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Response of bean to foliar spray of titanium

NAND RAM, M. VERLOO and A. COTTENIE
Laboratory of Analytical and Agrochemistry, Faculty of Agriculture, State University Ghent, Belgium

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Summary To compare the effectiveness of two sources of Ti: – dicyclopentadienyl titanium chloride (organic Ti) and titanium chloride (inorganic Ti) a pot experiment was conducted with bean at 0.25, 0.5 and 1 ppm levels of water-soluble Ti applied as foliar spray. Application of Ti enhanced the chlorophyll content of leaves, suggesting its influence to promote photosynthesis. Dry matter yield of bean was increased by 5.6, 8.9 and 20 per cent over control due to addition of 0.25, 0.5 and 1 ppm levels of water-soluble Ti, respectively. However, organic and inorganic sources of Ti were equally effective. Spray of Ti also increased the uptake of major and trace elements.

Introduction

Rutile, anatase and ilmenite are the dominant titanium bearing minerals in soil[2], constituting about 3 to 4 thousand ppm Ti mainly bound to silicates leading to considerably lower quantities of available or soluble Ti[8]. From the plant nutrition point of view, Ti has been suggested to play a role in the fixation of nitrogen by legumes[1] and increasing the yields of crop plants[7,8]. The present investigation was carried out with bean to study the effect of foliar spray of water-soluble Ti on

(i) the chlorophyll content of bean leaves
(ii) fresh and dry matter yields, and
(iii) uptake of major and trace elements by bean plants.

Materials and methods

A Belgian sandy soil – Oostakker of pH 6.8 (Udipsamment) having 0.22, 1.72 and 72 ppm water-soluble, ammonium acetate-EDTA (0.5 *M* NH_4Ac + 0.5 *M* HAc + 0.02 *M* EDTA, pH 4.65) and aqua-regia extractable quantities of Ti, respectively, was used in this study.

Two sources of Ti: – dicyclopentadienyl titanium chloride ($C_{10}H_{10}Cl_2Ti$) and titanium chloride ($TiCl_4$) having Ti in organic and inorganic form, respectively, were compared at 0.25, 0.5 and 1 ppm levels of water-soluble Ti applied as foliar spray. The treatments were replicated four times in a completely randomised design. One kg soil in each pot was incubated with nutrient solution consisting 0.25 g each of NH_4NO_3, $CaH_2PO_4 \cdot 2H_2O$, K_2SO_4 and $MgSO_4$ for two weeks at field capacity moisture and 8 bean seeds were sown in each pot in order to maintain 5 healthy plants after emergence. At the 4- and 6-leaf stage, the plants were sprayed with water-soluble Ti. Green leaves of 50-day-old plants from one of the replicate were taken for chlorophyll determination. After extracting the green pigments with acetone and transferring them to ether; absorbance was measured at 660 and 642.5 nm spectrophotometrically to determine chlorophyll a, chlorophyll b and total chlorophyll adopting the procedure described by Smith and Benitez[9]. After 60 days of sowing, plants from the remaining replicates were harvested and washed with distilled water. Fresh yield and dry matter yields of whole plants (total), leaf, pod and stem were recorded. Following dry-ashing at 450°C, the plant samples were analyzed for major: N, P, K, Ca and Mg[4] and for trace elements: Ti, Cu, Zn, Mn, Fe, Al and V by Inductively Coupled Plasma Spectrophotometer[3].

Results and discussion

Chlorophyll content

The content of chlorophyll a, chlorophyll b and total chlorophyll were calculated according to the equations[9]:

$$\text{Chlorophyll a mg/l} = 9.93 \text{ Absorbance}_{660} - 0.777 \text{ Absorbance}_{642.5} \quad (1)$$

$$\text{Chlorophyll b mg/l} = 17.6 \text{ Absorbance}_{642.5} - 2.81 \text{ Absorbance}_{660} \quad (2)$$

$$\text{Total chlorophyll mg/l} = 7.12 \text{ Absorbance}_{660} + 16.8 \text{ Absorbance}_{642.5} \quad (3)$$

From Table 1 it is inferred that concentrations of chlorophyll a, chlorophyll b and total chlorophyll were increased after application of Ti and this might be due to either a direct effect of Ti or an indirect effect caused by the increased concentration of Mg and other elements in the leaves (Fig. 1) suggesting a possible role of Ti in promoting photosynthetic activity of leaves. Pais *et al.*[7] also reported similar results with sugar beet.

Fresh and dry matter yields

Data pertaining to fresh and dry matter yields of bean, presented in Table 2,

Table 1. Effect of Ti application on the chlorophyll content of green leaves of bean

Source of Ti*	Level of water soluble Ti (ppm)	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Total chlorophyll (mg/g)
DT	0.25	1.42	0.52	1.94
	0.50	1.29	0.49	1.78
	1.00	1.58	0.58	2.16
TC	0.25	1.42	0,50	1.92
	0.50	1.24	0.47	1.71
	1.00	1.35	0.52	1.87
Control	0	1.17	0.43	1.60

*DT = dicyclopentadienyl titanium chloride
TC = titanium chloride

Table 2. Fresh and dry matter yields of bean (g/pot)

Source of Ti*	Levels of water soluble Ti (ppm) 0.25	0.50	1.00	Mean
Fresh yield of whole plants				
DT	53.6	53.4	56.7	54.56
TC	51.6	53.8	58.6	54.66
Mean	52.6	53.6	57.65	
Control	50.1			
C.D. at 5%	(i) control *vs* treatments 3.3			
	(ii) levels of Ti 2.8			
Dry matter yield of the whole plants				
DT	6.04	6.06	6.64	6.24
TC	5.63	5.96	6.61	6.06
Mean	5.83	6.01	6.62	
Control	5.52			
C.D. at 5%	(i) control *vs* treatments 0.30			
	(ii) levels of Ti 0.26			
Dry matter yield of leaf				
DT	2.04	2.08	2.31	2.14
TC	2.02	2.05	2.31	2.12
Mean	2.03	2.06	2.31	
C.D. at 5%	(i) control *vs* treatments 0.16			
	(ii) levels of Ti 0.15			
Dry matter yield of pod				
DT	1.94	2.00	2.31	2.08
TC	1.86	2.11	2.08	2.02
Mean	1.90	2.05	2.19	
Control	1.85			
Dry matter yield of stem				
DT	2.06	1.98	2.02	2.02
TC	1.75	1.80	2.22	1.92
Mean	1.90	1.89	2.12	
Control	1.81			
C.D. at 5%	(i) control *vs* treatments 0.18			
	(ii) levels of Ti 0.17			

*DT = dicyclopentadienyl titanium chloride
TC = titanium chloride

indicate that foliar spray of water-soluble Ti led to significantly higher production of fresh and dry matter yields of the whole plant and leaf and stem dry yields. Compared to control, an increase of 5, 7 and 15 per cent in total fresh yield and 5.6, 8.9 and 20 per cent in total dry matter yield was noted after spraying 0.25, 0.5 and 1 ppm water-soluble Ti, respectively.

In general, 1 ppm water-soluble Ti was superior to other levels in increasing the fresh and dry matter yields of bean. Both sources of Ti: – dicyclopentadienyl titanium chloride (organic Ti) and titanium chloride (inorganic Ti) were equally effective in influencing the bean yields.

Concentration of Ti

Concentration of Ti in leaf, pod and stem (Table 3) were increased with increasing levels of water-soluble Ti applied. In leaves, 1 ppm of water soluble Ti increased the Ti-concentration about 2.5 times compared to control. Moreover, the concentration of Ti was highest in the leaves followed by stem and pod.

Uptake of major and trace elements

Uptake of major and trace elements, summarized in Fig. 1, reveals that spraying Ti markedly increased the uptake by leaf. Higher uptake of elements

Table 3. Concentration of Ti (ppm) in leaf, pod and stem of bean plants

Sources of Ti	Levels of water soluble Ti (ppm)			
	0.25	0.50	1.00	Mean
Leaf				
DT	3.27	3.48	5.42	4.05
TC	3.04	3.66	5.55	4.08
Mean	3.15	3.57	5.48	
Control	2.36			
Pod				
DT	0.58	0.72	0.76	0.68
TC	0.58	0.77	0.72	0.69
Mean	0.58	0.74	0.74	
Control	0.46			
Stem				
DT	1.14	1.24	1.31	1.23
TC	1.15	1.26	1.29	1.23
Mean	1.14	1.25	1.30	
Control	0.94			

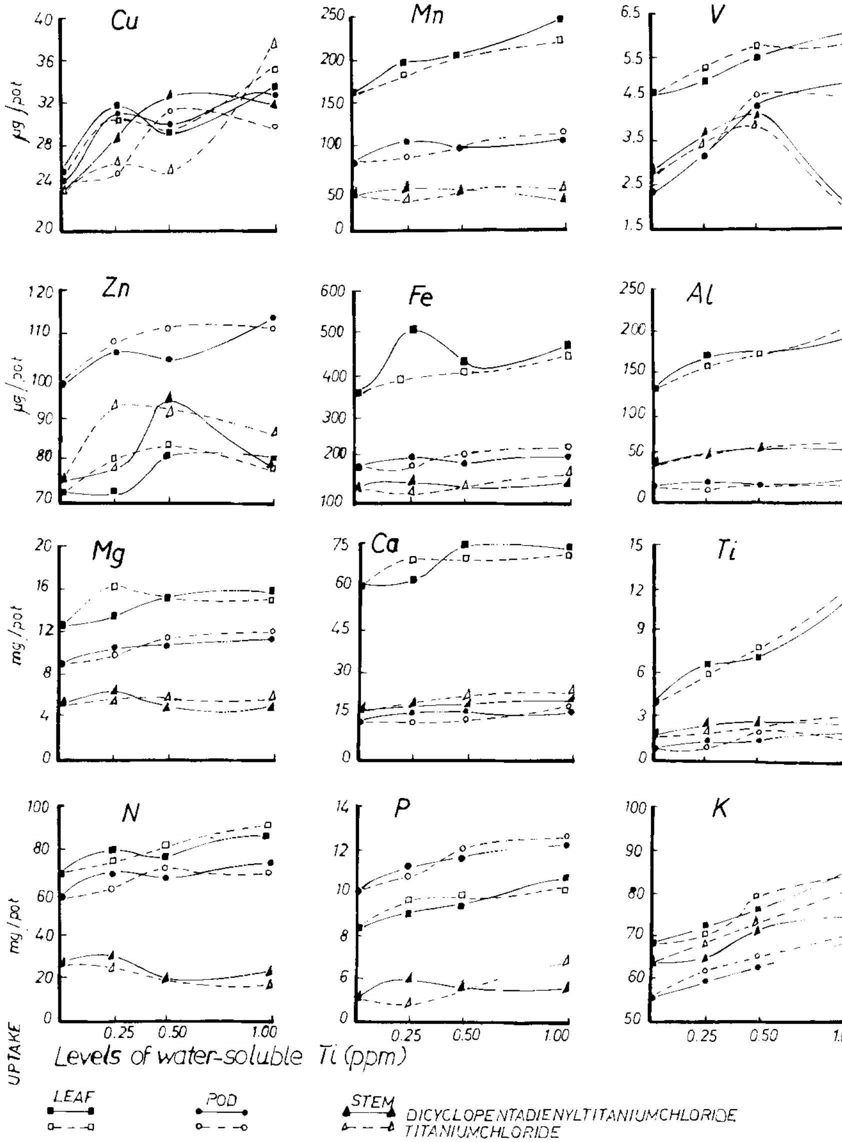

Fig. 1. Effect of titanium application on the uptake of major and trace elements by bean.

may be attributed to enhanced photosynthetic activity leading to higher nutrient demand. Concentrations of all elements were relatively higher in leaves.

From the results of this study it is concluded that foliar nutrition of Ti at lower concentrations is beneficial for bean plants. Titanium application at concentrations more than 1 ppm has been reported to be phytotoxic[5] and at higher concentrations precipitation as TiO_2 may occur, thus making it unavailable to the plants. Moreover, the total concentration of Ti in this soil was 72 ppm, which is considerably lower than 400 ppm reported as toxic level in neutral to acidic soils[6], therefore, a better response of bean to Ti could be expected.

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