

## Phosphorus Nutrition Provoked Improvement on the Growth and Yield of 'MD-2' Pineapple

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### ABSTRACT

Phosphorus (P) is one of the essential nutrients needed by plants in large amount. However, response of fruit crops to phosphorus application may vary depending on soil and climatic conditions of the area. Hence, this study was conceptualized to evaluate the growth, yield and fruit quality of 'MD-2' pineapple in response to varying rates of P under Aduyon clay soil in Bukidnon, Philippines. The experiment was laid out in a randomized complete block design (RCBD) with five amounts (0, 84, 127, 169 and 211 kg ha<sup>-1</sup>, respectively) of P as treatments with three replications. Results revealed that 'MD-2' pineapple growth was significantly influenced by P application. However, highest dose (211 kg ha<sup>-1</sup>) of P in Aduyon clay soil did not provoked significant P uptake of 'MD-2' pineapple. Instead, P uptake declined beyond 169 kg P ha<sup>-1</sup> application. Zn uptake of pineapple declined also as P applied in soil was beyond 169 kg P ha<sup>-1</sup>. Unpredictably, 'MD-2' pineapple plants starved with P still produced fruits (mean fruit mass of 1.28 kg) with a yield of 76.80 tons ha<sup>-1</sup>, however it could not be denied that higher doses of P ( $\geq 169$  kg ha<sup>-1</sup>) improved the fruit mass ( $\geq 1.42$  kg) as well as yield ( $\geq 96.92$  tons ha<sup>-1</sup>) of 'MD-2' pineapple. Fruit physico-chemical properties of 'MD-2' pineapple was not dependent on the amount of P applied in the soil. In general, 169 kg P ha<sup>-1</sup> was found as the optimal amount of P for 'MD-2' pineapple production in Aduyon clay soil.

*Keywords:* Aduyon clay, *Ananas comosus*, 'MD-2' pineapple, phosphorus, pineapple nutrition

### ARTICLE INFO

*Article history:*

Received: 12 November 2018

Accepted: 11 February 2019

Published: 30 May 2019

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### INTRODUCTION

Pineapple (*Ananas comosus* L.) ranks third in tropical fruit crops production next to banana and citrus. In the Philippines, pineapple ranks second produced major fruit crop next to banana (Philippine Statistics

Authority [PSA], 2017). “Smooth Cayenne” is the predominant pineapple cultivar grown in the Philippines. The said cultivar is ideal for fresh consumption as well as processing. It was in the late 1990’s when some local pineapple growers started to cultivate ‘MD-2’ pineapple. This pineapple cultivar has exceptional flavour making it ideal for fresh consumption than any other cultivars.

Pineapple is a perennial crop which demands high amount of nutrients. Hence, commercial pineapple production intended for export requires heavy fertilizer dosage. Moreover, it cannot be denied that different pineapple cultivars require varying amount of nutrients. Further, plant nutrition studies conducted to assess the growth and yield of crops focused mainly on the three primary nutrients (N, P and K). In pineapple, NPK fertilization researches were carried out in Smooth Cayenne (Spironello et al., 2004) and MD-2 (Sakimin et al., 2017) pineapple cultivars, respectively under varying soil types.

This study primarily focused only on phosphorus (P) fertilization level for ‘MD-2’ pineapple grown under Adtuyon clay soil in Bukidnon, Philippines. Adtuyon clay is the most extensive soil type covering almost exclusively the entire Bukidnon plateau (Philippine Council for Agriculture, Forestry and Natural Resources Research and Development [PCARRD], 2006). T. S. Castro (personal communication, November 8, 2013) stated that the physical and chemical properties of Adtuyon clay soil was ideal for pineapple production, except for P (4-10 ppm) which was below the

critical level (20 ppm). Garcia et al. (2017) recommended only two rates of P (138 kg hectare<sup>-1</sup> and 161 kg hectare<sup>-1</sup>) depending on the cultivars grown and soil classifications under Mexico condition.

This study was conducted to evaluate the growth of ‘MD-2’ pineapple in response to varying rates of P; assess the nutrient uptake of ‘MD-2’ pineapple applied with varying amounts of P; evaluate the yield and fruit quality of ‘MD-2’ pineapple in response to varying rates of P; and determine the optimum P fertilization level for the production of ‘MD-2’ pineapple under Adtuyon clay soil in Bukidnon, Philippines.

## MATERIALS AND METHODS

The research was carried out at Mt. Kitanglad Agricultural Development Corporation (MKADC), Lurugan, Valencia City, Bukidnon, Philippines with an elevation of 510 meters above sea level (masl). The soil was identified as Adtuyon clay. Based on laboratory analysis, soil texture was classified as clay. Soil pH was within the optimum range of growing pineapple. Extractable Ca and Mg were above the critical levels, whereas organic matter (OM), P and K of the experiment area were found below the critical levels (Table 1) for pineapple production.

Prior to the conduct of experiment, three months fallow period was employed in the particular research field. Harrowing of the experiment area was conducted twice at monthly interval. Deep plowing (mouldboard) then commenced one month

Table 1

*Soil physico-chemical properties of the experiment area prior to land preparation*

Depth (cm)	Texture	pH	OM (%)	P	K	Ca	Mg
-----ppm-----							
0-30	clay	5.49	1.68	7.98	187	430	151
31-60	clay	5.11	0.70	8.97	160	370	96
Mean	clay	5.30	1.19	8.48	174	400	199
Critical level <sup>1/</sup>	---	≤4.50 & ≥5.20	≤3.00	≤20	≤300	≤100	≤50

<sup>1/</sup>- Source: Malézieux and Bartholomew (2003)

after the last harrow activity. Raised beds with a height of 25-30 cm were established using a tractor-drawn mound implement.

The experiment was laid out in a randomized complete block design (RCBD) with five levels of P (0, 84, 127, 169 and 211 kg ha<sup>-1</sup>, respectively) as treatments as shown on Table 2. Each treatment was replicated into four with a total of 20 experiment units. Each experiment unit had an area of 26.8 m<sup>2</sup>. A total of 200 medium sucker (300 to 350 grams) were planted per experiment unit. The 100 suckers planted within the inner two raised beds served as the data plants, whereas the other 100 suckers planted within the outer two raised beds served as border plants. In this way, fertilizer treatment contamination from one experiment unit to the other was prevented.

Similar cultural management practices such as rate/timing of fertilizer application, pest/disease control, and flower induction treatment were employed to all treatments after planting except for the P levels which served as treatments. The five levels of P was applied in the form of triple superphosphate (0-46-0) as side band to pineapple plants at two months old after planting (2 MAP) and at 4 MAP. Other essential plant nutrients (462 kg N, 523 kg K, 223 kg Ca, 205 kg Mg, 24 kg Fe, 4 kg Zn, 3 kg B and 560 kg S kg ha<sup>-1</sup>, respectively) were applied through pre-plant application (dolomite), side band applications (ammonium sulphate, potassium sulphate and magnesium sulphate) and foliar applications (urea, iron sulphate, zinc sulphate, solubor, potassium sulphate and calcium boron) based on MKADC farm

Table 2

*Varying amounts of P which served as treatments*

Treatment description	Amount of applied P (kg ha <sup>-1</sup> )
0% P (Control treatment)	0
50% P of local pineapple grower practice (LPGP)	84
75% P of LPGP	127
100% P of LPGP	169
125% P of LPGP	211

*Note:* LPGP- MKADC commercial pineapple practice as of calendar year 2010 (T. S. Castro, personal communication, November 8, 2013)

fertilization program. Flower induction treatment (Ethrel + urea) was applied at 11.5 months after planting (MAP). As a standard practice in commercial pineapple production, degreening or fruit ripening solution (Ethrel + phosphoric acid) was applied 155 days after flower induction treatment. Fruits were harvested at shell color index 2-3. In this experiment, three harvest rounds were executed to clear all data fruits in all experiment units.

Data gathered includes:

1. Plant height - measurement of plant height was performed a day prior to flower induction treatment. Height (ground level to the tip of tallest leaf) of plant was measured using a measuring stick. Average plant height was computed using the formula (Valleser, 2019):

Plant height =

$$\frac{\sum \text{Plant height}}{\text{Number of data plants}}$$

2. Plant mass - this data was taken a day prior to flower induction treatment. Three representative plants from the border rows were pulled-out and weighed excluding the stem apex (below ground level). The mass of three representative plants served as baseline data in estimating the plant mass of data plants through visual examination. Average plant mass was computed using the formula (Valleser, 2019):

Plant mass =

$$\frac{\sum \text{Plant mass}}{\text{Number of data plants}}$$

3. D-leaf mass - D-leaf is the longest leaf of pineapple plant. 20 D-leaves from 20 randomly selected data plants were collected and weighed a day prior to flower induction treatment. Average D-leaf mass was computed using the formula (Valleser, 2018):

D-leaf mass =

$$\frac{\sum \text{D-leaf mass}}{20}$$

4. Crop nutrient level - this parameter was taken at flower induction treatment. 20 D-leaves were collected from randomly selected data plants per experiment unit. As a standard practice of MKADC, the middle 2/3 part (5 cm length) of the D-leaf was cut-off for N, Fe and B analyses. Likewise, the basal white portion (5 cm length) of the D-leaf was cut-off for P, K, Ca, Mg analyses. Three pineapple stem apices were collected and brought to plant tissue laboratory for Zn analysis. Nutrient analyses were performed by the laboratory technicians of the Biotechnology Research Services laboratory at Alanib, Lantapan, Bukidnon, Philippines.

5. Fruit mass - fruits with peel color index 2-3 based on MKADC pineapple color index guide were harvested. A total of five harvest rounds (3 days interval) were conducted to clear all fruits inside the data rows. All harvested fruits were weighed using a pre-calibrated weighing scale. Mean fruit mass was computed using the formula:

Fruit mass =

$$\frac{\sum \text{Fruit mass}}{\text{Number of data fruits}}$$

6. Yield - this parameter was expressed in tons hectare<sup>-1</sup>. Yield was computed using the formula:  
Yield = [(fruit mass, kg x planting density hectare<sup>-1</sup>) x (percent plant mortality ÷ 100)] x [1 ton ÷ 1000 kg]
7. Translucency rating - five samples per experiment unit per harvest round were utilized in this parameter. Fruits were cut vertically into halves. Translucency rating was determined using the hedonal rating scale as shown in Table 3 (Valleser, 2019):

Average translucency rating was computed using the formula:

Average translucency rating =

$$\frac{\sum \text{Translucency rating}}{\text{Number of fruit samples}}$$

8. Total soluble solids (TSS) - five samples per experiment unit per harvest round were utilized in this parameter. 10 mL of pineapple fruit juice was extracted and brix was measured using an Atago handheld refractometer following the guidance on objective tests to determine quality of fruits and vegetables and dry and dried produce (Organization for Economic Co-operation and Development [OECD], 2005; Valleser, 2019).
9. Titratable acidity (TA) - five samples per experiment unit per harvest round were utilized in this parameter. 10 mL pineapple juice was placed inside a beaker, and 2 mL of phenolphthalein solution was added. Titration then follows by adding a basic solution (0.1 N sodium hydroxide, NaOH) to the fruit juice until the color turns to

Table 3  
*Determination of translucency rating using the hedonal rating scale*

Translucency rating	Description	Remarks
1	No translucency	Good fruit for export
3	Translucence affecting ≤ 10 % of flesh	Tolerable for export
5	Translucence affecting ≤ 15 % of flesh	Tolerable for local
7	Fruits with translucence affecting > 15% of flesh	Reject

light red. The formula was then used to determine the TA in the form of citric acid (OECD, 2005; Valleser, 2019):

$$\text{TA} = [\text{volume (mL) of NaOH added} \times 0.1 \text{ (NaOH concentration)} \times 0.064 \times 100] \div \text{volume of juice (mL)}$$

10. TSS/TA- mean TSS and mean TA values of the fruits evaluated were used to determine this data. TSS/TA value was basically determined using the formula (OECD, 2005; Valleser, 2019):

$$\text{TSS/TA} = \text{mean TSS value} \div \text{mean TA value}$$

### Statistical Analysis

All data gathered were subjected to analysis of variance (ANOVA). Post hoc comparison between means was performed through Duncan's Multiple Range Test (DMRT) using the Statistical Package for Social Sciences (SPSS) 14.0 for Windows Evaluation software.

## RESULTS AND DISCUSSION

### Growth

Growth of 'MD-2' pineapple plants prior to flower induction treatment were found to be significantly influenced by the amount of phosphorus applied in the soil. An increasing height of 'MD-2' pineapple plant was noticeable with the increasing amount of phosphorus application (Figure 1). Tallest plants (106.55 cm) were those applied with 211 kg of P ha<sup>-1</sup>. In contrast,

no application of P resulted to the shortest height of pineapple plants (80.22 cm) among treatments. This result implies that the dearth phosphorus availability for 'MD-2' pineapple plants would cause underdeveloped plant growth. According to Malézieux and Bartholomew (2003), growth of all plant parts is reduced as a result of phosphorus deficiency although pineapple requires only little amount of the said essential nutrient. Based on local pineapple grower's experience, T. S. Castro (personal communication, November 8, 2013) stated that 'MD-2' pineapple plants should reach a minimum height of 90 cm prior to flower induction treatment to produce marketable fruits.

On the other hand, the heaviest plant (2.23 kg) was obtained with the application of 211 kg P ha<sup>-1</sup> treatment although comparable with the plant mass (2.16 kg) of 'MD-2' pineapple applied with 169 kg P ha<sup>-1</sup> (Figure 2). On the contrary, inferior plant mass (1.74 kg) was exemplified by 'MD-2' pineapple starved with phosphorus. Plant mass at flower induction treatment can be used as baseline to predict fruit size of pineapple. Correlation between plant mass and fruit mass can be as low as 0.4 in areas with warm nights and fast growth rates and can exceed 1.0 where irradiance is high and night temperatures are cool (Hepton, 2003).

'MD2' pineapple showed an increasing D-leaf mass as amount of phosphorus applied increases (Figure 3). A D-leaf is the youngest among the adult leaves of pineapple as well as the most physiologically active. Its mass is reflective of the readiness of pineapple for flower forcing and bases

for forecasting fruit mass. In 'Flhoran 41' pineapple, a D-leaf of 70 g is sufficient to get exportable fruits, whereas 80 g is the standard for "MD2" and "Smooth Cayenne"

(Fornier et al., 2007). Results of this study revealed that 'MD-2' pineapple not applied with phosphorus were the only plants having D-leaf mass (77.98 g) below 80 g.

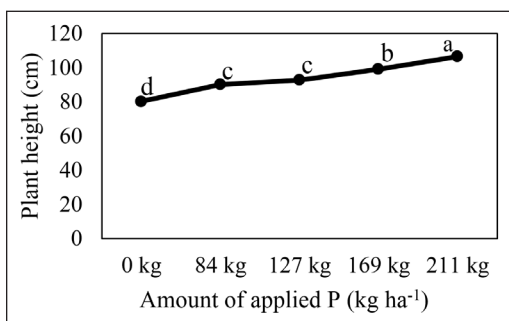


Figure 1. Plant height of 'MD-2' pineapple a day prior to flower induction treatment in response to varying amounts of applied P

Note: Data expressed in figures with same letter as superscript are not significantly different at 0.05 level DMRT

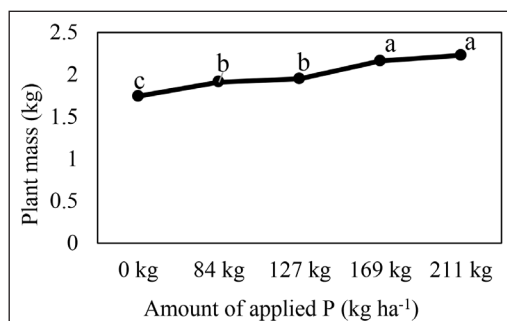


Figure 2. Plant mass of 'MD-2' pineapple a day prior to flower induction treatment in response to varying amounts of applied P

Note: Data expressed in figures with same letter as superscript are not significantly different at 0.05 level DMRT

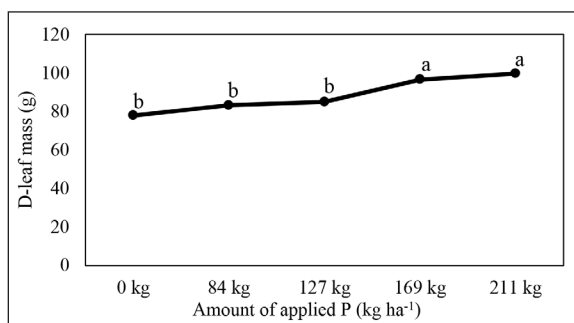


Figure 3. D-leaf mass of 'MD-2' pineapple plant a day prior to flower induction treatment in response to varying amounts of applied P

Note: Data expressed in figures with same letter as superscript are not significantly different at 0.05 level DMRT

## Nutrient Levels

Visual deficiency symptoms and critical nutrient levels are used to check the nutritional status of plants. In pineapple, the D-leaf is used because it is the only leaf that can be consistently identified and, as the youngest almost physiologically mature

leaf, it reflects current plant nutrient status with acceptable accuracy (Malézieux & Bartholomew, 2003).

Results indicate that all plants have sufficient nutrient levels at flower induction treatment except for nitrogen (Table 4). Nitrogen is very mobile in plants, hence

D-leaf tissue analysis is not preferred by pineapple growers to assess nitrogen level (T. S. Castro, personal communication, November 8, 2013). On the other hand, all treatment plants have comparable nutrient levels except for P and Zn.

Moreover, the highest P uptake (0.29%) was notable in plants applied with 169 kg P hectare<sup>-1</sup>. However, this result was comparable to 84 kg P hectare<sup>-1</sup> and 127 kg P hectare<sup>-1</sup> treatments which resulted to 0.28% and 0.27% P uptakes of plants, respectively. In contrary, the highest amount of P (211 kg P hectare<sup>-1</sup>) application resulted to least P uptake (0.21%) of 'MD-2' pineapple plants. Although P uptakes of all treatment plants were beyond the critical level (T. S. Castro, personal communication, November 8, 2013), results of this study revealed that plants not applied with P had higher P level at flower induction treatment compared to plants applied with the highest amount (211 kg hectare<sup>-1</sup>) of P. There could be other factors involved in this condition. Mourichon

(as cited in Malézieux & Bartholomew, 2003, p. 150) stated that mycorrhizal associations existed in pineapple roots. However, mycorrhizal fungi apparently do not contribute significantly to the P nutrition of pineapple, except where soil P is extremely low according to Aziz et al. (as cited in Malézieux & Bartholomew, 2003, p. 150). The soil analysis of the experiment area has low available P (8.48 ppm) based on soil analysis. Hence, it was hypothesized that the mycorrhizal fungi contributed to P nutrition of 'MD-2' pineapple plants. Conversely, excessive P (211 kg hectare<sup>-1</sup>) application in Adtuyon clay soil does not warrants increase in P uptake of 'MD-2' pineapple plants. Spironello et al. (2004) reported also that the addition of P fertilizer had a little effect only on the concentration of leaf P. Moreover, Garcia et al. (2017) suggested only two rates (138 kg hectare<sup>-1</sup> and 161 kg hectare<sup>-1</sup>) of P depending on the type of cultivars grown and soil classifications of the area in Mexico.

Table 4

*Nutrient levels of 'MD-2' pineapple plants a day prior to flower induction treatment as influenced by varying amounts of applied P*

Amount of applied P (kg ha <sup>-1</sup> )	Nutrient levels							
	-----%-----					-----ppm-----		
	N	P	K	Ca	Mg	Fe	B	Zn
0	0.70	0.25 <sup>b</sup>	4.77	0.18	0.24	97.59	20.72	86.57 <sup>a</sup>
84	0.72	0.28 <sup>ab</sup>	4.79	0.16	0.24	86.11	18.78	90.56 <sup>a</sup>
127	0.73	0.27 <sup>ab</sup>	4.33	0.17	0.23	94.68	19.80	85.18 <sup>ab</sup>
169	0.76	0.29 <sup>a</sup>	4.52	0.15	0.22	102.4	22.10	97.83 <sup>a</sup>
211	0.74	0.21 <sup>c</sup>	4.64	0.17	0.21	76.96	22.38	71.76 <sup>b</sup>
Critical level <sup>1/</sup>	1.00	0.20	3.50	0.10	0.20	80.00	10.00	36.00
Significance	ns	**	ns	ns	ns	ns	ns	*

<sup>1/</sup> critical nutrient levels adopted by MKADC farm as of calendar year 2010 (T. S. Castro, personal communication, November 8, 2013)

Mean(s) within same column with same superscript(s) is/are not significantly different at 0.05 level DMRT ns- not significant; \*- significant; \*\*- highly significant



With regards to Zn, the highest uptake (97.83 ppm) was remarkable in plants applied with 169 kg P hectare<sup>-1</sup>. This data was comparable to lower amounts (0, 84 and 127 kg hectare<sup>-1</sup>, respectively) of P applications. On the other hand, plants applied with the highest amount (211 kg hectare<sup>-1</sup>) of P have the lowest Zn level at flower induction treatment. Excessive application of P leads to Zn deficiency in pineapple (Malézieux & Bartholomew, 2003). However, results of stem apex analysis have shown that Zn uptakes of all treatment plants were beyond the critical level. Malézieux and Bartholomew (2003) suggested that a level of 36 ppm on a dry mass basis in the stem apex of pineapple would be associated with typical zinc-deficiency symptoms.

#### Fruit Mass and Yield per Hectare of 'MD-2' Pineapple Plants as Influenced by Varying Amounts of P Application

The heavier fruits (means of 1.42 kg and 1.44 kg) were obtained from plots applied with 169 and 211 kg hectare<sup>-1</sup> P

applications (Figure 4) although these fruit mass data were comparable to the mass of fruits harvested in plots applied with 0, 84 and 127 kg P hectare<sup>-1</sup>, respectively. In terms of yield per hectare (Figure 5), application of 211 kg P hectare<sup>-1</sup> resulted to the heaviest yield (98.28 tons hectare<sup>-1</sup>) of 'MD-2' pineapple. This yield was followed and statistically comparable with 169 kg P hectare<sup>-1</sup> treatment with 96.92 tons hectare<sup>-1</sup>. The pineapple plants starved with P produced the lowest yield (76.80 tons hectare<sup>-1</sup>) and was comparable to yields (80.91 and 83.16 tons hectare<sup>-1</sup>) obtained from plots applied with 84 kg P hectare<sup>-1</sup> and 127 kg P hectare<sup>-1</sup> treatments, respectively. Results indicate that 'MD-2' pineapple still produce fruits even without P in the fertilizer program under Aduyon clay soil. Spironello et al. (2004) reported that 'Smooth Cayenne' pineapple had slight response to P, despite its low availability in the soil. In this study, the yield differences of 21.48 tons hectare<sup>-1</sup> (between 211 and 0 kg P hectare<sup>-1</sup> treatments) as well as 20.12 tons hectare<sup>-1</sup> (between 211 and 0 kg P hectare<sup>-1</sup>

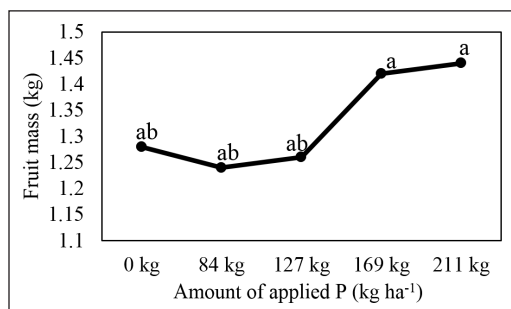


Figure 4. Fruit mass of 'MD-2' pineapple at harvest in response to varying amounts of applied P

Note: Data expressed in figures with same letter(s) as superscript are not significantly different at 0.05 level DMRT

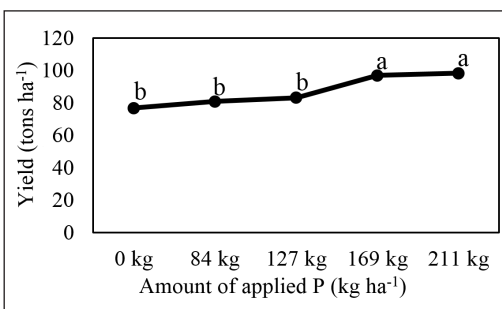


Figure 5. Yield per hectare of 'MD-2' pineapple in response to varying amounts of applied P

Note: Data expressed in figures with same letter as superscript are not significantly different at 0.05 level DMRT

treatments) would still be economical to commercial pineapple growers. Cost of P application can be compensated by the yield of 'MD-2' pineapple. In Jimma, Southwest Ethiopia condition, Tewodros et al. (2018) suggested the application of 134.8 kg hectare<sup>-1</sup> as the economical dose of P application.

### Fruit Physico-Chemical Properties of 'MD-2' Pineapple at Harvest as Influenced by Varying Amounts of P Application

Fruit physico-chemical properties of 'MD-2' pineapple at harvest in response to varying amounts of P revealed that translucency was not displayed by 'MD-2' pineapple

fruits in response to varying amounts of P applications (Table 5). On the other hand, TSS values ranged from 16.96-17.50, whereas TA values ranged from 0.47-0.50 and TSS/TA values ranged from 36.46-39.18. These values surpassed the market standard which requires only a minimum TSS value of 13, TA range value of 0.5-0.7 and TSS/TA range value of 20-40 ("Fresh fruit varieties", 2006). Results indicate that P nutrition has no significant effects on the fruit physico-chemical properties of 'MD-2' pineapple grown in Aduyon clay soil. This result was in line to the findings of Spironello et al. (2004) of which phosphorus had little importance in the fruit quality of 'Smooth Cayenne' pineapple.

Table 5

*Fruit physico-chemical properties of pineapple at harvest in response to varying amounts of applied P*

Amount of applied P (kg ha <sup>-1</sup> )	Physico-chemical properties			
	Translucency rating	Total soluble solids (TSS)	Titrateable acidity (TA)	TSS/TA
0	1	17.18	0.48	37.50
84	1	17.46	0.50	36.46
127	1	17.73	0.47	39.18
169	1	17.50	0.48	37.94
211	1	16.96	0.48	37.36
Market requirement <sup>1/</sup>	1	14.00	0.5-0.7	20-40
Significance	ns	ns	ns	ns

<sup>1/</sup> Source: "Fresh fruit varieties" (2006)

ns- not significant

### CONCLUSIONS

The application of 169 kg P hectare<sup>-1</sup> would result in optimum growth and yield of 'MD-2' pineapple under Aduyon clay soil in Bukidnon, Philippines. On the other hand, fruit physico-chemical properties of 'MD-2'

pineapple is not dependent on the amount of P applied in the soil. These results can be used as guide to commercial pineapple growers in order to have a sound decision making with regards to phosphorus fertilizer application.

## ACKNOWLEDGMENT

The author conveyed his sincere gratitude to Mt. Kitanglad Agricultural Development Corporation for funding this research. Engr. Tomy S. Castro, Mr. Roel R. Dayondon, MKADC-Technical Research Group technical assistants, data gatherers and field workers are likewise acknowledged for their significant contributions during the conduct of the research.

## REFERENCES

- Fresh fruit varieties. (2006). Retrieved November 8, 2018, from [https://www.daf.qld.gov.au/\\_\\_data/assets/pdf\\_file/0005/51449/Ch-7-Fresh-Fruit-Varieties.pdf](https://www.daf.qld.gov.au/__data/assets/pdf_file/0005/51449/Ch-7-Fresh-Fruit-Varieties.pdf)
- Fornier, P., Soler, A., & Marie-Alphonsine, P. A. (2007). *Newsletter of the pineapple working group*. Retrieved November 9, 2018, from <https://scholarspace.manoa.hawaii.edu/bitstream/10125/41082/1/PineNews%2014.pdf>
- Garcia, S. S., Lopez, D. J. P., Cruz, J. Z., Garcia, C. F. O., Espinoza, L. C. L., Estrada, M. C., ... Sánchez, S. C. (2017). Integrated system for recommending fertilization rates in pineapple (*Ananas comosus* (L.) Merr.) crop. *Acta Agronomica*, 66(4), 566-573. doi: <https://doi.org/10.15446/acag.v66n4.62257>
- Hepton, A. (2003). Cultural system. In D. P. Bartholomew, R. E. Paull, & K. G. Rohrbach (Eds.), *The pineapple botany, production and uses* (pp. 109-142). London, United Kingdom: CABI Publishing.
- Malézieux, E., & Bartholomew, D. P. (2003). Plant nutrition. In D. P. Bartholomew, R. E. Paull, & K. G. Rohrbach (Eds.), *The pineapple botany, production and uses* (pp. 143-165). London, United Kingdom: CABI Publishing.
- Organization for Economic Co-operation and Development. (2005). *International standardisation of fruits and vegetables: Guidance on objective tests to determine quality of fruits and vegetables and dry and dried produce*. Retrieved October 28, 2018, from [https://www.ble.de/SharedDocs/Downloads/EN/Nutrition-Food/Quality-Control/BestimmungFruechteEN.pdf?\\_\\_blob=publicationFile&v=1](https://www.ble.de/SharedDocs/Downloads/EN/Nutrition-Food/Quality-Control/BestimmungFruechteEN.pdf?__blob=publicationFile&v=1)
- Philippine Council for Agriculture, Forestry and Natural Resources Research and Development. (2006). *The Philippine recommends for soil fertility management: Philippine recommends series No-36-D*. Los Baños, Philippines: Philippine Council for Agriculture, Forestry and Natural Resources Research and Development.
- Philippine Statistics Authority. (2017). *Major fruit crops quarterly bulletin: October-December 2017*. Retrieved November 9, 2018, from [https://psa.gov.ph/sites/default/files/Major%20Fruitcrops%20Quarterly%20Bulletin%2C%20October%20-%20December%202017\\_0.pdf](https://psa.gov.ph/sites/default/files/Major%20Fruitcrops%20Quarterly%20Bulletin%2C%20October%20-%20December%202017_0.pdf)
- Sakimin, S. Z., Abu Samah, M. N. G., Juraimi, A. S., Alam, M. A., & Aslani, F. (2017). Effects of different type of fertilizers on growth and physiology of MD2 pineapple. *Bangladesh Journal of Botany*, 46(1), 489-495.
- Spironello, A., Quaggio, J. A., Teixeira, L. A. J., Furlani, P. R., & Sigrist, J. M. M. (2004). Pineapple yield and fruit quality effected by NPK fertilization in a tropical soil. *Revista Brasileira de Fruticultura*, 26(1), 155-159.
- Tewodros, M., Mesfin, S., Getachew, W., Ashenafi, A., & Neim, S. (2018). Effect of inorganic N and P fertilizers on fruit yield and yield components of pineapple (*Ananas comosus* Merr L. var. Smooth Cayenne) at Jimma, Southwest Ethiopia. *Agrotechnology*, 7(1), 1-6. doi: 10.4172/2168-9881.1000178.

- Valleser, V. C. (2018). Planting density influenced the fruit mass and yield of 'Sensuous' pineapple. *International Journal of Scientific and Research Publications*, 8(7), 113-119. doi: 10.29322/IJSRP.8.7.2018.p7919
- Valleser, V. C. (2019). Growth and fruit physico-chemical characteristics of 'MD-2' pineapple (*Ananas comosus* L.) at varying seedbed configurations. *Pertanika Journal of Tropical Agricultural Science*, 42(1), 377-386.