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Annual changes of iron, manganese, zinc and copper concentrations in both types of citrus fruit

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Abstract: Annual changes in concentrations of iron(Fe), manganese(Mn), zinc(Zn) and copper(Cu) were measured in whole fruits from parthenocarpic Kamei satsuma mandarin(*Citrus unshiu*) and self-pollinated Egan 1 tangerine(*C. reticulata*) trees. The results were showed as follows: (1) Zn and Cu concentrations in the ovary of Kamei were relatively high before flowering and at full bloom, and decreased after flowering, whereas those of Egan 1 decreased obviously and were relatively low at full bloom, thereafter significant increases were observed. There were no significant differences in changes of Fe and Mn concentrations in the ovaries(fruitlets) between the two cultivars, which presented similarly decreasing trends after flowering. (2) Fe, Mn, Zn and Cu concentrations were relatively high in whole fruits of both cultivars during young fruit development, and decreased remarkably during early fruit enlargement (drought spell), whereas increased dramatically at the middle stage of fruit enlargement, thereafter decreased gradually. Dynamics of micronutrients concentrations in developing fruit and their possible relation with fruits development is discussed herein.

Key words: citrus; ovary(fruitlet); fruit; iron; manganese; zinc; copper

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Fruit mineral concentrations have been related to ripening, internal disorders and disease severity in number of fruit (Marcelle, 1995; Tagliavini *et al.*, 2000). In order to manipulate mineral content and balance in fruits, it is important to know the dynamics of nutrients accumulation in developing fruits. Although there are many reports about dynamics of mineral nutrients uptake by fruit during fruit development (Zavalloni *et al.*, 2001; Storey & Treeby, 2000, 2002; Xiao *et al.*, 2004b, 2005), as to seasonal trends of micronutrients such as Fe, Mn, Zn and Cu in whole fruits from parthenocarpy and self-pollinated citrus cultivars remain obscure and no prior studies have been comparatively analyzed. It has been reported that dynamics of Ca, K, B and Mg throughout fruit development of the two typical citrus cultivars, which indicated that stimulation of fertilization was very important to Ca and B uptake by seedy fruit, whereas there was not direct relationship between K and Mg uptake by fruit and fertilization (Xiao *et al.*, 2004a, b, c, 2005). Many reports demonstrated that Fe and Mn, similar to Ca, were difficult to move and be recycled in most phloem of plants, while Zn and Cu were characterized as being intermediate phloem-mobile (Marschner, 1995). As for parthenocarpic satsuma mandarin and self-pollinated tangerine, it's not very clear that whether or not the same mechanism is

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involved. Therefore, in the present work, the annual changes of Fe, Mn, Zn and Cu concentrations were investigated in the ovaries (fruitlets) and whole fruits from parthenocarpic satsuma mandarin and self-pollinated tangerine trees, with the aim of identifying variations of Fe, Mn, Zn and Cu nutrients uptake by fruit and their possible relation with fruit development, which will play a theoretical and basic role in taking practical steps for production.

1 Materials and methods

Samples were collected from 8-year-old trees of satsuma mandarin (*Citrus unshiu* cv. Kamei) and self-pollinated tangerine (*C. reticulata* cv. Egan 1) grafted on trifoliate orange rootstock (*Poncirus trifoliata*) growing at the experimental orchard of Research Institute of Fruit Tea, Hubei Academy of Agricultural Science of China. The experiment was a randomized complete block design with three replications, plots consisted of five trees of each cultivar. Fruits were collected from before flowering to final harvest. Around flowering, ovaries or fruitlets were sampled every 6—7 days, and then sampled every half a month. 2—5 fruits (20—50 ovaries or fruitlets around flowering) were collected

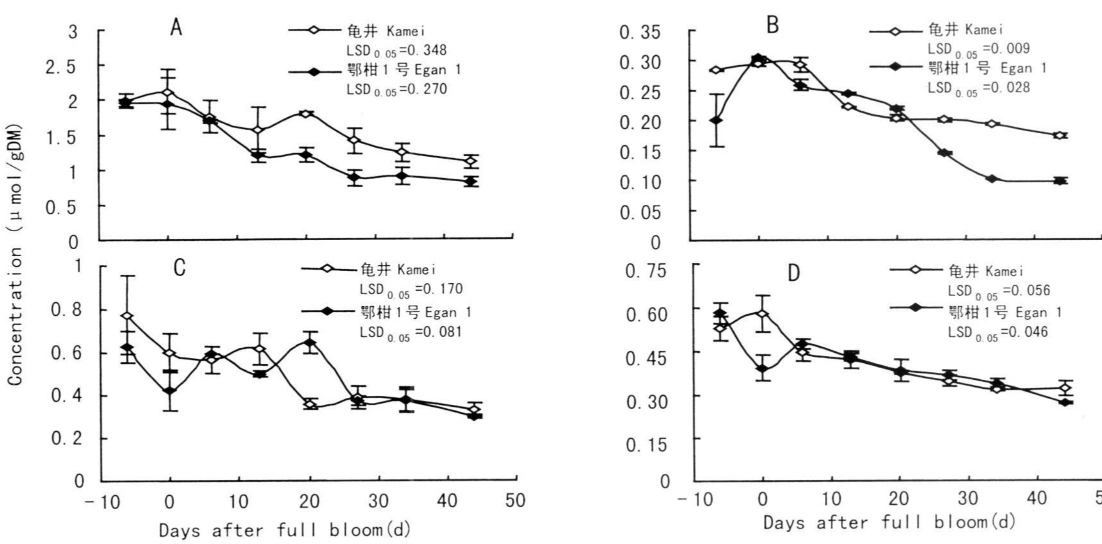

Fig. 1 Changes in concentrations of iron (**A**), manganese (**B**), zinc (**C**) and copper (**D**) in the ovary (fruitlet) around citrus flowering. DM, Dry mass. $LSD_{0.05}$ was value of the least significant difference ($P < 0.05$). The same bellow.

from each tree at each harvest. Fruits were representative of average size of fruits on each tree. After sampling, the whole fruits were dried to constant weight in an oven at 75 ℃, milled through a 0.5 mm stainless steel screen and stored in airtight glass container for subsequent analysis.

Fe, Mn, Zn and Cu concentrations were measured by an atomic absorption spectrophotometer (Varian SpectrAA-220) according to the method as described by Zhuang (1994). Mean separation was performed by analysis of variance followed by a test for the least significant difference with a probability of 0.05 ($LSD_{0.05}$).

2 Results and analysis

2.1 Changes in concentrations of Fe, Mn, Zn and Cu in the ovary (frutlet) around flowering

Dynamics of Fe and Mn concentrations were similar in the ovaries (fruitlets) between Kamei and Egan 1 around flowering (Fig. 1: A, B). Fe and Mn concentrations in the ovaries of both cultivars were relatively high from-6 to 0 days after full bloom (DAFB), thereafter gradually decreased. In addition, Fe and Mn concentrations in fruitlet of Kamei were relatively higher than those of Egan 1 from 27 to 44 DAFB.

Changes of Zn and Cu concentrations in the ovaries (fruitlets) were obviously different between the two cultivars (Fig. 1: C, D). Zn concentration was relatively high in the ovary of Kamei before flowering, followed by a progressive decline coming to the lowest value at 44 DAFB, whereas that of Egan 1 was relatively low at flowering, thereafter increased significantly and reached the peak at 20 DAFB, thereafter decreased (Fig. 1: C).

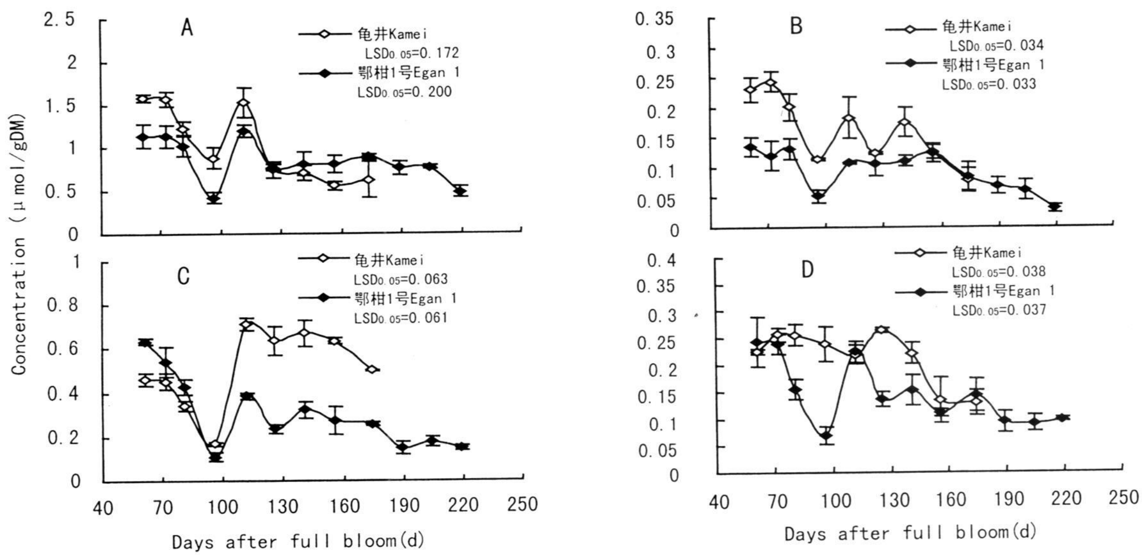

Fig. 2 Changes in concentrations of iron (**A**), manganese (**B**), zinc (**C**) and copper (**D**) in whole fruit during citrus fruit development

Similarly, Cu concentration in the ovary of Kamei was at relatively high level before flowering and at full bloom, thereafter decreased progressively, whereas that of Egan 1 decreased significantly and remained relatively low at flowering, and significant increase was detected at 7 DAFB, thereafter presented decreasing trend (Fig. 1: D).

2.2 Changes in concentrations of Fe, Mn, Zn and Cu in whole fruit during fruit development

Seasonal trends were the same in whole fruits for micronutrients between Kamei and Egan 1 (Fig. 2). During young fruit development (from 61 to 72 DAFB), Fe, Mn, Zn and Cu concentrations in whole fruits were relatively high, followed by decreases to the relatively low values at 96 DAFB, whereas significantly increased at 112 DAFB, with exception of Cu in whole fruit from Kamei that changed slightly and remained relatively high from 61 to 141 DAFB, thereafter presented decreasing trends up to final harvest. In addition, from 61 to 112 DAFB, Fe and Mn concentrations in whole fruit of Kamei was relatively higher than that of Egan 1 (Fig. 2: A, B), while fruit Zn concentrations were significantly higher in Kamei than in Egan 1 from 112 DAFB to final harvest (Fig. 2: C).

3 Discussion

The present research shows that Zn and Cu concentrations in the ovary (fruitlet) from parthenocarpic Kamei satsuma mandarin were at relatively high levels before flowering and at full bloom, thereafter decreased, but Zn and Cu concentrations in the ovary (fruitlet) from self-pollinated Egan 1 tangerine was in the reversed trend, being at relatively low level at full bloom, and significantly increased after flowering (fertilization finished), which were similar to Ca and B uptake by seedy fruit (Xiao *et al.*, 2004a, b, c). However, no significant differences in changes of Fe and Mn concentrations were observed in the ovaries (fruitlets) between the two cultivars, which showed decreasing trends after flowering, as revealed by Fig. 1, indicating that there was no direct relation between the uptake of Fe and Mn by fruit and fertilization, which were similar to K and Mg found in other citrus fruit (Xiao *et al.*, 2004b, 2005). It has been reported that seeds in self-pollinated fruit are important sites of hormone production, especially auxin and gibberellin, that can enhance fruit growth and facilitate mineral elements (Xiao *et al.*, 2004c; Buccheri & Vaio, 2004). The data from current work show that change patterns of Zn and Cu between parthenocarpy and self-pollinated ovary (fruitlet) were reverse around flowering, whereas those of Fe and Mn were of little differences (Fig. 1). Thus, the differences in Fe, Mn and Zn, Cu nutrients uptake by ovary (fruitlet) and their metabolism in the ovary (fruitlet) around flowering may be related to endogenous phytohormones and interactions between mineral elements.

The results of the present study demonstrate that Fe, Mn, Zn and Cu concentrations in whole fruits of both cultivars experienced sharp decreases during early fruit enlargement (at 96 DAFB) and dramatic increases at the middle stage of fruit enlargement (at 112 DAFB) (Fig. 2), which were similar to dynamics of B in the pulp during the same time (Xiao *et al.*, 2005). In 2003, severe drought experienced in Huazhong district of China during early fruit enlargement, which induced that micronutrients concentrations decreased dramatically in fruit because fruit growth and development were seriously restrained during this time (eg. at 96DAFB), while fruit growth came back to normal situation at 112 DAFB, micronutrients concentrations increased rapidly in fruit (Fig. 2), this seasonal trends were conspicuously different to accumulation characteristics of macronutrients such as Ca, K and Mg reported before in both types of citrus fruit (Xiao *et al.*, 2004a, b, 2005). Therefore, we thought that the stage of fruit enlargement was the key phase for micronutrients uptake by fruit, although the accumulations of Fe, Mn, Zn and Cu were strongly affected by environment stress such as drought.

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References:

Buccheri M, Vaio C D. 2004. Relationship among seed number, quality, and calcium content in apple fruits[J]. *J Plant Nutr*, **27**(10): 1 725—1 746

Marcelle R D. 1995. Mineral nutrition and fruit quality[J]. *Acta Hort*, **383**: 219—226

Marschner H. 1995. Mineral nutrition of higher plants[M]. London: Academic press: 243—267

Paramasivam S, Alva A K, Hostler K H, *et al.*, 2000. Fruit nutrient accumulation of four orange varieties during fruit development[J]. *J Plant Nutr*, **23**(3): 313—327

Storey R, Treeby MT. 2000. Seasonal changes in nutrient concentrations of navel orange fruit[J]. *Sci Hort*, **84**: 67—82

Storey R, Treeby M T. 2002. Nutrient uptake into navel oranges during fruit development[J]. *J Hort Sci Biotech*, **77**(1): 91—99

Xiao JX, Peng SA, He HP. 2004a. Seasonal changes of total calcium, soluble Ca^{2+} concentrations and Ca^{2+}-ATPase activity of citrus fruit[J]. *J Fruit Sci*, **21**(6): 530—534

Xiao JX, Peng SA, He HP. 2005. Studies on dynamics of boron and magnesium nutrients during fruit development of parthenocarpy and self-pollinated citrus cultivars[J]. *Acta Bot Yunnan*, **27**(4): 419—424

Xiao JX, Peng SA, Zhang HY. 2004b. Studies on dynamics of calcium and potassium during fruit development of parthenocarpic and self-pollinated citrus varieties[J]. *Acta Hort Sin*, **31**(1): 7—10

Xiao JX, Peng SA. 2004c. Studies on dynamics of calcium, boron nutrients and IAA, $GA_{1/3}$ in ovary (fruitlet) around citrus flowering[J]. *J Fruit Sci*, **21**(2): 132—135

Zavalloni C, Marangoni B, Tagliavini M, *et al.* 2001. Dynamics of uptake of calcium, potassium and magnesium into apple fruit in a high density planting[J]. *Acta Hort*, **564**: 113—121

Zhuang YM. 1994. Citrus Nutrition and Fertilizer[M]. Beijing: Agriculture Press: 174—176

两结实类型柑橘果实铁锰锌铜含量的年周期变化

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摘　要：对单性结实的龟井温州蜜柑和自花授粉结实的鄂柑 1 号柑橘果实的铁、锰、锌和铜含量的年周期变化进行了测定。结果表明：(1)龟井子房的锌和铜含量在花前至花期居较高，花后趋下降，而鄂柑 1 号对应值在花期出现明显下降并居较低，花后却有一明显上升；两品种子房（幼果）的铁和锰含量变化却无明显差异，花后呈类似的下降趋势。(2)幼果阶段的果实铁、锰、锌和铜含量均居较高，在果实膨大初期（干旱期）均出现一明显下降，而在果实膨大中期却出现显著上升，之后又趋下降。本文还对果实发育中的微量元素含量动态及其与果实发育之间的关系进行了讨论。

关键词：柑橘；子房（幼果）；果实；铁；锰；锌；铜

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液的相对电导率表现出明显的差异。因此，相对电导率适宜作麝香百合抗热性鉴定的指标。(6)为了更准确地鉴定麝香百合的抗热性，本研究用隶属函数值法来综合评价抗热性的强弱。结果表明，麝香百合基因型间存在着明显的差异，评定结果与田间的表现基本一致。即 Wforest、G、Wfox 等抗热性能比较弱，而 K_{1-1}、K_{2-7}、K_{1-2}为比较抗热的优良基因型，在华南地区种植较为理想。(7)抗热性是一个受多因素影响的复杂的数量性状，不同品种某一具体抗热指标对高温胁迫的反应不一定相同，因此用单一指标难以全面准确地反映植物品种抗热性强弱。本试验中上述 4 个指标的表现和变化与麝香百合基因型间的变化相一致，且相互间有一定的相关。因此，均可作为麝香百合抗热性的评价指标。但指标间的相互关系，有待进一步探讨。

参考文献：

李合生，孙群，赵世杰，等．2000．植物生理生化实验原理和技术[M]．北京：高等教育出版社：164，182－185

邹琦．2000．植物生理学实验指导[M]．北京：中国农业出版社：11－12

赵祥云．2000．百合[M]．北京：中国农业出版社：18－20

Chen LS（陈立松），Liu XH（刘星辉）．1997．Kinds of index for crop drought resistance identification and comprehensive evaluation（作物抗旱鉴定指标的种类及其综合评价）[J]．*J Fujian Agric Univ*（福建农业大学学报），**26**(1)：48－55

Ye CL（叶陈亮），Ke YQ（柯玉琴），Chen W（陈伟）．1996．A study on the physiology of heat tolerance in Chinese cabbage II. Metabolism of water and proteins in leaves and heat tolerance（大白菜耐热性的生理研究 II. 叶片水分和蛋白质代谢与耐热性）[J]．*J Fujian Agric Univ*（福建农业大学学报），**25**(4)：490－493

Wang FL（王凤兰），Zhou HG（周厚高），Huang YY（黄玉源），*et al*．2003．A study on heat-resistance indices of the seedlings of four *Lilium formolongi* lines（4 个新铁炮百合品系幼苗的抗热指标测定）[J]．*J Zhongkai Univ Agric Tech*（仲恺农业技术学院学报），**16**(2)：38－42

Zhou HG（周厚高），Ning YF（宁云芬），Zhang SJ（张施君），*et al*．2003．The physiological and biochemical changes in bulb development of *Lilium formolongi*（新铁炮百合生长发育过程的一些生理生化变化）[J]．*Guihaia*（广西植物），**23**(4)：357－361

Zhang SJ（张施君），Zhou HG（周厚高），Pan WH（潘文华），*et al*．2005．Preliminary studies on the physiology of heat tolerance in *Lilium longiflorum*（麝香百合的抗热生理指标初探）[J]．*Chin Agric Sci Bull*（中国农学通报），**21**(3)：240－242