{Ad}±0.32	2.95^{Bcd}±0.23	6.58^{Ac}±1.18

Lightness (L), Redness (a*) and Yellowness (b*)*

-The results are means of triplicates with a standard deviation for each response variable.

-Mean values within a column for fertilizer treatment for each farm with same superscript (abcdef) are not significantly different (p>0.05) from each other.

-Mean values across a row for each treatment between farms with same superscript (AB) are not significantly different (p>0.05) from each other

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