J Bangladesh Agril Univ 22(4): ***404–411****, 2024* https://doi.org/10.3329/jbau.v22i4.78838

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Effect of Industrial Soil Contamination and Fertilizer Management on Growth, Yield and Metal Uptake by BARI Tomato 8

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ARTICLE INFO

Article history
Received: 8 April 2024
Accepted: 24 December 2024
Published: 31 December 2024

Keywords
Industrially polluted soil, Fertilizer, Heavy metals accumulation, Growth and yield, Tomato

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OPEN ACCESS

Abstract

The concern about industrial pollution and food safety is growing due to crop contamination and a major route to human exposure. The experiment was completed at a net house of Sher-e-Bangla Agricultural University during November 2021 to April 2022 to find out the effect of industrial soil pollution and fertilizer management on growth, yield and metal accumulation by BARI Tomato 8. Industrially polluted soils were collected from contaminated areas considering the soil pollution intensity. The physico-chemical properties were determined in soils. The experiment consists of two-factor, as Factor A: Six different soils (S_0: Non-polluted soil; S_1: Polluted soil-1, S_2: Polluted soil-2; S_3: Polluted soil-3, S_4: Polluted soil-4 and S_5: Polluted soil-5) and Factor B: Three fertilizer treatments (T_0: Control; T_1: 100% soil test basis dose of fertilizer; T_2: 50% soil test basis dose of fertilizer and 50% nutrient from cowdung). High yielding tomato variety BARI Tomato 8 was used for experiment. Among the soils, the highest tomato yield was found in S_1 and S_5 polluted soils, while the lowest was obtained in S_4 and S_0 soils. The highest tomato yield was recorded in T_2 treatment and the lowest in T_0 treatment. The highest tomato fruit dry matter, Pb (1.359 mg kg^{-1}) and Cd (0.759 mg kg^{-1}) concentrations were found in T_0 treatment and the lower levels were obtained in T_1 (100% RDCF) and T_2 (100% RDCF + 50% nutrient from cowdung) treatments. The higher tomato Pb and Cd concentrations were recorded in polluted soils with T_0 and T_1 treatments and the lower with T_2. The highest tomato Pb concentration (1.656 mg kg^{-1}) was obtained in S_4T_1 and the lowest (0.501 mg kg^{-1}) in S_3T_2. The highest tomato Cd concentration (1.149 mg kg^{-1}) was obtained in S_5T_0 and the lowest (0.097 mg kg^{-1}) in S_2T_2 treatment combinations.

Introduction

Large quantities of industrial effluents and sewage sludge are potential sources of metal contamination in water and soil environments (Murtaza *et al.*, 2010). Toxic heavy metals are pollutants of the environment, and their excessive level in arable soil can pose serious threats to normal plant growth and development but also to human health (Nawaz *et al.*, 2017; and Hashem *et al.*, 2018). The toxic heavy metals may be released in agricultural soil due to anthropogenic sources (mining, wastewater sludge, and pesticides) and this activity is the major cause of global heavy metal pollution (Saleem *et al.*, 2020). There is rapid establishment of textile and dyeing industries in many areas of Bangladesh. Gazipur, Bhaluka, Mymensingh are the commercially important areas where industrial clusters have developed as part of the rapid economic growth of the country. Long-term deposition of untreated industrials effluents into agricultural lands in known to have significant contribution to trace elements such as Cd, Cu, Zn, Cr, Ni, Pb and Zn in surface soils (Mapanda et al., 2005). Industrial effluents contain appreciable amount of trace metals, which may accumulate in the soil, thus create a problem for soil contamination of agricultural soils (Chen *et al*., 2005). Phosphatic fertilizers contain the higher levels of heavy metal contaminants (Wei *et al.*, 2020). Accumulation of higher levels of trace metals in agricultural soils may affect food quality and safety (Sharma et al., 2007). The levels of heavy metals in soil affect biological, chemical and physical soil properties, which results in decreased soil fertility and also contamination of food crops (Demkova *et al*., 2017). Heavy metals pollution and their toxicity problems are increasing significantly (Zainab *et al*., 2021).

Tomato is the most important winter vegetable in our country. According to John et al. (2010), tomatoes are a good source of vitamins, minerals, and lycopene, a

Cite This Article
M. Shamsuzzoha and Khan, M.A. 2024. Effect of Industrial Soil Contamination and Fertilizer Management on Growth, Yield and Metal Uptake by BARI Tomato 8. *Journal of Bangladesh Agricultural University,* 22(4): 404-411. https://doi.org/10.3329/jbau.v22i4.78838

powerful antioxidant. The toxicity of heavy metals in various crops might vary significantly (Komarek et al., 2008). If contaminated vegetables are used as food by humans, high levels of heavy metals are accumulated and cause physiological disorder and human health is affected (Sharma *et al*., 2007). Plants need some essential metals such as iron, copper, zinc, manganese and others, for their growth and metabolic activities. If plant exceed, specific limits of metals, then these metals adversely affect plant growth (Ikhajiagbe *et al*., 2013). Higher levels of heavy metals accumulation in plant adversely affect plant growth, yield and quality (Adesina and Ashamo, 2019). Considering the above situation, the present study was conducted

To evaluate the effects of soil pollution and fertilizer management on growth and yield of tomato to assess the effects of soil pollution and fertilizer management on the accumulation of some heavy metals namely Lead, Cadmium, Zinc, Iron, Manganese and Copper in soil and tomato.

Materials and Methods

Experimental Site and Soil

The experiment was completed at the net house of Sher-e-Bangla Agricultural University from November 2021 to April 2022. Six soils (S_0: Non-polluted soil; S_1: Polluted soil-1, S_2: Polluted soil-2; S_3: Polluted soil-3, S_4: Polluted soil-4 and S_5: Polluted soil-5) were collected from the Bhaluka industry site considering the levels of soil metal pollution. Polluted soils were collected from Maduari, Bhaluka union. Polluted soils S_1, S_2, S_3, S_4 and S_5 were collected from Maduari, Bhaluka union; Pakistani Textile Dying Mill, Pantgaon, Varadhoba Union, Bhaluka; Muntasim Spinning Mill, Ward No. 3, Varadhoba Union; GTL Textile Mill, Village: Nijuri, Union: Maduari; Dying Bangladesh Limited, Nature Dying Industries, Bhaluka Pourasava; and Shaferd Industries Ltd, Nature Chemical Industry, Bhaluka Pourasava; respectively. The industrially polluted soils of the experiment belong to the AEZ No. 28, Madhupur Tract in Bangladesh. Firstly, higher number samples were collected and analyzed and finally six soils were selected for collection by considering metal concentration. The higher levels of Cd, Zn, Fe, Mn and Cu concentrations were obtained those were collected from adjacent to five industry sites where industrial waste water was deposited and mentioned as S_1- S_5 and another soil was collected from normal cultivable land of same area where lower levels of metals were obtained and mentioned as S_0. The collected polluted and non-polluted soils belong to the Madhupur Tract (AEZ No. 28) of Bangladesh. The initial soil samples were processed and analyzed for nutrient content by using different standard methods. Glass electrode pH meter was applied for determining soil pH (McLean, 1982). Wet oxidation method was used to determine soil organic matter content (Nelson and Sommers, 1982). Initial soils Cd, Pb, Zn, Fe, Mn and Cu concentrations were determined by acid digestion (Lindsay and Norvel, 1987). The physico-chemical properties, macro-nutrient, Cd, Pb, Zn, Fe, Cu and Mn concentrations in the collected soil are mentioned in Table 1 and 2.

Table 1. Physico-chemical properties and nutrient concentrations in industrially polluted initial soils

Soils	Soil texture	pH	% OC	% Sand	% Silt	% Clay	Avail. P(ppm)	Avail. S(ppm)	Total K (%)
S_0	Loam	6.4	1.65	28.24	46.00	25.76	17.99	14.72	0.159
S_1	Loam	6.0	1.91	44.24	28.00	27.76	7.58	17.95	0.164
S_2	Clay loam	6.3	2.18	42.24	24.00	33.76	10.10	48.08	0.238
S_3	Clay loam	6.4	2.16	28.24	36.00	35.76	15.16	9.50	0.058
S_4	Clay	6.4	1.72	42.24	8.00	49.76	14.90	6.11	0.315
S_5	Sandy clay loam	6.5	2.26	56.24	24.00	19.76	18.19	43.02	0.132

Soils (S_0: Non-polluted; S_1: Polluted-1, S_2: Polluted-2; S_3: Polluted-3, S_4: Polluted-4 and S_5: Polluted-5)

Treatments and experimental design

The experiment consists of two-factor. Six different soils (S_0: Non-polluted soil; S_1: Polluted soil-1, S_2: Polluted soil-2; S_3: Polluted soil-3, S_4: Polluted soil-4 and S_5: Polluted soil-5) were used as factor-A and three fertilizer treatments (T_0: Control; T_1: 100% soil test basis dose of fertilizer and T_2: 50% soil test basis dose of fertilizer and 50% nutrient from cowdung) were applied as factor B. The soil test basis fertilizer doses were calculated for this experiment following BARC fertilizer recommendation guide, 2018. The Randomized Complete Block Design was used in this experiment using two factors (6 different soils × 3 fertilizer treatments) having three replications. There were altogether 54 pots (6 × 3 × 3) and 8 kg soil was taken in each pot for tomato cultivation.

Tomato cultivation

BARI Tomato 8 seed was collected from the Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI) at Joydebpur, Gazipur. Tomato seedlings were raised in seedbed of 2 m x 1 m size. The soil was well prepared and converted into loose friable and dried mass by spading. Four gram of seeds was sown on each seedbed.

Treatment wise required amounts of fertilizer were applied in the pots for tomato cultivation. The treatment wise calculated amounts of P, K, S, Zn and one third of nitrogenous fertilizers were applied during pot soil preparation. Healthy and uniform 30 days old seedlings were uprooted separately from the seed bed and seedlings were transplanted in the first week of November, 2021. Two seedlings were transplanted in each pot, and crop management practices, irrigation, pesticide were applied according to necessity.

Table 2. Cd, Pb, Zn, Fe, Mn and Cu concentrations in industrially polluted initial soils

Soils	Cd (ppm)	Pb (ppm)	Zn (ppm)	Fe (%)	Mn (ppm)	Cu (ppm)
S_0	1.570	12.52	85.80	1.60	84.45	19.49
S_1	2.415	11.90	71.35	1.716	112.95	20.23
S_2	2.195	11.73	114.25	1.705	296.90	26.64
S_3	1.475	17.87	116.75	1.706	182.60	34.23
S_4	3.140	19.18	146.7	1.782	292.80	36.18
S_5	2.920	10.19	226.55	1.669	208.90	107.65

Soils (S_0: Non-polluted; S_1: Polluted-1, S_2: Polluted-2; S_3: Polluted-3, S_4: Polluted-4 and S_5: Polluted-5)

Data Collection and Analysis

The data of yield and yield contributing parameters were taken during this study. The fruit dry matter samples of each pot were analyzed for K, P, Fe, Mn, Cu, Cd, Pb, and Zn concentrations following standard methods. 500 mg of dry ground tomato sample was digested with high purity nitric acid and perchloric acid (HNO_3:$HClO_4$ = 87:13) (Jones and Case, 1990). The atomic absorption spectrophotometer (Model: novAA400P, Brand: analytic jena at SAU) was used to determine K, Fe, Mn, Cu, Cd, Pb, and Zn concentrations in tomato fruit (Scott et al., 1991). The MSTAT-C software was used for statistical analysis of data. The Duncan's Multiple Range Test (DMRT) was applied for estimation of treatments difference at 5% level of significance (Gomez and Gomez, 1984).

Results and Discussion

Effect of soil on yield parameters and yield of tomato

The plant height, branches plant^{-1}, leaves plant^{-1}, fruit diameter, average fruit weight (g), fresh weight of plant biomass (g pot^{-1}) and fruit yield (g pot^{-1}) were significantly varied with difference of polluted and non-polluted soils (Table 3). The tallest plant (66.33 cm) was recorded in S_5 soil (polluted soil-5) which was statistically comparable to the plant height of S_0 (non-polluted soil) and S_1 (polluted soil-1) soil, whereas the shortest plant (48.06 cm) was documented in S_4 soil (polluted soil-4). The maximum number of branches per plant (3.89) and average fruit dry weight (2.95 g) were found in S_3 and lowest number branches per plant (3.33) and average fruit dry weight (1.75 g) were recorded in S_4 soil. The highest leaves per plant (17.67), average fruit weight (39.66 g) and plant biomass dry weight (19.64 g) were obtained from S_4 soil and lowest values of all parameters were recorded in S_0 soil and the highest average fruit weight and plant biomass dry weight were statistically similar with other polluted soils. The highest total fruit weight (330.8 g) was observed in S_1 soil that was statistically comparable to the soils S_0, S_2 and S_3 and lowest fruit weight was recorded in S_4 soil which was closely similar to S_5 soil (Table 3). The yield increased in polluted soils due to enrichment of nutrient and other elements in soil from industrial wastes and other sources.

The plant height, average fruit weight (g), average fruit dry weight (g), were not significantly affected by fertilizer treatments and higher average fruit weight (g) was recorded in T_0 and T_1 treatments and lowest in T_2 treatment (Table 3). The highest branches per plant (4.83), leaves per plant (20.06) and tomato yield (322.0 g pot^{-1}) were obtained in T_2 (50% soil test basis dose of fertilizer and 50% nutrient from cowdung) and minimum results were recorded in T_0 treatment. The maximum dry plant biomass weight (21.10 g) was observed in T_1 and lowest in T_0 treatment. The application of integrated plant nutrient management in polluted soils performed better for increasing tomato yield and reducing toxic metals accumulation in tomato.

The plant height, branches per plant, leaves per plant, average dry tomato fruit weight (g) were not affected significantly with interaction effects of soil and fertilizer (Table 4). The highest plant height (72.67 cm) was obtained in S_5T_0 and the minimum (39.33 cm) in S_4T_1 treatment combination. The highest number of branches per plant (5.33) was observed in S_3T_2 and the minimum (1.0) in S_4T_0 treatment combination. The maximum number of leaves per plant (23.00) was obtained in S_4T_2 and minimum was recorded in S_4T_0 treatment combination. Average fresh tomato fruit weight, fruit dry weight, dry weight of plant biomass and fruit yield were significantly influenced for combined effect of soil and fertilizer. The maximum average tomato fruit weight (49.51 g) was observed in S_4T_1 that was statistically comparable to S_1T_0, S_1T_1, S_2T_0, S_3T_1, S_3T_2 and S_4T_0 treatment combinations and lowest average weight (23.47 g) was obtained in S_5T_1 treatment combination and this result indicate that polluted soils produced higher individual tomato weight. The highest average fruit dry weight (3.28 g) and lowest fruit dry weight (1.58 g) were observed in S_3T_1 and S_4T_0 treatment combinations, respectively. The maximum tomato plant biomass dry weight (30.60 g pot^{-1}) was found in S_4T_1 whereas lowest (8.07 g) in S_4T_0 treatment combination. The highest tomato fruit yield (465.3 g pot^{-1}) was observed in S_3T_2 treatment combination that was statistically comparable to S_1T_2 and lowest in S_3T_0 treatment combination. The findings indicate that the application of fertilizers plus cowdung performed better on polluted soils for increasing the fruit yields of tomato. The industrially polluted soils gave higher tomato yields in comparison non-polluted soils due to presence of higher nutrient and soil organic matter and suitable soil texture.

Table 3. Effect of soil and fertilizer on yield parameters of tomato

Soil	Plant height (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}	Average fruit weight (g)	Average fruit dry weight (g)	Plant biomass dry weight (g pot^{-1})	Fruit weight (g pot^{-1})
Different soils							
S_0	58.94 ab	3.78	15.44	30.08 bc	2.07 b	15.63 b	294.6 ab
S_1	56.61 a-c	3.44	17.56	35.34 ab	2.07 b	18.08 ab	330.8 a
S_2	51.67 bc	3.78	15.22	32.30 abc	1.92 b	16.06 ab	262.6 ab
S_3	52.89 bc	3.89	16.11	34.53 ab	2.95 a	15.57 b	298.5 ab
S_4	48.06 c	3.33	17.67	39.66 a	1.75 b	19.64 a	234.2 b
S_5	66.33 a	3.33	15.11	24.64 c	2.04 b	18.98 ab	234.3 b
SE	2.83	NS	NS	2.28	0.185	0.954	18.55
Fertilizer							
T_0	55.25	1.83 b	9.56 b	35.26	2.13	11.99 b	197.7 b
T_1	55.28	4.11 a	18.94 a	33.10	2.15	21.10 a	307.9 a
T_2	56.72	4.83 a	20.06 a	29.91	2.12	18.88 a	322.0 a
SE	NS	0.26	0.85	NS	NS	0.674	13.11

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT.

Soils (S_0: Non-polluted; S_1: Polluted-1, S_2: Polluted-2; S_3: Polluted-3, S_4: Polluted-4 and S_5: Polluted-5)

Fertilizer treatments (T_0: Control; T_1: 100% recommended dose of fertilizer; and T_2: 50% recommended dose of fertilizer and 50% nutrient from manure)

Effect of industrial soil pollution and different fertilizer management on P and K accumulation in dry matter of tomato fruit

The P and K concentrations in tomato were significantly affected with different polluted, non-polluted soils and fertilizer treatments (Table 5). The higher P concentrations were recorded in some polluted soils and the highest tomato P (0.421%) concentration was found in S_4 (polluted soil 4) and the lowest (0.296%) in S_1 soil. The highest tomato K (1.787%) concentration was recorded in S_0 (non- polluted soil) soil that was comparable statistically with all soils except S_2, while the minimum fruit dry matter K was recorded in S_2 soil.

The highest tomato P (0.391%) concentration was found in T_0 treatment and lowest (0.294%) in T_1 treatment (Table 5). Tomato dry matter potassium concentrations were significantly increased with increasing fertilization. The T_1 treatment gave highest K concentration (2.25%) and the lowest (1.19%) was observed in T_0 where fertilizer was not used. The level of K in tomato increased in T_1 treatment due to increasing soil K level for application of inorganic fertilizer.

Table 4. Interaction effect of soil and fertilizer on yield parameters of tomato

Soil × Fertilizer	Plant height (cm)	Number of branches plant^{-1}	Number of leaves plant^{-1}	Average fruit weight (g)	Average fruit dry weight (g)	Plant biomass dry weight (g pot^{-1})	Fruit weight (g pot^{-1})
$S_0 \times T_0$	58.83	2.00	9.00	39.22 a-c	2.49	13.60 d-g	324.7 bc
$S_0 \times T_1$	59.67	4.67	19.00	25.93 c-e	1.65	18.73 b-d	247.5 cd
$S_0 \times T_2$	58.33	4.67	18.33	25.03 de	2.05	14.57 c-e	311.7 bc
$S_1 \times T_0$	56.83	2.00	12.33	36.89 a-e	1.64	14.43 c-f	285.8 b-d
$S_1 \times T_1$	54.33	4.00	17.67	36.19 a-e	2.39	19.93 bc	340.1 bc
$S_1 \times T_2$	58.67	4.33	22.67	32.95 b-e	2.17	19.87 bc	366.6 ab

$S_2 \times T_0$	46.67	2.00	10.00	41.79 ab	2.47	10.23 e-g	178.8 de
$S_2 \times T_1$	56.33	4.33	19.00	25.38 c-e	1.68	18.97 b-d	338.0 bc
$S_2 \times T_2$	52.00	5.00	16.67	29.73 b-e	1.61	18.97 b-d	271.1 b-d
$S_3 \times T_0$	50.00	1.67	6.67	28.30 b-e	3.00	8.07 g	97.7 e
$S_3 \times T_1$	58.00	4.67	20.00	38.10 a-d	3.28	19.03 b-d	332.4 bc
$S_3 \times T_2$	50.67	5.33	21.67	37.18 a-e	2.58	19.60 bc	465.3 a
$S_4 \times T_0$	46.50	1.00	8.33	38.91 a-d	1.58	8.87 fg	120.1 e
$S_4 \times T_1$	39.33	3.33	21.67	49.51 a	1.84	30.60 a	328.4 bc
$S_4 \times T_2$	58.33	5.67	23.00	30.56 b-e	1.81	19.47 bc	254.2 b-d
$S_5 \times T_0$	72.67	2.33	11.00	26.45 c-e	1.59	16.77 b-d	179.0 de
$S_5 \times T_1$	64.00	3.67	16.33	23.47 e	2.05	19.33 b-d	260.8 b-d
$S_5 \times T_2$	62,33	4.00	18.00	24.02 e	2.48	20.83 b	263.3 b-d
SE	NS	NS	NS	3.96	NS	1.65	32.12

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT.

Table 5. Effect of soil and fertilizer on P and K concentration in tomato

Soil	Phosphorus (%)	Potassium (%)
Different soils		
S_0	0.296 d	1.787 b
S_1	0.318 cd	1.559 b
S_2	0.360 b	1.547 a
S_3	0.355 bc	1.696 b
S_4	0.421 a	1.660 b
S_5	0.231 e	1.592 b
SE	0.011	0.07
Fertilizer		
T_0	0.391 a	1.189 b
T_1	0.294 b	2.249 a
T_2	0.305 b	1.983 a
SE	0.008	0.05

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT.

The P and K concentrations of tomato were significantly affected with the combined effects of soils and fertilizer (Table 6). The increased levels of P concentrations in tomato were found in S_2, S_3 and S_4 soils with different fertilizer treatments. The maximum P concentration (0.585%) was recorded in S_4T_0 and minimum (0.142%) in S_5T_1. Higher K accumulations were noted in S_0, S_2 and S_3 soils with all fertilizer treatments. The highest tomato fruit dry matter K concentration (3.963%) was recorded in S_2T_1 and lowest (0.772%) was recorded in S_1T_0. The findings indicate that higher P accumulated in polluted soils with fertilizer control treatment due to presence of higher levels P in polluted soils. The highest tomato K was accumulated in S_2T_1 treatment combination due to presence of higher levels K in polluted soil-2 (S_2) and increasing available K level with the application of 100% recommended dose of inorganic fertilizer(T_1).

Table 6. Interaction effects of soil and fertilizer on P and K concentration in tomato

Soil × Fertilizer	Phosphorus (%)	Potassium (%)
$S_0 \times T_0$	0.259 fg	1.319 i-k
$S_0 \times T_1$	0.310 d-f	2.357 bc
$S_0 \times T_2$	0.318 d-f	1.685 f-i
$S_1 \times T_0$	0.292 ef	0.772 l
$S_1 \times T_1$	0.367 cd	2.121 b-e
$S_1 \times T_2$	0.294 ef	1.785 e-h
$S_2 \times T_0$	0.456 b	1.466 h-j
$S_2 \times T_1$	0.291 ef	3.963 a
$S_2 \times T_2$	0.332 de	2.213 b-d
$S_3 \times T_0$	0.421 bc	1.190 jk
$S_3 \times T_1$	0.283 ef	1.892 d-g
$S_3 \times T_2$	0.361 cd	2.004 c-f
$S_4 \times T_0$	0.585 a	0.978 kl
$S_4 \times T_1$	0.370 cd	1.526 g-j
$S_4 \times T_2$	0.307 d-f	2.475 b
$S_5 \times T_0$	0.333 de	1.405 h-j
$S_5 \times T_1$	0.142 h	1.637 f-i
$S_5 \times T_2$	0.219 g	1.734 e-i
SE	0.019	0.12 1

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT.

Effect of industrially polluted soil and different fertilizer on cadmium, lead, zinc, iron, manganese and copper accumulation in tomato

Zn, Fe, Mn, Cu, Pb and Cd concentrations in tomato were significantly affected with the difference of polluted and non-polluted soils (Table 7). The maximum level of tomato Zn (87.67 ppm) was obtained in polluted soil S_4 where higher level of soil Zn was obtained and lowest (70.42 ppm) in S_1 soil where lowest level of soil Zn was noted which are statistically similar with all other soils except the soil S_4. The highest Fe concentration (110.94 ppm) was recorded in normal soil (S_0) and lowest (75.24 ppm) in S_1 soil that was comparable statistically to S_2 and S_3 soils. The highest tomato Mn (47.78 ppm) concentration was obtained in polluted soil S_2 that was statistically and closely similar with polluted soil S_3 and S_4 and minimum Mn (21.97 ppm) found in soil S_5. The highest soil Mn concentration was observed in polluted soil S_2 and higher soil Mn levels were found in polluted soil S_4 and S_3. Similarly, the highest tomato Cu (40.21 ppm) concentration was obtained in polluted soil S_2 that was statistically comparable with soil S_3 and minimum Cu (21.02 ppm) was found in non-polluted S_0 soil. The higher tomato Mn and Cu levels were observed in S_2 soil where higher soil Mn and Cu concentrations were recorded. The highest Pb concentration (1.316 ppm) in tomato fruit dry matter was found in polluted soil S_4 that was statistically similar with S_2 soil and minimum (0.808 ppm) was obtained in S_5 soil. The highest soil Pb concentration was obtained in the same polluted soil S_4 and accumulated in tomato. The maximum tomato Cd (0.924 ppm) was noticed in polluted soil S_5 that was comparable statistically to S_0 and minimum tomato Cd concentration (0.20 ppm) was recorded in S_2 soil. The higher level of Cd was found in polluted soil S_5 and lower soil Cd concentration was observed in polluted soil S_2. Higher level of tomato Cd was found in non-polluted soil may be due to the presence of higher levels of available Cd in this soil. The higher concentrations of lead, cadmium and manganese in tomato of industrially polluted soils of Bhaluka indicates that industrial wastes of industries contaminated or increased the level of soil heavy metals. These results are similar to the results of Srikanth and Reddy (1991), where they mentioned that industrial polluted soils have higher levels of Cd and Pb than soil non-polluted soils. The higher tomato Cd concentrations were also obtained in non-polluted soils and toxic metals may be accumulated in soils through adulterated fertilizer, pesticide and similar findings were obtained by Wei *et al*. (2020). Higher tomato metals concentration in the soils of contaminated area's due to cause of high contents of soil metals deposited through irrigation with metal contaminated water released from industries. The soils of Bhaluka industrial areas are contaminated through industrial waste water.

Table 7. Effect of soil and fertilizer on Zn, Fe, Mn, Cu, Pb and Cd concentration in tomato

Soil	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Pb (ppm)	Cd (ppm)
Different soils						
S_0	71.94 b	110.94 a	36.62 a	21.02 d	0.956 bc	0.710 b
S_1	70.42 b	75.24 c	39.95 a	25.41 cd	1.066 b	0.772 b
S_2	74.80 b	86.32b c	47.78 a	40.21 a	1.141 ab	0.200 d
S_3	74.17 b	84.66b c	44.35 a	34.72 ab	0.921 bc	0.265 d
S_4	87.67 a	89.69 b	46.20 a	31.87 bc	1.316 a	0.421 c
S_5	72.08 b	95.22 b	21.97 b	23.97 d	0.808 c	0.924 a
SE	3.20	3.79	2.95	1.92	0.062	0.025
Fertilizer						
T_0	64.53 b	74.73 b	34.15 b	24.47b	1.359a	0.759
T_1	79.94 a	90.65 ab	53.81 a	36.74a	1.107a	0.576
T_2	81.08 a	105.66 a	30.49 b	27.39b	0.638b	0.391
SE	2.26	2.68	2.09	1.35	0.044	0.018

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT.

The concentrations of tomato fruit dry matter Zn, Fe, Mn, Cu and Pb were varied significantly with fertilizer treatments. The highest Zn (81.08 ppm) and Fe (105.66 ppm) concentrations were obtained in T_2 (50% soil test basis dose of fertilizer and 50% nutrient from cowdung) those were comparable statistically with the T_1(100% soil test basis dose of chemical fertilizer) and minimum Zn and Fe levels were recorded in treatment T_0 treatment where fertilizer was not applied. The maximum tomato fruit dry matter Mn (53.81 ppm) and Cu (36.74 ppm) concentrations were found in T_1 treatment, while the lowest level was obtained in T_0 treatment. The highest tomato fruit dry matter Pb concentration (1.359 ppm) was found in T_0 and lower Pb concentration (1.107 ppm) was noted in T_1 that was same statistically with the T_0 treatment and minimum Pb concentration (0.638 ppm) was recorded in treatment T_2 and it indicates that application of manure reduced Pb accumulation in tomato. The tomato fruit Cd accumulation was not affected significantly by the fertilizer treatments. The uppermost tomato fruit dry matter Cd concentration (0.759 ppm) was found in T_0 and second uppermost Cd concentration (0.576 ppm) was noted in T_1 treatment and the minimum Cd concentration (0.391 ppm) was found in treatment T_2 and it indicates that application of manure reduced the Cd accumulation in tomato. The results indicate that application of fertilizer decreased the toxic Pb and Cd uptake in tomato and accumulation more reduced in T_2 where inorganic fertilizer plus manure were applied.

Table 8. Interaction effect of soil and fertilizer on Zn, Fe, Mn, Cu, Pb and Cd concentration in tomato

Soil × Fertilizer	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Pb (ppm)	Cd (ppm)
$S_0×T_0$	48.22 h	61.20 fg	38.83 c-f	12.83 f	1.046 b-d	0.780 b
$S_0×T_1$	88.36 a-c	95.92 b-d	50.06 b-d	29.38 b-e	1.032 c-e	0.795 b
$S_0×T_2$	79.29 a-e	175.70 a	20.98 fg	20.85 d-f	0.689 ef	0.734 b
$S_1×T_0$	59.63 f-h	59.63 g	43.84 b-e	18.97 ef	1.612 a	1.038 a
$S_1×T_1$	70.31 c-g	81.34 b-g	54.55 bc	32.63 bc	0.694 e	0.701 bc
$S_1×T_2$	81.32 a-d	84.74 b-e	21.46 fg	24.65 c-e	0.892 d-f	0.578 cd
$S_2×T_0$	55.66 gh	97.22 b-d	25.32 fg	31.54 b-d	1.444 ab	0.377 ef
$S_2×T_1$	79.17 a-e	79.17 c-g	87.22 a	54.65 a	1.427 ab	0.126 gh
$S_2×T_2$	89.56 a-c	82.59 b-f	30.81 e-g	34.44 bc	0.552 f	0.097 h
$S_3×T_0$	60.92 e-h	71.28 e-g	44.36 b-e	19.62 ef	1.366 a-c	0.397 ef
$S_3×T_1$	87.18 a-d	84.59 b-d	52.60 b-d	55.13 a	1.307 a-c	0.272 fg
$S_3×T_2$	74.41 b-g	88.11 b-e	36.09 d-g	29.42 b-e	0.501 f	0.126 gh
$S_4×T_0$	75.27 a-f	74.82 d-g	28.41 e-g	24.98 c-e	1.529 a	0.516 de
$S_4×T_1$	94.49 a	94.88 b-d	57.82 b	35.61 bc	1.656 a	0.492 de
$S_4×T_2$	93.26 ab	99.38 bc	52.37 b-d	35.02 bc	0.762 ef	0.254 fg
$S_5×T_0$	87.45 a-d	84.24 b-e	24.12 fg	38.90 b	1.059 c-e	1.149 a
$S_5×T_1$	60.15 e-h	97.98 bc	20.58 g	13.03 f	0.526 f	1.067 a
$S_5×T_2$	68.63 d-g	103.43 b	21.21 fg	19.98 d-f	0.840 d-f	0.555 cd
SE	5.545	6.57	5.11	3.32	0.11	0.043

In a column figures having similar letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per DMRT.

The tomato fruit dry matter Zn, Fe, Mn, Cu, Pb and Cd concentrations were influenced significantly with the combined effects of soils and fertilizer (Table 8). The maximum tomato fruit dry matter Zn concentration (94.49 mg kg^{-1}) was recorded in S_4T_1 that was comparable statistically with the value of S_4T_2, S_3T_1, S_2T_2, S_2T_1 S_1T_2 S_0T_2 and S_0T_1 treatment combinations and lowest Zn (48.22 mg kg^{-1}) concentration was found in S_0T_0. The tomato Zn accumulation increased due to presence of higher levels of Zn in polluted soil and Zn fertilization in different soils and all soils lower levels of Zn were noted in fertilizer control treatment. The highest tomato fruit Fe concentration (175.70 ppm) was observed in S_0T_2 and the lowermost (59.63 mg kg^{-1}) was found in S_1T_0 treatment combination. This result indicates that higher Fe accumulated in tomato fruit from non-polluted soil. The upper levels of tomato fruit Mn and Cu contents were recorded in polluted soils S_2, S_3, S_4 and lower levels in S_5 soils with different fertilizer treatments. The highest tomato fruit dry matter Mn (87.22 ppm) and Cu (54.65 ppm) concentrations of were recorded in S_2T_1 and lowest Mn (20.58 ppm) in S_5T_1 and Cu (12.83 ppm) in S_0T_0 treatment combinations. The higher Pb concentrations were recorded in polluted soils in comparison to normal pollution free soil. The highest Pb concentration (1.656 mg kg^{-1}) was found in S_4T_1 that was same statistically with the Pb concentration of tomato fruit dry weight of S_4T_0 (1.529 ppm), S_1T_0 (1.612 ppm) S_2T_0 (1.444 ppm), S_3T_0 (1.366 ppm) treatment combinations and lowest Pb accumulation (0.501 ppm) was noticed in S_3T_2 that was same statistically with S_2T_2 (0.552 ppm), S_0T_2 (0.689 ppm), S_1T_2 (0.892 ppm), S_5T_2 (0.840 ppm) and S_5T_1 (0.526 ppm) treatment combinations. The higher levels of Pb accumulated in polluted soil S_4 with 100% inorganic fertilizer or control treatment due to presence of higher level of soil Pb and lower accumulation was recorded in T_2 (50% soil test basis dose of fertilizer and 50% nutrient from cowdung) may be due to formation of metal-organic complex. The higher tomato fruit dry matter Cd concentrations were recorded in S_5 and S_1 soils with different fertilizer treatment. The highest tomato fruit dry matter Cd concentration (1.149 ppm) was observed in S_5T_0 treatment combination that was same statistically with S_5T_1 (1.067 ppm), S_1T_0 (1.038 ppm) and the lowest (0.097 ppm) Cd accumulation was recorded in S_2T_2 that was statistically comparable to S_2T_1 (0.126 ppm), S_3T_2 (0.126 ppm) treatment combinations. Higher soil Cd level was found in polluted soil S_5 and these findings indicate that higher Pb and Cd accumulated by tomato in industrially polluted soils where higher levels of Pb and Cd present in soils. The concentrations of metals were higher in tomato which was grown in contaminated soils and these results are similar with previous studies of Essien and Douglass (2012). The present findings indicate that higher Cd accumulation observed in fertilizer control treatment with different soils, and lower levels of Cd accumulation were recorded in fertilizer applied treatments with different soils. In maximum cases, lower levels of Pb and Cd concentrations were recorded in different soils with 50 % RDCF plus 50% nutrient from manure (T_2).

Conclusion

The influences of fertilizer and contaminated soils on the metal uptake in tomato yield parameters and yields were studied in net house experiment. The tomato was grown in five industrially contaminated and one non-polluted normal cultivated field soils. The metal concentration in tomato yield contributing characters and yield changed with soils and fertilizer. The higher tomato fruit yields were recorded in three industrially contaminated and normal soil in comparison to remaining two contaminated soils of industrial areas of Bhaluka. The higher fruit yields of tomato were recorded in fertilizer applied treatments and highest tomato yield was obtained in T_2. The highest tomato yields were obtained in S_3T_2 and S_2T_1 treatment combinations. The tomato Pb and Cd accumulation reduced in T_2 treatment and higher concentrations were observed in fertilizer treatment T_0. The uppermost tomato fruit Pb (1.656 ppm) and Cd (1.149 ppm) concentrations were recorded in S_4T_1 and S_5T_0 treatment combinations, respectively and lowest Pb and Cd concentrations were obtained in S_3T_2. The higher levels of Pb and Cd accumulated in tomato from polluted soils with fertilizer control treatment. Fifty percent RDCF plus 50% inorganic fertilizer is suitable for reducing toxic metal accumulation from industrially polluted soils and this treatment is suggested for vegetable cultivation in polluted soils. In maximum soils, the levels of Pb and Cd in tomato did not exceed the permissible limits. The accumulation of toxic heavy metals in vegetables growing concern and monitoring is essential in order to prevent excessive build-up of these metals in the food chain. Fifty percent inorganic fertilizer plus 50% nutrient from manure is recommended for tomato cultivation in polluted soil for reducing toxic metal accumulation.

Acknowledgment

The authors would like to acknowledge Information, Communication Technology-ICT Division, Ministry of Post Telecommunication and ICT, Govt. of the People's Republic of Bangladesh for PhD fellowship and research grant from SAURES.

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