EFFECTS OF POTASSIUM, CALCIUM AND MAGNESIUM RATIOS IN SOIL ON NUTRIENT UPTAKE BY PUMMELO (*Citrus maxima* Merr.)

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Abstract: Potassium (K), calcium (Ca), and magnesium (Mg) are important nutrients for the pummelo's growth and productivity. However, these nutrients are strongly antagonistic to each other. This study aims to examine the effects of different K, Ca, and Mg ratios in soil on nutrient uptake of pummelo plant. Soil samples were collected under pummelo canopies at a depth of 0 cm to 20 cm. Leaf samples of 3 to 5 month old were obtained from the same trees. The soil's chemical properties and nutrient concentrations in the leaves were determined. The results showed that the P uptake was inhibited by a high Ca concentration in soil. High K/Mg ratio in soil (0.52 $\pm$ 0.27) positively affected on K uptake. Low K/Mg ratios in soil (0.42 $\pm$ 0.20) negatively affected on K uptake, although exchangeable K in soil was much higher than optimum ranges. The K/Ca mole ratio in the leaves was higher than that in the soil; therefore, the uptake of K was better than that of Ca, despite the lower concentration of K in the soil. Moreover, the uptake of K was better than that of Mg, because the K/Mg ratio in the leaves higher than that in the soil. Low exchangeable Ca negatively affected on Ca uptake, although Ca/Mg mole ratio in soil was high (2.77 $\pm$ 1.18).

Keywords: Nutrient uptake; nutrition; Pummelo; cation ratios.

1. Introduction

Pummelo (*Citrus maxima* Merr.) is the biggest fruit of citrus species and high yield like other citrus. It requires larger amounts of K, Ca and Mg for growth and productivity. According to Maneepong, the quantities of K, Ca and Mg which required for fruit growth were 3005, 1506, and 228 mg/fruit, respectively [9]. However, the nutrient uptake processes of K, Mg, and Ca are strongly antagonistic resulting in a deficiency of the depressed nutrient [14]. A deficiency of one element could imply a relative or absolute excess of the others resulting in an imbalance for the plants [3]. A sufficient Ca concentration in soil or nutrient solution is important; however, major cations frequently interfere with Ca uptake [1]. Magnesium may strongly modify the uptake of Ca and K, whereas K and Ca can restrict the uptake and translocation of Mg from the roots to the upper plant parts [11]. On the other hand, ability of nutrient uptake does not depend only on its concentration in the soil, because the mobility of each nutrient into plant root is different.

The optimum K, Ca, and Mg for pummelo growth in soil and nutrient concentrations in leaves were recommended by Maneepong [9].

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However, the effects of K, Ca, and Mg ratios in soil on their uptake were ambiguous. Hence, the present study aims to examine the effects of K, Ca and Mg ratios in soil on nutrient uptake.

2. Materials and Methods

The research was conducted from 2015 to 2017. Two representative pummelo orchards in Pakpanang District (latitude 8^0 31' 0749'' N longitude 100^0 12' 05516'' E) and Khanom District (latitude 9^0 21' 1369'' N longitude 99^0 79' 0178'' E), Nakhon Si Thammarat Province, Thailand were selected for this study. The Tuptim Sayam and Thong Dee cultivars were selected. Most of the pummelo were planted using air-layering stocks in 1997. Some plants that were replanted later were not included in this study. Thirty pummelo trees were selected, and soil samples were collected from 4 positions directly beneath the canopy of each tree between 0 and 20 cm depth by a sampling tube. The samples were mixed, air-dried, ground then sieved through a 2 mm screen. Soil pH and electrical conductivity (EC) were measured using 1:2.5 and 1:5 of soil: water ratios, respectively. EC at the saturated point (ECe) was estimated by multiplying the EC by 6 [12]. Available P was extracted by 0.03 M NH_4F in 0.10 M HCl (Bray II solution), and its concentration was analyzed by the molybdenum blue method. Exchangeable K, Ca and Mg were extracted with 1 M NH_4OAc at pH 7.0. Concentration of K was analyzed by a flame photometer. Concentrations of Ca and Mg were analyzed by an atomic absorption spectrophotometer (AAS) [6, 7].

Three to five-month-old pummelo leaves were sampled from 3rd or 4th position of newly flush and non-fruiting twig on the outer canopy. Thirty pummelo trees were selected, and 12 to 16 leaves from each tree were collected. The samples were dried at 65˚C, ground, passed through 1 mm sieve. Nitrogen was analyzed by the Kjeldahl method. The samples were digested with 2:1 mixed of HNO_3: $HClO_4$ for P, K, Ca and Mg analysis. The concentration of P was analyzed using the vanadomolybdate method. Concentration of K was analyzed by a flame photometer. Concentrations of Ca and Mg were analyzed by AAS [13].

3. Results and Discussion

The soil chemical properties and their mole ratio were listed in Table 1. The soil pH in Pakpanang orchard was neutral and higher than its optimum ranges, whereas the soil pH in Khanom orchard was in optimum ranges. Soil ECe in Pakpanang varied greatly in a range of 1.3 to 5.2 mS/cm; however, most of these values fell in the optimum range. Slightly saline soil is recommended for pummelo growing. Although the soil tends to retard growth rate, but better fruit quality can be obtained [9, 10]. While the ECe in Khanom was very low compared with optimum ranges. Available P was much higher than its optimum ranges in both Pakpanang and Khanom. Therefore, P fertilizers should not to be more applied to pummelo growing in the orchards. The exchangeable K, Ca and Mg in soil of Pakpanang orchard were higher than their optimum ranges, whereas the exchangeable of K and Mg in Khanom were in the optimum ranges, but the exchangeable Ca was lower than the optimum ranges. If nutrient assimilation depends only on the nutrient concentration, the amounts of K, Ca and Mg in Pakpanang should be sufficient for pummelo. However, these nutrients are strongly antagonistic to each other. High Mg concentration either in soil or plant often causes poor K status in plant [8]. Zamaniyan et al. [15] found that the K uptake by chicory cultured in nutrient solution depends on K/Ca ratio, increasing the K/Ca ratio also increased K concentrations both in leaves and root. A K/Ca ratio higher than 1.5 decreased the yield and caused morphological damage related to Ca deficiency, such as pith hole and tip burn. The concentrations of K in the study soils were lower than those of Ca and Mg; therefore, the K/Ca and K/Mg ratios oppose to those of nutrient solution for soilless culture.

The nutrient concentrations in pummelo leaves and their optimum ranges were listed in Table 2. The N concentration in Pakpanang was lower than its optimum range according to Maneepong [9], and fell at lower margin according to Zhuang et al. [16]. The N fertilizer may not apply sufficiently, or may cause from a high N loss in NH_3 form, while the N concentration in Khanom was in optimum ranges. The leaf P concentration in Pakpanang was also low, despite its high concentration in the soil, whereas it was in optimum ranges in Khanom. Although, the available P in Pakpanang was higher than in Khanom, but exchangeable Ca in Pakpanang was higher than in Khanom. Restriction in P uptake may be ascribed to a high Ca concentration in the soil together with a neutral pH. Jakobsen [4] demonstrated that Ca could both support and inhibit P uptake. The inhibition affected results from the precipitation of less soluble calcium phosphate in the rhizosphere. The leaf K concentration in Pakpanang was lower than that in Khanom. However, leaf K concentration was lower than its optimum ranges in Pakpanang, while it was slightly higher than its optimum ranges in Khanom. Although, the exchangeable K in soil of Pakpanang orchard was much higher than its optimum ranges, but low K/Ca mole ratio in soil (0.42 ± 0.20) (Table 1) inhibited the uptake of K in leaves; high K/Mg mole ratio in soil of Khanom orchard (0.52 ± 0. 27) (Table 1) was positive effect on K uptake. Moreover, the concentration of Mg in both soils and leaves was higher in Pakpanang than Khanom (Table 1 and 2). Pummelo plant in Pakpanang cannot uptake K to a sufficient level despite the excessive K concentration in the soil, because of low K/Ca mole ratio in soil. An antagonism between K and Mg was previously described [5, 8]. On the other hand, low the K/Mg ratio in soil negatively affected on K uptake. Although the soil Ca/Mg mole ratio was higher in Khanom (2.77 ± 1.18) than in Pakpanang (1.30 ± 0.55), but the leaf Ca concentration was higher in Pakpanang than in Khanom. The cause might be due to the low exchangeable Ca in soil can affect on the Ca uptake by pummelo plant. The Mg concentration in leaves was higher than the optimum ranges in Pakpanang, whereas it was lower than the optimum ranges in Khanom, that is caused by the influence of too high exchangeable Mg in soil. The K/Mg ratio in the leaves was higher than that in the soil, indicating that pummelo prefers K to Mg. The K/Ca and Ca/Mg mole ratios in the leaves were also higher than those in the soil. These results indicated that the preference order of the pummelo over these nutrients is K > Ca > Mg. However, this preference order does not agree with the concentration order in the leaves (Ca > K > Mg) (Table 2). Because farmers applied a large amount of K but small amount of Ca and Mg fertilizer, Ca and Mg were deficient [2, 4, 14].

Table 1: *Chemical properties of pummelo growing soils (0-20 cm)*

Soil properties	Unit	Pakpanang orchard (Mean ± SD)	Khanom orchard (Mean ± SD)	Optimum range (Maneepong, 2008)
pH	-	7.1 ± 0. 3	5.7 ± 0.4	5.5 ÷ 6.5
ECe	mS/cm	2.7 ± 0.9	0.4 ± 0.1	2.0 ÷3.0
Available P	mg/kg	177 ± 94	117 ± 59	15 ÷ 25
Exchangeable K	mg/kg	1,013 ± 407	123 ± 36	100 ÷ 150
Exchangeable Ca	mg/kg	3,224 ± 1,030	738 ± 302	1,000 ÷ 2,000
Exchangeable Mg	mg/kg	1,568 ± 178	167 ± 52	120 ÷ 240
K/Ca mole ratio	-	0.35 ± 0.16	0.19 ± 0.10	-
K/Mg mole ratio	-	0.42 ± 0.20	0.52 ± 0. 27	-
Ca/Mg mole ratio	-	1.30 ± 0.55	2.77 ± 1.18	-

Table 2: *Nutrient concentrations in pummelo leaves*

Nutrients	Unit	Pakpanang orchard (Mean ± SD)	Khanom orchard (Mean ± SD)	Optimum range (Maneepong, 2008)
N	g/kg	26.1 ± 1.2	27 ± 1.0	27 ÷ 30
P	g/kg	1.4 ± 0.1	1.6 ± 0.1	1.5 ÷ 2.0
K	g/kg	13.9 ± 2.0	22 ± 1.6	15 ÷ 20
Ca	g/kg	31.4 ± 9.3	22 ± 3.4	30 ÷ 40
Mg	g/kg	6.0 ± 0.8	4.5 ± 0.6	3 ÷ 5
K/Ca mole ratio	-	0.50 ± 0.16	1.05 ± 0.2	-
K/Mg mole ratio	-	1.48 ± 0.34	3.07 ± 0.4	-
Ca/Mg mole ratio	-	3.16 ± 0.78	3.0 ± 0.6	-

The K/Ca, K/Mg and Ca/Mg mole ratios in pummelo leaves according to the optimum ranges suggested by Maneepong [9] were 0.5, 2.8 and 5.4, respectively. Similar ratios suggested by Zhuang *et al*. [16] were 0.6, 2.8 and 4.3, respectively. The results in Pakpanang showed that leaf K was lower than optimum range, low K/Ca (0.50 ± 0.16) and K/Mg (1.48 ± 0.34) mole ratio in soil affected the uptake of K.

Excessive Mg in the soil inhibited K and Ca uptake. This problem may be solved by applying K fertilizers. The leaf K/Ca and K/Mg ratios in Khanom were higher than their optimum ranges, therefore pummelo trees can uptake K and Mg to sufficient levels. However, the leaf Ca/Mg ratios in Khanom was lower than its optimum ranges, it was affected by a low Ca concentration in soil. This problem may be solved by applying Ca fertilizers.

4. Conclusion

The exchangeable K, Ca, Mg, and available P concentrations in Pakpanang orchard soils were higher than their optimum ranges. The exchangeable K and Mg in Khanom orchards ranged in the optimum concentrations, the exchangeable Ca was lower than its optimum ranges, and available P was much higher than the optimum ranges. The P uptake was restricted by a high concentration of Ca in the soil. The antagonistic effect of Mg inhibited the uptake of K, thereby causing an excessive consumption of Mg. High K/Mg ratio in soil positively affected on K uptake. Low K/Mg ratios in soil (0.42 ± 0.20) negatively affected on K uptake, although exchangeable K in soil was much higher than optimum ranges. Low exchangeable Ca in Khanom orchard soils negatively affected on Ca uptake although Ca/Mg ratio in soil was high.

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TÓM TẮT

ẢNH HƯỞNG CỦA TỶ LỆ KALI, CANXI VÀ MAGIÊ TRONG ĐẤT TRỒNG ĐẾN KHẢ NĂNG HẤP THU DINH DƯỠNG CỦA CÂY BƯỞI

Kali (K), canxi (Ca) và magiê (Mg) là những yếu tố dinh dưỡng có vai trò quan trọng đối với quá trình sinh trưởng và năng suất của cây bưởi. Tuy nhiên, những yếu tố dinh dưỡng này lại có tính đối kháng rất cao. Mục đích của nghiên cứu này là đánh giá ảnh hưởng của tỷ lệ K, Ca và Mg trong đất đến khả năng hấp thu dinh dưỡng. Mẫu đất được lấy xung quanh tán cây bưởi ở độ sâu từ 0 đến 20 cm. Mẫu lá từ 3 đến 5 tháng tuổi được lấy trên cây cùng với mẫu đất. Thành phần hóa học trong đất và hàm lượng dinh dưỡng trong lá được phân tích. Kết quả nghiên cứu cho thấy khả năng hấp thu lân (P) bị ức chế bởi hàm lượng Ca trong đất cao. Tỷ lệ K/Mg trong đất cao (0,52 ± 0,27) ảnh hưởng tích cực đến sự hấp thu K. Tỷ lệ K/Mg trong đất thấp (0,42 ± 0,20) ảnh hưởng tiêu cực đến sự hấp thu K, mặc dù hàm lượng K dễ tiêu trong đất cao hơn ngưỡng thích hợp cho cây bưởi. Tỷ lệ mole K/Ca trong lá cao hơn so với trong đất, do vậy khả năng hấp thu K tốt hơn so với Ca, mặc dù hàm lượng K trong đất thấp hơn. Hơn thế nữa, khả năng hấp thu K tốt hơn so với Mg, bởi vì tỷ lệ K/Mg trong lá cao hơn so với trong đất. Tuy nhiên, hàm lượng K trong lá ở vườn bưởi Pakpanang thấp hơn ngưỡng thích hợp, bởi vì hàm lượng Mg dễ tiêu trong đất cao đã ức chế khả năng hấp thu K. Hàm lượng Ca dễ tiêu trong đất thấp ảnh hưởng tiêu cực đến sự hấp thu Ca, mặc dù tỷ lệ mole Ca/Mg trong đất cao (2,77 ± 1,18).

Từ khóa: Hấp thu dinh dưỡng; dinh dưỡng; cây bưởi; tỷ lệ cation.