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Effects of High Phosphorus Supply on Zn and Cu Uptake by Mulberry(*Morus alba* L.)

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高濃度 燐酸 水耕液중에서 뽕나무의 Zn과 Cu 吸收

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SUMMARY

Water culture studies were conducted in the greenhouse with mulberry plants to investigate the nutrient uptake, especially Zn and Cu, under high phosphrous concentration. Mulberry plants were grown with five phosphorus levels(0, 0.2, 0.5, 2.0, 5.0 mM). Leaves and roots were analyzed for water content, total nitrogen, P, K, Ca, Mg, Fe, Mn, total Zn, soluble Zn, Cu, Cl, NO_3 HPO_4 and SO_4. Dry matter increased upto 2.0mM phosphorus level, and then decreased. Water content, total nitrogen, P, K, and Fe in leaves increased with increasing phosphorus level. Total Zn content in leaves showed little change, whereas soluble Zn increased and Cu decreased with increasing phosphorus level. With increasing phosphous level, SO_4 and Cl decreased and then sharply increased abovc 2.0mM phosphorus. Lower uptake of Cu and higher uptake of SO_4 and Cl suggest a cause of mulberry yield decline with high accumulation of soil phosphorus.

INTRODUCTION

Fertilizer consumption in Korea increased 2.33 fold from 1960s to 1980s. As a consequence, the available phosphate content increased in upland soil from 114ppm in 1960s to 231ppm in 1980s (Park, 1991).

Mulberry fields showed the same trend. Seventy-one percent of mulberry fields in Kyounggi Province contained more than 200ppm(generally accepted as optimum) of phosphate and 2,117ppm as the highest record(Lee, 1990).

Mulberry leaves are the primary food of the silkworm. Phosphorus in mulberry leaves influences quality. Insufficient phosphorus in leaves prolongs the growth period of silkworms and increases silkworm mortality. Silkworm growth rate is propotional to phosphorus content(Ide, 1969).

Increasing levels of inorganic phosphate(Pi) in soil or solution culture induced retardation of plant growth(Loneragan and Asher, 1967). The reported reasons are mainly Zn deficiency caused by P, generally called "P-induced Zn deficiency" (Robson and Pitman, 1983). Phosphate also insolubilized Cu or Fe(Mengel and Kirkby, 1982). P-induced Zn deficiency accompanies the decreases in chlorophyll and superoxide dismutase activity in cotton leacves(Cakmak and Marschner, 1987).

The objective of the present work was to investigate the uptake of Cu and Zn by mulberry pla-

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nts under high phosphorus concentration in culture solution.

MATERIALS AND METHODS

Water culture experiments were conducted under controlled envionment in a glass house at the Sericultural Experiment Station, Suwon, Korea. One-year old grafted mulberry trees, Kaeryanppong(*Morus alba* L) received 1/3 strength nutrient solutions for the frist week and 1/2 strength solutions(Table 1) for the second week in 3,000㎤ pot.

Table 1. Composition of nutrient solutions with various phosphorus concentrations

Chemicals	P concentrations(mM)				
	0	0.2	0.5	2.0	5.0
NH_4NO_3	2.5	2.8	2.8	2.8	2.8
KNO_3	1.0	1.0	0.4	0.4	0.4
$NaH_2PO_4.2H_2O$	0	0.2	0.2	0.8	2.5
$Ca(NO_3)_2.2H_2O$	0.5	0.5	0.5	0.5	0.5
$CaCl_2.2H_2O$	0.3	0.3	0.3	0.3	0.3
KH_2PO_4	0	0	0.3	1.2	2.5
$MgSO_4.7H_2O$	0.3	0.3	0.3	0.3	0.3

All solutions contained micro-elements as follows(mg/ℓ) : H_3BO_3 : 2.86, $CuSO_4$ 5aq : 0.08, $ZnSO_4$.7aq : 0.22, $MnSO_4$.4aq : 2.00, $(NH_4)_6M_{07}$ O_{24}.4aq : 0.02, Fe-EDtA 35g/ℓ

Nutrient solutions with five P levels(0, 0.2, 0.5, 2.0 and 5mM) then were applied for 2 months. Solutions were made in distilled water and pH was adjusted to 6.5 and were refreshed weekly. Plants were harvested after 2.5 months of growth.

Data shown in tables and figures are means of at least 4 replications.

After rinsing roots 3 times with distilled water, plants were separated into roots and leaves. Plant parts were dried at least 18hours at 75℃ and then treated with H_2O_2 in the presence of salicilic acid(Walinga et. al., 1989).

Total nitrogen was analyzed by the micro-Kejdhal method, phosphorus by a modification of the molybdovanadophosphate method(Murphy and Riley, 1962), and K, Ca, Mg, Fe, Mn, Zn and Cu by flamephotometry.

Dried plant material was extracted with distilled water and NO_3^-, HPO_4^{2-}, SO_4^{2-} and Cl^- were determined by a ionchromatographic method and water-soluble Zn by atomic absorption spectrometry(Cakmak and Marschner, 1987).

RESULTS AND DISCUSSION

Leaf dry matter per tree increased with increasing P level up to 2.0mM and decreased at 5.0 mM phosphorus. Trend for shoot length, leaf area per tree and area per leaf were the same as for the dry matter per tree. Leaf number per tree increased at 5.0mM phosphorus(Table 2).

Table 2. Influence of P concentration in nutrient concentrations in nutrient solution upon the growth of mulberry trees.

P concentration (mM)	Shoot length (cm tree^{-1})	Leaf area (㎠ tree^{-1})	Leaf area (㎠ tree^{-1})	No. of leaf per tree	Dry weight (g tree^{-1})
0	19.0	402	42.7	9.5	2.27
0.2	49.5	1,415	73.2	19.5	6.32
0.5	57.6	1,707	78.4	21.8	7.49
2.0	69.8	2,368	99.3	23.8	10.11
5.0	66.8	2,248	92.5	24.3	9.73

Kitano et. al.(1988) reported that mulberry yield increased up to 1.5g P_2O_5 and decreased at 3.0g/pot P_2O_5, equivalant to a concentration in soil of 359ppm phosphate.

Water content in leaf increased with increasing phosphorus level up to 2.0mM and then decreased(Table 3).

Total-N in leaves increased with phosphorus level and plateaued between the 2.0 and 5.0mM P

Table 3. Effect of P concentration in the nutrient solution upon nutrient concentration in leaves and roots of mulberry.

Part	P concentration (mM)	Water Content(%)	Total −N	P	K	Ca	Mg	Fe	Mn	NO_3^-	HPO_3^{2-}	SO_4^{2-}	Cl^-
		mg/kg DM						mg/kg DM					
Leaf	0	66.3	33.0	5.16	16.3	4.43	1.26	74	38	3,446	2,930	6,021	1,122
	0.2	72.5	44.7	10.66	18.3	7.15	1.63	89	59	3,561	5,195	2,979	650
	0.5	75.0	47.9	13.77	19.3	7.58	1.51	99	67	3,695	8,578	1,892	599
	2.0	75.5	49.0	13.85	20.6	8.65	1.44	109	56	4,077	9,689	1,740	617
	5.0	74.3	48.8	14.73	20.8	9.08	1.30	112	52	5,692	12,049	6,408	1,126
Root	0		32.7	6.82	7.3	2.00	0.66	24	63	441	540	378	24
	0.2		38.3	11.10	10.4	1.36	0.66	384	91	5,007	8,524	5,649	1,003
	0.5		34.8	11.53	9.2	1.64	0.72	294	138	4,935	9,641	4,869	1,180
	2.0		38.8	14.46	15.1	1.72	0.78	267	289	6,171	12,359	6,590	1,429
	5.0		35.3	15.47	18.7	1.64	0.84	206	235	6,995	15,892	8,891	1,739

treatments. Phosphorus in null P treatment came from the graftage and was translocated to new parts. Phosphorus content in the leaf increased up to 5.0mM phosphorus level. Total phosphorus content was not much different between leaf and root. Ionic phosphorus(HPO_4^{2-}) in plant tissue increased rapidly from the null through 0.5mM P treatments, and increased less conspicuously thereafter(Table 3). HPO^{2-} content in root was higher than that in leaf except in the null treatment.

NO_3^- in leaf increased with increasing P supply. SO_4^{2-} decreased with increasing P supply up to 2.0mM and then increased dramatically at 5.0mM. Permeability of root cell wall may be affected by higher P supply, but no damage was observed visually.

SO_4^{-2} in root increased with P supply. This suggests that roots accumulate sulfate to a certain amount and do not translocate sulfate upward until concentration reach that level. Cl^- showed the same tendency as SO_4^{-2}.

The K and Ca content in the leaf increased, whereas Mg did not change with P supply. K content in leaf did not increase proportionally with K supplied as counter-cation of phosphorus.

Higher supply of P hinders the absorption and translocation in plant organs of micro-elements such as Cu, Fe and especially Zn(Elsokkary et. al, 1983 : Cakmak and Marschner, 1987). Generally, P-Zn interactions are often termed "P-induced Zn deficiency".

Total Zn did not change, moreover, soluble Zn increased with P supply(Fig. 1). This result was opposite that found for other plants(Elsokkary et. al., 1983 : Cakmak and Marschner, 1987 : Michael and Loneragan, 1988).

Contrary to Zn, Cu uptake decreased with P supply in mulberry(Fig. 2). Cu content in root

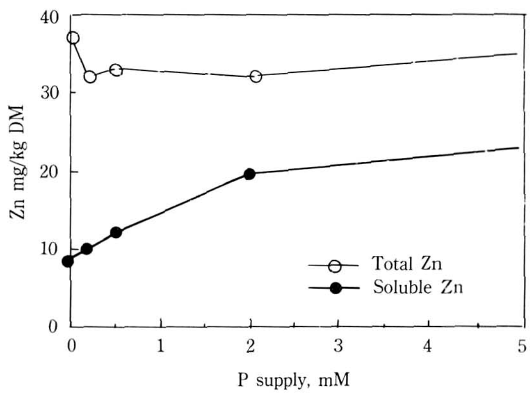

Fig. 1. Effect of P supply on the total and soluble Zn content in leaves

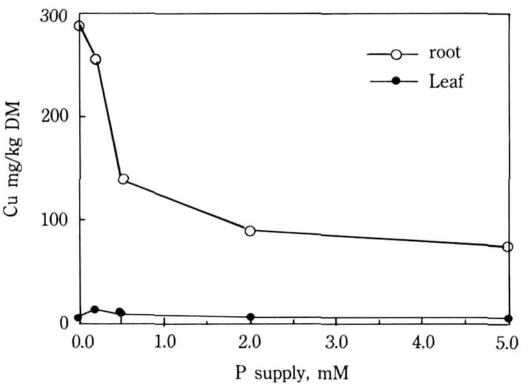

Fig. 2. Effect of P supply on the Cu content in roots and leaves

was 15~21 times higher than in leaf. Root Cu concentration decdlined more dramaticaly with increasing P level than leaf Cu. High P concentration seems to interfere with Cu uptake and translocation upward.

Mn in root increased clearly up to 2.0mM phosphorus and then decreased. This result coinsides with corn and faba beans(Elsokkary et. al. 1983), but was opposite to that is observed in rice(Alam 1981).

The results of this experiment suggest that high soil P levels afect mulberry production by decreasing Cu uptake, increasing SO_4^{2-} and Cl^- uptake, and hence, decreasing yield of mulberry leaves.

摘 要

燐酸을 高濃度로 공급하였을 때, 양분의 吸收 특히 Zn과 Cu의 흡수를 알기 위하여 온실에서 水耕栽培로 시험을 수행하였다. 공급 인산 수준은 0, 0.2, 0.5, 2.0, 5.0mM의 5水準이었으며, 개량뽕(*Morus alva* L.)을 공시품종으로 2.5개월을 재배한 후, 식물체를 收穫하여 分析하였다.

乾物重은 2.0mM 인산수준까지 계속 增加한 후 減少하였다. 잎의 水分含量, total-N, P, K, Fe 등은 인산 공급수준과 比例하여 증가하였다. Total-Zn 함량은 인산수준에 따라 큰 차를 보이지 않았으나, 水溶性 Zn은 증가하는 반면 Cu는 감소하였다. 燐酸水準의 증가에 따라 SO_4와 Cl는 감소하다가 인산 2.0 mM 이상에서 현저히 증가하였다. 인산 蓄積 뽕밭에서의 뽕잎 감소는 Cu의 흡수 저하와 SO_4와 Cl의 현저한 吸收 증가에서 오는 것으로 推定되었다.

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