EFFECT OF PHOSPHORUS ON N, P, K, Mg ACCUMULATION AND PLANT GROWTH OF DIFFERENT CITRUS ROOTSTOCKS

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(Received 11th Aug 2017; accepted 11th Jan 2018)

Abstract. Phosphorus is an essential nutrient for the growth of citrus plants. A pot experiment was conducted in greenhouse to investigate the citrus cultivars grafted on 10 rootstocks (Cuningmeng, Suanju, Suancheng, Honglimeng, Zhike, Goutoucheng, Xiangyuan, Hongju, Xiangcheng, and Zhicheng) in response to the different phosphorus treatments viz, low P (LP) = 0.01 mmol L^{-1}, moderate P (MP) = 0.5 mmol L^{-1}, high P (HP) = 1 mmol L^{-1}) concentrations. All P concentrations were employed in pots containing Hoagland solution. The leaves, branch, root, and total dry weight, and nitrogen, phosphorus, potassium and magnesium concentrations in the different plant parts were determined. Results showed that P application increased N, P, K and Mg content in different plant parts. With increasing P application, the root dry weight, branch dry weight, leaves dry weight, and total dry weight increased whilst low P treatment affected the P, K, and Mg accumulation in root and ultimately plant growth. Moreover, low P concentrations also affected Mg content in leaves, that can lead to low plant photosynthesis and finally decreased the plant dry biomass
Keywords: *citrus rootstocks, phosphorus treatment, plant growth, plant nutrients accumulation*

Introduction

The rootstocks have a critical role in the fruit cultivation (Shafieizargar et al., 2012; Cantuarias-Avilés et al., 2010, 2011; Tazima et al., 2013). Rootstock affects the horticultural characteristics in citrus, such nutritional quality (Zhang et al., 2011), tree performance (Cantuarias-Avilés et al., 2010), stress resistance (Simpson et al., 2014), fruit yield (Hussain et al., 2013), and quality (Benjamin et al., 2013). Thus, it is meaningful to choose various rootstocks for investigating citrus plant growth, elements absorption, yield, quality; however, studies are still needed to evaluate the adopted rootstocks for citrus trees.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1601_819836

Phosphorus is important for plant growth, development and reproduction for it is constituent of phospholipids, nucleic acid and many proteins. Low P availability in soil is one of the most critical aspects that limit the productivity of many crops (Sanchez and Salinas, 1981; Liao and Yan, 2003). P deficiency or excess could cause nutritional imbalance in citrus tree, then may reduce the yield and fruit quality (Fan and Wang, 2012; Fan and Luo, 2015). Too low or too high P concentrations may disturb the uptake of N, K, Fe, Zn, and B in plants (Fan and Wang, 2012). P also affects the root morphological and physiological characteristics of different root stocks (Fan and Luo, 2015). On the other hand, Syvertsen (1987) did not find any relationship between the P level in leaves and photosynthetic capacity of orange and pomelo seedlings. Moreover, Bernardi et al. (2015) reported that P had little effects on photosynthesis. Zambrosi et al. (2013a) indicated that P uptake by young citrus plants in low P soil depends on rootstock varieties and nutrient management. Significant variations in the ability of citrus rootstocks to acquire P from the soil was differs with the nature of the rootstock (Wutscher, 1989; Mattos et al., 2006). Additionally, P application could mitigate the effects of hostile environment (Pestana et al., 2005; Gimeno et al., 2010). Zambrosi et al. (2013b) stated that sufficient P might contribute to increase the ability of young citrus trees to cope with Cu toxicity. Hence, P application could alter morpho-physiological characteristics, yield and quality and nutrient uptake in plants, however, there are still some specific mechanisms that explain the differential responses of cultivated citrus to P fertilization are not yet fully explored. The specific objective of this study was to evaluate the effect of the P on nutritional accumulation and citrus tree growth.

Materials and Methods

Experimental design

A pot experiment was conducted in greenhouse in South China Agricultural University. Citrus cultivars Cuningmeng (*Citrus jambhiri* Lush), Suanju (*Citrus reticulata* Blanco), Suancheng, Honglimeng (*Citrus limonia* Osbeck), Zhike [*Poncirus trifoliate* (L.) Raf.], Goutoucheng (*Citrus aurantium* L.), Xiangyuan (*Citrus medica* var . *ethrog* Engl.), Hongju (*Citrus reticulata* Blanco cv. Red tangerine), Xiangcheng (*Citrus junons* Sieb.), and Zhicheng (hybird of *Citrus sinensis* Osbeck. ×*Poncirus trifoliate* Raf) were used as rootstocks in this study. Five leaf old seedlings were transferred to the different P treatments in Hoagland solution. Three P treatments *viz*, low P treatment (LP) = 0.01 mmol L^{-1}, moderate P treatment (MP) = 0.5 mmol L^{-1}, high P treatment (HP) = 1 mmol L^{-1}) were employed in Hoagland solution with four replications. The nutrient solution was renewed once every three days.

Sampling and measurement

Dry weight measurement

After 45 days of treatment, three representative plants in each treatment and each cultivar were harvested and separated into root, branch and leaves. The plant samples were then oven dried at 105°C for 30min and then at 75°C to a constant weight for measurement of dry weight.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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N, P, K and Mg content measurements

The plant root, branch and leaves sample were then ground into powder for measurement of N, P, K and Mg content and calculation of N, P, K and Mg accumulation.

The N, P, and K content in plant root, branch and leaves were determined as described by Lu (1999). For N, P and K contents, the dried samples (~0.3 g) were digested using the H_2SO_4-$HClO_4$ method. The digestion mixtures were then used to determine the total N content by the Kjeldahl method with a 2300 Kjeltec Analyzer Unit (Foss Tecator AB, Sweden), total P concentration by using a spectrophotometer (Shimadzu UV-2550), and total K concentration by atomic absorption spectrometry (SHIMADZU AA- 6300C AA spectrometer).

Dry sample of plant root, branch and leaves were ground, and approximately 0.100 g of the plant samples were dry-digested in a muffle furnace at 500°C for 6 h, and then 10 ml of HNO_3: H_2O (1:1) was added to extract the ions. The contents of concentration were detected by using an atomic absorption spectrometry (SHIMADZU AA- 6300C AA spectrometer). The Mg content in plant root, branch and leaves was recorded and expressed in mg g^{-1}.

Statistical Analysis

Analyses of variances (ANOVA) and correlation analyses were performed by Statistix version 8 (Statistix 8, Analystical, Tallahassee, FL, USA). Comparisons of means among different P treatments were made according to the least significant difference (LSD) test at 5% probability level.

Results

Citrus plant growth

Significant impacts of cultivars, phosphorus and C×P on citrus plant growth i.e., root, branch, leaves and total plant dry weight were observed. Compared with LP treatment, middle level phosphorus supplement (MP) significantly increased root dry weight, branch dry weight, leaves dry weight, and total dry weight by 18.41%, 79.84%, 91.65%,and 67.72%, respectively; high level phosphorus supplement (HP) remarkably improved root dry weight, branch dry weight, leaves dry weight, and total dry weight by 18.18%, 85.05%, 103.21%, and 74.15%, respectively. For MP treatment, higher root dry weight (73.79% and 50.28%), leaves dry weight (200.78 % and 154.76%), total dry weight (166.43 % and 108.77%) in Cuningmeng and Suanju; while higher branch dry weight (190.57%, 115.32% and 116.16%) was investigated in Cuningmeng, Suanju and Suncheng. However, the root dry weight in Hongju and Xiangcheng was inhibited by 34.53% and 30.63%, respectively. Zhike gained lower branch, leaves and total dry weight improvement, Goutoucheng had lower branch dry weight improvement, and lower leaves dry weight and total dry weight improvement in Hongju was observed. For HP treatment, Cuningmeng and Suanju produced higher root dry weight (85.24 % and 115.08%), branch dry weight (116.60 % and 246.77%), leaves dry weight (167.03% and 279.21%), and total dry weight (133.40% and 214.10%). However, the root dry weight in Suancheng, Goutoucheng, Hongju, Xiangcheng, Zhicheng was inhibited. Zhike and Zhicheng had lower branch dry weight, leaves dry weight and total dry weight gained.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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Therefore, it can be stated that Cuningmeng and Suanju were high P efficiency cultivars but Zhike, Zhicheng or Hongju were low phosphorus efficiency cultivars (*Table 1*).

Table 1. *Effects of phosphorus treatment on citrus plant growth.*

Phosphorus	Cultivar	Root dry weight (g)	Branch dry weight (g)	Leaves dry weight (g)	Total dry weight (g)
LP	Cuningmeng	1.31±0.14	1.38±0.09	2.56±0.25	5.25±0.32
	Suanju	0.60±0.03	0.41±0.05	0.70±0.09	1.71±0.15
	Suancheng	1.31±0.12	1.00±0.14	2.39±0.27	4.70±0.47
	Honglimeng	1.53±0.10	2.09±0.17	2.74±0.17	6.36±0.43
	Zhike	0.76±0.08	0.79±0.02	0.89±0.05	2.44±0.13
	Goutoucheng	0.70±0.03	0.86±0.07	1.26±0.17	2.83±0.27
	Xiangyuan	1.61±0.13	2.52±0.16	3.21±0.23	7.34±0.48
	Hongju	1.02±0.06	0.38±0.04	0.88±0.07	2.29±0.15
	Xiangcheng	1.07±0.06	1.02±0.06	1.83±0.08	3.92±0.19
	Zhicheng	1.67±0.12	1.34±0.06	1.44±0.10	4.44±0.16
	Mean	*1.1587 b*	*1.1781 b*	*1.7902 b*	*4.1269 b*
MP	Cuningmeng	2.28±0.25	4.01±0.22	7.71±0.47	14.00±0.89
	Suanju	0.90±0.10	0.89±0.03	1.78±0.16	3.57±0.29
	Suancheng	1.69±0.06	2.15±0.11	4.44±0.22	8.28±0.38
	Honglimeng	1.92±0.10	3.44±0.23	4.93±0.32	10.29±0.46
	Zhike	0.98±0.09	0.97±0.08	1.14±0.13	3.09±0.29
	Goutoucheng	0.82±0.13	1.17±0.06	2.06±0.17	4.04±0.32
	Xiangyuan	1.94±0.12	4.29±0.16	5.93±0.09	12.16±0.37
	Hongju	0.67±0.03	0.71±0.06	1.32±0.09	2.70±0.12
	Xiangcheng	0.74±0.08	1.60±0.17	2.82±0.20	5.16±0.42
	Zhicheng	1.78±0.14	1.95±0.03	2.18±0.05	5.91±0.20
	Mean	*1.3720 a*	*2.1187 a*	*3.4308 a*	*6.9215 a*
HP	Cuningmeng	2.43±0.18	2.99±0.16	6.85±0.61	12.26±0.76
	Suanju	1.28±0.16	1.43±0.10	2.65±0.23	5.37±0.43
	Suancheng	1.08±0.09	1.46±0.21	3.57±0.21	6.12±0.44
	Honglimeng	1.78±0.24	3.66±0.21	5.72±0.23	11.15±0.60
	Zhike	0.86±0.09	1.01±0.05	1.30±0.09	3.17±0.23
	Goutoucheng	0.63±0.04	1.33±0.08	2.13±0.11	4.09±0.20
	Xiangyuan	2.50±0.31	5.16±0.39	6.90±0.61	14.55±1.3
	Hongju	0.82±0.10	0.91±0.04	1.77±0.1	3.51±0.18
	Xiangcheng	1.00±0.08	2.37±0.13	3.82±0.19	7.19±0.30
	Zhicheng	1.31±0.09	1.48±0.10	1.67±0.12	4.45±0.28
	Mean	*1.3693 a*	*2.1801 a*	*3.6378 a*	*7.1872 a*
F value					
	Cultivar(C)	53.07**	186.02**	143.66**	150.66**
	Phosphorus (P)	8.11**	154.92**	174.77**	140.75**
	C×P	4.91**	13.33**	13.29**	12.98**

Note: different lowercase letters are used to indicate values that are significantly different at $p < 0.05$ among P treatments.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1601_819836

N content and N accumulation

Significant effects of cultivars, phosphorus and C×P on citrus plant N content and accumulation in different plant part were observed, except for the C×P effect on N content in branch. MP treatment significantly increased N content in root, branch, leaves, N accumulation in root, N accumulation in branch, N accumulation in leaves, and total N accumulation by 34.52%, 24.58%, 24.43%, 56.24%, 112.35%, 124.73%, and 103.25%, respectively. HP treatment significantly increased the N content in root, branch, leaves, N accumulation in root, N accumulation in branch, N accumulation in leaves, and total N accumulation by 31.82%, 29.35%, 25.87%, 52.09%, 126.56%, 142.72%, and 114.33%, respectively. Highest N content increment were observed in Goutoucheng for MP and HP treatment, while lowest increment in N content in branch and leaves were investigated in Cuningmeng for MP and HP. The highest increment in N content in branch and leaves were found in Quenching for MP and in Goutoucheng for HP. For the accumulation of N in citrus plant, Hongju and Xiangcheng had lower N accumulation in root for MP treatment, the highest N accumulation in branch was observed in Suancheng but the lowest N accumulation in branch was investigated in Zhike for MP. Higher N accumulation in leaves and total N accumulation were detected in Suancheng and lower N accumulation in leaves and total N accumulation were found in Zhike for MP. Suancheng had the highest N accumulation in plant while Zhicheng had the highest N accumulation in plant for HP (*Table 2*).

P content and P accumulation

Cultivars, phosphorus and C×P significantly affected P accumulation in citrus plants. MP treatment significantly increased P content in root, branch, and leaves. P accumulation in root, P accumulation in branch, P accumulation in leaves, and total P accumulation increased by 182.05%, 189.96%, 193.30%, 231.51%, 420.40%, 474.22%, and 388.03%, respectively. HP treatment dramatically increased P content in root, P content in branch, P content in leaves, P accumulation in root, P accumulation in branch, P accumulation in leaves, and total P accumulation by 211.06%, 197.08%, 205.49%, 257.99%, 455.24%, 547.75%, and 437.76%, respectively. For MP treatment, the increment in P content in root ranged from 129.46% to 298.85%, P content in branch ranged from 72.85% to 251.95%, P content in leaves ranged from 73.82% to 272.43% and P accumulation in root ranged from 73.08% to 586.10%, P accumulation in branch ranged from 113.59% to 847.09%, P accumulation in leaves ranged from 124.77% to 901.49%, and total P accumulation ranged from 145.38% to 812.48%. The data showed that Cuningmeng had higher increment in P content and accumulation, but that of Zhike was lower. For HP treatment, the increment in P content in root ranged from 134.58% to 347.99%, P content in branch ranged from 83.32% to 291.78%, P content in leaves ranged from 80.36% to 304.84% and P accumulation in root ranged from 107.59% to 725.85%, P accumulation in branch ranged from 134.27% to 834.43%, P accumulation in leaves ranged from 164.64% to 920.37%, and total P accumulation ranged from 162.06% to 961.33%. Among the cultivars, Cuningmeng showed higher P content and accumulation, but lower P content and accumulation was observed for Zhike (*Table 3*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1601_819836

Table 2. *Effects of phosphorus treatment on N content and N accumulation in citrus plants.*

Phosphorus	Cultivar	N content in root (mg g^{-1})	N content in branch (mg g^{-1})	N content in leaves (mg g^{-1})	N accumulation in root (mg)	N accumulation in branch (mg)	N accumulation in leaves (mg)	Total N accumulation (mg)
LP	Cuningmeng	19.73±2.13	8.60±0.52	25.47±1.54	26.00±4.21	11.95±1.47	66.07±10.45	104.02±8.82
	Suanju	16.17±0.81	11.42±0.85	24.48±2.33	9.68±0.94	4.65±0.26	16.74±1.13	31.06±1.32
	Suancheng	20.37±0.41	10.02±0.32	18.39±1.07	26.67±1.99	9.98±1.41	43.30±2.57	79.94±5.27
	Honglimeng	18.97±0.54	8.63±0.07	22.96±1.16	29.12±2.70	18.02±1.53	62.60±1.89	109.74±4.86
	Zhike	18.27±0.83	12.38±1.18	26.48±2.27	13.75±0.87	9.73±0.70	23.63±2.77	47.11±4.16
	Goutoucheng	23.13±2.33	11.10±0.99	24.93±1.48	16.40±2.37	9.43±0.42	31.08±2.41	56.91±4.58
	Xiangyuan	16.67±0.82	9.57±1.01	26.46±2.35	27.00±3.20	24.39±4.15	85.97±14.12	137.36±21.14
	Hongju	18.97±1.08	11.60±0.71	24.72±0.86	19.52±2.22	4.47±0.70	21.95±2.42	45.94±5.11
	Xiangcheng	28.80±1.27	11.24±0.23	24.45±0.35	30.87±3.09	11.49±0.83	44.75±2.39	87.12±6.25
	Zhicheng	15.27±0.69	13.36±0.98	30.15±2.32	25.56±2.49	17.97±2.04	43.83±6.10	87.35±8.58
	Mean	*19.633 b*	*10.793 b*	*24.850 b*	*22.457 b*	*12.208 b*	*43.99 c*	*78.66 b*
MP	Cuningmeng	26.4±1.72	8.31±0.53	23.53±0.41	59.68±5.66	33.47±3.80	181.16±8.26	274.31±17.69
	Suanju	20.70±0.93	13.76±1.03	29.58±1.45	18.60±2.33	12.22±0.88	52.88±6.00	83.71±9.06
	Suancheng	29.73±1.53	14.25±0.33	26.45±0.95	50.21±2.77	30.75±2.14	117.49±7.75	198.45±11.00
	Honglimeng	21.53±1.77	9.77±0.75	25.49±2.07	41.37±4.20	33.51±2.59	125.79±13.29	200.68±11.88
	Zhike	22.40±1.07	14.32±1.60	34.42±1.53	21.87±1.34	13.89±1.95	39.51±5.70	75.28±8.42
	Goutoucheng	34.70±0.64	14.61±0.65	35.10±1.32	28.52±4.70	17.01±0.63	71.70±3.48	117.23±6.61
	Xiangyuan	25.70±0.31	11.72±0.66	30.76±1.06	49.81±2.69	50.45±4.38	182.53±9.14	282.78±15.48
	Hongju	25.87±0.93	15.96±0.59	33.70±1.22	17.36±1.14	11.30±0.85	44.36±1.73	73.02±1.54
	Xiangcheng	36.70±0.31	14.75±0.58	32.14±1.15	27.16±2.99	23.42±1.97	90.30±4.18	140.88±8.97
	Zhicheng	20.37±0.13	17.02±0.21	38.04±0.59	36.29±2.56	33.20±0.36	82.89±1.19	152.37±4.07
	Mean	*25.880 a*	*13.446 a*	*30.921 a*	*35.087 a*	*25.923 a*	*98.86 b*	*159.87 a*
HP	Cuningmeng	24.07±2.29	9.30±1.02	25.57±2.26	58.97±9.42	27.56±2.55	172.35±1.08	258.87±9.40
	Suanju	22.67±1.90	15.20±0.67	31.24±1.07	29.69±6.30	21.68±0.83	82.76±6.75	134.13±10.58

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1601_819836

	Suancheng	28.17±2.87	14.57±1.00	29.01±1.53	30.76±4.95	20.93±1.43	103.02±0.68	154.72±4.52
	Honglimeng	22.73±1.63	11.57±1.69	27.68±1.16	40.91±7.40	41.73±4.22	158.32±9.88	240.97±19.34
	Zhike	23.63±0.50	15.13±1.06	31.40±2.18	20.29±2.11	15.17±0.51	40.47±0.73	75.93±2.17
	Goutoucheng	37.53±1.34	16.57±0.47	38.14±0.42	23.56±0.79	21.96±0.94	81.29±3.50	126.80±4.01
	Xiangyuan	23.40±2.29	11.12±1.64	28.22±3.04	60.02±12.87	56.41±5.65	192.00±13.55	308.43±19.53
	Hongju	25.47±0.60	15.97±0.47	33.56±0.48	20.90±2.71	14.58±0.49	59.47±2.96	94.96±5.62
	Xiangcheng	32.73±0.99	13.07±0.88	29.96±1.05	32.59±1.52	31.19±3.82	114.77±9.86	178.54±13.53
	Zhicheng	18.40±1.85	17.10±0.20	37.99±0.78	23.86±1.90	25.36±1.78	63.31±4.96	112.54±8.53
	Mean	*26.410 a*	*13.960 a*	*31.279 a*	*34.155 a*	*27.657 a*	*106.78 a*	*168.59 a*
F value								
	Cultivar(C)	36.05**	29.16**	15.94**	22.81**	119.82**	114.83**	98.11**
	Phosphorus (P)	70.17**	33.05**	56.86**	23.16**	109.86**	276.30**	251.27**
	C×P	1.91*	1.10ns	2.46**	3.01**	4.33**	9.62**	10.26**

Note: different lowercase letters are used to indicate values that are significantly different at $p < 0.05$ among P treatments.

Table 3. *Effects of phosphorus treatment on P content and P accumulation in citrus plants.*

Phosphorus	**Cultivar**	**P content in root (mg g^{-1})**	**P content in branch (mg g^{-1})**	**P content in leaves (mg g^{-1})**	**P accumulation in root (mg)**	**P accumulation in branch (mg)**	**P accumulation in leaves (mg)**	**Total P accumulation (mg)**
LP	Cuningmeng	0.64±0.03	0.54±0.02	0.72±0.01	0.84±0.13	0.75±0.07	1.85±0.19	3.45±0.25
	Suanju	1.22±0.08	1.02±0.11	1.06±0.05	0.72±0.02	0.43±0.09	0.74±0.11	1.90±0.19
	Suancheng	0.84±0.06	0.83±0.09	0.72±0.06	1.10±0.12	0.80±0.05	1.73±0.28	3.63±0.35
	Honglimeng	0.82±0.06	0.73±0.01	0.88±0.07	1.26±0.15	1.52±0.13	2.38±0.09	5.16±0.23
	Zhike	1.08±0.11	1.19±0.08	1.32±0.13	0.82±0.12	0.94±0.04	1.17±0.11	2.93±0.16
	Goutoucheng	0.99±0.00	0.83±0.02	0.81±0.05	0.70±0.03	0.72±0.08	1.03±0.18	2.45±0.28
	Xiangyuan	0.91±0.06	0.51±0.04	1.01±0.04	1.48±0.22	1.28±0.17	3.25±0.38	6.01±0.73
	Hongju	1.17±0.10	0.89±0.02	0.90±0.06	1.21±0.16	0.34±0.04	0.80±0.11	2.35±0.30
	Xiangcheng	0.87±0.04	0.84±0.02	0.79±0.02	0.92±0.01	0.85±0.05	1.45±0.08	3.23±0.14

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1601_819836

	Zhicheng	0.96±0.09	0.96±0.09	1.09±0.09	1.61±0.22	1.30±0.17	1.58±0.23	4.49±0.25
	Mean	*0.9497 c*	*0.8337 b*	*0.9307 c*	*1.0657 b*	*0.8936 c*	*1.600 c*	*3.559 c*
MP	Cuningmeng	2.54±0.17	1.77±0.07	2.41±0.08	5.79±0.75	7.09±0.45	18.58±0.90	31.45±1.93
	Suanju	3.03±0.10	3.04±0.19	2.98±0.12	2.72±0.34	2.72±0.27	5.36±0.73	10.80±1.33
	Suancheng	2.63±0.07	2.69±0.05	2.38±0.05	4.45±0.26	5.81±0.34	10.60±0.72	20.85±1.30
	Honglimeng	2.39±0.10	2.41±0.13	3.13±0.21	4.58±0.26	8.25±0.38	15.27±0.25	28.10±0.35
	Zhike	2.58±0.06	2.07±0.01	2.30±0.07	2.55±0.28	2.01±0.18	2.63±0.35	7.19±0.80
	Goutoucheng	3.25±0.05	2.75±0.04	2.89±0.05	2.67±0.44	3.21±0.15	5.91±0.39	11.79±0.87
	Xiangyuan	2.39±0.23	1.61±0.08	2.80±0.14	4.64±0.51	6.91±0.59	16.61±1.08	28.17±1.95
	Hongju	3.12±0.04	3.12±0.19	3.36±0.17	2.09±0.06	2.19±0.06	4.41±0.11	8.69±0.06
	Xiangcheng	2.65±0.07	2.51±0.05	2.40±0.05	1.97±0.26	4.00±0.39	6.78±0.52	12.75±1.10
	Zhicheng	2.2±0.14	2.21±0.03	2.62±0.07	3.88±0.03	4.32±0.05	5.71±0.16	13.91±0.22
	Mean	*2.6773 b*	*2.4173 a*	*2.7263 b*	*3.5331 a*	*4.6501 b*	*9.187 b*	*17.370 b*
HP	Cuningmeng	2.86±0.17	2.12±0.15	2.92±0.13	6.97±0.85	6.29±0.29	19.88±0.96	33.14±1.11
	Suanju	3.63±0.12	2.83±0.05	2.86±0.04	4.64±0.56	4.05±0.20	7.56±0.57	16.26±1.22
	Suancheng	3.41±0.06	2.96±0.1	2.59±0.11	3.70±0.36	4.31±0.53	9.23±0.33	17.24±1.08
	Honglimeng	2.08±0.09	2.32±0.18	3.10±0.22	3.66±0.37	8.55±1.11	17.81±2.02	30.02±3.34
	Zhike	2.75±0.10	2.19±0.08	2.38±0.06	2.38±0.33	2.20±0.06	3.09±0.19	7.67±0.54
	Goutoucheng	4.05±0.07	2.74±0.02	2.99±0.04	2.56±0.19	3.63±0.2	6.38±0.40	12.57±0.62
	Xiangyuan	2.13±0.18	1.67±0.15	2.95±0.20	5.44±1.10	8.50±0.37	20.11±0.59	34.05±1.53
	Hongju	3.32±0.10	3.19±0.07	3.50±0.05	2.73±0.38	2.92±0.18	6.21±0.40	11.86±0.68
	Xiangcheng	2.74±0.02	2.35±0.07	2.23±0.04	2.74±0.19	5.58±0.42	8.52±0.57	16.83±0.95
	Zhicheng	2.56±0.14	2.4±0.16	2.89±0.16	3.34±0.2	3.58±0.43	4.83±0.55	11.75±0.88
	Mean	*2.9527 a*	*2.4760 a*	*2.8393 a*	*3.8152 a*	*4.9614 a*	*10.363 a*	*19.140 a*
F value	Cultivar(C)	43.04**	31.11**	16.32**	16.41**	45.48**	119.62**	85.80**
	Phosphorus (P)	955.26**	1072.93**	964.39**	147.22**	514.50**	668.34**	667.66**
	C×P	7.82**	8.18**	5.61**	4.93**	15.35**	30.53**	23.49**

Note: different lowercase letters are used to indicate values that are significantly different at $p < 0.05$ among P treatments.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1601_819836

K content and K accumulation

The cultivars, phosphorus and their interaction C×P significantly affected the K content and accumulation in citrus plant. MP treatment significantly increased K content in root, K content in branch, K content in leaves, K accumulation in root, K accumulation in branch, K accumulation in leaves, and total K accumulation by 51.99%, 21.46%, 21.27%, 87.18%, 122.44%, 138.65%, and 124.73%, respectively. HP treatment dramatically increased K content in root, K content in branch, K content in leaves, K accumulation in root, K accumulation in branch, K accumulation in leaves, and total K accumulation by 41.09%, 17.01%, 16.64%, 69.81%, 120.57%, 142.22%, and 122.91%, respectively. For MP treatment, Xiangyuan had the highest increment in K content in root, K content in branch, K content in leaves and K accumulation in root; while Cuningmeng had the highest increment in K accumulation in branch, K accumulation in leaves, and total K accumulation. The lowest increment in K content in branch, K content in leaves, K accumulation in branch, K accumulation in leaves, and total K accumulation was observed in Zhike for MP treatment. The lowest increment in K content in root and K accumulation in root was investigated in Suanju and Hongju for MP, respectively. For HP treatment, Cuningmeng had the highest increment in K content in root and K accumulation in root when compared to LP. Suanju decreased K content in branch and K content in leaves but had the highest increment in K accumulation in branch, K accumulation in leaves, and total K accumulation for HP treatment. Hongju had the highest increment in K content in branch and K content in leaves. Zhicheng showed lowest highest increment in K accumulation (*Table 4*).

Mg content and Mg accumulation

The cultivars, phosphorus and C×P on Mg content and Mg accumulation in different plant part were observed, except for the P treatment effect on Mg content in leaves and C×P effect on Mg content in branch and leaves. MP treatment significantly increased Mg content in root, Mg accumulation in root, Mg accumulation in branch, Mg accumulation in leaves, and total Mg accumulation by 26.58%, 52.06%, 81.35%, 95.35% and 84.81%, respectively. HP treatment dramatically increased Mg content in root, Mg content in branch, Mg accumulation in root, Mg accumulation in branch, Mg accumulation in leaves, and total Mg accumulation by 27.88%, 7.65%, 52.30%, 101.68%, 111.60% and 99.33%, respectively. MP treatment increased Mg content in root in range of 7.03 ~76.54 %. However, Zhike and Hongju decreased Mg content in root for HP treatment was detected. There observed decrease in Mg content in branch and leaves for Cuningmeng, Suanju, Zhike, Xiangcheng for MP treatment. Mg content in branch and leaves in Suanju, Goutoucheng and xiangcheng was decreased for MP treatment, and decrement in Mg content in branch for Honglimeng and Mg content in leaves for Zhike was investigated. Decrement in Mg accumulation in root in Hongju was observed for MP and HP treatment and in Xiangcheng for MP treatment (*Table 5*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1601_819836

Table 4. *Effects of phosphorus treatment on K content and K accumulation in citrus plants.*

Phosphorus	Cultivar	K content in root (mg g^{-1})	K content in branch (mg g^{-1})	K content in leaves (mg g^{-1})	K accumulation in root (mg)	K accumulation in branch (mg)	K accumulation in leaves (mg)	Total K accumulation (mg)
LP	Cuningmeng	8.17±0.11	10.33±0.34	17.75±1.21	10.70±1.14	14.28±1.24	46.02±7.17	71.00±8.10
	Suanju	14.40±1.07	14.05±0.35	21.23±0.80	8.52±0.15	5.80±0.65	14.75±1.60	29.07±1.76
	Suancheng	11.39±0.86	11.12±0.31	17.43±0.59	14.82±1.08	11.04±1.38	41.60±5.07	67.46±6.67
	Honglimeng	7.52±0.09	10.74±0.07	21.83±0.99	11.49±0.66	22.4±1.81	59.53±1.61	93.42±3.58
	Zhike	14.43±0.68	8.89±0.64	18.30±1.73	11.05±1.60	7.00±0.35	16.26±1.73	34.32±3.28
	Goutoucheng	10.58±0.47	11.89±0.51	20.37±0.56	7.46±0.58	10.18±0.57	25.60±2.75	43.25±3.81
	Xiangyuan	7.46±0.60	11.82±1.17	17.74±1.88	12.05±1.56	30.09±4.78	57.77±10.32	99.91±16.5
	Hongju	10.20±0.21	10.96±0.73	18.37±0.81	10.43±0.55	4.24±0.72	16.33±1.98	31.01±3.09
	Xiangcheng	9.15±0.21	13.50±0.35	15.44±0.61	9.78±0.76	13.78±0.85	28.31±2.20	51.87±3.72
	Zhicheng	11.01±1.2	13.64±0.27	18.32±0.49	18.63±3.08	18.21±0.57	26.34±1.91	63.18±3.45
	Mean	*10.431 c*	*11.694 b*	*18.680 b*	*11.493 b*	*13.703 b*	*33.252 b*	*58.45 b*
MP	Cuningmeng	12.57±1.29	12.90±0.30	21.32±0.52	28.92±5.4	51.70±3.26	164.16±8.36	244.78±16.95
	Suanju	17.33±0.3	15.02±0.53	23.67±0.91	15.50±1.46	13.40±0.96	42.25±4.52	71.16±6.84
	Suancheng	18.30±1.11	14.75±0.32	23.16±0.62	31.02±2.75	31.86±2.25	103.00±7.49	165.87±12.21
	Honglimeng	13.70±0.40	13.35±1.25	26.70±1.61	26.34±1.76	45.48±2.44	130.55±0.29	202.37±3.42
	Zhike	18.87±0.64	9.05±0.47	17.54±0.48	18.48±1.34	8.86±1.13	20.08±2.65	47.41±5.10
	Goutoucheng	13.27±0.39	14.50±0.59	23.96±1.05	10.95±1.93	16.93±1.03	48.98±3.01	76.85±5.58
	Xiangyuan	19.11±0.44	16.81±0.50	26.24±0.86	36.99±1.67	72.33±4.86	155.72±7.49	265.04±13.98
	Hongju	17.00±0.97	15.18±0.42	25.91±0.53	11.44±1.10	10.82±1.21	34.26±2.46	56.52±2.81
	Xiangcheng	14.43±0.99	16.48±0.68	18.85±1.09	10.76±1.74	26.16±2.2	52.78±1.87	89.70±5.42
	Zhicheng	13.97±0.99	14±0.75	19.19±0.96	24.74±1.55	27.26±0.97	41.78±1.70	93.78±1.34
	Mean	*15.854 a*	*14.204 a*	*22.654 a*	*21.512 a*	*30.480 a*	*79.356 a*	*131.35 a*
HP	Cuningmeng	14.67±1.43	13.21±1.06	22.86±2.03	35.95±5.83	39.15±1.74	154.11±2.88	229.2±8.79
	Suanju	18.27±1.15	13.32±0.15	20.64±0.39	23.59±4.02	19.12±1.49	54.78±4.91	97.49±10.05

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1601_819836

	Suancheng	19.13±1.24	15.16±0.23	23.99±0.49	20.72±2.26	22.10±2.75	85.90±6.47	128.73±7.74
	Honglimeng	10.65±0.45	12.45±0.53	23.37±1.19	18.93±2.57	45.72±4.45	134.12±12.16	198.76±17.80
	Zhike	16.00±2.81	9.85±0.18	18.89±0.22	14.19±3.51	9.95±0.64	24.59±1.82	48.73±5.79
	Goutoucheng	13.73±0.43	12.50±0.37	22.47±0.89	8.68±0.78	16.56±0.60	47.76±1.51	73.00±2.29
	Xiangyuan	10.41±1.35	15.42±0.87	24.05±1.74	26.87±6.65	78.85±1.89	163.69±2.00	269.41±10.32
	Hongju	15.17±0.27	15.12±0.09	26.13±0.69	12.49±1.77	13.82±0.61	46.43±3.53	72.75±5.00
	Xiangcheng	13.50±0.23	14.57±0.63	16.27±0.65	13.48±0.91	34.39±0.75	61.87±1.06	109.74±2.39
	Zhicheng	15.63±0.92	15.24±0.81	19.22±0.98	20.26±0.29	22.60±1.96	32.19±3.63	75.05±5.40
	Mean	*14.716 b*	*13.684 a*	*21.788 a*	*19.516 a*	*30.225 a*	*80.544 a*	*130.29 a*
F value	Cultivar(C)	15.55**	20.11**	13.72**	12.01**	90.62**	121.95**	86.44**
	Phosphorus (P)	86.52**	51.97**	42.32**	46.95**	355.88**	447.71**	401.89**
	C×P	3.68**	3.29**	3.32**	4.77**	27.40**	30.59**	27.00**

Note: different lowercase letters are used to indicate values that are significantly different at p < 0.05 among P treatments.

Table 5. *Effects of phosphorus treatment on Mg content and Mg accumulation in citrus plants.*

Phosphorus	**Cultivar**	**Mg content in root ($mg\ g^{-1}$)**	**Mg content in branch ($mg\ g^{-1}$)**	**Mg content in leaves ($mg\ g^{-1}$)**	**Mg accumulation in root(mg)**	**Mg accumulation in branch (mg)**	**Mg accumulation in leaves(mg)**	**Total Mg accumulation (mg)**
LP	Cuningmeng	0.72±0.06	0.77±0.07	2.06±0.16	0.94±0.12	1.07±0.15	5.36±0.93	7.38±1.11
	Suanju	1.26±0.08	1.92±0.03	2.74±0.09	0.75±0.01	0.79±0.10	1.91±0.23	3.45±0.28
	Suancheng	1.23±0.04	1.14±0.08	2.27±0.14	1.61±0.12	1.12±0.07	5.43±0.79	8.16±0.93
	Honglimeng	0.80±0.02	0.70±0.04	2.07±0.09	1.23±0.07	1.46±0.11	5.67±0.42	8.36±0.59
	Zhike	0.98±0.04	1.57±0.08	3.32±0.20	0.74±0.10	1.24±0.09	2.97±0.35	4.96±0.53
	Goutoucheng	1.51±0.03	0.90±0.05	2.32±0.17	1.06±0.03	0.77±0.09	2.95±0.47	4.79±0.58
	Xiangyuan	0.87±0.05	1.77±0.11	1.74±0.09	1.41±0.17	4.47±0.52	5.60±0.58	11.48±1.21
	Hongju	1.21±0.06	1.05±0.07	2.17±0.19	1.24±0.11	0.41±0.06	1.93±0.28	3.58±0.41
	Xiangcheng	0.98±0.03	1.81±0.10	1.86±0.10	1.04±0.07	1.84±0.03	3.39±0.05	6.27±0.11

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1601_819836

	Zhicheng	0.49±0.08	1.54±0.22	2.50±0.25	0.84±0.17	2.05±0.28	3.57±0.40	6.46±0.48
	Mean	*1.0057 b*	*1.3173 b*	*2.3050 a*	*1.0872 b*	*1.5219 c*	*3.8787 c*	*6.488 c*
MP	Cuningmeng	0.97±0.03	0.74±0.03	1.85±0.04	2.21±0.32	2.96±0.16	14.31±0.97	19.49±1.34
	Suanju	1.54±0.09	1.89±0.09	2.72±0.10	1.37±0.09	1.68±0.13	4.87±0.62	7.93±0.83
	Suancheng	1.32±0.06	1.31±0.06	2.41±0.13	2.23±0.15	2.84±0.23	10.74±1.03	15.81±1.41
	Honglimeng	1.12±0.04	0.71±0.09	2.37±0.16	2.14±0.07	2.43±0.28	11.57±0.22	16.14±0.55
	Zhike	1.05±0.03	1.46±0.17	3.08±0.38	1.03±0.07	1.42±0.23	3.55±0.67	6.00±0.96
	Goutoucheng	2.09±0.13	0.97±0.08	2.47±0.13	1.69±0.23	1.13±0.05	5.03±0.20	7.85±0.41
	Xiangyuan	1.54±0.22	1.88±0.17	1.88±0.21	2.98±0.42	8.05±0.55	11.1±1.09	22.13±1.97
	Hongju	1.33±0.05	1.12±0.05	2.44±0.18	0.89±0.06	0.80±0.10	3.25±0.45	4.95±0.49
	Xiangcheng	1.14±0.07	1.78±0.11	1.83±0.12	0.84±0.12	2.82±0.29	5.17±0.52	8.84±0.75
	Zhicheng	0.64±0.02	1.77±0.10	2.83±0.15	1.14±0.08	3.47±0.26	6.17±0.41	10.77±0.65
	Mean	*1.2730 a*	*1.3647 ab*	*2.3877 a*	*1.6531 a*	*2.7599 b*	*7.5773 b*	*11.990 b*
HP	Cuningmeng	1.09±0.04	0.91±0.08	2.36±0.31	2.67±0.29	2.70±0.09	15.84±1.27	21.21±1.60
	Suanju	1.72±0.03	1.74±0.01	2.54±0.02	2.20±0.26	2.49±0.19	6.75±0.63	11.44±0.97
	Suancheng	1.62±0.18	1.39±0.02	2.66±0.08	1.78±0.32	2.04±0.32	9.51±0.67	13.33±0.8
	Honglimeng	1.06±0.06	0.68±0.06	2.21±0.10	1.87±0.19	2.49±0.22	12.67±1.06	17.02±1.38
	Zhike	0.96±0.13	1.98±0.09	3.26±0.45	0.85±0.19	2.00±0.16	4.18±0.39	7.03±0.38
	Goutoucheng	2.19±0.10	0.88±0.05	2.13±0.06	1.39±0.14	1.17±0.09	4.55±0.35	7.11±0.52
	Xiangyuan	1.02±0.06	1.99±0.06	1.92±0.05	2.59±0.46	10.19±0.42	13.2±0.80	25.99±1.65
	Hongju	1.19±0.01	1.20±0.06	2.41±0.11	0.97±0.11	1.09±0.06	4.29±0.38	6.35±0.52
	Xiangcheng	1.29±0.06	1.63±0.03	1.66±0.08	1.30±0.15	3.87±0.19	6.36±0.53	11.52±0.78
	Zhicheng	0.73±0.05	1.77±0.08	2.83±0.17	0.95±0.08	2.64±0.24	4.74±0.54	8.33±0.71
	Mean	*1.2860 a*	*1.4177 a*	*2.3983 a*	*1.6557 a*	*3.0693 a*	*8.2072 a*	*12.932 a*
F value	Cultivar(C)	48.73**	116.82**	12.72**	23.13**	327.60**	47.56**	66.01**
	Phosphorus (P)	41.59**	2.54*	1.16ns	25.41**	105.48**	188.53**	159.23**
	C×P	3.88**	1.48ns	1.17ns	3.88**	11.13**	10.52**	9.24**

Note: different lowercase letters are used to indicate values that are significantly different at $p < 0.05$ among P treatments.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1601_819836

Correlation analysis

For all treatments, total dry weight showed significant correlation relationship with root dry weight (r=0.8950, *P*<0.001), branch dry weight (r=0.9720, *P*<0.001), leaves dry weight (r=0.9846, *P*<0.001), N accumulation in root (r=0.9475, *P*<0.001), N accumulation in branch (r=0.8796, *P*<0.001), N accumulation in leaves (r=0.9684, *P*<0.001), total N accumulation (r=0.9724, *P*<0.001), P accumulation in root (0.7906, *P*<0.001), P accumulation in branch (0.8581, *P*<0.001), P accumulation in leaves (0.9244 *P*<0.001), total P accumulation (0.9070, *P*<0.001), K accumulation in root (0.7764, *P*<0.001), K accumulation in branch (0.9414, *P*<0.001), accumulation in leaves (0.9717, *P*<0.001), total K accumulation (0.9790, *P*<0.001), Mg accumulation in root (0.8365, *P*<0.001), Mg accumulation in branch (0.7293, *P*<0.001), Mg accumulation in leaves (0.9488, *P*<0.001), total mg accumulation (0.9699, *P*<0.001). Similar correlation relationships were observed for MP and HP treatment. However, for LP, there investigated no significant correlation relationship between total dry weight and P, K, Mg P accumulation in root. Significant negative correlation relationship between total dry weight and N content in branch was found. Significant negative correlation relationship between total dry weight and N content in leaves was observed for MP and HP only. Significant negative correlation relationship between total dry weight and P content in root was observed for LP. There investigated significant negative correlation relationship between total dry weight and P content in branch for LP, MP and HP. Significant negative correlation relationship between total dry weight and K content in root was observed for LP and HP. Total dry weight showed significant negative correlation with Mg content in leaves for all treatment, LP and MP (*Table 6*).

Discussion

In this study, we observed significant effects of rootstock on root dry weight, branch dry weight, leaves dry weight, and total dry weigh (*Table 1*). Similar to many previous reports (Li and Zhang, 2008; Shafieizargar et al., 2012; Cantuarias-Avilés et al., 2010; 2011; Tazima et al., 2013). Rootstock affects the horticultural characteristics in citrus (Cantuarias-Avilés et al., 2010; Zhang et al., 2011; Hussain et al., 2013; Benjamin et al., 2013; Simpson et al., 2014). The P efficiency is defined as the ability of the plant growth under low effective P concentration condition (Zhang, 1993). Researcher used the plant dry weight to evaluate the plant resistance to low phosphorus stress (Cao et al., 2000; Zhang et al., 2005; Zhou et al., 2005). Here, we found significant effects of phosphorus on N, P, K and Mg content, and their accumulation in plant (*Table 2-5*). It confirmed that it could have significant differences in responses of citrus trees to P fertilization (Wutscher, 1989; Mattos et al., 2006; Fan and Luo, 2015). Previously it was reported that different citrus trees respond to P differently due to the difference in the acid phosphatase activity of rhizosphere soil, for various factors affecting the acid phosphatase activity (Bonmati et al., 1991; Oberson et al., 1993; Luo and Fan, 2014).

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DOI: http://dx.doi.org/10.15666/aeer/1601_819836

Table 6. *Correlation relationship between total dry weight and the investigated parameters.*

Investigated parameters	All treatment		LP		MP		HP	
	Correlation coefficient	*P* value	Correlation coefficient	*P* value	Correlation coefficient	*P* value	Correlation coefficient	*P* value
Root dry weight	0.8950	0.0000	0.8650	0.0012	0.9101	0.0003	0.9319	0.0001
Branch dry weight	0.9720	0.0000	0.9584	0.0000	0.9790	0.0000	0.9591	0.0000
Leaves dry weight	0.9846	0.0000	0.9658	0.0000	0.9857	0.0000	0.9841	0.0000
N content in root	0.1028	0.5888	-0.0982	0.7873	-0.0712	0.8451	-0.2058	0.5685
N content in Branch	-0.4494	0.0127	-0.6534	0.0405	-0.8189	0.0038	-0.9109	0.0002
N content in leaves	-0.2151	0.2536	-0.0400	0.9127	-0.7052	0.0227	-0.7310	0.0163
N accumulation in root	0.9475	0.0000	0.7889	0.0067	0.9423	0.0000	0.9721	0.0000
N accumulation in branch	0.8796	0.0000	0.8917	0.0005	0.8538	0.0017	0.8728	0.0010
N accumulation in leaves	0.9674	0.0000	0.9723	0.0000	0.9790	0.0000	0.9846	0.0000
Total N accumulation	0.9724	0.0000	0.9815	0.0000	0.9769	0.0000	0.9927	0.0000
P content in root	0.1221	0.5203	-0.7387	0.0147	-0.5794	0.0792	-0.6262	0.0527
P content in Branch	0.0446	0.8148	-0.7919	0.0063	-0.7098	0.0215	-0.7050	0.0228
P content in leaves	0.3448	0.0621	-0.2859	0.4232	-0.1991	0.5813	0.0998	0.7837
P accumulation in root	0.7906	0.0000	0.6066	0.0630	0.9293	0.0001	0.7646	0.0100
P accumulation in branch	0.8581	0.0000	0.7685	0.0094	0.9303	0.0001	0.9410	0.0000
P accumulation in leaves	0.9244	0.0000	0.9719	0.0000	0.9816	0.0000	0.9771	0.0000
Total P accumulation	0.9070	0.0000	0.9396	0.0001	0.9857	0.0000	0.9834	0.0000
K content in root	-0.0701	0.7129	-0.8036	0.0051	-0.2148	0.5513	-0.6357	0.0482

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DOI: http://dx.doi.org/10.15666/aeer/1601_819836

K content in Branch	0.2894	0.1208		-0.1185	0.7444		0.1328	0.7145		0.2188	0.5437
K content in leaves	0.3703	0.0440		-0.1351	0.7097		0.2725	0.4462		0.2653	0.4588
K accumulation in root	0.7764	0.0000		0.3851	0.2718		0.8299	0.0030		0.7066	0.0223
K accumulation in branch	0.9414	0.0000		0.9342	0.0001		0.9316	0.0001		0.9332	0.0001
K accumulation in leaves	0.9717	0.0000		0.9587	0.0000		0.9788	0.0000		0.9721	0.0000
Total K accumulation	0.9790	0.0000		0.9934	0.0000		0.9811	0.0000		0.9903	0.0000
Mg content in root	-0.1220	0.5206		-0.5616	0.0911		-0.2087	0.5628		-0.2887	0.4185
Mg content in Branch	-0.1617	0.3934		-0.2026	0.5746		-0.3008	0.3983		-0.1497	0.6798
Mg content in leaves	-0.4858	0.0065		-0.6563	0.0393		-0.6525	0.0408		-0.5292	0.1157
Mg accumulation in root	0.8365	0.0000		0.5384	0.1084		0.8343	0.0027		0.8284	0.0031
Mg accumulation in branch	0.7293	0.0000		0.7295	0.0166		0.6554	0.0396		0.7234	0.0180
Mg accumulation in leaves	0.9488	0.0000		0.9224	0.0001		0.9730	0.0000		0.9304	0.0001
Total Mg accumulation	0.9699	0.0000		0.9643	0.0000		0.9683	0.0000		0.9785	0.0000

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P is an important for plant growth, development and reproduction as it is an essential constituent of phospholipids, nucleic acid and many proteins. With increasing P application, the root, branch and leaves dry weight, and total dry weight increased, however different cultivars responded differently (*Table 1-5*). Low P availability in soil is one of the most critical aspects that limit the productivity of many crops (Sanchez and Salinas, 1981). P deficiency or excess phosphate fertilization could cause nutrient imbalance in citrus tree and reduce the yield and fruit quality (Fan and Wang, 2012; Fan and Luo, 2015). When the phosphorus nutrition level was extremely low or high, P, Mg, Mn and Cu content was deficient or excessively high and inhibited absorption of N, K, Fe, Zn, and B (Fan and Wang, 2012). In our study, we found that low P treatment affected the P, K, and Mg accumulation in root (*Table 3-6*). Moreover, Syvertsen (1987) reported that P level in leaves showed no relationship with photosynthetic in orange and pomelo seedlings. Bernardi et al. (2015) reported that P had little interference on photosynthesis. Zambrosi et al. (2013a) indicated that phosphorus uptake by young citrus plants in low-P soil depends on rootstock varieties and nutrient management. Therefore in our work, low P treatment may affected Mg content in leaves may lead to low plant photosynthesis and finally decreased total dry weight (*Tables 5* and *6*). Further study to investigate the improvement citrus rootstocks growth under low P condition by Mg application is need.

Conclusion

In crux, P application increased N, P, K and Mg accumulation in citrus plants. With increasing P application, the plant total plant dry biomass was increased. Low P treatment affected P, K, and Mg accumulation in root and ultimately plant growth. Moreover, low P treatment may affect Mg content in leaves that may lead to low plant photosynthesis and finally decreased total dry weight.

Acknowledgements. This work was supported by the National Natural Science Foundation (project no. 31372008), Agriculture Fund (no. 2014A020208085, 2014A020209081, 2015A020209110 and 2016LM3174) in Guangdong Province, National Key Research and Development Planning Project (2016YFD0200404-1) and National Science and Technology Planning Project (2013BAD05B04). The authors would like to thank Dr. Zhaowen Mo and Umair Ashraf for their contributions to the manuscript.

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