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BRIEF COMMUNICATION

Differential responses of iron, magnesium, and zinc deficiency on pigment composition, nutrient content, and photosynthetic activity in tropical fruit crops

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Abstract

Fe, Mn, and Zn affected the chlorophyll (Chl) content whereas Fe deficiency caused larger reduction of total chlorophyll content than Mg and Zn deficiencies. Mg deficient mango had a higher Chl *a/b* ratio than the respective healthy plants. The foliar contents of Fe, Zn, and Mg in the deficient leaves were lower than the critical level. Nutrient deficiency significantly affected the F_v/F_m ratios as observed from the Chl fluorescence induction curves. Fe deficiency resulted in larger reduction of variable fluorescence than Mg and Zn deficiency.

Additional key words: *Achras*; chlorophyll fluorescence; *Citrus*; *Eugenia*; jamun; *Mangifera*; mango; nutrient deficiency; sapota; sweet orange.

The use of fertilisers free from micronutrients coupled with intensive cropping has resulted in widespread micronutrient deficiency in many parts of India (Balakrishnan *et al.* 1994). Among the different micronutrients, Zn deficiency is more widespread accounting for 47 % of cultivated area in India followed by Fe deficiency with 11 % (Ganeshamurthy *et al.* 1997). Widespread Mg deficiency was reported by Biswas *et al.* (1985). Nutrient deficiency alters the metabolism (Lavon *et al.* 1995, Siedlecka and Krupa 1999) and results in expression of deficiency through the changes in Chl content (Shetty and Miller 1966). The reduction in Chl content leads to chlorosis in leaves ultimately affecting the chloroplast structure and photosynthesis (Terry and Abadía 1986). The aim of this work was to study the effects of Fe, Zn, and Mg deficiencies on pigment composition, nutrient content, and photosynthetic activity in field grown fruit trees of sapota, mango, jamun, and sweet orange.

The deficiency of Fe in sapota (*Achras sapota* L.) cv. PKM-1 and local type of jamun (*Eugenia jambolana* L.), of Mg in mango (*Mangifera indica* L.) cv. Neelam, and of Zn in sweet orange (*Citrus sinensis* L.) cv. Sathgudi were identified based on the visible symptoms in 15-years-old trees grown in sandy loam soils of college orchard at the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam, India. The soil had the following characteristics: pH 8.1, 0.8 % organic carbon, EC, 3.8 dsm, 1.2 mg kg^{-1} available Fe (DTPA), and 38.5 mg kg^{-1} exchangeable Mg. The healthy as well as nutrient deficient leaves of sapota (10th leaf from a new flush), jamun (3rd leaf from the top), and mango and sweet orange (middle leaves from the current shoot) were used for further analysis (Chapman 1984). Fe, Zn, and Mg contents of the healthy and deficient leaves were analysed by atomic absorption spectrophotometry (*Pye Unicam* model *PU 9000*). Variable Chl *a* fluorescence was followed in intact leaves after excitation with broad band blue radiation (400-620 nm) filtered by the *Corning 4-96* filter. Prior to the excitation, the leaves were incubated in the dark for 10 min and care was taken to avoid wilting. The signal was processed in a digital oscilloscope (*Iwatzu SS-5802*) and then transferred to a *Hitachi* recorder (Lingakumar and

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Abbreviations: Chl – chlorophyll; F_0 - initial level of fluorescence; F_m - maximum fluorescence; F_v - variable fluorescence.
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Table 1. The effect of nutrient deficiency on the amounts of Chl *a*, *b*, (*a*+*b*) and carotenoids [g kg^{-1}(f.m.)], content of nutrients, and ratio of variable to maximum fluorescence (F_v/F_m) in fruit crops. Figures in parentheses are percentage decrease with reference to respective healthy plants. Mean±SE, n = 5.

Crop		Chl *a*	Chl *b*	Chl (*a*+*b*)	Chl *a*/*b*	Carotenoids	Nutrients	F_v/F_m
Sapota	Healthy	0.75±0.02	0.35±0.04	1.10±0.05	2.14	0.15±0.02	107.00±3.92	0.27±0.01
	Fe-deficient	0.11±0.05	0.09±0.01	0.20±0.03	1.22	0.03±0.01	28.70±2.67	0.18±0.05
		(85.0)	(74.3)	(81.8)		(80.0)	(73)	(33)
Mango	Healthy	0.85±0.07	0.47±0.05	1.32±0.07	1.81	0.08±0.01	0.81±0.05	0.45±0.07
	Mg-deficient	0.48±0.01	0.21±0.03	0.69±0.04	2.29	0.06±0.01	0.41±0.02	0.40 ±0.03
		(43.5)	(55.3)	(47.7)		(25.0)	(49)	(11)
Jamun	Healthy	1.07±0.06	0.46±0.05	1.53±0.06	2.33	0.14±0.01	135.90±2.50	0.69±0.02
	Fe-deficient	0.13±0.02	0.12±0.06	0.25±0.02	1.08	0.04±0.01	20.10±1.02	0.53±0.03
		(87.8)	(73.9)	(83.7)		(71.4)	(85)	(23)
Sweet orange	Healthy	0.69±0.01	0.32±0.04	1.01±0.08	2.16	0.09±0.01	85,00±2.50	0.64±0.04
	Zn-deficient	0.56±0.03	0.27±0.06	0.83±0.05	2.07	0.07±0.01	12.50±1.80	0.60±0.00
		(18.8)	(15.6)	(17.8)		(22.2)	(85)	(6)

Kulandaivelu 1993). Pigments were extracted in 80 % acetone and concentrations of Chl *a*, *b*, and carotenoids were calculated using the coefficients of Wellburn and Lichtenthaler (1984).

On the basis of unit fresh mass, both Chl *a* and Chl *b* contents were remarkably decreased in Fe-, Mg-, and Zn-deficient plants. The deficiency of Fe and Zn had much more pronounced effect on Chl *a* than Chl *b* whereas the Mg deficiency resulted in greater reduction of Chl *b* than Chl *a*. The Chl (*a*+*b*) content also decreased considerably in all the three deficient crops. Large reduction of total Chl was observed in Fe deficient jamun (83.7 %) and sapota (81.8 %). In contrast to this, Mg deficiency in mango caused 48 % loss in total Chl, while Zn deficiency in sweet orange caused only 18 % loss (Table 1). Such a differential response in total Chl upon deficiency of Fe, Zn, and Mg was either due to reduced Chl biosynthesis or due to poor development and assembly of chloroplast. Since the Mg content in Chl is only about 15-20 % of the total Mg present in leaf tissue (Mengel and Kirkby 1982) and 60 % of all leaf Fe is present in Chl (Chen and Barak 1982), Fe is directly involved in Chl biosynthesis. The Chl *a*/*b* ratio was altered considerably by the deficiency of Fe, Zn, and Mg. Large reduction in Chl *a*/*b* ratio in Fe-deficient plants of sapota and jamun observed in the present study was consistent with the findings of Abadía *et al.* (1991). Increased Chl *a*/b ratio in Mg-deficient mango as compared to the healthy plants could be attributed to the reduced synthesis of Chl *b*-binding proteins. The carotenoid content of the leaf was very much reduced by the deficiency of Fe followed by Mg and Zn deficiencies. A similar influence of Fe-deficiency on carotenoid contents was reported also by Val *et al.* (1987).

The content of Fe in deficient sapota (28.7 mg kg^{-1}) and jamun (20.1 mg kg^{-1}) was much below the critical level. According to Bennett (1993), 50 mg kg^{-1} is the critical concentration for optimum plant growth. Direct determination of Fe in samples of two crops confirmed the Fe deficiency. In Zn-deficient sweet orange plants showing sickle size little leaves and interveinal chlorosis,

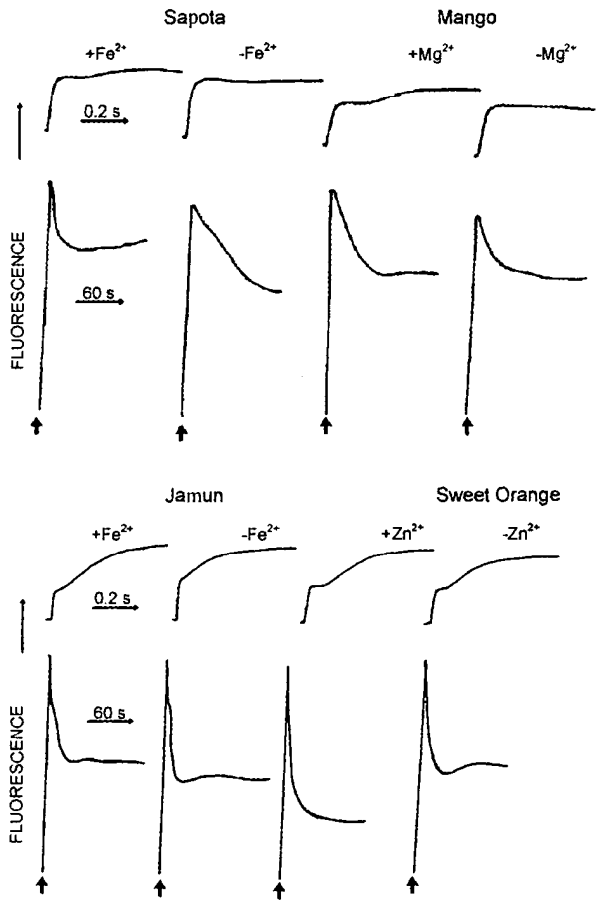

Fig. 1. Changes in fast (*top*) and slow (*bottom*) fluorescence transients obtained from Fe-, Mg-, and Zn-deficient tropical fruit crops. The leaves were incubated in dark for 10 min prior to excitation. The arrows indicate switching on the blue radiation.

the Zn content was 12.5 mg kg^{-1} which was less than that of the critical level (Chundawat *et al.* 1991). In the present study, the concentration of Mg was 0.14 % in Mg deficient mango leaves, which was far below the critical level (Biswas *et al.* 1987). Among the four horticultural crops studied, the healthy leaves of jamun and sweet orange exhibited a fast OP rise during Chl fluorescence induction while sapota and mango showed a slow rise (Fig. 1). The variable fluorescence (F_v) was totally lost in Fe-deficient sapota leaves. Similarly, Mg deficiency resulted in slow PS2 activity. Since F_v represents the redox status of Q_A, the PS2 activity was lowered in both mango and sapota under Mg and Fe deficiency. In contrast to F_v, the constant fluorescence (F_0) was not affected in any of the deficiency conditions. Irrespective of the micronutrient, all the deficient plants exhibited low F_v/F_m ratios (measure of PS2 primary photochemistry) when compared to their respective healthy controls (Table 1). Prominent reduction in F_v/F_m in Fe deficient crops could be attributed to the alterations in the levels of Chl biosynthetic pathway or due to an altered stoichiometry between PS1, PS2, or Cyt b_6f components (for similar observation see Perez *et al.* 1995). As Fe constitutes the Cyt b_6f complex and other proteins of PS1 and PS2, this possibility could not be ruled out.

In the slow fluorescence kinetics, typical P, S, and T changes were observed in healthy leaves of jamun and sweet orange (Fig. 1). In all the transients, the M peak was not observed which is due to dampening of oscillations of fluorescence or dependency of CO_2 fixation (Walker 1981). The P-S quenching was much affected in Fe-deficient sapota and Mg-deficient mango. In the Fe-deficient jamun, the attainment of T-state was prolonged as compared to control. Such a delay may be due to activation of PS1. The SMT sector of slow transient is linked to the redistribution of excitation energy of absorbed quanta between PS1 and PS2 in which the latter is more favoured (Chow *et al.* 1981). The Zn-deficiency had caused inhibition in both PS1 and PS2 activation. The low fluorescence level observed in Fe- and Mg-deficient plants indicates that both the micronutrients are vital for Chl biosynthesis and cytochrome assembly and their deficiency leads to depressed excitation of the photo-systems as well as slow energy transfer between PS1 and PS2.

References

Abadía, A., Poc, A., Abadía, J.: Could iron nutrition status be evaluated through photosynthetic pigment changes? - J. Plant Nutr. **14**: 987-999, 1991.

Balakrishnan, K., Venkatesan, K., Thandapani, T., Sambandamurthi, S.: Diagnosis of zinc deficiency in fruit crops. – Micronutrient News – Bull. Indian Microfertilizer Manufacturers' Assoc. **8**: 1-4, 1994.

Bennett, W.F.: Plant nutrition utilisation and diagnostic plant symptoms. - In: Bennett, W.F. (ed.): Nutrient Deficiencies and Toxicities in Crop Plants. Pp. 1-10. APS Press, Amer. Phytopathol. Soc., St. Paul 1993.

Biswas, B.C., Yadav, D.S., Maheswari, S.: Role of calcium and magnesium in Indian agriculture. - Fertilizer News **30**: 15-35, 1987.

Biswas, P.P., Joshi, O.P., Rajput, M.S.: Establishment of critical leaf concentrations on mango cultivar "Dashehari" based on soil test. - J. Indian Soc. Soil Sci. **35**: 331-334, 1985.

Chapman, H.D.: Suggested foliar sampling and handling techniques for determining the nutrient status of some field, horticultural and plantation crops. - Indian J. Hort. **21**: 97-119, 1984.

Chen, Y., Barak, P.: Iron nutrition of plants in calcareous soils. - Adv. Agron. **35**: 217-239, 1982.

Chow, W.S., Telfer, A., Chapman, D.J., Barber, J.: State 1-state 2 transitions in leaves and its association with ATP induced chlorophyll fluorescence quenching. - Biochim. biophys. Acta **638**: 60-68, 1981.

Chundawat, B.S., Khimani, R.A., Kikani, K.P.: Nutritional survey of citric acid lime orchards in Gujarat. - Indian J. Hort. **48**: 183-186, 1991.

Ganeshamurthy, A.N., Singh, M.V., Takkar, P.N.: An estimate of the current and future micronutrient fertilizer needs. - Fertilizer News **42**: 43-45, 47-49. 1997.

Lavon, R., Goldschmidt, E.E., Solomon, R., Frank, A.: Effect of potassium, magnesium and calcium deficiencies on carbohydrate pools and metabolism in citrus leaves. - J. amer. Soc. hort. Sci. **120**: 54-58, 1995.

Lingakumar, K., Kulandaivelu, G.: Regulatory role of phytochrome on ultraviolet-B (280-315 nm) induced changes in growth and photosynthetic activities of *Vigna sinensis* L. - Photosynthetica **29**: 341-351, 1993.

Mengel, K., Kirkby, E.A.: Principles of Plant Nutrition. 3rd Ed. - Pp. 461-472. International Potash Inst., Worblaufen - Bern 1982.

Perez, C., Val, J., Monge, E.: Effects of iron deficiency on photosynthetic structures in peach (*Prunus persica* L. Batsch) leaves. - In: Abadía, J. (ed.): Iron Nutrition in Soils and Plants. Pp. 183-189. Academic Press, Orlando 1995.

Shetty, A.S., Miller, G.W.: Influence of iron chlorosis on pigment and protein metabolism in leaves of *Nicotiana tabacum* L. - Plant Physiol. **41**: 415-421, 1966.

Siedlecka, A., Krupa, Z.: Cd/Fe interaction in higher plants – its consequences for the photosynthetic apparatus. – Photosynthetica **36**: 321-331, 1999.

Terry, N., Abadía, J.: Function of iron in chloroplasts. - J. Plant Nutr. **9**: 609-646, 1986.

Val, J., Monge, E., Heras, L., Abadía, J.: Changes in photosynthetic pigment composition in higher plants as affected by iron nutrition status. - J. Plant Nutr. **10**: 995-1001, 1987.

Walker, D.A.: Secondary fluorescence kinetics of spinach leaves in relation to the onset of photosynthetic carbon assimilation. - Planta **153**: 273-278, 1981.

Wellburn, A.R., Lichtenthaler, H.: Formulae and program to determine total carotenoids and chlorophylls *a* and *b* of leaf extracts in different solvents. - In: Sybesma, C. (ed.): Advances in Photosynthesis Research. Vol. II. Pp. 9-12. Martinus Nijhoff/Dr W. Junk, The Hague - Boston - Lancaster 1984.