YIELD AND QUALITY OF TOMATO AS AFFECTED BY DIFFERENT METHODS OF IRRIGATION WITH MUNICIPAL WASTEWATER

A THESIS
BY

PRITHA SARKER
Examination Roll No.: 1605563
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MASTER OF SCIENCE (MS)
IN
IRRIGATION AND WATER MANAGEMENT

DEPARTMENT OF AGRICULTURAL AND INDUSTRIAL ENGINEERING

HAJEE MOHAMMED DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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Dedicated
To My
Beloved Parents
And
Respected Teachers

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I express the deepest sense of gratefulness to the “Almighty God” who has enabled me to complete the thesis work. I take the opportunity with pride and enormous gratification to express the feelings of thanks and gratefulness from the bottom of my heart to all of the persons who backed me directly or indirectly throughout the materialization of this research work at this magnitude.

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The Author

ABSTRACT

Proper irrigation methods and management can help farmers to harvest the benefits of wastewater irrigation while minimizing the risk of its use for crop production. The study was carried out at the outskirt of Rajshahi city of Bangladesh during November 2017 – March 2018 to investigate the effect of municipal wastewater (hereafter called wastewater) irrigation on the yield and quality of tomato under different irrigation methods. Five irrigation methods- viz., M1: traditional furrow irrigation (TFI), M2: alternate furrow irrigation (AFI), M3: bed and furrow irrigation (BFI) with wastewater at 10 days intervals, M4: drip irrigation at 3 days interval and M5: flood irrigation with wastewater were tested in a Randomized Complete Block Design (RCBD) with three replications. The yield contributing characters and yield of tomato under four different improved irrigation methods were compared with the flood irrigation method. Almost all yield contributing parameters like number and weight of fruit per plant were varied significantly when compared with flood irrigation system. Among the irrigation methods, drip irrigation gave the highest fruit yield of tomato (80.86 t/ha) and the yield under AFI (73.67 t/ha), BFI (72.58 t/ha) and TFI (70.86 t/ha) were identical and the lowest yield (50.42 t/ha) was obtained from flood irrigation. Like yield, the highest number and weight of fruit per plant were also obtained from drip irrigation. The effects of irrigation systems on water use and water productivity were also evaluated. Total water use ranged from 234 to 385 mm with minimum in drip irrigation and maximum in flood irrigation. Among the different furrow irrigation systems, water use was found higher in TFI system than that of AFI and BFI systems. As far as biological quality is concerned, drip irrigation found the best with the lowest bacterial contamination compared to other irrigation techniques. BFI was also found good where contamination considerably reduced. So, these irrigation techniques need to be practiced by the wastewater farmers to improve the product quality by reducing the contamination and to protect consumer health.

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LISTS OF SYMBLES, ABBREVIATIONS AND ELABORATIONS

AEZ	Agro-ecological Zone
AFI	Alternate Furrow Irrigation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBFI	Broad Bed Furrow Irrigation
BBS	Bureau of Bangladesh Statistics
BOD	Biochemical Oxygen Demand
CFU	Colony-Forming Unit
CV	Coefficient of variation
DAP	Days after planting
DI	Drip Irrigation
ds	Deci Siemen
EC	Electrical Conductivity
FAO	Food and Agricultural Organization
FC	Fecal Coliform
FI	Flood Irrigation
g	Gram
ha	Hectare
IW	Irrigation Water
LSD	Least Significant Difference
MT	Metric Ton
ns	Non-significant
RFD	Recommended Fertilizer Dose
T	Ton
TC	Total Coliform
TDS	Total Dissolved Solids
TFI	Traditional Furrow Irrigation
WPI	Irrigation Water Productivity

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

1.1 Background

Now a days irrigated agriculture throughout the world is facing problem due to the decreasing of freshwater availability. The agriculture of Bangladesh is also under pressure for growing more food with limited resources such as land and water to feed her ever-increasing population. Not only the availability of land and water resources is decreasing, but also the productivity of land is decreasing for intensive cultivation without supplementing adequate organic manure. The two tribulations: limited land and water, and decreasing fertility of soil are the main constraints to fulfilling the target of self-sufficiency in food and thereby to ensure food security for all.

Bangladesh has developed a predominantly agrarian economy over the century. The agriculture contributes to about 14.74% of GDP in the fiscal year of (2017-2018). In Bangladesh, as in most developing countries, agriculture plays a key role in the overall economic performance of the country, not only in terms of its contribution to GDP, but also as a major source of foreign exchange earnings, and in providing employment to a large segment of the population, particularly the poor. There are 7.56 million ha are suitable for irrigation. But according to the present estimate of available water resources, only about 6.8 million ha can be irrigated. Bangladesh has a plenty of ground water resource but during the summer season, layer of ground water is depleted in many regions which creates a scarcity of water. Besides, surface water source like pond, lake or rivers dried making the situation worse. In order to cope with the present situation, irrigation water sources need to be explored.

In many countries and regions, freshwater is relatively scarce, but there are considerable resources of low quality water, which could be used for if proper crops, soil and water management practices were established (Mantell *et al.,* 1985; Rhoades *et al.,* 1992). Any water source that might be used economically and effectively need to be considered to promote further irrigation development. In this context, use of non-conventional water resources, such as wastewater, must be taken into consideration in agricultural and industrial use (Baterseh *et al.,* 1989). Water of higher quality can be preserved for domestic use while that of lower quality can be utilized for irrigation and washroom.

Among the low quality water sources, municipal wastewater is less expensive and considered an attractive source for irrigation in water scarce region (Al-Rashed and Sherif, 2000; Mohammad and Mazahreh, 2003). Moreover, in general, distribution of municipal wastewater for irrigation over large land areas causes minimal pollution hazard. Irrigation by using reclaimed wastewater may often be an alternative source of water that could be an economic, decreasing pollution of surface waters and providing groundwater recharge.

In Pakistan, for example, 26% of national vegetable is produced under irrigation by wastewater (Ensink *et al.,* 2004), and in Hanoi, 80% of vegetable production is from urban and peri-urban areas (Lai, 2000). In Ghana, informal irrigation involving diluted wastewater from rivers and streams occurs on 11,500 ha, an area larger than the reported extent of formal irrigation in the country (Keraita and Drechsel, 2004). In Mexico, 260,000 ha lands are irrigated with wastewater, mostly untreated (Mexico CNA, 2004). Most of these cases, the farmers irrigate their lands with diluted, untreated or partly treated wastewater. Currently, in the United States, municipal wastewater use accounts for 1.5% of water withdrawals and California residents reuse 656 million cubic meters of municipal wastewater annually.

The cities of Bangladesh produce a considerable amount of sewage water, most of which is discharged into rivers, canals and nearby open water bodies with a consequent nuisance to public health and environment. Disposal of this wastewater through irrigation can help to minimize the pollution of the environment compared to its direct disposal to the surface or groundwater bodies (Papadopoulos, 1995; Mohammad and Mazareh, 2003). In addition, wastewater is a valuable source of plant nutrients and organic matter needed for maintaining fertility and productivity of soils. Application of wastewater to croplands is an attractive option not for its disposal only; it can improve yield, physical properties and fertility of soils (Pomares *et al.,* 1984) as well. Wastewater irrigation not only provides water and nutrients but also organic matter, which can improve productivity of poor-fertility soils (Jimenez-Cisneros, 1995; Siebe, 1998; Angin *et al.,* 2005). The use of reclaimed wastewater in agriculture is a growing practice that may help ensure more and sustainable food crops.

1.2 Municipal wastewater

Wastewater is a generic term used for any water that has been adversely affected in quality by anthropogenic activities. Municipal wastewater may be a combination of some or all domestic effluents, water from commercial establishments, industrial effluent and storm water that does not infiltrate into soil and other urban run-off. Municipal wastewater is mainly comprised of water (99.9%) together with relatively small concentrations of suspended and dissolved organic and inorganic solids. Among the organic substances present in sewage are carbohydrates, lignin, fats, soaps, synthetic detergents, proteins and their decomposition products, as well as various natural and synthetic organic chemicals from the process industries. Municipal wastewater also contains a broad spectrum of contaminants such as macro- and micronutrient; salts and specific ions; inorganic substances, including a number of potentially toxic elements such as arsenic, cadmium, chromium, copper, lead, mercury, zinc, etc. Even if toxic materials are not present in concentrations likely to affect humans, they might well be at phytotoxic levels, which would limit their agricultural use, laundries and washroom, etc.

Municipal wastewater consists of domestic water, commercial water and storm water where domestic water includes black and grey water. Grey water includes laundries, washroom, kitchen, etc and black water consists of urine feace's, water closet flushes. Generally typical domestic wastewater consists of some major constituents concentration. These are total solids (TS), dissolved solids (DS), suspended solids (SS), Nitrogen (N), Phosphorus (P), Chloride, Alkanity and Biochemical Oxygen Demand (BOD) .For strong domestic wastewater, TS is about 1200, DS (850), SS (350), N (85), P (20), Chloride (100), Alkanity (200) and BOD (300). For medium domestic wastewater, TS is about 700, DS (500), SS (200), N (40), P (10), Chloride (50), Alkanity (100) and BOD (200) and for weak domestic wastewater, the TS is about 350, DS (250), SS(100), N(20), P(6), Chloride (30), Alkanity (50) and BOD (100) (UNDTCD, 1985)

Municipal wastewater provides appreciable quantity of nutrients that creates hazard if disposed of in surface waters. In contrast, conservation and proper utilization of these nutrients through wastewater recycling in a soil-plant system can augment the fertility of soil (Shende and Chakrabarti, 1987), especially for soils with poor fertility it is an important source of nutrients for crop production (Kiziloglu *et al.,* 2007). But, when raw wastewater is used for irrigation continuously, excessive amount of nutrients are accumulated in the soil that may cause unfavorable effects on productivity and quality of crops, and soil as well as groundwater by leaching. Wastewater irrigation with excess nitrogen can create a nitrate hazard to groundwater if aquifer is overlaid by coarse textured soil. A field survey conducted at 12 peri-urban areas and 2 sugar mills areas in Bangladesh (Mojid *et al.,* 2010) reveals that wastewater irrigation is being practiced sporadically around the cities without any restriction. Use of wastewater for irrigation can also relief the water crisis to some extent on one hand, and provides livelihood of the resource-poor farmers through saving fertilizer and irrigation cost, and increasing the crop yield on the other hand.

Wastewater irrigation has recently emerged as a focus of study in some developing countries where its use by urban and peri-urban farming communities is increasingly becoming a livelihood reality. Like other developing countries, peri-urban farmers of Bangladesh are already using wastewater for agriculture due to the fact that the surface water resources are polluted by untreated sewage discharged directly into the rivers. The indirect use of these untreated or partly treated wastewaters can increasingly be found in the direct vicinity of expanding mega-cities. The practice has manifold benefits in the form of water conservation, nutrient recycling and prevention of surface and groundwater pollution. Irrigation of olive trees with treated wastewaters in arid and semi-arid regions is becoming a necessary alternative to addressing issues of water shortages. The irrigation requires a careful monitoring of soil and plants for a range of parameters including salts, nutrients, microelements, heavy metals, toxic pollutants (Petousi *et al.,* 2015). In agricultural soils, the presence of metals is of increasing concern because they have the potential to get accumulated in less soluble forms, get transferred into soil solution, and subsequently deteriorate the groundwater and crop quality (Kelepertzis, 2014).

The use of wastewater for irrigation is not well documented in Bangladesh in spite of its sporadic use by the peri-urban farmers. A large quantity of household wastewater is produced and disposed of from the densely populated urban areas of the country. According to the Economic and Social Commission for Asia and the Pacific (ESCAP, 2000), 725 million cubic meter of wastewater is being produced every year from the urban areas of Bangladesh, of which 525 million cubic meter of wastewater is of domestic origin. Utilization of this wastewater for irrigation can minimize water shortage for irrigation to a considerable extent.

Wastewater application can result in a number of problems such as pathogenic infection and heavy metal accumulation in soil, underground water and crops to toxic levels. Wastewater usage for irrigation has the benefits of conserving water and nutrients, reducing the pollution of rivers and canals, providing micronutrients, organic matter, all required nitrogen and much of the required phosphorus and potassium for normal crop production. Irrigation with wastewater leads to increasing accumulation of K, Na, Fe, Mn, Zn, Cu and B in the soil, compared to freshwater irrigated areas studied the effect of irrigation schedules of domestic wastewater on growth and yield of fodder sorghum. Continuous use of wastewater for irrigation tended to increase soil electrical conductivity and decreased soil pH. Revealed that, the wastewater does not cause pollution to soil and crops by accumulation of heavy metals (Cd, Cr, Cu, Zn) and the index for heavy metals content is far below the critical value of the national standard. The heavy metals in the soil are less than that taken away by the crops irrigated with wastewater. The output and input quantities have small effects on the heavy metals balance in the soil, Results showed that irrigation with treated wastewater increased soil pH, EC, OM, major elements (N, P, K, Na, Cl and Mg), salts and heavy metals such as Mn, Zn and Fe contents compared with well water irrigation (CSN ISO,I in Czech).

1.3 Effect of wastewater irrigation on yield and quality of crops

Wastewater contains valuable plant nutrients and thus its reuse in agriculture serves as an important source of nutrients and irrigation water for crops. Most crops give higher yields under irrigation with wastewater than with fresh water. Wastewater reduces the need for chemical fertilizers that eventually results in net cost savings to farmers. If the total nitrogen delivered to the crop via wastewater irrigation exceeds the recommended nitrogen dose for optimal yields, it may stimulate vegetative growth, but delay ripening and maturity, and in extreme circumstances, cause yield losses. Crop scientists have attempted to quantify the effects of treated and untreated wastewater on a number of qualities and yield parameters under various agronomic scenarios (Hussain *et al.,* 2002).

Use of wastewater for irrigation has not only increased crop production, water use and nitrogen use efficiencies but also served as a source of plant nutrients. In Saudi Arabia, Sheik *et al.* (1987) observed that crops irrigated with the effluent, which had raised concentrations of inorganic nutrients, produced higher yields than similar crops irrigated with groundwater. Minhas and Samra (2004) recorded approximately 11% higher yield of wheat under wastewater irrigation, while 36% increase in wheat yield was reported by Qadir *et al.* (2007). Chakrabarti (1995) obtained higher yield of rice when irrigated with raw or partially diluted wastewater compared to groundwater. He noted that initially the rice did better when fertilizer was used in conjunction with wastewater, but the requirement of additional fertilizer decreased over time due to accumulation of nutrients in soil.

Reynolds *et al.* (1978) worked on the effect of land application of secondary treated municipal wastewater on 12 accumulations of heavy metals in alfalfa. The plant receiving water generally showed better growth than those irrigated with normal irrigation water. Plants grown with wastewater accumulated high amount of Na and less amount of heavy metals like Cu, Fe and Zn. It was inferred that treated municipal waste water was of satisfactory quality for crop irrigation and significant accumulation of Cd, Cr, Cu, Ni, Pb and Zn could be attributed to waste water irrigation.

Integrating management of wastewater reuse to minimize treatment costs and increase agricultural productivity is gaining interest in many countries. Irrigation with raw or diluted wastewater will continue to increase in many areas of developing countries as long as it gives high yields of crops. Surveys and research studies carried out in different countries revealed that fields irrigated with untreated wastewater produced more than those irrigated with freshwater. Shende (1985) reported 29%, 34% and 31% higher yield of potato, tomato and cabbage under untreated wastewater-irrigated plots than those of freshwater irrigated plots in India. Minhas and Samra (2004) recorded approximately 11% higher yield of wheat under wastewater irrigation, while 36% increase in wheat yield was reported by Qadir *et al.* (2007).

The use of untreated municipal wastewater practicing in many countries, experience whole set of different problems. The high concentration of plant food nutrients becomes an incentive for the farmers to use untreated wastewater as it reduces fertilizer costs, even when the higher nutrient concentrations may not necessarily improve crop yields. Most crops, including those grown in peri-urban agriculture, need specific amounts of NPK for maximum yield. Once the recommended level of NPK is exceeded, crop growth and yield may be negatively affected. For example, effluent from a urea plant is a rich source of liquid fertilizer but in concentrated forms, they have adverse effects on rice and corn yields (Singh and Mishra, 1987). Wastewater induced salinity may reduce crop productivity due to general growth suppression at early seedling stage, but due to nutritional imbalance, and growth suppression due to toxic ions (Kijne *et al.,* 1998). The net effect on growth may be a reduction in crop yields and potential loss of income to farmers. Therefore, benefits of irrigation with wastewater can be realized with proper irrigation management practices that results in higher yields and quality of crops.

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important edible and nutritious vegetable crops in Bangladesh. It belongs to the family Solanaceae. It is cultivated in almost all home gardens and also in the field for its adaptability to wide range of soil and climate in Bangladesh. It ranks next to potato and sweet potato in respect of vegetable production in the world (FAO, 2003). Its food value is high because of higher contents of vitamin A, B and C (Bose and Sam, 1990). The popularity of tomato and its product is rising continuously. It is a nutritious and delicious vegetable used in salad, soups and processed into stable products like ketchup, sauce, pickles paste, chutney and juice.

In spite of its importance and well adaptability in the agro-climate condition of Bangladesh, the average yield performance is very low compared to other developed countries due to improper cultural management practices. Recent statistics showed that tomato was grown in 19,433 ha of land and the total production was approximately 137,000 metric tons in 2006 - 2007 (BBS, 2007). Thus the average yield of tomato was 7.05 MT/ha in China, 9.37 MT/ha in Indonesia and 46.01 MT/ha Japan (FAO, 2003). Among the various factors that limit tomato yield, water stress is one of the oldest and most serious environmental problems in Bangladesh, although the yield potential is promising.

1.4 Objectives of the study

The overall objective of this study was to use of municipal wastewater as an alternate source of irrigation water for tomato production with reduction in crop contamination from wastewater especially biological contamination. The specific objectives are:

i. to characterization of municipal wastewater for irrigation
ii. to evaluate the effects of wastewater irrigation on the yield of tomato and
iii. to assess the quality of wastewater irrigated produce under different irrigation techniques.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Irrigation with wastewater has gained importance throughout the world for the last hundred years or even more in some countries. The focus of this chapter is to provide a selected review of the past research works which are related to present study. Fairly a small number of studies have so far been conducted on wastewater irrigation of tomato. This chapter makes an effort to review important past and contemporary studies relating to tomato cultivation by waste water and its effect on yield and quality of tomato.

Day *et al.* (1975) conducted an experiment to study the effects of irrigation with treated municipal wastewater and well or ground water plus commercial inorganic fertilizers on the growth, fiber, acid-soluble nucleotides, protein and amino acid content in wheat grain. Their study revealed that the average number of heads per unit area and grain yield were higher in plots that received wastewater. Average days from planting to maturity, plant height, seeds per head and seed weight obtained with wastewater were similar compared to those obtained with well or ground water. Grain from the plants irrigated with wastewater contained more total protein, more alanine, histidine, isoleucine and proline than did grain produced with well or ground water plus suggested N, P and K or with well water plus N, P and K in amounts equal to wastewater.

Day *et al.* (1979) carried out another experiment to study the effects of irrigating wheat with a mixture of pump water and wastewater, and with pump water alone on growth, grain yield, grain quality and soil properties. They reported taller plants, more heads per unit area, heavier seeds, higher grain yields and higher straw yields of wheat under blends of pump water and wastewater than that under only pump water when wheat was grown in small size plots. But when wheat was grown in large fields, an opposite result was obtained. The blends of pump water and wastewater produced taller plants, more lodging, lower grain volume and weights, and lower grain yields than did wheat produced with pump water.

Oron and DeMalach (1988) also reported the higher yield of wheat irrigated with domestic wastewater without any additional fertilizer. In Jordan, Sahalam *et al.* (1998) conducted an experiment on tomato using wastewater and freshwater with and without fertilizer. They obtained higher yield of tomato in plots irrigated with wastewater and fertilizer than the plots irrigated with freshwater and fertilizer.

Pradhan *et al.* (2001) conducted an experiment with sewage water to see its effect on the growth and yield parameters of wheat under different fertilizer levels in the field condition. They observed no significant difference on the yield and yield attributing characters of wheat. However, yield attributing characters like number of tillers per plant, panicle length, number of grains per panicle and 1000-grain weight showed increasing trend to the tune of 13.29, 1.59, 5.49 and 3.79 percent, respectively over the tube well irrigated crop. Interactions between irrigation and fertilizer levels were insignificant. However, sewage water with recommended fertilizer responded better on tillering, panicle length, number of grains per panicle and yield of wheat than the tube well water.

A case study in Haroonabad in Pakistan's Southern Punjab by Matsuno *et al.* (2001) revealed that farmers using wastewater achieved higher productivity than farmers using freshwater. On the negative side, nutrient levels in the wastewater were higher than the crops needed, and solute concentrations in the underlying groundwater became elevated.

The effects of different irrigation water qualities on the grain yield and nutrient uptake of rice and on the heavy metal concentration in the grains were evaluated by El-Sharkawi *et al.* (2004). They found that grain yield, uptake of N, P and K in the plant biomass, and the concentration of heavy metals in the grains were significantly affected by the water quality. The yield of rice grain exhibited a close correlation with the irrigation water quality. The highest grain yield was obtained in the freshwater treatment and the lowest yield was obtained in the treatment with low quality water. The uptake of N, P and K was detrimentally affected by poor quality water. However, the uptake-trend for these elements was similar across all the irrigation treatments. The concentrations of heavy metals in the grains were significantly higher in plots irrigated with poor quality water.

Sahalam *et al.* (1998) conducted an experiment on tomato using wastewater and freshwater with and without fertilizer. They obtained higher yield of tomato in plots irrigated with wastewater and fertilizer than the plots irrigated with freshwater and fertilizer.

As reported by Kiziloglu *et al.* (2008), wastewater irrigated treatments (untreated, preliminary and primary treated) increased the yield of cauliflower and red uptake-trend for these elements was similar across all the irrigation treatments. The concentrations of heavy metals in the grains were significantly higher in plots irrigated with poor quality water.

In Iran, Ghanbari *et al.* (2007) conducted an experiment on wheat using wastewater and freshwater and reported obtaining increased yield and biomass production in wastewater-irrigated treatment than those in freshwater (control) treatment. They observed no significant changes in accumulation of heavy metals in plant grains. The higher yield of wheat irrigated with domestic wastewater without any additional fertilizer was also reported by Oron and DeMalach (1988). The highest yields, macro- and micro-nutrients uptake of cauliflower and cabbage plants were obtained with untreated wastewater. No heavy metal contamination was observed in the plants due to application of wastewater.

Wang *et al.* (2007) stated that both water and nitrogen positively affect crop yields, and replacing some wastewater with freshwater and nitrogen fertilizer increase production.

The effects of different irrigation water qualities on the grain yield and nutrient uptake of rice and on the heavy metal concentration in the grains were evaluated by El-Sharkawi *et al.* (2004). They found that grain yield, uptake of N, P and K in the plant biomass, and the concentration of heavy metals in the grains were significantly affected by the water quality. The yield of rice grain exhibited a close correlation with the irrigation water quality. The highest grain yield was obtained in the freshwater treatment and the lowest yield was obtained in the treatment with low quality water. The uptake of N, P and K was detrimentally affected by poor quality water. However, the uptake-trend for these elements was similar across all the irrigation treatments. The concentrations of heavy metals in the grains were significantly higher in plots irrigated with poor quality water.

Prakash and Narayana (2005) conducted an experiment to analyze the presence of heavy metals in the contaminated soils and wheat irrigated with sewage wastewater and freshwater. The results were correlated with the predicted uptake of trace metals by plants. Irrigation with untreated sewage wastewaters was found to give better yield than that of treated water. It was also found that the concentration of metal ions was continuously increasing found no evidence of heavy metals accumulation in soils irrigated with treated sewage effluent. The concentrations of heavy metals in crop seeds were also found much lower than the critical values of the Chinese National Standard. It, therefore, implies that short-term irrigation with treated sewage effluent could not result in environmental hazard both in soils and field crops in the study area. Meanwhile, no significant difference was detected for the contents of heavy metals in soils irrigated with different quantities of treated sewage effluent, and the recovery of heavy metals at harvest of winter wheat showed much higher than the total heavy metals added to the soils by irrigation with treated sewage effluent during the winter wheat growing season.

In order to evaluate the effects of irrigation with reclaimed wastewater on the quality of maize and soybean, an experiment was conducted by Min *et al.* (2007). On the quality of crude protein and starch, no significant differences were observed between the control of freshwater irrigation and the treatments of reclaimed wastewater irrigation. On micro-elements, there was no significant difference between the control and reclaimed wastewater treatments for soybean grains while the influence is related to the reclaimed wastewater quality for maize. Compared with the control treatment, the cadmium content of maize increased under the reclaimed wastewater treatment.

Rusan *et al.* (2007) found that plant essential nutrients (Total-N, NO3, P and K) were higher in plants grown in soils irrigated with wastewater. Kumar and Reddy (2010) reported significant increase in growth performance in terms of plant height, branches, root length and biomass in the tree 14 saplings irrigated with untreated municipal raw sewage and treated sewage compared to that irrigated with unpolluted potable water over a period of 13 months. Fertigation of the crops by various concentrations of olive mill wastewaters with high electrical conductivity (1856 dS m^{-1}) showed significant adverse effects on wheat, maize, chickpea and tomato (El Hadrami *et al.,* 2004). A reduction in seed germination, shoot and root weights, ramification and leaf extension rates, accompanied with a significant reduction in yield, was observed for all the crops, especially for wheat. The irrigation with treated pulp and paper mill wastewater did not affect the germination of wheat (Thawale *et al.,* 1999). Grain and straw yields of wheat generally increased due to irrigation with wastewater compared with normal water.

Tripathi *et al.* (1999) tested industrial effluent and contaminated well water for effects on germination and seedling growth of wheat, sesame, cowpeas and Indian goose berry. They observed no adverse effect of industrial effluent on wheat germination. However, germination of wheat generally decreased by contaminated well water, particularly at higher concentrations.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment area was located in the urban area of Rajshahi district in the year of 2017-2018 (October- March) and the experimental field was adjacent to sewage canal carrying municipal wastewater of Rajshahi city because of its availability. Details of the locations, techniques, treatments and materials used in the experiment are described below.

3.1 Description of the experimental site

3.1.1 Location of the study site

The research work is situated in the agro ecological zone (AEZ) 11 that located at 24^{o}-40' N latitude and 89^{o}-00'E longitude in the northern part of Rajshahi district, Bangladesh and elevation is about 23.5 m above the mean sea level. This research work done at the experiment plot under BARI (Bangladesh Agricultural Research Institute).

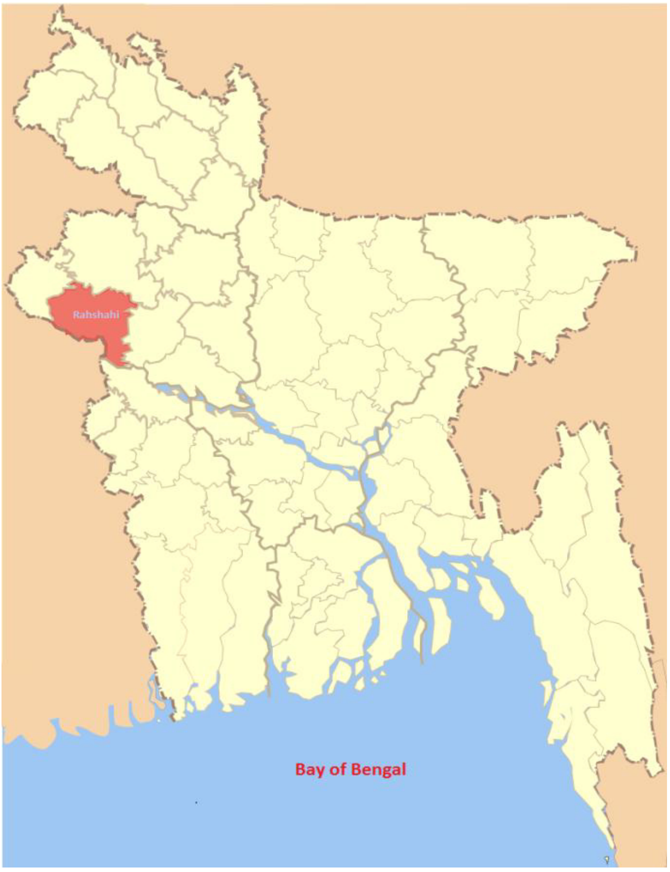

Figure 3.1 Rajshahi District in Bangladesh

Figure 3.2 24°-40' N latitude and 89°-00'E longitude location of Rajshahi District

Figure 3.1 and 3.2 represents the location of experiment site of Rajshahi District in Bangladesh.

3.1.2 Soil of the experimental field

Experimental land or soil type varies from clay loam to sandy loam and it belongs to the High Ganges River Floodplain (BRAC, 2005). Soil size is medium low, fertility conditions or organic material moderate (1.433%) and medium. At the beginning of the experiment, soil samples were taken with an auger from 0-30 cm soil profile. The field capacity and permanent wilting point of the soil of the experimental field were 29.5% and 14.56 % (v/v), respectively and the bulk density was 1.41 g cm^{-3}. The characteristics of the experimental soil samples are given in Table 3.1.

Table 3.1 Initial soil properties in the experimental field.

Soil Properties	**At 0-30 cm soil depth**
Organic matter (%)	1.433
P (ppm)	20.24
N (%)	0.062
P^H	7.38
S (ppm)	22.57
EC	0.34
K (meq/100g)	0.198

3.1.3 Hydro-climate of the experimental field

Table 3.2 Mean monthly temperature, precipitation and relative humidity data during the tomato growing season

Month (2017-2018)	**Temperature (°C)**			**Precipitation (mm)**	**Relative Humidity (%)**
	Maximum	**Minimum**	**Average**		
October	31.9	23.4	27.65	112	66
November	29.5	17.6	23.55	14	62
December	26.1	12.8	19.45	2	59
January	25.4	10.2	17.8	13	40
February	28	13.3	20.65	15	35
March	33.5	18	25.75	27	37

Source: Bangladesh Meterological Department, 2018

The experimental area possess tropical climate. Usually the rainfall is heavy during kharif season (March- September) and scantly in Rabi season (October-February). About 1419 mm of precipitation falls annually. The greatest amount of precipitation is 299 mm. Precipitation is the lowest in December, with an average of 2 mm.During the growing period of the crop, the atmospheric temperature was moderately low during Rabi season and increased as the seasons proceed towards Kharif season with occasional gusty winds. The mean of maximum temperature in summer is 33.5°C. The average annual temperature is 25.8°C.

3.2 Collection of wastewater samples and analysis

Wastewater samples were collected before each irrigation event to examine its suitability for irrigation over the season. The samples were collected from the drainage canal carrying sewage effluent of Rajshahi municipality. The wastewater samples were collected in white plastic bottles filling up to the brim and immediately sealed to avoid exposure to air. Before taking samples, the bottles were rinsed several times with water to be sampled. Then the samples were labeled and brought to the laboratory in an ice bag for chemical and biological analysis. Chemical analysis was done in the laboratories of BARC, Gazipur and Soil Science Division, BARI, Gazipur, while bacteriological analysis was done in the Environmental Microbiological Laboratory of ICCDR'B.

3.3 Details of Experiment

3.3.1 Planting materials

In the resource work, BARI Tomato-3, locally known as *Ratan* was used for the study. The seedlings were collected from BADC farm, Rajshahi.

3.3.2 Treatments of the experiment

The following five irrigation treatments were tested for this experiment with three replications.

T_1 = Traditional furrow irrigation (TFI) at 10 days interval with wastewater
T_2 = Alternate furrow irrigation (AFI) at 10 days interval with wastewater
T_3 = Bed and furrow irrigation (BFI) with wastewater at 10 days interval
T_4 = Drip irrigation (DI) at 3 days interval with wastewater
T_5 = Flood irrigation (FI) at 10 days interval with wastewater

3.3.3 Design and Layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The entire experimental plot was divided into 3 blocks each containing 5 unit plots. In total, there were 15 unit plots. The selected treatments were randomly assigned to each unit plot so as allocated one treatment once in each block. The unit plot was 4.8 m × 4 m in size with a distance between the blocks 1 m and that between unit plots was 0.50 m to avoid any interference of fertilizers from one plot to other ones.

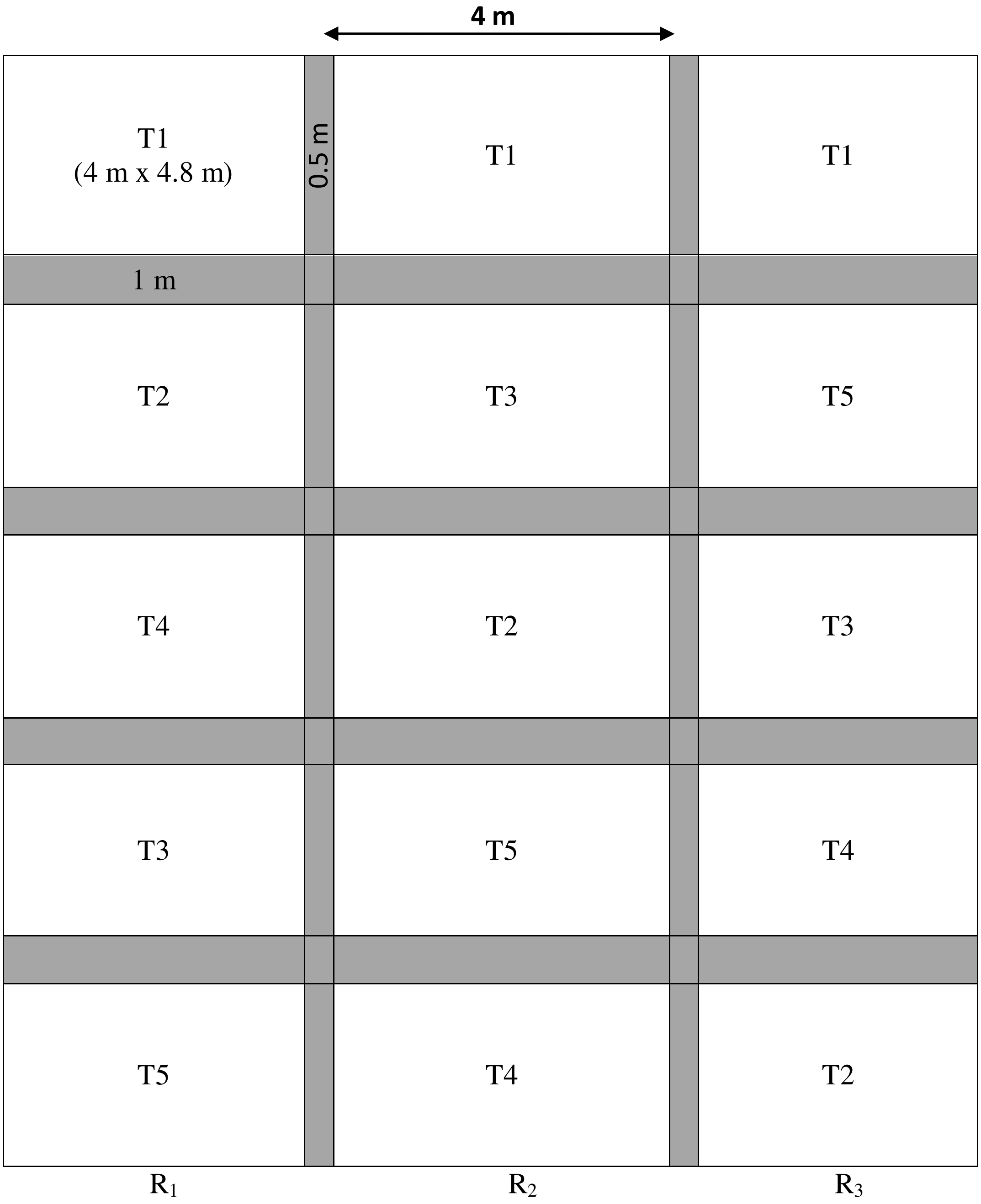

Figure 3.3 Field layout of tomato cultivation with five irrigation techniques with three replications

3.3.4 Land preparation

The selected land for growing the crop was first opened with power tiller and kept exposed to the sun prior to next ploughing. It was prepared afterwards by ploughing and cross ploughing followed by laddering for breaking up the clods and leveling the surface of soil. All weeds and stubbles removed from the field during land preparation. After final land preparation, the plots were demarcated and levees around individual plots are made along with the addition of the basal doses of manures and fertilizers.

Tomato seedlings of 35 days old were transplanted on 03 December 2017. Recommended spacing of 60 cm from line to line and 45 cm from plant to plant was maintained. Light irrigation was given immediately after transplanting by using a watering cane. In order to gap filling and to check the border effect, some extra seedlings were also transplanted around the border area of the experimental field.

3.3.5 Manures and fertilizers

Recommended doses of various fertilizers for tomato are listed in table 3.3. The entire amount of these fertilizers under specific doses, except nitrogen, were applied and incorporated into soil at the time of final land preparation. Nitrogen was applied in three equal splits: one-third each at final land preparation and at 25 and 45 DAP as top dressed.

Table 3.3 The amount of nutrient needed for tomato from fertilizers.

Sources	Nutrient	Amount of nutrient (kg/ha)
Urea	Nitrogen (N)	140
TSP	Phosphorus (P)	33
MOP	Potassium (K)	50
Gypsum	Sulpher (S)	18

3.3.6 Intercultural operations

The following intercultural operations were done for better growth and development of the plants during the period of the experiment.

Gap filling: Gap filling was done in place of dead or wilted seedlings in the field using healthy seedlings of the same stick previously planted in the border area on the same date of transplanting. The soil around the base of each seedling was pulverized after the establishment of seedlings.

Weeding: Weeding was done to keep the crop free from weeds.

Staking and pruning: When the plants were well established, each plant was staked with ‘Bamboo’ sticks to keep the plants erect. Within a few days of staking, as the plants grew up, they were pruned. At initial stage, the plants were pruned to keep them single-stem and thereafter only two or three main branches were kept before going to flowering stage.

3.3.7 Source of irrigation water and irrigation application

Source of irrigation water was the municipal wastewater of Rajshahi City Corporation flowing through a concrete drain in close proximity of the experimental field was used as irrigation water. Low lift pump (LLP) was used to supply the wastewater to the experimental field through polyethylene pipe. A light irrigation amounting 10 mm was applied just after planting to ensure proper growth of tomato seedlings. Thereafter, irrigation was applied based on pan evaporation for drip irrigated tomato while other treatments were irrigated as per treatments schedule filling the soil moisture content up to field capacity.

Figure 3.4 Urban wastewater carrying canals of Rajshahi city

3.3.8 Crop protection

As preventive measure against insect pests, Admire was applied at the rate of 2 ml/litre. The insecticide was applied at 10 days interval from a week after transplanting to a week before first harvesting. Furadan 5G was also applied during the final land preparation as soil insecticide. During foggy weather, precautionary measures against disease infestation, especially late blight of tomato, was taken by fortnightly spraying of Secure at the rate of 2 g/litre.

3.4 Harvesting

Harvesting of tomato fruits were done through 22 February 2018 to 20 March 2018 in a total of 7 harvests when 80-90% of the fruits showed becoming red senescence and the top started drying up. First, ten sample plants were harvested from each plot, and then the whole plot was harvested manually.

3.5 Data Recording

Five plants were selected randomly from each plot for data collection in such a way that the border effect could be avoided. Data on the following parameters were recorded from the sample plants during the course of experiment.

3.5.1 Plant height (cm)

Plant height at maximum vegetative growth stage was recorded in centimeter from the ground level to the tip of the longest stem, and the mean value for each treatment was calculated.

3.5.2 Number of fruits per plant

It was recorded by the following formula:

$$\text{Number of fruits per plant} = \frac{\text{Total number of fruits from 5 sample plants after final harvest}}{5}$$

3.5.3 Fruit length (cm)

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 10 selected marketable fruits from each plot and their average was taken in cm as the length of fruit.

3.5.4 Fruit diameter (cm)

Diameter of fruit was measured at the middle portion of 10 selected marketable fruits from each plot a slide calipers and their average was taken in cm as the diameter of fruit.

3.5.5 Weight of individual fruit/ Unit fruit weight (g)

It was recorded by the following formula:

$$\text{Weight of individual fruit}\left(\text{g}\right) = \frac{\text{Total weight of fruits from 5 harvested of sample plant}}{\text{Total number of fruits from 5 harvested of sample plant}}$$

3.5.6 Weight of fruits per plant (kg)

It was measured by the following formula:

$$\text{Weight of fruits per plant}\left(\text{kg}\right) = \frac{\text{Total weight of fruits from 5 sample plants}}{5}$$

3.5.7 Fruit yield per plot (kg)

A balance was used to take the weight of fruits per plot. It was measured by totaling of fruit yield from each unit plot separately during the period from first to final harvest and was recorded in kilogram (kg).

3.5.8 Fruit yield per hectare (t)

It was calculated by the following formula:

$$\text{Fruit yield per hectare}\left(\text{t}\right) = \frac{\text{Fruit yield per plot}\left(\text{kg}\right)\times 10000}{\text{Area of plot}\left(\text{m}^2\right)\times 1000}$$

3.6 Collection of plant samples and analysis

Fresh plant samples of tomato were collected at their maturity stage. About 1 kg of each samples were harvested from the fields and labeled keeping them in a transparent poly bag. Then it was brought to the laboratory in an ice box for maintaining cool chain for biological analysis. Some samples were oven dried at 65^{o} C for 72 hours. Then the samples were finely ground and stored in a sealed polyethylene bag for chemical analysis in the laboratories of BRAC, Gazipur and BARI, Gazipur, All bacteriological tests were done in the Environmental Microbiological Laboratory of ICCDR'B and WAFFEN (Water –Food –Feed - Environment) research Laboratory, Dhaka.

3.7 Determination of water requirement

The irrigation quantities were calculated using the following equation:

$$I = K_c \times E_{pan} \times WR \text{.....................} \quad \text{(i)}$$

Where, I is the irrigation quantity (mm), K_c is the pan coefficient, E_{pan} is the cumulative pan evaporation between the two irrigations (mm), and WR is the wetting ratio. (WR= 1 for flood irrigation, 0.7 for alternate furrow and broad bed furrow irrigation)

3.8 Determination of water productivity

Water productivity was evaluated with irrigation water use efficiency (IWUE) which indicates the yield per unit irrigation (Howell, 2001). The IWUE was calculated using the following equation (ii):

$$IWUE = \frac{Y}{I} \text{.......................(ii)}$$

Where, IWUE is the irrigation water use efficiency (kg m^{-3}), Y is the total marketable yield (kg $decare^{-1}$) and I is the amount of seasonal irrigation quantity (mm).

3.9 Data analysis

The data in respect of yield and yield contributing parameters were subjected to statistical analysis to find out the statistical significance of the variations associated with different treatments. Statistical analyses were carried out using computer software MSTATC.

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Evaluation of wastewater for irrigation/agricultural use

Evaluation of wastewater quality is essential before it's use in agriculture. In Rajshahi, there is no regulation or monitoring for application of wastewater in agriculture. Therefore, the poor peri-urban farmers apply wastewater to their fields, as and when required without any restrictions. In the present study, wastewater quality was evaluated for agricultural uses, and Table 4.1 presents the analyzed wastewater quality, and degree of restriction for agricultural use set by WHO (2006), FAO (1999), and DoE (1997) guidelines.

Table 4.1. Chemical parameters of urban wastewater of Rajshahi used for irrigation

Quality parameters	Location	Restriction for agricultural use (Ayres and Westcot, 1985; cited in WHO, 2006)		
	Rajshahi	No restriction	Moderate restriction	Severe restriction
pH	7.26	Normal range 6.5-8.0		
EC (dS/m)	1.26	<0.7	0.7-3.0	>3.0
Total Nitrogen, N (mg/l)	20.39	<30	30-40	>40
Total Phosphorus, P (mg/l)	2.17	<10	10-16	>16*
Potassium, K (mg/l)	13.32	<30		>30
Sulpher, S (mg/l)	2.51	<1000		>1000***
Boron, B (mg/l)	0.64	<0.7	0.7-3.0	>3.0
Zinc, Zn (mg/l)	0.12	<10		>10**
Copper, Cu (mg/l)	0.05	<3		>3**
Iron, Fe (mg/l)	0.36	<5		>5
Manganese, Mn (mg/l)	0.66	<5		>5**
TC (CFU/100ml)	7.1 x 10^6	1000		
FC (CFU/100ml)	6.4 x 10^6	1000		

(*Pescod, 1992; ** GoB, 1997; ***DoE, 1997)

4.1.1 Hydrogen-ion concentration (P^H)

Hydrogen-ion concentration affects both crops and soils. The normal range of pH for irrigation water is between 6.5 and 8.0 (Pescod, 1992). A lower pH indicates increasing acidity, while a high pH indicates increasing alkalinity. The wastewater used in irrigating the tomato was slightly alkaline with the average pH value of 7.26. A pH above 8.5 is often caused by high bicarbonate (HCO^{3-}) and carbonate ($CO_2{}^-$) concentrations which could intensify alkine soil conditions, which is detrimental to agriculture. The wastewater used in this experiment with a pH value of 7.26 was not a problem in the experimental crops.

4.1.2 Electrical conductivity (EC)

The EC of wastewater was recorded 1.26 dS/m, which was slightly greater than no restriction level. The Food and Agriculture Organization (FAO) has developed guidelines for the evaluation of water quality for irrigation and suggested that there needs: no restrictions on the use of irrigation water with an EC of 0.7 dS/m, slight to moderate restrictions if EC's of water are in the range 0.7-3.0 dS/m and severe restrictions for water with an EC of greater than 3.0 dS/m. The salinity of irrigation water is important because of the potential for deleterious effects both on crops and soils. So, this water was used for irrigating the tomato with no restriction.

4.1.3 Nutrients

Nitrogen (N)

The wastewater used for irrigation of tomato contains considerable amount of nitrogen, phosphorus and potassium which are necessary for improving plant growth and soil fertility. A concentration of total nitrogen (N) higher than 30 mg/L may cause problems in many crops (Middelebrooks, 1982). The usual values observed in domestic wastewater- 20 mg/L is considered weak, 40 mg/L as medium and 80 mg/L as strong (Metcalf and Eddy, 2003). According to Ayres and Westcot (1985); cited in WHO (2006), below 30 mg/L N present in waste water needs no restriction of using irrigation water, 30-40 mg/L require moderate restriction and above 40 mg/L require severe restriction. The amount of N present in the waste water was 20.39 mg/L which is not detrimental to quality of tomato.

Phosphorus (P)

Municipal wastewaters may contain 4-16 mg/L of phosphorus (P) and its typical value for wastewater treated in a conventional treatment plant is 10 mg/L (Metcalf and Eddy, 2003; Pescod, 1992). The concentration of P in wastewater was 2.17 mg/L ; this value of P was within acceptance range.

Potassium (K)

Potassium (K) is absorbed by plants in larger amounts than any other mineral elements except nitrogen. The use of wastewater in agriculture does not normally cause negative environmental impacts associated with potassium (Mikklesen and Camberato 1995; cited in WHO, 2006). The normal concentration of K in treated wastewater is 30 mg/L and 0 – 2 mg/L in irrigation water (Pescod, 1992; Ayres and Westcot, 1985). The amount of K for the wastewater used in the experiment was 13.32 mg/L.

As the lower concentration of N, P and K present in waste water, chemical fertilizer application is almost necessary for successful production of tomato. Considering the variation in the composition of wastewater, wastewater management practices should account for the content of N, P and K before determining the volume of wastewater application.

Boron (B)

Boron is essential for plant growth and development but it can be detrimental if required level is exceeded. The concentration of boron ranged from 0.63 mg/L to 0.75 mg/L in wastewater with an average value of 0.69 mg/L. These values of B are within the safe limit (0.3–1.0 mg/L) for irrigation even for highly boron sensitive crops. Tomato (B semi tolerant) can withstand up to a concentration of 1.1 mg/L (Shainberg and Oster, 1978). The amount of B present in the wastewater was 0.64 mg/L which is effective for plant growth rather than vulnerable to tomato production.

Copper (Cu), Zinc (Zn), Iron (Fe) and Manganese (Mn)

The concentrations of Cu, Zn, Fe and Mn were comparatively low (mentioned in the table 4.1) but met the standard of wastewater reuse in irrigation. The concentrations of Cu, Zn, Fe and Mn in wastewater were far below their values set by WHO (2006) for safe use in agriculture.

Total coliform and fecal coliform

The average total coliform (TC) and fecal coliform (FC) remained in the wastewater were 17.1 x 10^6 and 6.4 x 10^6 CFU per 100 ml respectively due to a number of different municipal waste.

4.2 Effect of irrigation techniques on tomato with wastewater

4.2.1 Plant height and number of branch plant

Table 4.2 Effect of different irrigation methods on plant height and number of branch plant of tomato

Treatments	Plant height (cm)	No. of branch/plant
T_1 (TFI)	116.9	4.08
T_2 (AFI)	117.8	3.92
T_3 (BBFI)	116.6	3.98
T_4 (Drip)	120.3	4.02
T_5 (Flood)	101.7	3.40
CV (%)	9.34	7.41
$LSD_{0.05}$	10.84	4.95

The raw wastewater irrigation combined with five irrigation techniques and different wastewater apply with several days interval had significant impact on plant height. The highest plant height (120.3 cm) which was obtained by T_4 treatment that received by using drip irrigation technique at 3 days interval. There existed the decreasing trend of plant height with the increasing wastewater apply with flood irrigation ($T_2>T_1>T_3>T_5$). T_2 treatment represents the second highest plant height which was 117.8 cm where alternate furrow irrigation was applied at 10 days interval. The lowest plant height (101.7 cm) was found in T_5 treatment (flood irrigation).

Table 4.2 shows the plant height and no. of branch/plant of tomato under five (5) irrigation treatments.

Similarly, the highest no. of branch/plant (4.08) was obtained by T_1 treatment that received by using traditional furrow irrigation technique at 10 days interval. There existed the decreasing trend of no. of branch/plant with the increasing wastewater apply with flood irrigation (T_4>T_3>T_2>T_5). T_4 treatment represents the second highest branch/plant which was 4.02 where drip irrigation was applied at 3 days interval. The lowest branch/plant (3.40) was found in T_5 treatment (flood irrigation). .

4.2.2 Fruit size

Table 4.3 Effect of different irrigation methods on fruit size of tomato

Treatments	Fruit size	
	Fruit length (cm)	Fruit diameter (cm)
T1	4.69	5.86
T2	4.51	5.72
T3	4.53	5.61
T4	4.74	4.95
T5	3.56	4.42
CV (%)	6.28	5.33
$LSD_{0.05}$	0.512	0.395

As compared to the fruit length of the five irrigation techniques, the highest fruit length was 4.74 cm which was obtained by T_4 treatment that received by using drip irrigation technique at 3 days interval. The second highest fruit length was 4.69 cm which was obtained by T_1 treatment that received by TFI technique at 10 days interval. The lowest fruit length was 3.56 cm which was found in T_5 treatment (flood irrigation). From table 4.3 it was found that the increasing trend of fruit length with the decreasing wastewater apply with flood irrigation (T_1>T_3>T_2>T_5).

Table 4.3 shows the fruit diameter of tomato under five (5) irrigation treatments. The lowest fruit diameter (4.42cm) was found in T_5 treatment that received by using flood irrigation technique at 10 days interval. T_5 treatment represented the second lowest fruit diameter which was 4.42 cm where flood irrigation was applied at 10 days interval. Besides the highest fruit diameter (5.86 cm) which was obtained by T_1 treatment that received by using traditional furrow irrigation technique at 10 days interval. T_2 treatment represented the second highest fruit diameter which was 5.72 cm where alternate furrow irrigation was applied at 10 days interval. There existed the increasing trend of fruit diameter with the increasing wastewater apply with flood irrigation (T_2>T_3>T_4>T_5).

4.2.3 Number and weight of fruit/plant

Table 4.4 Number and weight of fruit/plant under different irrigation method

Treatment	No. of fruit/plant	Wt. of fruit/plant (kg)
T_1 (TFI)	40.08	2.03
T_2 (AFI)	42.24	2.59
T_3 (BBFI)	41.98	2.64
T_4 (Drip)	46.02	2.74
T_5 (Flood)	27.40	1.23
CV (%)	7.41	5.22
$LSD_{0.05}$	4.95	0.650

Irrigation treatments always showed insignificant effect on number of fruit per plant. As compared to five irrigation treatments the number of fruit per plant was T_4>T_2>T_3>T_1>T_5 which shows at table 4.4. The highest fruit per plant number was 46.02 that recorded at T_4 treatment where wastewater applied by drip irrigation at 3 days interval. T_2 treatment represents the second highest no. of fruit/plant which was 42.24 where alternate furrow irrigation was applied at 10days interval. But the lowest fruit number was 27.40 that received from waste water flood irrigation (T_5).

Table 4.4 represents the weight of fruit per plant which were according to T_4>T_3>T_2>T_1>T_5 and it is cleared that irrigation treatments always showed insignificant effect on weight of fruit per plant. The highest weight of fruit per plant was 2.74 that recorded at T_4 treatment where wastewater applied by drip irrigation at 3 days interval. T_3 treatment represents the second highest weight of fruit per plant which was 2.64 where bed and furrow irrigation was applied at 10 days interval. But the lowest weight of fruit/plant was 1.23 that received from waste water flood irrigation (T_5).

4.2.4 Unit weight of fruit per plant

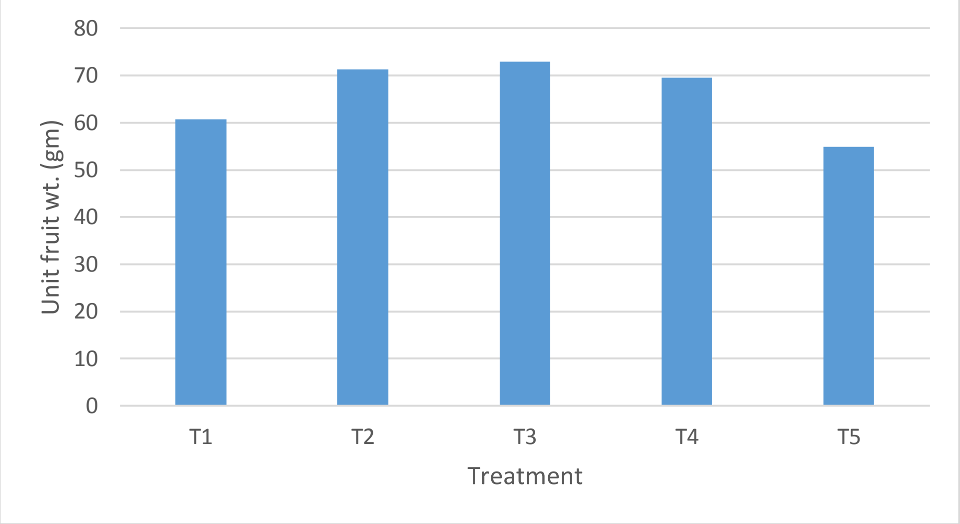

Figure 4.1 Unit weight of fruit per plant under 5 irrigation techniques

Figure 4.1 shows that there existed the decreasing trend of unit weight of fruit per plant with the increasing wastewater apply with flood irrigation ($T_3>T_2>T_4>T_1>T_5$). T_3 treatment represents the highest 72.89 gm unit weight of fruit per plant where wastewater applied by bed and furrow irrigation at 10 days interval. T_2 treatment represents the second highest 71.32 gm unit weight of fruit where wastewater applied by alternate furrow irrigation at 10 days interval where T_5 treatment gives the lowest value 54.89 gm where wastewater applied by flood irrigation at 10 days interval.

4.2.5 Fruit yield (t/ha)

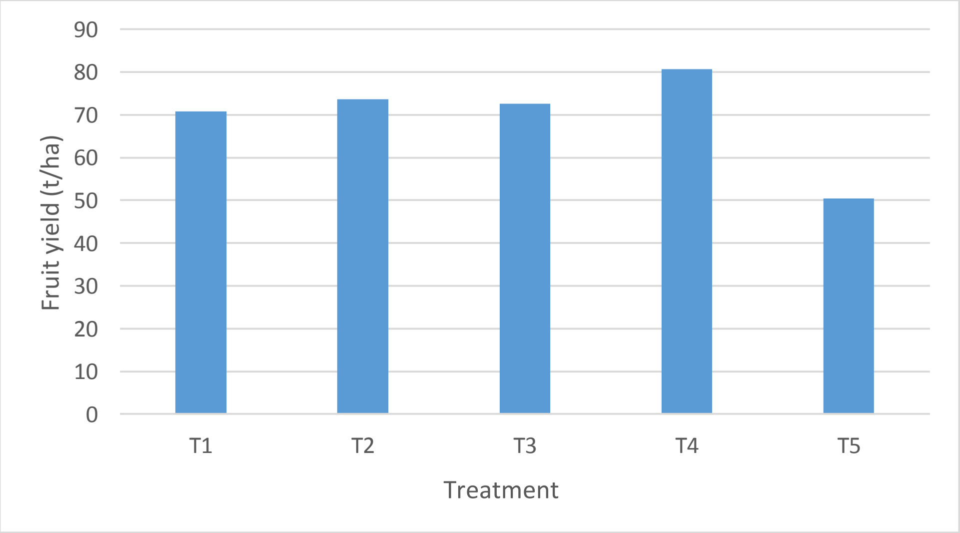

Figure 4.2 Fruit yield of tomato plant under 5 irrigation techniques

The relationships of different irrigation treatments versus the fruit yields under five irrigation techniques with standard fertilized and recommended wastewater conditions are shown in figure 4.2. The yield decreased as the amount of increasing wastewater applied. The highest fruit yield was recorded 80.76 t/ha at T_4 treatment while the lowest was 50.42 t/ha at T_5 treatment. As compared to five irrigation treatments fruit yield was $T_4>T_2>T_3>T_1>T_5$ which is shown at figure 4.2.

4.3 Water use and water productivity

The effect of irrigation systems on water use and water productivity were also evaluated and demonstrated in Fig 4.3.

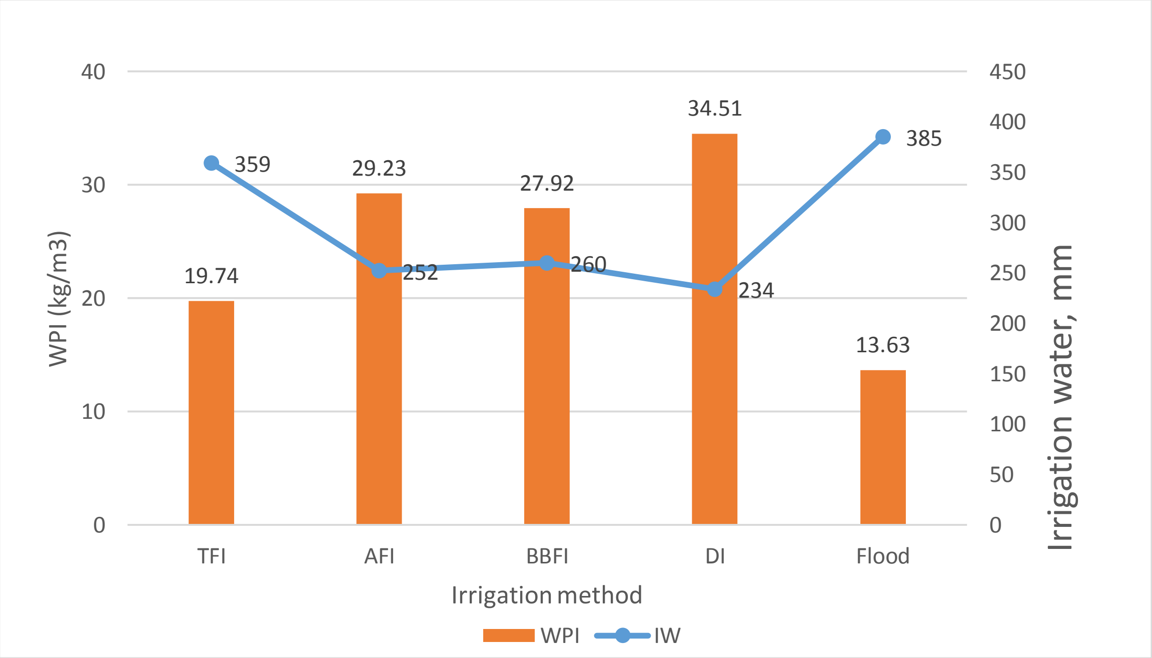

Fig 4.3 Irrigation water applied and water productivity of tomato grown under different irrigation systems

WP (water productivity) was calculated from the mean yields of tomato and depth of water applied for all the irrigation systems. Total water use ranged from 234 to 385 mm at Rajshahi with minimum in DI system and maximum in flood irrigation system. Among the different furrow irrigation systems, water use was found higher in TFI system than that of AFI and DI systems. Over the locations, water use for TFI was ranging from 365 to 359 mm significantly followed by AFI (246 to 252 mm) and DI (242 to 260 mm).

These phenomena happened to realize higher water productivity (31.33 kg/m^3) in AFI than that of in TFI (21.29 kg/m^3). However, the highest water productivity of 36.90 kg/m^3 was obtained from the treatment that received a total of 17 irrigations at 3 days interval through drip system and the lowest (13.36 kg/m^3) from flood irrigation system Though drip irrigated treatment had the highest water productivity, it was comparable to WP of AFI and DI systems. So, all of these water saving methods can be advised to adopt by the farmers for cultivation of tomato.

4.4 Microbiological quality of tomato

Microbiological contamination of tomato crops grown under different irrigation systems with wastewater is illustrated in Fig 4.4. The total coliform, TC, fecal coliform, FC, and *Escherechia coli* (*E. coli*) were detected in fresh tomatoes. Among the irrigation systems, drip irrigation considerably reduced the total coliform compared to other irrigation systems.

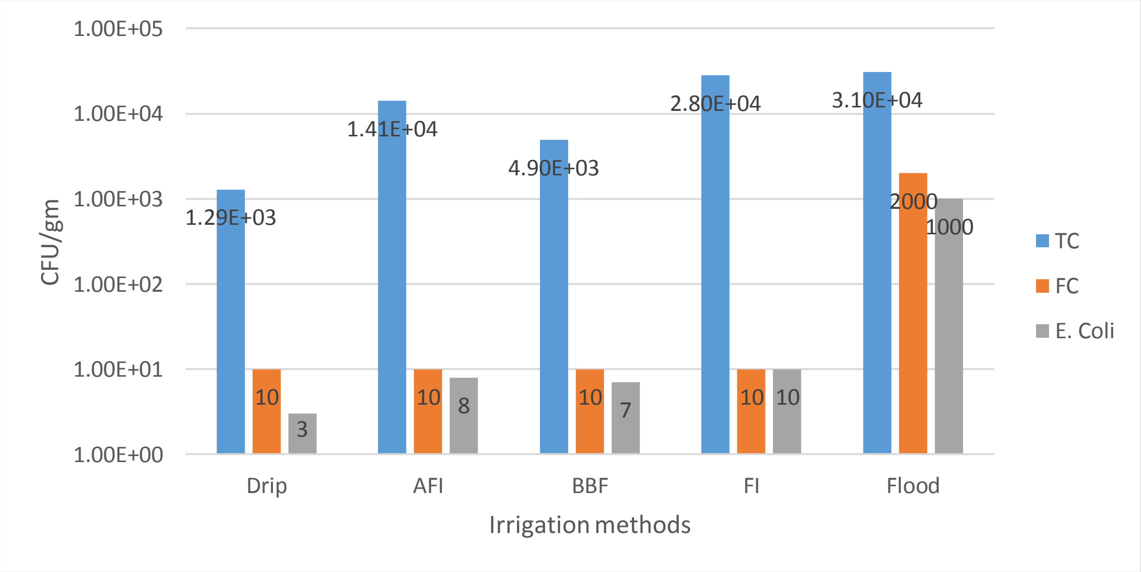

Figure 4.4 Bacterial contamination of tomato grown with wastewater irrigation in different irrigation methods

The reduction of total coliform under BBF was comparable to drip system. In general, the microbial population content in tomatoes was found higher in flood irrigation system followed by traditional furrow (TFI/FI) and alternate furrow irrigation (AFI) while the population was the lowest in drip irrigation system. This is because the contamination of wastewater irrigated crops mainly depends on its contact opportunity with wastewater.

In the case of drip irrigation system, irrigation application being localized, the possibility of contact was truncated. This fact is also reflected in flood irrigation system where direct contact between crop and wastewater happened to intensifying the contamination. However, the pathogenic bacteria *Salmonella* and *vibrio coli* were not detected in any treatments.

Tomato being a salad crop, usually it is consumed in raw form and uncooked. Therefore, care must be taken to avoid the contact of wastewater with the crops to mitigate the hygienic problems. In a similar study with lettuce and radish, Bastos and Mara (1995) reported that contamination of wastewater irrigated produce was less under drip than furrow technique.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Use of municipal wastewater for irrigation has gained importance throughout the world due to limited water sources and costly wastewater treatment for discharge. The utilization of municipal wastewater of Rajshahi municipality in irrigation not only reduce the scarcity of irrigation water and the problems of its disposal, but also improves soil fertility with an eventual increase of crop yield. Based on the results of this study, the following conclusions were drawn:

1. The wastewater contained limited amount of nitrogen, phosphorus and potassium that are essential nutrients for plant growth, soil fertility and productivity levels. The electrical conductivity and the concentration of Na, K, Cu, Zn, Mn and the wastewater was much below their critical limits for use in irrigation. So, the wastewater of Rajshahi city did not have any negative impact on soil properties.
2. The growth attribute of tomato plant (plant height, fruit per plant) did not show any clear response of using wastewater with different wastewater application method. But drip irrigation system gave insignificantly better growth and yield of tomato than TFI, AFI, and BFI systems. Compared to other methods, drip irrigation gave the highest water productivity (34.51 kg/m^3) with the less amount of water use (19.74 kg/m^3).
3. Bacterial contamination for DI were total coliform (1.29E+03), fecal coliform (10), and *E. coli* (3). For AFI bacterial contamination were total coliform (1.41E+04), fecal coliform (10), and *E. coli* (8). Bacterial contamination for BBFI were total coliform (4.90E+03), fecal coliform (10), and *E. coli* (7). Bacterial contamination for TFI were total coliform (2.80E+04), fecal coliform (10), and *E. coli* (10). Bacterial contamination for FI were total coliform (3.10E+04), fecal coliform (2000), and *E. coli* (1000). Those above bacterial contamination were found from five irrigation methods for wastewater application and these bacterial contaminations considerably lower in drip

irrigation and higher in flood irrigation than other irrigation methods. While the lowest counts of all categories of bacteria was recorded in flood irrigation.

5.2 Recommendations

Based on this study, the following recommendations were made:

1. Municipal wastewater of Rajshahi district did not contain any harmful content like heavy metals and contained limited amount of nitrogen, phosphorus and potassium that are essential for crop production. So, this water can be used for agricultural purpose.
2. Since the effect on the quality of tomato using wastewater irrigation is not clear, it needs more analysis.
3. The hygienic aspects of wastewater irrigated crops are not investigated in this study. So, it requires more investigation.

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APPENDICES

APPENDICES

APPENDIX 1 Major constituents of typical domestic wastewater

Constituents **Concentration, mg/l**	**Strong**	**Medium**	**Weak**
Total Solids	1200	700	350
Dissolved Solids	850	500	250
Suspended Solids	350	200	100
Nitrogen	85	40	20
Phosphorus	20	10	6
Chloride	100	50	30
Alkanity	200	100	50
BOD	300	200	100

Source: UN Department of Technical Cooperation for Development (1985)

APPENDIX 2 Yield and yield contributing parameters of tomato as affected by different irrigations techniques with wastewater

Treatment	Plant height(cm)	No. of fruit/plant	Wt. of fruit/plant (kg)	Unit fruit wt. (g)	Fruit yield (t/ha)
T_1 (TFI)	116.9	40.08	2.03	60.65	70.86
T_2 (AFI)	117.8	42.24	2.59	71.32	73.67
T_3 (BBFI)	116.6	41.98	2.64	72.89	72.58
T_4 (Drip)	120.3	46.02	2.74	69.54	80.76
T_5 (Flood)	101.7	27.40	1.23	54.89	50.42
CV (%)	9.34	7.41	5.22	5.08	9.10
LSD0.05	10.84	4.95	0.650	7.18	4.62

APPENDIX 3 Chemical parameters of urban wastewater of Rajshahi used for irrigation

Quality parameters	Location	Restriction for agricultural use (Ayres and Westcot, 1985; cited in WHO, 2006)		
	Rajshahi	No restriction	Moderate restriction	Severe restriction
p^H	7.26	Normal range 6.5-8.0		
EC (dS/m)	1.26	<0.7	0.7-3.0	>3.0
Total Nitrogen, N (mg/l)	20.39	<30	30-40	>40
Total Phosphorus, P(mg/l)	2.17	<10	10-16	>16*
Potassium, K (mg/l)	13.32	<30		>30
Sulpher, S (mg/l)	2.51	<1000		>1000***
Boron, B (mg/l)	0.64	<0.7	0.7-3.0	>3.0
Zinc, Zn (mg/l)	0.12	<10		>10**
Copper, Cu (mg/l)	0.05	<3		>3**
Iron, Fe (mg/l)	0.36	<5		>5
Manganese, Mn (mg/l)	0.66	<5		>5**
TC (CFU/100ml)	7.1×10^6	1000		
FC (CFU/100ml)	6.4×10^6	1000		

(*Pescod, 1992; ** GoB, 1997; ***DoE, 1997)