STUDY ON THE SOURCES OF IRRIGATION WATER ON THE GROWTH AND QUALITY OF TOMATO

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STUDY ON THE SOURCES OF IRRIGATION WATER ON THE GROWTH AND QUALITY OF TOMATO

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CERTIFICATE

*This is to certify that thesis entitled **"STUDY ON THE SOURCES OF POLLUTED WATER ON THE GROWTH AND QUALITY OF TOMATO"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **MD. JOSIM UDDIN, Registration no. 12-05197** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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TO

MY BELOVED

PARENTS

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ABSTRACT

A field experiment was conducted in the horticulture experimental field of Sher-e-Bangla Agricultural University to find out the heavy metal concentration on tomato grown by the irrigation water from polluted river, cultivated during Rabi season (October, 2018 to March, 2019). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Two variety (V_1-BARI Tomato-14 and V_2-BARI Tomato-15) and three types of irrigation water (T_1-Normal water; T_2-Burigonga river water and T_3-Shitalokkha river water) were used to conduct the experiment. Thus, the experimental treatments were V_1T_1 (BARI tomato 14 with normal water); V_1T_2 (BARI tomato 14 with Burigonga River water); V_1T_3 (BARI tomato 14 with Shitalokkha River water); V_2T_1 (BARI tomato 15 with normal water); V_2T_2 (BARI tomato 15 with Burigonga River water); V_2T_3 (BARI tomato 15 with Shitalokkha River water). The concentration of Cadmium, Lead, Chromium and Nickel in BARI Tomato 14 (V_1) were 0.159, 0.253, 0.025 and 0.472 mg/kg, respectively; while, its' were 0.168, 0.259, 0.028 and 0.473 mg/kg respectively, in BARI tomato 15 (V_2) and all these concentration in both of the tomato varieties were high than the permissible level of FAO. Though, BARI Tomato absorbed less heavy metal than the BARI Tomato 15. The concentration of Cadmium, Lead, Chromium and Nickel in irrigation water collected from normal irrigation source (T_1) were 0.124, 0.137, 0.017 and 0.397 mg/kg, respectively; while, it were 0.188, 0.269, 0.032 and 0.497 mg/kg, respectively in Buriganga river water (T_2) and 0.179, 0.364, 0.031 and 0.524 mg/kg, respectively in Sitalakkha river water (T_3). The irrigation water collected from Buriganga and Sitalakkha River were statistically similar and higher than the permissible level of FAO. Cd, Cr and Ni were high in the irrigation water collected from the rivers. The highest number of cluster per plant (13.67) was observed in BARI tomato 14 irrigated with normal water (V_1T_1) whereas the lowest number of cluster per plant (10.33) was observed in BARI tomato 15 irrigated with normal water (V_2T_1). The highest no. of flower per cluster (5.33) was observed in V_1T_1 but lowest was observed in BARI tomato varieties with all types of irrigation water. Similarly, the highest number of fruit per cluster was also found in V_1T_1 and fruit number per cluster was lowest when both of the varieties were irrigated with Sitalakkha river water. The highest life cycle of tomato plant (114.00 days) was recorded in V_2T_1 comprised with BARI tomato 15 irrigated with normal water and the lowest cycle was (101.00 days) was found in V_1T_2 comprised with BARI tomato 14 irrigated with Buriganga river water. The harvest duration of tomato was highest (66.00 days) in V_1T_1 and lowest (46.33 days) in V_2T_3 comprised with BARI tomato 15 irrigated with Sitalakkha river water. The highest number of fruit per tomato plant (42.67) was recorded in V_1T_1 whereas the lowest number of fruit per plant (28.33) was found in V_2T_2. Similarly, highest amount of tomato per plant (2.99 kg) was found in V_1T_1 whereas the lowest amount of fruit (2.48 kg) was found in V_1T_3. Considering the results of the present study and environmental issues it can be concluded that irrigation water is a major factor for tomato cultivation.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
As	Aersenic
BARI	Bangladesh Agricultural Research Institute
CV	Coefficient of variation
^{o}C	Degree Celsius
d.f.	Degrees of freedom
et al.	And others
FAO	Food and Agriculture Organization
Gm	Gram
Ha	Hectare
Cd	Cadmium
Cu	Copper
Hg	Mercury
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
mg	Milligram
ml	Milliliter
Mn	Manganese
MP	Muriate of Potash
Ni	Nickel
Pb	Led
%	Per cent
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate
µg	Micro-gram
Zn	Zinc

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and nutritious vegetable crop in Bangladesh, which is used in salad, soups and processed into stable products like ketchup, sauce, pickles paste, chutney and juice. It belongs to the family Solanaceae. In Bangladesh, it ranks 2nd which is next to potato (BBS, 2012) and top the list of canned vegetables. Its food value is very rich because of higher contents of vitamin A, B and C (Bose and Sam, 1990). In Bangladesh tomato cultivated in 58854 acres of land in the year 2010-2011 with a total production of 190213 M.T. and approximately showing an average yield of 2855kg/acre (BBS, 2012). The average yield of tomato in Bangladesh is very low as compared to world average or some other tomato growing countries. Average yield of tomato in the world is 27 ton /ha whereas in Bangladesh it is around 7 t/h (Anonymous, 2004). Besides this, due to heavy metal contamination from the irrigation water this vegetable loss its food value. Farmers use the contaminated water to irrigate vegetables, causing heavy metal contamination in vegetables especially tomato, potato, brinjal, cucumber, chilli and other leafy vegetables in the district. In the industrial area of the Dhaka Export Processing Zone (DEPZ), vegetables are contaminated with high levels of Cr, Zn, Cu, Fe, Pb, Ni, and Cd (Ahmed and Goni, 2010). Ahmed *et al.,* (2012) and Zakir *et al.,* (2015) reported that the surface water and soil of the industrial area in Dhaka and Gazipur District are highly contaminated with Zn, Cr, Cu, Pb, and Cd due to wastewater discharge from industries. Most of these vegetables are sold to the wholesale market in Dhaka, the capital, and are consumed by many people. It is more dangerous for the vegetables which were used as raw like tomato.

Food security is one of the most important problems of the world (D'Mello, 2003; Mapanda *et al.,* 2007; Gebrekidsn *et al.,* 2013). When agricultural lands are exposed to polluted water for a long time, toxic metals can reach up to high concentrations (Nayek *et al.,* 2010). The amount and content of water is one of the factors limiting irrigation. Considering the gradual decrease of water resources in recent times, the proper use of available water sources is one of the most important responsibilities of human kind.

The quality of irrigation water available to farmers and others has a considerable impact on the type of plants that can be grown, the productivity of the plants, water infiltration and other soil physical conditions. In developing countries, heavy metal contamination of farmland is occurring, which is a severe environmental problem due to the toxicity of heavy metals (Agca and Özdel, 2014). In recent decades, the concentrations of heavy metals and metalloids in irrigation water, soil, and vegetables have been greatly increasing on farmland due to anthropogenic activities including the expansion of industrialization and urbanization (Islam, *et al.,* 2017). Irrigation water contaminated with industrial wastewater has caused significant heavy metal contamination in soils and crops. If soil is irrigated with wastewater, heavy metal concentration will be high in the edible parts of growing plants (Arora, *et al.,* 2008). The highly contaminated irrigation water by heavy metals are used in agricultural fields, where soil of these field accumulated these heavy metals. As a result, vegetables and crops of these fields uptake heavy metals from soil, which are mostly harmful for human health.

In Bangladesh, food safety is a major health concern. In the country, most foodstuffs are thought to be contaminated with heavy metals and not safe for human ingestion (Sultana, *et al.,* 2017). Due to unplanned industrialization and urbanization in the country, wastewater contaminated with heavy metals is continuously released into irrigation canals, thus soil and crops are contaminated with heavy metals, and many people consume the contaminated crops after they have been transported and sold in retail markets (Ikeda, *et al.*, 2000), and thus face the risk of health problems. Effects of toxic heavy metals on the growth of plants and microorganisms have been investigated by several researchers (Cu, 2015; Nazar *et al.*, 2012; Aydinalp & Marinova, 2009; Mahmood *et al.*, 2007; Fayiga *et al.*, 2004; Rout & Das, 2003; Baccouch *et al.*, 1998; Coppola *et al.*, 1988).

Considering the above facts, the experiment has been undertaken with the following objectives:

- To know quality of irrigated water for vegetables production.
- To study the effect of polluted river water on soil and tomato fruits.

CHAPTER II

REVIEW OF LITERATURE

Studies were conducted by Ngole and Ekosse (2009) to investigate sludge application to improve the yield of carrot and spinah. Three year old sludge and two months old sludge were applied in 20:80 and 40:60 sludge: soil ratio. Vegetables were grown on this sludge amended soils for 9 and 13 weeks respectively and then the concentration of Zn was determined. Sludge application resulted in an increase in total Kjeldahl nitrogen, available phosphorous, organic matter content and cation exchange capacity of soils. Sludge application increased the fresh weight of spinach by up to 31% and carrots by up to 10%. Zn accumulation in spinach was more than that of carrots.

Irrigation by sewage water effluents is the main reason for the accumulation of heavy metals in vegetables (Amin *et al.*, 2013, Sinha *et al.*, 2008). Long term irrigation with sewage water can induce changes in the quality of soil and trace element inputs are sustained over long periods (Zhang *et al.*, 2008). There are various reports (Singh *et al.*, 2004, Bharose *et al.*, 2013), where sewage water is being used for the irrigation of edible plants and it is a matter of great concern due to the presence of pollutants particularly, toxic metals.

Lokeshwari and Chandrappa (2006) conducted a study to assess the extent of heavy metal contamination of vegetation due to irrigation with sewage mixed lake water on agricultural land, water, soil and crop samples were collected and analyzed for seven heavy metals namely Fe, Zn, Cu, Ni, Cr, Pb and Cd. Study revealed that wastewater irrigation considerably increased accumulation of some heavy metals beyond the limits of Indian standards in rice and vegetables. Transfer factor of heavy metals from soil to vegetation also found significant for Zn, Cu, Pb and Cd. Vegetation showed higher amount of heavy metals when compared with that of irrigational water and soil.

Rusan *et al.,* (2007) studied the long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. From their study, the concentration of Pb and Cd content increased with wastewater irrigation and their levels were higher the longer the period of wastewater irrigation.

Farooq *et al.,* (2008) studied the heavy metal content in various leafy vegetables viz. spinach, coriander, lettuce, radish, cabbage and cauliflower grown in an effluent irrigated field in the vicinity of the industrial area. The study revealed that Pb and Cd were above the toxicity level in leafy vegetables grown in the vicinity of an industrial area whereas other heavy metals such as Zn, Cu and Cr were within the permissible limits. The leaves of leafy vegetables contained higher concentration of heavy metals than other plant parts.

Groundwater irrigation was being supplemented by wastewater. The continuous use of contaminated water for irrigation can remarkably increase the uptake of metals into plant tissues (Al-Chaarani *et al.,* 2009).

Appreciable amounts of copper have earlier been reported by Llorens *et al.,* (2001) from coal-based power plants in Spain; however, the researchers were not able to analyze flyash from the thermal power plants in the vicinity of the sampling sites.

Other researchers also observed higher levels of metals in agricultural soils because of the use of different quality wastewater, proximity of field to main roads and highways, presence of thermal power plants, and use of different types of agrochemicals containing heavy metals (Rattan *et al.,* 2002; Marshall *et al.,* 2007).

Tawfik (2008) studied the impact of polluted water from different sources on cultivated areas of Helwan. Both the disposal of industrial wastes and sanitary wastewater to agricultural canals upsets the environmental balance. Study was based on the evaluation of water and soil chemistry by pollution load considering major ions, soluble heavy metals and plant growth. Results revealed that water, soil and plants were polluted from different sources. Irrigational water soil contamination reduced plant photosynthetic pigments and plants grown in farms receiving industrial wastes exhibited higher values of heavy metals than the maximum permissible limits.

The flyash from thermal power plants in India has been found to contain all four metals; however, the differential availability in soil could also depend on the leaching tendency of these metals which have been found to be in the order of Zn. Cu. Pb. Cd (Prasad and Mondal, 2008).

The heavy metal concentrations were, however, below the safe limits of Indian standards (Bhatnagar and Awasthi, 2000). The lower concentration of heavy metals at all PAS was because of the continuous removal of heavy metals by the vegetables grown in this area and leaching of heavy metals into the deeper layer of the soil. Singh *et al.,* (2004) also reported increments of 40.29% for copper, 2.05% for lead, 41.42% for zinc and 15.7% for chromium in soil of the Dinapur area irrigated by treated wastewater compared to the site irrigated by clean water. Low levels of contamination at Alipur were because of its semirural background and limited industrialization. Singh and Kumar (2006) observed similar variation in metal content at PAS because of proximity of the fields to highways, presence of thermal power plants, and use of agrochemicals containing heavy metals. In this study, the presence of higher load of heavy metals at the Najafgarh, Yamunapusta, and Okhla sites could be because of the use of wastewater irrigation at the these sites. However, it was observed that cadmium levels in soils at Alipur were not significantly different from the three other sites, which suggests that phosphate fertilizer and metal-containing pesticide application may be taking place at this location.

Several studies emphasize that *DIM* (Daily Intake Matels) values of vegetables irrigated with heavy metal contaminated waters are very high (Chopra and Pathak, 2015; Khan *et al.,* 2015). However, according to the guidelines of WHO (WHO, 2002), the *DIM* for Cu, Zn, Fe, Pb and Ni is 0.01, 0.025, 0.05, 0.005, 0.002, respectively.

Ramesh and Murthy (2012) had found significantly high concentration of lead in spinach (28.4–149.5 lg/g) and coriander (54.7–75.5 lg/g) in vegetable samples collected from Bangalore Urban district in India.

Bvenura and Afolayan (2012) observed that heavy metals in vegetables ranged from 0.01 to 1.12 μg/g for cadmium, 0.92 to 9.29 μg/g for copper, and 4.27 to 89.8 μg/g for zinc. Lead, however, was undetectable in all the samples collected from home gardens in South Africa.

Lui *et al.,* (2006) found 12-fold higher metal content in tomatoes collected from the wastewater irrigated area of Zhengzhou City, China. The variations in metal concentrations in vegetables may also be attributed to absorption of metals and their further translocation within the plants.

Cui *et al.,* (2004) also have reported that residents near a smelting unit in China were exposed to cadmium and lead through consumption of vegetables; however, no risk was found from copper and zinc.

Heavy metal (Cr, Cu, Zn, As, Cd, and Pb) contamination in irrigation water, soil, and vegetables was investigated in farmland adjacent to a multi-industry zone in Bangladesh in dry and wet seasons. In the zone, many factories release wastewater into nearby irrigation canals, and vegetables cultivated with this water could be a major food chain route for human exposure. In the irrigation water and vegetables, heavy metal concentrations exceeded permissible levels in the two seasons, but this was not the case in soil. Zn had the highest concentration, and Cd had the lowest concentration in irrigation water, soil, and vegetables. All heavy metal concentrations were found to be lower in the wet than in the dry season, which is due to the dilution of water by rainfall, lower absorption of heavy metals from the diluted irrigation water, and heavy metal absorption from low concentrated irrigation water and/or soil. The cluster analysis data of irrigation water, soil, and vegetables revealed that the heavy metals in vegetables were considered to be absorbed from irrigation water in the wet season and from soil in the dry season. In the dry season, the high heavy metal concentrations in vegetables might be caused by a high bio-concentration factor (mostly >20%) (Ahmed, *et al.,* 2019).

Jouzdan *et al.,* (2007) studied the effect of using urban treated and untreated effluents on soil and agricultural crops pollution in Syria. Concentration of As, Cr, Cd and Pb increased in fruits and leaves of vegetables (egg plant and lettuce) as well as in the grain and straw of field crops (wheat and corn) studied.

Chen *et al.,* (1992), who found high levels of heavy metals in soils which are irrigated by polluted industrial waste water. El-Gendi *et al.,* (1997) indicated that irrigating sandy soil in the Abou-Rawash area with drainage water increased total Cu, Zn, and Fe, which reached 125, 170, and 5 times that of the virgin soil in the same area. Reported by Nassef *et al.,* (2006) and Suciu *et al.,* (2008), both Cd and Pb levels in soils were higher.

Ahmed *et al.,* (2012) and Zakir *et al.,* (2015) reported that the surface water and soil of the industrial area in Dhaka and Gazipur District are highly contaminated with Zn, Cr, Cu, Pb, and Cd due to wastewater discharge from industries. Farmers use the contaminated water to irrigate vegetables, causing heavy metal contamination in vegetables in the district. In the industrial area of the Dhaka Export Processing Zone (DEPZ), vegetables are contaminated with high levels of Cr, Zn, Cu, Fe, Pb, Ni, and Cd (Ahmed and Goni, 2010).

In Bangladesh, cultivation in the dry season mostly depends on irrigation by deep shallow tube wells (STWs). Bangladesh has the highest percentage of As-contaminated STWs, and yearly increases of up to 0.1 mg of As per kg of soil can occur as a result of irrigation, especially in paddy fields (Mehrag and Karim, 2003). Duxbury *et al.,* (2003) stated that paddy fields irrigated with As-contaminated water for ten years would add 5–10 mg/kg As into soil. Agricultural soil irrigated with Shitalakhya river water in Narayangonj presents elevated Pb (28.13 mg/kg), Cd (0.97 mg/kg), and Cr (69.75 mg/kg), which are higher than safe limits (Ratul *et al.,* 2018). Rice is the staple food in Bangladesh, with average rice consumption of 400 to 600 g per day by an adult (Ahsan and Valls, 2011). Therefore, risks from inorganic As in rice from regions of high soil As pollution may affect local people directly (Ahsan and Valls, 2011; Joseph *et al.,* 2015; Raessler, 2018).

Heavy metals content in rice and maize shoots exceeded the defined limits reported by Kabata-Pendias and Pendias (1992) and were above the levels acceptable for elemental composition of uncontaminated plant tissue. Alloway (1990) reported that in angiosperms, uncontaminated plant tissue contains 0.64, 2.4, 160, and 14mg kg 1 of Cd, Pb, Zn, and Cu, respectively.

Wang *et al.,* (2008) made a study to assess the heavy metal content in sewage sludge and its effect in Chinese cabbage grown in soil amended with sewage sludge. Study revealed that total content of Cd, Cr, Pb, Ni, Cu, Zn, Fe, Mg and Mn except as was below the top limits for land application of sewage sludge in China. the study also reported the positive correlation of metal with sludge amendment and Chinese cabbage can be used as candidate plant to remediate the soil contaminated with heavy metals.

Analysis showed that soils near high traffic and industrial areas contain high concentrations of heavy metals and metalloids. Agricultural land and vegetables in sewage-irrigated areas were also found to be heavy metal- and metalloid-contaminated. River water, sediment, and fish from the Buriganga, Turag, Shitalakhya, and Karnaphuli rivers are highly contaminated with cadmium (Cd), lead (Pb), and chromium (Cr). Particularly, groundwater arsenic (As) pollution associated with high geological background levels in Bangladesh is well reported and is hitherto the largest mass poisoning in the world (Islam, *et al.*, 2018).

The concentrations of Ca, Na and K in tomatoes grown in SW water-irrigated area were significantly higher than the tomatoes grown in the groundwater, water-irrigated control area (Alghobar and Suresha, 2017).

Cabbage (*Brassica oleracea*) from agricultural land nearby DEPZ contains Pb (22.09 mg/kg), Cd (2.05 mg/kg), and Cr (7.58m mg/kg) in higher concentrations than the safe limits (Ahmad and Goni, 2010). Edible parts of Spinach (*Spinacia oleracea*) from the Hazaribagh leather industrial area of Dhaka presented higher levels of As (0.26-0.22 mg/kg), Pb (11.48-4.98 mg/kg), Cd (0.32-0.094 mg/kg), and Cr (44.48-12.59 mg/kg) (Mottalib *et al.*, 2016). Bottle gourd (*Lagenaria siceraria*) (Pb 1.16-0.01 mg/kg) and water spinach (*Ipomoea aquatica*) Cr (3.21-0.023 mg/kg) from the Vatiary industrial area of Chittagong both exceeded the safe limits (Parvin *et al.*, 2014). Potato (*Solanum tuberosum*) from Bogra was found to be polluted by Pb and Cd (Islam *et al.*, 2016).

Impact of different irrigation sources on metals (Cd, Pb, Zn, Cr, Cu, Ni and Fe) uptake by Tomato (*Solanum lycopersicum*), Onion (*Allium cepa* L.), Pepper (*Capsicum annuum* L.) and Beans (*Phaseolus vulgaris* L.) grown in Nevsehir Province were determined using ICP-OES (Inductively Coupled Plasma Optical Emission Spectroscopy). Heavy metal concentrations in vegetables irrigated by wastewater and river water were significantly ($P < 0.05$) higher than tube well water and exceeded the permissible limits of WHO/FAO. Among the edible parts of vegetables, maximum accumulation of Fe and Cr occurred in onion; Zn and Pb accumulation were determined in tomato followed by Ni in beans, while Cd and Cu were high in pepper. Also Bio-concentration Factor (BCF) and Daily Intake Metal (DIM) values were calculated and it was determined that DIM values were free of risk, as the dietary intake limits of Cu, Fe, Zn, and Mn in adults can range from 1.2 to 3.0, 10.0 to 50.0, 5.0 to 22.0, and 2.0 to 20.0 mg, respectively. As a result, wastewater and river water are not appropriate for agriculture, especially when the river water is used for irrigation, because the significant metal contamination in soils causes several health problems (Leblebici and Kar, 2018).

The vegetation analysis showed the presence of high levels of Cd in Ayaguz 0.346 mg/kg, which exceeded the National limit 0.2 mg/kg. Considerable quantity of Pb 1.96 mg/kg, Zn 20.7 mg/kg, Cu 11.1 mg/kg was measured in Naualy. In water samples of Urdzhar region Pb value of 0.039 mg/dm3 was a little higher than the National limit of 0.03 mg/dm3. Zn content in Naualy 1.5 mg/dm3, in Kabanbai 1.25 mg/dm3, in Urdzhar 1.05 mg/dm3 was found to exceed the National limit 1.0 mg/dm3 (Kakimov *et al.*, 2013).

Some of the vegetables such as lettuce, spinach, radish, and carrot, can easily take up heavy metals, e.g., Cu, Cd, Pb, Zn, and Mn, in their tissue. The uptake of these metals by the plant is generally increased when they are grown on contaminated soils (Yang *et al.,* 2011).

In general both river and waste water are dangerous in terms of heavy metal, but we can claim that the river water has more adverse effect than wastewater according to heavy metal uptake. In a study conducted in Pakistan, results were similar to our findings (Amin *et al.,* 2013).

Naser *et al.,* (2012) found that pumpkin (*Cucurbita maxima*) grown close to the highway in Joydevpur, Gazipur, contained Pb (4.76 _ 1.03 mg/kg) and Cd (0.20 _ 0.02 mg/kg) in concentrations much higher than those grown in distant areas.

Red amaranth (*Amaranthus cruentus*) collected from agricultural land surrounding the Turag River were considerably polluted by Pb (1.99- 0.44 mg/kg) and Cd (0.84-0.17 mg/kg) (Islam and Hoque, 2014). Purple amaranth (*Amaranthus lividus*) from agricultural land surrounding the Shitalakhya river was polluted by Pb and Cd as well (Ratul *et al.,* 2018).

Chitdeshwari *et al.,* (2002) reported that the use of sewage water increased the uptake of Cd and Cr in *Amaranthus* crops.

Heavy metal concentrations in leafy vegetables (Red spinach) grown in along the Dhaka-Aricha road and their statistical analysis were ranged: Pb: 0.695 ± 3.155; Cr: 1.173 ± 3.83; Cd: 0.180 ± 2.305; Cu: 0.2568 ± 3.5294 and Zn: 1.452 ± 8.298 mg/kg (Aktaruzzaman, *et al.,* 2013).

Luksiene and Racaite (2008) conducted a study to analyze the accumulation of different heavy metals in spring wheat despite their toxicity. Transfer factors were calculated for all the heavy metals studied. Accumulation of heavy metals in both over ground and under-ground portions was calculated. According to the transfer factor values the following uptake efficiency rank has been prepared for the spring wheat over ground part: Mn> Zn> Pb> Ni> Co> Cd> Cu> Cr, and for the underground part (roots): Mn> Ni> Zn> Cd> Co> Cr> Cu> Pb.

Some important heavy metals have individual effect on vegetables as well as soil. Some of them are given bellow:-

Cobalt: The higher contamination of Co was detected in cabbage. 2.10 ± 0.002 at Paspanga and 0.50 ± 0.06 at Loumbila. The average concentration of Co in spinach was 1.26 ± 0.1, lettuce 1.28 ± 0.08. Co was not detected in pepper leaves, pepper fruit and Tomato. The vegetable from Paspanga were more contaminated than those from Loumbila, this can due to the high concentration of Co in Pasanga irrigation water. The Co concentrations of all vegetable were between the normal concentration ranges 0.1-10 mg.kg (Hajara *et al.,* 2013).

Chromium: Tomato is the only vegetable where the chromium was detected and the average concentration was 4.5 ± 0.04 mg/kg. In cabbage, pepper, spinach and lettuce, the concentration were below detectable limits. The mean concentration of chromium in the tomato was the permissible limit recommended by FAO in vegetables (2.3 mg/kg) (Shakya and Khwaounjoo, 2013; Girmaye, 2014; Lalitagauri *et al.,* 2010).

In Pakistan, Leaves accumulated higher concentration (above the permissible limits as set by Anon., 1996) and fruits accumulated lower concentration of Cr (Khan *et al.,* 2011).Khan *et al.,* 2007 observed that, elevated level of Cr in tomato leaves and fruits receiving effuents , there were high concentration in both leaves and fruit.

Cr concentration did not exceed the limits determined by WHO (0.1 µg g-1) and accumulated least in cabbage (Ferri *et al.,* 2012). Saggoo and Grewal (2003) reported that Cr accumulation in the leaves of spinach and amaranths raised on Cr rich soil. Heavy metals play an important role in the environment.

Cadmium: Shaheen *et al.,* (2016) showed that tomatoes (*Solanumly copersicum*) contained excess Cd. According to Roy and McDonald (2013), carrots grown in soils contaminated by Cd have the potential to cause toxicological problems in men, women, and young children.

Li *et al.,* (1994) found that plants absorb Cd more readily than other heavy metals and levels are often reached that are hazardous to human health before any stress symptoms appear.

Habib *et al.,* (2009) reported that Cd concentrations was 1.40 mg/kg in spinach sample of industrial area of Bangladesh.

The mean level of Cd (1.00 ± 0.683 mg/kg) was measured in vegetables collected from along the Dhaka-Aricha road near Savar area in Bangladesh, which was lower than the vegetables from Titagarh, West Bengal, India (10.37-17.79 mg/kg) (Gupta *et al.,* 2008).

Demirezen and Aksoy (2006) analyzed various vegetables from Turkey and reported the Cd content range 0.24-0.97 mg/kg. Rapheal and Adebayo (2011) reported that, in Nigeria, the concentration of Cd ranged from 0.07-0.11, 0.08-0.14, 0.11-0.16, 0.10-0.13 and 0.06-0.12 µg/g for tomatoes, okra, pumpkin, spinach and pepper, respectively, in which the high level Cd was found in pumpkin.

Singh and Pandeya (2000) conducted a pot experiment to evaluate the influence of application of organically complexed Cd on soils and Phaseolus vulgaris grown there. Experiment was conducted on ten sewage sludge treated old alluvium, non calcareous and non saline soils on Rajmash crops with different sludge rates. Application of Cd through cadmium-fulvic acid complex in soil did not influence the dry matter yield of the crop whereas Cd uptake by plants increased significantly. Soil characteristics such as soil organic carbon content, cation exchange capacity, clay content and pH of the soils were found to be the dominant determinants of Cd in plants. The soluble and exchangeable Cd and organically complexed Cd were the two major chemical pools of Cd in soils responsible for supply of Cd to the plants.

Iron: the highest concentration of iron was found in Tomato 28.98 ppm, followed by cabbage 6.21 ppm, lettuce 3.47 ppm, pepper leaves 1.176 ppm, spinach 0.646 ppm and pepper fruit 0.204 ppm. The average concentration of Iron is the vegetable was very low than the permissible limit recommended by FAO in vegetables (425.5 mg/kg) (Boamponseem *et al.,* 2012; Shuaibu, *et al.,* 2013).

In Pakistan, Iron concentration level was beyond the permissible limits (150 mg/kg) of Annon 1996 of tomato leaves and fruits (Khan *et al.,* 2011). The highest accumulation of Fe was in the stems of the tomatoes, while roots of onions and peppers accumulated high levels and the leaves of beans were major sinks for Fe. Iron, which is used in the synthesis of chlorophyll in all green plants, was detected in high concentrations. (Ravet *et al.,* 2009) Fe toxicity occurs when they accumulate an amount of Fe greater than 300 (μg g-1), at less than 5.0 soil pH value. Amin *et al*. (2013) determined high Fe concentration in the plants they analyzed; and they emphasized the importance of its role in chlorophyll syntheses and abundance in the earth crust.

Manganese: Manganese concentration is high in vegetable from Loumbila site than those from Pasanga site. The highest concentration of Manganese was found in pepper leaves 6.96 ppm, followed by tomato 2.8 ppm, cabbage 0.4 ppm, spinach 0.38 ppm and lettuce 0.28 ppm. The irrigation water in Loumbila and Pasanga were polluted by Manganese but the average concentration of Manganese in the vegetable was very low than the permissible limit recommended by FAO in vegetables (500 mg/kg) (Boamponseem *et al.,* 2012).

In Pakistan, manganese concentration was higher in leaves compared to fruits of tomato (Khan *et al.,* 2011). Rapheal and Adebayo (2011) reported that, the maximum Mn content was found in spinach with 7.80 µg/g.

Zinc: The highest concentration of zinc was found in Tomato 4.52 ppm, followed by cabbage 0.82 ppm, lettuce and spinach with the same concentration 0.40 ppm, pepper leaves 0.36 ppm and pepper fruit 0.26 ppm. The average concentration of zinc in the vegetable was very low than the permissible limit recommended by FAO in vegetables (99.4 mg/kg) (Shakya and Khwaounjoo, 2013; Shuaibu, *et al.,* 2013).

In Pakistan, in tomato leaves the concentration of zinc was higher than the permissible limit (Annon, 1996) and the concentration of zinc was below the permissible limit in tomato fruits (Khan *et al.,* 2011).

Aktaruzzaman, *et al.,* (2013) reported that, the mean concentration of Zn (4.50 mg/kg) in vegetables collected from along the Dhaka-Aricha road was substantially lower than the Zn concentrations (3.00 ± 171.03 mg/kg) in vegetables from Titagarh, West Bengal, India (Gupta *et al.,* 2008), vegetables of Varanasi, India (59.61-79.46 mg/kg) (Sharma *et al.,* 2007). Rapheal and Adebayo (2011) reported that, Zn concentrations ranged from 4.45-9.35 µg/g, and the highest concentration of Zn was found in okra with 9.35 µg/g.

Arsenic: The higher concentration of arsenic was detected in cabbage and pepper fruit with the same value 0.12 ppm, followed by tomato 0.06 ppm. The average concentrations were smaller than permissible limits set by FAO (0.43 mg/kg) (Shakya and Khwaounjoo, 2013).

Irrigation with As-contaminated ground water is the primary cause of food As contamination in Bangladesh. Organic As in foods is considered to be less harmful. However, As-contaminated crops may contain a large portion of inorganic As (Meharg *et al.,* 2009; Rahman and Hasegawa, 2011). Besides drinking water, food As exposure was also found to an be important pathway responsible for As poisoning (Meharg and Rahman, 2003; Alam *et al.,* 2003; Al Rmalli *et al.,* 2005; Khan *et al.,* 2010). Alam *et al.,* (2003) found that vegetables grown in the Samta village were contaminated by As. Rice from Brahmanbaria also was observed to contain As (0.24 mg/kg) and Cd (0.331 mg/kg) in higher concentrations than the established safe limits (Khan *et al.,* 2010). Safe limits for main metals and metalloids in food stuffs are as follows: As 0.1 mg/kg; Pb 0.05 mg/kg; Cd 0.05 mg/kg; and Cr 2.3 mg/kg (FAO/WHO, 2011).

Copper: Copper concentration level in both leaves and fruits were below the permissible levels (10 mg/kg) of Annon, 1996 in Pakistan. For the Cu-contaminated soils planted with tomato (*Solanum lycopersicum* L.), these values would range between 32.9 and 1696.5mg kg 1, depending on soil properties (Sacristán *et al.,* 2015). Accumulation of toxic heavy metals in living plant cells results in various deficiencies, reduction of cell activities, and inhibition of plant growth (Farooqi *et al.,* 2009).

Alam *et al.,* (2003) reported that the mean Cu concentrations in leafy and non-leafy vegetables 15.5 and 8.51 mg/kg, respectively from Samata village, Jessor.

Aktaruzzaman, *et al.,* (2013) reported that, the mean concentration of Cu (0.25-3.52 mg/kg) in vegetable grown in along the Dhaka-Aricha road in Savar area in Bangladesh, which was lower than the concentration of Cu (22.19-36.50 mg/kg) in the leafy vegetable species from Turkey (Demirezen and Aksoy, 2006).

Rapheal and Adebayo (2011) reported that, Cu concentrations in vegetables ranged from 1.22-5.22 µg/g, pumpkin and spinach were found to contained highest concentration of 5.22 and 5.12 µg/g, respectively.

Nickel: Tomato leaves accumulated more nickel then fruits. But the concentration of nickel in fruits remain below the permissible level and the concentration of nickel in tomato leaves higher than the permissible level (Khan *et al.*, 2011).

In Nevsehir, it is extensively used as a catalyst in different industrial and chemical processes, so, Ni concentration was especially high in river water irrigated vegetables (Leblebici and Kar, 2018).

Pot experiments were conducted by Maiti and Singh (2003) in Indian mustard plants to evaluate the effect of different rates on yield characteristics and metal availability on loamy sand soil. Sewage sludge application significantly increased the yield of mustard stovers thereby exhibiting the beneficial effect of swage sludge on soil. Even low levels of Zn and Ni exert stimulatory effect on mustard stovers and seed yield. Application of Zn in combination with Ni or Cd significantly reduced the heavy metal content in mustard stovers and seed in both the soils. Also therer observed a significant reduction in Ni but the same level of Ni was applied in combination as compared to individual metal application.

Lead: In Pakistan, the concentration of lead was beyond the permissible level (Annon 1996) in both leaves and fruits of tomato (Khan *et al.*, 2011).

Aktaruzzaman, *et al.*, (2013) reported that, Red Spinach collected from Dhaka-Aricha road side area, the concentration of lead levels ranged 0.693 ± 3.155 mg/kg. The mean concentration of Pb was 1.94 ± 0.90 mg/kg. Similar levels (1.44 mg/kg) were also reported by Habib *et al.*, (2009) in Spinach sample of industrial area of Bangladesh. Fytianos *et al*. (2001) examined a high concentration of Pb in spinach grown in industrial and rural areas of Greece. Al Jassir *et al.,* (2005) studied green leafy vegetables from Saudi Arabia and noted the highest concentration of Pb in the coriander 0.171 mg/kg and purslane (0.226 mg/kg).

Kumar *et al.* (2007) claimed that; the high level of lead in wastewater irrigated vegetables could be attributed to acid-lead batteries, urban and industrial wastes discharged into the irrigation system.

Rapheal and Adebayo (2011) reported that, in vegetable and fruit Pb content was generally very low due to its low bioavailability. Pb concentration in various vegetable and fruit samples studied ranged from 0.11-0.28 µg/g with highest concentration of 0.28 µg/g were found in pumpkin and spinach.

Effect on human health

The food chain is the most important pathway for heavy metals in their exposure to the humans (Li *et al.,* 2006).

Transfer factor of heavy metals depends upon bioavailability of metals, which in turn depends on the metals' concentration in the soil and its chemical form and the plants' uptake capability and growth (Tinker, 1981). The transfer factor was highest for cadmium probably because of its high mobility from soil to edible tissue. Cadmium and zinc are more mobile elements compared to lead (Vamerali *et al.,* 2010). Fytianos *et al.,* (2001) have reported a higher transfer factor for cadmium through leafy vegetables.

Zhuang *et al.,* (2009) also made similar observations of transfer factor for heavy metals (i.e., Cd.Zn.Cu.Pb) in different vegetables grown in the vicinity of a mining site in South China. However, the effect of pH on the mobility of metallic elements in the soil is highly variable and depends on the content and type of organic matter (Violante *et al.,* 2010). Low transfer factor values were obtained for lead in okra and cauliflower. This likely occurred because atmospheric deposition may be a more likely pathway for lead to enter the aboveground tissues of plants compared to transfer from soil. The order of metal uptake based on transfer factor was highest in okra, followed by cauliflower and spinach. Singh *et al.,* (2010) in a study of heavy metal in vegetables at a wastewater-irrigated site obtained higher transfer factor of metals for okra as compared to cauliflower and spinach. Sharma *et al.,* (2009) observed higher metal concentrations in cauliflower than in spinach at crop sites close to national highways. The higher uptake of heavy metals in vegetables from soil may be because of higher transpiration rates needed to maintain the growth and moisture content of plants (Tani and Barrington, 2005). The higher uptake of heavy metals in okra, for example, was probably because of its large size and large number of leaves compared to other vegetables, which led to higher transpiration rate to maintain its growth and moisture content.

Heavy metal contamination of agricultural soils from wastewater irrigation is of serious concern since it has implications on human health. A study carried out by Mensah *et al.,* (2008) in Ghana using water to which Cd and Pb had been added to irrigate cabbage, carrots and lettuce revealed that Cd and Pb concentrations increased with irrigation water concentrations significantly with p-value of Cd<0.0001 and for Pb<0.05.

Several pathological conditions such as nervous and immune systems disorders, anemia and reduced Haemoglobin synthesis, cardiovascular diseases, and bone metabolism, renal and reproductive dysfunction are associated with Pb intoxication in children and adults (Al-busaidi *et al*. 2015).

Demirezen and Aksoy (2006) reported Cd content (0.24-0.97 μg g-1) in various vegetables and suggested that its consumption was inappropriate for human health.

CHAPTER III

MATERIALS AND METHODS

The present study regarding assessment of heavy metal on tomato grown by the irrigation water from polluted water had been conducted during rabi season (October 2018 to March 2019) in the horticulture farm of Sher-e-Bangla Agricultural University, Dhaka. Required materials and methodology are described below under the following sub-headings.

3.1 Location

The experiment was conducted in the horticulture experimental farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The location of the experimental site was 23074//N latitude and 90035//E longitude and an elevation of 8.2 m from sea level (Anon., 1989).

3.2 Climate

The climate of the study site was under the subtropical climate, characterized by three distinct seasons, the Rabi from November to February and the Kharif- I, pre-monsoon period or hot season from March to April and the Kharif- II monsoon period from May to October (Edris *et al*., 1979). The monthly average temperature, relative humidity and rainfall during the crop growing period were collected from weather yard, Bangladesh Meteorological Department and presented in Appendix I.

3.3 Soil

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, CEC-25.28 22 (Haider *et al*., 1991). The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). Details of the mechanical analysis of soil sample are shown in Appendix II.

3.4 Seed collection

The seeds of tomato variety BARI Tomato-14 and BARI Tomato-15 were collected from Bangladesh Agricultural Research Institute (BARI).

3.5 Experimental design and layout

The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. The experimental pot was divided into three blocks maintaining 0.75m block to block distance and each block was subdivided into 6 pots. Thus the total number of pots was 16. The pot to pot distance was 0.5 m was kept to facilitate different intercultural operations. The figure 1 show the experimental layout.

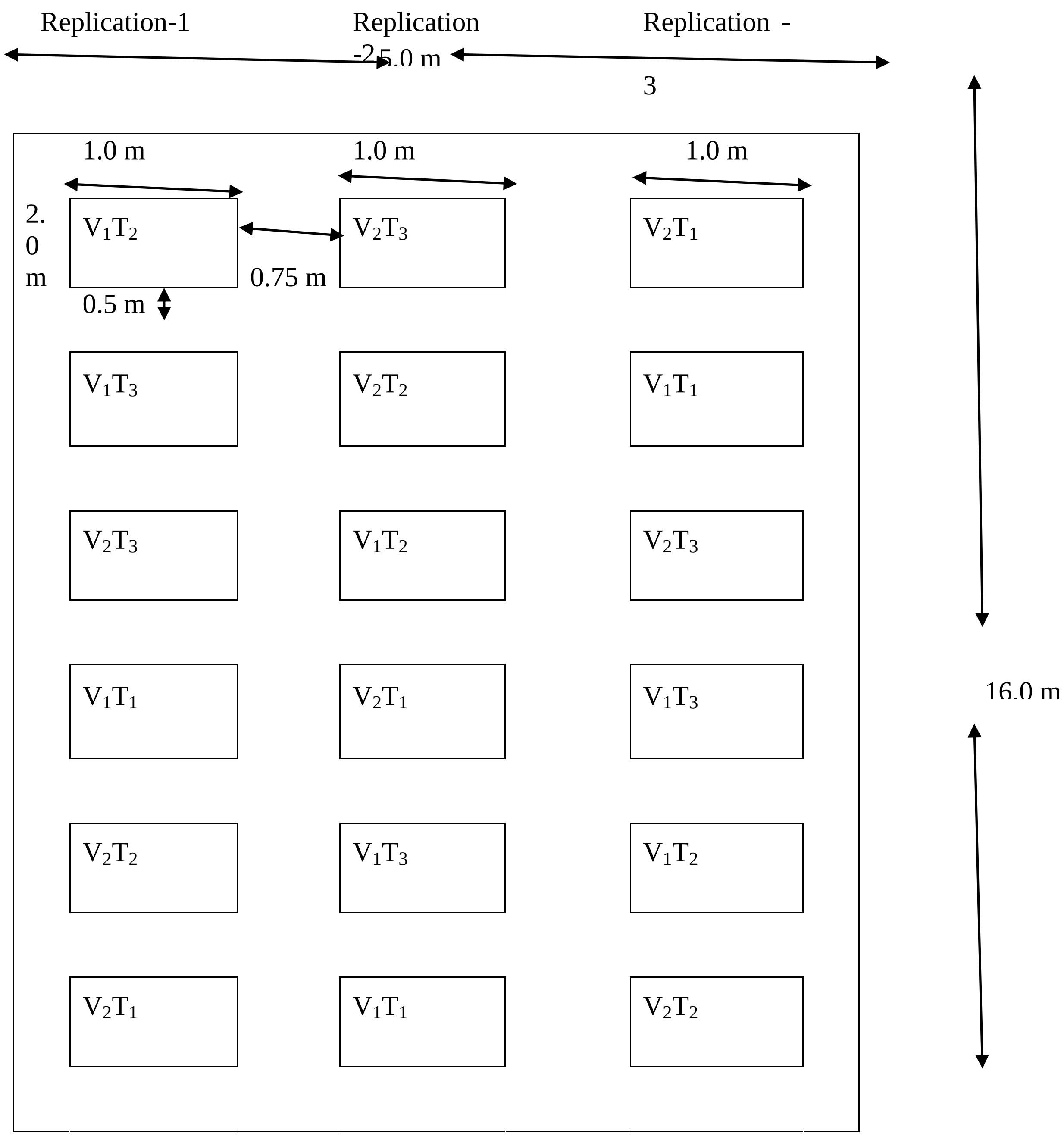

Figure 1. Field lay-out of the experiment

3.7. Raising of seedling and transplanting

Tomato seed (Vatiety: BARI Tomato-14 and BARI Tomato-15) were collected from BARI, Gazipur, Dhaka. A small seedbed measuring 5m × 1m was prepared and seeds were sown in the nursery bed at SAU Experimental field on 05 October 2018. Standard seedling raising practice was followed (Rashid, 1999). The pots were lightly irrigated regularly for ensuring seed proper development of the seedlings. The seedbed was mulched for ensuring proper seed germination, proper growth and development of the seedlings. Thirty-days-old healthy seedlings were transplanted in polybag for hardening. After twenty days that seedlings were transplanted on 25 November 2018 in the experimental pot.

3.8 Manure and fertilizer

The fertilizers N, P, K in the form of Urea, Triple Super Phosphate (TSP), Muriate of Potash (MP) respectively and as an organic manure, Cow dung were applied.

Table 2. Doses of manures and fertilizer and their methods of application used for this experiment (Haque, 1993)

Manure/Fertilizer	Dose per ha (kg)	Basal dose (kg/ha)	Top dressing(kg/ha)	
			First*	Second**
Cow dung	5000	Entire amount	-	-
Urea	150	-	75	75
TSP	120	Entire amount	-	-
MP	110	Entire amount	-	-

*25 days after sowing, **45 days after sowing

Entire amount of cow dung, TSP and MP were applied during final land preparation. The entire amounts of urea were applied as top dressing in two equal splits at 25, 45 days after seed sowing.

3.9 Treatments

There are two tomato variety-

- V_1-BARI Tomato-14 and
- V_2-BARI Tomato-15.

Three types of irrigation water was used in this experiment.

- T_1-Normal Water
- T_2-Burigonga River Water
- T_3-Shitalokkha River Water

Therefore, Treatment combinations of this experiment were as follows:

Table 1. List of treatments used in the study

Treatment	Name
V_1T_1	BARI tomato 14 with normal water
V_1T_2	BARI tomato 14 with Burigonga River water
V_1T_3	BARI tomato 14 with Shitalokkha River water
V_2T_1	BARI tomato 15 with normal water
V_2T_2	BARI tomato 15 with Burigonga River water
V_2T_3	BARI tomato 15 with Shitalokkha River water

After transplanting light irrigation with different types of water was given to each pot at an interval of 2-3 days.

Plate 1: Different sources of water used as irrigation during experiment

3.10. Data recorded

- Fruit per plant
- Individual fruit weight

- Life time
- Harvest time
- Number of cluster per plant
- Number of flower per plant
- Number of fruit per cluster
- Yield per plant

3.11. Harvesting

As the seeds were sown in the field at times, the crops were harvested at different times. Fruits were harvested at two days interval when they attained edible stage. Fruit harvesting was started from 10 February, 2018 and was continued up to 10 March, 2018.

Plate 2. Healthy fruit

3.12 Yield per hectare

Total yield of tomato per hectare for each treatment was calculated in tons from cumulative fruit production in a pot.

3.19 Statistical analysis of data

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was done with the help of computer package MSTAT program (Gomez and Gomez, 1976). The treatment means were separated by Duncan's Multiple Range Test (DMRT).

CHAPTER IV

RESULTS AND DISCUSSION

This study was done to assess heavy metals on tomato which were grown by the irrigation water from polluted rivers at Horticulture farm, SAU, Dhaka. The results are collected in different parameters and then discussed it in bellow headings:

4.1. Effects of heavy metals on tomato variety

The average concentration of heavy metals like Cd, Pb, Cr and Ni in tomato are shown in Table 1. From this table it is revealed that the concentration of heavy metals were high in BARI tomato 15 than BARI tomato 14. Though there was no statistically difference among Pb, Cr and Ni but Cd. In case of Cd, 0.159 mg/kg Cd was found in BARI tomato 14 and 0.168 mg/kg in BARI tomato 15, both concentrations was the higher than the permissible concentration (0.05 mg/kg) by FAO. Again, 0.253 mg/kg Pb was found in BARI tomato 14 and 0.259 mg/kg in BARI tomato 15. Here, the both concentrations of Pb were higher than FAO recommended concentration (0.1 mg/kg). In case of Cr, the higher concentration (0.028 mg/kg) was found BARI tomato 15 and 0.025 mg/kg in BARI tomato 14. These concentrations were little bit higher that FAO permissible concentration (2.3 mg/kg). On the other hand, the 0.472 and 0.473 mg/kg Ni were found in BARI tomato 14 and BARI tomato 15, respectively. Both concentration of Ni in tomato were lower than FAO recommended level.

Table 1: Quantity of heavy metals found in tomato varieties

Variety	**Concentration of heavy metals (mg/kg)**			
	Cd	**Pb**	**Cr**	**Ni**
BARI tomato 14	0.159 ± 0.029 a	0.253 ± 0.099 a	0.025 ± 0.007 a	0.472 ± 0.059 a
BARI tomato 15	0.168 ± 0.032 b	0.259 ± 0.098 a	0.028 ± 0.007 a	0.473 ± 0.057 a
Permissible level by FAO (2011)	0.05	0.1	2.3	-

From this above findings it is revealed that, BARI tomato 15 uptake higher amount of heavy metals form soil than BARI tomato 14 in case of tomato irrigated of river polluted water. This study is strongly supported by different researchers like Ray *et al.* (2010), Pawan *et al.*(2013), Benti (2014) and Bambara *et al.* (2015).

4.2. Heavy metals found in irrigation water

The concentration of heavy metals in different sources of irrigation water were presented in Table 2. The concentration of Cadmium, Lead, Chromium and Nickel in irrigation water collected from normal irrigation source were 0.124, 0.137, 0.017 and 0.397 mg/kg, respectively. Meanwhile, the concentration of the same heavy metal parameters in irrigated water collected from Buriganga river were 0.188, 0.269, 0.032 and 0.497 mg/kg, respectively. And, the concentration of the same heavy metals in irrigated water collected from Sitalakkha river were 0.179, 0.364, 0.031 and 0.524 mg/kg, respectively. The irrigation water collected from Buriganga and Sitalakkha River were statistically similar and higher than the permissible level of FAO. Cd, Cr and Ni were high in the irrigation water collected from the rivers. The concentration of Pb was lower than the permissible limit of FAO.

Table 2: Quantity of heavy metals found in different river irrigation water

Treatments	**Concentration of heavy metals (mg/kg)**			
	Cd	**Pb**	**Cr**	**Ni**
Normal water	0.124 b	0.137 c	0.017 a	0.397 b
Buriganga river water	0.188 a	0.269 b	0.032 a	0.497 a
Sitalakkha river water	0.179 a	0.364 a	0.031 a	0.524 a
LSD (0.05)	0.055	0.055	0.055	0.055
CV (%)	0.72	0.45	4.16	1.59
FAO (1985)	0.1	0.5	0.01	0.2

From the above findings, it is revealed that the irrigation water of Buriganga and Sitalakkha river were highly contaminated by heavy metals like Cd, Pb, Cr and Ni. So, the concentration of heavy metals in the vegetables become high due to this types of irrigation water. The normal water source mainly ground water contain also these heavy metals but the concentration of these heavy metals remain lower. This study was strongly supported by different researchers like Kawatra and Bakhetia (2008) and Singh *et al.* (2010).

4.3. Effect of heavy metals in tomato irrigated by the polluted water

The effect of the heavy metals concentration in tomato irrigated by the polluted water were given in the Table 3. The concentration of Cd was high (0.194 mg/kg) in case of V_2T_2 comprised with BARI tomato 15 irrigated with Buriganga river water and followed by V_2T_3, V_1T_2 and V_1T_3. The lowest concentration (0.121 mg/kg) of Cd was found in V_1T_1 comprised with BARI tomato 14 irrigated with normal water which was statistically similar with V_2T_1. In case of Pb, the highest concentration was found in V_2T_3 (0.366 mg/kg) comprised with BARRI tomato 15 irrigated with Sitalakkha river water, which was statistically similar with V_1T_3 and followed by V_2T_2 and V_1T_2. On the other hand, the lowest concentration of Pb (0.134 mg/kg) was found in V_1T_1 comprised with BARI tomato 14 irrigated with normal water which was statistically similar with V_2T_1. In case of Cr, the highest concentration was found in V_2T_2 (0.033 mg/kg) comprised with BARRI tomato 15 irrigated with Sitalakkha river water, which was statistically similar with V_2T_3, V_1T_2 and V_1T_3. On the other hand, the lowest concentration of Cr (0.015 mg/kg) was found in V_1T_1 comprised with BARI tomato 14 irrigated with normal water which was statistically similar with V_2T_1. In the term of Ni, the highest concentration was found in V_1T_3 (0.526 mg/kg) comprised with BARRI tomato 14 irrigated with Sitalakkha river water, which was statistically similar with V_2T_3 and followed by V_2T_2 and V_1T_2. On the other hand, the lowest concentration of Ni (0.395 mg/kg) was found in V_1T_1 comprised with BARI tomato 14 irrigated with normal water which was statistically similar with V_2T_1.

Table 3: Quantity of heavy metals (mg/kg) in tomato irrigated by the polluted water

Sources	BARI tomato 14				BARI tomato 15			
	Cd	**Pb**	**Cr**	**Ni**	**Cd**	**Pb**	**Cr**	**Ni**
Normal water	0.121 d	0.134 c	0.015 b	0.395 c	0.126 d	0.140 c	0.018 b	0.399 c
Buriganga river water	0.181 b	0.265 b	0.030 a	0.495 b	0.194 a	0.272 b	0.033 a	0.499 b
Sitalakkha river water	0.175 c	0.361 a	0.030 a	0.526 a	0.183 b	0.366 a	0.032 a	0.521 a

From this above findings it is revealed that, BARI tomato 14 irrigated with normal water showed the best result and contain low amount of heavy metal concentrations and BARI tomato 15 contain high amount of heavy metal concentration. This result is more or less similar with Misra and Mani (1991) and Bennett (1993).

4.4. Effect of polluted water on soil

The average concentration of heavy metals like Cd, Pb, Cr and Ni in soil are shown in Table 4. From this table it is revealed that the concentration of heavy metals of soil collected from the tomato field before irrigation were Pb (7.79 ppm), Cd (0.10 ppm), Cr (50.0 ppm) and Ni (25.52 ppm) respectively. Again, the concentration level of heavy metals into soil collected from the same field after irrigation were Pb (8.39 ppm), Cd (0.27 ppm), Cr (54.0 ppm) and Ni (29.63 ppm), respectively.

Table 4: Concentration of heavy metals found in soil collected from the tomato field

Specification	Amount of heavy metal found in soil (ppm)		
	Before irrigation	**After irrigation**	**% Increase**
Pb	7.79	8.39	7.70
Cd	0.10	0.27	170.00
Cr	50.0	54.0	8.00

Ni	25.52	29.63	16.11

From this above findings it is revealed that, the concentration of heavy metals of tomato field was higher after irrigation of tomato field with river polluted water. The concentration of Pb, Cd and Cr were higher than the sufficient level, but in case of Ni, the concentration of Ni was lower than the sufficient level. This study is strongly supported by different researchers like Benti (2014) and Bambara *et al.* (2015).

4.5. Effect of polluted water irrigated to tomato

4.5.1. Number of cluster per plant

Effect of cluster number per plant of tomato were given in Table 4. The highest number of cluster of tomato per plant (13.67) was recorded in V_1T_1 comprised with BARRI tomato 14 irrigated with normal water, followed by V_1T_2, V_1T_3, V_2T_2 and V_2T_3. On the other hand, the lowest number of cluster per plant (10.33) was found in V_2T_1 comprised with BARI tomato 15 irrigated with normal water.

From the findings it is revealed that, the highest number of cluster per plant was observed in BARI tomato 14 irrigated with normal water whereas the lowest number of cluster per plant was observed in BARI tomato 15 irrigated with normal water.

4.5.2. Number of flower per cluster

Effect of flower number per cluster of tomato were given in Table 4. The highest number of flower per cluster (5.33) was recorded in V_1T_1 comprised with BARRI tomato 14 irrigated with normal water, followed by V_1T_2 and V_1T_3. On the other hand, the lowest number of flower per cluster (4.33) was found in V_2T_1 comprised with BARI tomato 15 irrigated with normal water which was similar with V_2T_2 and V_2T_3.

From the findings it is revealed that, the highest number of flower per cluster was observed in BARI tomato 14 irrigated with normal water whereas the lowest number of flower per cluster was observed in BARI tomato 15 irrigated with normal water.

4.5.3. Number of fruit per cluster

Effect of fruit number per cluster of tomato were given in Table 4. The highest number of fruit per cluster (3.67) was recorded in V_1T_1 comprised with BARRI tomato 14 irrigated with normal water, followed by V_2T_1, V_1T_2 and V_2T_2. On the other hand, the lowest number of fruit per cluster (2.67) was found in V_2T_3 comprised with BARI tomato 15 irrigated with Sitalakkha river water.

From the findings it is revealed that, the highest number of fruit per cluster was observed in BARI tomato 14 irrigated with normal water whereas the lowest number of fruit per cluster was observed in BARI tomato 14 irrigated with Sitalakkha river water.

Table 5: Effect of number of flower per cluster, number of cluster per plant and number of fruit per cluster by the irrigation with polluted water to tomato

Combinations	No. cluster/plant	No. flower/cluster	No. fruit/cluster
V_1T_1	13.67 a	5.33 a	3.67 a
V_1T_2	13.00 b	4.67 b	3.00 c
V_1T_3	12.67 c	4.67 b	2.67 d
V_2T_1	10.33 e	4.33 c	3.33 b
V_2T_2	11.67 d	4.33 c	3.00 c
V_2T_3	11.33 d	4.33 c	2.67 d
LSD (0.05)	1.82	0.99	0.91
CV (%)	8.70	12.52	16.94

[V_1T_1= BARI tomato 14 irrigated with normal water; V_1T_2= BARI tomato 14 irrigated with Buriganga river water; V_1T_3= BARI tomato 14 irrigated with Sitalakkha river water; V_2T_1= BARI tomato 15 irrigated with normal water; V_2T_2= BARI tomato 15 irrigated with Buriganga river water; V_2T_3= BARI tomato 15 irrigated with Sitalakkha river water]

4.5.4. Life time of tomato

Effect of life time of tomato were given in Table 5. The highest life time of tomato (114.00) was recorded in V_2T_1 comprised with BARRI tomato 15 irrigated with normal water, which was statistically similar with V_2T_3, and followed by V_2T_2. On the other hand, the lowest life time was (101.00) was found in V_1T_2 comprised with BARI tomato 14 irrigated with Buriganga river water, V_1T_3 and V_1T_1.

From the findings it is revealed that, the highest life time of tomato was observed in BARI tomato 14 irrigated with normal water whereas the lowest life time of tomato was observed in BARI tomato 14 irrigated with Buriganga river water.

4.5.5. Duration of tomato harvest

Effect of harvested time of tomato were given in Table 5. The highest harvest time of tomato (66.00 days) was recorded in V_1T_1 comprised with BARRI tomato 14 irrigated with normal water, which was statistically similar with V_1T_2, and V_1T_3. On the other hand, the lowest harvested time was (46.33 days) was found in V_2T_3 comprised with BARI tomato 15 irrigated with Sitalakkha river water, which was followed by V_1T_2 and V_1T_1.

From the findings it is revealed that, the highest harvested time of tomato was observed in BARI tomato 14 irrigated with normal water whereas the lowest harvested time of tomato was observed in BARI tomato 15 irrigated with Sitalakkha river water.

Table 6: Effect of life time and harvested duration of tomato irrigated with polluted water

Combinations	Life time of tomato	Harvested time of tomato

V_1T_1	104.67 c	66.00 a
V_1T_2	101.00 cd	65.33 ab
V_1T_3	103.00 c	65.33 ab
V_2T_1	114.00 a	46.33 d
V_2T_2	109.67 b	48.00 c
V_2T_3	111.67 a	46.33 d
LSD (0.05)	2.44	3.25
CV (%)	1.32	3.25

[V_1T_1= BARI tomato 14 irrigated with normal water; V_1T_2= BARI tomato 14 irrigated with Buriganga river water; V_1T_3= BARI tomato 14 irrigated with Sitalakkha river water; V_2T_1= BARI tomato 15 irrigated with normal water; V_2T_2= BARI tomato 15 irrigated with Buriganga river water; V_2T_3= BARI tomato 15 irrigated with Sitalakkha river water]

4.6. Yield attributed

4.6.1. Number of fruit per plant

Effect of number of fruit per plant of tomato were given in Table 6. The highest number of fruit of tomato per plant (42.67) was recorded in V_1T_1 comprised with BARRI tomato 14 irrigated with normal water, followed by $V_1T_{2,}$ and V_1T_3. On the other hand, the lowest number of fruit per plant (28.33) was found in V_2T_2 comprised with BARI tomato 15 irrigated with Buriganga river water.

From the findings it is revealed that, the highest number of fruit per plant was observed in BARI tomato 14 irrigated with normal water whereas the lowest number of fruit per plant was observed in BARI tomato 15 irrigated with Buriganga river water.

4.6.2. Single fruit weight of tomato

Effect of single fruit weight of tomato were given in Table 6. The highest single fruit weight of tomato (91.67 gm) was recorded in V_2T_1 comprised with BARRI tomato 15 irrigated with normal water, followed by $V_2T_{2,}$ and V_2T_3. On the other hand, the lowest single fruit weight (64.67 gm) was found in V_1T_3 comprised with BARI tomato 14 irrigated with Sitalakkha river water.

From the findings it is revealed that, the highest single fruit weight was observed in BARI tomato 15 irrigated with normal water whereas the lowest single fruit weight was observed in BARI tomato 14 irrigated with Sitalakkha river water.

4.6.3. Yield of tomato

Effect of yield of tomato plant were given in Table 6. The highest yield of tomato per plant (2.99 kg/plant) was recorded in V_1T_1 comprised with BARRI tomato 14 irrigated with normal water, which was statistically similar with V_2T_1, and followed by V_2T_3. On the other hand, the lowest yield of tomato per plant (2.48 kg/plant) was found in V_1T_3 comprised with BARI tomato 14 irrigated with Sitalakkha river water.

From the findings it is revealed that, the highest yield of tomato per plant was observed in BARI tomato 14 irrigated with normal water whereas the lowest yield of tomato per plant was observed in BARI tomato 14 irrigated with Sitalakkha river water.

Table 7: Effect of number of fruit per plant, single fruit weight and yield of tomato irrigated with polluted water

Combinations	No. fruit/plant	Single fruit wt. (gm)	Yield (kg/plant)
V_1T_1	42.67 a	70.00	2.99 a
V_1T_2	38.67 b	66.67	2.58 c
V_1T_3	38.33 b	64.67	2.48 d
V_2T_1	32.00 c	91. 67	2.93 a
V_2T_2	28.33 e	90.00	2.55 c
V_2T_3	30.67 d	90.67	2.78 b
LSD (0.05)	1.82	2.76	3.25
CV (%)	3.00	2.02	0.69

[V_1T_1= BARI tomato 14 irrigated with normal water; V_1T_2= BARI tomato 14 irrigated with Buriganga river water; V_1T_3= BARI tomato 14 irrigated with Sitalakkha river water; V_2T_1= BARI tomato 15 irrigated with normal water; V_2T_2= BARI tomato 15 irrigated with Buriganga river water; V_2T_3= BARI tomato 15 irrigated with Sitalakkha river water]

4.7. Relationship between heavy metal in irrigation water and tomato fruit

4.7.1. In case of Cadmium

Relationship of concentration of Cd between irrigation water sample and tomato fruit was shown in Figure 1. From this regression analysis, it was evident that the concentration level of Cd was higher in irrigation water sample than the concentration of Cd of tomato fruit. So, from Figure 1 we can concluded that, the higher concentration of Cd level in irrigation water is responsible for the higher concentration of Cd in tomato fruit. So, Cd level is higher in vegetable found where Cd polluted water is used as irrigation to agricultural field.

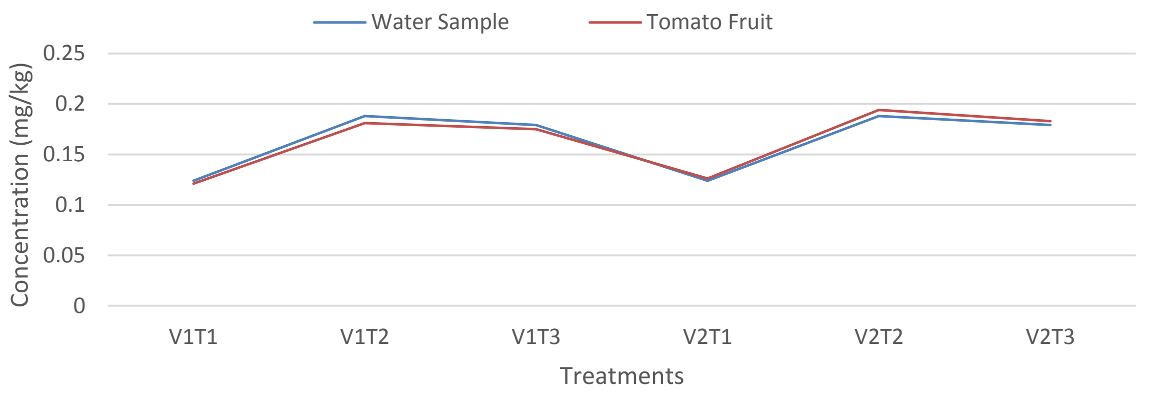

Figure 1: Relationship of concentration of Cd between water sample and tomato fruit

4.7.2. In case of Lead

Relationship of concentration of Pb between irrigation water sample and tomato fruit was shown in Figure 2. From this regression analysis, it was evident that the concentration level of Pb was higher in irrigation water sample than the concentration of Pb of tomato fruit. So, from Figure 1 we can concluded that, the higher concentration of Pb level in irrigation water is responsible for the higher concentration of Pb in tomato fruit. So, Pb level is higher in vegetable found where Pb polluted

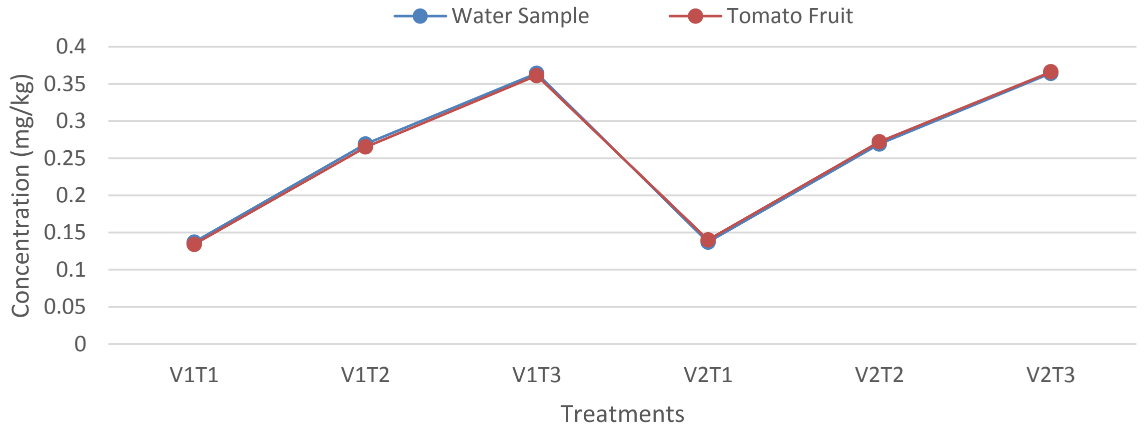

Figure 2: Relationship of concentration of Pb between water sample and tomato fruit

water is used as irrigation to agricultural field.

4.7.3. In case of Chromium

Relationship of concentration of Cr between irrigation water sample and tomato fruit was shown in Figure 3. From this regression analysis, it was evident that the concentration level of Cr was higher in irrigation water sample than the concentration of Cr of tomato fruit. So, from Figure 3 we can concluded that, the higher

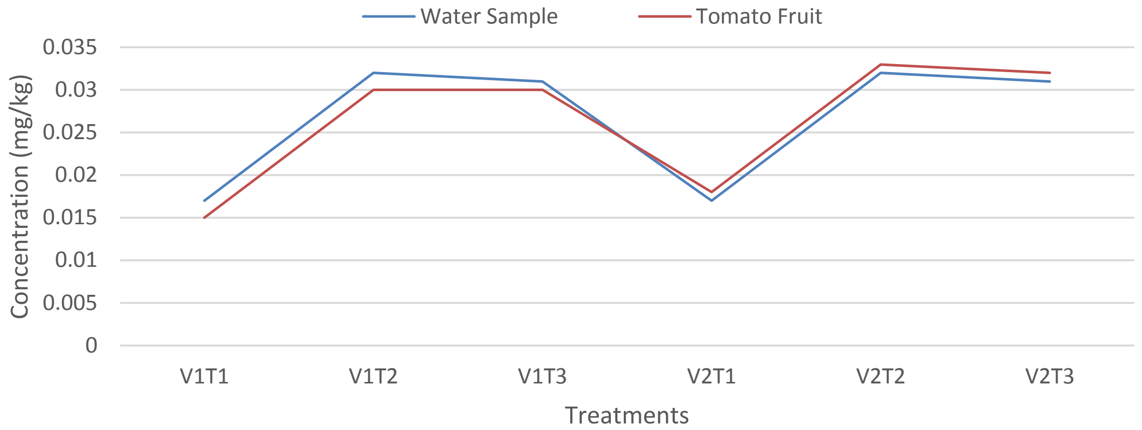

Figure 3: Relationship of concentration of Cr between water sample and tomato fruit

concentration of Cr level in irrigation water is responsible for the higher concentration of Cr in tomato fruit. So, Cr level is higher in vegetable found where Cr polluted water is used as irrigation to agricultural field.

4.7.4. In case of Nichel

Relationship of concentration of Ni between irrigation water sample and tomato fruit was shown in Figure 4. From this regression analysis, it was evident that the concentration level of Ni was higher in irrigation water sample than the concentration of Ni of tomato fruit. So, from Figure 4 we can concluded that, the higher concentration of Ni level in irrigation water is responsible for the higher concentration of Ni in tomato fruit. So, Ni level is higher in vegetable found where Ni polluted water is used as irrigation to agricultural field.

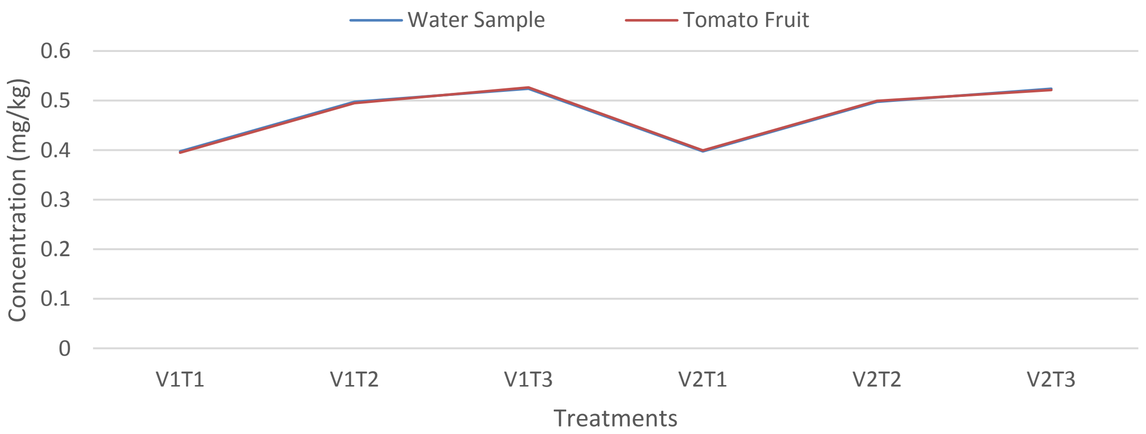

Figure 4: Relationship of concentration of Ni between water sample and tomato fruit

4.8. Relationship between the accumulation of heavy metal by tomato and number of fruits per plant

4.8.1. Relationship with Cd concentration

Correlation study was done to establish the relationship between Cd concentration and number of tomato fruit per fruit during the production of tomato. From the study it was revealed that significant correlation was observed between the Cd concentration and total number of tomato fruit per plant (Figure 5). It was evident from the Figure 5 that the regression equation y = -80.364x + 48.238 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.206) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between Cd concentration and total number of tomato fruit per plant, i.e., the fruit number decreased with the increase of Cd concentration.

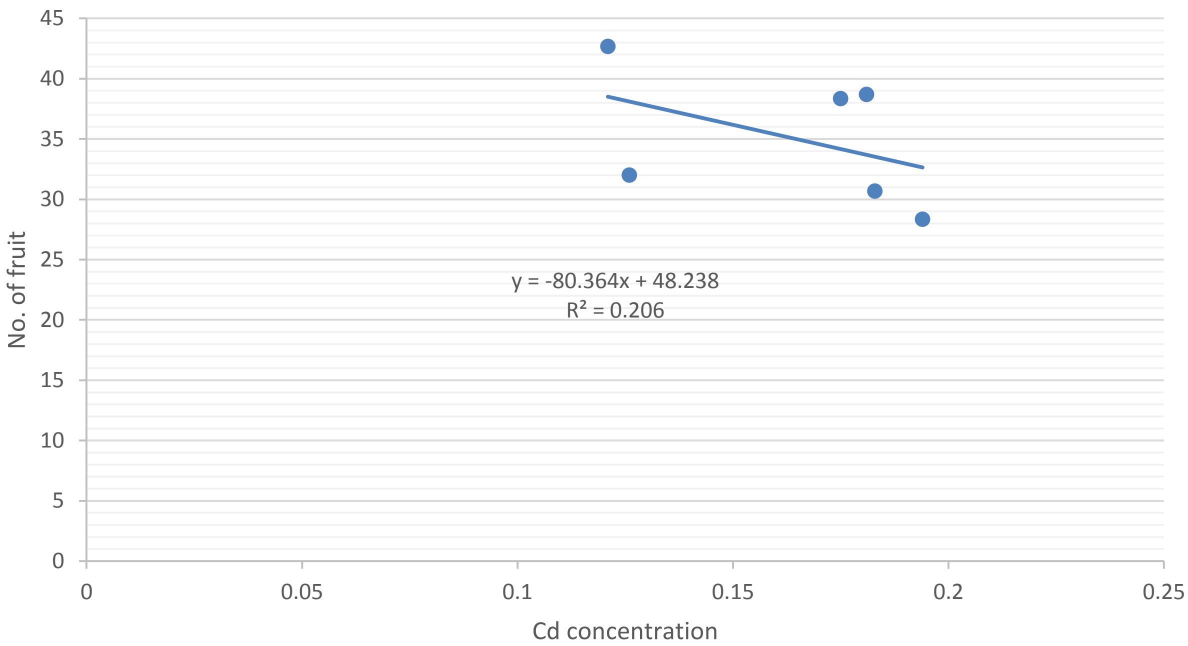

Figure 5: Relation between Cd accumulation by tomato plant and number of fruit per plant

4.8.2. Relationship with Pb concentration

Correlation study was done to establish the relationship between Pb concentration and number of tomato fruit per plant during the production of tomato. From the study it was revealed that significant correlation was observed between the Pb concentration and total number of tomato fruit per plant (Figure 6). It was evident from the Figure 6 that the regression equation y = -15.218x + 39.013 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.0771) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between Pb concentration and total number of tomato fruit per plant, i.e., the fruit number decreased with the increase of Pb concentration.

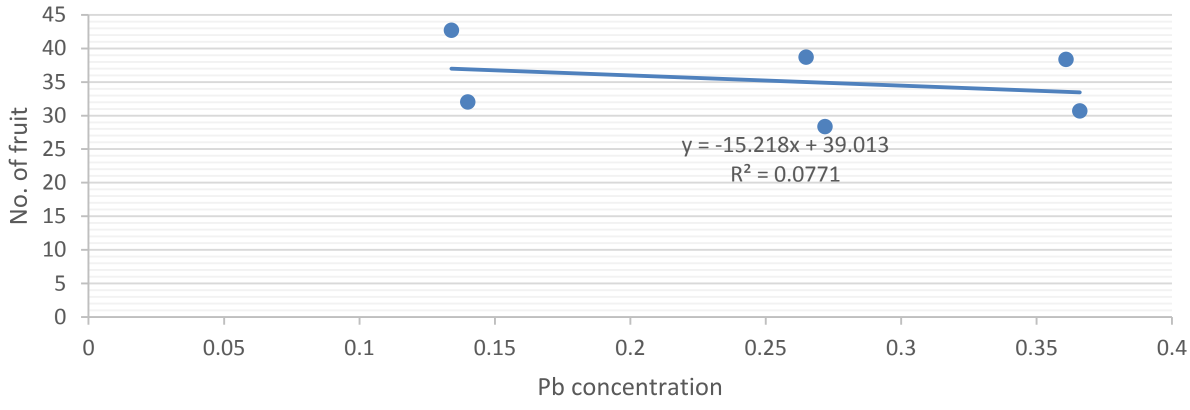

Figure 6: Relation between Pb accumulation by tomato plant and number of fruit per plant

4.8.3. Relationship with Cr concentration

Correlation study was done to establish the relationship between Cr concentration and number of tomato fruit per plant during the production of tomato. From the study it was revealed that significant correlation was observed between the Cr concentration and total number of tomato fruit per plant (Figure 7). It was evident from the Figure 7 that the regression equation y = -349.33x + 44.311 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.2364) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between Cr concentration and total number of tomato fruit per plant, i.e., the fruit number decreased with the increase of Cr concentration.

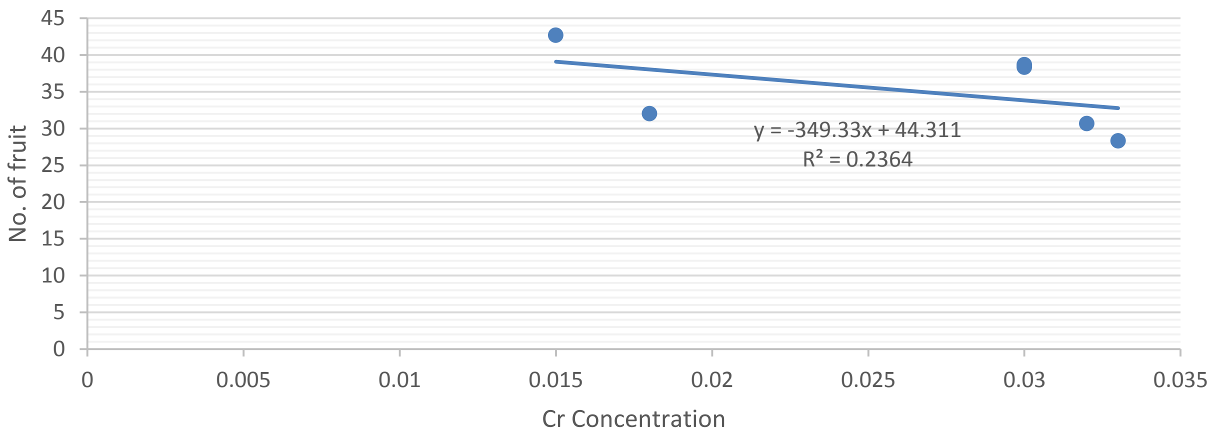

Figure 7: Relation between Cr accumulation by tomato plant and number of fruit per plant

4.8.4. Relationship with Ni concentration

Correlation study was done to establish the relationship between Ni concentration and number of tomato fruit per plant during the production of tomato. From the study it was revealed that significant correlation was observed between the Ni concentration and total number of tomato fruit per plant (Figure 8). It was evident from the Figure 8 that the regression equation y = -28.038x + 48.359 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.0901) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between Ni concentration and total number of tomato fruit per plant, i.e., the fruit number decreased with the increase of Ni concentration.

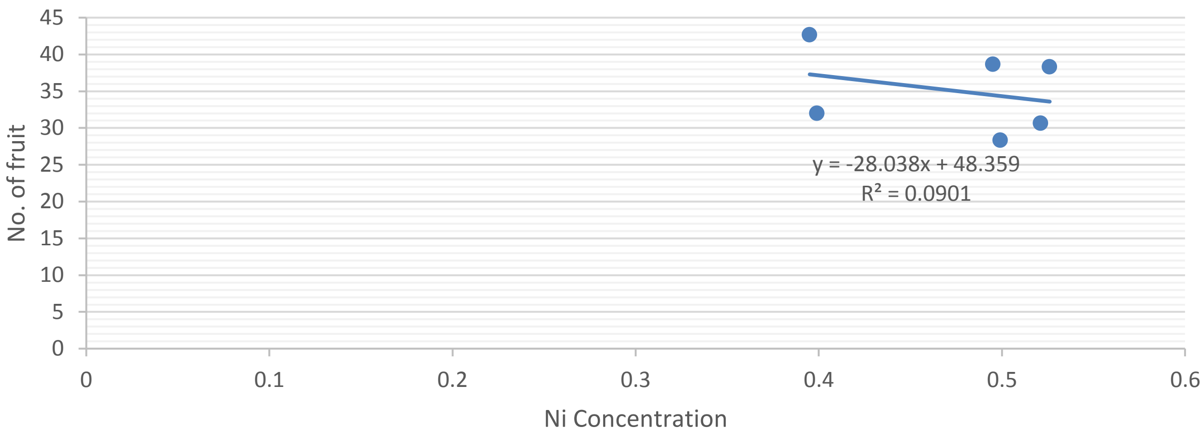

Figure 8: Relation between Ni accumulation by tomato plant and number of fruit per plant

4.9. Relationship between the accumulation of heavy metal by tomato plant and yield of fruits (kg) per plant

4.9.1. Relationship with Cd concentration

Correlation study was done to establish the relationship between Cd concentration and yield of tomato (kg) per plant during the production of tomato. From the study it was revealed that significant correlation was observed between the Cd concentration and yield of tomato fruit per plant (Figure 9). It was evident from the Figure 9 that the regression equation $y = -5.7599x + 3.6591$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.7261$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between Cd concentration and yield of tomato fruit (kg) per plant, i.e., the yield decreased with the increase of Cd concentration.

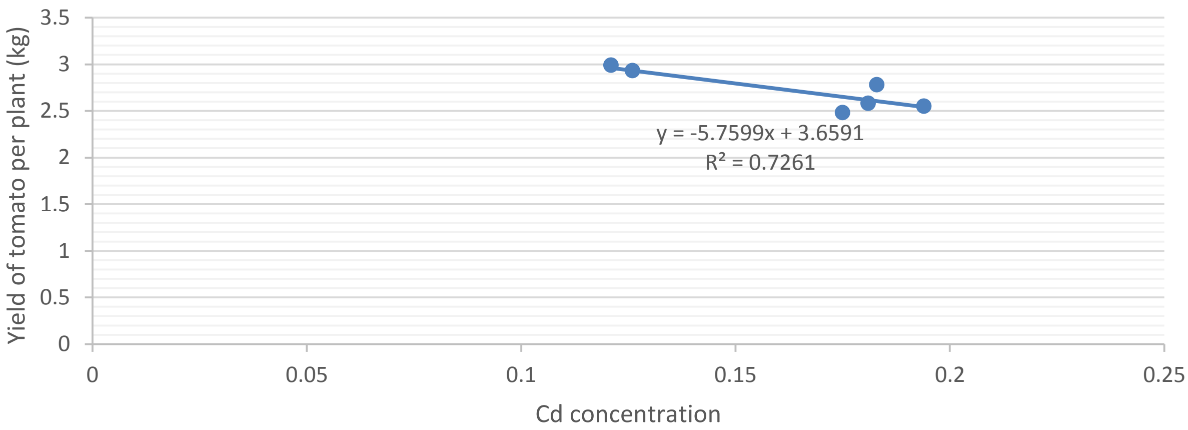

Figure 9: Relation between Cd accumulation by tomato plant and yield of tomato (kg) per plant

4.9.2. Relationship with Pb concentration

Correlation study was done to establish the relationship between Pb concentration and yield of tomato (kg) per plant during the production of tomato. From the study it was revealed that significant correlation was observed between the Pb concentration and yield of tomato fruit per plant (Figure 10). It was evident from the Figure 10 that the regression equation y = -1.542x + 3.1136 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.5433) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between Pb concentration and yield of tomato fruit (kg) per plant, i.e., the yield decreased with the increase of Pb concentration.

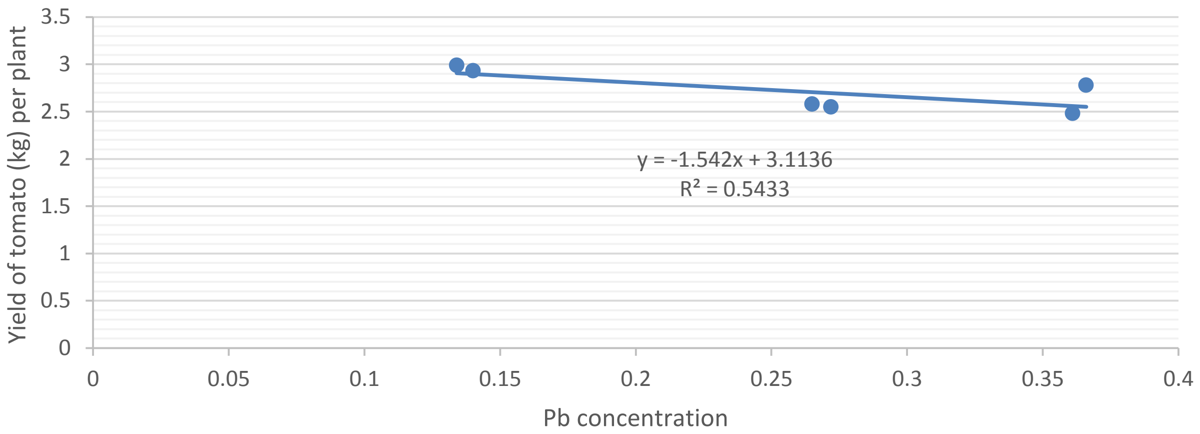

Figure 10: Relation between Pb accumulation by tomato plant and yield of fruit (kg) per plant

4.9.3. Relationship with Cr concentration

Correlation study was done to establish the relationship between Cr concentration and yield of tomato (kg) per plant during the production of tomato. From the study it was revealed that significant correlation was observed between the Cr concentration and yield of tomato fruit per plant (Figure 11). It was evident from the Figure 11 that the regression equation y = -23.219x + 3.3298 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.7167) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between Cr concentration and yield of tomato fruit (kg) per plant, i.e., the yield decreased with the increase of Cr concentration.

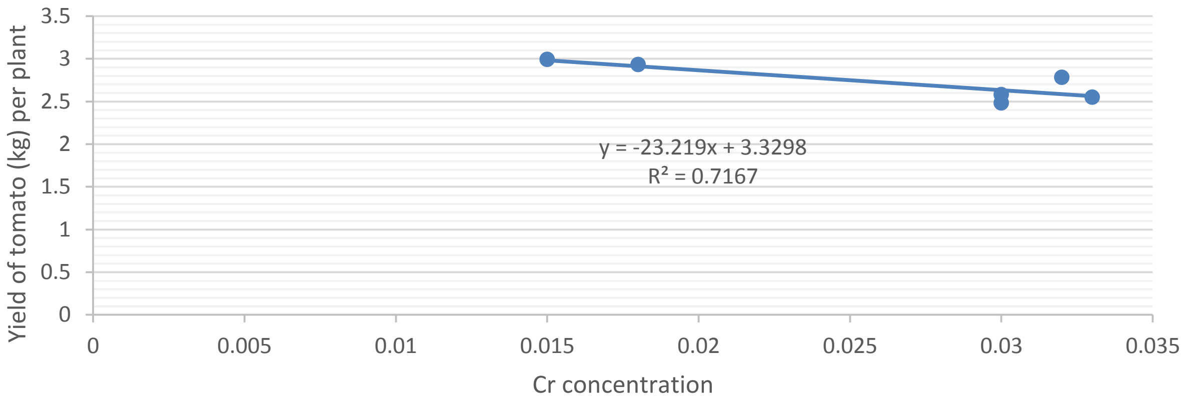

Figure 11: Relation between Cr accumulation by tomato plant and yield of fruit (kg) per plant

4.9.4. Relationship with Ni concentration

Correlation study was done to establish the relationship between Ni concentration and yield of tomato (kg) per plant during the production of tomato. From the study it was revealed that significant correlation was observed between the Ni concentration and yield of tomato fruit per plant (Figure 12). It was evident from the Figure 12 that the regression equation y = -3.0253x + 4.1478 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.7199) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between Ni concentration and yield of tomato fruit (kg) per plant, i.e., the yield decreased with the increase of Ni concentration.

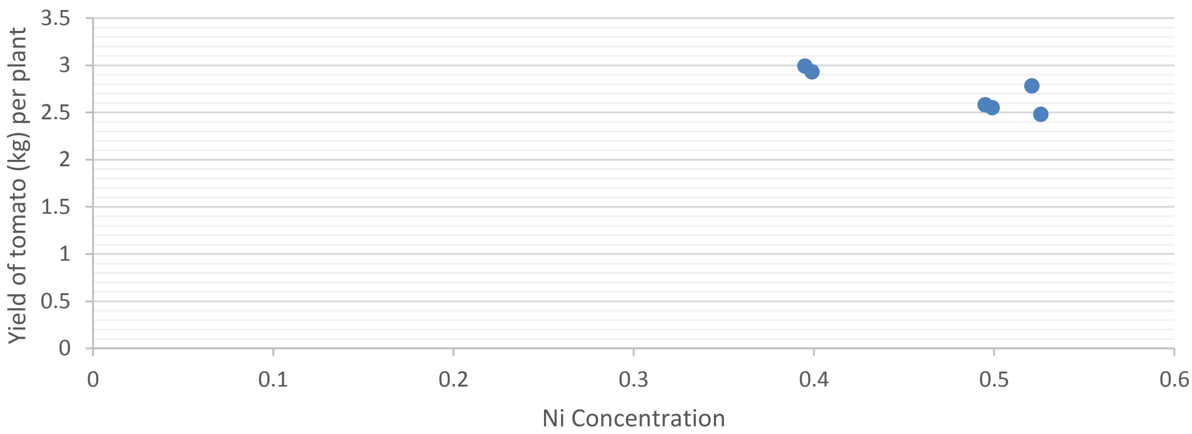

Figure 12: Relation between Ni accumulation by tomato plant and yield of fruit (kg) per plant

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the horticulture experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2018 to March, 2019 to assess of heavy metal on tomato grown by irrigation water from polluted river. The experiment consisted of two tomato varieties and three types of irrigation water.

SUMMARY

The concentration of heavy metals were high in BARI tomato 15 than BARI tomato 14. Though there was no statistically difference among Pb, Cr and Ni but Cd. In case of Cd, 0.159 mg/kg Cd was found in BARI tomato 14 and 0.168 mg/kg in BARI tomato 15, both concentrations was the higher than the permissible concentration (0.05 mg/kg) by FAO. Again, 0.253 mg/kg Pb was found in BARI tomato 14 and 0.259 mg/kg in BARI tomato 15. Here, the both concentrations of Pb were higher than FAO recommended concentration (0.1 mg/kg). In case of Cr, the higher concentration (0.028 mg/kg) was found BARI tomato 15 and 0.025 mg/kg in BARI tomato 14. These concentrations were little bit higher that FAO permissible concentration (2.3 mg/kg). On the other hand, the 0.472 and 0.473 mg/kg Ni were found in BARI tomato 14 and BARI tomato 15, respectively. Both concentration of Ni in tomato were lower than FAO recommended level. So, it is revealed that BARI tomato 15 uptake higher amount of heavy metals form soil than BARI tomato 14 in case of tomato irrigated of river polluted water.

The concentration of Cadmium, Lead, Chromium and Nickel in irrigation water collected from normal irrigation source were 0.124, 0.137, 0.017 and 0.397 mg/kg, respectively; while, it were 0.188, 0.269, 0.032 and 0.497 mg/kg, respectively in

Buriganga river water and 0.179, 0.364, 0.031 and 0.524 mg/kg, respectively in Sitalakkha river water. The irrigation water collected from Buriganga and Sitalakkha River were statistically similar and higher than the permissible level of FAO. Cd, Cr and Ni were high in the irrigation water collected from the rivers.

The highest number of cluster per plant was observed in BARI tomato 14 irrigated with normal water whereas the lowest number of cluster per plant was observed in BARI tomato 15 irrigated with normal water.

The highest number of flower per cluster was observed in BARI tomato 14 irrigated with normal water whereas the lowest number of flower per cluster was observed in BARI tomato 15 irrigated with normal water.

The highest number of fruit per cluster was observed in BARI tomato 14 irrigated with normal water whereas the lowest number of fruit per cluster was observed in BARI tomato 14 irrigated with Sitalakkha river water.

The highest life time of tomato (114.00) was recorded in V_2T_1 comprised with BARI tomato 15 irrigated with normal water and the lowest life time was (101.00) was found in V_1T_2 comprised with BARI tomato 14 irrigated with Buriganga river water.

The highest harvest time of tomato (66.00 days) was recorded in V_1T_1 comprised with BARI tomato 14 irrigated with normal water and lowest harvested time was (46.33 days) was found in V_2T_3 comprised with BARI tomato 15 irrigated with Sitalakkha river water.

The highest number of fruit of tomato per plant (42.67) was recorded in V_1T_1 comprised with BARRI tomato 14 irrigated with normal water whereas the lowest number of fruit per plant (28.33) was found in V_2T_2 comprised with BARI tomato 15 irrigated with Buriganga river water.

The highest single fruit weight of tomato (91.67 gm) was recorded in V_2T_1 comprised with BARI tomato 15 irrigated with normal water but the lowest single fruit weight (64.67 gm) was found in V_1T_3 comprised with BARI tomato 14 irrigated with Sitalakkha river water.

From the correlation curve it was found that there are negative relationship between heavy metal concentration and fruit weight except Cd and Ni. Same result was also found in case of total number of fruit per plant and yield of tomato (kg) per plant. That means that, single fruit weight, total no. of fruit as well as total yield of fruit decreased with the increase of the accumulation of heavy metal from irrigation water by the plant.

CONCLUSION

From the present study, it may be concluded that the concentration of heavy metal in Buriganga and Sitalakkha river water was high than the permissible level of FAO. On the other hand the accumulation of heavy metal was higher in BARI tomato 15 compare to BARI tomato 14. The overall study revealed that the highest performance was achieved from BARI Tomato 14 irrigated with normal water at 3 days interval showed better performance against heavy metal concentration. The number of cluster per plant, number of flower per cluster, number of fruit per cluster, harvest duration, number of fruit per plant were higher in BARI Tomato 14 which were irrigated with normal water. On the other hand, the life duration and the single fruit weight is higher in BARI Tomato 15 variety which were irrigated with normal water. Considering the results of the present study and environmental issues it can be concluded that irrigation water is a major factor for tomato cultivation.

Considering the findings of the study the following recommendations can be drawn:

1. River water should be less used for irrigation of vegetables like tomato, brinjal etc.
2. BARI Tomato 14 variety should be more used to cultivation where safe irrigation water is inadequate.
3. Further study should be needed in different locations of Bangladesh for accuracy of the results obtained from the present experiment.

CHAPTER VI
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