

Role of Soil Conditions and Agronomic Practices on Disease Incidence and Yield of Pineapple (*Ananas comosus* L.) in Hoa Luu Commune, Can Tho City, Vietnam

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Abstract This study investigated the influence of soil conditions and agronomic practices on disease incidence and yield of pineapple (*Ananas comosus* (L.) Merr.) grown on acid sulfate soils in Hoa Luu commune, Can Tho City, Vietnam. A survey of 78 farming households was conducted from December 2024 to March 2025, collecting data on drainage systems, fertilization practices, disease occurrence, and yield. Descriptive statistics and Chi-square tests were used to analyze relationships among variables. Results showed substantial variation in cultivation practices. About 33.3% of orchards had poor drainage due to low ridge height and shallow ditches, while 66.7% of households applied imbalanced fertilization, mainly deficient in phosphorus and potassium. Waterlogged acidic soil was significantly associated with higher disease incidence, with 76.9% of affected orchards reporting soil-related diseases, compared to 35.3% in well-drained systems ($p < 0.05$). Similarly, nutrient imbalance was linked to increased disease occurrence ($p < 0.05$). Yield analysis indicated that poorly drained orchards had a higher proportion of low yields, whereas well-drained systems achieved greater productivity ($p < 0.01$). Balanced fertilization also contributed to improved yields ($p < 0.05$). These findings highlight the importance of improving drainage systems and adopting balanced fertilization to enhance pineapple productivity and sustainability.

Keywords Acid sulfate soils, Agronomic practices, Pineapple productivity

1. Introduction

Pineapple (*Ananas comosus* (L.) Merr.) is an important tropical fruit crop widely cultivated in many countries and plays a significant role in the livelihoods of farmers, particularly in areas with constrained agricultural conditions. In the Mekong Delta of Vietnam, pineapple is commonly grown in low-lying regions where acid sulfate soils are prevalent. These soils provide opportunities for agricultural production but also present considerable challenges in soil and water management [1,2].

Acid sulfate soils are characterized by low pH, high concentrations of active iron and aluminum, and seasonal fluctuations in groundwater levels. These conditions adversely affect plant growth, especially for species with shallow root systems and sensitivity to anaerobic conditions [3,4]. Under climate change conditions, the frequency and intensity of waterlogging in lowland areas are increasing, further exacerbating the constraints of these soils and negatively

impacting perennial fruit production systems [5].

For pineapple cultivation, soil conditions and water management play a fundamental role in shaping the root environment, influencing nutrient uptake, and determining the occurrence of physiological disorders and soil-related diseases. Previous studies have indicated that inappropriate ridge-ditch systems, particularly low ridges and poor drainage, are strongly associated with increased root diseases and reduced yields [1,6]. In addition, fertilization practices in acidic and acid sulfate soils often tend to favor nitrogen while lacking a balanced supply of essential nutrients such as phosphorus and potassium, leading to reduced fertilizer efficiency and weakened plant resilience [7].

Although the effects of soil conditions and agronomic practices on pineapple growth and productivity have been widely discussed, field-based studies that simultaneously integrate soil conditions, farming practices, disease incidence, and yield at the household scale remain limited, particularly under acid sulfate soil conditions in the Mekong Delta. Therefore, a comprehensive assessment of these interacting factors is necessary to provide a scientific basis for improving pineapple production systems.

Based on this context, the present study was conducted to:
(i) evaluate soil conditions and pineapple farming systems

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in Hoa Luu commune, Can Tho City; (ii) analyze the relationships between soil conditions, agronomic practices, and soil-related disease incidence; and (iii) assess the relationships between these factors and pineapple yield. The findings are expected to contribute to the development of appropriate soil management and agronomic strategies, thereby improving the efficiency and sustainability of pineapple production on acid sulfate soils.

2. Materials and Methods

2.1. Time and Location

The study was conducted in pineapple-growing areas in Thanh Thang hamlet, Hoa Luu commune, Can Tho City. This area is characterized by acid sulfate soils and a ridge-ditch farming system adapted to seasonal hydrological fluctuations. Within this system, ridge structure and drainage capacity are considered fundamental factors influencing the root environment, thereby affecting pineapple growth and the occurrence of soil- and moisture-related diseases.

Data were collected from December 2024 to May 2025.

2.2. Research Design and Sampling

The study targeted households cultivating pineapple (*Ananas comosus* (L.) Merr.) in the selected area. A total of 78 households were included in the survey, representing the most recent production cycle. Households were selected using purposive sampling to ensure variability in orchard age, ridge height, drainage conditions, and applied agronomic practices.

A sample size of 78 households was considered sufficient for descriptive analysis and group comparisons using Chi-square tests. In farm-level survey studies, such a sample size is generally acceptable when the objective is to describe patterns and analyze relationships among variables rather than estimate population parameters [8,9,10].

2.3. Data Collection on Soil Conditions and Agronomic Practices

Information related to soil conditions and agronomic practices was collected through direct interviews with farmers. The recorded data included ridge height, characteristics of the drainage system, fertilizer use history, and application rates during the production year.

Fertilizer inputs were standardized to kg/ha/year. Based on the types of fertilizers used, nutrient balance was classified into two groups: *imbalanced* (deficient in phosphorus and/or potassium) and *relatively balanced*.

Based on ridge height relative to water level and drainage ditch depth, drainage capacity was classified into three levels: poor, moderate, and good. Specifically, the poor drainage group included orchards with ridge height ≤ 0.4 m and/or ditch depth ≤ 1.0 m; the moderate group had ridge height from 0.4–0.6 m and ditch depth from 1.0–1.5 m; and the good drainage group had ridge height > 0.6 m and ditch

depth > 1.5 m.

2.4. Disease Assessment

The status of diseases in pineapple was recorded through farmer surveys at the time of investigation. Disease assessment was based on farmers' descriptions of field symptoms collected during interviews and field observations. Reported symptoms were cross-checked using common symptom descriptions provided in pineapple disease diagnostic references and extension documents, particularly for leaf tip dieback and root rot symptoms associated with poorly drained soils and prolonged moisture conditions [11,12]. However, no laboratory-based pathogen identification was conducted; therefore, the results should be interpreted as indicative rather than definitive disease diagnosis.

2.5. Determination of Pineapple Yield

Pineapple yield was recorded based on the number of fruits harvested per unit area in one year, reflecting the production performance of orchards under low-pH environments. This indicator was used to classify yield levels and compare among groups of households with different soil conditions and agronomic practices. Yield categories were established based on the observed distribution of production levels among surveyed households and local cultivation practices in the study area. Orchards producing fewer than 5,000 fruits/ha/year were classified as low yield, those producing 5,000–15,000 fruits/ha/year as medium yield, and those exceeding 15,000 fruits/ha/year as high yield. This classification was intended to facilitate comparative analysis among cultivation conditions rather than to define universal production standards.

2.6. Data Processing and Analysis

After collection, data were compiled and processed using descriptive statistical methods to determine the distribution of cultivation factors, disease incidence, and pineapple yield levels in the study area. In addition, the Chi-square (χ^2) test was used to evaluate the relationships between drainage capacity and nutrient balance with disease incidence and pineapple yield. Before conducting Chi-square analysis, contingency tables were examined to ensure that expected frequencies satisfied the assumptions required for categorical analysis. All analyzed tables met the minimum expected frequency requirements for application of the Chi-square test.

Data were initially compiled using Microsoft Excel and subsequently analyzed using R software (R Core Team).

3. Results and Discussion

3.1. Characteristics of Soil Conditions and Pineapple Farming Systems

The survey results indicated that soil conditions and ridge-ditch systems in pineapple orchards in Hoa Luu commune varied markedly (Table 1). Although most households had medium to large production scales, ridge structure and drainage

capacity, two factors determining the root environment, differed considerably among orchards.

A large proportion of orchards had low ridge heights (≤ 0.4 m), while the proportion of orchards with ridge heights above 0.6 m was relatively small. At the same time, many orchards had shallow drainage ditches or ditches with limited dimensions. When combining the criteria of ridge and ditch characteristics, approximately one-third of the orchards were classified as having poor drainage capacity. The Chi-square test indicated that the distribution of drainage capacity groups was uneven and statistically significant ($p < 0.05$).

Under the acid sulfate soil conditions characteristic of the study area, drainage capacity is considered a fundamental factor affecting crop growth. Previous studies have indicated that low ridges and waterlogging in lowland acidic soils restrict the root environment and increase the risk of soil-related physiological disorders [2,3,4]. Therefore, the differences in drainage capacity among pineapple orchards observed in this study reflect a structural limitation of the local farming system.

In addition to ridge-ditch structure, supporting measures such as windbreaks and bunds also varied among households, reflecting differences in investment levels and soil management experience. However, these factors mainly played a supporting role and did not alter the overall pattern of variation in drainage capacity among orchards.

Overall, the results indicate that soil conditions and ridge-ditch systems in pineapple cultivation in the study area still present several limitations, particularly regarding ridge height and drainage capacity. These characteristics provide an important basis for analyzing the relationships between soil conditions, disease incidence, and pineapple yield in the following sections, consistent with findings reported in previous studies on crop cultivation in acid sulfate soils [2,3].

Table 1. Characteristics of soil conditions and ridge-ditch systems in surveyed pineapple orchards

Indicator	Category	Percentages (%)
Pineapple area (m ²)	< 5,000	29.5
	5,000 – 10,000	41.0
	> 10,000	29.5
Ridge height (m)	≤ 0.4	48.7
	0.4 – 0.6	38.5
	> 0.6	12.8
Ditch depth (m)	≤ 1.0	35.9
	1.0 – 1.5	46.2
	> 1.5	17.9
Drainage capacity	Poor	33.3
	Moderate	44.9
	Good	21.8
Windbreak trees	No	61.5
	Yes	38.5
Bund presence	No	26.9
	Yes	73.1

3.2. Fertilization Practices and Technical Management

The survey results indicated that fertilization practices and the application of agronomic measures in pineapple cultivation in the study area varied markedly among households (Table 2), reflecting differences in nutrient management and technical investment. Most households applied fertilizers 4–6 times per year, indicating a tendency to split fertilizer applications to meet the nutrient requirements of pineapple at different growth stages.

Regarding fertilizer types, nitrogen fertilizers and NPK formulations with high nitrogen content were commonly used, whereas the proportion of households applying phosphorus and potassium separately remained limited. When aggregating fertilizer types used during the year, approximately two-thirds of households were classified as having imbalanced nutrient management, mainly due to deficiencies in phosphorus and/or potassium. The Chi-square test showed that the distribution between imbalanced and relatively balanced nutrient groups was uneven and statistically significant ($p < 0.01$).

Under acidic and acid sulfate soil conditions, imbalanced fertilization practices, particularly those favoring nitrogen, are common and have been reported in various cropping systems [4]. Deficiencies in phosphorus and potassium may restrict root development and reduce plant tolerance to environmental stresses.

Table 2. Characteristics of fertilizer use and agronomic practices in pineapple cultivation in the surveyed area (n = 78)

Indicator	Category	Percentage (%)
Total number of fertilizer applications times/year	≤ 3	25.6
	4–6	53.8
	> 6	20.6
Main fertilizer type	Nitrogen fertilizer (Urea/DAP)	71.8
	Compound NPK	59.0
	Phosphorus fertilizer	17.9
	Potassium fertilizer	10.3
Nutrient balance*	Imbalanced (deficient in P/K)	66.7
	Relatively balanced	33.3
Common NPK formulations	30–10–10	32.1
	25–25–5	23.1
	30–30–10	20.5
	Others	24.3
Total fertilizer cost (VND/ha/year)	< 10 million	38.5
	10–15 million	44.9
	> 15 million	16.6

Note: Indicators were compiled from household survey data and standardized per hectare per year. Nitrogen fertilizers include urea and DAP. Nutrient balance was determined based on whether nitrogen, phosphorus, and potassium fertilizers were applied simultaneously within the production year.

For pineapple, previous studies have indicated that balanced nutrition among nitrogen, phosphorus, and potassium contributes to stable growth and improved nutrient use efficiency, especially under acidic soil conditions [1,7,13]. Therefore, the high proportion of orchards with imbalanced nutrient management observed in this study highlights a common technical limitation in the pineapple farming system of the study area.

3.3. Disease Status in Pineapple

3.3.1. Effect of Drainage Capacity on Disease Status

The proportion of orchards reporting disease incidence was markedly higher in the group with poor drainage compared to those with moderate and good drainage (Table 3). The Chi-square test indicated that the relationship between drainage capacity and disease occurrence was statistically significant ($p < 0.05$), suggesting that soil conditions and water management play an important role in the disease status of pineapple. Under prolonged waterlogged conditions, the root zone becomes oxygen-deficient, resulting in reduced root respiration and poorer nutrient uptake. Anaerobic soil conditions may also increase the accumulation of toxic reduced compounds such as Fe^{2+} and Al^{3+} in acid sulfate soils, thereby impairing root growth and weakening plant physiological stability [4,5].

Under acid sulfate soil conditions, prolonged waterlogging and anaerobic conditions can impair root function and increase the risk of physiological disorders and soil-related diseases [3,4]. Previous studies have also reported that inefficient ridge-ditch systems are a major risk factor contributing to increased root diseases and reduced growth in pineapple and other crops sensitive to waterlogging [1,6,14].

3.3.2. Effect of Nutrient Balance on Disease Status

In addition to drainage conditions, nutrient management also showed a significant relationship with disease status.

Orchards with imbalanced nutrient management (deficient in phosphorus and/or potassium) exhibited a higher incidence of disease compared to those with relatively balanced nutrition (Table 4). The Chi-square test indicated that the relationship between nutrient balance and disease occurrence was statistically significant ($p < 0.05$).

From a soil-plant physiological perspective, imbalanced nutrition, particularly deficiencies in phosphorus and potassium, may restrict root development, reduce water regulation capacity, and weaken plant resistance to environmental stresses related to soil and water conditions [4]. These physiological limitations may reduce stress tolerance and contribute to lower pineapple productivity under acid sulfate soil conditions. For pineapple, previous studies have emphasized the role of balanced nutrition in maintaining stable growth and improving adaptability under acidic soil conditions [1,7]. Potassium plays an important role in stomatal regulation, osmotic adjustment, and stress tolerance, while phosphorus is essential for root development and energy transfer processes [15]. Deficiencies in these nutrients may reduce root growth and weaken physiological resilience under acidic and waterlogged conditions, thereby increasing susceptibility to soil-related diseases and limiting yield performance. Therefore, the higher disease incidence observed in orchards with imbalanced nutrition in this study is consistent with previous findings, although the study does not aim to establish a causal relationship.

3.4. Pineapple Yield and Its Relationship with Cultivation Conditions

The survey results indicated that pineapple yield in the study area varied considerably among households, reflecting differences in soil conditions and cultivation practices (Table 5). Yield was distributed into three categories, with the medium-yield group accounting for the highest proportion, while a considerable proportion of orchards still recorded low yields.

Table 3. Relationship between drainage capacity and disease status

Drainage capacity	Orchards with soil-related diseases	Orchards without disease	Total
Poor	20 (76.9%)	6 (23.1%)	26
Moderate	18 (51.4%)	17 (48.6%)	35
Good	6 (35.3%)	11 (64.7%)	17
Total	44	34	78

Note: Values in parentheses represent row percentages (%). Disease status was recorded through field surveys and analyzed using the Chi-square (χ^2) test; significance level at $p < 0.05$.

Table 4. Relationship between nutrient balance and disease status in surveyed pineapple orchards

Nutrient balance	Orchards with soil-related diseases	Orchards without disease	Total
Imbalanced (deficient in P/K)	34 (65.4%)	18 (34.6%)	52
Relatively balanced	10 (38.5%)	16 (61.5%)	26
Total	44	34	78

Note: Disease status and nutrient balance were standardized for analysis using the Chi-square (χ^2) test; significance level at $p < 0.05$.

Table 5. Relationship between cultivation conditions and pineapple yield levels in Hoa Luu commune, Can Tho City (n = 78)

Cultivation conditions	Yield			χ^2	df	p-value
	Low (<5,000 fruits/ha)	Medium (5,000–15,000 fruits/ha)	High (>15,000 fruits/ha)			
Drainage capacity				10.42	4	0.005
Poor	14 (53.8%)	9 (34.6%)	3 (11.6%)			
Moderate	9 (25.7%)	17 (48.6%)	9 (25.7%)			
Good	3 (17.6%)	6 (35.3%)	8 (47.1%)			
Nutrient balance				6.31	2	0.043
Imbalanced	18 (34.6%)	24 (46.2%)	10 (19.2%)			
Relatively balanced	8 (30.8%)	8 (30.8%)	10 (38.4%)			

Note: Pineapple yield was classified based on the number of fruits harvested per unit area per year. Drainage capacity was categorized based on ridge height and ditch depth, while nutrient balance was determined based on the combined use of nitrogen, phosphorus, and potassium fertilizers. Chi-square (χ^2) values, degrees of freedom (df), and p-values were calculated to assess the relationships between cultivation conditions and yield distribution; statistical significance was considered at $p < 0.05$.

Analysis of the relationship between drainage capacity and yield levels revealed clear differences among orchard groups (Table 5). Orchards with poor drainage capacity had a higher proportion of low yield, whereas those with good drainage had a higher proportion of high yield. The Chi-square test indicated that the relationship between drainage capacity and yield level was statistically significant ($p < 0.01$), confirming the important role of soil conditions and water management in pineapple production.

Under acid sulfate soil conditions, waterlogging limits the root environment and nutrient uptake, thereby negatively affecting plant growth and yield [3,4] (Dent, 1986; Brady & Weil, 2016). Previous studies on tropical fruit crops have also shown that improving ridge structure and drainage capacity is a fundamental solution for enhancing productivity under acidic and seasonally waterlogged conditions [1,6]. The combined effects of restricted root aeration and nutrient imbalance likely contributed to reduced fruit production in poorly drained orchards. Under acid sulfate soil conditions, impaired root activity may limit nutrient uptake efficiency and reduce assimilate allocation to fruit development, thereby decreasing overall productivity [4,5].

In addition to soil conditions, nutrient balance also showed a significant relationship with pineapple yield. Orchards with relatively balanced nutrient management recorded a higher proportion of high yield compared to those with imbalanced nutrition (Table 5). The Chi-square test confirmed that this relationship was statistically significant ($p < 0.05$), highlighting the role of balanced nutrition in maintaining stable growth and improving resource use efficiency [7].

4. Conclusions and Technical Implications

4.1. Conclusions

The study shows that soil conditions and agronomic practices are closely associated with disease incidence and pineapple yield in Hoa Luu commune, Can Tho City. Among

these, drainage capacity and nutrient balance are the two most influential cultivation factors.

Orchards with low ridge-ditch systems and poor drainage recorded higher disease incidence and lower yields compared to those with moderate and good drainage conditions. In addition, imbalanced nutrient management, mainly characterized by deficiencies in phosphorus and/or potassium, was significantly associated with increased disease occurrence and reduced yield. These relationships were statistically significant, indicating that they reflect common trends in the pineapple farming system of the study area.

4.2. Management Implications and Recommendations

The results indicate that the effectiveness of pineapple cultivation on acid sulfate soils is influenced by both inherent soil conditions and agronomic practices. Therefore, management strategies should focus on factors that can be adjusted at the farm level.

First, for orchards with suboptimal drainage conditions, improving ridge-ditch structure should be prioritized to create a more favorable root environment for pineapple plants. Adjusting ridge height and maintaining appropriate drainage ditches are important for reducing the risk of soil-related diseases, rather than relying solely on disease control after symptoms appear.

Second, given that most farmers apply fertilizers based on experience, promoting nutrient-balanced fertilization is necessary to improve fertilizer use efficiency. Technical recommendations should focus on identifying and correcting phosphorus and potassium deficiencies rather than increasing nitrogen application, thereby enhancing plant growth under acidic soil conditions.

Finally, the results suggest that improving pineapple production efficiency requires an integrated approach combining soil management and improved agronomic practices. This approach is consistent with the characteristics of farming on acid sulfate soils and may contribute to improving the sustainability of pineapple production systems at the household level.

This study was based primarily on household survey data and field observations; therefore, the identified relationships should be interpreted as associative rather than causal. Disease assessment relied on symptom observation without laboratory confirmation, and fertilizer practices were evaluated based on farmer-reported information. Future studies should incorporate controlled field experiments, soil analyses, and pathogen identification to validate the mechanisms linking soil conditions, nutrient management, disease development, and pineapple yield under acid sulfate soil conditions.

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