The Current Status of Cultivation and Soil Fertility of Coconut Plantations in Vinh Long Province, Vietnam

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ABSTRACT

Background: Vinh Long has about 120,000 ha (equivalent to about 22 million coconut trees), ranking first and accounting for over 50% of the country's coconut area. Many studies showed that coconut yield, whether high or low, is influenced by numerous factors.

Methods: This study conducted a survey of 400 coconut-growing households and directly assessed soil fertility in 198 coconuts gardens to identify factors affecting the yield of copra coconut, drinking coconut and Sap coconut in Vinh Long province.

Result: The results showed that two-thirds of coconut growers were middle-aged, between 36-55-year-olds, with education levels at or above high school, accounting for 61.1%. Household coconut planting areas were small, ranging from 0.3 to 1.0 ha, accounting for 90.5%. The planting density for copra coconut and Sap coconut ranged from 233-254 trees ha^{-1}, with an average yield of 42.1-47.5 fruits/tree/year; drinking coconuts averaged 317 trees ha^{-1} with an average yield of 76.7 fruits/tree/year. No strong correlation was found between tree age and coconut yield. Factors such as electrical conductivity (EC) and temperature suitable for coconut growth, as well as the correlation between soil moisture and pH with coconut yield, were very low. However, prolonged low moisture averaging 13.9% can affect coconut growth and reproduction. Only 12.1% of the coconut gardens had readily available nitrogen at good to rich levels (>120 mgN kg^{-1}), but 85.4% of the gardens were rated from rich to very rich in readily available phosphorus (>21 mgP kg^{-1}) and 51.5% from medium to very rich in available potassium (>100 mg K kg^{-1}). No strong correlation was found between the readily available nitrogen, phosphorus and potassium in the soil at the time of survey and coconut yield. It is necessary to increase soil nitrogen levels by increasing the dosage and splitting fertilization events or using nitrogen in organic forms.

Key words: Copra coconut, Drinking coconut, Sap coconut, Soil fertility, Yield.

INTRODUCTION

Coconut trees were distributed in 94 countries around the world and the demand for coconut products were projected to continuously increase until 2030 (APCC, 2017; Rodrigues *et al*., 2018). Coconuts were crops that adapt well under conditions of limited water and nutrients (Bandyopadhyay *et al*., 2019). Coconut trees absorbed about 24.1 tons of CO_2/ha/year and helped counteract the negative impacts that may be caused by climate change (Magat, 2009).

Vietnam currently was about 188,000 ha of coconut trees, accounting for 1.67% of the world's coconut area. Coconut trees are mainly distributed in the provinces of the Mekong Delta. It is estimated that by the end of 2025, Vinh Long will have 120,000 ha (equivalent to approximately 22 million coconut trees), ranking first and accounting for over 50% of the country's coconut areas, an increase of 11,335 ha compared to 2020 (an average annual growth rate of about 2%). Specifically: former Vinh Long 11,000 ha, former Tra Vinh 28,350 ha, former Ben Tre 79,920 ha. The coconut trees were fruits about 110,120 ha (equivalent to about 20.3 million coconut trees), accounting for 92.3% of the province's total coconut area, including: former Vinh Long 9,725 ha, former Tra Vinh 25,115 ha, former Ben Tre 75,281 ha (Vinh Long Department of Agriculture and Environment, 2025). Vietnam was over 50 coconut varieties, divided into two main groups: tall coconut varieties for oil production, including Ta, Dau, Sap, Bung Bi and dwarf coconut varieties for drinking water such as Xiem, Dua, Tam Quan, Eo. In addition, there was high economic value coconut varieties like Sap and Dua (Thao, 2010). Coconut varieties used in Vinh Long province include: oil-producing varieties (tall coconuts) such as green Ta, yellow Ta, green Dau, yellow Dau, which occupy a relatively large are of 99,909 ha, about 83.8% of the provincial area; drinking varieties (dwarf coconuts) such as green Xiem, Xiem Luc, yellow hybrid, red hybrid and hybrid varieties covering about coconuts 18,000 ha, accounting for 15.10% of the area; the remaining Sap coconut was 1,361 ha, accounting for 1.14% of the area (embryo-cultured coconut was 31.1 ha). Coconut planting density in Vinh Long ranged from 190-200 trees ha^{-1} depending on the coconut variety, soil fertility and farming practices of households (Vinh Long Department of Agriculture and Environment, 2025).

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Many studies have shown that coconut productivity in Mekong Delta depends on various factors: the quality of the variety, cultivation area, farmers' production skills and experience, irregular changes in rainfall and temperature, tidal flooding, saltwater intrusion, *etc*. In addition, soil degradation causes unfavorable conditions for soil fertility, such as moisture, pH, EC, nitrogen, phosphorus and potassium content in the soil. Pests and diseases were also significant factors affecting coconut productivity. This study was conducted to further strengthen the scientific basis of the factors affecting coconut productivity mentioned above, with a specific focus in Vinh Long province.

MATERIALS AND METHODS

Sample

Primary data collected through surveys and interviews with coconut-growing households using questionnaires from February to August 2025. A survey was conducted on 400 coconut-growing households in 4 communes: Cang Long, Chau Thanh, Tieu Can and Cau Ke in Vinh Long province (These communes were formerly 4 districts belonging to the old Tra Vinh province before being merged into Vinh Long province). Each commune surveyed 100 randomly selected households according to Slovin's formula:

$$n = N/(1+N \times e^2)$$

Where,

N= The sample size to be surveyed.

N= Population = 41,448 coconut-growing households.

E= Allowable error = 0.05.

Specifically, soil samples and actual coconut yield were taken from 50% of the farms of the households surveyed in the communes.

Method of selecting observation samples: Coconut growers: those with coconut planting areas >0.3 ha, coconut age from 4-25 years belonging to the groups of copra coconut, drinking coconut and Sap coconut. The soil measurement producedures and equipment used in study for soil samples and coconut yield: Connect the sensor to the main machine, then insert the probe into the soil, determine the physical and chemical properties of the soil measured directly at the surface layer, 1.5 m from the base of the coconut tree in the farmer's coconut garden and count the total number of fruits on the tree at the time of survey. Soil moisture was determined directly. Indicators for N, P, K, pH and EC are determined after watering until the soil reached a moisture content of 25-30%. The equipment Handheld terminal instruction manual JXBS-3001-SCY-PT. Ver1.0. Made in China was used to measure soil indicators. With land evaluation scale (Table 1).

Data processing and analysis method

Survey data was checked, analyzed, coded and entered Microsoft Excel Office 2013 and SPSS for calculation and data analysis. Descriptive statistics, correlation analysis: area, age, professional qualifications, experience, planting density, yield and soil physical and chemical parameters.

RESULTS AND DISCUSSION

Current status of coconut cultivation by households

Table 2 results showed that the age group with the highest proportion is 36-45 years old (36.5%) and 46-55 years old (30.8%), accounting for more than two-thirds of coconut growers in the middle working-age range. The number of young and elderly people was relatively low. Education level from high school and above accounted for the highest proportion at 61.1%, indicating that most current coconut growers were an intermediate to high level of education. Compared to domestic and international studies, the age and education level of coconut grower was similar. Therefore, policies were needed to attract, support and train young human resources and to improve farmers' skills to access and apply new technical advances in coconut cultivation in Vinh Long province.

Table 1: The land evaluation scale.

Grade	Total N N: mg kg^{-1}	Total P P: mg kg^{-1}	Total P K: mg kg^{-1}	Rating scale
1	150	40	200	Very rich
2	120~150	20~40	150~200	Rich
3	90~120	10~20	100~150	Medium
4	60~90	5~10	50~100	Low

Table 2: Age and educational level of coconut growers in Vinh Long province.

Age of coconut growers			Educational level of coconut growers		
Age	Frequency	Percentage (%)	Educational level	Frequency	Percentage (%)
≤35 years old	36	9.0	Primary school	19	4.8
36-45 years old	146	36.5	Secondary school	137	34.3
46-55 years old	123	30.8	High school	175	43.8
56-65 years old	83	20.8	Vocational/College	41	10.3
>65 years old	12	3.0	University/Postgraduate	28	7.0
Total	400	100		400	100

Table 3 showed that smallholder coconut farms with an area of 0.3-0.5 ha accounted for 63.2%. The age group of 5-11 years accounted for 92.8%. Most of the coconut area belongs to trees in the middle age stage, starting to bear fruit steadily and not yet old. The coconut-growing area in Tra Vinh was smaller compared to the coconut growing areas in some districts of Ben Tre province, which ranged from 0.5 to 1.0 ha, with Giong Trom districts having up to 50% of surveyed households cultivating 1.0-2.0 ha of coconut (Thu *et al*., 2024).

Table 4 showed that the planting density of copra coconut ranged from 160-300 trees/ha, with an average of 254 trees ha^{-1} and an average yield of 42.1 fruits/tree/year; drinking coconut ranged from 180-400 trees ha^{-1}, with an average of 317 trees ha^{-1} and an average yield of 76.7 fruits/tree/year; Sap coconut ranged from 160-300 trees/ha, with an average of 233 trees ha^{-1} and average yield of 47.5 fruits/tree/year. The reason why the planting density of the drinking coconut group was higher than that of the copra and Sap coconut groups was mostly because drinking coconut belonged to the dwarf coconut group, which was smaller biomass due to a shorter growth period and a shorter harvesting cycle. The higher yield of drinking coconut was due to smaller fruit weight and a higher fruit set rate, as most belong to self-pollinating or semi-self-pollinating trees. According to Thomas *et al*. (2018), the density of coconut planting in regons around the world varies greatly, depending on soil characteristics, varieties and cultivation methods. Appropriate density helped coconut trees were given the right amount of light for growth and development (Bhat *et al*., 2024). The research results by Thu *et al*. (2024) showed that tall coconut varieties were a planting density of 160-240 trees ha^{-1} and an average fruit of 80-100 fruits/tree/year for dwarf coconuts and 40-80 fruits/tree/year for tall coconuts, Nhu *et al*. (2024) reported Sap coconut yields ranged from 40.8 to 96.3 fruits/tree/year. The yield coconut of Tien Giang province fluctuated from 30-91 fruits/tree/year (Tri *et al*., 2024). According to Gunathilake (2013), coconut trees were generally spaced 8 m × 8 m apart (160 trees ha^{-1} thereby 75% of the area remains below it was production potential from the age of 20 years or so.

The equation Y = ax + b in Fig 1 showed that fruit yield per tree per year increased slightly (0.1257 fruits) with each additional year of coconut age. However, the correlation coefficient (R^2) was very low (0.0542), meaning that only about 5.42% of the annual fruit yield variation was explained by the age of the coconut. The correlation between coconut age and yield was very weak. Therefore, coconut age was not a major determinant of annual fruit yield (Author's own survey, 2025). Many studies worldwide also indicated that coconut yield can peak at mature ages (7-20 years), then gradually decreased as the tree ages, but this effect also depends on the variety, cultivation conditions and care. In countries like India and Thailand, the correlation between age and yield was often higher ($R^2 \approx 0.2$-0.4), especially for pure coconut varieties or intensive cultivation (Thomas *et al*., 2018).

Physicochemical characteristics of coconut cultivation soil

Results from Table 5 showed that the average pH value was neutral, with soil pH ranging from 6 to 9, average 7.19. The suitable pH value for coconut trees to grow and develop strongly that was 6-7 (Ve *et al*., 2005; Issaka *et al*., 2012). The mean soil electrical conductivity (EC) of 0.63 mS cm^{-1} suggests that the soil was within the non-saline range. Nghia *et al*. (2024) surveyed coconut-growing areas in Ben Tre province and found EC ranging from 1.01 to 1.56 mS cm^{-1}. The appropriate EC for crops ranged from 0.4 to 1.0 mS cm^{-1} (Hoa *et al*., 2012), while the best EC for coconut growth and development was 2 mS cm^{-1} (Ve *et al*., 2005). Soil temperatures ranged from 28-34°C, suitable for coconut

Table 3: Area of coconut cultivation and age of coconut trees.

Coconut plantation area of households			Coconut tree age		
Area (ha)	Frequency	Percentage (%)	Coconut age group	Frequency	Percentage (%)
0.3-0.5	253	63.2	<4	18	4.5
0.51-1.0	109	27.3	5-11	371	92.8
>1.0	38	9.5	12-18	10	2.5
			19-25	1	0.2
Total	400	100		400	100

Table 4: Density and yield of coconut varieties in Vinh Long province.

Coconut group	Sample size	Planting density (Trees ha^{-1})			Productivity (fruits/tree/year)		
		Mean	Min	Max	Mean	Min	Max
Copra coconut	150	254	160	300	42.1	14	57
Drinking coconut	100	317	180	400	76.7	25	210
Sap coconut (wax)	150	233	160	300	47.5	23	84
Total	400						

growth. Soil moisture was low, averaging 13.94%. Low moisture affected the solubility and transport of nutrients from the soil to the plant, photosynthesis, cell structure growth and temperature regulation within the plant. The reason for the low soil moisture in coconut plantations was due to the traditional practice of not irrigating coconuts directly but applying seepage irrigation by retaining water in the ditches within the coconut planting contour system. Survey results on coconut garden yields showed that coconut trees that had good water absorption conditions will yield high and stable productivity and vice versa. According to the Philippine National Standard (2018), good coconut-growing soil usually have been suitable soil moisture content of 15-30%, ideally 20-25%. Too low (<10%) would been result in poor growth, small fruits and easy shoot death in the dry season. However, integrated use 25% recommended dose of fertilizers and 75% recommended dose of nitrogen from arganic sources were brought upland rice in Arunachal Pradesh (Borah *et al*., 2016).

The results in Table 6 showed that most soil samples was low nitrogen content, accounting for 76.8%, while only a small proportion ranged from rich to very rich, accounting for 12.1%. This may be due to farmers mainly using inorganic fertilizers and the low moisture content in the soil, which increased the risk of nitrogen loss in gaseous form, leading to low nitrogen levels in the soil that affected leaf and stem development and coconut yield. In Vietnam, according to various sources, agricultural soils in the midland and mountainous provinces were often nitrogen-poor, mostly below 100 mg kg^{-1}, with only intensively cultivated areas showing levels above 100 mg kg^{-1} (Vietnam Academy of Agricultural Sciences, 2015). In countries with developed agriculture, the available nitrogen content in agricultural soils was generally much higher. An average of 150-300 mg kg^{-1} was common for intensively cultivated land with proper chemical and organic fertilization (FAO, 2020). According to Kumar *et al*. (2012) showed farmers who applied lime (3 t ha^{-1}) into the furrows, increased maize yield by 32% compared to the others.

The results in Table 7 showed that the proportion of soil very rich available phosphorus was the majority about 68.2%, followed by moderately to rich soil (17.2%), with only a very small amount being poor (6.1%). The cause may be due to farmers' habits of applying more phosphorus fertilizer than the plant' needed to also reduce soil acidity, leading to phosphorus accumulation in the soil. Thuy *et al*. (2020)

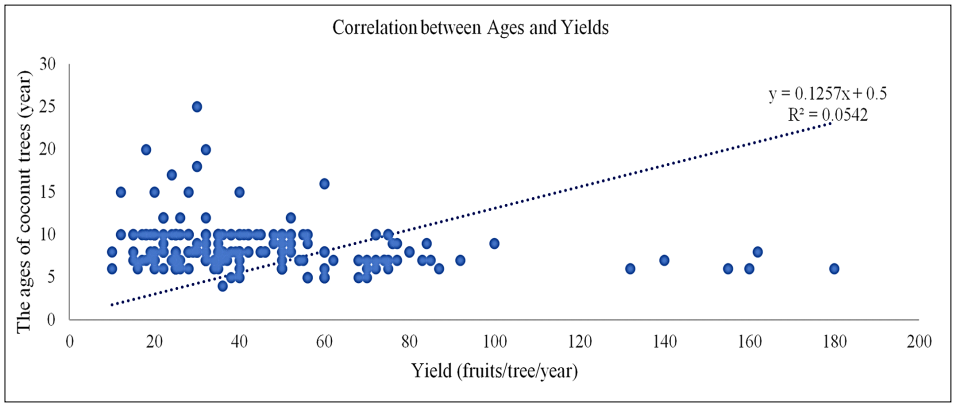


Fig 1: Correlation coefficient between yield and coconut and age in Vinh Long province.

Table 5: Physical and chemical properties of coconut planting soil in Vinh Long province.

Evaluation criteria	Sample size	Min	Max	Mean	Standard deviation (SD)
pH	198	6.0	9.0	7.19	0.85
EC (mS cm^{-1})	198	0.02	0.32	0.63	0.54
Temperature (°C)	198	28	34	32.1	1.52
Moisture (%)	198	3.4	31.1	13.94	4.26

Table 6: Available nitrogen content of coconut planting soil in Vinh Long province.

Serial number	Rating scale	Sample size	Percentage (%)	Mean	Standard deviation (SD)
1	Low	152	76.8	35.5	20.7
2	Medium	22	11.1	106.1	8.8
3	Rich	6	3.0	134.7	10.9
4	Very rich	18	9.1	250.2	231.9
Total		198	100	65.8	95.5

were found that in vegetable-growing soil in the Mekong Delta, available phosphorus-rich soil accounted about 74%. The nutrient interactions between these nutrient and others together that measured in terms of growth, yield response and changes in concentration and uptake of nutrients (Ramamoorthy *et al*., 2023).

As shown in Table 8, survey results of 198 soil samples, the proportion of potassium-poor soil (<100 mg kg^{-1}): 48.5%, with more than 50% of the remaining samples ranged from medium to very rich in potassium. The cause may be that farmers have applied little potassium for a long time while the potassium requirement for coconut trees was higher than both nitrogen and phosphorus. According to many studies in the Mekong Delta and rice-growing areas in Vietnam, the proportion of potassium-poor soils was usually 40-60%, with an average of around 30-40% and rich soils accounted about 10-20% of samples (Vietnam Academy of Agricultural Sciences, 2015). In industrialized countries like the United States, potassium-deficient soil was very rare (only about 10-15%), mostly thanks to good fertilizer management and proper crop rotation. Researchers reported that globally, about 20% of agriculture land faces severe potassium deficiency, with specific regions experiencing even more serious shortages, including 44% of agricultural land in Southeast Asia, 39% in Latin America, 30% in the South Asia subregion, sub-Saharan Africa and 20% in East Asia, largely due to more intensive agriculture activities (Ministry of Agriculture, 2024).

Correlation between yield and soil physicochemical properties

Fig 2(a) showed that R^2 coefficient was extremely low (0.0104), meaning that the moisture content in the soil had almost no significant effect on the yield of coconuts in the study sample. The reason should be that the current survey scope was not a fruit-bearing cycle time series of coconut trees (Author's Own Survey, 2025). International studies all emphasize that soil moisture was an important factor for coconut growth, especially during the fruiting and flowering stages (Thuy *et al*., 2020). Water deficiency would lead to the phenomenon of hanging coconuts and a

Table 7: Available phosphorus content of coconut planting soil in Vinh Long province.

Serial number	Rating scale	Sample size	Percentage (%)	Mean	Standard deviation (SD)
1	Low	12	6.1	4.33	3.6
2	Medium	17	8.6	16.1	2.90
3	Rich	34	17.2	30.6	4.89
4	Very rich	135	68.2	106.7	71.2
Total		198	100	79.6	71.2

Table 8: Available potassium content of coconut planting soil in Vinh Long province.

Serial number	Rating scale	Sample size	Percentage (%)	Mean	Standard deviation (SD)
1	Low	96	48.5	54.4	27.8
2	Medium	48	24.2	112.0	12.3
3	Rich	19	9.6	172.4	13.3
4	Very rich	35	17.7	326.3	104.6
Total		198	100		

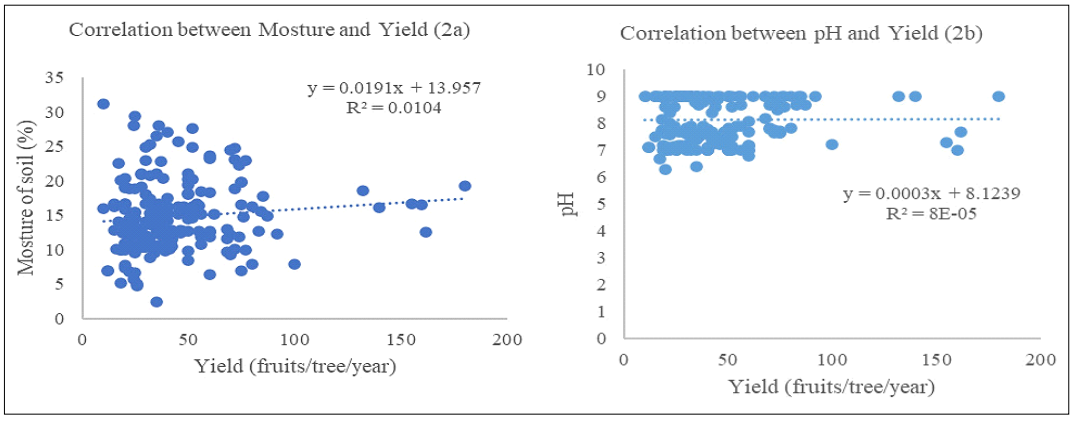
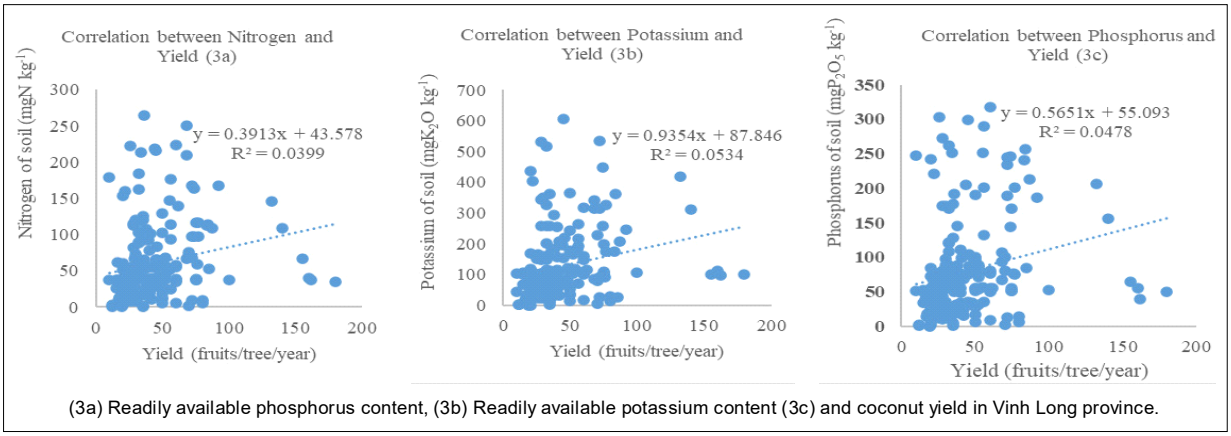


Fig 2: (a) Correlation between soil moisture, (b) Soil pH and coconut yield in Vinh Long province.



(3a) Readily available phosphorus content, (3b) Readily available potassium content (3c) and coconut yield in Vinh Long province.

Fig 3: Correlation between readily available nitrogen content.

significant decline in productivity (Hau and Duong, 2011). Moreover, Fig 2(b) also proved that the correlation between pH and fruit yield per year in this study was very weak, almost statistically insignificant. Many international studies also showed that the effect of soil pH on fruit tree yield depend on the type of tree, ecological region and cultivation practices (Author's Own Survey, 2025). In some studies, extreme soil pH (too acidic or too alkaline) often caused a significant reduction in yield. The optimal pH for the growth and yield of coconut ranges from 5.5 to 6.5 (Philippine National Standard, 2018). Fig 3 (a) Coefficient of determination (R^2=0.0399). This was very small value (close to 0), indicating that the correlation between soil nitrogen content and coconut yield was very weak. Only about 3.99% of the variation in yield (fruit production) could be explained by the variation in soil nitrogen content. Although the trend suggested that higher nitrogen may slightly increase yield (R^2), the difference was not important and the predictive value was very low. The reason may be that soil nitrogen was not the main determining factor for coconut yield in the surveyed area. Other factors, such as water, variety, care and other minerals, may play a more significant role (Author's Own Survey, 2025). According to Thuy *et al*. (2020), coconut yield can be increased through the application of organic and inorganic fertilizers. Similarly to the correlation coefficient between soil nitrogen and coconut yield, the correlation coefficient between available phosphorus in the soil and coconut yield (Fig 3b) and available potassium in the soil and coconut yield (Fig 3c) were very low. The reason may be that yield is determined by many factors and nutrient values need to be assessed throughout the entire fruiting period.

CONCLUSION

Study results revealed that more than two-thirds of coconut growers were in the middle working age group from 36 to 55 years old, with 61.1% having education at the high school level or higher. The coconut-growing area of households is about 0.3 to 1.0 ha. The coconut planting density was quite high, for copra and sap coconut ranged from an average of 233-254 trees/ha, with an average yield of 42.1-47.5 fruits/tree/year; for drinking coconut, the average is 317 trees/ha with an average yield of 76.7 fruits/tree/year. So attention should be paid to ensuring adequate light space for optimal photosynthesis and sufficient soil surface area for root development. The prolonged low soil moisture averaging 13.94% can affected the growth and reproductive processes of coconut trees. To increase and maintain coconut yield during the year and avoid flowering drop during dry months, it was important to maintain high soil moisture through supplemental irrigation during the dry months. Only 12.1% of coconut gardens had available nitrogen content from rich to very rich level (>120 mg N kg^{-1}), but 85.4% of gardens are rated from rich to very rich in available phosphorus content (>21 mg P kg^{-1}) and 51.5% of gardens ranged from medium to very rich in easily available potassium (>100 mg P kg^{-1}). It was necessary to increase the amount of nitrogen in the soil by increasing the dosage and splitting applications, or by using organic nitrogen.

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Two authors contributed to the conceptualization, draft preparation of this manuscript, data collection and analysis. Both authors have read and agreed to the published version of the manuscript.

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Conflict of interest

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