iGRC02010047

# The Relationship between Soil Properties and Climate on Quality of Geographical Indication "Phuket Pineapple" (*Ananas comosus*)

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## Abstract

The relationship between properties of soil and climate conditions on the quality (physicochemical properties) of Phuket pineapple was investigated. Fifteen fully ripe Phuket pineapples and soil samples were taken from 20 Phuket pineapple plantations in Phuket Province. Climate data was obtained from the Thai Meteorological Department. The results revealed that soil textures were sandy loam, sandy clay loam, and loam. Average values of soil pH, EC, OM, $NH_4^+$, $NO_3^-$, available P, K, Na, Ca, Mg, Fe, Mn, Cu, Zn, B, $Cl^-$ and S were 4.5, 0.038 dS/m, 2.30%, 39.2, 37.4, 35, 33, 9, 103, 14, 49.15, 6.35, 0.35, 0.56, 0.55, 14.19, and 17 mg/kg, respectively. Physical and chemical characteristics of 300 Phuket pineapples showed that mean weight, length, and width were 1,078 g, 16 and 11 cm, respectively. Most colors of ripe Phuket pineapple pulp, measured with R.H.S. System, were 13B, 13C, 12B, and 12A, when transformed to L, a and b system, they were 85, 6, and 63, respectively. The average firmness of the fruit was 8.42 N. Mean titratable acidity, pineapple juice pH, and total soluble solid (TSS) were 0.66%, 3.80, and 16%, respectively. Climate data, averages of temperature, relative humidity, air pressure, wind speed, annual precipitation, and overall precipitation, were 28.5°C, 75.2%, 1,009.1 hPa, 6.2 km/h, 2,935, and 4,421 mm, respectively. Simple and multiple linear regressions were applied to test any relationship between soil properties and climate conditions on the features of Phuket pineapple. Only Cu and TSS relation was found in SLR analysis with $R^2$ of 0.47 as the model presented TSS = 15.2838 + 2.0886(Cu). MLR further conducted also demonstrated the relationship between Na ($X_1$) and Cu ($X_2$) on TSS (Y) with $R^2$ of 0.62 as the model displayed TSS = 15.8163 - 0.0605(Na) + 2.1263(Cu). No relationship between all climate variables on physicochemical characteristics of Phuket pineapple was found.

**Keywords:** Phuket pineapple, Phuket, Geographical indication, Soil properties, Climate

## INTRODUCTION

Phuket pineapple, *Ananas comosus*, Queen Cultivar, one of the most economically and symbolically important plants grown particularly in Phuket Province, has been registered as a geological indication (GI) by the Department of Intellectual Properties since 26 October 2007; due to specification of the product when grown in Phuket area. Phuket pineapple uniquely features a sweet and slightly sour taste, aroma smell, low fiber, eatable crispy core with yellow texture (1). Phuket pineapple is not only grown in Phuket Province, but is also cultivated in Phangnga and Krabi Provinces, including other cultivated areas of Thailand such as Chumphon (Sawee variety), Trat (Tratsithong variety), Chiang rai (Phulae, most renowned Phuket pineapple cultivar grown outside Phuket), Phetchaburi (Phetchaburi 1) and Pattani (Pattani). All the pineapples grown outside Phuket Province have the same genotype characteristics of Queen group, but different in phenotype characteristics; (2,3) possibly depending on soil fertility, geography, climate condition, crossbreeding, *etc*..

Although the plant has been cultivated throughout Phuket Province, mostly in Thalang District, its product quality still varies primarily depending on soil fertility, climate condition, cultivation and management practices; for instance, altitude, soil texture, original plant nutrient in

soil, formula and amount of applied fertilizer, *etc*.. Due to high market demand, Phuket pineapple products are sometime inadequate, resulting from increasing number of domestic and international tourists each year. Phuket pineapple retailers will collect Phuket variety pineapples (called for Phuket pineapple grown outside Phuket area in accordance with GI regulation) leading to product quality problems. Phuket pineapple produced outside Phuket province is somewhat lower in quality than that produced in Phuket. For example, lower total soluble solid, lighter yellow color, and a less crispy core and texture, including fragrance. This possibly results from the differences in soil properties, climate condition, as well as cultivation practice, especially in regards to the method of fertilizer application. However, its product price is cheaper.

Little knowledge is known or provided on the soil properties used to grow Phuket pineapple. Most of them are grown in the 1st to 3rd year of rubber tree plantations (Figure 1a) then moved to other new rubber tree plantations. Only few owners have their own lands and repeat their crop production. In the last decade, rubber tree gardens in Phuket are decreasing dramatically in favor of construction serving the expanding tourism industry.

Knowledge of physical and chemical characteristics of soil, including climate information relating to the quality of Phuket pineapple product, will be useful for pineapple farmers to improve planting practices to get higher quality product, or at least similar quality attribute of fruit through Phuket pineapple farms. Furthermore, it will provide specific data to registered GI Product and can be used to enhance its product quality when grown outside Phuket area.

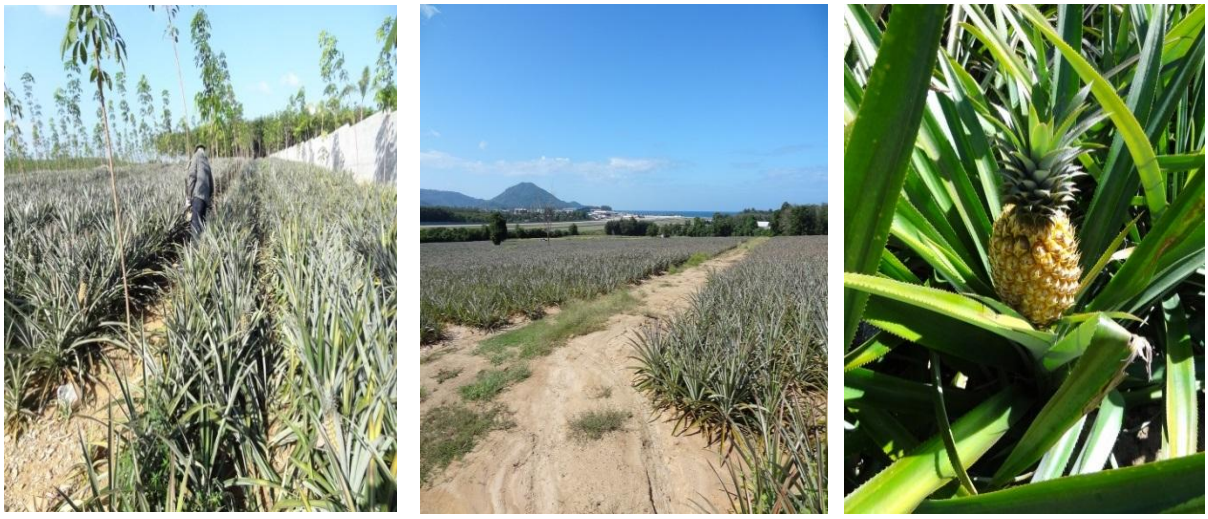
Therefore, the aims of this study are 1) to examine soil properties, Phuket pineapple characteristics, and climate condition for growing the Phuket pineapple 2) to see whether or not there is a relationship between physical and chemical properties of soil and climate condition effecting or relating to the physical and chemical features of Phuket's most famous fruit 3) to support GI product data 4) to improve Phuket pineapple cultivation and management practices inside and outside Phuket Province.

## MATERIALS AND METHODS

### Soil and Phuket pineapple sampling

Soil and Phuket pineapple samples, taken only in Thalang District at the time (no Phuket pineapple farm found in Kathu District and only one pineapple farm existed in Muang District, but it was not in a ripening stage), were collected from 20 Phuket pineapple plantations.

15 fully ripe Phuket pineapple samples (Figure 1c) were obtained from each pineapple farm (Figure 1a,1b)



(a) (b) (c)

**Figure 1** (a) Phuket pineapple grown in 1st to 3rd year of rubber tree; (b) not grown in rubber tree

(c) Fully ripe Phuket pineapple

Soil samples were taken at the base of the harvested pineapple plants (total 15 points in each farm) at the depth of 15-20 centimeters (Figure 2).

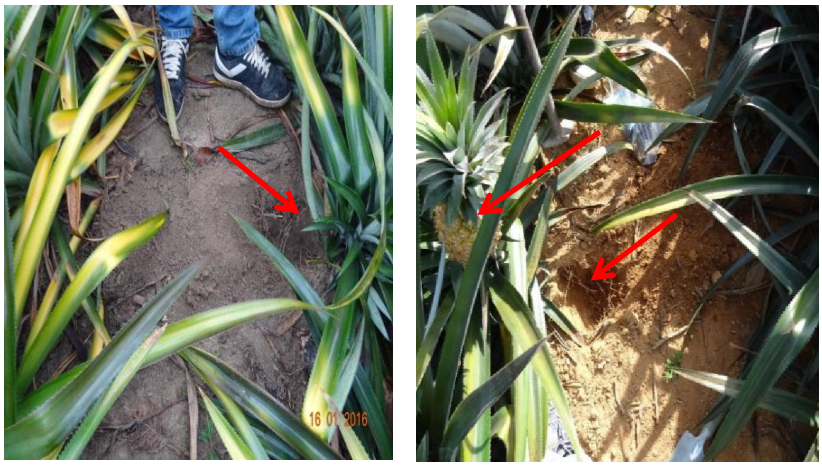



**Figure 2** Collecting soil sample at the base of harvested Phuket pineapple plant.

**Soil testing and preparation**

All soil samples collected from each pineapple cultivation were mixed thoroughly and air-dried to make a composite sample. Dried, pulverized, and sieved soil samples were determined for the following physical and chemical properties; texture (hydrometer) (4); pH (soil:water, 1:1) (5); lime requirement (Woodruff's method) (6); electric conductivity (soil:water, 1:5) (7); organic matter (Walkley-Black method) (4); extractable ammonium and nitrate (2N KCl/Kjeldahl method) (8); available phosphorus (Bray II) (9); exchangeable Ca, Mg, Na, K (1 $NH_4OAc$, pH 7 extraction) (4); extractable Fe, Mn, Cu, Zn (DTPA method) (4); extractable B (Hot water/Azomethine method) (10); extractable S ($CaH_4(PO_4)_2 \cdot H_2O$ method) (4); extractable chloride (water extraction) (11).

**Determination of Phuket pineapple quality**

Fully ripe Phuket pineapples, 15 fruits/farm, were measured and analyzed for weight, size, firmness (penetrometer), color (RHS Color Chart) (12), total soluble solid (TSS) (refractometer), juice pH (pH meter), and titratable acidity (TA) (AOAC 942.15 method) (13).

**Climate Data**

Climate data comprising of temperature, relative humidity, air pressure, wind speed, annual precipitation, and overall precipitation covering a growth period (year 2014 to 2016) of sampled pineapple plants were acquired from the Phuket Airport Observing Station, Thai Meteorological Department.

**Data Analysis**

Soil, climate, physical and chemical components of Phuket pineapple data were averaged across the two replications (except for climate data). Relationships between soil and/or climate data and physical on chemical characteristics of Phuket pineapple were tested with simple and multiple linear regressions. Assumption violations of a linear regression were also tested before fitting a

regression model using a residual plot, Cook's distance, DFITTS, DFBETAS and Variance Inflation Factor (VIF). Any assumption violated will be fixed with data transformation or alternative statistics. Variable selection using sequential variable selection techniques (forward selection, backward elimination and stepwise regression) was further conducted and followed by a model selection among all subset using the Cp statistic and coefficient of determination ($r^2$). The best multiple linear regression model will be chosen to predict the characteristics of Phuket pineapple (y as a function of explanatory X variable, dependent variable) that are related to soil and/or weather condition variables (depending on what x variables are chosen for the model) (14,15). All statistical analyses were performed with the SAS statistical analysis software.

**RESULTS AND DISCUSSION**

Mean values of the physical and chemical characteristics of the soil used for growing Phuket pineapple plant were as follows; **soil textures** were sandy loam, sandy clay loam, and loam suitable for pineapple growth due to well-aerated soil; **soil pH** was 4.5 with no lime requirement due to high tolerance to low pH of the plant. It is corresponding with the research reporting that the Queen Cultivar can be grown on tropical peat soil where a pH of 2.8 without a symptom of nutrient deficiency (16). Phuket pineapple grew well in acidic soil in which pH ranged from 3.8 to 6.0, mostly below 5, however, raising soil pH to 5.5 or at least 5.0 with lime materials would favor the availability of plant nutrient; **electrical conductivity** was 0.038 dS/m; **organic matter** content was 2.30% indicating low level in cultivated soil compared to 3.75% of Phuket (Pk) Series, regular dressing with animal manure or returning crop residues to the field are an effective way to improve it; nitrogen content, as **ammonium and nitrate**, were 39.2 and 37.4 mg/kg, respectively, the amount of both forms of nitrogen were lower than the suitable level (120 mg/kg) (17), nevertheless, no N deficiency symptom was found; **available phosphorus** was 35 mg/kg, unlike other plants, pineapple needs comparatively low phosphorus and its content in most soil was adequate for the pineapple plant; **exchangeable basic cation** concentrations, comprising of K, Na, Ca, and Mg, were 33, 9, 103, and 14 mg/kg, respectively, the levels of potassium and magnesium were not favorable for pineapple cultivation, they were below minimum requirement level (150 mg/kg) with an improper ratio of K and Mg (should not be greater than one) (17), although, Ca concentration in soil was suitable for plant; **basic micronutrient values**, composing of Fe, Mn, Cu, and Zn, were 49.15, 6.35, 0.35, and 0.56 mg/kg, respectively, concentrations of Fe and Mn in soil were appropriate for pineapple planting, no optimum levels of Cu and Zn in soil have been reported; **anion micronutrient** concentrations of extractable B, $Cl^-$ and S were 0.55, 14.19, and 17 mg/kg, respectively, less information available on optimum content or impact on productivity or quality of pineapple.

Physicochemical data of Phuket pineapple indicated that mean **weight**, **length**, and **width** of 300 Phuket pineapples were 1,078 g, 16 cm and 11 cm, respectively; the color codes of fresh-cut, ripe Phuket pineapples, measured with the R.H.S. System (5th Edition) were 13B, 13C, 12B, and 12A. They were among the most color code of fully ripe Phuket pineapple found in Yellow-orange-red group of the R.H.S. System. The color codes of the R.H.S. System were then transformed to the international color system, CIE Lab, and mean values of L, a, and b, were 85, 6, and 63, respectively; **firmness** was also analyzed in 3 positions, top, middle and bottom of the fruit. The mean firmness of three positions on the fruit were 9.91, 8.24, and 7.12 N, respectively, and the grand mean was 8.42 N; means of **titratable acidity (TA)**, **juice pH** and **total soluble solid** (TSS) were 0.66%, 3.80, and 16%, respectively.

According to physicochemical data it revealed that the quality of the fruit even grown in Phuket Province were still different, for instance, TSS ranged from 13.6 to 21.2$^o$ Brix and the GI standard of Phuket pineapple's sweetness is 17 to 20 $^o$ Brix. To improve the quality of GI product and maintain fruit quality, management practices such as new fertilizer program, soil and water management appropriate for individual pineapple producing region, should be adopted.

Climate data, averages of temperature, relative humidity, air pressure, wind speed, annual precipitation and overall precipitation were 28.5$^o$C, 75.2%, 1,009.1 hPa, 6.2 km/h, 2,935 mm, and 4,421 mm, respectively. Effects of climate on growth in pineapple are well described in many texts or research

articles. Temperature, rainfall and water, light intensity, and wind are among the most important climate factors influencing pineapple growth (18). All climate variable values were in optimum condition for Phuket pineapple cultivation.

There was one relationship found between soil properties, Cu (X variable) and chemical characteristics of Phuket pineapple, TSS (Y variable), implying that Cu variable can be used to predict TSS when tested with a simple linear regression (SLR) at the probability of 0.01 and the coefficient of determination ($R^2$) was 0.47 as a simple linear regression model presented below

$$\mathbf{TSS = 15.2838 + 2.0886(Cu)}$$

Multiple linear regression (MLR) was applied to see if there was a relationship between multiple chemical and physical properties of soil and/or weather condition (X variables), on quality of fruit product (in term of chemical and physical characteristics, Y variable). It turned out the relationship between multiple X variables, Na (X1) and Cu (X2) on TSS (Y) ($p<0.01$) with coefficient of determination ($R^2$) of 0.62 meaning that TSS (highly correlated with sweetness) of the fruit is controlled by the concentrations of Na and Cu in soil as a multiple linear regression model displayed below

$$\mathbf{TSS = 15.8163 - 0.0605\ (Na) + 2.1263\ (Cu)}$$

No relationship between all climate variables and physical and chemical features of Phuket pineapple was found ($p>0.05$).

An unexpected result came from the relationship between Na and Cu on TSS of the fruit when tested with simple and multiple linear regression analysis. An increase in 1 unit of Na results in decrease in 0.0605 unit of TSS, on the other hand, an increase in 1 unit of Cu will increase in 2.0886 units of TSS as a multiple regression model described earlier. Normally, sweetness or total sugar in fruit (in term of TSS due to high correlation between TSS and total sugar) is related to K concentration (19, 20), therefore, further study should be done on this issue.

No relationship between climate and the quality feature of Phuket pineapple was found in this study. This possibly results from the optimum condition of all climate variables during the research period.

## CONCLUSIONS

Most of physical and chemical properties of soil used for pineapple cultivation in Phuket Province were appropriate for plant growth, except for some parameters such as potassium, magnesium, nitrogen, and organic matter still lower than minimum plant requirement. More application of those plant nutrients would be favorable to plant growth, yield, and fruit quality, furthermore, the ratio of plant nutrient elements, one of the essential factors in plant cultivation, K/Mg and Ca/Mg, were not proper in term of plant uptake.

The quality of Phuket pineapple grown in Phuket Province differed in some parameters. This should be done by strictly following GI manual for growing pineapple plant.

All climates were optimum for plant growth at the time of study. No relation between fruit quality and climate was found.

There was a positive relationship between TSS and Cu in the SLR model as shown below.

$$\mathbf{TSS = 15.2838 + 2.0886(Cu)} \qquad \mathbf{r^2 = 0.47} \qquad \mathbf{(p<0.0009)}$$

Multiple linear regressions analysis confirmed that two X variables (Cu and Na) can be used in the MLR model to predict TSS, but the relationship of both X variables on TSS is opposite. It is a

positive relationship between Cu and TSS, in other words, the negative relationship between Na and TSS as the model presented below

$$\mathbf{TSS = 15.8163 - 0.0605\,(Na) + 2.1263\,(Cu) \quad r^2 = 0.62 \quad (p<0.0003)}$$

Based on the findings of this research we possibly sweeten Phuket pineapple by adding Cu in Phuket pineapple soil. However, further study particularly in field should be done.

## ACKNOWLEDGEMENTS

The authors gratefully acknowledge the National Research Council of Thailand for its financial support and Phuket Rajabhat University for giving the opportunity to pursue the research, Mr.Chalee Sittabut, Head of Strategy and Information Section, Phuket Provincial Agricultural Extension Office, for pineapple farmer information and useful guidance. Dr.Siriwan Dangcham, Facultyof Agricultural Technology, Phetchaburi Rajabhat University, for method advice. Statistical guidance provided by Dr.Teerawat Simmachan, Department of Mathematics and Statistics, Thammasat University, is also highly appreciated. We are very grateful for the kindness of all Phuket pineapple owners providing soil and pineapple samples, including useful information. Special thanks are expressed to our family for understanding and encouragement.

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