TREE AGE AFFECTS SOIL PHYSICO-CHEMICAL PROPERTIES OF MANGO ORCHARD IN DONG THAP PROVINCE

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Abstract

The study was carried out to investigate the effect of tree age to soil physical and chemical characteristics of mango orchard. Effect of 4 different tree ages (<10, 10 - 20, 21 - 30, and over 30 years) on soil physic-chemical properties of farmers' Mango field in Dong Thap province. The research was handled from June to November 2021. Soil samples at two depths (0 - 20 and 20 - 50 cm) were collected from the tree basin and were subjected to laboratory analysis from November to December 2021. Data showed that soil properties varied across mango tree' age and depths. Bulk density was higher in over 10-year-old tree and soil texture of silty clay-loam represented in the whole observed orchards. The results showed that the chemical properties of the soils were characterized by the low to rather low pH values (4.0 - 6.0) of the topsoil and tended to decrease gradually with depths and tree ages. Unimpacted EC (electrical conductivity) in mango orchards was recorded, while total N, P, K, soil organic carbon and CEC tended to decrease with tree age and depths. These values declined for 10 years old onwards for both depths of 0 - 20 and 20 - 50 cm.

Keywords*: Dong Thap, orchard, soil depth, tree ages.*

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ẢNH HƯỞNG CỦA TUỔI CÂY ĐẾN ĐẶC TÍNH LÝ, HÓA ĐẤT VƯỜN TRỒNG XOÀI TỈNH ĐỒNG THÁP

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Tóm tắt

Nghiên cứu được thực hiện nhằm khảo sát ảnh hưởng của tuổi cây đến tính chất lý hóa học đất của vườn xoài. Nghiên cứu thực hiện trên 4 tuổi cây khác nhau (gồm <10, 10 - 20, 21 - 30 và trên 30 năm tuổi) trên đất trồng xoài của nông dân tỉnh Đồng Tháp. Thời gian thực hiện từ tháng 6 đến tháng 11 năm 2021. Các mẫu đất tại một địa điểm được thu ở hai độ sâu gồm 0 - 20 và 20 - 50 cm, sau đó được phân tích trong phòng thí nghiệm trong thời gian từ tháng 11 đến tháng 12 năm 2021. Kết quả cho thấy đặc tính của đất biến động theo thời gian canh tác của cây. Dung trọng của đất có xu hướng cao (nén dẽ) sau hơn 10 năm canh tác. Sa cấu của các vườn chủ yếu là Silty Clay loam (thịt trung bình pha sét). Giá trị pH khá thấp (dao dộng khoảng 4-6) ở tầng mặt và càng giảm theo độ sâu tầng canh tác và theo tuổi cây lớn dần. Giá trị EC ở mức không ảnh hưởng đến sự phát triển của cây xoài. Hàm lượng N, P, K tổng số, chất hữu cơ và khả năng trao đổi cation (CEC) giảm theo tuổi cây từ năm thứ 10 trở đi cho cả 2 độ sâu 0 - 20 và 20 - 50 cm.

Từ khóa: *Đồng Tháp, đất vườn, độ sâu, tuổi cây.*

1. Introduction

Dong Thap is one of the largest mango orchard provinces in the Mekong Delta with about 12,171 ha and an annual output of nearly 124,000 tons (Department of Agriculture and Rural Development of Dong Thap province, 2020). In addition, quantification of soil health index is very important and essential for assessing the sustainability of fruit orchards and growers' profitability in which soil physico-chemical and biological properties are typical indication to the present status of the orchard health and productivity (Adak et al., 2018; Gucci et al., 2012). Besides, soil depth wise distribution of physical, chemical and biological properties are very much helpful to quantify the actual status of these properties for developing the relationship with fruit yield (Morugán-Coronado et al., 2020).

Researchers have examined soils of fruit orchards across different agro-climatic zones and express the concern of yield gap regarding water, nutrient, canopy, pest soil and other management (Adak et al., 2018; Bhattacharyya et al., 2015; Kumari et al., 2020; Morugán-Coronado *et al.*, 2020). Soil types, particularly in problematic soils like gravel/sandstone/sand, and salinity/solidity, might affect dynamic changes of soil characteristics such as soil structure and compaction, nutrient deficiency and soil bio-ecosystem. Compaction due to tillage, irrigation water qualities and farming time etc. has been reported to lower yield (Kuht & Reintam, 2004; Morugán-Coronado et al., 2020). Besides, tree age drastically influences not only soil physical properties, but also chemical phenomenon. Soil physical and chemical degradations cause serious impediment to agricultural sustainability and environmental quality. Major causes of soil degradation are compaction, soil erosion, organic matter loss, salinization, nutrient depletion, and pollution. Topsoil degradation may be easily mitigated, whereas that of subsoils is much more difficult to restore, and the degradation may even be permanent (Pham et al., 2012).

Therefore, this study was carried out to assess the depth wise soil physicochemical properties in mango orchards concerning possible correlations between tree ages and productivity/yield.

2. Materials and methods

2.1. Soil sample collection

Soil samples were collected from June to November 2021 (before fertilizer application) from the border of the tree basin, i.e., around 2.5 m distance from the tree trunk as most of the feeder root of mangos is usually concentrated in that region. The samples were collected in five positions from each experimental tree at two different depths, including 0 - 20 cm and 20 - 50 cm by using a metal core. Thereafter, five soil samples for each depth were mixed to make a final sample. All sampled soils were air-dried except bulk density, passed through a 2 mm sieve, and kept at 4°C for analysis of the different chemical properties of the soil.

2.2. Selection of tree age group

The mango trees were selected from four different age groups (<10, 10 - 20, 20 - 30 and over 30 years old) and planted at spacing of 2.5 m ×2.5 m in the orchard. These four tree age groups are important for mango crop as trees start to bear fruits at the age of 5 - 6 and their productivity reaches at peak between 15 - 18 years, followed by a declining phase after 25 - 30 years. For each age groups, five trees were observed and collected relative samples.

2.3. Measurement of soil physico-chemical properties

The pH and electrical conductivity (EC) of the soil samples were measured with the pH meter and conductivity meter, respectively, using a soil to KCl 1N ratio of 1:5 for pH value and using a soil to water ratio of 1:5 for EC value. All soil samples on each plot were collected and analyzed for soil texture through a measurement of Robinson, bulk density using 100 cm^3 cylinder oven-dried at 105°C for 24 h. Porosity was measured by The thermo-TDR technique method. Soil organic matter (% C) was measured by dry combustion method at 830°C. In addition, the Kjeldhal method was used to determine the content of total nitrogen. The content of phosphorus was determined calorimetrically based on phosphomolybdate with agent $SnCl_2$, colorimetric at 880 nm. The potassium content was determined by atomic absorption spectrometer, using emission method (AES). The cation exchange capacity (CEC) was extracted with 0.1 M $BaCl_2$, and then titrated with 0.01 M EDTA.

2.4. Statistical analysis

The data obtained from different treatments with respect to various physico-chemical parameters were subjected to Analysis of Variance by using single-factor factorial Completely Randomized Design (CRD) with three replications. Mean value was compared using Duncan test ($P < 0.05$). All statistical analysis was carried out using SPSS software version 20.0.

3. Results and discussion

3.1. Soil physical characteristics of mango orchard

Tree age and depth wise distribution of soil physical properties in mango orchards were presented in Table 1. Higher bulk density (DB) and lower porosity for orchard with over than 10 years old were recorded. A range of 1.21 to 1.38 g/cm^3 BD for topsoil and 1.09 to 1.38 g/cm^3 DB for subsoil, respectively. Meanwhile, porosity across tree age in topsoil decreased dramatically from 50.60% for under 10 years cultivation and that of 40.10%, 42.0%, and 36.18% for 10 to 20-year orchards, 21 to 30-year trees and over 30-year trees, respectively. These porosities also showed a similar tendency for subsoil (20 - 50 cm) with 53.21%, 39.64, 44.01%, and 37.81%, respectively. The soil in orchards was a silty loam-clay soil with no significant differences in the sand, silt and clay contents for all tree age levels in each depth (Table 1). Hence, these results showed that there were statistical differences in physical characteristics of soil according to tree age. Soil bulk density and porosities in old-age orchards varied significantly, affecting negatively tree growth. These results indicated that DB in orchard with over 30 years old got higher than that in younger orchards, inversely, porosity in over 30-year-old trees showed lower compared to orchard cultivated under 20 years old.

The result also showed that in the topsoil DB was not significantly correlated with the clay content; however, the correlation was weak negative for subsoil, suggesting a DB decrease with increasing clay content. According to Hillel (1982), soil DB generally increases in association with increases sand and silt content in soil texture. This is suggesting that the DB may decrease with increasing long-term cultivating. Generally, result indicated that DB was positively correlated with the age and depth.

Table 1. Soil physical properties of mango orchard according to tree ages in different soil depths

Tree Ages (years)	Bulk density	Porosity	Soil texture			Type of Soil texture (USDA Soil Taxonomy)
			% Sand	% Silt	% Clay	
	0 -20 cm					
<10	1.21^{b}	50.60^{a}	4.31	58.80	36.89	Silty Clay Loam
10-20	1.29^{a}	40.10^{ab}	5.43	58.43	36.14	Silty Clay Loam
21-30	1.33^{a}	42.00^{ab}	2.97	57.66	39.37	Silty Clay Loam
>30	1.38^{a}	36.18^{b}	4.01	57.41	38.58	Silty Clay Loam
CV (%)	**12.54**	**18.93**				
Tree Ages (years)	20 - 50 cm					
<10	1.09^{b}	53.21^{a}	7.66	55.13	37.22	Silty Clay Loam
10-20	1.24^{ab}	39.64^{b}	7.00	57.10	35.89	Silty Clay Loam
21-30	1.32^{a}	44.01^{b}	5.11	56.62	38.27	Silty Clay Loam
>30	1.38^{a}	37.81^{b}	6.46	57.59	35.96	Silty Clay Loam
CV (%)	**15.84**	**16.25**				

Note: Means followed by same letter along columns for each treatment not significantly different at 5% level.

3.2. Soil chemical properties of mango orchard

Soil plays a vital role in the growing of crops, and it is also a major source of plant nutrients. The constituents of soil include living organisms, residual mineral matter, organic matter so-called "humus", air and water. Each of these components is not only highly important in soil genesis, but also plays a major role in determining the suitability of the soil for crop production (Bhattacharyya et al., 2015; Gucci et al., 2012). Imbalances of soil nutrients due to human activities may directly or indirectly disrupt chemical properties of soil. It is obvious that one cannot get healthy plants from unhealthy soils. Generally, chemical properties (or soil fertility) depend on a favorable interaction between soil components and phases that optimize the soil physical and chemical quality.

3.2.1. pH

This study addresses two main issues of a low soil pH and a nutrient deficiency or nutrient imbalance in long-term planting orchards wise depths. Soil pH indicated a significant variation among the long-term cultivating mango orchard for each depth (Fig. 1). Soil pH was significantly increased by over 10-year-old mango orchard and decreased by younger planting garden at depth of 0-20 cm, ranging from 4.53 (over 10 years cultivating) to 3.92 (for under 10-year-old orchard), respectively. In contrast, the pH value decreased statistically over the cultivation time for the 20-50 cm depth layer, reducing between 5.15 (for 10 years old), and 3.1 (for older 30-year-old orchards). Generally, orchard soil pH values presented acid soil at all depths and low pH may lead to a deficiency of major plant nutrients such as Ca^{2+} and Mg^{2+} as well as Nitrogen and Phosphorus. In addition, adsorbed H^{+} and Al^{3+} ions may predominate over the cation exchange capacity. At soil pH (<5), aluminum and manganese could become toxic to plants (Adak et al., 2018).

3.2.2. EC

As EC is strongly influenced by management practices, it can be used as an indicator of the extended use of fertilizers in soil. An increase in the EC in conventionally managed soils could be due to the higher input of salts (in the forms of chemical fertilizers and/or pesticides), which was further supported by the higher Na concentration in the conventionally managed soil. In topsoil, EC were low, indifferent statistically and did not influence plant growth according to tree age levels (Fig. 2).

However, EC fluctuated significant statistically among long-term orchard plantings. EC value increases with tree age. These values reached 152.2 µS/cm and 202.5 µS/cm for orchards under 10-year-old and over 30-year-old, respectively. In sum, no significant impact on EC change of the soils was found, but we could trace minor changes in EC at 20 - 50 cm soil depth and long-term cultivation time.

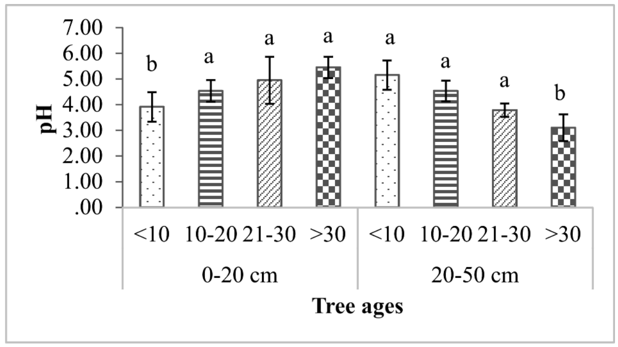

Figure 1. Change of pH value with tree age at two soil depths

Note: Different letters indicate significant differences (Duncan) at p ≤ 0.05 after analysis of variance (ANOVA) within tree age at each soil depth.

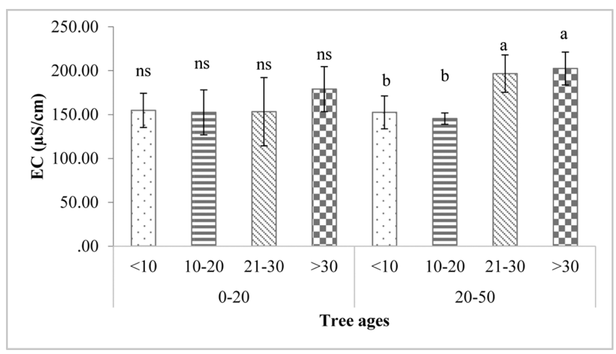

Figure 2. Change of EC value with tree age at two soil depths

Note: Different letters indicate significant differences (Duncan) at p ≤ 0.05 after analysis of variance (ANOVA) within tree age at each soil depth.

3.2.3. Soil organic matter (SOM)

The SOM is usually considered to be one of the most important properties of soils due to its significant impact on other biological and physicochemical soil properties. It is noteworthy that there was no significant difference in the levels of SOM between orchards with under 30-year-old planting time at depth of 0 - 20 cm (approximately 7.11%), exception for over 30 years old gardens (about 4.7%) (Fig. 3), which is in accordance with the data reported by Gasparatos et al. (2011). Higher data have been previously reported by Sánchez et al. (2007), who found low SOM levels (< 2%) in the topsoil under an organic fruit production system.

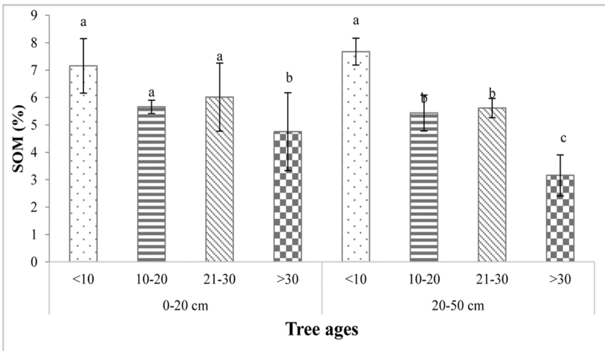

Figure 3. Change of soil organic matter with tree age at two soil depths

Note: Different letters indicate significant differences (Duncan) at $p \leq 0.05$ after analysis of variance (ANOVA) within tree age at each soil depth.

Researched results also showed that soil organic contents tended to decrease with both cultivating time and soil depth. As an example, in subsoil, the soil organic content decreased gradually in fruit gardens under 10 years old (7.67%), from 10 to 20 years old (5.6%) and after 30 years growing (3.1%), respectively.

These results indicate that the continuous addition of higher quantities of organic fertilizers under an organic management system is important to maintain a sufficient level of SOM, which is easily oxidized, especially under the semi-arid climatic conditions in Vietnam. Similar observation with Morugán-Coronado et al. (2020), although the soil properties evaluated were not the main drivers of long-term yield variability, they depended on organic matter supplied in soil.

3.2.4. Total Nitrogen

Total soil nitrogen showed a similar pattern (Fig. 4) to that observed for SOM with values ranging from 0.08% - 0.16% N for the top 20 cm of soil depth to 0.04% - 0.11% N at the depth of 50 cm.

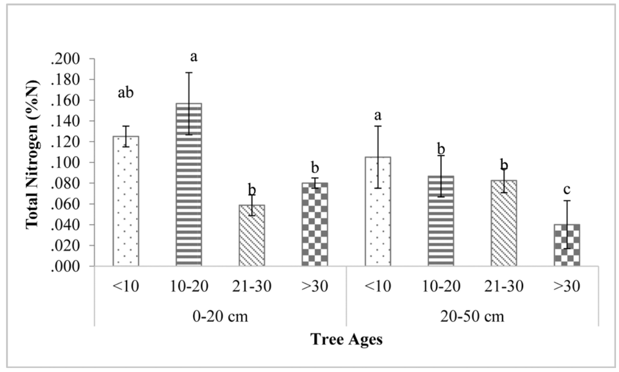

Figure 4. Change of total nitrogen with tree age at two soil depths

Note: Different letters indicate significant differences (Duncan) at $p \leq 0.05$ after analysis of variance (ANOVA) within tree age at each soil depth.

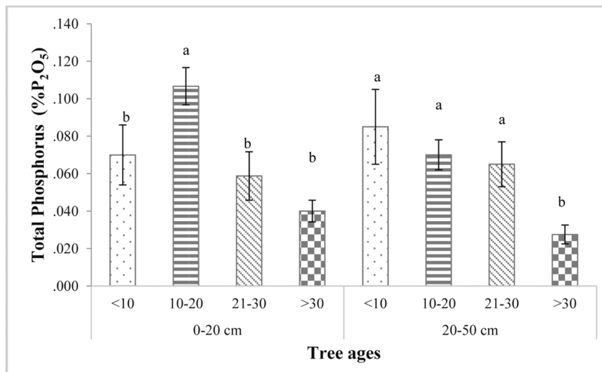

Figure 5. Change of total phosphorus with tree age at two soil depths

Note: Different letters indicate significant differences (Duncan) at $p \leq 0.05$ after analysis of variance (ANOVA) within tree age at each soil depth.

3.2.5. Total phosphorus (P)

The content of P at the depth of 0 - 20 cm decreased from 0.11 %P_2O_5 for under 20-year-old mango trees to 0.04% P_2O_5 for orchard older over 30 years old. At a depth of 20 - 50 cm, there was a similar tendency with those of total P at topsoil. The total phosphorus content decreased after 20-year-long term or longer cultivation (Fig. 5).

3.2.6. Total potassium (K)

At the depth of 0 - 20 cm, the content of K fluctuated from 2.41 % K_2O to 2.9% K_2O and did not significant difference in mango trees among 10 and 20 years old, respectively. However, these K values were statistically higher than those of over 30-year-planting mango soil (1.75% K_2O). In addition, at the depth of 20 - 50 cm, K increased from 2.62 to 2.9%

K_2O for under 20-year-old mango orchards and from 2.07 % to 32.27% K_2O for over 20 long-term growing orchards (Fig. 6). Total K content in the surface 20 cm of orchard soil was significantly affected by planting time and orchard depths. Over the soil sampling, inorganic and organic fertilizers resulted in increased exchangeable soil K, leading relatively to total K in soil. Long-term cultivation also affected total K with a steady decline in exchangeable soil K (Ojeda-Barrios et al., 2020; Pham et al., 2012). Generally, the total K value in the organic surface layer was lower than those in the subsoil due to the application of mineral fertilization. The application of a fertilizer containing K_2O in high quantities in the conventional mango orchard maintained high in soil K levels.

3.2.7. Cation exchangeable capacity (CEC)

A decrease in organic matter with the aging of raised beds may contribute to the decrease in negatively charge components and this may then reduce nutrient holding capacity of the soil. Restrictions of soil nutrients to plants was reflected through a moderate CEC and an imbalance of cations in the observed raised-bed soils, which was clarified by the concentrations of exchangeable cations K^+, Mg^{2+} and Ca^{2+} and a low base saturation percentage of calcium, magnesium, and potassium in the soil.

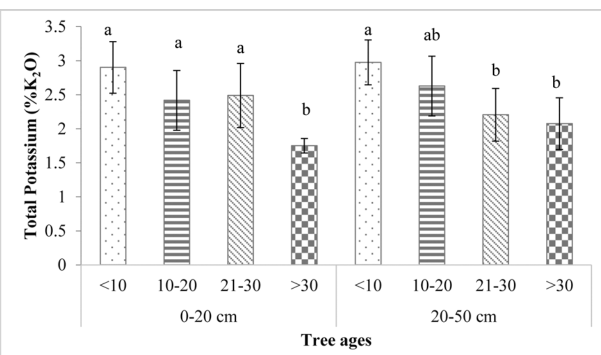

Figure 6. Change of total potassium with tree age at two soil depths

Note: Different letters indicate significant differences (Duncan) at $p \leq 0.05$ after analysis of variance (ANOVA) within tree age at each soil depth.

Researched results showed that the CEC value was highest in less than 10-year-old gardens for both depths of 0 - 20 and 20 - 50 cm, reaching between 16.9 and 20.3 respectively. These values decreased gradually over cultivating time, dropping from 16.9 meq/100 g (under 10-year-old mango trees) to 12.2 meq/100g (over 10 years old) for surface layer. Similarly, the CEC values at subsoil tended to fall off towards tree ages, ranging 20.3 and 7.7 meq/100 g for 10 years old and greater than 10 years old, respectively. The CEC value reached the lowest content to over 30 years old orchard at both depths of topsoil and subsoil, varying orderly from 11.4 meq/100 g and 7.7 meq/100 g (Fig. 7).

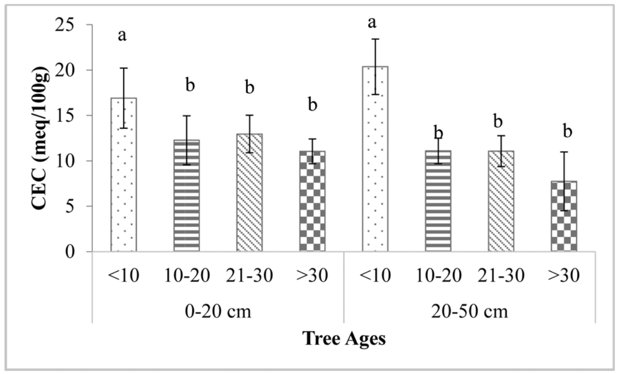

Figure 7. Change of CEC value with tree age at two soil depths

Note: Different letters indicate significant differences (Duncan) at $p \leq 0.05$ after analysis of variance (ANOVA) within tree age at each soil depth.

Commonly, the orchard management differs from one place to another place and variable rate of fertilization may be the reason for variability in nutrients. For effective orchard management, special unit-based zones need to be identified and appropriate recommendations may be developed based on soil properties (Gucci et al., 2012; Laboski et al., 2006; Neilsen et al., 2003). Similarly, ecology of the orchard also plays an important role and differs from one place to another contributing towards the significant change in soil properties (Montanaro et al., 2017). Cropping system under semi-arid or arid in tropical or subtropical areas differs in enzymatic activities because of climate and soil mediated factors (Phong et al., 2011; Võ et al., 2009).

4. Conclusion

Soil physico-chemical properties showed variations in different mango orchards and long-term planting reduced the soil fertility status. Soil physical and chemical properties were also estimated and showed lower status toward over 30-year-old trees. There showed the need for more organic resource application to improve orchard soils for improving the soil properties./.

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