Print ISSN : 0972-8813
e-ISSN : 2582-2780

[Vol. 22(1) January-April 2024]

Pantnagar Journal of Research

(Formerly International Journal of Basic and
Applied Agricultural Research ISSN : 2349-8765)

G.B. Pant University of Agriculture & Technology, Pantnagar

PANTNAGAR JOURNAL OF RESEARCH

Vol. 22(1) January-April 2024

CONTENTS

Interactive impact of heavy metals and mycorrhizal fungi on growth and yield of pepper (*Capsicum annuum* Linn.)

SHARMILA CHAUHAN*[1], MOHINDER SINGH[1], SNEHA DOBHAL[2], DEEKSHA SEMWAL[3] and PRAVEEN[2]

[1]*Dr YS Parmar University of Horticulture and Forestry Nauni, Solan (Himachal Pradesh),* [2]*VCSG Uttarakhand University of Horticulture and Forestry, College of Forestry, Ranichauri (Uttarakhand),* [3]*Department of Horticulture, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar-263 145 (U. S. Nagar, Uttarakhand)*

**Corresponding author's email id: sharmila.chauhan15@gmail.com*

ABSTRACT: *Capsicum annuum* Linn. plants were raised in pots containing soil, treated with various concentrations of Cd and Pb for assessment of impact of heavy metals on growth, quality and yield parameters. In pot experiment, the graded doses of Cd and Pb exerted significant influence on the morphological characters like leaf area, number of branches and leaves, plant height, fruit yield, above ground biomass (AGB) and dry root weight. Highest dose combination of $Cd_{40}Pb_{200}$ exerted maximum adverse influences. The highest doses of Cd_{40} and Pb_{200} resulted in minimum leaf area (10.35cm^2), number of branches (2.19), number of leaves (190.00), plant height (40.06cm), fruit yield/plant (343.2g/plant), AGB (16.39g) and dry root weight (1.39g/plant). This high dose treatment combination also caused 49.15% reduction in fruit yield and 21.81% decrease in the above ground biomass. The lowest chlorophyll contents were found (1.706mg/g) in $Cd_{40}Pb_{200}$ combination as compared to 2.059mg/g in control. Ascorbic acid content in fruits was increased considerably with increase in levels of Cd and Pb which ranged between 113.19 to 120.31mg/100g. Mycorrhizal fungi inoculations for bio-remedified of toxic effect of Cd and Pb, resulted in lower build up of these metals in soil and various plant parts of capsicum.

Key words: Bioremediation, Cadmium, heavy metal, Lead, mycorrhizal effects, pepper

Heavy metals in air, soil and water are becoming global threats to the environment. Environmental contamination of heavy metals is a major problem for both human health and quality of the environment, due to their persistence and non biodegradable nature (Sharma and Agarwal, 2005). Mainly, anthropogenic activities tend to increase the levels of heavy metals in the soil up to levels that are dangerous for plants, animals and human beings (Florea and Busselberg, 2006; Himshikha *et al.*,2022). Uptake and accumulation of heavy metals by plants reduce qualitative and quantitative productivity and cause a serious health hazard through the food chain to other life forms. *Capsicum annuum* L. (Capsicum) commonly known as Bell Pepper, constitutes an important vegetable crop of the human diet. It takes up metals by absorbing them from contaminated soils and deposits on different parts of the plant (Sobukola *et al.*, 2010). Heavy metals get accumulated in soil and plants, and obstruct with several physiological processes like reducing photosynthesis, gaseous exchange, nutrient absorption, etc. (Jamal *et al.*, 2006), determining the reductions in plant growth, dry matter accumulation and yield.

Among the various heavy metals, Cadmium (Cd) and Lead (Pb) are considered potentially important environmental pollutants (Radwan and Salama, 2006) and are also the most significant that affecting many vegetable crops (Kachenko and Singh, 2006). Excess of Pb in plants causes stunted growth, chlorosis and blackening of the root system (Sharma and Dubey, 2005). The increase concentration of Cd is due to both natural as well as anthropogenic factors which are toxic to organisms and plants even at low doses. When Cd is present in the soil, they are translocated to different parts of the plant, thereby affecting its various morphological & biochemical parameters (Pandey *et al.,* 2011; Kubo *et al.*, 2016), decreasing microbial activity and soil fertility (Gu *et al.,* 2007).

Microorganisms are very important in the bioremediation of contaminated soil and wastewater, due to their ability to change the chemical content of the metal ions (Khan *et al.,* 2009). Among microorganisms like fungi are very influential for bio-remediation, while arbuscular mycorrhizal fungi have appeared as the most prominent inter-dependent fungus for plant remediation (Gadd, 1993). When arbuscular mycorrhizal fungi make alliances with plant roots, it may improve plant growth and increase heavy metal tolerance (Latef, 2011). Arbuscular mycorrhizal enhances plant growth and resistance to adverse conditions, including toxicity produced by heavy metals. It also affects the phyto-availability of heavy metals in soil, the absorption of metal by plants from the soil and translocation from root to shoot (Xavier and Boyetchko, 2002; Azcon *et al.*, 2010). Regular monitoring of these heavy metals in capsicum is essential for preventing excessive buildup of the metals in the food chain. Hence, there is a need to develop a remediation technique that should be efficient, economical and rapidly deployable in a wide range of physical setting.

MATERIALS AND METHODS

The seedlings of Bell Pepper was raised in experimental farm of Department of Environmental Science, College of Forestry, Dr Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan, (H.P.), after that seedlings were transplanted in pots containing the mixture of sand, soil and FYM in the ratio 1:1:1.The selected treatment combinations were imposed after complete establishment of plants in the pots (Table 1). In order to study, the effect of Cadmium and Lead toxicity on Capsicum, the heavy metals were applied at three levels viz. 0, 20 and 40ppm of Cd and 0, 100 and 200ppm of Pb. Both metals was applied through $CdCl_2.H_2O$ [M.W. 201.324g/mol] and $Pb(NO_3)_2$ [M.W.331.21g/mol]. Mycorrhizal fungi, Consortium (*Glomus constrictum* and *G. fasciculatum*) became implemented @ 150g/pot containing 750 to 900 fungal spores. The remedy combinations have been replicated 4 instances and the chosen doses have been implemented at 15 days durations after the status quo of plant life and also decided on remedy combination have been implemented to the capsicum plant for 4 months (Fig.1 to 3). The numerous morphological parameters i.e., leaf area, number of leaves, number of branches, plant height, fruit yield, AGB and dry root weight had been recorded.

Fresh matured leaf samples had been harvested in the month of August, 2015 and 2016 and taken to laboratory in paper bags for evaluation of biochemical parameters. At the termination of experiment, complete plants were uprooted and then stem, leaves and branches of every plant had been separated. These plant parts were taken to laboratory and weighed separately for their fresh and dry weights. Plant samples had been dried at 60 ± 5°C until a steady weight was attained; after that, unfold on floor and saved in polythene bags for chemical analysis.

The method of Hiscox and Israeistam (1979) was used to analyze the leaf chlorophyll content, where fresh leaves have been chopped into small pieces below subdued light. The sample of a 100mg of chopped leaves changed into vials containing 7ml of dimethyl sulphoxide and after that the vials have been incubated at 65°C for 1/2 of an hour, extracted and then transferred to new test tubes and final volume made to 10ml with dimethyl sulphoxide. The optical density (O.D.) values of the above extract have been recorded on spectrophotometer at 645nm and 663nm wavelength towards dimethyl sulphoxide blank. The total chlorophyll content was calculated by using formula:

$$\text{Total chlorophyll (mg/g)} = \frac{20.2\,A_{645} + 8.02\,A_{663}}{a \times 1000 \times w} \times V$$

Where,

V = volume of extract made; a = length of light path in cell (usually 1cm); w = weight of sample; A_{645} = absorbance at 645nm; A_{663}= absorbance at 663nm

For ascorbic acid (vitamin C) estimation, aliquot were prepared by macerating fruits in the presence of meta-phosphoric acid solution and was titrated to a pink end point against 2, 6-dichlorophenol indophenols dye as per titrimetric method (Pearson, 1976). For heavy metal analysis in soil, 0.5g of soil sample were collected at the termination of experiment and were stored in cloth bags after sieving and air dry in shade. The sample was digested in concentrated HNO_3 and H_2O_2 mixture by using US-EPA 3050 B method (APHA, 2005). The dried leaf, stem and branches samples were digested in di-acid (HNO_3+$HClO_4$) mixture by taking 1gm of sample as per standard procedure given by Singh *et al.* (2005). Both Cd and Pb were estimated by injecting filtered samples of soil and plant in solution form into inductively coupled plasma emission spectrometer and concentration was expressed as mg/kg. The accumulation of Cd and Pb in soil and above ground plant parts of capsicum excluding fruits were estimated by using the following formula:

$$\text{Uptake} = \frac{(\text{Leaf Nutrient \% x Leaf dry weight}) + (\text{Shoot Nutrient \%, x Shoot dry weight})}{100} \text{ x } 1000$$

The observation was recorded on various parameters of plants and soils were subjected to statistical analysis under completely randomized design (CRD). The analysis of variance (ANOVA) was worked out and critical difference at 5% level of significance was calculated as suggested by Cochran and Cox (1957).

RESULTS AND DISCUSSION

Lead can disturb microtubule organization in meristematic cells (Eun *et al.*, 2000). The higher accumulation of Cd as compare to Pb by plants. This is because, Cadmium is a mobile element which is easily absorbed by roots and transported into the shoots, it depends upon the amount of concentration present in the soil. The uptake of both the metals i.e. Cd and Pb, dependent on the increase the application of doses (Chauhan *et al.*, 2021).

Effect of Cd and Pb and mycorrhizal fungi on growth characters of *Capsicum annuum*

The graded doses of Cd (20ppm and 40ppm) and Pb (100ppm and 200ppm) and mycorrhizal inoculations exerted tremendous impact on growth parameters viz; leaf area, number of branches & leaves/plant and plant height. These parameters showed reduction of growth and development of plant as increasing the level of doses of Cd and Pb. The reduction in 26.29%, 52.70%, 18.78% and 27.41% were noticed in leaf area, number of branches, number of leaves and plant height, respectively and it was due to the application of $Cd_{40}Pb_{200}$ treatment over control (Table 2 to 5). The reduction in leaf size may be due to the death of the cells contaminated with Cadmium and Lead which has also been reported by Koeppe and Miller (1973). Rehman *et al.* (2011) found a linear negative relationship with the dose of Cadmium @ 10-50¼M on leaf number and area in tomato plants. It may be due to the fact that heavy metal contamination may reduce the oxidative, water and nutrient stress of plant growth and development. Similarly, decrease in number of branches in carrot grown in contaminated soil with Lead and Cadmium has been reported by Malik *et al.* (2014). Opeolu *et al.* (2010) observed that Pb $(NO_3)_2$ treatment at various concentrations i.e., 300, 600 and 1800ppm significantly reduced number of leaves, branching and plant height in tomato plants.

The mycorrhizal fungi have been found to bioremedify heavy metals and increase plant growth. When metal contaminated plant was treated with mycorrhizal applications, the leaf area increased from 11.76 to 12.04 cm^2 (Table 2) and number of branches from 3.06 to 3.36 (Table 3) in capsicum plants. The number of leaves/plant was observed higher in pots which received mycorrhizal inoculations (212.33) as compared to those without mycorrhiza (208.25) (Table 4). In our experiment, maximum plant height (55.88cm) was recorded in pots with mycorrhiza and without heavy metal application; whereas, minimum (38.88cm) was observed when plant was treated with $Cd_{40}Pb_{200}$ treatment without mycorrhiza (Table 5). Our results are confirmative with the finding of Malik *et al.* (2014), who observed that reduced plant height, number of leaves & branches and fresh & dry weight (yield) of the carrot with increase in both Lead and Cadmium contaminated soil in comparison to control. Vanitha *et al.* (2005) reported that significant increase in plant height, number of leaves & branches and fresh & dry weight in Ocmium on

Table 1: The following are the different treatment combinations of Cd and Pb applied to *Capsicum annuum*

T_1 - Cd_0Pb_0 (Without Mycorrhiza)	T_{10} – Cd_{20} Pb_{200} (With Mycorrhiza)
T_2 - Cd Pb_0(With Mycorrhiza)	T_{11} – Cd_{40} Pb_{100} (Without Mycorrhiza)
T_3 – Cd_0 Pb_{100} (Without Mycorrhiza)	T_{12} – Cd_{40} Pb_{100} (With Mycorrhiza)
T_4 – Cd_0 Pb_{100} (With Mycorrhiza)	T_{13} – Cd_{40} Pb_{200} (Without Mycorrhiza)
T_5 – Cd_0 Pb_{200} (Without Mycorrhiza)	T_{14} – Cd_{40} Pb_{200} (With Mycorrhiza)
T_6 – Cd_0 Pb_{200} (With Mycorrhiza)	T_{15} – Cd_{20} Pb_0 (Without Mycorrhiza)
T_7 – Cd_{20} Pb_{100} (Without Mycorrhiza)	T_{16} – Cd_{20} Pb_0 (With Mycorrhiza)
T_8 – Cd_{20} Pb_{100} (With Mycorrhiza)	T_{17} – Cd_{40} Pb_0 (Without Mycorrhiza)
T_9 – Cd_{20} Pb_{200} (Without Mycorrhiza)	T_{18} – Cd_{40} Pb_0 (With Mycorrhiza)

Table 2: Effect of graded doses of Cd and Pb alone and in conjunction with mycorrhiza on leaf area (cm^2) in *Capsicum annuum*

Treatments	2015			2016			Pooled			Per cent
	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	over decrease control
Cd_0Pb_0	13.91	14.19	14.05	13.90	14.14	14.02	13.91	14.16	14.04	—
Cd_0Pb_{100}	12.75	12.99	12.87	12.72	12.97	12.85	12.74	12.98	12.86	8.39
Cd_0Pb_{200}	11.83	12.15	11.99	11.80	12.17	11.99	11.82	12.16	11.99	14.59
$Cd_{20}Pb_{100}$	11.17	11.67	11.42	11.16	11.65	11.41	11.17	11.66	11.41	18.68
$Cd_{20}Pb_{200}$	11.06	11.22	11.14	11.07	11.08	11.08	11.06	11.15	11.11	20.87
$Cd_{40}Pb_{100}$	10.92	11.02	10.97	10.78	11.01	10.89	10.85	11.01	10.93	22.11
$Cd_{40}Pb_{200}$	10.16	10.55	10.36	10.15	10.53	10.34	10.15	10.54	10.35	26.29
$Cd_{20}Pb_0$	12.50	12.78	12.64	12.49	12.77	12.63	12.49	12.78	12.64	9.98
$Cd_{40}Pb_0$	11.69	11.94	11.82	11.67	11.93	11.80	11.68	11.94	11.81	15.87
Mean	11.78	12.06		11.75	12.03		11.76	12.04		
$CD_{0.05}$			0.15			0.16			0.15	
Treatment (T)			0.07			0.08			0.07	
Mycorrhizal			NS			NS			NS	
Application (M) T x M										

Table 3: Effect of graded doses of Cd and Pb alone and in conjunction with mycorrhiza on number of branches in *Capsicum annuum*

Treatments	2015			2016			Pooled			Per cent
	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	over decrease control
Cd_0Pb_0	4.50	4.75	4.63	4.50	4.75	4.63	4.50	4.75	4.63	__
Cd_0Pb_{100}	3.75	4.00	3.88	3.50	3.75	3.63	3.63	3.88	3.75	18.52
Cd_0Pb_{200}	3.25	3.50	3.38	3.00	3.25	3.13	3.13	3.38	3.25	29.49
$Cd_{20}Pb_{100}$	3.00	3.25	3.13	3.00	3.25	3.13	3.00	3.25	3.13	32.39
$Cd_{20}Pb_{200}$	2.75	3.00	2.88	2.75	3.00	2.88	2.75	3.00	2.88	37.79
$Cd_{40}Pb_{100}$	2.50	2.75	2.63	2.25	2.75	2.50	2.38	2.75	2.56	44.70
$Cd_{40}Pb_{200}$	2.00	2.50	2.25	2.00	2.25	2.13	2.00	2.38	2.19	52.70
$Cd_{20}Pb_0$	3.25	3.75	3.50	3.25	3.75	3.50	3.25	3.75	3.50	24.40
$Cd_{40}Pb_0$	3.00	3.25	3.13	2.75	3.00	2.88	2.88	3.13	3.00	35.20
Mean	3.11	3.42		3.00	3.31		3.06	3.36		
$CD_{0.05}$			0.52			0.52			0.49	
Treatment (T)			0.25			0.24			0.23	
Mycorrhizal Application			NS			NS			NS	
(M)T x M										

inoculation with *Glomus fasciculatum* compared to non mycorrhizal plants. John *et al.* (2009) observed that exposure of Cd and Pb in *Brassica juncea*, resulted in decrease in plant growth.

Table 4: **Effect of graded doses of Cd and Pb alone and in conjunction with mycorrhiza on number of leaves in *Capsicum annuum***

Treatments	2015			2016			Pooled			Per cent
	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	over decrease control
Cd_0Pb_0	229.25	236.75	233.00	232.50	237.25	234.88	230.88	237.00	233.94	—
Cd_0Pb_{100}	218.75	222.25	220.50	216.25	219.75	218.00	217.50	221.00	219.25	6.28
Cd_0Pb_{200}	212.50	215.25	213.88	212.50	215.75	214.13	212.50	215.50	214.00	8.52
$Cd_{20}Pb_{100}$	205.25	210.00	207.63	203.75	208.50	206.13	204.50	209.25	206.88	11.57
$Cd_{20}Pb_{200}$	193.00	198.25	195.63	191.50	196.25	193.88	192.25	197.25	194.75	16.75
$Cd_{40}Pb_{100}$	201.00	202.75	201.88	199.25	200.50	199.88	200.13	201.63	200.88	14.13
$Cd_{40}Pb_{200}$	189.75	193.25	191.50	185.50	191.50	188.50	187.63	192.38	190.00	18.78
$Cd_{20}Pb_0$	216.50	219.75	218.13	214.75	217.50	216.13	215.63	218.63	217.13	7.19
$Cd_{40}Pb_0$	214.75	219.25	217.00	211.75	217.50	214.63	213.25	218.38	215.81	7.75
Mean	208.97	213.06		207.53	211.61		208.25	212.33		
$CD_{0.05}$			2.03			2.68			1.89	
Treatment (T)			0.96			1.26			0.89	
Mycorrhizal Application (M)			NS			NS			NS	
T x M										

Table 5: **Effect of graded doses of Cd and Pb alone and in conjunction with mycorrhiza on plant height (cm) in *Capsicum annuum***

Treatments	2015			2016			Pooled			Per cent
	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	over decrease control
Cd_0Pb_0	54.25	55.75	55.00	54.75	56.00	55.38	54.50	55.88	55.19	—
Cd_0Pb_{100}	50.25	51.75	51.00	49.75	51.25	50.50	50.00	51.50	50.75	8.04
Cd_0Pb_{200}	46.75	47.75	47.25	46.00	46.75	46.38	46.38	47.25	46.81	15.18
$Cd_{20}Pb_{100}$	45.25	46.25	45.75	44.75	45.75	45.25	45.00	46.00	45.50	17.56
$Cd_{20}Pb_{200}$	43.00	44.25	43.63	42.75	43.50	43.13	42.88	43.88	43.38	21.40
$Cd_{40}Pb_{100}$	43.25	44.00	43.63	42.50	43.50	43.00	42.88	43.75	43.31	21.52
$Cd_{40}Pb_{200}$	39.25	41.75	40.50	38.50	40.75	39.63	38.88	41.25	40.06	27.41
$Cd_{20}Pb_0$	49.25	51.25	50.25	48.75	51.00	49.88	49.00	51.13	50.06	9.29
$Cd_{40}Pb_0$	45.50	46.50	46.00	45.75	46.75	46.25	45.63	46.63	46.13	16.42
Mean	46.31	47.69		45.94	47.25		46.13	47.47		
$CD_{0.05}$			0.52			0.52			0.36	
Treatment (T)			0.25			0.24			0.17	
Mycorrhizal Application (M)			0.74			0.73			0.51	
T x M										

Fig.1: Effect of Cd and Pb in conjunction with mycorrhizal fungi on plant growth

Fig. 2: Symptom of Cd and Pb toxicity in Capsicum

Fig. 3: Bioremediation of Cd and Pb toxicity by mycorrhizal fungi

Table 6: Effect of graded doses of Cd and Pb alone and in conjunction with mycorrhiza on fruit yield (g/plant) in *Capsicum annuum*

Treatments	2015			2016			Pooled			Per cent
	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	over decrease control
Cd_0Pb_0	668.50	679.50	674.00	671.00	681.25	676.13	669.75	680.38	675.06	—
Cd_0Pb_{100}	554.75	604.25	579.50	551.00	600.00	575.50	552.88	602.13	577.50	14.44
Cd_0Pb_{200}	453.75	536.00	494.88	452.00	531.00	491.50	452.88	533.50	493.19	26.94
$Cd_{20}Pb_{100}$	409.25	433.00	421.13	407.50	430.75	419.13	408.38	431.88	420.13	37.76
$Cd_{20}Pb_{200}$	391.75	405.25	398.50	387.25	400.25	393.75	389.50	402.75	396.13	41.32
$Cd_{40}Pb_{100}$	385.25	397.75	391.50	381.00	393.75	387.38	383.13	395.75	389.44	42.31
$Cd_{40}Pb_{200}$	337.00	354.00	345.50	333.00	349.00	341.00	335.00	351.50	343.25	49.15
$Cd_{20}Pb_0$	541.50	587.50	564.50	536.75	579.25	558.00	539.13	583.38	561.25	16.86
$Cd_{40}Pb_0$	447.25	524.50	485.88	441.25	519.25	480.25	444.25	521.88	483.06	28.44
Mean	465.44	502.42		462.31	498.28		463.88	500.35		
CD $_{0.05}$										
Treatment (T)			1.53			1.14			0.96	
Mycorrhizal Application (M)			0.72			0.54			0.45	
T x M			2.17			1.61			1.36	

Table 7: Effect of graded doses of Cd and Pb alone and in conjunction with mycorrhiza on above ground biomass (g) in *Capsicum annuum*

Treatments	2015			2016			Pooled			Per cent
	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	over decrease control
Cd_0Pb_0	20.41	21.57	20.99	20.38	21.52	20.95	20.39	21.54	20.97	—
Cd_0Pb_{100}	19.02	19.70	19.36	18.99	19.67	19.33	19.00	19.69	19.34	7.74
Cd_0Pb_{200}	18.36	18.92	18.64	18.34	18.82	18.58	18.35	18.87	18.61	11.25
$Cd_{20}Pb_{100}$	18.27	18.63	18.45	18.25	18.60	18.43	18.26	18.62	18.44	12.05
$Cd_{20}Pb_{200}$	17.81	18.00	17.91	17.76	17.95	17.86	17.79	17.98	17.88	14.72
$Cd_{40}Pb_{100}$	17.01	17.37	17.19	16.98	17.34	17.16	17.00	17.36	17.18	18.08
$Cd_{40}Pb_{200}$	16.08	16.74	16.41	16.06	16.69	16.37	16.07	16.72	16.39	21.81
$Cd_{20}Pb_0$	18.99	19.18	19.08	18.94	19.13	19.03	18.96	19.15	19.06	9.10
$Cd_{40}Pb_0$	18.18	18.80	18.49	18.15	18.78	18.46	18.16	18.79	18.48	11.88
Mean	18.23	18.77		18.20	18.72		18.22	18.74		
CD $_{0.05}$			0.17			0.16			0.16	
Treatment (T)			0.08			0.08			0.07	
Mycorrhizal Application (M)			0.24			0.23			0.22	
T x M										

Effect of Cd and Pb and mycorrhizal fungi on fruit yield of *Capsicum annuum*

Both Cd and Pb metals also caused significant reductions (14.44 to 49.15%) in fruit yield of capsicum. Minimum fruit yield (343.25g/plant) was observed in pots which received highest levels of heavy metals treatment ($Cd_{40}Pb_{200}$). Higher fruit yield (500.35g/plant) was observed in pots which were inoculated with mycorrhiza as compared to the doses without mycorrhizal inoculation (463.88g/plant) (Table 6). Sharma and Agrawal (2005) have reported that combined treatments of Cd & Zn enhanced the uptake and bioaccumulation of metals in different plants parts of carrot. The accumulation of heavy metals in plant tissues may cause reduction in physiological and biochemical activities of plants, resulting in lower biomass and yield (Scoccianti *et al.* 2006). Similarly, Constantino *et al.* (2008) also reported that root inoculation of Bell Pepper with arbascular mycorrhizal fungi or rhizobacteria significantly increased fruit yield.

Table 8: Effect of graded doses of Cd and Pb alone and in conjunction with mycorrhiza on dry root weight (g) in *Capsicum annuum*

Treatments	2015			2016			Pooled			Per cent
	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	over decrease control
Cd_0Pb_0	2.50	2.65	2.58	2.50	2.70	2.60	2.50	2.68	2.59	—
Cd_0Pb_{100}	2.30	2.45	2.38	2.33	2.45	2.39	2.31	2.45	2.38	7.97
Cd_0Pb_{200}	2.15	2.20	2.18	2.15	2.20	2.18	2.15	2.20	2.18	15.94
$Cd_{20}Pb_{100}$	1.90	1.98	1.94	1.90	1.98	1.94	1.90	1.98	1.94	25.12
$Cd_{20}Pb_{200}$	1.75	1.80	1.78	1.75	1.80	1.78	1.75	1.80	1.78	31.40
$Cd_{40}Pb_{100}$	1.70	1.75	1.73	1.65	1.70	1.68	1.68	1.73	1.70	34.30
$Cd_{40}Pb_{200}$	1.38	1.45	1.41	1.35	1.40	1.38	1.36	1.43	1.39	46.14
$Cd_{20}Pb_0$	2.25	2.28	2.26	2.23	2.28	2.25	2.24	2.28	2.26	12.80
$Cd_{40}Pb_0$	2.10	2.23	2.16	2.10	2.25	2.18	2.10	2.24	2.17	16.18
Mean	2.00	2.09		1.99	2.08		2.00	2.08		
$CD_{0.05}$			0.10			0.10			0.10	
Treatment (T)			0.05			0.05			0.04	
Mycorrhizal Application (M)			NS			NS			NS	
T x M										

Table 9: Effect of graded doses of Cd and Pb alone and in conjunction with mycorrhiza on chlorophyll content (mg/g) in *Capsicum annuum*

Treatments	2015			2016			Pooled			Per cent
	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	over decrease control
Cd_0Pb_0	2.056	2.060	2.058	2.058	2.061	2.059	2.057	2.061	2.059	—
Cd_0Pb_{100}	1.968	1.984	1.976	1.968	1.985	1.976	1.968	1.984	1.976	4.03
Cd_0Pb_{200}	1.893	1.903	1.898	1.892	1.904	1.898	1.893	1.904	1.898	7.81
$Cd_{20}Pb_{100}$	1.843	1.904	1.874	1.844	1.905	1.875	1.843	1.905	1.874	8.98
$Cd_{20}Pb_{200}$	1.844	1.860	1.852	1.845	1.861	1.853	1.844	1.861	1.852	10.05
$Cd_{40}Pb_{100}$	1.783	1.795	1.789	1.785	1.797	1.791	1.784	1.796	1.790	13.06
$Cd_{40}Pb_{200}$	1.695	1.716	1.705	1.696	1.718	1.707	1.695	1.717	1.706	17.14
$Cd_{20}Pb_0$	1.914	1.973	1.944	1.916	1.974	1.945	1.915	1.974	1.944	5.58
$Cd_{40}Pb_0$	1.885	1.736	1.810	1.886	1.737	1.812	1.885	1.737	1.811	12.04
Mean	1.876	1.881		1.877	1.882		1.876	1.882		
$CD_{0.05}$			0.001			0.001			0.001	
Treatment (T)			0.002			0.002			0.002	
Mycorrhizal Application(M)			0.003			0.002			0.002	
T x M										

Effect of Cd and Pb and mycorrhizal fungi on above ground biomass of *Capsicum annuum*

There was significant rise in biomass, when plant was treated with mycorrhizal as compare to the plant which is feeded by heavy metals. There was significant rise in biomass (18.74g), when plant was treated with mycorrhiza fungi as compared to without mycorrhiza (18.22 g) plant. Maximum AGB of plant (21.54g) was recorded in control treatment (Cd_0Pb_0) with mycorrhiza and found to be statistically different from other treatments, whereas, minimum (16.07g) was observed in $Cd_{40}Pb_{200}$ treatment combination without mycorrhiza. Maximum decrease (21.81%) over control in AGB of capsicum was recorded in $Cd_{40}Pb_{200}$ treatment (Table 7). The reduction of biomass by Cd toxicity could be the direct consequence of the inhibition of chlorophyll synthesis which ultimately affected the photosynthesis (Padmaja *et al.*, 1990). Lin and Aarts (2012) also observed drastic reduction in biomass, shoot height and root vigor of C. *annuum* with Cadmium & Lead exposure. Similarly, in tomato seedlings, fresh & dry biomass of roots, shoots and leaves were negatively affected by increasing Lead

Table 10: Effect of graded doses of Cd and Pb alone and in conjunction with mycorrhiza on ascorbic acid (Vitamin C) contents (mg/100g) in *Capsicum annuum* fruits

Treatments	2015			2016			Pooled			Per cent
	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	over decrease control
Cd_0Pb_0	113.00	113.25	113.13	113.00	113.50	113.25	113.00	113.38	113.19	—
Cd_0Pb_{100}	115.00	115.50	115.25	115.25	115.75	115.50	115.13	115.63	115.38	1.93
Cd_0Pb_{200}	115.75	116.25	116.00	116.00	116.50	116.25	115.88	116.38	116.13	2.60
$Cd_{20}Pb_{100}$	117.00	117.25	117.13	117.50	117.75	117.63	117.25	117.50	117.38	3.70
$Cd_{20}Pb_{200}$	118.00	119.25	118.63	118.25	119.50	118.88	118.13	119.38	118.75	4.91
$Cd_{40}Pb_{100}$	118.75	119.50	119.13	118.75	119.75	119.25	118.75	119.63	119.19	5.30
$Cd_{40}Pb_{200}$	119.75	120.75	120.25	119.75	121.00	120.38	119.75	120.88	120.31	6.29
$Cd_{20}Pb_0$	115.25	116.00	115.63	115.50	116.25	115.88	115.38	116.13	115.75	2.26
$Cd_{40}Pb_0$	116.75	117.50	117.13	117.00	117.50	117.25	116.88	117.50	117.19	3..53
Mean	116.58	117.25		116.78	117.50		116.68	117.38		
$CD_{0.05}$										
Treatment (T)			0.48			0.47			0.41	
Mycorrhizal Application (M)			0.23			0.22			0.19	
(T x M)			NS			NS			NS	

Table 11: Concentrations of Cd (mg/kg) in soil

Treatments	2015			2016			Pooled		
	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean
Cd_0Pb_0	0.18	0.16	0.17	0.18	0.16	0.17	0.18	0.16	0.17
Cd_0Pb_{100}	0.30	0.25	0.27	0.30	0.26	0.28	0.30	0.25	0.27
Cd_0Pb_{200}	0.40	0.37	0.38	0.40	0.37	0.39	0.40	0.37	0.38
$Cd_{20}Pb_{100}$	8.66	7.95	8.30	8.68	8.00	8.34	8.67	7.97	8.32
$Cd_{20}Pb_{200}$	9.70	8.99	9.34	9.72	9.01	9.37	9.71	9.00	9.35
$Cd_{40}Pb_{100}$	14.65	13.38	14.02	14.86	13.33	14.09	14.76	13.35	14.05
$Cd_{40}Pb_{200}$	17.46	16.55	17.00	17.58	16.70	17.14	17.52	16.62	17.07
$Cd_{20}Pb_0$	7.33	6.22	6.77	7.38	6.32	6.85	7.35	6.27	6.81
$Cd_{40}Pb_0$	14.20	12.32	13.26	14.27	12.34	13.31	14.23	12.33	13.28
Mean	8.09	7.35		8.15	7.39		8.12	7.37	
$CD_{0.05}$			0.26			0.26		0.25	
Treatment (T)			0.12			0.12		0.12	
Mycorrhizal Application (M)			0.36			0.36		0.35	
T x M									

concentrations (Akinci *et al.,* 2010). Sreenivasa (1992) observed that increase in dry biomass of pepper plants, when inoculated with arbuscular mycorrhizal fungi. The mycorrhizal inoculation (*Glomus constrictum* and *Glomus fasciculatum*) ameliorated negative impact of Cadmium and Lead.

Effect of Cd and Pb and mycorrhizal fungi on dry root weight of *Capsicum annuum*

The interactive effect of Cd and Pb and mycorrhizal treatment was found to exert significant influence on root dry weight in C. *annuum*. The average dry root weight in pots inoculated with mycorrhiza was 2.08g which was higher than those without mycorrhizal treatment (2.00g). Maximum root dry weight (2.68g) was recorded in pots where only water and mycorrhiza was applied; whereas, minimum (1.36g) was observed in the $Cd_{40}Pb_{200}$ treatment without mycorrhiza (Table 8). These results are in agreement with findings of Da-lin *et al.* (2011) who reported that decreased root activity in sorghum, when Cd was applied at 50 mg/kg and 100 mg/kg soil. Similarly, Sandalio *et al.* (2001) observed that inhibition of root growth and number of leaves/plant of pea, when $CdCl_2$ (0-50ug) was applied. In Pepper plants with mycorrhiza applied,

Table 12: Concentrations of Pb (mg/kg) in soil

Treatments	2015			2016			Pooled		
	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean	Without Mycorrhiza	With Mycorrhiza	Mean
Cd_0Pb_0	0.36	0.33	0.34	0.36	0.32	0.34	0.36	0.32	0.34
Cd_0Pb_{100}	84.25	82.25	83.25	84.50	82.50	83.50	84.38	82.38	83.38
Cd_0Pb_{200}	172.75	171.75	172.25	173.00	172.25	172.63	172.88	172.00	172.44
$Cd_{20}Pb_{100}$	85.75	82.75	84.25	85.75	83.25	84.50	85.75	83.00	84.38
$Cd_{20}Pb_{200}$	173.50	172.25	172.88	173.50	172.75	173.13	173.50	172.50	173.00
$Cd_{40}Pb_{100}$	86.75	84.75	85.75	87.00	85.25	86.13	86.88	85.00	85.94
$Cd_{40}Pb_{200}$	175.50	174.00	174.75	175.50	174.00	174.75	175.50	174.00	174.75
$Cd_{20}Pb_0$	0.44	0.41	0.42	0.44	0.42	0.43	0.44	0.41	0.42
$Cd_{40}Pb_0$	0.54	0.52	0.53	0.54	0.52	0.53	0.54	0.52	0.53
Mean	86.65	85.45		86.73	85.70		86.69	85.57	
$CD_{0.05}$			0.45			0.38			0.35
Treatment (T)			0.21			0.18			0.16
Mycorrhizal Application (M)			0.63			0.54			0.49
T x M									

dry weights of root and shoot were found higher than non-mycorrhizal plants (Latef, 2013). The reduction of dry shoot and root biomass caused by Cd application has also been demonstrated in many plants, including, tomato (Haouari *et al.*, 2012), eggplant (Arao *et al.*, 2008) and soybean (Shamsi *et al.*, 2010).

Effect of Cd and Pb and mycorrhizal fungi on biochemical parameters of *Capsicum annuum*

The chlorophyll and ascorbic contents in capsicum were influenced by Cd and Pb applications. Highest chlorophyll content (2.059mg/g) was recorded in capsicum plants without Cd and Pb application (control); whereas, it was lowest (1.706mg/g) with highest levels of these metals ($Cd_{40}Pb_{200}$). The inoculation of mycorrhizal fungi reduced the adverse effects of heavy metals and resulted in higher chlorophyll contents (1.882 mg/g) as compared to those plants without fungal inoculations (1.876mg/g) (Table 9). Ascorbic acid in fruits was increased considerably with increase in level of doses of Cd and Pb, which ranged between 113.19 to 120.31mg/100g. The mycorrhizal inoculation also resulted in higher (117.38 mg/100g) ascorbic acid contents as compared to plants without mycorrhiza (116.68 mg/100g) (Table 10). The present findings also get support from other earlier studies, which have revealed that reduction of photosynthetic pigments with an increasing Cd content in tomato (Haouari *et al.*, 2012) and brinjal (Arao *et al.*, 2008). The fall in chlorophyll content in *Phaseolus vulgaris,* when exposed to Cd and Pb stress is believed to be due to inhibition of key enzymes such as d-aminolevulinic acid dehydratase (ALA-dehydratase) (Padmaja *et al.*, 1990). Latef (2013) observed that Cadmium Chloride at 0.1mM and 0.5mM, decreased the leaf chlorophyll contents, while mycorrhizal inoculated plants had greater contents of chlorophyll, total sugar & protein and P & Mg than non mycorrhizal plants. Similarly, John *et al.* (2009) also observed that gradual increase in the activity of antioxidants as Cd concentration increased.

Effect of Cd and Pb and mycorrhizal fungi on soil properties of *Capsicum annuum*

The application of highest dose of Cd along with Pb ($Cd_{40}Pb_{200}$) resulted in maximum (17.07mg/kg) concentration in soil; whereas, it remained lowest (0.17mg/kg) in control. The inoculation of mycorrhizal fungi to pots resulted in lower (7.37mg/kg) accumulation of Cd in soil as compared to those without mycorrhiza (8.12mg/kg) (Table 11). The application of highest dose Pb along with Cd ($Cd_{40}Pb_{200}$) resulted in maximum (174.75mg/kg) concentration in soil; whereas, it remained lowest (0.34mg/kg) in control. The inoculation of mycorrhizal fungi to pots resulted in lower (85.57mg/kg) accumulation of Pb in soil as compared to those without mycorrhiza (86.69mg/

kg) (table 12). In present studies, the application of Cd in combination with Pb influenced the uptake of Pb by the capsicum plants. Similar results were obtained by Okada *et al.* (1997) who showed that the Pb level in the soil, increase due to edible parts of tuber vegetables. Bioaccumulation of a single metal was influenced by the presence of other metals, which resulted in inhibited or enhanced bioaccumulation of one metal in the mixture (Peralta-Videa *et al.* 2002).

CONCLUSION

Graded doses of Cd and Pb adversely influenced various morphological and biochemical parameters of capsicum plants. The concentrations of these two metals in both soil and plants increased with the increase in application rates. The highest dose combination i.e., $Cd_{40}Pb_{200}$ exerted maximum adverse influences and synergistic effects i.e. one metal influenced the accumulation of other metal in capsicum plants. The mycorrhizal inoculations for bio-remedified of toxic effect of both Cadmium and Lead, improved various morphological and biochemical parameters of capsicum. In capsicum plants, the maximum accumulation of these two metals was found in stem length, followed by branches and leaves.

REFERENCES

Akinci S., Atilgan I., Eda and Aksoy S. (2010). Re-assessment of E-S-Qual and E-RecS-Qual in a pure service setting. *Journal of Business Research*, 63(3): 232-240.

APHA. (2005). Standard methods for water and waste water. 20thedn. American Public and Health Association, American water works association and water environment federation, Washington, DC, 1339p.

Arao T., Takeda H. and Nishihara E. (2008). Reduction of Cadmium translocation from roots to shoots in eggplant (*Solanum melongena*) by grafting onto *Solanum torvum* rootstock. *Soil Science and Plant Nutrition,* 54(4):555-559.

Azcon R., Peralvarez M. C., Roldan A. and Barea J.M. (2010). Arbuscular mycorrhizal fungi, *Bacillus cereus* and *Candida parapsilosis* from a multi-contaminated soil alleviate metal toxicity in plants. *Microbiology Ecology,* 59(4): 668–677.

Chauhan S., Singh M., Bhardwaj S.K., Dobhal S., Bhardwaj R. and Thakur M. (2021). Assessment of heavy metal accumulation in *Capasicum annum* fruits collected from different market and farmer fields of district Solan. *Chemical Science Review and Letters*, 10(37): 141-145.

Cochran W.G. and Cox G.M. (1957). Experimental Design. 2nd Edition, John Wiley and Sons, New York, 615 p.

Constantino M., Gómez-Álvarez R., Álvarez-Solís J.D., Geissen V., Huerta E. and Barba E.(2008). Effect of inoculation with rhizo-bacteria and arbuscular mycorrhizal fungi on growth and yield of *Capsicum chinense* Jacquin. *Journal of Agricultural and Rural Development,* 109(2): 169-180.

Da-lin L., Kai-qi H., Jing-jing M., Wei-wei Q., Xiu-ping W. and Shu-pan Z. (2011). Effects of Cadmium on the growth and physiological characteristics of sorghum plants. *African Journal of Biotechnology,* 10(70): 15770-15776.

Eun S. O., Youn H.S. and Lee Y. (2000). Lead disturbs microtubule organization in the root meristem of *Zea mays*. *Physiologia Plantarum,* 103: 695-702.

Florea A. M. and Busselberg D. (2006). Occurrence, use and potential toxic effects of metals and metal compounds. *Biometals,* 19(4):419–427.

Gadd G.M. (1993). Interaction of fungi with toxic metals. *New Phytology,* 124(1):25-60.

Gu J.,Qi L., Wusheing J. and Liu D. (2007). Cadmium accumulation and its effects on growth and gas exchange in four *Populus* cultivars. *Acta Biologica Cravoviensi,* 49(2): 7–14

Haouari C.C., Nasraoui A.H., Bouthour D., Houda M.D., Daieb C.B., Mnai J. and Gouia H.(2012). Response of Tomato (*Solanum lycopersicon*) to Cadmium toxicity: growth, element uptake, chlorophyll content and photosynthesis rate. *African Journal of Plant Science,* 6(1): 1-7.

Himshikha, Dobhal S., Ayate D. and Lal P.(2022). Influence of anthropogenic activities on the biological diversity of forest ecosystem. In: Towards Sustainable Natural Resources (pp.215-233). Springer Nature Singapore.doi:10.1007/978-3-031-06443-2-12.

Hiscox J. D. and Israelstam G.F. (1979). A method for the extraction of chlorophyll from leaf tissue without maceration. *Cannadian Journal of Botany,* 57:1332-1334.

Jamal S. H. N., Iqbal M.Z. and Athar M. (2006). Effect of aluminum and chromium on the growth and germination of mesquite *Prosopis juliflora Swartz. International Journal of Environment Science and Technology,* 3(2): 173-176.

John R., Ahmad P., Gadgila K. and Sharma S. (2009). Heavy metal toxicity: effect on plant growth, biochemical parameters and metal accumulation by *Brassica juncea* L. *International Journal of Plant Production*, 3(3):65-76.

Kachenko A. G. and Singh B. (2006). Heavy metals contamination in vegetables grown in urban and metal smelter contaminated sites in Australia. *Water, Air and Soil Pollution,* 169:101–123.

Khan M. S., Zaidi P., Wani A. and Oves M. (2009). Role of plant growth promoting rhizobacteria in the remediation of metal contaminated soils. *Environmetal Chemistry,* 7: 1-19.

Koeppe R. A. and Millar R. A. (1973). Uptake and some physiological effects of Cadmium on corn. In: *Proceeding Annual on Trace Contamination*, 14(5): 459-74.

Kubo K.H., Kobayashi M., Fujita T., Minamiyama O., Watanabe Y., Nakajima T. and Shinano T. (2016). Varietal differences in the absorption and partitioning of Cadmium in common wheat (*Triticum aestivum* L). *Environmental and Experimental Botany,* 124:79-88.

Latef A. (2011). Influence of arbuscular mycorrhizal fungi and copper on growth, accumulation of osmolyte, mineral nutrition and antioxidant enzyme activity of Pepper (*Capsicum annuum* L.). *Mycorrhiza,* 21(6):495-503.

Latef A. (2013). Growth and some physiological activities of Pepper (*Capsicum annuum* L.) in response to Cadmium stress and mycorrhizal Symbiosis. *Journal of Agricultural Science and Technology,* 15(7): 1437-1448.

Lin Y. F. and Aarts M.G. (2012). The molecular mechanism of Zinc and Cadmium stress response in plants. *Cellular and Molecular Life Sciences*, 69(19):3187-206.

Malik Z. A., Lal E. P. and Mir Z.A. (2014). Diverse effect of Cadmium and Lead on growth and yield of carrot (*Daucus carota*). *International Journal of Pharma and Bio Sciences,* 5(4):231- 236.

Okada I. A., Sakuma A.M.F, Maio D., Dovidauskas S. and Zenebon O. (1997). Evaluation of Lead and Cadmium levels in milk due to environmental contamination in parabia valley region of South Eastern. *Revista-de-Saude-Publica,* 31(2): 140-143.

Opeolu B. O., Adenuga O.O., Ndakidemi P.A. and Olujimi O.O. (2010). Assessment of phyto-toxicity potential of Lead on Tomato (*Lycopersicon esculentum* L.) planted on contaminated soils. *International Journal of Physical Sciences,* 5(2): 1-6.

Padmaja K., Prasad D. D. K. and Prasad A. R. K. (1990). Inhibition of chlorophyll synthesis in *Phaseolus vulgaris* seedlings by Cadmium acetate. *Photosynthetica,* 24:399-405.

Pandey P.,Tripathi A.K. and Dwivedi V. (2011). Effect of heavy metals on some biochemical parameters of Sal (*Shorea robusta*) seedling at nursery level, Doon Valley. *Indian Journal of Agriculture Sciences,* 2(1): 45-51.

Pearson D. (1976). Chemical Analysis of Foods. 7th Edition, Churchhill Livingstone, London.

Peralta-Videa J. R., Gardea-Torresdey J. L., Gomez

E., Tiermann K. J., Parson J. G. and Carrillo G. (2002). Effect of mixed Cadmium, Copper, Nickel and Zinc at different pH upon alfafa growth and heavy metal uptake. *Environment Pollution,* 119(3):291–301.

Radwan M. A. and Salama A. K. (2006). Market basket survey for some heavy metals in Egyptian fruits and vegetables. *Food Chemistry Toxicology,* 44(8):1273–1278.

Rehman F., Khan F.A., Varshney D., Naushin F. and Rastogi J. (2011). Effect of Cadmium on the growth of Tomato. *Biology and Medicine,* 3(2): 187-190.

Sandalio L. M., Dalurzo H.C., Gómez M., Romero-Puertas M.C. and del-Río L.A.(2001). Cadmium-induced changes in the growth and oxidative metabolism of Pea plants. *Journal of Experimental Botany,* 52:2115–2126.

Scoccianti V., Crinelli R., Tirillini B., Mancinelli V. and Speranza A. (2006). Uptake and toxicity of Cr (III) in celery seedlings. *Chemosphere*, 64(10):1695-1703.

Shamsi U., Hatcher J., Shamsi A., Zuberi N., Qadri Z. and Saleem S. A. (2010). Multicentre matched case control study of risk factors for preeclampsia in healthy women in Pakistan. *BMC Women's Health*,10:1-17.

Sharma R.K. and Agarwal M. (2005). Biological effects of heavy metals. *Journal of Environmental Biology,* 26:301-313.

Sharma P. and Dubey R.S. (2005). Lead toxicity in plants. *Brazilian Journal of Plant Physiology,* 17(1):35-52.

Singh D., Choonkar P. K. and Dwivedi B.S. (2005). Manual on soil, plant and water analysis. New Delhi, Pp.78-79.

Sobukola O. P., Adeniran O. M., Odedairo A. A. and Kajihausa O.E. (2010). Heavy metal levels of some fruits and leafy vegetables from selected markets in Lagos, Nigeria. *African Journal of Food Science*, 4(2): 389- 393.

Sreenivasan M.N. (1992). Selection of efficient vesicular-arbuscular mycorrhizal fungi for Chili (*Capsicum annuum* L.). *Scientia Horti-culturae*, 50(1-2): 53-58.

Vanitha J., Srikar L. N. and Eranna N. (2005). Response of *Ocimum kilimandscharicum* to inoculation with *Glomus fasciculatum*, *Azotobacter chroococcum* and *Aspergillus awamori*. *J. Soil Biol*.,25(1-2):7279.

Xavier I. J. and Boyetchko S.M.(2002). Arbuscular mycorrhizal fungi as biostimulants and bioprotectants of crops. *Applied Mycology and Biotechnology,* 2: 311–330.

Received: February 16. 2024
Accepted: April 16, 2024