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Efficiency of Treated Domestic Wastewater to Irrigate Two Rice Cultivars, PK 386 and Basmati 515, under a Hydroponic Culture System

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Abstract: The increasing human population continues to exert pressure on the freshwater scarcity. The availability of freshwater for crop irrigation has become challenging. The present study aimed to use domestic wastewater (DWW) for the irrigation of two rice cultivars (CVs) after treatment with the bacterial strain *Alcaligenes faecalis* MT477813 under a hydroponic culture system. The first part of this study focused on the bioremediation and analysis of the physicochemical parameters of DWW to compare pollutants before and after treatment. The biotreatment of DWW with the bacterial isolate showed more than 90% decolourisation, along with a reduction in contaminants. The next part of the study evaluated the impacts of treated and untreated DWW on the growth of two rice cultivars, i.e., PK 386 and Basmati 515, under a hydroponic culture system which provided nutrients and water to plants with equal and higher yields compared to soil. Growth parameters such as the shoot and root length and the wet and dry weights of the rice plants grown in the treated DWW were considerably higher than those for the plants grown in untreated DWW. Therefore, enhanced growth of both rice cultivars grown in biotreated DWW was observed. These results demonstrate the bioremediation efficiency of the bacterial isolate and the utility of the DWW for rice crop irrigation subsequent to biotreatment.

Keywords: domestic wastewater; *Alcaligenes faecalis* MT477813; irrigation; *Oryza sativa*; hydroponic culture system

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1. Introduction

The growing population, urbanisation, industrialisation, agriculture and the lack of water management collectively exert stress on the freshwater supply. Therefore, the demand for water supply is increasing because of rapid growth in all the aforementioned areas [1]. Pakistan, as an agricultural and industrial country, has been ranked third in the list of the most water-scarce countries [2]. Moreover, the Pakistan Council of Research in Water Resources stated that the country would run short of clean, drinkable water before 2030 [3]. These circumstances necessitate the pursuit of alternate water resources as an essential requirement to meet the rapidly increasing demand for fresh water [4].

Domestic wastewater has long been considered an important alternative source of irrigation water and is utilised for irrigation in agriculture [5–7]. The wastewater is directly utilised for agriculture all over the country, near towns/municipalities with populations of more than 10,000 people [8]. Domestic wastewater typically includes organic matter and various important nutrients (N, K, P, Ca, Mn, S, Cu, Zn, Mn) that support agriculture by enhancing crop output as well as food quality [6]. Along with nutrients, domestic wastewater carries hazardous toxins, which may accumulate in agricultural plants. These nutrients and heavy metals, like cadmium, copper, iron, lead, nickel or zinc, induce phytotoxicity and pose a menace to human beings and other animals [9]. Local communities reuse raw wastewater to irrigate crops, which can be very detrimental to animal life, including humans [10–13]. The bioremediation of domestic wastewater with microbes has been considered an excellent biological activity due to metabolic activities of microorganisms such as bacteria [14–16], and their biological activity and metabolic flexibility might be tremendously advantageous in the conversion and degradation of harmful contaminants into non-toxic compounds [17]. A number of indigenous bacteria have the potential to discolour, detoxify and degrade the pollutants of different types of wastewater [16].

Rice is Pakistan's second most important cash crop and requires abundant irrigation water throughout its growing period [18–21]. Due to water scarcity, farmers are compelled to use wastewater for crop irrigation. Out of the various types of wastewater, domestic wastewater may be utilised to irrigate these paddy fields. As domestic wastewater contains nutrients, organic matter, a high biological oxygen demand (BOD) value and many contaminants [22–25], its application for rice irrigation without adequate biotreatment has proven to be damaging to rice plants [13]. After appropriate biotreatment, wastewater can be utilised for mass production of nutritious rice crops [23,25–27].

Rice crops require excessive amounts of water, which is a challenge that appears daunting for farmers in water-scarce nations. [28]. Therefore, biotreated domestic wastewater may be used in hydroponic systems, as these systems assist in the early maturation of seedlings, provide higher crop yield, use 95% less water than usual irrigation and cope with late rainfall due to the changing climate [29]. This kind of hydroponic system also avoids the risks associated with soil diseases and salinity and waterlogging issues [30]. Some previous studies have asserted that biotreated domestic wastewaters lack certain nutrients up to the desired levels for crop growth; therefore, a hydroponic system needs additional ingredients to acquire quality-oriented rice production [31–39]. Researchers have also designated the Hoagland solution as a promising culture for hydroponic systems to grow different crops like wheat [31–33], tomatoes [34,35], lettuce [36,37], Arabidopsis [38] and onions [39].

Considering the aforementioned factors, the objectives of this work were to decolourise and degrade harmful contaminants in DWW using the bacterial isolate *Alcaligenes faecalis* MT477813. Also, this work compares the effect of untreated and biotreated domestic wastewater on the growth of rice cultivars (PK 386 and Basmati 515) in a hydroponic culture system to obtain sustainable agricultural output.

2. Materials and Methods

2.1. Collection and Characterisation of Domestic Wastewater

According to the APHA (2002) standard procedure [40], domestic wastewater was collected from the main point of discharge at Mohni Road, adjacent to Band Road, Lahore. The wastewater sample was screened for visible contaminants in the research lab at the Centre of Environmental Protection Studies, Pakistan Council of Scientific and Industrial Research, Lahore. The physicochemical parameters of the domestic wastewater (in four different treatments) such as the BOD, biodegradability index (BI), chemical oxygen demand (COD), colour, dissolved oxygen (DO), electrical conductivity (EC), heavy metal quantification (Zinc—Zn, Manganese—Mn and Iron—Fe) and NPK estimation, odour, pH, salinity, temperature, total suspended solids (TSSs), total dissolved solids (TDSs) and turbidity, were analysed pre- and post-biotreatment according to the standard methods of APHA [40] using a pH meter (Extech pH100, Nashua, NH, USA), an EC meter (Extech EC300, Nashua, NH, USA), a DO meter (Extech DO200, Nashua, NH, USA), BOD (Lovibond BOD5+, USA) and COD digesters (Merck COD digester T320, Darmstadt, Germany), a turbidity meter (Extech TB400, Nashua, NH, USA) and an atomic absorption spectrophotometer (AA 7000 F, Shimazdu Corporation, Kyoto, Honshu, Japan). These parameters were then compared with the National Environmental Quality Standard values [41] to assess the efficiency of the treatment.

2.2. Source of Alcaligenes Faecalis MT477813 Culture

The bacterial strain *A. faecalis* MT477813 was acquired from the Plant Biotechnology Lab, Botany Department, GC University Lahore. The strain was used to decolourise DWW because it had a bioremediation efficiency of more than 90% [15]. Initially, the strain was grown and streaked on plates containing solidified nutrient agar medium (Figure 1a). These plates were incubated at 37 °C for 24 h and colonies were prepared (Figure 1b). The LB (Lysogeny broth) agar slants were used to store the pure bacterial culture (Figure 1c,d) while keeping it at a temperature of 4 °C in a refrigerator [42].

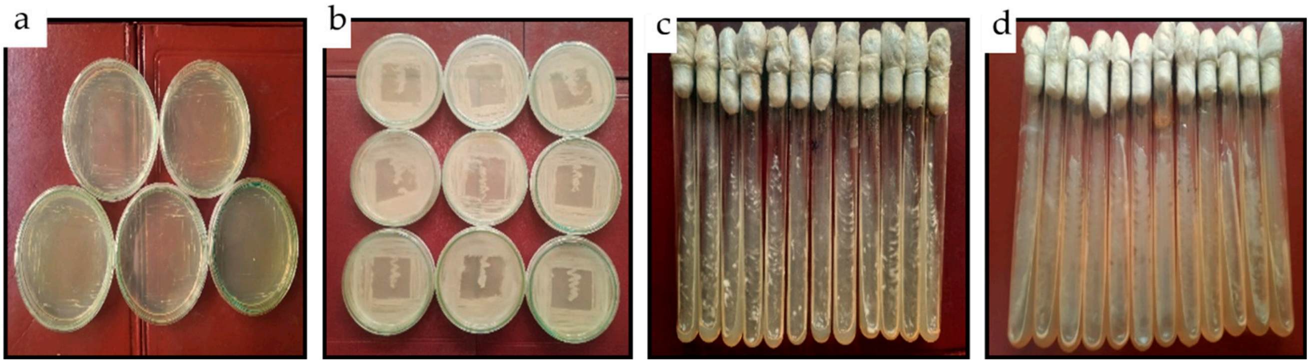

Figure 1. Culture of bacterial strain; (**a**) streaking of bacterial strain (*A. faecalis* MT477813) on NB plates, (**b**) bacterial growth on plates, (**c**) bacterial streaking on agar slants, and (**d**) bacterial growth on agar slants.

2.3. Domestic Wastewater Treatment

The decolourisation potential of *A. faecalis* MT477813 was tested at the following optimal conditions: duration (48 h), inoculum (10%) and temperature (37 °C) [14,15]. Each conical flask (250 mL) was inoculated with 10% bacterial strain solution (10 mL) in autoclaved domestic wastewater (90 mL). For the bacterial strain solution preparation, an inoculum loop full of bacterial colony was taken from slant and added to distilled water (100 mL). The optical density (OD) of 1 at 545 nm was achieved (A and E Labmed, AE-S80) to ensure an equal concentration of bacterial cells in each inoculum. The flasks having wastewater after inoculation were placed in a shaking incubator (PMI Labortechnik GMBH, WIS-20R) for 48 h at 37 °C and 120 rpm [43]. The decolourisation percentage was computed by Equation (1):

$$Decolourisation(\%age) = \frac{\text{Absorbance before inoculation} - \text{Absorbance after treatment}}{\text{Absorbance before inoculation}} \times 100 \quad (1)$$

All decolourisation experiments were carried out in triplicates.

2.4. Germination of Rice Seedlings for Hydroponic Cultures

Two rice cultivars under the names PK 386 and Basmati 515 were obtained from the Rice Research Centre, Kala Shah Kaku, Pakistan [44]. The characteristic profile of these two cultivars is provided in Table 1. Chemicals used in this experiment were procured from “Thermo Fisher Scientific USA”, through “Worldwide Scientific” Syed Plaza, 30 Lahore—Kasur Rd, Jinnah Town, Lahore, Punjab, Pakistan.

Table 1. Characteristic profile of rice cultivars data taken from [44].

Characteristics	PK386	Basmati 515
Type	Fine	Fine Basmati
Class	Long grain	Extra long grain
Aroma	Yes	Yes
Chalkiness	Absent	Absent
Height of plant (cm)	117	130
Grain length (mm)	6.85	7.56
Grain width (mm)	1.78	1.64
Grain thickness (mm)	1.56	1.52
Nitrogen (N) (mg/L)	22	24
Phosphorus (P) (mg/L)	115	119
Potassium (K) (mg/L)	115	123
Iodine (I) (mg/L)	Nd	Nd
Zinc (Zn) (mg/L)	1.1	1.3
Manganese (Mn) (mg/L)	2	2.4
Iron (Fe) (mg/L)	0.8	1.1

Note: Nd = Not detected.

Viable seeds of both rice CVs were selected for germination and surface sterilization of seeds was carried out using chemical treatment. Seeds were washed with tap water and treated with 70% ethanol solution for 40 s and with 30% sodium hypochlorite solution (added with a few drops of Tween^{20}) for 3 min stepwise. The seeds were thoroughly washed with sterile distilled water after each chemical treatment. Under aseptic conditions, the sterile seeds were placed at equal spacing in Petri plates on filter paper (Whatman filter paper 42 having pore size of 2.5 μM) soaked with 5 mL autoclaved distilled water. Five sets of replicates were made for each cultivar. The plates were placed in growth room for seed germination under continuous fluorescent light at 26 °C ± 1 for 15 days (Figure 2).

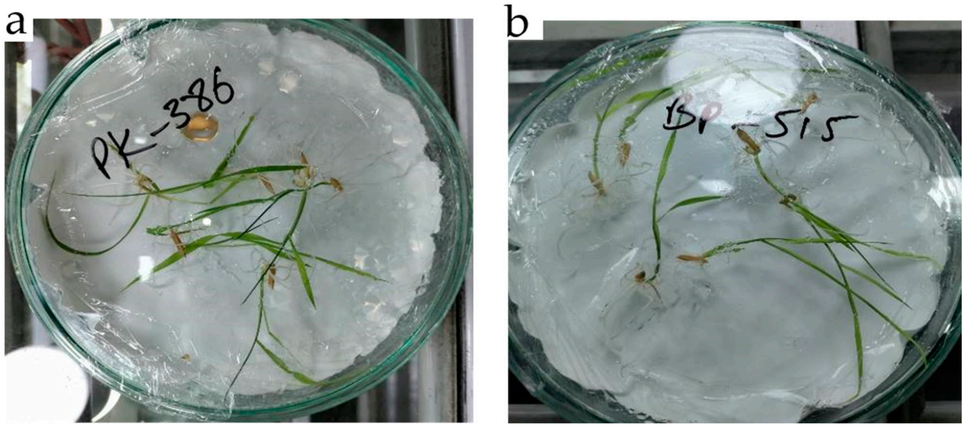

Figure 2. Germination of rice seeds on filter paper; seedlings of 15 days: (**a**) PK 386, (**b**) Basmati 515.

Hoagland solution [45] was prepared as nutrient medium for hydroponic growth of rice seedlings of both cultivars. The hydroponic culture system was designed using 1 L glass beakers. Each beaker possessed a piece of spherical recycled foam sheet one-inch-thick as a floater. Five holes of equal size were made to accommodate seedlings (each hole containing one seedling). Five sets of triplicates (1 L beaker each) were prepared under aseptic conditions; each set of replicates contained 500 mL of water types presented in Table 2.

Table 2. Types of treatments and their composition.

Treatment Type	Composition of Treatment	Water + Hoagland Concentration
Control	Distilled water with Hoagland Solution (DWH)	400 mL distilled wastewater + 100 mL Hoagland solution
Treatment 1	Untreated Domestic wastewater with Hoagland Solution (UTDWWH)	400 mL untreated domestic wastewater + 100 mL Hoagland solution
Treatment 2	Treated domestic wastewater with Hoagland Solution (TDWWH)	400 mL treated domestic wastewater + 100 mL Hoagland solution
Treatment 3	Untreated domestic wastewater (UTDWW)	500 mL untreated domestic wastewater
Treatment 4	Treated domestic wastewater (TDWW)	500 mL treated domestic wastewater

2.5. Transfer of Seedlings to Hydroponic Cultures

Fifteen day old rice seedlings germinated in Petri plates were transplanted to 500 mL liquid nutrient medium in 1 L beakers under aseptic conditions. Rice seedlings were planted in the holes, being one seedling in each hole; roots passing through the hole were submerged in hydroponic culture medium and shoot exposed above the floater sheet (Figure 3). Seedlings of both rice cultivars were uniformly transplanted across all five sets of treatments in triplicates, as previously specified.

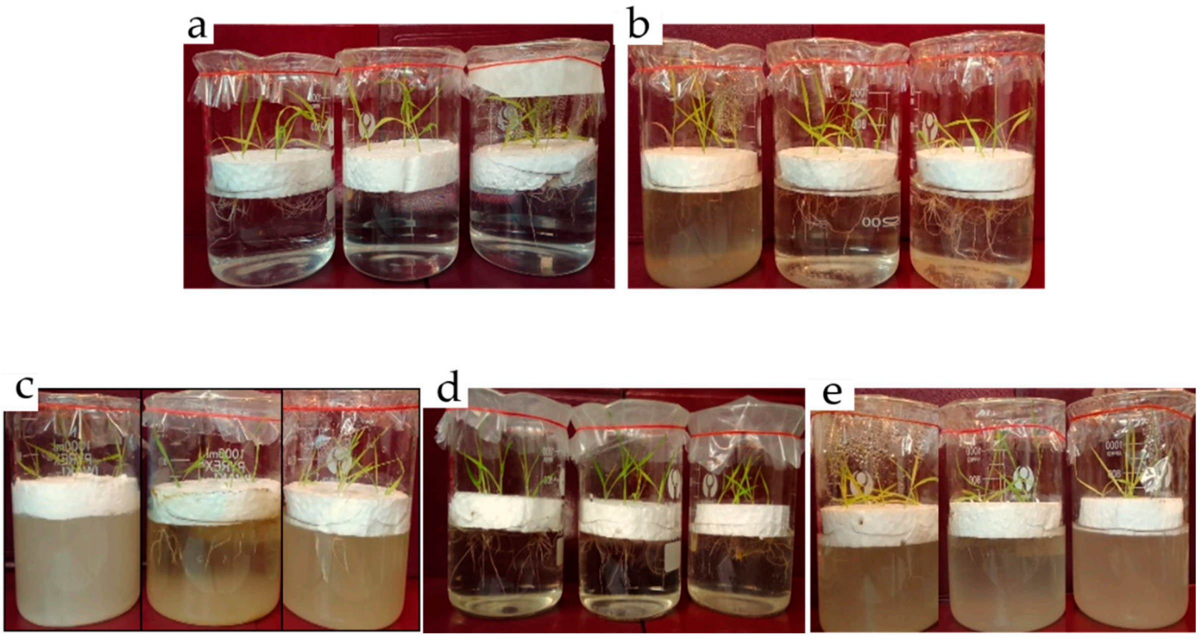

Figure 3. Rice seedlings in hydroponic culture; (**a**) Control, (**b**) Treatment 1, (**c**) Treatment 2, (**d**) Treatment 3, (**e**) Treatment 4.

2.6. Growth of Seedlings and Analysis in Hydroponic Cultures

Beakers were wrapped in thick black polyethylene sheets with the exposed surface wrapped with a transparent PVC plastic sheet containing small holes to ensure the smooth acclimatization of seedlings. Beakers were placed in a growth room under 16/8 light/dark 24 h cycle at 26 °C ± 1. The plants increased gradually and the polythene sheet was completely removed from the beakers after 1 week. The growth experiment continued for 21 days. The plants were harvested after a growth period of 21 days and morphological growth parameters of the plants such as seedling length, shoot length, root length, wet and dry weight of seedling, shoot and root were recorded for each treatment.

2.7. Statistical Analyses

The data were analysed using SPSS as mean of triplicates ±SD (standard deviation) and comparisons of variance. Data values of different replicates and treatments were compared by One-Way ANOVA and *t*-test was run with two-tailed *p*-value to assess the magnitude of differences of corresponding means of four different treatments. These differences were only considered significant when *p*-values were <0.05.

3. Results and Discussion

3.1. Physiochemical Characterisation of Treatments

Physiochemical characterisation of the treatments revealed that values of all parameters before treatment (UTDWW) such as EC (973 µs/cm), BOD (295.7 mg/L), COD (412.8 mg/L), pH (8.5), turbidity (38.5 NTU), TSS (383 mg/L), TDS (730 mg/L) and salinity (0.43 ppt) decreased significantly after treatment (Table 3). Results showed that the values of various physicochemical parameters were within the levels of the National Environment Quality Standards (NEQS) after treatment with a Hoagland solution. For instance, the value of TSS was 930 mg/L in untreated domestic wastewater. The NEQS value for TSS was 500 mg/L. After biotreatment, the TSS value reduced to 300 mg/L and with an additional Hoagland solution, the value reduced to 298 mg/L. Similarly, turbidity reduced from 38.5 NTU to 18.3 NTU in biotreated domestic wastewater and then to 4.2 NTU in biotreated domestic wastewater with the addition of the Hoagland solution. The values of BOD and COD also reduced from 295.7 mg/L and 412.8 mg/L to 171.5 mg/L and 140 mg/L while their NEQS ranges were 80–250 mg/L and 150–400 mg/L, respectively. Other reduced physicochemical parameters including EC, TDS, salinity, pH, N, P, K, Zn, Mn and Fe also agree well with a previous research treating DWW with *Alcaligenes faecalis* MT477813 [41] and with our previous work [14,15].

Table 3. The physicochemical characterisation of different treatments.

Characters	Units	NEQS [41]	Control (DWH)	Treatment-1 (UTDWWH)	Treatment-2 (TDWWH)	Treatment-3 (UTDWW)	Treament-4 (TDWW)
pH		6.6–8.5	7.6	7.8 ****	7.2 ****	8.5 ****	8.2 ****
EC	µs/cm	-	170	413.2 ***	215.4 ***	973 ***	345.9 ****
TDS	mg/L	1000	298.3	500 ****	221.3 **	730 ****	330 ****
TSS	mg/L	<500	200	930 ****	298 ****	383 ***	300 ****
Salinity	ppt	-	0.02	0.3 ****	0.12 ****	0.42 ****	0.2 ****
Turbidity	NTU	5	2.5	13.5 ****	4.2 ***	38.5 ****	18.3 ****
COD	mg/L	150–400	200	273.2 ****	140.5 ****	412.8 ****	266 ****
BOD	mg/L	80–250	140	266.9 ****	171.5 ***	295.7 ****	190 ****
Nitrogen (N)	mg/L	-	210	140.7 ****	86 ****	40.7 ****	16 ****
Phosphorous (P)	mg/L	-	31	47.5 ****	27.3 ****	17.5 ****	7.3 ****
Potassium (K)	mg/L	-	235	260 ****	83.6 ****	60 ****	22.6 ****
Zinc (Zn)	mg/L	5	0.023	2.099 ****	1.83 ****	2 ****	1.3 ****
Manganese (Mn)	mg/L	1.5	0.11	0.064 ****	0.094 ****	0.044 ****	0.004 ****
Iron (Fe)	mg/L	2	1	3.3 ****	1.36 ****	2.3 ****	0.36 ****

Note: NEQS = National Environment Quality Standards; significance is indicated by ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$.

In our study, *A. faecalis* strain MT477813 led to the decolourisation percentage above 90%. *A. faecalis* has been also reported as a biocontrol agent [46,47] that may explain the reason BOD values reduced in all the treatments. Previously, the physiochemical analysis of biotreated and untreated domestic wastewater samples (without Hoagland solution) revealed a reduction (40–70%) in the peak intensities of many unwanted compounds, which have been shown to be harmful like phenol (876 μg/L), caffeine (7 μg/L), salicylic acid (48 μg/L), naproxen (23 μg/L), diazepam (14 μg/L) and octadecene (185 μg/L) [14,15,48–52]. However, in our work, the implementation of Hoagland's solution treatments resulted in a decrease in these parameters by over 80%. Drawing upon prior research [14,15], it is conceivable that this amplified percentage reduction stemmed from the implementation of the Hoagland solution. In contrast, in our earlier studies (without the application of Hoagland solution), the diminution in physicochemical parameter values was comparatively milder (ranging from 40% to 70%). The comparison of all four treatments shows the following order in terms of treatment efficiency: Treatment 2 > Treatment 4 > Treatment 1 > Treatment 3. Here, Treatment 2 contains treated DWW with Hoagland solution which highlights higher treatment efficacy of *A. faecalis* with the Hoagland solution. Other scientists have also designated the Hoagland solution as a promising solution for a hydroponic culture system to grow different crops like wheat [31–33], tomatoes [34,35], lettuce [36,37], Arabidopsis [38] and onion [39].

3.2. Growth Parameters of Rice Cultivars in Different Hydroponic Treatments

Growth parameters were assessed under different treatments for both rice cultivars. Higher values were seen mainly in biotreated domestic wastewater with the Hoagland solution (Treatment 2) and the treatment efficiencies of both rice cultivars were compared (Figure 4a–c). The shoot length of both cultivars was observed to be the highest (14.5 and 18.3 cm) in Treatment 2 (TDWWH) as compared to other treatments of cultivar PK386 (13.8, 10.6 and 10.1 cm), BP515 (16.2, 14.8 and 13.7 cm) as well as the control (12.5 and 15.6 cm). Moreover, it was concluded from these readings that the treatment UTDWW has a negative impact, even with the Hoagland solution. This may be due to the presence of toxic compounds in domestic wastewater that overshadowed the benefits of the Hoagland solution [53]. Previous studies have also shown reduction in seedling length (mainly root length) as compared to the control when grown in raw wastewater mixed with the Hoagland solution in a hydroponic system [31,33,36–39].

Comparison between Basmati 515 and PK386 under different treatments for morphological parameters, seedling length, shoot length, and root length showed that Basmati 515 performed better than PK386 in treatment 2 and 4 while PK386 gave better performance in treatment 3 and 1 as well as in the control (Figure 4). As treatments 1 and 3 were having untreated domestic wastewater, this implies that PK386 exhibit greater resilience to untreated wastewater, whereas Basmati 515 thrive in the presence of treated domestic wastewater, suggesting a higher level of sensitivity. This result is supported by the characteristic profile provided by the Rice Research Centre Kala Shah Kaku where Basmati 515 contains more N, P, K, iodine (I), Zn and Mn content compared to PK 386 (see Table 1) [44]. Hence, the resilience of PK386 is also attributed to the presence of macro- and micronutrients like N, P, K, I, Zn and Mn. Moreover, the projected yield for Basmati rice is estimated at 75 Maund per Acre, surpassing that of PK386 by 8%. This disparity further underscores the robustness of bananas in their growth [44]. This discrepancy not only highlights the strength of Basmati 515's growth, but also reinforces their resilient role.

In hydroponic cultures, the average shoot and root weights of PK 386 (both dry and wet) were found to be higher in treatment 1 (UTDWWH) (shoot (dry weight: 0.018 g; wet weight: 0.282 g)); (root (dry weight: 0.009 g; wet weight: 0.141 g)) than the untreated DWW (shoot (dry weight: 0.0114 g; wet weight: 0.343 g)); (root (dry weight: 0.0057 g; wet weight: 0.217 g)), respectively (Table 4). This indicates three possibilities for the increased weight: (1) PK386 can grow well under stressed conditions [54]; (2) the weight was more due to toxic contaminants present in the untreated DWW [55]; and (3) the nutrients present in the

Hoagland solution favoured the growth [55,56]. As far as the potential of the Hoagland solution is concerned, overall seedling wet weight was larger in treated DWW with the Hoagland solution than in untreated DWW with the Hoagland solution. This result agrees well with similar studies where total wet and dry weights of plants were more in those hydroponic cultures with Hoagland solution [57,58].

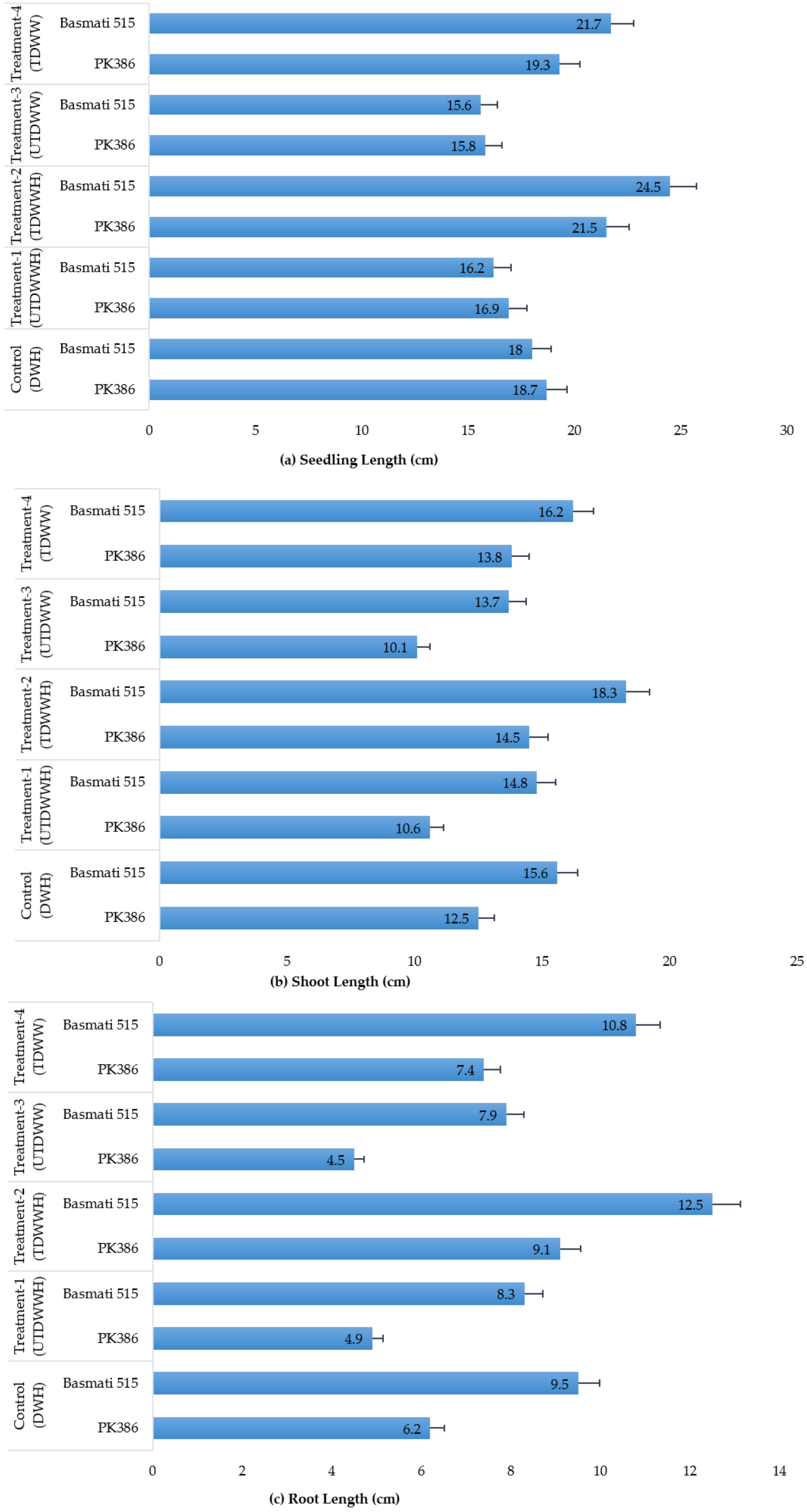

Figure 4. Comparison between Basmati 515 and PK386 under different treatments for morphological parameters: (**a**) seedling length, (**b**) shoot length, and (**c**) root length.

Table 4. Morphological parameters of PK 386 in different hydroponic cultures.

Morphological Parameters	Categories	Types of Hydroponic Cultures				
		Control (DWH)	Treatment-1 (UTDWWH)	Treatment-2 (TDWWH)	Treatment-3 (UTDWW)	Treament-4 (TDWW)
Wet weight (g)	Shoot	0.248 (±0.034, 1.71×10^{-3})	0.282 (±0.016, 3.86×10^{-4}) *	0.278 (±0.026, 1.15×10^{-3}) *	0.343 (±0.032, 1.56×10^{-3}) *	0.282 (±0.026, 8.86×10^{-4}) *
	Root	0.124 (±0.017, 8.56×10^{-4})	0.141 (±0.08, 1.93×10^{-4}) *	0.139 (±0.013, 5.76×10^{-4}) **	0.217 (±0.0161, 7.83×10^{-4}) **	0.141 (±0.013, 4.43×10^{-4}) *
	Seedling	0.372 (±0.051, 2.57×10^{-3})	0.412 (±0.024, 5.8×10^{-4}) *	0.416 (±0.039, 1.73×10^{-3}) *	0.38 (±0.0485, 2.35×10^{-3}) *	0.424 (±0.039, 1.33×10^{-3}) *
Dry weight (g)	Shoot	0.0128 (±0.002, 1.05×10^{-5})	0.013 (±0.0014, 3.33×10^{-6}) *	0.0014 (±0.002, 1.35×10^{-5}) *	0.0114 (±0.0022, 6.6×10^{-6}) *	0.018 (±0.003, 1.82×10^{-5}) *
	Root	0.0064 (±0.001, 5.26×10^{-6})	0.0063 (±0.0007, 1.66×10^{-6}) **	0.007 (±0.001, 6.76×10^{-6}) *	0.0057 (±0.0011, 3.3×10^{-6}) *	0.009 (±0.0015, 9.1×10^{-6}) *
	Seedling	0.0194 (±0.0039, 1.58×10^{-5})	0.019 (±0.002, 5.0×10^{-6}) *	0.022 (±0.004, 2.03×10^{-5}) *	0.017 (±0.0032, 1.0×10^{-5}) *	0.028 (±0.0045, 2.73×10^{-5}) *
F-value		*0.0244*	*0.0437*	*0.0028*	*0.091*	*0.058*

Note: ±values in the table above represent standard deviation and variance. *p*-value indicates significance of the value of treatments in following manner: $p < 0.01$ = *, $p < 0.001$ = **.

In hydroponic cultures, the average shoot and root weights of Basmati 515 (both dry and wet) were found to be higher in bio treated DWW with Hoagland solution (shoot (dry weight: 0.012 g; wet weight: 0.138 g)); (root (dry weight: 0.0061 g; wet weight: 0.069 g)) than in the untreated DWW with Hoagland (Table 5). This shows the potential of Basmati 515 cultivar for domestic treated domestic wastewater and confirms the resilience of PK386 to toxic untreated domestic wastewater environment. Based upon previous research, two suppositions may be drawn from these observations: (1) *A. faecalis* led treated domestic wastewater with Hoagland solution is suitable for the Basmati 515 rice cultivar; and (2) PK386 has more potential to grow well under toxic conditions such as untreated DWW. Moreover, it is also evident that the Hoagland solution is nutrient-rich and adequate for hydroponic culture systems [57,58].

Table 5. Morphological parameters of Basmati 515 in different hydroponic cultures.

Morphological Parameters	Categories	Types of Hydroponic Cultures				
		Control (DWH)	Treatment-1 (UTDWWH)	Treatment-2 (TDWWH)	Treatment-3 (UTDWW)	Treament-4 (TDWW)
Wet weight (g)	Shoot	0.138 (±0.072, 6.86×10^{-4})	0.172 (±0.021, 7.13×10^{-4}) ***	0.204 (±0.014, 1.53×10^{-4}) ***	0.198 (±0.0264, 2.86×10^{-4}) ***	0.242 (±0.022, 1.11×10^{-3}) ***
	Root	0.069 (±0.036, 3.43×10^{-4})	0.086 (±0.010, 3.56×10^{-4}) ***	0.102 (±0.007, 7.66×10^{-5}) ***	0.099 (±0.013, 1.43×10^{-4}) ***	0.121 (±0.011, 5.56×10^{-4}) ***
	Seedling	0.208 (±0.107, 1.03×10^{-3})	0.258 (±0.031, 1.07×10^{-3}) ***	0.306 (±0.021, 2.3×10^{-4}) ***	0.296 (±0.0397, 4.3×10^{-4}) ***	0.364 (±0.034, 1.67×10^{-3}) ***
Dry weight (g)	Shoot	0.012 (±0.0028, 1.21×10^{-5})	0.012 (±0.0016, 5.95×10^{-3}) ***	0.015 (±0.002, 1.18×10^{-5}) ***	0.094 (±0.021, 1.58×10^{-5}) ***	0.016 (±0.002, 4.1×10^{-3}) ***
	Root	0.006 (±0.0014, 6.06×10^{-6})	0.0061 (±0.0008, 2.97×10^{-3}) ***	0.007 (±0.001, 5.9×10^{-6}) ***	0.047 (±0.0103, 7.93×10^{-6}) ***	0.008 (±0.0.001, 2.5×10^{-3}) ***
	Seedling	0.019 (±0.0043, 1.82×10^{-5})	0.0184 (±0.0023, 8.93×10^{-3}) ***	0.022 (±0.004, 1.77×10^{-5}) ***	0.0142 (±0.031, 2.38×10^{-5}) ***	0.024 (±0.0029, 6.15×10^{-3}) ***
F-value		*0.0042*	*0.0392*	*0.0494*	*0.0589*	*0.0658*

Note: ± values in the table above represent standard deviation and variance. *p*-value indicates significance of the value of treatments in following manner: $p < 0.0001$ = ***.

Previous studies have found that saplings irrigated with untreated textile wastewater had shorter length and weight [59–61]. As far as the Hoagland solution is concerned, studies also endorsed its efficacy in synthesizing bacterial strains that may be helpful in the treatment of different wastewaters and assist in the growth of crop plants [53]. In our work, the Hoagland solution fulfilled the same purpose. The results of the hydroponic experiment were surprisingly significant. The impact of UTDWW and TDWW treatments (Treatments 1, 2, 3 and 4) on growth of the two rice cultivars under study indicated that the growth parameters under TDWW with the Hoagland solution were considerably higher than with only TDWW. Furthermore, UTDWW with or without the Hoagland solution demonstrated lower values of the growth parameters (Figure 4). A comparable pattern of seedling biomass (both wet and dry weights) was predominantly observed, with TDWWH, exhibiting the highest biomass levels (Tables 4 and 5). The possible reasons for this increased biomass are two: (1) presence of organic matter and nutrients (N, K, P, Ca, Mn, S, Cu, Zn, Mn) in domestic wastewater [6] or (2) due to the presence of Hoagland solution [31–39].

4. Conclusions

Domestic wastewater irrigation tends to have a long past, passing through many stages in both high- and low-income countries, including Pakistan. Furthermore, farmers are compelled to use DWW for irrigation due to the scarcity of water. Irrigation by UTDWW has been reported to produce a number of environmental problems. The hazardous materials in wastewater promote chemical and biological changes in the environment, posing health risks to humans and ecosystems. Our study aimed to contribute to the approaches used to tackle hazardous pollutants in wastewater in order to make wastewater useful for irrigation. Biotreatment of DWW with *A. faecalis* MT477813 decreased the values of physicochemical parameters such as EC, BOD, COD, pH, temperature, turbidity, TSS, TDS, salinity, odour and colour. Biotreatment of DWW with the bacterial isolate showed more than 90% decolourisation along with reduction in contaminants. Upon germination under hydroponic culture system, PK386 and Basmati 515, growth parameters such as shoot and root length, wet and dry weights of rice plants grown in treatment 2 (TDWWH) were considerably higher than the plants grown in untreated DWW. The biotreatment of DWW in presence of Hoagland solution showed an increase in growth parameters such as shoot length of both rice cultivars. Overall, an enhanced growth of both cultivars grown in biotreated DWW with Hoagland solution was observed. The current study aligns with the perspective advocating for the utilization of indigenous bacterial populations to mitigate the impact of pollutants present in wastewater on living organisms. We recommend further research into the quality of fruit yield derived from these hydroponic systems.

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