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The effect of copper and zinc on the morphological parameters of *Sesuvium portulacastrum* L.

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A B S T R A C T

The present work deals with the effect of copper and zinc on the morphological parameters of *Sesuvium portulacastrum* L. The *Sesuvium portulacastrum* plants are grown in pots containing the soil amended with various levels of copper and zinc (control, 100, 200, 300, 400, 500 and 600 mg kg^{-1}). All pots were irrigated as and when necessary. The experiments were replicated five times. The various morphological parameters and dry weight of the plants were measured at four different intervals (30, 60, 90 and 120th day). The results indicated that the various morphological parameters such as the root and shoot length, number of leaves, total leaf area and dry weight of root and shoot of *Sesuvium portulacastrum* increased at low levels (copper, 100-200 mg kg^{-1} and zinc, 100-300 mg kg^{-1}) and decreased at high levels (copper, 300-600 mg kg^{-1} and zinc, 400-600 mg kg^{-1}) of metals in the soil.

Introduction

Increasing industrialization and urbanization has given an increasing problem of heavy metals which are listed as priority pollutants by the US Environmental Protection Agency (Rai, 2007). Human actions are causing the slow extinction of fauna, flora and fungi in natural environment through toxic pollution owing to industrial and technological advancement in recent decades (Ives and Cardinale, 2004). Soil and water pollution by toxic heavy metals is a major environmental concern worldwide. Heavy metals are extremely toxic and they are present in our immediate environment. They occur in soil, surface water and plants, and readily mobilized by human activities that include mining and discarding industrialized waste materials in natural ecosystems that include forests, rivers, lakes and ocean (Larison *et al*., 2000). Consequently, heavy metals pose a potential threat to various terrestrial and aquatic organisms including human health (Hsu *et al*., 2006). However, scientific data on the toxic level of heavy metals found in mangrove forest plants are limited in India, which is experiencing economic boom and industrial out burst in recent decades. Agricultural soils in many parts of the world are slightly to moderately contaminated with heavy metals, this could be due to long term use of excessive fertilizers, pesticides, fungicides, sewage sludge and bad watering practices (Yadav, 2010). Zinc, copper and nickel are considered as soil pollutant metals due to their widespread occurrence and their acute effect on plants grown in such soils. In trace amount, they are essential elements for plants. Phytotoxicity results in weak plants growth and yield depression. Copper and zinc, although essential nutrients for plants, become hazardous at higher levels. Since copper and zinc play a vital role in the growth and developments of plants, they were chosen for the present study. The *Sesuvium portulacastrum* was selected owing to the reasons that it is an important halophyte, and it has remarkable ability to survive under stress conditions. Keeping these points in view, the present investigation has been carried out to analyse the effect of copper and zinc on growth of *Sesuvium portulacastrum*. The present investigation deals with the effect of copper and zinc on morphological parameters (root and shoot length, number of leaves, total leaf area and dry weight of root and shoot) of *Sesuvium portulacastrum*.

Materials and Methods

Plant cutting

The experimental plant, the *Sesuvium portulacastrum* L. belongs to the family Aizoaceae is one of the important halophytic plants of India. Plant cuttings of *Sesuvium portulacastrum* used in the experiments were collected from T.S. pettai village nearer to pichavaram mangrove forest [11˚ 43´ N and 79˚ 77´ E] on the south east coast of Tamil Nadu, India. Plant cutting with each 5 cm length with uniform thickness were chosen for experimental purpose.

Pot culture experiments

The experiments were conducted during January-April 2012. *Sesuvium portulacastrum* L. plants were grown in pots in untreated soil (control) and in soil to which copper and zinc had been applied (100, 200, 300, 400, 500 and 600 mg kg^{-1} soil). The inner surfaces of pots were lined with a polythene sheet.

Each pot contained 3 kg of air dried soil. The copper and zinc as finely powdered ($Cu SO_4 .5H_2O$, $ZnSO_4 .7H_2O$) was applied to the surface soil and thoroughly mixed with the soil. Ten plant cuttings were planted in each pot. All pots were watered to field capacity daily. Plants were thinned to a maximum of six per pot, after a week of planting. Each treatment including the control was replicated five times.

Sample collection

The plant samples were collected at thirty days interval, up to four months *viz.,* 30, 60, 90 and 120th day for the measurement of various morphological growth parameters(root and shoot length and number of leaves, total leaf area and dry weight root and shoot). Six plants from each replicate of a pot was analyzed for its various parameters and the average was calculated. These mean values were used for statistical analysis.

Morphological parameters

The various morphological parameters such as length of root and shoot, number of leaves, total leaf area, dry weight of root and shoot per plant were determined for every samples.

Leaf area (cm^2 $plant^{-1}$)

The leaf area was calculated by measuring the length and breadth and multiplied by a correlation factor (0.69), derived from the method of Kalra and Dhiman (1977).

Result and Discussion

Pot culture

Pot culture experiments were conducted at Botanical garden in Annamalai University during January to April, 2012. Periodical observations were made to record the morphological responses of treated and untreated *Sesuvium portulacastrum* L. The data gathered from periodical observations were processed, statistically analyzed and the results are presented in the form of tables.

Root length (cm $plant^{-1}$)

Root lengths of *S. portulacastrum* at different stages of growth under copper and zinc treatment are represented in Table 1. Copper treatment at lower levels (100 and 200 mg kg^{-1} of soil) increased the root length of *S. portulacastrum* in all the sampling days (*viz.*, 7.88, 11.56, 15.92 and 18.20; 8.13, 12.35, 16.25 and 19.27). There was a progressive decline in root length with increase in copper level. The minimum root length was recorded at 600 mg kg^{-1} of copper level (*viz.*, 3.87, 5.86, 7.56 and 9.08) in all the sampling days.

In zinc treated *S. portulacastrum* plant, higher root length was recorded at 100, 200 and 300 mg kg^{-1} of soil (*viz.*, 7.96, 11.65, 16.20, 19.20; 8.60, 12.38, 17.42, 20.45 and 9.25, 13.20, 19.23, 21.56 respectively). However, 600 mg kg^{-1} of zinc level showed the minimum length of root in all the sampling days (*viz.*, 4.36, 6.89, 9.26 and 10.56). F values calculated for the treatment, sampling days and interaction between treatment and sampling days were significant at 1 per cent level in both copper and zinc treated *S. portulacastrum* plants.

Shoot length (cm $plant^{-1}$)

The results on the effect of different concentrations of copper and zinc on shoot length of *Sesuvium portulacastrum* are presented in Table 2. The mean shoot length decreased progressively with increase in copper level. The 200 mg kg^{-1} of *S. portulacastrum* showed the highest shoot length in all the sampling days (*viz.*, 19.46, 25.65, 32.76 and 37.13), while the 600 mg kg^{-1} copper treated *S. portulacastrum* plants exhibited the lowest shoot length in all the sampling days (*viz.*, 9.46, 13.20, 17.13 and 18.84).

In zinc treated *S. portulacastrum* plants, at 100, 200 and 300 mg kg^{-1} of soil, increased shoot length was observed in all the sampling days. Zinc concentrations beyond this level produced adverse effect on the root length. The lowest root length was recorded at 600 mg kg^{-1} of zinc level in all the sampling days (*viz.*, 10.10, 13.73, 17.46 and 19.35). The shoot length of *S. portulacastrum* increased with respect to sampling days and decreased with an increase in the concentration of copper and zinc in the soil. Significant variations (F values at 1 per cent level) were observed with treatment, sampling days and with interaction between treatment and sampling days for copper and zinc treated *S. portulacastrum* plants.

Leaf number ($plant^{-1}$)

The number of leaves of *S. portulacastrum* recorded at different stages of growth are represented in Table 3. The maximum leaf number was recorded at 200 mg kg^{-1} copper treated *S. portulacastrum* (*viz.*, 36, 51, 62 and 55) in all the sampling days. The minimum leaf number was noticed at 600 mg kg^{-1} of copper treated *S. portulacastrum* (*viz.*, 16, 23, 30 and 24) in all the sampling days. F test values calculated for the copper treated *S. portulacastrum* were significant at 1 per cent level in different treatments and interaction between treatments and sampling days and non-significant for sampling days.

Zinc treatment at low levels (100, 200 and 300 mg kg^{-1} of soil) increased the leaf number (*viz.*, 34, 49, 61, 53; 36, 52, 63, 57 and 38, 54, 67, 59 respectively) of *S. portulacastrum*. With further increase of zinc level (400-600 mg kg^{-1}), the leaf number was reduced in all the sampling days. The leaf number showed a progressive trend up to the 90th day and it gradually declined on the 120th day due to the senescence of leaves. F test values calculated for the zinc treated *S. portulacastrum* were significant at 1 per cent level in different treatments and sampling days, interaction between treatments and sampling days.

Total leaf area (cm^2 $plant^{-1}$)

The results presented in Table 4. indicate that the maximum total leaf area occurred at 200 mg kg^{-1} of copper treated *S. portulacastrum* (*viz.*, 224.29, 251.98, 319.13 and 288.93) and minimum total leaf area was recorded at 600 mg kg^{-1} of copper level (*viz.*, 96.40, 112.16, 134.12 and 130.16) in various sampling days.

The total leaf area of *S. portulacastrum* under zinc treatment, increased with increasing concentration of applied zinc in the soil up to 300 mg kg^{-1} (*viz.*, 214.99, 235.07, 296.06, 278.69; 228.22, 260.55, 322.29, 292.52 and 235.10, 268.62, 330.29, 302.62 respectively). For further higher concentrations the total leaf area decreased. The lowest total leaf area was recorded at 600 mg kg^{-1} of zinc level (*viz.*, 103.96, 116.23, 143.38 and 137.07) in all the sampling days. The total leaf area increased up to the 90th day and it gradually declined on the 120th day due to the senescence of leaves. The F values were significant at 1 per cent level for treatment, sampling days and interaction between treatment and sampling days in both copper and zinc treated *S. portulacastrum* plants.

Root dry weight (g $plant^{-1}$)

Root dry weight of *S. portulacastrum* at different stages of growth is presented in Table 5. The root dry weight of copper treated *S. portulacastrum* was higher than that of control plants, for an applied copper concentration of 100 and 200 mg kg^{-1} of soil (*viz.*, 0.735, 0.915, 1.11 and 1.52; 0.778, 0.983, 1.16 and 1.61) in all the sampling days and decreased further with an increase in copper level in the soil.

The lowest root dry weight of *S. portulacastrum* was recorded at 600 mg kg^{-1} of soil level (*viz.*, 0.335, 0.461, 0.523 and 0.702) in all sampling days. F test values calculated for treatment were significant at 1 per cent level and non-significant for sampling days and interaction between treatment and sampling days in copper treated *S. portulacastrum* plants.

The root dry weight of *S. portulacastrum* increased at 100 mg kg^{-1} (0.763, 0.981, 1.18 and 1.60), 200 mg kg^{-1} (*viz.,* 0.806, 1.05, 1.24 and 1.70) and 300 mg kg^{-1} (*viz.,* 0.842, 1.08, 1.30 and 1.76) in all the sampling days and decreased further with an increase in the concentration of zinc in the soil. The F values calculated for the treatment, sampling days and interaction between treatment and sampling days were significant at 1 per cent in zinc treated *S. portulacastrum* plants.

Shoot dry weight (g $plant^{-1}$)

The shoot dry weight of *S. portulacastrum* raised in various levels of copper and zinc at different stages of growth is furnished in Table 6. The maximum shoot dry weight was recorded at 200 mg kg^{-1} of copper level in *S. portulacastrum* (*viz.,* 7.06, 9.61, 13.45 and 10.96) in all the sampling days. There was a progressive decline in shoot dry weight with an increase in copper level. The minimum shoot dry weight was recorded at 600 mg kg^{-1} of copper level (*viz.,* 3.15, 3.98, 5.82 and 4.89) in all the sampling days.

The dry weight of zinc treated *S. portulacastrum* shoots increased with increasing concentrations of applied zinc in soil up to 300 mg kg^{-1}. For further higher concentrations, the dry weight of zinc treated *S. portulacastrum* plants decreased. The lowest dry weight was recorded at 600 mg kg^{-1} of zinc treated *S. portulacastrum* (*viz.,* 3.60, 4.70, 6.42 and 5.28) in all the sampling days. Statistical analysis revealed significant variations (F values at 1 per cent level) for treatment, sampling days and interaction between treatment and sampling days in both copper and zinc treated *S. portulacastrum* plants.

Root and shoot length

Root and shoot length of *Sesuvium portulacastrum* plants differed with different level of copper and zinc in the soil. For lower concentrations of applied copper (100-200 mg kg^{-1}) and zinc (100-300 mg kg^{-1}) the root and shoot length of *S.portulacastrum* plants were higher than that of control plants, which may be taken as an indication of beneficial range, while for higher concentrations of copper (300-600 mg kg^{-1}) and zinc (400-600 mg kg^{-1}) a decreasing trend was observed, which confirms the toxic effect of these metals to *S. portulacastrum* plants. In agreement with our results, water plant *Pistia stratiotes* has also been reported to show higher tolerance to Cu and Zn (Odjegba and Fasida, 2004). These results are also in consonance with the observations of Kalyanaraman and Sivagurunathan (1993) in blackgram, Lidon and Henriques (1993) in rice, Ouzounidou (1994a) in *Alyssum montanum,* Mocquot *et al.* (1996) in maize, Saravanan *et al*. (2001) in soybean, Xu *et al*. (2005) in rice under copper treatment and Ren *et al*. (1993) in American ginseng plants, Kopponen *et al.* (2001) in birch, Kaya *et al*. (2002) in tomato, Bameri *et al*. (2012) in wheat, Dube *et al.* (2003) and Vijayarengan (2012) in radish and Sivasankar *et al*. (2012) in chilli, marigold, mustard and pigeon pea under zinc treatment.

Significant increase in growth of *S. portulacastrum* is possibly due to the utilization of copper and zinc by *S.portulacastrum* plants in trace amounts. Under lower application of these metals, improved root system, helped the plants in better absorption of water and other

Table.1 Effect of copper and zinc on root length (cm plant^{-1}) of *Sesuvium portulacastrum* L.

Metals added in the soil (mg kg^{-1})	Copper				Zinc			
	Sampling days				Sampling days			
	30	60	90	120	30	60	90	120
Control	7.06	10.30	14.06	16.27	7.06	10.30	14.06	16.27
100	7.88(+11.61)	11.56(+12.23)	15.92(+13.23)	18.20(+11.86)	7.96(+12.75)	11.65(+13.11)	16.20(+15.22)	19.20(+18.01)
200	8.13(+15.15)	12.35(+19.90)	16.25(+15.58)	19.27(+18.44)	8.60(+21.81)	12.38(+20.19)	17.42(+23.90)	20.45(+25.69)
300	6.15(-12.89)	9.11(-11.55)	12.10(-13.94)	13.85(-14.87)	9.25(+31.02)	13.20(+28.15)	19.23(+36.77)	21.56(+32.51)
400	5.55(-21.39)	7.82(-24.08)	10.12(-28.02)	11.25(-30.85)	6.26(-11.33)	9.26(-10.10)	12.25(-12.87)	14.10(-13.34)
500	4.65(-34.13)	6.90(-33.01)	8.84(-37.13)	10.32(-36.57)	5.66(-19.83)	7.98(-22.52)	11.07(-21.27)	13.14(-19.24)
600	3.87(-45.18)	5.86(-43.11)	7.56(-46.23)	9.08(-44.19)	4.36(-38.24)	6.89(-33.11)	9.26(-34.14)	10.56(-35.09)

Comparison of significant effects	F test	CD P= 0.05	F test	CD P= 0.05
Metal levels	**	0.0345	**	0.1941
Sampling days	**	0.0336	**	0.1352
Interaction	**	0.0888	**	0.3577

Average of five replications

Figures in parentheses represent per cent reduction (-) over control

Table.2 Effect of copper and zinc on shoot length (cm $plant^{-1}$) of *Sesuvium portulacastrum* L.

Metals added in the soil ($mg\ kg^{-1}$)	Copper				Zinc			
	Sampling days				Sampling days			
	30	60	90	120	30	60	90	120
Control	15.90	21.35	27.46	31.28	15.90	21.35	27.46	31.28
100	17.70(+11.32)	23.65(+10.77)	30.87(+12.42)	34.76(+11.12)	18.06(+13.58)	23.98(+12.32)	31.67(+15.33)	35.14(+12.34)
200	19.46(+22.39)	25.65(+20.14)	32.76(+19.30)	37.13(+18.70)	19.82(+24.65)	26.12(+22.34)	34.42(+25.34)	38.12(+21.87)
300	13.86(-12.83)	19.10(-10.54)	24.35(-11.32)	27.06(-13.49)	21.46(+34.97)	28.56(+33.77)	37.10(+35.10)	41.23(+31.81)
400	12.50(-21.38)	16.15(-24.35)	21.10(-23.16)	24.18(-22.70)	14.02(-11.82)	19.25(-9.84)	24.53(-10.67)	27.32(-12.66)
500	10.78(-32.20)	14.21(-33.44)	19.06(-30.59)	21.32(-31.84)	12.16(-23.52)	16.86(-21.03)	21.19(-22.83)	25.32(-19.05)
600	9.46(-40.50)	13.20(-38.17)	17.13(-37.62)	18.84(-39.77)	10.10(-36.48)	13.73(-35.69)	17.46(-36.42)	19.35(-38.14)

Comparison of significant effects	F test	CD P= 0.05	F test	CD P= 0.05
Metal levels	**	0.5197	**	0.8754
Sampling days	**	0.6021	**	0.6160
Interaction	**	0.0204	**	1.6298

Average of five replications

Figures in parentheses represent per cent reduction (-) over control

Table.3 Effect of copper and zinc on leaf number (plant^{-1}) of *Sesuvium portulacastrum* L.

Metals added in the soil (mg kg^{-1})	Copper				Zinc			
	Sampling days				Sampling days			
	30	60	90	120	30	60	90	120
Control	27	38	48	42	27	38	48	42
100	32(+18.52)	46(+21.05)	58(+20.83)	50(+19.05)	34(+25.92)	49(+28.95)	61(+27.08)	53(+26.19)
200	36(+33.33)	51(+34.21)	62(+29.17)	55(+30.95)	36(+33.33)	52(+36.84)	63(+31.25)	57(+35.71)
300	24(-11.11)	33(-13.16)	42(-12.50)	36(-14.28)	38(+40.74)	54(+42.10)	67(+39.58)	59(+40.48)
400	22(-18.52)	30(-21.50)	38(-20.33)	32(-23.81)	25(-7.40)	34(-10.53)	43(-10.42)	37(-11.90)
500	19(-29.63)	26(-31.58)	32(-33.33)	27(-35.71)	23(-14.81)	32(-15.79)	39(-18.75)	35(-16.66)
600	16(-40.74)	23(-39.47)	30(-37.50)	24(-42.86)	19(-29.63)	28(-26.31)	35(-27.08)	30(-28.57)

Comparison of significant effects	F test	CD P= 0.05	F test	CD P= 0.05
Metal levels	**	5.3039	**	4.0330
Sampling days	NS	NS	**	2.5549
Interaction	**	7.7537	**	6.7596

Average of five replications

Figures in parentheses represent per cent reduction (-) over control

Table.4 Effect of copper and zinc on leaf area (cm^2 $plant^{-1}$) of *Sesuvium portulacastrum* L.

Metals added in the soil ($mg\ kg^{-1}$)	Copper				Zinc			
	Sampling days				Sampling days			
	30	60	90	120	30	60	90	120
control	168.33	190.61	238.06	219.62	168.33	190.61	238.06	219.62
100	208.63(+23.94)	228.91(+20.09)	288.10(+21.10)	262.07(+19.33)	214.99(+27.72)	235.07(+23.32)	296.06(+24.36)	278.69(+26.90)
200	224.29(+33.24)	251.98(+32.20)	319.13(+34.05)	288.93(+31.56)	228.22(+35.58)	260.55(+36.69)	322.29(+35.38)	292.52(+33.22)
300	145.26(-13.70)	167.38(-12.19)	210.63(-11.52)	188.13(-14.34)	235.10(+39.67)	268.62(+40.93)	330.29(+38.74)	302.62(+37.79)
400	132.69(-21.17)	142.12(-25.44)	180.09(-24.35)	168.10(-23.46)	148.52(-11.77)	170.42(-10.59)	216.21(-9.18)	192.56(-12.32)
500	110.54(-34.33)	126.23(-33.77)	163.13(-31.47)	149.12(-32.10)	117.56(-30.16)	131.40(-31.10)	170.09(-28.55)	155.21(-29.33)
600	96.40(-42.73)	112.16(-41.16)	134.12(-43.66)	130.16(-40.73)	103.96(-38.24)	116.23(-39.02)	143.38(-39.77)	137.07(-37.59)

Comparison of significant effects	F test	CD P= 0.05	F test	CD P=0.05
Metal levels	**	2.9652	**	1.7631
Sampling days	**	2.0666	**	2.4562
Interaction	**	5.4678	**	1.2321

Average of five replications

Figures in parentheses represent per cent reduction (-) over control

Table.5 Effect of copper and zinc on root dry weight (g plant^{-1}) of *Sesuvium portulacastrum* L.

Metals added in the soil (mg kg^{-1})	Copper				Zinc			
	Sampling days				Sampling days			
	30	60	90	120	30	60	90	120
control	0.613	0.781	0.935	1.250	0.613	0.781	0.935	1.250
100	0.735(+19.90)	0.915(+17.16)	1.11(+18.72)	1.52(+21.60)	0.763(+24.47)	0.981(+25.61)	1.18(+26.74)	1.60(+28.01)
200	0.778(+26.92)	0.983(+25.86)	1.16(+24.06)	1.61(+28.80)	0.806(+31.48)	1.05(+34.44)	1.24(+32.62)	1.70(+36.02)
300	0.535(-12.72)	0.676(-13.44)	0.825(-11.76)	1.12(-10.40)	0.842(+37.36)	1.08(+38.28)	1.30(+39.04)	1.76(+40.80)
400	0.445(-27.41)	0.557(-28.68)	0.659(-29.52)	0.922(-26.24)	0.548(-10.60)	0.685(-12.29)	0.832(-11.02)	1.13(-9.60)
500	0.396(-35.40)	0.490(-37.26)	0.576(-38.39)	0.789(-36.88)	0.483(-21.21)	0.618(-20.87)	0.750(-19.79)	0.975(-22.01)
600	0.335(-45.35)	0.461(-40.97)	0.523(-44.06)	0.702(-43.84)	0.376(-38.66)	0.499(-36.11)	0.605(-35.29)	0.781(-37.52)

Comparison of significant effects	F test	CD P=0.05	F test	CD P= 0.05
Metal levels	**	0.0656	**	0.0225
Sampling days	NS	NS	**	0.0631
Interaction	NS	NS	**	0.0977

Average of five replications

Figures in parentheses represent per cent reduction (-) over control

Table.6 Effect of copper and zinc on shoot dry weight (g plant^{-1}) of *Sesuvium portulacastrum* (L.).

Metals added in the soil (mg kg^{-1})	Copper				Zinc			
	Sampling days				Sampling days			
	30	60	90	120	30	60	90	120
control	5.32	7.08	10.05	8.13	5.32	7.08	10.05	8.13
100	6.74(+26.69)	9.15(+29.24)	12.86(+27.96)	10.45(+28.54)	6.95(+30.64)	9.27(+31.21)	12.97(+29.05)	10.63(+30.75)
200	7.06(+32.71)	9.61(+35.73)	13.45(+33.83)	10.96(+34.81)	7.23(+35.90)	9.78(+38.13)	13.55(+34.82)	11.06(+36.04)
300	4.65(-12.59)	6.14(-13.28)	8.96(-10.80)	7.19(-11.56)	7.43(+39.66)	10.08(+42.37)	13.70(+36.32)	11.21(+37.88)
400	4.19(-21.24)	5.39(-23.87)	7.25(-25.87)	6.12(-24.72)	4.70(-11.65)	6.21(-12.29)	9.08(-09.65)	7.30(-10.21)
500	3.65(-31.39)	4.65(-34.32)	6.45(-35.82)	5.20(-36.04)	4.28(-19.55)	5.52(-22.03)	7.96(-20.80)	6.38(-21.52)
600	3.15(-40.79)	3.98(-43.78)	5.82(-42.09)	4.89(-39.85)	3.60(-32.72)	4.70(-33.61)	6.42(-36.12)	5.28(-35.05)

Comparison of significant effects	F test	CD P= 0.05	F test	CD P= 0.05
Metal levels	**	0.0578	**	0.0297
Sampling days	**	0.0274	**	0.0231
Interaction	**	0.0726	**	0.0686

Average of five replications

Figures in parentheses represent per cent reduction (-) over control

nutrients dissolved in the soil and consequently improved the growth of different organs and the entire plant (Reichman, 2002). The decrease in growth due to heavy metal treatment is in conformity with the findings of other researchers (Rahman *et al*., 2010). Shen *et al*. (1998) showed that Cu and Zn toxicity might cause multiple direct indirect influences on practically all processes of physiological metabolism in plants. The primary toxicity mechanism of heavy metals were shown as altering the catalytic function of enzymes, damaging cellular membrane, inhibiting root growth. The inhibitory action of excess of copper and zinc in root and shoot length might be due to reduction in cell division, toxic effect of heavy metals on photosynthesis, respiration and protein synthesis. These obviously contributed to the retardation of normal growth (Kupper *et al*., 1996). Hagemayer and Breckle (2002) and Machano *et al*., (2002) also suggested the morphological and structural effects caused by metal toxicity in plants was due to decrease in root elongation, root tip damage, collapsing of root hairs, decrease in root formation, enhancement of suberification and lignification, decrease in vessel diameter and structural alterations of hypodermis and endodermis. A marked decrease in plant height with concomitant decrease of root growth was previously reported by Lombardi and Sebastiani (2005) in *Prunus cerasifera*, Souguir *et al*. (2008) in *Vicia faba* and *Pisum sativum* and Israr *et al*. (2011) in *Sesbania drummondii* plants under copper toxicity.

Number of leaves and total leaf area

Number of leaves and total leaf area of *S. portulacastrum* plants varied in proportion to copper and zinc level. They were higher at 100-200 mg kg^{-1} of copper and 100-300 mg kg^{-1} of zinc level in the soil in all the sampling days. The number of leaves and total leaf area showed a gradual decline when there was a further increase in copper and zinc level in the soil, in all the sampling days. Similar observations were made by Mocquot *et al*. (1996) and Mc Bride (2001) in maize, Saravanan *et al*. (2001) in soybean under copper treatment, Ajay and Rathore (1995) in rice, Selvaraju (1999) in *Vigna radiata*, Mankar *et al*. (2003) in mustard under zinc treatment, Sharma and Sharma (1993) in wheat due to chromium and Vijayarengan and Lakshmanachary (1995) in blackgram due to nickel.

An increase in the number of leaves and total leaf area under low level of copper and zinc might be due to the active involvement of these elements in chlorophyll synthesis, cell division, meristematic activity of the tissue, and expansion of cells, as suggested by Martin (1966). A decrease in the number of leaves and leaf area at higher concentrations of copper and zinc might be attributed to either a reduction in the number of cells as judged by Nieman (1965) in the leaves of *Phaseolus vulgaris* or due to reduction in cell size (Meiri and Poljakaff-Mayber, 1967). The metals might inhibit mitotic activity or produce cytological abnormalities, mutagenic activities and degradation of DNA (Rohr and Baughinger, 1976).

Both these parameters increased upto 90th day, but they showed a gradual decline on 120th day. This was due to the senescence of lower leaves in the later stages of growth.

Dry weight of root and shoot

Plants treated with low level of copper (100-200 mg kg^{-1}) and zinc (100-300 mg

kg^{-1}) showed a significant increase in the dry weight, while higher concentration of copper (300-600 mg kg^{-1}) and zinc (400-600 mg kg^{-1}) showed a gradual decline in the dry weight in all the sampling days. Similar results were obtained by several authors in a number of plants such as Lidon and Henriques (1991) in rice, Mocquot *et al*. (1996) in maize, Mc Barik and Chandel (2001) in soybean under copper treatment and Shrikrishna and Singh (1992) in Indian mustard, Aery *et al*. (1994) in soybean and fenugreek, Dube *et al.* (2001) in pigeon pea, Mahalakshmi (2002) in tomato, Dube *et al*. (2003) in radish, Sudhan and Shakila (2003) in rice, corn, dry bean and soybean, Khan *et al*. (2009b) in sunflower, Ejaz *et al*. (2011) in tomato and Vijayarengan (2012) in radish under zinc treatment.

Growth inhibition and reduction in biomass production are general responses of higher plants to heavy metal toxicity (Ouariti *et al*., 1997). The decrease in biomass in excess of these metals might be due to low protein formation, resulting in the inhibition of photosynthesis, as well as hampering carbohydrate translocation (Manivasagaperumal *et al*., 2011). Arduini *et al*. (1994) suggested that inhibition of both cell elongation and division by heavy metals could explain, in part, the decline in biomass production. Joshi *et al*. (1999) also suggested that the reduction of dry matter of various parts at various stages was due to depletion of moisture content in plant organs and also due to degradation of roots as well as reduction of newer roots. The plant biomass was also significantly reduced in all treated plants (Verma *et al*., 2011).

The results indicated that the various morphological parameters such as the root and shoot length, number of leaves, total leaf area and dry weight of root and shoot of *Sesuvium portulacastrum* increased at low levels (copper, 100-200 mg kg^{-1} and zinc, 100-300 mg kg^{-1}) and decreased at high levels (copper, 300-600 mg kg^{-1} and zinc, 400-600 mg kg^{-1}). From the present investigation it was concluded that the 100-200 mg kg^{-1} level of copper, 100-300 mg kg^{-1} level of zinc in the soil was beneficial for the growth of *Sesuvium portulacastrum* plants. The level of copper in the soil above 300 mg kg^{-1}, zinc in the soil above 400 mg kg^{-1} proved to be toxic. The results indicated that the copper, 100-200 mg kg^{-1} and zinc, 100-300 mg kg^{-1} can be applied for increased the growth and dry weight of *Sesuvium portulacastrum*.

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