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Study of soil properties after pomelo orchard restoration from flooding in Sam Phran district, Nakhon Pathom province, Thailand

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Abstract

The objective of this research was to evaluate soil fertility in pomelo orchard after restoration from flooding. The research was conducted at pomelo orchards in Sam Phran district, Nakhon Pathom province, Thailand. Results indicated no significant differences in soil pH, organic matter content, soil nutrient (N, P, K, Ca and Mg) concentrations among the ridged new bed orchards, the used old bed orchards and the survived orchard from flooding ($P > 0.05$). While, the soil physical property analysis for the 1st sampling showed that the ridged new bed orchards had the significantly highest soil bulk density (1.57 g cm^{-3}) compared to the survived orchard (1.47 g cm^{-3}) and the used old bed orchards (1.30 g cm^{-3}) ($P \leq 0.05$), respectively. For soil porosity, the used old bed orchards had the significantly highest soil porosity (52.49 %) compared to the survived orchard (44.28%) and the ridged new bed orchard (40.26 %) ($P \leq 0.05$), respectively and the same soil physical property results expressed in the 2nd sampling. However, there were no significant differences in leaf nutrient concentrations, shoot length and leaf length among those orchards. Thus, it can be concluded that the different methods in pomelo orchard restoration affected soil physical properties but it did not affect plant growth or leaf nutrients. However, it might be site specific unsuitable management in orchard restoration as the same research conducted in the other area gave no significant differences in any soil property studied.

Keywords: flooding, pomelo, restoration, soil properties

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1. Introduction

The big flooding in the year of 2011 in Thailand caused the damage of pomelo orchards in Nakhon Pathom province. Those have made the decrease in pomelo production area in Nakhon Pathom province. Nowadays, some farmers have restored the orchard to start growing pomelo trees again. The methods of orchard restorations used by farmer were separated into 2 groups: 1) the ridged new bed orchards and 2) the used old bed orchards. The ridged new bed orchards means the farmer made new bed after flooding for planting pomelo seedling, whereas the used old bed means the farmer used the old bed to grow pomelo seedling after flooded soil dried out. Moreover, some pomelo orchards were not destroyed by flooding and still have survived pomelo trees that keep continually growing. However, the farmers had noticed that the different methods of orchard restoration gave the different plant growth after pomelo seedling planted but it has not been proved. There has been possibility that the different methods in orchard restoration affect soil properties which might cause the different plant growth such as soil porosity, soil bulk density, soil pH and soil nutrients. Thus, the objective of this research was to study effect of the different methods on soil property in pomelo orchard restoration from flooding.

2. Materials and methods

The research was conducted in the pomelo growing areas in Sam Phran districts, Nakhon Pathom province, Thailand during August 2015 - July 2016. The orchard restoration methods studied were separated into 3 methods as follows: 1) the ridged new bed orchards, 2) the used old bed orchards and 3) the survived pomelo orchard (control). Four pomelo orchards for each restoration method were selected for the study totally 12 pomelo orchards were used. All pomelo orchards had the same soil series (Bang Khen series: Bn) [1]. Five similar size and age of *Thong Dee* pomelo trees in each orchard were selected for soil and plant sampling and plant growth measurement. Soil and plant samples were taken to laboratory for soil physical property analysis, soil pH analysis, soil nutrient analysis and plant nutrient analysis by methods as describe below.

2.1 Plant nutrient concentration analysis

Twenty index leaves (the 4th leaf position from shoot tip) from each orchard (four leaves per tree) were collected and taken for plant nutrient concentration analysis. The plant material was dried and ground before nutrient analysis. From this dried material nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), zinc (Zn),

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Table 1 Methods for the soil physical property, soil chemical property and soil nutrient tests

Parameter	Method	Reference
pH	1:1 soil:water	[2]
Soil organic matter	Walkley and Black	[3]
Available P	Bray II	[4]
Extractable K, Ca and Mg	1 M NH_4OAc pH 7	[5]
Extractable Fe, Cu, Mn and Zn	DTPA	[6]
Soil porosity	Core method	[7]
Soil bulk density	Core method	[7]

Table 2 Effect of the methods of orchard restoration from flooding on leaf macronutrient concentration in pomelo grown in Sam Phran district, Nakhon Pathom province. Data presented in the table were mean ± SD

Method of restoration	Leaf nutrient concentration (%)				
	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
The ridged new bed orchards	2.64±0.21	0.18±0.01	1.38±0.14	2.22±1.16	0.34±0.04
The used old bed orchards	2.75±0.22	0.17±0.01	1.54±0.09	2.75±0.47	0.32±0.02
The survived pomelo orchard	2.90±0.15	0.16±0.03	1.55±0.03	2.81±0.53	0.32±0.07
F-test	ns	ns	ns	ns	ns
p-value	0.23	0.37	0.15	0.53	0.77

ns indicates non-significant difference among treatments analyzed by the analysis of variance (ANOVA) at 0.05 significant levels.

copper (Cu) and iron (Fe) concentrations were determined. Levels of N were determined using the Microkjeldahl method. P, K, Ca and Mg were extracted by HNO_3-$HClO_4$ (5:1) then the solution was left to cool down. Phosphorus in solution was determined calorimetrically by the Molybdate-vanadate yellow color method. K, Ca, Mg, Fe, Mn, Zn and Cu were determined using an atomic absorption spectrophotometer. All plant nutrient analysis was done at the Soil Plant and Agricultural Material Testing and Research Unit, Central Laboratory, Kasetsart University, Kamphaeng Saen Campus.

2.2 Soil property analysis

Composite soil samples were collected at 0 - 15 cm depth below the surface near fruit trees using auger at the edge of canopy. The soil samples were collected avoiding the applied fertilizer site. The samples were collected at January 2016 (the 1st time of soil sampling) and July 2016 (the 2nd time of soil sampling) and taken to the laboratory for soil chemical property testing. These included pH, soil organic matter (SOM), P, K, Ca, Mg, Cu, Fe, Mn and Zn concentrations. Soil physical properties were also analyzed. The methods used for soil chemical property analysis, soil nutrient analysis and soil physical analysis (soil porosity and soil bulk density) were identified in Table 1.

2.3 Plant growth evaluation

Four currently flush shoots and four mature leaves for each pomelo tree were selected around canopy for shoot length and leaf length measurement, respectively, total of 20 shoots and 20 leaves per orchard**.** The measurement was done at the end of vegetative growth of pomelo tree (before flowering).

2.4 Statistical analysis

All parameters were statistically tested by the analysis of variance (ANOVA) at the 0.05 significant levels and the mean difference was tested by Duncan‘s New Multiple Range Test at the 0.05 significant levels. The completely randomized design was employed.

3. Results and discussion

The effect of orchard restoration method from flooding on leaf nutrient concentration in pomelo was studied. The results showed that the different methods of orchard restoration did not have any effect on leaf macronutrient concentration. The range of leaf macronutrient concentrations were 2.64 - 2.90%, 0.16 - 0.18%, 1.38 - 1.55%, 2.22 - 2.81% and 0.32 - 0.34% for N, P, K, Ca and Mg, respectively (Table 2). Moreover, there were not any significant differences in leaf micronutrient concentration among restoration methods. The range of leaf micronutrient concentrations were 6.97 - 10.37 mg g^{-1}, 131.07 - 261.44 mg g^{-1}, 21.84 - 25.15 mg g^{-1} and 16.14 - 21.95 mg g^{-1} for Cu, Fe, Mn and Zn, respectively (Table 3).

For soil chemical property, the methods of orchard restoration did not have any effect on soil nutrient concentration. The range of soil nutrient concentrations were 174.56 - 488.63 mg g^{-1}, 215.18 - 402.53 mg g^{-1}, 3056.60 - 3337.31 mg $g^{-1}$and 706.76 - 820.73 mg g^{-1} for P, K, Ca and Mg, respectively (Table 3). Also, the methods of orchard restoration did not have any effect on organic matter or soil pH as organic matter ranged 1.98 - 2.17%, whereas soil pH ranged 5.22 - 6.15 (Table 4).

Table 3 Effect of the methods of orchard restoration from flooding on leaf micronutrient concentration in pomelo grown in Sam Phran district, Nakhon Pathom province. Data presented in the table were mean ± SD

Method of restoration	Leaf nutrient concentration (mg kg^{-1})			
	Copper	Iron	Manganese	Zinc
The ridged new bed orchards	8.90±5.79	131.07±18.70	22.63±2.85	21.95±7.30
The used old bed orchards	10.37±6.61	261.44±142.73	25.15±4.62	19.57±6.93
The survived pomelo orchard	6.97±4.04	181.89±47.19	21.84±5.85	16.14±5.04
F-test	ns	ns	ns	ns
p-value	0.79	0.16	0.59	0.77

ns indicates non- significant difference among treatments analyzed by the analysis of variance (ANOVA) at .05 significant levels.

Table 4 Effect of the methods of orchard restoration from flooding on soil chemical properties in pomelo orchards in Sam Phran district, Nakhon Pathom province. Data presented in the table were mean ± SD

Method of restoration	Organic matter (%)	Soil nutrient concentration (mg kg^{-1})				Soil pH
		Phosphorus	Potassium	Calcium	Magnesium	
The ridged new bed orchards	2.17±0.53	488.63±436.17	402.53±189.04	3056.60±192.52	820.43±25.09	6.15±0.34
The used old bed orchards	2.20±0.56	332.38±209.38	374.56±145.59	3337.31±690.48	706.76±113.78	5.22±0.61
The survived pomelo orchard	1.98±0.64	174.56±125.96	215.18±66.91	3208.97±727.58	798.75±86.41	5.85±1.47
F-test	ns	ns	ns	ns	ns	ns
p-value	0.18	0.35	0.19	0.80	0.65	0.40

ns indicates non- significant difference among treatments analyzed by the analysis of variance (ANOVA) at .05 significant levels.

Table 5 Effect of the methods of orchard restoration from flooding on soil micronutrient concentration in pomelo grown in Sam Phran district, Nakhon Pathom province. Data presented in the table were mean ± SD

Method of restoration	Soil nutrient concentration (mg kg^{-1})			
	Copper	Iron	Manganese	Zinc
The ridged new bed orchards	7.94±4.78	85.43±59.04	78.27±14.07	6.30±3.13
The used old bed orchards	19.44±12.14	106.85±10.16	78.37±17.57	7.99±2.92
The survived pomelo orchard	14.60±12.45	71.96±30.98	76.82±13.75	6.81±4.85
F-test	ns	ns	ns	ns
p-value	0.55	0.47	0.13	0.17

ns indicates non- significant difference among treatments analyzed by the analysis of variance (ANOVA) at .05 significant levels.

For soil micronutrient concentrations, the results in Table 5 showed no significant difference in soil Cu, Fe, Mn and Zn concentrations among the methods of orchard restoration. The range of soil Cu, Fe, Mn and Zn concentrations were 7.94 - 19.44 mg g^{-1}, 71.96 - 106.85 mg g^{-1}, 38.27 - 78.37 mg g^{-1} and 3.30 - 7.99 mg g^{-1}, respectively.

The analysis of soil physical properties showed the significant difference ($P \leq 0.05$) among the methods of orchard restoration. The results in Table 6 showed that, in the 1st sampling, the ridged new bed orchard and the survived pomelo orchard gave the highest soil bulk density (1.57% and 1.47%, respectively), whereas, the used old bed orchard gave the lowest soil bulk density (1.30%). However, the used old bed orchard gave the highest soil porosity (52.49%), whereas, the survived pomelo orchard and the ridged new bed orchard gave the lower soil porosity (44.28% and 40.26%, respectively). Moreover, the same results were obtained in the 2nd sampling (Table 6). However, the measurements of pomelo shoot length and leaf length showed non-significant difference among the methods of orchard restoration (Figure 1).

The results showed that the methods of orchard restoration did not have any effect on soil nutrient concentrations, organic matter or soil pH in pomelo orchard. Moreover, there were not any significant differences in leaf nutrient concentration, shoot and leaf growth of pomelo trees among the methods of orchard restoration. These may be due to this research was done after 3 years of flooding which, among 1-3 year after orchard restoration, the farmer applied chemical and organic fertilizer including agricultural lime to the soil every year for soil amendment. Moreover, the chemical fertilizer formulas and chemical fertilizer content used by the farmer in different orchards were similar (information from farmers) which may result in the same soil nutrient concentration among orchards. Nevertheless, all of pomelo orchard used in this research

Table 6 Effect of the methods of orchard restoration from flooding on soil physical properties in pomelo orchards in Sam Phran district, Nakhon Pathom province. Data presented in the table were mean ± SD

Method of restoration	1st time sampling		2nd time sampling	
	Soil bulk density (g cm^{-3})1/	Soil porosity (%)1/	Soil bulk density (g cm^{-3}) 1/	Soil porosity (%)1/
The ridged new bed orchards	1.57±0.11a	40.26±3.61b	1.45±0.13a	28.58±4.56b
he used old bed orchards	1.30±0.05b	52.49±4.05a	1.29±0.07b	39.69±4.01a
The survived pomelo orchard	1.47±0.18ab	44.28±6.32b	1.36±0.16ab	33.94±3.88b
F-test	*	*	*	*
p-value	0.04	0.02	0.03	0.02

* indicates significant difference among treatments analyzed by the analysis of variance (ANOVA) at .05 significant levels.
1/ Means followed by the same letter within a column do not differ significantly at .05 significant levels according to Duncan's New Multiple Range Test.

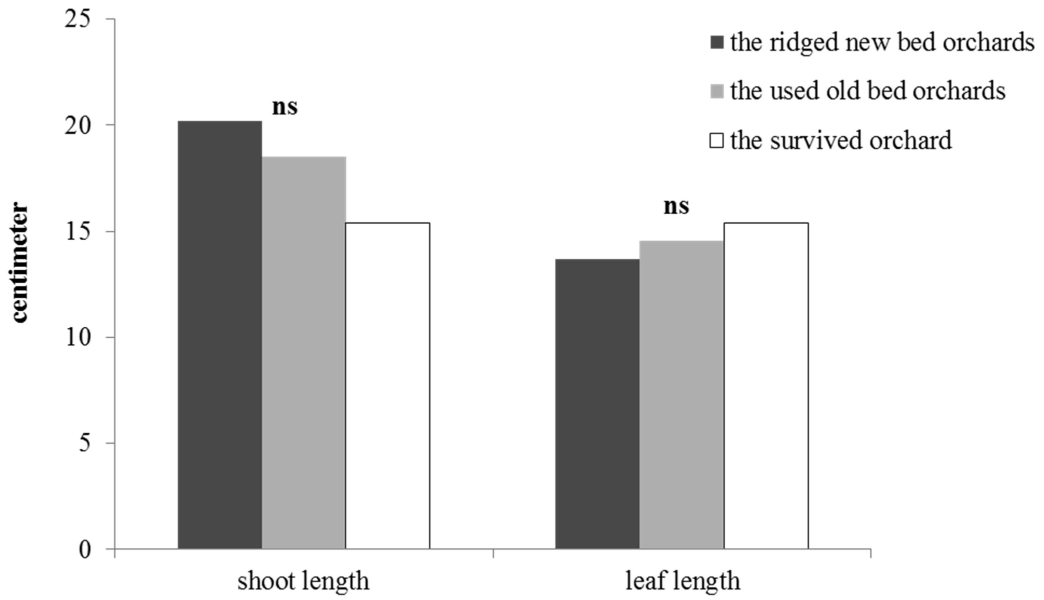

Figure 1 Effect of the methods of orchard restoration from flooding on shoot and leaf length in pomelo grown in Sam Phran district, Nakhon Pathom province. (ns indicates non- significant difference among treatments analyzed by the analysis of variance at 0.05 significant levels)

had the same soil series (Bang Khen series) [1], therefore the basic soil properties in all orchards were very similar.

From those reasons above, soil nutrient concentrations, organic matter and soil pH in all orchards restored by the different methods were similar. Thus, the similar soil nutrient concentration may result in the same leaf nutrient concentration among orchards restored by the different methods. However, based on standard soil and leaf nutrient concentrations for pomelo production the range of soil and leaf nutrient concentration in all pomelo orchards studied were in the suitable range. Nartvaranant [8] and Maneepong [9] reported that the suitable leaf N, P, K, Ca, Mg, Cu, Fe, Mn and Zn concentrations for pomelo production were 2.7 - 2.9%, 0.18 - 0.21%, 2.4 - 3.5%, 3.7 - 4.2% , 0.48 - 0.55%, 14 - 26 mg kg^{-1}, 739 - 850 mg kg^{-1}, 38 - 49 mg kg^{-1} and 37 - 60 mg kg^{-1} respectively, and the suitable soil P, K, Ca, Mg, Cu, Fe, Mn and Zn concentrations for pomelo production were 15 - 25 mg kg^{-1}, 100 - 150 mg.kg^{-1}, 1000 - 2000 mg kg^{-1}, 120 - 240 mg kg^{-1}, 1.1 - 3.0 mg kg^{-1}, 9 - 12 mg kg^{-1}, 0.9 - 1.2 mg kg^{-1} and 11 - 16 mg kg^{-1}, respectively. However, the pomelo orchards survived from flooding had the lowest organic matter (1.44%) and lower than the suitable range (1.5 - 2.5%) [9]. These might be due to less organic fertilizer applied to the flooded soil by the farmer.

The analysis of soil physical properties showed the significant differences in soil porosity and soil bulk density among the methods of orchard restoration. Soil porosity basically refers to the amount of pore, or open space between soil particles. Pore spaces may be formed due to the movement of roots, worms, and insects; expanding gases trapped within these spaces by groundwater; and/or the dissolution of the soil parent material. Important aspect of soil porosity concerns the oxygen found within these pore spaces. All plants need oxygen for respiration, so a well-aerated soil is important for growing crops. Promoting the maintenance and development of pores enhances these processes. Conversely, destruction of pores will diminish them. Moreover, compaction by construction equipment or our feet can decrease soil porosity and negatively impact the ability of soil to provide oxygen and water. While, soil bulk density is defined as the ratio of the mass of dry solids to the bulk volume of the soil occupied by those dry solids. The bulk density of the soil is an important site characterization parameter since it changes for a given soil. The bulk density varies indirectly with the total pore space present in the soil and gives a good estimate of the porosity of the soil. Generally soils with low bulk densities have favorable physical conditions and it is important to note that bulk density and porosity are inversely related. It is an absolute rule that as porosity increases, bulk density decreases or as bulk density increases, porosity decreases [10].

The ridged new bed orchards gave the highest soil bulk density and lowest soil porosity, whereas, the used old bed orchards gave the lowest soil bulk density and the highest soil porosity. There was a possibility that, in the ridged new bed method, the farmer used machinery for making a new bed, when the soil was not sufficiently dry. These could create soil compaction [11] resulted in the less soil porosity and the high soil bulk density. As it was reported that soil compaction decreases porosity as bulk density increases. If compaction increases bulk density from 1.3 to 1.5 g cm^{-3}, porosity decreases from 50 percent to 43 percent [12]. According to Hardy *et al.* [11] who suggested not take heavy machinery onto soils which are waterlogged or flooded as this will cause further compaction and structural damage to soil, exasperating drainage problems. Bulk density is an indicator of soil compaction and soil health. It affects infiltration, rooting depth/restrictions, available water capacity, soil porosity, plant nutrient availability, and soil microorganism activity, which influence key soil processes and productivity. It is generally desirable to have soil with a low bulk density (<1.5 g cm^{-3}) [13] for optimum movement of air and water through the soil. The critical value of bulk density for restricting root growth varies with soil type [13] such as a normal range of bulk densities for clay is 1.0 to 1.6 g cm^{-3} and a normal range for sand is 1.2 to 1.8 g cm^{-3} [14] but in general bulk densities greater than 1.6 g cm^{-3} tend to restrict root growth [15]. From the result, the highest soil bulk density was 1.57 g cm^{-3} found in the ridged new bed orchards. It was lower than 1.6 g cm^{-3}, therefore this could not restrict root growth or shoot growth.

Moreover, the low soil porosity in this research did not have any effect on plant growth as reflected by no significant difference in shoot or leaf length. Although the soil porosity in the ridged new bed orchards and the survived pomelo orchards were 40.26% and 44.28%, respectively, which were lower than the suitable soil porosity (50%) [16]. It could be that the soil in pomelo orchard is clay soil which normally has 51 - 55% soil porosity [10]. Thus, the soil porosity ranges found in this study were still in the normal range for clay soil which the pomelo trees can grow normally. However, the soil porosity in all restored method was decreased from approximately 40 - 52% in the 1st time of sampling to 28 - 39% in the 2nd time of sampling. These may be due to the soil samples in the 2nd time of sampling were taken at the end of growing season (near harvesting time) which many farm activities happened in the pomelo orchards inducing more soil compaction. Also, it might be that the soil application of chemical fertilizer to the pomelo tree during growing season decreased soil porosity due to using too much chemical fertilizer could result in poor physical soil property [11].

Based on all results obtained, the method of orchard restoration had effect on physical soil properties which were affected by flooding. According to Bly [17] reported that a 21% reduction in aggregate stability after 14 days of flooding in cultivated soils that might be irreversible. If an annual crop is ended due to flooding, efforts to help flooded soils improve would be planting of a cover crop to help improve the soil physical properties. However, the same research conducted in Nakhon Chai Si district, Nakhon Pathom province in the same period of Sam Phran district showed no significant differences in all soil properties (data not showed). Thus, the differences in soil physical properties found in Sam Phran district may be site specific unsuitable management during orchard restoration such as using agricultural machinery made the new ridge in the flooded soil when it was not sufficiently dry. Meanwhile, the low soil porosity in the survived orchards can be due to farmer‘s activity performed to the flooded soil before it was sufficiently dry without proper organic matter management.

Also, the farmers applied continually organic fertilizer (farm manure) approximately 30 - 40 kg $tree^{-1}$ $year^{-1}$ and chemical fertilizer approximately 3 - 4 kg $tree^{-1}$ $year^{-1}$ (data from farmers interview) to the flooded area every year after orchard restoration to improve soil properties. These may be the reasons of non - differences in flooded soil properties at 3 years later after flooding. These were according to Bly [17] who suggested that planting a cover crop would help improve soil physical properties and Coyne and Thompson [10] reported that increasing amounts of organic matter in the soil promote more stable structure and lead to increased porosity and decreased bulk density. Thus, the relationship between organic matter and structural development is the answer of why porosity and bulk density influenced by management practices. Meanwhile, chemical fertilizer applied every year to the flooded area would make non-difference in soil and plant nutrient concentrations among the different methods of orchard restoration. It is also possible that the methods of orchard restoration might affect properties of flooded soil in the early time of 3 years restoration resulting in the different plant growth as noticed by pomelo farmers. After orchard restoration, soil properties had improved continuously by lime application, organic and chemical fertilizer application. Thus, this research found non-differences in soil properties and plant growth.

Finally, it can be suggested that the flooded pomelo orchard may be restored by the used old bed and the ridged new bed methods but the flooded soil must be sufficiently dry before restoration and do not use agricultural machines or having any activities on the flooded soil before the flooded soil dried out. Using agricultural machines or any farm activities carried out on the flooded soil would induce soil compaction resulting in unsuitable soil properties. Moreover, the farmers should try to increase soil organic matter for soil physical property improvement and as much as necessary applying chemical fertilizer for soil nutrient concentration improvement.

4. Conclusions

From all results it can be concluded that there were no significant differences in soil pH, organic matter content, soil nutrient (N, P, K, Ca and Mg) concentrations among the ridged new bed orchards, the used old bed orchards and the survived orchard from flooding. While the ridged new bed orchards had the significantly highest soil bulk density as compared to the survived orchard and the used old bed orchards. For soil porosity, the used old bed orchards had the significantly highest soil porosity as compared to the survived orchard and the ridged new bed orchards. However, there were no significant differences in leaf nutrient concentrations, shoot length or leaf length among those orchards. Thus, the different methods in pomelo orchard restoration affected soil physical properties but it did not affect plant growth and leaf nutrients. However, it might be site specific unsuitable management in orchard restoration since the same research conducted in the other area at the same time gave no significant differences in any soil property studied.

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