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Influence of essential heavy metals on vegetative growth of tuberose *cv.* Prajwal

L Gowthami, V Vijaya Bhaskar, K Swarajya Lakshmi, G Srinivasa Rao and VV Padmaja

L Gowthami
College of Horticulture, Dr. Y.S.R. Horticultural University, Anantharajupeta, Railway Kodur Mandal, Kadapa District, Andhra Pradesh, India

V Vijaya Bhaskar
College of Horticulture, Dr. Y.S.R. Horticultural University, Chinalataripi, Prakasam, Andhra Pradesh, India

K Swarajya Lakshmi
College of Horticulture, Dr. Y.S.R. Horticultural University, Anantharajupeta, Railway Kodur Mandal, Kadapa District, Andhra Pradesh, India

G Srinivasa Rao
Horticultural Polytechnic, Dr. Y.S.R. Horticultural University, Madakasira, Anantapuramu, Andhra Pradesh, India

VV Padmaja
College of Horticulture, Dr. Y.S.R. Horticultural University, Anantharajupeta, Railway Kodur Mandal, Kadapa District, Andhra Pradesh, India

Corresponding Author:
L Gowthami
College of Horticulture, Dr. Y.S.R. Horticultural University, Anantharajupeta, Railway Kodur Mandal, Kadapa District, Andhra Pradesh, India

Abstract
An experiment was conducted with 3 essential heavy metals *viz.,* $MnSO_4$, $CuSO_4$, and $ZnSO_4$ with three different concentrations *i.e.,* $MnSO_4$ @ 1000, 2000 and 3000 mg kg^{-1} soil, $CuSO_4$ @ 100, 200 and 300 mg kg^{-1} soil, $ZnSO_4$ @ 200, 400 and 600 mg kg^{-1} soil in addition with no application of nutrients and treated as Control. The experiment was carried out in polybag culture method and conducted with a Completely Randomized Design using three replications. Data recorded on vegetative growth parameters of tuberose *cv.* 'Prajwal' were analyzed using OPSTAT software and least significant difference was used to differentiate the treatments. Analysis of results indicated that soil application of $ZnSO_4$ @ 400 mg kg^{-1} soil recorded a significant improvement in many of the vegetative growth parameters *viz*., plant height (47.03 cm and 48.78 cm respectively during 2018-19 and the pooled data analysis), number of leaves per plant (53.60 and 54.91 respectively during 2018-19 and the pooled data analysis), plant spread (1466.26 cm^2, 1742.23 cm^2 and 1604.24 cm^2 respectively during 2018-19, 2019-20 and the pooled data analysis) at 360 days after planting (DAP) interval.

Keywords: $CuSO_4$, heavy metals, $MnSO_4$, plant height, plant spread, tuberose and $ZnSO_4$

1. Introduction
Contamination of soils with heavy metals is considered as one of the serious environmental concerns due to persistence nature of heavy metals as well as their bio-magnification potential in soil. Presence of high concentration of both essential and non-essential heavy metals are considered to affect the plant growth and development adversely and sometimes even lead to death under extreme conditions and thus heavy metal toxicity has been considered as one of the major abiotic stresses leading to hazardous effects in plants as many of them were found toxic even at a very low level concentration in the soil. Industrial revolution has accelerated the biosphere with heavy metals all over the world. A common response of heavy metal toxicity on plants was excessive accumulation of reactive oxygen species (ROS) which can cause peroxidation of lipids, oxidation of proteins, inactivation of enzymes, DNA damage and/or interact with other vital constituents of plant cells (Bohra *et al*., 2015) [8]. Certain heavy metals were found nutritionally essential for healthy growth of plant in very small quantities such as iron (Fe), copper (Cu), manganese (Mn), Magnesium (Mg) and zinc (Zn). These metals were found required in specific amounts and their deficiencies or elevated concentrations will result in deleterious effects on plant growth and development and thus reduce plant productivity. Out of the several heavy metals of essential and non-essential nature, three essential heavy metals *viz.,* Mn, Cu and Zn were found required in trace amounts for better growth, development and metabolic activity of plants and thus have been selected in the present investigation to identify their level of beneficial and toxic effects on the plant's metabolic activity under heavily accumulated condition in the soil. General metabolic functions and toxicity of these essential heavy metals on plant's growth and metabolism has been briefly discussed to show the basis for selection of tuberose plants to remove these elements from soil through the process of phytoremediation in the present investigation with the main objective to find out the influence of graded levels of essential heavy metals (Mn, Cu, Zn) on the vegetative growth of tuberose *cv*. 'Prajwal'.

Materials and Methods
The present investigation was carried out during the period from *Rabi*-2018 to *Kharif*-2020 at College of Horticulture, Dr. Y.S.R. Horticultural University, Anantharajupeta, Kadapa district of Andhra Pradesh. The experiment was laid out in a completely randomized design (CRD)

with factorial concept and replicated thrice. The experiment has consisted of 10 treatments *viz.*, T_1 = RDF+$MnSO_4$ @ 1,000 mg kg^{-1} soil, T_2 = RDF+$MnSO_4$ @ 2,000 mg kg^{-1} soil, T_3 = RDF+$MnSO_4$ @ 3,000 mg kg^{-1} soil, T_4 = RDF+$CuSO_4$ @ 100 mg kg^{-1} soil, T_5 = RDF+$CuSO_4$ @ 200 mg kg^{-1} soil, T_6 = RDF+$CuSO_4$ @ 300 mg kg^{-1} soil, T_7 = RDF+$ZnSO_4$ @ 200 mg kg^{-1} soil, T_8 = RDF+ $ZnSO_4$ @ 400 mg kg^{-1} soil, T_9 = RDF+ $ZnSO_4$ @ 600 mg kg^{-1} soil, T_{10} = Control (No RDF and no heavy metals). The main objective of the investigation was to find out the influence of graded levels of essential heavy metals (Mn, Cu, Zn) on the vegetative growth of tuberose *cv*. 'Prajwal'. All the vegetative parameters *viz.*, plant height, number of leaves per plant and plant spread were recorded as per the standard procedures established by several research workers earlier. Plant height was calculated as length from base of plant to the tip of the longest leaf of five randomly selected plants in every replication was measured using a meter scale and the value was expressed in centimeters. The first observation was recorded at 90 days after planting and further readings were recorded at every 90 days interval. Number of leaves produced per plant was calculated as number of fully opened leaves on five randomly selected plants in every replication was counted at every 90 days interval for two years and the average value was recorded as number of leaves per plant. Plant spread of tuberose was measured in North-South and East-West directions with the help of meter scale and the average values of two sides was expressed in square centimeters. The data obtained was analyzed using OPSTAT software.

Results and Discussion

Significant variation was noticed in the plant height of tuberose *cv.* 'Prajwal' by soil application of graded levels of essential heavy metal concentrations (Table 1). Among the graded levels of essential heavy metal concentrations, application of $ZnSO_4$ @ 400 mg kg^{-1} soil recorded significantly highest plant height (40.13 cm, 49.65 cm and 44.89 cm respectively during 2018-19, 2019-20 and the pooled data analysis) followed by application of $ZnSO_4$ @ 600 mg kg^{-1} soil. Among the concentrations of $ZnSO_4$, application @ 200 mg kg^{-1} soil recorded significantly lowest plant height during both the years of study as well as in the pooled data analysis exhibiting the toxic nature of $ZnSO_4$ on the metabolic activity of tuberose. Among the concentrations of $MnSO_4$, non-significant differences were noticed with respect to the plant height during the 1st year of study *i.e.*, 2018-19, whereas non-significant differences were noticed in the concentrations in between $MnSO_4$ applied @ 2000 and 3000 mg kg^{-1} soil during 2019-20. However, significant differences were noticed in the pooled data analysis with respect to plant height of tuberose. Further, it was noticed that application of $MnSO_4$ @ 1000 mg kg^{-1} soil recorded significantly highest plant height among the concentrations of $MnSO_4$ during the entire period of two years study. Soil application of graded levels of $CuSO_4$ recorded a decreasing trend in the plant height with an increase in the concentration of $CuSO_4$ during both the years of study as well as in the pooled data analysis. However, the data were found non-significant with regard to plant height during 2019-20 and the pooled data analysis. Among all the treatments, untreated control plants recorded significantly lowest plant height (26.02 cm, 31.57 cm and 28.79 cm respectively during 2018-19, 2019-20 and the pooled data analysis). Based on the analysis of results it may be concluded that application of $ZnSO_4$ @ 400 mg kg^{-1} soil recorded a significant increase in plant height in comparison to the application of $ZnSO_4$ @ 200 and 600 mg kg^{-1} soil as well as the other chemical concentrations. Based on the results obtained in the present study, it may be concluded that soil application of $ZnSO_4$ @ 400 mg kg^{-1} soil was found optimum for the regular biological activities in tuberose plant mainly for the synthesis of tryptophan (Dikshit, 1961) [12], the precursor of auxin. Mengel and Kirkby (2001) [19] have reported that Zn is an essential element in the nitrogen metabolism which stimulates the plant growth and development and thus, application of $ZnSO_4$ @ 400 mg kg^{-1} soil might have enhanced the plant height in tuberose *cv.* 'Prajwal'. Further, Omidian *et al.* (2012) [21] reported that zinc in its elemental form has been observed to hasten the enzymatic activities of many enzymes in the plant system and thus was found responsible for an increase in plant height. The present results were found in concurrence with the earlier findings of Reddy and Chaturvedi (2009) [25], Singh *et al.* (2012) [27], Memon *et al.* (2013) [18], Amin *et al.* (2014) in gladiolus and Navyashree *et al.* (2012) [20] in rain fed maize.

Significant variation was observed in the plant height of tuberose cv. 'Prajwal' at different intervals of data recorded by soil application of graded levels of essential heavy metal concentrations. Among the intervals of observation recorded, significantly highest plant height (34.84 cm, 39.86 cm and 37.35 cm respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded at 360 DAP interval during both the years of study as well as in the pooled data analysis. Among the intervals of observation recorded, significantly lowest plant height (26.89 cm, 36.83 cm and 31.86 cm respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded at the initial 90 DAP interval during both the years of study as well as in the pooled data analysis. Based on the analysis of results it may be concluded that a gradual and significant increase in plant height was recorded with the progress of the investigation during both the years of study.

The data pertaining to interaction effect between graded levels of essential heavy metal concentrations and the intervals of observation recorded with respect to plant height was found significant during the 1st year of study *i.e.*, 2018-19 and the pooled data, but the data were found non-significant during the 2nd year of study *i.e.*, 2019-20. Among the intervals of observation recorded, significantly highest plant height (47.03 cm and 48.78 cm respectively during 2018-19 and the pooled data analysis) was recorded by application of $ZnSO_4$ @ 400 mg kg^{-1} soil at 360 DAP followed by application of $ZnSO_4$ @ 400 mg kg^{-1} soil at 270 DAP (46.43 cm and 48.33 cm respectively during 2018-19 and the pooled data analysis), whereas significantly lowest plant height (23.56 cm and 26.83 cm respectively during 2018-19 and the pooled data analysis) was recorded in the untreated control plants at 90 DAP interval. Based on the analysis of results, it may be concluded that significant increase recorded in plant height of tuberose *cv.* 'Prajwal' by application of $ZnSO_4$ @ 400 mg kg^{-1} soil might be attributed to the increased cell division and cell enlargement with a coincidence of protoplast enlargement by increased water uptake from soil thereby maintained the polarity and apical dominance in plants and thus enhanced the growth rate (Bhaskarwar *et al.*, 2017) [6]. Paswan and Saravanan (2019) [22] noticed an increase in the rate of nitrogen metabolism by application of zinc thus noticed a significant stimulation in the growth of plant. The present results were found in close conformity with the above results.

Further, Dashora and Verma (2004) [11] as well as Kakade *et al.* (2009) [13] in China aster, Rahmati *et al.* (2009) [24] in pot marigold, Khosla *et al.* (2011) [16] in gerbera and Khalifa *et al.* (2011) [15] in iris reported similar kind of observation with respect to an increase in plant height by application of zinc.
Significant variation was noticed among the treatments with respect to number of leaves produced per plant in tuberose *cv.* 'Prajwal' by soil application of graded levels of essential heavy metal concentrations (Table 2). Among the graded levels of soil applied essential heavy metal concentrations, application of $ZnSO_4$ @ 400 mg kg^{-1} soil recorded significantly highest number of leaves produced per plant (34.75, 55.54 and 45.15 respectively during 2018-19, 2019-20 and the pooled data analysis) followed by application of $ZnSO_4$ @ 600 mg kg^{-1} soil. Among the $ZnSO_4$ concentrations, application of $ZnSO_4$ @ 200 mg kg^{-1} soil recorded significantly lowest number of leaves produced per plant during both the years of study as well as in the pooled data analysis. Number of leaves produced per plant by soil application of $ZnSO_4$ @ 600 mg kg^{-1} soil was found at par with the application of $ZnSO_4$ @ 200 mg kg^{-1} soil during 2019-20. Non-significant differences were noticed among the graded levels of $MnSO_4$ with respect to the number of leaves produced per plant during both the years of study as well as in the pooled data analysis. A significant increase in the number of leaves produced per plant in tuberose *cv.* 'Prajwal' was recorded with an increase in the concentration of $CuSO_4$ during 2018-19, whereas analysis of the data during 2019-20 and the pooled data has revealed that an increase in the number of leaves produced per plant was only up to 200 mg kg^{-1} soil application of $CuSO_4$, but further increase in the concentration of $CuSO_4$ up to 300 mg kg^{-1} soil recorded a significant decrease in the number of leaves produced per plant. Among all the treatments, untreated control recorded significantly lowest number of leaves produced per plant (15.46, 30.42 and 22.94 respectively during 2018-19, 2019-20 and the pooled data analysis). Based on the analysis of data, it was noticed that application of $ZnSO_4$ at 400 mg kg^{-1} soil might have influenced the metabolic activity in the plant cells and thus leading to an increase in the tryptophan production, the precursor of IAA oxidase in plant which caused an increase in the cell division and cell differentiation, which led to an increase in the number of leaves produced per plant. The present results were found in accordance with the earlier findings of Reddy and Chaturvedi (2009) [25], Singh *et al.* (2012) [27] and Amin *et al.* (2014) [2] in gladiolus, Bordiemi and Bodi (1966) [9] in trees, Bharti *et al.* (2013) [5] in *Bacopa monnieri*, Chattopadhyay *et al.* (2001) [10] and Kumar *et al.* (2003) [17] in tuberose.
Significant differences were recorded among the intervals of observation recorded with respect to number of leaves produced per plant in tuberose *cv.* 'Prajwal' by soil application of graded levels of essential heavy metal concentrations. Among the intervals of observation recorded, significantly highest number of leaves produced per plant (35.38, 39.40 and 37.41 respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded at 360 DAP interval, whereas significantly lowest number of leaves produced per plant (13.40, 37.70 and 25.55 respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded at the initial 90 DAP interval. An exponential growth was observed in the number of leaves produced per plant at each successive interval of observation recorded up to 360 DAP during 1st year of study *i.e.,* 2018-19 in comparison to 2nd year of study *i.e.,* 2019-20. A little bit reduced number of leaves produced between the intervals during the 2nd year of study might be due to the saturation of plant growth.
The data pertaining to interaction effects between graded levels of essential heavy metal concentrations and the intervals of observation recorded with respect to number of leaves produced per plant was found significant during the 1st year of study *i.e.,* 2018-19 and the pooled data analysis, but the data was found non-significant during the 2nd year of study *i.e.,* 2019-20. Significantly highest number of leaves produced per plant (53.60 and 54.91 respectively during 2018-19 and the pooled data analysis) was noticed by application of $ZnSO_4$ @ 400 mg kg^{-1} soil at 360 DAP interval followed by application of $ZnSO_4$ @ 400 mg kg^{-1} soil at 270 DAP interval (44.50 and 50.18 respectively during 2018-19 and the pooled data analysis), whereas significantly lowest number of leaves produced per plant (9.73 and 19.58 respectively during 2018-19 and the pooled data analysis) was noticed in the untreated control plants at 90 DAP interval. Based on the analysis of results, it may be concluded that soil application of $ZnSO_4$ @ 400 mg kg^{-1} soil recorded a significant increase in in the number of leaves produced per plant at the end of the observation recorded at 360 DAP interval during both the years of study as well as in the pooled data analysis. The reason might be due to enhanced activity of meristematic cells in the plant due to increased cell division and expansion of cells. Further, Patil *et al.* (2009) [23] reported that soil application of $ZnSO_4$ might have increased the physiological activities in the plant. Bhattal *et al.* (2004) reported that soil application of Zn plays an important role in the biosynthesis of endogenous hormones specially tryptophan, the precursor of auxin. Similar kind of observation with respect to increase in the number of leaves per plant was also reported by Memon *et al.* (2013) [18] in gladiolus. Senthamizhselvi (2000) [26] reported that Zn and Fe application to plants, favoured the storage of more carbohydrates in the plant through photosynthesis, which in turn might have attributed the positive effect on production of more number of leaves per plant in tuberose cv. 'Prajwal'.
The data pertaining to influence of graded levels of soil applied essential heavy metal concentrations and their interaction effects with intervals on plant spread was presented in Table 3. Significant differences were noticed among the treatments with respect to plant spread of tuberose *cv.* 'Prajwal' by soil application of graded levels of essential heavy metal concentrations during both the years of study as well as in the pooled data analysis. Among the graded levels of essential heavy metal concentrations, application of $ZnSO_4$ @ 400 mg kg^{-1} soil recorded significantly maximum plant spread (1142.41 cm^2, 1678.53 cm^2 and 1410.46 cm^2 respectively during 2018-19, 2019-20 and the pooled data analysis) followed by application of $ZnSO_4$ @ 600 mg kg^{-1} soil. Among the concentrations of $ZnSO_4$, application of $ZnSO_4$ @ 200 mg kg^{-1} soil recorded significantly lowest plant spread during both the years of study as well as in the pooled data analysis. An increase in the concentration of $MnSO_4$ significantly decreased the plant spread of tuberose *cv.* 'Prajwal' during 2019-20 and the pooled data analysis, whereas an increase in the concentration of $MnSO_4$ recorded a significant increase in the plant spread up to 2000 mg kg^{-1} soil during 2018-19 and further increase in the concentration *i.e.,* up to 3000 mg kg^{-1} soil recorded a significant decrease in the plant spread. Among the concentrations of $CuSO_4$, an increase in the concentration of $CuSO_4$ has recorded a significant

decrease in plant spread up to 200 mg kg^{-1} soil, whereas further increase in the concentration of $CuSO_4$ up to 300 mg kg^{-1} soil has recorded a significant increase over the previous lower concentration of $CuSO_4$ during both the years of study as well as in the pooled data analysis. Among all the treatments, untreated control recorded significantly lowest plant spread (645.92 cm^2, 756.70 cm^2 and 701.31 cm^2) during 2018-19, 2019-20 and the pooled data analysis respectively. An increase in the quantity of photosynthates might have increased the activity of root, thus resulted an increase in the absorption of more water and nutrients from the soil for better utilization in the cell division and differentiation thereby increased the plant spread. Improvement in plant spread might be attributed to the improvement of many more vegetative growth parameters of plant which might be related to an increase in the production of tryptophan, the precursor of auxin in the meristematic cell so of the plant, thus responsible for an increase in the plant spread. The present results were found in accordance with the earlier findings of Barman and Pal (1993) [4] in tuberose, Balakrishnan (2005) [3] in marigold, Kakade *et al.* (2009) [13] in China aster, Ahmad *et al.* (2010) [1] in rose and Kendra *et al.* (2013) [14] in chrysanthemum. Soil application of graded levels of $MnSO_4$ and $CuSO_4$ at their lower concentrations were found better in comparison to their increased concentrations with regard to plant spread. Further, an increase in the concentrations of $MnSO_4$ and $CuSO_4$ recorded a significant reduction in the plant spread which might be attributed to toxic effects of elevated concentrations on the plant growth and development.

Significant differences were noticed among the intervals of observation recorded with respect to plant spread of tuberose *cv.* 'Prajwal' by soil application of graded levels of essential heavy metal concentrations. Among the intervals of observation recorded, significantly highest plant spread (974.79 cm^2, 1113.93 cm^2 and 1044.35 cm^2 respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded at 360 DAP interval, whereas significantly lowest plant spread (729.87 cm^2, 1070.89 cm^2 and 900.38 cm^2 respectively during 2018-19, 2019-20 and the pooled data analysis) was noticed at the initial 90 DAP interval. A gradual increase in plant spread noticed in tuberose *cv.* 'Prajwal' which might be attributed to the increasing age of the crop during both the years of study as well as in the pooled data analysis.

The data pertaining to interaction effects between graded levels of essential heavy metal concentrations and the intervals of observation recorded with respect to plant spread in tuberose *cv.* 'Prajwal' was found significant during 2018-19, 2019-20 and the pooled data analysis. Among the combination treatments, significantly highest plant spread (1466.26 cm^2, 1742.23 cm^2 and 1604.24 cm^2 respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded by application of $ZnSO_4$ @ 400 mg kg^{-1} soil at 360 DAP interval followed by application of $ZnSO_4$ @ 400 mg kg^{-1} soil at 270 DAP interval (1119.00 cm^2, 1662.53 cm^2 and 1390.76 cm^2 respectively during 2018-19, 2019-20 and the pooled data analysis), whereas significantly lowest plant spread (414.33 cm^2, 738.13 cm^2 and 576.23 cm^2 respectively during 2018-19, 2019-20 and the pooled data analysis) was recorded in the untreated control plants at 90 DAP interval. Based on the analysis of results, it may be concluded that soil application of Zn in the form of $ZnSO_4$ improved the plant spread of tuberose *cv.* 'Prajwal' in comparison to the soil application of graded levels of $MnSO_4$ and $CuSO_4$. Application of $ZnSO_4$ @ 400 mg kg^{-1} soil might have encouraged the cell division as well as cell differentiation in the plant thus resulted an increase in the total leaf area there by an increase in the total quantity of photosynthates produced in the plant. An increase in the rate of photosynthesis might have led to accumulation of more carbohydrates in the developing tissue of the plant which caused an increase in the plant growth and development thereby recorded an increase in the plant spread. Soil application of $ZnSO_4$ might have improved the plant root system by an enhancement in the production of tryptophan, thereby resulted an increase in the absorption of more water and mineral nutrients from soil for better utilization in the plant growth and development. Based on the analysis of results, it may be concluded that application of $ZnSO_4$ @ 400 mg kg^{-1} soil might have significantly increased the cell division as well as cell differentiation in the plant tissue thereby increased the plant height and number of leaves per plant thereby increased the rate of accumulation of photosynthates which in turn might have contributed to an increase in the plant spread.

Table 1: Influence of applied essential heavy metals (Cu, Mn and Zn) on plant height of *Polianthes tuberosa cv.* 'Prajwal'

Treatment (mg of element kg^{-1} soil)	Plant height (cm)														
	2018 - 2019					2019 - 2020					Pooled (2018-20)				
	I_{90}	I_{180}	I_{270}	I_{360}	Mean	I_{90}	I_{180}	I_{270}	I_{360}	Mean	I_{90}	I_{180}	I_{270}	I_{360}	Mean
$MnSO_4$ 1000	26.26	26.50	32.60	33.93	29.82	38.23	41.46	41.56	41.76	40.75	32.25	33.98	37.08	37.85	35.29
$MnSO_4$ 2000	26.53	26.90	27.73	32.83	28.49	33.56	37.00	37.23	37.66	36.36	30.04	31.95	32.48	35.25	32.43
$MnSO_4$ 3000	25.43	25.53	30.83	32.93	28.68	35.33	35.43	35.80	37.43	35.99	30.38	30.48	33.31	35.18	32.33
$CuSO_4$ 100	26.73	27.00	32.40	34.60	30.18	37.40	38.63	38.96	39.20	38.54	32.06	32.82	35.68	36.90	34.36
$CuSO_4$ 200	25.40	26.23	32.83	33.16	29.40	34.90	39.10	39.56	39.86	38.35	30.15	32.67	36.19	36.51	33.88
$CuSO_4$ 300	24.76	25.46	28.46	33.66	28.08	35.36	37.00	37.26	38.90	37.13	30.81	33.05	35.98	37.23	34.26
$ZnSO_4$ 200	29.56	29.73	30.70	32.73	30.68	35.33	37.00	37.26	38.83	37.10	32.44	33.36	33.98	35.78	33.89
$ZnSO_4$ 400	32.33	34.73	46.43	47.03	40.13	48.43	49.43	50.23	50.53	49.65	40.38	42.08	48.33	48.78	44.89
$ZnSO_4$ 600	28.36	32.60	35.40	38.80	33.79	39.66	41.60	42.03	42.23	41.38	34.01	37.10	38.71	40.51	37.58
Control	23.56	25.33	26.40	28.80	26.02	30.10	31.90	32.06	32.23	31.57	26.83	28.61	29.23	30.51	28.79
Mean	26.89	28.00	32.37	34.84		36.83	38.85	39.19	39.86		31.86	33.42	35.78	37.35	
Factor	T		I		T × I	T		I		T × I	T		I		T × I
S.Em±	0.22		0.14		0.45	0.53		0.33		1.06	0.28		0.18		0.56
CD at 5%	0.63		0.40		1.27	1.50		0.95		NS	0.80		0.50		1.60

Table 2: Influence of applied essential heavy metals (Cu, Mn, Zn) on number of leaves plant^{-1} of *Polianthes tuberosa cv.* 'Prajwal'

Treatment (mg of element kg^{-1} soil)	Number of leaves plant^{-1}														
	2018 - 2019					2019 - 2020					Pooled (2018-20)				
	I_{90}	I_{180}	I_{270}	I_{360}	Mean	I_{90}	I_{180}	I_{270}	I_{360}	Mean	I_{90}	I_{180}	I_{270}	I_{360}	Mean
$MnSO_4$ 1000	14.80	15.73	26.33	32.40	22.31	34.66	35.76	36.10	36.26	35.70	24.73	25.75	31.21	34.33	29.00
$MnSO_4$ 2000	12.46	13.60	29.26	33.33	22.16	35.33	36.06	36.40	36.26	36.11	23.90	24.83	32.83	35.00	29.14
$MnSO_4$ 3000	11.90	12.73	32.00	34.73	22.84	35.36	36.26	36.56	36.86	36.26	23.63	24.50	34.28	35.80	29.55
$CuSO_4$ 100	9.63	12.33	26.20	32.80	20.24	35.26	35.90	36.13	36.33	35.90	22.45	24.11	31.16	34.56	28.07
$CuSO_4$ 200	10.46	11.66	32.40	34.00	22.13	36.53	39.13	39.33	39.43	38.60	23.50	25.40	35.86	36.71	30.37
$CuSO_4$ 300	16.13	17.60	30.33	33.46	24.38	34.63	35.73	35.90	36.03	35.57	25.38	26.66	33.11	34.75	29.97
$ZnSO_4$ 200	13.40	14.33	32.26	35.23	23.80	37.40	39.70	39.86	40.26	39.30	25.40	27.01	36.06	37.75	31.55
$ZnSO_4$ 400	19.33	21.60	44.50	53.60	34.75	54.43	55.66	55.86	56.23	55.55	36.88	38.63	50.18	54.91	45.15
$ZnSO_4$ 600	16.23	19.56	37.26	43.40	29.11	44.00	44.83	45.10	45.30	44.80	30.11	32.20	41.18	44.35	36.96
Control	9.73	10.50	20.73	20.90	15.46	29.43	30.40	30.80	31.06	30.42	19.58	20.45	25.76	25.98	22.94
Mean	13.41	14.96	31.13	35.38		37.70	38.94	39.20	39.44		25.55	26.95	35.16	37.41	
Factor	T		I		T × I	T		I		T × I	T		I		T × I
S.Em±	0.27		0.17		0.55	0.73		0.46		1.46	0.34		0.21		0.69
CD at 5%	0.77		0.49		1.55	1.46		0.92		NS	0.97		0.61		1.95

Table 3: Influence of applied essential heavy metals (Cu, Mn, Zn) on plant spread of *Polianthes tuberosa cv.* 'Prajwal'

Treatment (mg of element kg^{-1} soil)	Plant spread (cm^2)														
	2018 - 2019					2019 - 2020					Pooled (2018-20)				
	I_{90}	I_{180}	I_{270}	I_{360}	Mean	I_{90}	I_{180}	I_{270}	I_{360}	Mean	I_{90}	I_{180}	I_{270}	I_{360}	Mean
$MnSO_4$ 1000	759.60	760.03	973.00	973.50	866.53	1114.00	1119.13	1122.56	1127.23	1120.73	936.80	939.58	1047.78	1050.36	**993.63**
$MnSO_4$ 2000	968.46	969.23	971.66	973.16	970.63	974.00	1006.73	1013.53	1015.96	1002.55	927.68	946.04	949.93	1035.68	**964.83**
$MnSO_4$ 3000	554.40	733.86	816.00	844.36	737.15	881.00	888.66	891.30	992.06	913.25	717.70	811.26	853.65	918.21	**825.20**
$CuSO_4$ 100	726.13	726.96	841.00	888.36	795.61	1115.00	1121.06	1127.60	1134.66	1124.58	920.56	924.01	984.30	1011.51	**960.09**
$CuSO_4$ 200	649.00	740.10	784.00	977.26	787.59	977.80	987.13	990.03	994.66	987.40	813.40	863.61	887.01	985.96	**887.49**
$CuSO_4$ 300	602.50	751.40	913.00	967.73	808.65	982.00	984.13	987.06	1005.86	989.76	792.25	867.76	950.03	986.79	**899.20**
$ZnSO_4$ 200	751.50	757.66	821.00	864.53	798.67	895.00	905.06	914.96	925.16	910.05	823.25	831.36	867.98	894.84	**854.35**
$ZnSO_4$ 400	991.46	992.93	1119.00	1466.26	1142.41	1653.00	1656.36	1662.53	1742.23	1678.53	1322.23	1324.64	1390.76	1604.24	**1410.46**
$ZnSO_4$ 600	881.36	885.36	886.33	1055.40	927.11	1379.00	1387.40	1388.06	1396.13	1387.65	1173.73	1178.31	1179.86	1184.64	**1179.13**
Control	414.33	711.03	721.00	737.33	645.92	738.13	740.70	742.63	805.36	756.70	576.23	725.86	731.81	771.34	**701.31**
Mean	729.87	802.86	884.60	974.79		1070.89	1079.64	1084.03	1113.93		900.38	941.24	984.31	1044.35	
Factor	T		I		T × I	T		I		T × I	T		I		**T × I**
S.Em±	0.31		0.19		0.63	0.74		0.47		1.49	0.29		0.18		0.59
CD at 5%	0.88		0.56		1.77	2.11		1.33		4.22	0.84		0.53		1.68

References

1. Ahmad I, Khan MA, Qasim M, Ahmad R, Randhawa MA. Growth, yield and quality of *Rosa hybrida* L. as influenced by various micronutrients. Pakistan Journal of Agricultural Sciences 2010;47(1): 5-12.
2. Amin MR, Tahmina S, Mahasen M, Mehraj H, Uddin J. Influence of zinc doses on flowering and production of corm and cormel of yellow gladiolus (*Gladiolus grandiflorus* L.). *Bangladesh Research Publications Journal* 2014;10(1):54-57.
3. Balakrishnan VM, Effect of micronutrients on flower yield and xanthophylls content of African marigold (*Tagetus erecta* L.). M.Sc. (Hort.) thesis submitted to Tamil Nadu Agricultural University, Coimbatore, India 2005.
4. Barman D, Pal P. A note on effect of micronutrients on growth and yield of tuberose (*Polianthes tuberosa* L.) cv. Single. Horticultural Journal 1993;6(1):69-70.
5. Bharti N, Yadav D, Barnawal D, Maji D, Kalra A. Exiguobacterium oxidotolerans, a halotolerant plant growth promoting rhizobacteria, improves yield and content of secondary metabolites in *Bacopa monnieri* (L.) Pennell under primary and secondary salt stress. World Journal of Microbiology and Biotechnology 2013;29:379-87.
6. Bhaskarwar AC, Chopde N, Patokar MJ, Bayaskar S. Studies on effect of zinc sprays on growth and yield of rose cv. Centenary. Plant Archives. 2017;17(1):196-98.
7. Bhattal B, Sreevastava K, Singh MP. Studies on the effect of foliar application of micronutrients on growth, yield and economics of tomato (*Lycopersicon esculentum* Mill.). Progressive Horticulture 2004;36(2):331-34.
8. Bohra A, Dheera S, Chauhan R. Heavy metal toxicity and tolerance in plants with special reference to cadmium: A Review. Journal of Plant Science Research 2015;31(1):51-74.
9. Bordiemi T, Bodi I. The influence of fertilizer on the growth of tree. IVCR State Institute of Care and Horticulture 1966;37(4):930.
10. Chattopadhyay MK, Das SK, Mondal SK, Das DK. Effects of zinc, copper and iron fertilization on tuberose (*Polianthes tuberosa* Linn) cv. Single. Journal of Interacademicia 2001;5(2):180-85.
11. Dashora RM, Verma LKP. Effect of growth retardants and micronutrients on growth and yield of African marigold (*Tagetus erecta* L.) cv. Pusa Basanti Gainda. Scientific Horticulture 2004;9:213-18.
12. Dikshit NN. Complete recovery of young citrus plants from chlorosis by application of nitrogen and sprays of zinc. Scientific Culture 1961;27:90-91.
13. Kakade DK, Rajput SG, Joshi KI. Effect of foliar application of Fe and Zn on growth, flowering and yield of China aster (*Callistephus chinensis* L. Nees). Asian Journal of Horticulture 2009;4(1):138-40.

14. Kendra KV, Junagadh M, Gujarat A. Response of chrysanthemum varieties to different levels of nitrogen, phosphorus and potash. Journal of Chemistry, Biology and Physics Science 2013;3(2):1584-93.
15. Khalifa R, Khan M, Shaaban SHA, Rawia A. Effect of foliar application of zinc sulfate and boric acid on growth, yield and chemical constituents of iris plants. Ozean Journal of Applied Science 2011;4(2):129-44.
16. Khosla SS, Younis A, Rayit A, Yasmeen S, Riaz A. Effect of foliar application of macro and micro nutrients on growth and flowering of *Gerbera jamesonii* L. American-Eurasian Journal of Agriculture and Environmental Sciences 2011;11(5): 736-57.
17. Kumar J, Amin M, Singh PV. Effect of Mn and Zn sprays on carnation. Journal of Ornamental Horticulture 2003;6(1):83.
18. Memon SA, Abdul RA, Muhammad AB, Mahmooda B. Effect of zinc sulphate and iron sulphate on growth and flower production of gladiolus (*Gladiolus hortulanus*). Journal of Agricultural Technology 2013;9(6):1621-30.
19. Mengel K, Kirkby EA. Principles of plant nutrition. 5th *edn*. Kluwer Academic Publishers, Dordrecht, the Netherlands 2001.
20. Navyashree MR, Ravi MV, Rao KN, Vidhyavathi G, Latha Y, Nagoli BS. Effect of sulphur, zinc and boron on growth and yield of rainfed maize. International Journal of Tropical Agriculture 2012;1(1):3741-43.
21. Omidian A, Seyadat SA, Naseri R, Moradi M. Effects of zinc-sulfate foliar spray on yield, oil content and seed protein of four cultivars of canola. Iranian Journal of Agricultural Science 2012;14:26-28.
22. Paswan DK, Saravanan SS. Effect of micronutrients on plant growth and flower yield of jasmine (*Jasminum grandiflorum* L.) cv. Double Mogra. The Pharma Innovation Journal 2019;8(6):286-89.
23. Patil VK, Yadlod SS, Tambe TB, Narsude PB. Effect of foliar application of micronutrients on flowering and fruit set of tomato (*Lycopersicon esculentum* Mill) cv. Phule Raja. International Journal of Agricultural Sciences 2009;6(10):164-66.
24. Rahmati M, Azizi M, Hassanzadeh MK, Neamati H. The effects of different levels of nitrogen and plant density on the agro morphological characters, yield and essential oils content of improved chamomile (*Matricaria chamomilla* L.) cv. Bodegold. Journal of Horticulture Science 2009;23(1):27-35.
25. Reddy AGK, Chaturvedi OP. Effect of zinc, calcium and boron on growth and flowering in gladiolus cv. Red Majesty. Crop Research Journal 2009;38(1/3):135-37.
26. Senthamizhselvi B. Studies on the flowering and productivity of gundumalli (*Jasminum sambac* Ait) as influenced by nutrient management technique. M.Sc. (Hort.) thesis submitted to Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India 2000.
27. Singh JP, Kumar K, Katiyar PN, Kumar V. Influence of zinc, iron and copper on growth and flowering attributes in gladiolus cv. Sapna. M.Sc. (Hort.) thesis submitted to Chandra Sekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India 2012.