NBU Journal of
Plant Sciences

Vol. 7, No. 1 March 2013 p. 43-49
ISSN No. 09746927

Effect of copper on seed germination, root elongation and shoot elongation of seedlings of commercially cultivated tea varieties

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Abstract

Tea (*Camellia sinensis* L. (O.) Kuntze) is an economically important plantation crop of India but is prone to attack by several fungal pathogens. Copper based fungicides are being used for decades to control fungal disease in tea which may lead to accumulation of copper in the soil. The aim of the present work was to investigate toxic effect of Cu^{2+} on seed germination, growth and morphological changes in tea seedlings. Different concentration of copper sulphate was applied on three different commercially cultivated tea varieties (TS-462, TS-520 and TS-463). The effect of different concentrations of copper (0.5 – 8 mM) on seed germination, root elongation and shoot elongation of the tea plant were evaluated. Percent germination was found to decrease progressively with increasing concentrations of Cu^{2+}. Maximum reduction of seed germination was showed by TS-463. Several damaging effects such as reduced root hair proliferation, structural deformation and reduction in length of root and shoot were observed when the germinated seedlings were allowed to grow at higher concentrations of copper solutions. Decrease in the dry mass of both root and shoot were also recorded. The results showed that excess copper have negative effect on germination of tea seeds and subsequent growth of the seedlings.

Key words: Tea seedlings, copper, germination, growth.

Introduction

Tea (*Camellia sinensis* (L.) O. Kuntze) is the most important and popular non-alcoholic beverage. Seeds or vegetative clones are the main sources of tea plant propagation. Successful production of crops is ordinarily associated with healthy shoot and root growth. Tea plants are prone to attack by several fungal pathogens which cause diseases such as blister blight, brown blight, grey blight, black rot, pink disease and thread blight leading to major economic losses (Tripathi 2006). To control the various diseases, copper-fungicides are used excessively in tea gardens of north-east India including Assam and sub-Himalayan West Bengal (Barua 1988, Singh 2005). The fungicides that are used most commonly include basic copper sulphate, Bordeaux mixture, Bicoxy (copper oxychloride 50% WP) and various customized formulations of copper sulphate and copper oxychloride (Worthing 1983, Sanjay *et al.* 2008). Agricultural practices with a long history of copper fungicide application have resulted in high levels of copper in soil that has affected a large portion of agricultural land (Brun *et al.* 1998).

Copper is a constituent of certain enzymes such as cyctochrome oxidase, polyphenol oxidase, tyrosinase, amine oxidase and superoxide dismutase. Thus copper in trace amount is essential for various metabolic processes in the plant but at higher concentrations it causes physiological stress (Dat *et al.* 2000, Saha *et al.* 2012). Copper content of whole plants exceed 20 ppm (on dry weight basis) and this value is most often considered to indicate the threshold limits (Singh *et al.* 2007). High levels of Cu^{2+} application to soil and leaves have been found to disrupt normal plant growth. The toxic effect of Cu^{2+} has been attributed to the redox nature of this element that induces over-production of reactive oxygen species which in turn interferes with the photosynthetic electron transport and damages the cell ultrastructure (Babu *et al.* 2001, Yruela 2005 and Quian *et al.* 2009).

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Applications of high levels of Cu^{2+} usually inhibit root growth and shoot production (Wisniewski and Dickinson, 2003, Peralta *et al.* 2000, Lombardi & Sebastiani, 2005). Sonmez *et al.* (2006) reported an increasing reduction in total yield, fruit number, dry root weight and plant height with increasing levels of Cu^{2+} application to soil and leaves. Increased copper concentrations have been reported to reduce percent germination, root and shoot elongation in maize (Hunter 1981), tomato (Mazhoudi *et al.* 1997), citrus (Alva *et al.* 2000), wheat (Singh *et al.* 2007), rice (Chen *et al.*2000, Lidon & Henriques, 1992) etc.

An initial survey of several tea gardens of North Bengal has revealed that copper-fungicides are extensively used in the tea gardens of the Dooars and Terai region and also in the Hilly region of West Bengal. This extensive use of copper over a long time has necessitated research on effect of copper on tea plants. The aim of the present work was to investigate toxic effect of Cu^{2+} on seed germination, growth and morphology of tea seedlings.

Materials and Methods

Plant Materials and Chemicals: Tea seeds of three different biclonal seed stocks (viz. TS-520, TS-463 and TS-462) were procured from Gayaganga Tea Estate, Siliguri, India. Sixteen different concentrations (0.5–8.0 mM) with 0.5 mM increments of copper solutions were prepared freshly and used for application. Control sets were treated with distilled water.

Application of copper and germination of tea seeds: To determine the percent germination in the treated and untreated seeds of TS-520, TS-463 and TS-462, metal application procedure as described by Munzuroglu and Geckil (2002) was followed with some modifications. Seed surfaces were sterilized with 0.01% $HgCl_2$ washed twice with sterile distilled water and sowed in earthen pots (6 cm diameter) containing moist sterilized sand. The pots were placed in dark in growth chamber at 25°C. Following rupturing of seeds which occurred after 20 d, the seeds were placed in sand and wetted with 4 ml of Cu^{2+} solution of each concentration. The pots were kept at 25°C in the growth chamber and the germination was noted every 24h. Seeds were considered to be germinated at one mm of radical emergence and percent germination was calculated. The length of the shoots as well as roots of each variety was recorded at 15, 18, 21, 24 and 27d after treatment and deformities, if any were noted. The dry weight of treated and untreated shoots and roots of the tested varieties were measured after 27d of treatment. This time duration was followed based on observations obtained during preliminary studies which showed that this time was necessary to test appropriate inhibitory effects. A set of plants (exposed to 6.5 mM Cu^{2+} concentration) were allowed to grow until 60 days for observing the progressive deformations in the roots over a longer period.

Results and Discussion

Figure 1 summarizes the effect of different concentrations of copper on seed germination of three tested tea seed varieties of north east India. In general there was a progressive reduction in seed germination as metal concentration increased in all the tested varieties. Minimum seed germination was recorded when 8 mM copper solution was applied. Germination percentage was found to be lowest in TS-463 (17%) and highest in TS-462 plants (25%). Peralta *et al.* (2000) investigated the individual effects of several doses of heavy metals on the growth of live alfalfa plants using solid media. They used 0, 5, 10, 20 and 40 ppm doses for experiment and according to them 20 ppm concentration of Cu^{2+} significantly affected

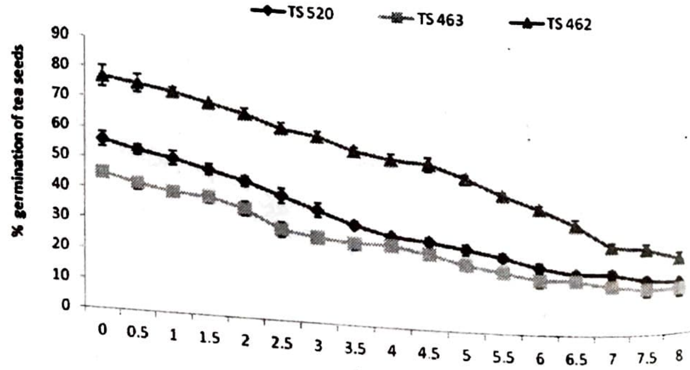

Fig. 1: Percent germination of seeds of TS-520, TS-463 and TS-462 at different concentrations of copper solution.

the seed germination and plant growth. Claire *et al.* (1991) obtained similar results in a study using copper and other heavy metals on cabbage, lettuce, millet, radish, turnip, wheat and alfalfa plants. Singh *et al.* (2007) observed that the germination (60%), plumule and radicle length, and number of lateral roots of wheat decreased with increase in copper concentration (5, 25, 50 and 100 mgl^{-1}) after 14th and 21st day of treatment.

Both root and shoot elongation was hampered with increase in the concentration of Cu^{2+} for all the three varieties. Maximum reduction in length of shoot (91%) was observed in TS-463 variety followed by TS-520 (86%) and TS-462 (68%) (Tables 1, 2, 3). Root elongation was most affected in TS-462 (96%) followed by TS- 463 (91%) and TS-520 (84%) (Tables 4, 5, 6). Higher concentration of Cu^{2+} (>6.5 mM) showed several damaging effects such as reduced root hair proliferation, reduction in the number of root hairs, blacking of the root tips, stunted growth, deformed root and shoot structure and substantial reduction in the length of the root and shoots in all tested varieties (Fig. 2). Sheldon and Menzies (2004) observed that excess copper in *Chloris gayana* seeds caused damage to the cuticle on the main root, reduction in the number and length of root hairs on the main root and damage to the root meristem. According to Peralta *et al.* (2000), Cu (II) exerts detrimental effects at the dose of 40 ppm and 10 ppm causing a shoot and root elongation reduction of 70.0%, 54% respectively in (*Medicago sativa*). Ali *et al.* (2006) observed that root treated with 50 µM copper resulted in 52% and 89% growth inhibition after 20 & 40 days of treatment respectively in *Panax ginseng*. Manivasagaperumal *et al.* (2011) reported that 100-200 mg/kg concentration of copper reduces the growth of the shoots and roots of *Vigna radiata*.

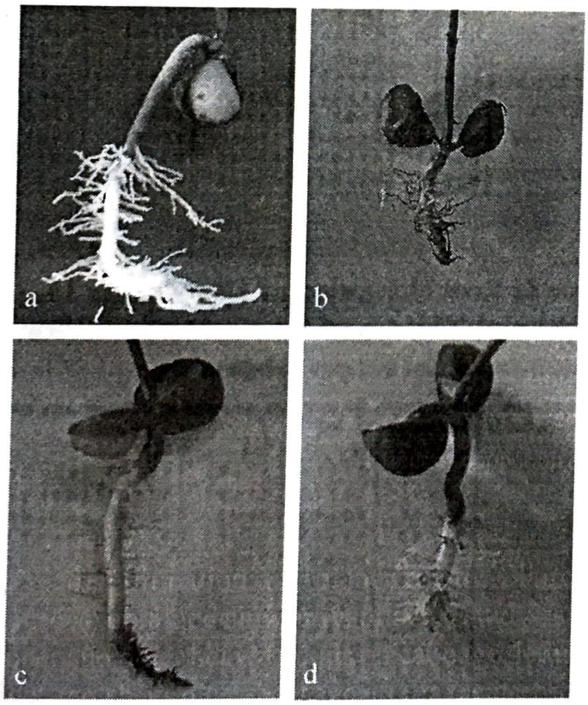

Fig. 2: Root deformations observed when tea seeds were allowed to germinate in high Cu^{2+} concentrations (6.5 mM) for 60 days. a: Control, b: TS-463; c: TS-520; d: TS-462.

Effect of high concentrations of copper on dry weight of shoots and roots were also tested and the results are summarized in Fig 3 & 4. Dry weight of both shoots and roots were decreased with increasing concentration of Cu^{2+}. Dry weight of roots reduced to 0.042 mg, 0.013 mg and 0.017 mg in tea seedlings treated with 8 mM concentration

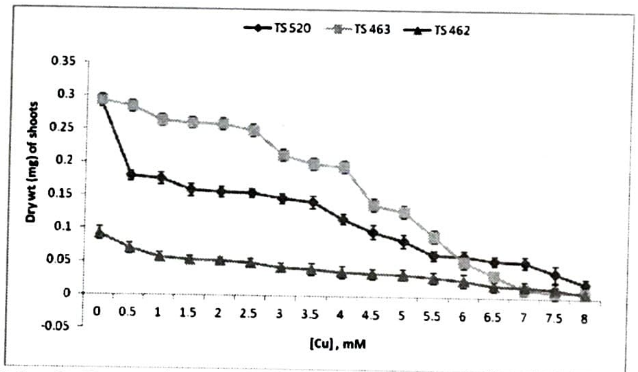

Fig. 3: Dry weight of shoots of TS-520, TS-463 and TS-462 at different concentrations of copper solution after 27 days of treatment

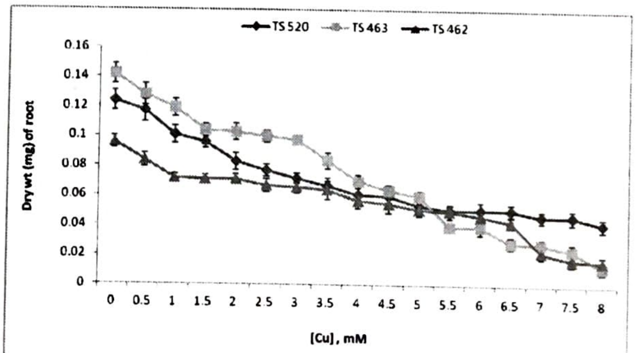

Fig. 4: Dry weight of root of TS-520, TS-463 and TS-462 at different concentrations of copper solution after 27 days of treatment

Table 1: Shoot elongation of TS-520 after 15, 18, 21, 24 and 27 days of treatment with different concentrations of copper solution

Concentration of $CuSO_4$ (mM)	Shoot length variety (in cm) was measured at different days after treatment in TS520				
	15d	18d	21d	24d	27d
0	9.2 ± 0.5	10.4 ± 0.45	11.2 ± 0.3	13.5 ± 0.25	15.2 ± 0.3
0.5	6.7 ± 0.3	8.4 ± 0.3	9.6 ± 0.3	10.3 ± 0.5	10.6 ± 0.45
1	6.5 ± 0.4	7.9 ± 0.2	8.9 ± 0.5	10.1 ± 0.65	10.5 ± 0.35
1.5	6.2 ± 0.4	7.2 ± 0.3	8.9 ± 0.2	10.1 ± 0.45	10.5 ± 0.1
2	5.7 ± 0.25	7.2 ± 0.15	8.7 ± 0.3	9.2 ± 0.4	9.9 ± 0.5
2.5	5.2 ± 0.2	6.3 ± 0.5	7.8 ± 0.15	8.8 ± 0.4	9.1 ± 0.15
3	4.7 ± 0.3	6.3 ± 0.4	7.3 ± 0.4	8.3 ± 0.5	9 ± 0.25
3.5	4.6 ± 0.3	6.2 ± 0.4	7.1 ± 0.3	8.3 ± 0.55	8.8 ± 0.5
4	4.6 ± 0.3	5.8 ± 0.4	6.7 ± 0.4	7.2 ± 0.15	8.1 ± 0.2
4.5	4.6 ± 0.2	5.5 ± 0.2	6.4 ± 0.5	6.9 ± 0.6	7.7 ± 0.3
5	3.6 ± 0.2	4.9 ± 0.7	5.2 ± 0.2	6.3 ± 0.6	6.5 ± 0.4
5.5	3.5 ± 0.3	4.2 ± 0.5	5.2 ± 0.2	5.4 ± 0.25	6.2 ± 0.4
6	2.1 ± 0.1	3.6 ± 0.4	4.8 ± 0.45	5.3 ± 0.2	5.7 ± 0.4
6.5	2.1 ± 0.45	3.6 ± 0.2	4.2 ± 0.2	4.7 ± 0.1	5.1 ± 0.4
7	1.5 ± 0.45	3.1 ± 0.3	3.8 ± 0.2	4.2 ± 0.3	4.6 ± 0.35
7.5	1.5 ± 0.1	2.7 ± 0.3	3.2 ± 0.3	4.2 ± 0.2	4.5 ± 0.3
8	1.2 ± 0.3	1.4 ± 0.3	1.6 ± 0.2	1.8 ± 0.5	2 ± 0.4

Table 2: Shoot elongation of TS-463 after 15, 18, 21, 24 and 27 days of treatment with different concentrations of copper solution

Concentration of $CuSO_4$ (mM)	Shoot length (in cm) was measured at different days after treatment in TS-463				
	15d	18d	21d	24d	27d
0	5.2 ± 0.5	6.5 ± 0.3	7.5 ± 0.3	9.8 ± 0.3	11.5 ± 0.7
0.5	5.1 ± 0.3	6.3 ± 0.1	7.1 ± 0.2	9.5 ± 0.45	11.5 ± 0.55
1	4.4 ± 0.3	6 ± 0.4	6.8 ± 0.1	9.2 ± 0.45	11.1 ± 0.6
1.5	4.3 ± 0.5	5.6 ± 0.4	6.4 ± 0.2	9.2 ± 0.2	10.5 ± 0.5
2	4.2 ± 0.2	5.3 ± 0.2	6.3 ± 0.1	9.2 ± 0.5	10.2 ± 0.5
2.5	4.1 ± 0.4	5.2 ± 0.2	6.3 ± 0.2	7.7 ± 0.5	10.1 ± 0.2
3	3.7 ± 0.4	5.1 ± 0.25	6.1 ± 0.2	7.7 ± 0.4	9.4 ± 0.5
3.5	3.3 ± 0.2	4.2 ± 0.1	5.9 ± 0.1	7.5 ± 0.4	8.5 ± 0.5
4	3.1 ± 0.3	3.9 ± 0.4	5.9 ± 0.1	7.1 ± 0.4	8.3 ± 0.2
4.5	3.1 ± 0.2	3.7 ± 0.2	4.9 ± 0.2	6.9 ± 0.3	7.3 ± 0.2
5	2.1 ± 0.2	3.2 ± 0.1	4.3 ± 0.1	6 ± 0.3	6.3 ± 0.25
5.5	1.8 ± 0.2	2.9 ± 0.15	4.2 ± 0.1	5.8 ± 0.3	6.2 ± 0.1
6	1.3 ± 0.2	2.8 ± 0.1	4 ± 0.2	4.8 ± 0.3	5.1 ± 0.1
6.5	1.2 ± 0.15	1.5 ± 0.2	1.9 ± 0.1	2.3 ± 0.2	2.7 ± 0.1
7	1 ± 0.1	1.2 ± 0.2	1.8 ± 0.1	2.1 ± 0.1	2.5 ± 0.1
7.5	0.4 ± 0.1	1.1 ± 0.15	1.3 ± 0.1	1.9 ± 0.15	2.1 ± 0.1
8	0.3 ± 0.2	0.6 ± 0.45	0.7 ± 0.1	0.9 ± 0.25	1 ± 0.3

Table 3: Shoot elongation of TS-462 after 15, 18, 21, 24 and 27 days of treatment with different concentrations of copper solution

Concentration of $CuSO_4$ (mM)	Shoot length (in cm) was measured at different days after treatment in TS-462				
	15 d	18 d	21d	24d	27d
0	4.4 ± 0.5	4.9 ± 0.15	5.5 ± 0.3	6.1 ± 0.1	7 ± 0.2
0.5	4.1 ± 0.4	4.8 ± 0.2	5.1 ± 0.5	5.9 ± 0.4	6.6 ± 0.2
1	3.9 ± 0.2	4.2 ± 0.5	4.2 ± 0.3	5.3 ± 0.3	6.2 ± 0.3
1.5	2.6 ± 0.1	3.8 ± 0.4	3.9 ± 0.2	4.2 ± 0.2	4.9 ± 0.1
2	2.5 ± 0.2	3.1 ± 0.2	3.8 ± 0.2	4 ± 0.3	4.5 ± 0.2
2.5	2.2 ± 0.4	3.1 ± 0.3	3.7 ± 0.1	4 ± 0.1	4.5 ± 0.4
3	2.1 ± 0.1	3 ± 0.3	3.6 ± 0.4	3.9 ± 0.2	4.3 ± 0.1
3.5	1.8 ± 0.3	2.9 ± 0.6	3.1 ± 0.1	3.7 ± 0.1	4.2 ± 0.1
4	1.4 ± 0.3	2.5 ± 0.3	3.1 ± 0.1	3.7 ± 0.1	4.2 ± 0.1
4.5	1.3 ± 0.1	2.4 ± 0.3	3.1 ± 0.15	3.7 ± 0.4	4.1 ± 0.15
5	1.3 ± 0.2	2.3 ± 0.4	3 ± 0.5	3.1 ± 0.3	3.9 ± 0.1
5.5	1.2 ± 0.1	1.9 ± 0.4	2.5 ± 0.3	2.9 ± 0.3	3.2 ± 0.3
6	1.1 ± 0.1	1.6 ± 0.2	2.1 ± 0.1	2.4 ± 0.2	2.8 ± 0.4
6.5	1.1 ± 0.1	1.6 ± 0.15	1.9 ± 0.1	2.3 ± 0.4	2.8 ± 0.2
7	1 ± 0.1	1.5 ± 0.1	1.9 ± 0.2	2.1 ± 0.15	2.5 ± 0.1
7.5	0.9 ± 0.1	1.5 ± 0.3	1.9 ± 0.25	2 ± 0.2	2.3 ± 0.2
8	0.7 ± 0.1	1.3 ± 0.5	1.8 ± 0.3	2 ± 0.2	2.2 ± 0.1

Table 4: Root elongation of TS-520 after 15, 18, 21, 24 and 27 days of treatment with different concentrations of copper solution

Concentration of $CuSO_4$ (mM)	Root length (in cm) was measured at different days after treatment in TS-520				
	15 d	18 d	21d	24d	27d
0	4.5 ± 0.3	6.8 ± 0.3	7.5 ± 0.6	7.7 ± 0.1	7.8 ± 0.1
0.5	4.3 ± 0.2	5.2 ± 0.3	5.9 ± 0.3	6.2 ± 0.2	6.7 ± 0.1
1	4.1 ± 0.2	5.1 ± 0.1	5.3 ± 0.3	5.7 ± 0.2	6.2 ± 0.2
1.5	4.1 ± 0.2	4.5 ± 0.2	4.8 ± 0.2	5.5 ± 0.6	5.7 ± 0.1
2	3.2 ± 0.1	4.2 ± 0.4	4.5 ± 0.45	5 ± 0.3	5.3 ± 0.1
2.5	3.2 ± 0.15	3.9 ± 0.35	4.3 ± 0.55	4.7 ± 0.2	5.1 ± 0.1
3	3.2 ± 0.2	3.5 ± 0.3	3.9 ± 0.5	4.1 ± 0.1	4.3 ± 0.2
3.5	2.9 ± 0.3	3.1 ± 0.1	3.5 ± 0.3	3.6 ± 0.1	3.8 ± 0.1
4	2.7 ± 0.2	3.1 ± 0.4	3.3 ± 0.4	3.4 ± 0.3	3.8 ± 0.1
4.5	2.7 ± 0.4	2.9 ± 0.4	3 ± 0.3	3.2 ± 0.1	3.5 ± 0.1
5	2.2 ± 0.1	2.8 ± 0.4	3 ± 0.5	3.1 ± 0.25	3.3 ± 0.1
5.5	2.1 ± 0.3	2.3 ± 0.2	2.6 ± 0.2	2.7 ± 0.1	2.9 ± 0.2
6	2.1 ± 0.06	2.3 ± 0.15	2.4 ± 0.1	2.6 ± 0.1	2.8 ± 0.1
6.5	1.5 ± 0.3	1.9 ± 0.3	2 ± 0.1	2.2 ± 0.3	2.5 ± 0.2
7	1.4 ± 0.3	1.7 ± 0.2	2 ± 0.25	2.1 ± 0.3	2.4 ± 0.1
7.5	1 ± 0.06	1.6 ± 0.35	1.8 ± 0.15	1.9 ± 0.2	2.1 ± 0.1
8	0.6 ± 0.3	0.7 ± 0.2	0.9 ± 0.1	1 ± 0.1	1.2 ± 0.1

Table 5: Root elongation of TS-463 after 15, 18, 21, 24 and 27 days of treatment with different concentrations of copper solution

Concentration of $CuSO_4$ (mM)	Root length (in cm) was measured at different days after treatment in TS-463				
	15 d	18 d	21d	24d	27d
0	3.8 ± 0.1	4.5 ± 0.2	6.3 ± 0.3	7.1 ± 0.2	8 ± 0.15
0.5	2.9 ± 0.5	3.1 ± 0.3	3.8 ± 0.3	4.7 ± 0.2	5.1 ± 0.1
1	2.5 ± 0.1	3.1 ± 0.1	3.6 ± 0.3	4.2 ± 0.15	4.9 ± 0.3
1.5	2.1 ± 0.3	2.9 ± 0.5	3.4 ± 0.3	4.1 ± 0.1	4.5 ± 0.3
2	2.1 ± 0.2	2.8 ± 0.6	3.2 ± 0.6	3.7 ± 0.1	4.4 ± 0.15
2.5	1.8 ± 0.4	2.1 ± 0.1	2.9 ± 0.2	3.3 ± 0.3	4.1 ± 0.15
3	1.7 ± 0.1	2.1 ± 0.5	2.8 ± 0.3	3.1 ± 0.15	3.8 ± 0.1
3.5	1.3 ± 0.2	1.9 ± 0.1	2.7 ± 0.1	3 ± 0.2	3.2 ± 0.1
4	1.3 ± 0.25	1.8 ± 0.2	2 ± 0.15	2.5 ± 0.2	2.9 ± 0.15
4.5	1.3 ± 0.2	1.7 ± 0.1	2 ± 0.75	2.4 ± 0.1	2.9 ± 0.15
5	1 ± 0.2	1.6 ± 0.2	1.8 ± 0.1	2.1 ± 0.1	2.8 ± 0.1
5.5	1 ± 0.4	1.4 ± 0.1	1.7 ± 0.2	2.1 ± 0.2	2.5 ± 0.1
6	0.9 ± 0.2	1.1 ± 0.1	1.6 ± 0.2	2 ± 0.1	2.2 ± 0.1
6.5	0.9 ± 0.3	1 ± 0.2	1.3 ± 0.2	1.9 ± 0.2	2.1 ± 0.1
7	0.7 ± 0.1	0.9 ± 0.45	1.1 ± 0.15	1.3 ± 0.1	1.6 ± 0.1
7.5	0.6 ± 0.1	0.8 ± 0.3	0.8 ± 0.1	0.9 ± 0.2	1 ± 0.1
8	0.2 ± 0.1	0.3 ± 0.1	0.4 ± 0.1	0.4 ± 0.15	0.7 ± 0.1

Table 6: Root elongation of TS-462 after 15, 18, 21, 24 and 27 days of treatment with different concentrations of copper solution

Concentration of $CuSO_4$ (mM)	Root length (in cm) was measured at different days after treatment in TS-462				
	15 d	18 d	21d	24d	27d
0	3.8 ± 0.1	4.7 ± 0.2	5.2 ± 0.1	5.8 ± 0.3	6.5 ± 0.1
0.5	3.5 ± 0.1	3.8 ± 0.1	4.1 ± 0.1	4.2 ± 0.15	4.4 ± 0.15
1	3.5 ± 0.1	3.8 ± 0.1	4 ± 0.2	4.1 ± 0.2	4.3 ± 0.15
1.5	3.1 ± 0.2	3.1 ± 0.1	3.5 ± 0.1	3.8 ± 0.25	4 ± 0.2
2	2.8 ± 0.1	3 ± 0.2	3 ± 0.1	3.2 ± 0.2	3.5 ± 0.1
2.5	2.8 ± 0.1	2.9 ± 0.1	2.9 ± 0.1	3.1 ± 0.2	3.5 ± 0.2
3	2.6 ± 0.15	2.8 ± 0.1	2.8 ± 0.1	3.1 ± 0.1	3.3 ± 0.1
3.5	2.5 ± 0.15	2.7 ± 0.1	2.8 ± 0.2	3 ± 0.1	3.3 ± 0.15
4	2.5 ± 0.1	2.7 ± 0.1	2.8 ± 0.4	3 ± 0.2	3.2 ± 0.1
4.5	2.4 ± 0.2	2.6 ± 0.2	2.8 ± 0.3	3 ± 0.15	3.2 ± 0.15
5	1.8 ± 0.1	2.1 ± 0.2	2.7 ± 0.1	2.8 ± 0.3	3.2 ± 0.2
5.5	1.5 ± 0.1	2 ± 0.1	2.5 ± 0.2	2.5 ± 0.2	3.1 ± 0.1
6	1 ± 0.1	1.8 ± 0.1	2 ± 0.15	2.1 ± 0.1	2.2 ± 0.1
6.5	0.9 ± 0.1	1 ± 0.15	1.1 ± 0.1	1.4 ± 0.1	1.5 ± 0.15
7	0.8 ± 0.2	1 ± 0.1	1.1 ± 0.1	1.3 ± 0.2	1.5 ± 0.1
7.5	0.4 ± 0.1	0.5 ± 0.1	0.6 ± 0.1	0.7 ± 0.1	0.7 ± 0.2
8	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.05	0.2 ± 0.1	0.2 ± 0.1

of Cu^{2+} in comparison to control which recorded 0.124 mg, 0.142 mg and 0.096 mg root dry weight of TS-520,TS-463 and TS-462 respectively. Dry weight in shoots also showed substantial reduction when exposed to high Cu^{2+} concentration. Zheng *et al.* (2004) worked on the response of three ornamental crops (*Dendranthema grandiflorum* L. 'Fina', *Rosa hybrid* L. 'Lavlinger', *Pelargonium hortorun* L. 'Evening glow') to different solution levels of Cu^{2+} (ranging from 0.4-40 µM). They observed that excessive copper reduced the shoot and root dry weight of all three species. Manivasagaperumal *et al.* (2011) reported the decline of dry weight of *Vigna radiata with* increasing copper concentration of 100-200 mg/kg. According to Azooz *et al.* (2012), copper concentration above 10 mM reduced the dry weight of wheat.

From these observations it can be concluded that excess copper had some effect on germination, growth and dry matter yield of three commonly grown tea varieties. Varietal differences in response towards Cu^{2+} were observed in the shoot elongation study. However, in the roots, the differences was less prominent possibly due to the fact that Cu^{2+} accumulation occurs much more in the roots than in the shoots leading to a greater damage in the roots which minimizes the differential effect within varieties. Differences among cultivars in response to Cu^{2+} stress have been found in other plants such as *Triticum durum* (Ciscato *et al.* 1997), *Holcus lanatus* (Hartley-Whitaker *et al.* 2001) and *Kummerowia stipulacea* (Xiong *et al.* 2008). Inhibitory action of excess copper in root and shoot elongation and in their damage observed during the present study may be due to reduction in cell division, toxic effect on respiration and protein synthesis (Manivasagaperumal *et al.* 2011, Kupper *et al.* 1996 and Sonmez *et al.* 2006). Our results indicate that a detail study on the effect of excess copper on tea plants is warranted.

Acknowledgement

S. Mandal wishes to thank the University Grants Commission, India for Rajiv Gandhi National Fellowship (No.F.14-2(SC)/2008(SA-III).

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