EFFECT OF WASTE WATER TREATMENT ON THE GROWTH OF SELECTED LEAFY VEGETABLE PLANTS

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Abstract. Quetta, the capital city of Baluchistan province which was once called as “little London” has been affected by severe drought since 1998. This situation led to fresh water shortage which compelled the local population to irrigate their crops by waste water. In this way, heavy metals started to accumulate in the soil and as well as in our food chain. The main objectives of this research were to elucidate the effect of waste water on leafy vegetables growth. For this purpose, three leafy vegetables were selected i.e. Coriander (*Coriandrum sativum),* Purslane *(Portulaca oleracea)* and Lettuce (*Lectuca sativa).* The research is also aimed to know the influence of waste water treated plants on human health. The experiments were performed in the botanical garden, Botany Department, University of Baluchistan. Waste water was collected from waste water channels of the Quetta city. From March 2016-14 June, 2016, after an extensive survey, different sites of the municipal were selected for the collection of waste water used as sample collected from the Agriculture Department of Quetta city. Vegetative growth parameters such as height, number of leaves, weight of fresh, dry leaves and rate of germination of seed were measured to know the impact of waste water treatment. Waste water treatment had found a significant effect on the growth of leafy plants. All the growth parameters were measured in the three selected leafy vegetable plant species i.e. Coriander (*Corianderum sativum),* Purslane *(Portulaca oleracae)* and Lactuca *(Lactuca sativa).* Comparatively, better results were found by treating the plant with waste water rather than fresh water. The usage of municipal wastewater for irrigation can be an abundant resource of the nutrients essential for plant’s growth. However, keeping in view the health hazards, edible crops irrigated with this untreated waste water should not be grown in spite of its positive impact on the physical parameters of some plants.
Keywords: *wastewater utilization, land irrigation, leafy vegetables plants growth, nutrients, human health*

Introduction

The use of waste water in the agricultural sector to overcome the severe drought is becoming a substitute throughout the world, particularly in China. In developing countries, wastewater is used in 70% of irrigations. Approximately, 20 million ha areas in the world is cultivated by using waste water. Waste water is composed of several minerals which are essential for plants growth. Similarly, using clean water for irrigation has itself some drawbacks. Its increases mainly the scarcity of drinking water. For that reason, in Mexico, peasants using dirty water can let their land at three times the price of those who use clean water, but these waters also contain risks of disease and pollution. Research studies revealed that Mexican children under four years old living in areas where wastewater is being used for irrigation of plants, have found sixteen times more intestinal problems than the other areas (Achakzai et al., 2011; Adenle et al., 2011).

The World Health Organization (WHO) reveals in one of its laboratory manuals titled "Analysis of waste water for use in agriculture" that the use of waste water for crop irrigation is becoming more common. As wastewaters contain mineral nutrients which are good for the development of plants growth, the yield is superior. However, there is a risk that irrigation with waste water facilitates may enable the transmission of diseases related to intestinal nematodes and fecal bacteria to consumers and farmers (WHO, 2006; ATSDR, 1993; Chang et al., 2002; Mushtaq et al., 2018).

Like in many other counties, untreated waste water is used for irrigation in over 80% of all Pakistan societies with a population of over 10,000 inhabitants. More specifically, considering the case of Quetta, which is the capital city of Baluchistan, with an area of 2,653 km^2, surrounded by the Takato and Murdaar mountains, it has been seen that in Quetta, people have started to fulfil the food requirement by growing the daily use vegetation and vegetables using the waste water of the city (Khalil et al., 2011; Saidi, 2010; Shah, 2014; Ahmad et al., 2004; Amerasinghe, 2004; Siraj et al., 2018).

In Pakistan, there are predominantly agricultural societies, most of the fresh water is used for irrigation purpose and with increased competition for water by rapidly renewed interest the total estimated area directly irrigated by waste water is 32,500 ha, with 19,250 households depending on direct waste water use for their livings. Quetta is the capital city of Baluchistan. Its population is approximately 3 million. It has a rocky landscape. Mostly, its climate is semi-arid with a great variation in the summer and winter temperature (Ensink, 2004; Amerasinghe, 2004; Nidaa et al., 2017; Siraj et al., 2018).

The Quetta city was once very famous for its scenic beauty but has now turned into probably the most polluted city in the country, especially with respect to sanitation and hygiene conditions. The workers reported herewith that due to overpopulation, the basic needs of life have become inadequate for the people. Therefore, the people have started to fulfil the food requirement by irrigating their crops with the wastewater in the areas of Sabzal Road, Spini Road, Saryab Road and Hazar Gangi. Polluted water is composed of hospital, domestic and industrial waste. The pH of sewage water range from 7.24-9.21. The concentration of essential nutrients (macro+ micro) and poisonous metals varied greatly in samples between two selected locations (Kakar et al., 2010; Amerasinghe, 2004' Shah, 2014; Bazai et al., 2005; Zahid et al., 2011; Siraj et al., 2018).

The concentration of P and K^+ was high (1.18 ppm) in Habib nala than Ispini and Subzal road sewage drain. The concentration of micro nutrients (Fe^{++}, Mn, Zn, Cu) were within acceptable limits. In relation with toxic metals, Pb was generally greater (0.12 ppm) in Ispini road drain wastewater as compared with (0.05-0.08 ppm) other sewage drains. According to Kakar et al. (2006), the minimum and maximum (0.09 and 0.18 ppm) Ni was found in Ispini and Subzal road drain. Wastewater has a drastic impact on the seed germination also. The results revealed that the germination of seed, and roots, shoot elongation was significantly affected by two types of waste water (Kakar et al., 2010; Shah, 2014; Bazai et al., 2005; Abdul et al., 2013).

Black Niger *(Nigella sativa)* plant was highly affected in domestic waste water treatment and pharmaceutical waste water treatment followed by Coriander (*Coriandrum sativum).* Germination percentages of Mustered (*Brassica juncea)* in domestic and pharmaceutical

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waste water usage were 18% and 22%, respectively. Fenugreek (*Trigonella foenum-graecum)* germination percentage was less affected by wastewaters as only 20% and 17% reduction was observed in the domestic and pharmaceutical industry waste water. Germination reduction in Barley (*Hordeumv ulgare)* showed 23% under domestic polluted water condition while its reduction under industrial waste water treatment was near to 35%. It has been determined that the germination and growth of seeds and seedlings of various species of plants are significantly affected by domestic and industrial waste water (Herpin, et al., 2012; Al-Jamal et al., 2002; Blumenthal et al., 2000).

The hospital waste of the city which comprises the awash of patient suffering from typhoid fever, malaria, hepatitis causes food borne illnesses. As the contaminants of waste water flow through the food chain of an ecosystem and affect each trophic level and disseminate the diseases in each level of food chain. The farmers of the developing countries prefer the use of waste water for irrigation just because it is economical and does not need organic fertilizers, but, the people are unaware of the consequences of using these vegetables. Waste water is a significant source of water and nutrients for irrigation in developing countries, particularly but not restricted to those located in arid and semi-arid areas. The use of waste water is extensive and represents around 10 percent of the total irrigated surface worldwide, although varying widely at local levels. While, the farmer gets benefits using the waste water, mainly related to their income level, but it has adverse effects on human health and the environment (Jimenez, 2006; Disciglio et al., 2015; Fonseca et al., 2007).

Materials and methods

Experimental research approach was chosen to conduct this research. As the experimental research approach is all about using manipulation and testing in a controlled manner to understand the casual processes, so, this is the reason this approach was best-suited considering the nature of the research. The study was based on mixed method approach; both descriptive and calculation analysis was done to describe the findings in an understanding way.

Geographical position of sampled plant species

Three types of leafy green vegetable plants i.e. Coriander (*Coriandrum Sativum)*, Lactuca (*Lactuca sativa)*, Purslane (*Portulaca oleracea)*, belonging to the family of Apiaceae, Asteraceae and Portulacaceae, respectively were selected for the experiments to assess the impact of waste water on their growth and phenotypic parameters and to examine the impact of plants irrigated with untreated wastewater on the health of the people. In Quetta city, the practice of growing these edible plants through municipal wastewater is common. Therefore, these types of plant seeds were selected for the investigation of impact of wastewater on these plants.

Seed sample collection

Fresh Certified Seeds of Coriander (*Coriandrum sativum)*, Lactuca *(Lactuca sativa)*, and Purslane (*Portulaca oleracae)* were collected from the Federal Certification Department, Quetta, Balochistan, Pakistan.

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Soil sample collection

Soil samples were collected from the water and soil testing center Quetta field through random selection method by digging out the soil inside the ring. Then this soil was air dried and sieved through a 2 mm sieve.

Particle size determination

Particle size distribution is a vital parameter in soil classification. The texture of the soil was determined by calculating the percentage of clay, silt and sand present in the soil sample. The standard size of soil particles are presented in *Table 1* (Glendon, 2002; Lado et al., 2012; Keller et al., 2002; Zafar et al., 2010).

Experimental procedure

The experiments were conducted in the Botanical Garden, Botany Department, University of Baluchistan, Quetta, Pakistan. Waste water was collected from waste water channels of the known Quetta city. Various concentrations of waste water i.e. T_0 (containing 100% pure or distilled water), T_1 (containing 20% waste water), T_2 (having 40% waste water), T_3 (containing 60% waste water), T_4 (containing 80% waste water), T_5 (containing 100% waste water) were employed in the experiment to check their effect on the growth of the selected plant species using tap water as control. The selected plant species were grown in 54 pots, 18 pots for each type of plant. Each plant in a pot was irrigated with a specific prepared concentration of waste water. After irrigating, the three types of plants with different percentage of waste water, the effect of waste water on the germination rate of seed and phenotypic parameters of these selected plant species were recorded.

Data collection

Different sites of the municipal wastewater were selected for the collection of waste water after an extensive survey from March 2016 to Jun 2016. After selection of sewage effluent sites, waste water was taken for the various experiments of the study. From the recommended cultivars, the seeds of Coriander (*Coriandrum sativum),* Purslane *(Portulaca oleracea)* and Lactuca (*Lectuca sativa)* were screened for germination potential in the laboratory.

Detailed experiments were held in the Botanical Garden of Baluchistan University. In the meanwhile, the resources used in this research were many including books and scientific journals, periodicals, research articles, digital media and the materials of Human Resource Department (HRD), University of Balochistan, Pakistan.

Results and discussion

Wastewater utilization

The scarcity of water increasingly makes agriculture dependent on the reuse of water, which has led to a search of alternative sources of irrigation that justify the yield potential of crops and can also be used as a substitute to fresh water in plants. It has been forecasted that by 2050, due to the population explosion, a severe water crisis would occur for irrigation of these crops. Waste water irrigation is becoming an attractive practice for agriculture as its use not only supplies nitrogen and phosphorus

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but also nitrogen to the plants and helps to recycle nutrients in wastewater to reduce and minimize the direct use of fertilizers. It is thus reducing significantly the pollution of receiving water bodies (Connor et al., 2017; Tarantino et al., 2009; Hein et al., 1992; Connor, 2015; Ensink et al., 2004).

The waste water of any city is mainly used for irrigating vegetables near the cities. Leafy vegetable plants such as cauliflower, cabbage, spinach, etc. grow by irrigating with waste water, while some vegetables such as radishes growth does not give positive response to wastewater. Vegetables irrigated with waste water contain many heavy metals that pose serious health risks for the community and animals. This problem is of particular importance, since untreated sewage is used for a long time for vegetable growing in urban areas (Mensah et al., 2002; Kakar et al., 2006; Borkin et al., 2000).

Soil management

Managing the productivity of soil is another problem that farmers face. The ability of soil to produce useful crops is called soil productivity. It produces valuable amounts of crop and is related to the physical and chemical properties of the soil as well as hydrological and atmospheric factors of the systems in which it is located. The loss of soil productivity has been a persistent problem worldwide. With regard to the application of waste water, its use increases the production of leafy vegetable plants in the short term. However, further use has serious consequences for the productivity of soil. The optimum parameters for soil management is given in the proposed *Table 1* (Gupta, 2008; Herpin et al., 2007; Leila et al., 2007).

Table 1. *Soil/particle parameters*

S/No.	Name particle diameter	Soil particle size
1	Clay below	0.002 mm
2	Silt	0.002 to 0.05 mm
3	Very fine sand	0.05 to 0.10 mm
4	Fine sand	0.10 to 0.25 mm
5	Medium sand	0.25 to 0.5 mm
6	Coarse sand	0.5 to 1.0 mm
7	Very coarse sand	1.0 to 2.0 mm
8	Grave	l 2.0 to 75.0 mm
9	Rock greater than	75.0 m (~2 inches)

Leafy vegetable plants

Vegetables have a significant role in meeting the food requirements of people in the world and are also a good source of various essential ingredients i.e. minerals, fibers and vitamins. Vegetables are also a rich source of essential nutrients like proteins, iron and calcium that have important health benefits. Beet is a great source of vitamins like vitamins A, vitamins B_6, vitamins C, vitamins E and folate, dietary fiber of copper, calcium and its consumption is very effective for preventing a wide range of health problems (Olaniran et al., 2013; Muchuweti et al., 2006; Adhikari et al., 1998; Hernandez et al., 1991).

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Radish has also many benefits for health point of views and used to treat various diseases, including pertussis, stomach problems, cancer, cough, constipation, dyspepsia, liver disorders, arthritis, gallbladder problems, gallstones, intestinal parasites and kidney stones. If leafy vegetable plants are irrigated with wastewater containing toxic heavy metals such as nickel, chromium, copper, lead, arsenic, cadmium and zinc etc., it has an adverse impact on human health (Ahmad et al., 2013; Ehmann et al., 1996; Henry et al., 2013).

Aluminum and chromium often occur concurrently in agricultural soils and causes enormous damage to plant productivity. The interactive effects of aluminum and chromium emphasize the absorption of nutrients and metals in barley. In such a situation, vegetable plant species accumulate increased amounts of heavy metals as compared to the soil not affected. This is because they absorb nickel, chromium, copper, lead, arsenic, cadmium and zinc through their leaves (Amoah et al., 2005; Joseph et al., 2002; Latare et al., 2014).

In general, urban waste water is a potential source of metals but it is still used to grow vegetables in cities. Irrigating of vegetable plants by these waste water containing toxic metals can cause various physiological and biochemical disorders (Ahmad et al., 2013; Alia et al., 2013).

This waste water is a rich source of organic matter as well as other plant nutrients. Waste water from industries of textile and paper is released into the water body or directly on the surface of agricultural land. This waste water is usually used for the irrigation of vegetables and fodder plant species due to fresh water scarcity. For increasing the soil productivity of soil mainly for leafy vegetable plants, use of untreated waste water can lead to the accumulation of metals in plants in phytotoxic amounts. The consumption of these toxic metals in vegetable plants cause diseases such as typhoid, cholera, leukemia, brain damage, diarrhea, vomiting, gastroenteritis, lung cancer, high blood pressure, pregnancy toxicity, pigmentation of the fingers nails, impairment of growth, heart failure, low blood pressure, liver neurosis, skeletal abnormalities, myocardial infarction, dermatitis, alcopia tumor, hair loss, depression and parkinsonism etc. (Ahmad et al., 1994; Husain et al., 2010).

Effect on seeds germination

Many researchers predict that the high pressure of textiles, paper, marble, dairy and brewery as well as strong osmotic pressure decreased seeds germination. Mohammad and Khan (1985) found that beans and ladyfingers plant species in the presence of industrial effluents reduced the percentage of seeds germination. However, there was no hazardous effect in the presence of treated waste water. Strong reduction in germs and early growth of radish, turnip and brassica occurred due to the use of untreated textile waste water. It was more pronounced in turnip, than in radish and brassica. Panasker and his co-workers studied the effect of textile mill effluent on the seeds germination and growth of black grams. Yousaf et al., found that with a lower concentration of sewage, seeds germination and seedling growth were higher than the control, but at higher concentrations, seeds germination and growth decreased gradually (Norton et al., 2007; Pathak et al., 1999; Saruhan et al., 2012).

The best growth of seeds germination and seedlings were observed at 25% concentration. They concluded that textile waste water is present and can be used safely for irrigation after proper treatment and recommended the 25% dilution, accordingly. Dayama (1987) reports that even in the presence of highly diluted industrial waste (5%),

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the germination of the seeds of Gram (*Cicer arietinum*) is diminished, whereas, Swaminanthan et al., found seed germination and chlorophyll improvement in the peanut plant (*Arachis hypogaea*) at 50% diluted waste. Mohammad et al., reported that 75-100% of concentrated waste water in the textile industry has harmful effects on seeds germination of Mung bean (*Phaseolus aureus)* and Okra (*Abelmoscus esculentus)*, whereas, a concentration up to 50% of the same effluent did not have any consequences (Dayama, 1987; Moreno et al., 2015).

Many researchers have documented that there are different concentrations of textile waste water and papers helping in the improvement of seedling lengths in various crops. However, it has been found that high levels of heavy metals in soils hinder the growth, metabolic processes and nutrient assimilation in plants. As per the given schedule, the rate of seeds germination were analyzed for all the plants species and checked proportionally by the waste water (Akbar et al., 2007; Dhanam, 2009).

It was clearly evident that increasing the percentage of waste water, the seeds germination were increased except in the Lactuca plant species. For clearer demonstration, the graphical representation rate of seed germination for every plant with every proportion of waste water is given in *Figure 1*. Lactuca is the plant with high effect on the growth of seed by the waste water. Increasing the waste water, its rate increased but in the other two plant species, the rate was partial. However, there is a decrease in germination of seed with waste water irrigation for coriander and purslane.

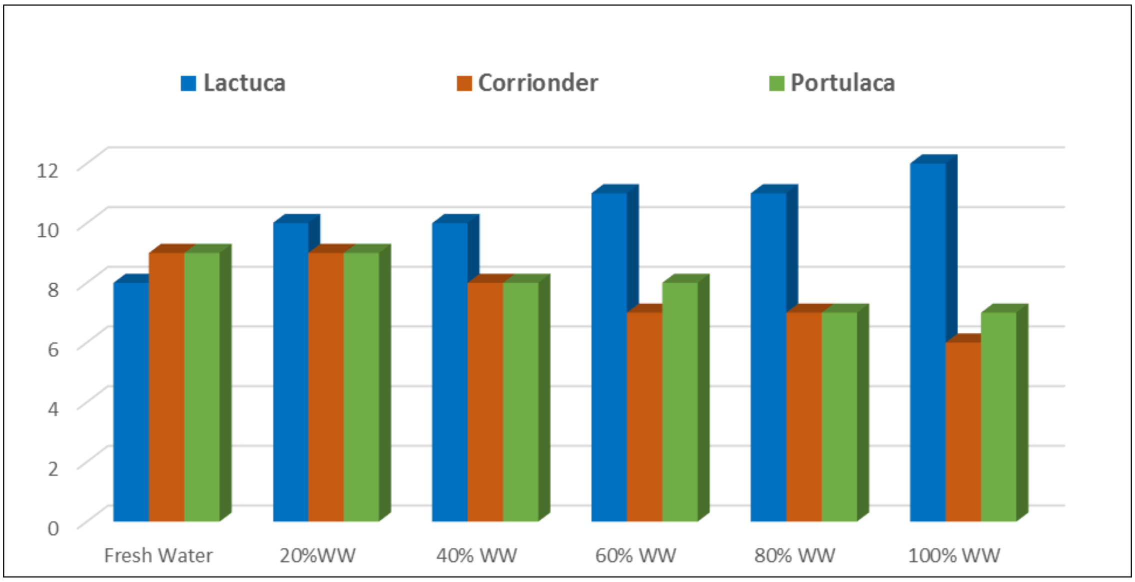

Figure 1. *Rate of seeds germination in different plant species*

It can be said that the rate of seed germination may or may not be influenced by the waste water irrigation depending on the environmental conditions. The next measuring parameter that was observed was height; the impact of waste water on the height of plants is shown in *Figure 2*. It is observed that with an increase in percentage of waste water, the height of plants was increased. An increase in height was measured in all the three plants but Purslane (*Portulaca oleracea)* has shown quicker response as compared to the other two plants.

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Effect on green leaves elongation

Examining the increase in number of green leaves, it was observed that the numbers of green leaves were increased with higher proportion in Purslane (*Portulaca oleracea)* and Coriander (*Corianderum sativum)* as compared to Lactuca (*Lactuca sativa).* The significant impact of waste water on the number of green leaves of the plants was reported as shown in *Figure 3*.

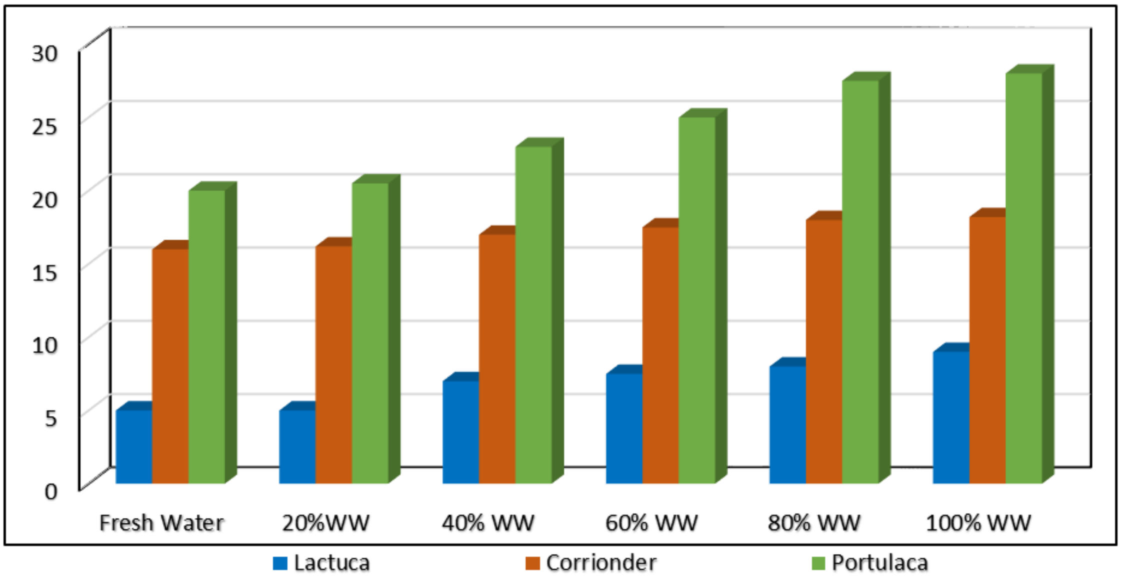

Figure 2. *Height status of different plants species (in cms)*

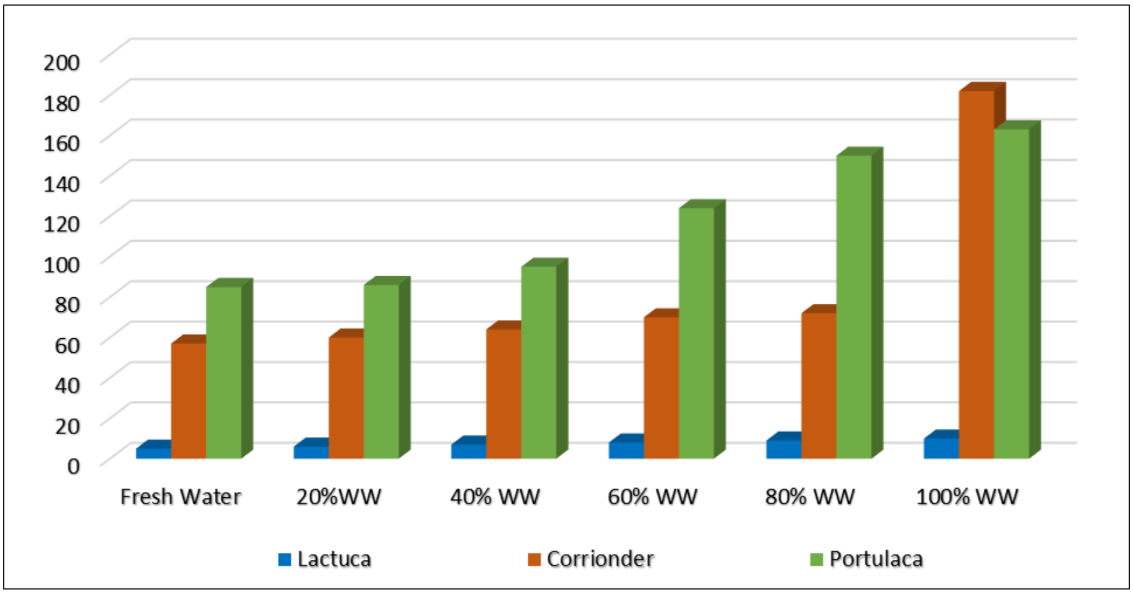

Figure 3. *Number of leaves per species in different plants*

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Effect on biomass growth

By increasing the concentration of waste water, the vegetative growth of plants were increased as previously reported by other researchers (Khalil et al., 2011; Emongor et al., 2004). Waste water containing sludge increases the root length. Coriander stem length also increases with increasing waste water concentration. The sludge present in waste water also raises the biomass of coriander plant. By adding sludge to the soil a positive impact may be reached on the soil porosity, water retention by root, water-holding capacity of the soil mixture. By application of sludge to the soil, moisture content modified but the number of seed in each type of plants reduced by increasing the waste water concentration. Significant reduction in the number of seed by increasing the concentration of waste water was also reported.

Examining the increase in weight of leaves per plant, it was observed that the weight of both fresh and dry leaves were increased in Purslane (*Portulaca oleracea),* Coriander *(Corianderm sativum),* and Lactuca *(Lactuca sativa)*. It should be noted that the rate of increase in every attribute is dependent on the nature and characteristics of the plant itself. However, the increase in rate was measured for every plant but one of the plants showed much more increase in values as compared to the other two. Overall, the significant impact of waste water on the weight on fresh and dry leaves per plant was reported as shown in *Figure 4*.

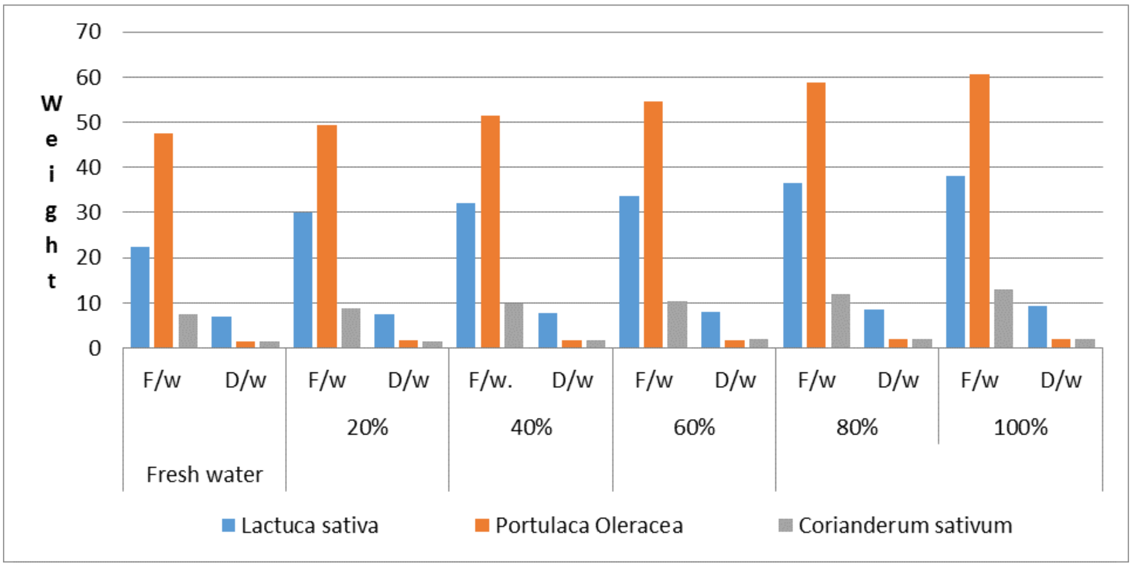

Figure 4. *Comparative weight of fresh and dry leaves in different plants species*

Conclusion

The sludge present in waste water showed a very positive impact on the growth of plants in general. By increasing the concentration of waste water, the concentration of sludge also increased and healthy vegetative growth had been observed in the waste water treated plant species. It is reported that application of sludge to the soil, moisture content was modified due to additional pores which are able to hold more water. Pore surface roughness, which enhance the water retention and reduction of micro-cracking of soil pores. Soils that hold water support more plant growth and are less susceptible to nutrient loss.

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Our study revealed that all growth parameters measured in the three selected leafy vegetable plants, i.e. Coriander *(Corianderum sativum),* Purslane *(Portulaca oleracae),* Lactuca *(Lactuca sativa)* were statistically greater in waste water irrigated plant species than in fresh water plants. The usage of municipal waste water for irrigation may be an abundant resource of nutrients and essential elements for plant's growth. In fact, waste water has high concentration of organic matter and nutrients as compared to fresh water. Therefore, the nutrient accumulation occurring in the soil and this high concentration of nutrients will make the plants easy to access these nutrients.

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Author contributions. Fahmeda Ali and Niaz Muhammad Tareen, Tahira Bibi participated in the research project, experimental findings, data compilation and participated in the preparation of manuscript draft. Kifayat Ullah, Anwar Ullah and Sadullah Laghari participated in sample collection, identification, systematic studies and the species feasibility recommendation, taxonomic studies for the proposed project, and helped to draft the manuscript. Saeed Ur Rehman supervised the overall techniques and participated in the article preparation to draft the manuscript.

Conflict of interests. All the authors listed above in the article authorship line have contributed equally to the proposed research project, and all those authors who are qualified accordingly the proposal preparation, laboratory work and report compilation are listed. To the best of our knowledge, no conflict of interests here in this research work exists.

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