METABOLIC CHANGES IN COTTON PLANTS SUBJECTED TO COPPER DEFICIENCY AND RECOVERY

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SUMMARY

Cotton (*Gossypium sp.* var Lohit) was grown with adequate (1 µM) and deficient (0.1 µM) copper in controlled sand culture. Copper deficiency caused reduction in growth and dry matter yield and was associated with decrease in Cu concentration in different plant parts. The leaves of Cu deficient plants showed lower chlorophyll concentration, Hill reaction activity, transpiration rate and higher diffusive resistance. The Cu deficient plants also showed increased accumulation of the cationic micronutrients, other than Cu, viz Fe, Mn and Zn. Increasing Cu supply from deficient to adequate reversed the Cu induced changes to varying extent.

Key words **: Coton, Cu deficiency, Hill activity, micronutrients, transpiration**

INTRODUCTION

Copper is an essential micronutrient for plants and plays a key role in diverse metabolic processes (Marschner 1995). Its deficiency leads to severe limitation in plant biomass and reproductive development (Dell 1981, Pandey *et al.* 1996). As a constituent of the Cu-protein plastocyanin (Sandmann and Boger 1983, Ayala and Sandmann 1989), it is involved in electron transport in photosystem I (Droppa *et al.* 1984, Casimiro *et al.* 1990) and Cu deficiency leads to lower photosynthetic rate (Pandey and Sharma 1996). It also affects lignification of xylem vessels (Rahimi and Bussler 1973) and plant water uptake (Graham 1976, Sharma and Sharma 1987, Pandey and Sharma 1996). The present investigation was aimed to study the effects of Cu deficiency on cotton biomass, chlorophyll, Hill reaction activity, transpiration rate and accumulation of cationic micronutrients and the extent to which these changes could be reversed on amelioration of Cu deficiency.

MATERIALS AND METHODS

Cotton (*Gossypium sp.* var. Lohit) was grown in controlled sand culture under green house conditions (Agarwala and Sharma 1976) with adequate (1 µM) and deficient (0.1 µM) copper in the form of $CuSO_4$. The other nutrients were supplied as 4mM KNO_3, 8mM $Ca(NO_3)_2$ 2mM $MgSO_4$, 1.33 mM NaH_2PO_4, 0.33 mM H_3BO_3, 0.1 mM Fe-EDTA, 0.1 mM NaCl, 10 µM $MnSO_4$, 1 µM $ZnSO_4$, 0.1 µM Na_2MoO_4, 0.1 µM $NiSO_4$ and 0.1 µM $CoSO_4$. After 41 d, when visual symptoms of Cu deficiency had initiated, the Cu deficient plants were separated into two lots and Cu supply to one of these was raised from 0.1 µM (deficient) to 1.0 µM (adequate). Four pots were maintained for each treatment viz. Cu sufficient (N), Cu deficient (D) and Cu deficient turned sufficient (D-N). Seven days after start of the recovery treatment (D-N), biomass yield, concentration of Cu and other micronutrient cations, chlorophyll (chl), Hill reaction (HR) activity, diffusive resistance (DR) and transpiration rate (E) were

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measured in comparable sub terminal leaves. The micronutrients were determined in HNO_3: $HClO_4$ (10:1) digests of the oven dry material following Atomic Absorption Spectrophotometry. Chlorophyll, Hill reaction activity, leaf diffusive resistance and transpiration were measured as described by Pandey and Sharma (1996).

RESULTS AND DISCUSSION

Copper deficiency led to suppression of growth after 36 d. About 41 d, the Cu deficient plants developed distinctive symptoms. The lamina of young leaves failed to expand and acquired a bluish green colouration. The apical part of the young leaflets turned white and necrotic. In a week time, after the appearance of deficiency symptoms the lamina of the young leaves became severely distorted and developed white bleached areas. The terminal growth was totally arrested and followed by development of auxiliary shoot. The symptoms resembled those described by Rahimi and Bussler (1973) and Alloway and Tills (1984). Raising the Cu supply from deficiency to adequacy led to renewed growth of branches leading to marginal increase in biomass yield (Table 1). The leaves of Cu deficient plants showed marked decrease in chlorophyll a + b concentration and Hill reaction activity (Table 2). On administering adequate supply of Cu to erstwhile Cu deficient plants, chlorophyll concentration was equal to that in Cu sufficient (N) plants, but recovery in Hill activity was only partial, indicating that the decrease in Hill reaction activity was not entirely due to the Cu effect on chlorophyll. Our results lend support to inhibition of plastocyanin mediated electron transport in photosystem I under Cu stress (Ayala and Sandmann 1989, Casimiro *et al.* 1990).

Table 1. Effect of copper deficiency and recovery on the dry matter yield (g $plant^{-1}$) of cotton.

Plant Parts	Copper supply N	D	D-N	LSD (P=5%)
Leaves	3.469	1.821	2.303	0.257
Stem	4.008	2.148	2.886	0.512
Root	1.134	0.662	0.785	0.313
Whole plant	7.477	3.969	5.189	0.637

N: sufficient, D: deficient, D-N: deficient turned sufficient (recovery treatment)

As a consequence of Cu deficiency, the rate of transpiration was reduced to one fourth of the Cu sufficient plants (Table 2). Adequate Cu supply reversed the effect but failed to restore normalcy. Change in transpiration rate under Cu deficiency was associated with leaf diffusive resistance. The diffusive resistance in leaves of Cu deficient plants showed four-fold increase and declined on raising the level of Cu supply from deficiency to sufficiency (Table 2). Observed changes in diffusive resistance and transpiration rate in Cu deficient cotton plants are similar to our earlier observations in safflower (Pandey and Sharma 1996), but at variance with Cu deficiency effects in cabbage (Sharma and Sharma 1987), showing differences in genotypic response to Cu stress. Supply of Cu deficient nutrient solution caused decrease in the Cu concentration in the different plant parts (Table 3). However, the decrease in Cu concentration, relative to the Cu sufficient plants, was more marked in leaves than in the stem and roots. This showed that Cu deficiency not only caused decrease in the Cu uptake but also in its

Table 2. Effect of copper deficiency and recovery on chlorophyll content Hill reaction activity, transpiration and diffusive resistance in the leaves of cotton.

	Copper supply N	D	D-N	LSD (P=5%)
Chlorophyll content (mg g^{-1}fw)				
Chlorophyll a	1.12	1.03	1.63	0.10
Chlorophyll b	0.48	0.35	0.64	0.09
Total chlorophyll	1.60	1.38	2.27	0.14
Hill reaction activity (Δ O.D. 620 nm)				
Activity 100 mg^{-1} fresh wt.	0.42	0.19	0.33	0.02
Activity mg^{-1} chlorophyll	0.63	1.38	1.45	0.12
Transpiration (μg s cm^{-2})	21.8	4.48	16.70	2.40
Diffusive resistance (s cm^{-1})	0.87	4.61	1.33	0.97

N : sufficient, D: deficient, D-N : deficient turned sufficient (Recovery treatment)

Table 3. Effect of copper deficiency and recovery on the leaf tissue concentration (µg g^{-1} dry w) of Cu, Fe, Mn and Zn in cotton.

Plant Parts	Copper supply N	D	D-N	LSD (P=5%)
		Copper		
Leaves	12.9	2.5	6.4	1.1
Stem	10.6	4.5	6.8	2.2
Root	4.9	1.4	4.3	1.8
		Iron		
Leaves	122	178	121.1	7
Stem	69	165	52	5
Root	73	81	53	7
		Manganese		
Leaves	101.8	173.2	128.2	5.7
Stem	21.9	45.8	24.3	4.7
Root	8.2	16.5	9.8	2.4
		Zinc		
Leaves	17.6	43.2	30.5	3.6
Stem	5.3	17.6	7.7	2.6
Root	5.1	10.3	2.9	0.3

N: sufficient, D: deficient, D-N: deficient turned sufficient (recovery treatment)

mobilization to leaves. Increase in Cu supply from deficiency to sufficiency led to increase in Cu uptake but leaf tissue concentration of Cu in Cu deficient turned sufficient plants still remained <50% that in plants maintained with Cu sufficient nutrition (Table 3).

Deficient supply of Cu favoured increased accumulation of the other cationic micronutrients - Mn, Cu, Zn in root and shoot (Table 3). While Fe and Zn showed relatively large accumulation in stem, accumulation of Mn was more in roots. Copper deficiency effect on accumulation of Zn was more marked than on Fe and Mn. Increase in Cu supply from deficiency to sufficiency level reversed the Cu deficiency effect on each Fe, Mn and Zn. While Fe concentration decreased to less than that in Cu sufficient plants, Mn and Zn concentration decreased to a level in between Cu deficient and Cu sufficient plants. The compensatory absorption of Fe, Mn and Zn as observed here in Cu stressed cotton plants has also been reported in lupins (Yu and Rengel 1999). There are various reports where limitation in supply of one micronutrient may facilitate the accumulation of other micronutrients (Del Rio *et al.* 1978, Iturbe-Ormaetxe *et al.* 1995) and help micronutrient homeostasis (Grusak *et al.* 1999).

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