Impact assessment of treated wastewater reuse for irrigation: growth potential and development of lettuce in Al Hoceima province, Morocco

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Abstract. The reuse of treated wastewater for agricultural practices is becoming increasingly important due to the growing demand for the transition to a circular economy. It has the major advantage of providing an alternative resource to the conventional water used for agricultural irrigation. The main objective of this work is to study, through tests on experimental installations, the effect of the type of irrigation water on the growth and development of lettuce. The types of irrigation water were prepared from purified wastewater, treated wastewater plus fertilizer, conventional water, and conventional water plus fertilizer. The physicochemical analyzes of wastewater from the Imzouren-Bni Bouayach WWTP resulted in different values of the parameters measured (pH, temperature, electrical conductivity, oxygen below, suspended matter, BOD_5, COD, nitrate, nitrite and phosphorus) which fall within the limited range of direct discharges and comply with Moroccan standards for the quality of water intended for irrigation. The results of the characterization of the soil showed that it is a basic soil (pH= 8.5), unsalted (electrical conductivity = 2.43 ms/cm) and poor in organic and nutrient elements (Carbon 0.8%, organic matter 1.46%, nitrogen 0.06 mg/l, phosphorus 10.5 mg/l, potassium 56.4 mg/l.) The main results of the plant analysis show that the production level of this study crop irrigated with conventional water is similar to that of this study crop irrigated with treated wastewater. In other words, irrigation with treated wastewater allows lettuce to guarantee irrigated production at least at the level of conventional water. Another motivated addition of nitrogen, phosphate and potash mineral supplement in the treated wastewater improves the production potential of lettuce.

1 Introduction

Water scarcity, environmental pollution and dwindling land resources for agriculture continue to be major global issues [1]. Securing the supply of fresh water for human use is one of the greatest challenges of the 21st century. It is predicted that half of the world's population could face severe water scarcity by 2030 [2].

The agricultural sector is one of the largest consumers of global freshwater resources (more than 70%), and these estimates are expected to increase in the coming years [3,4]. Specifically, according to the 2021 United Nations World Water and Development Report [5], by 2050 feeding a planet of over 9 billion people will require an estimated 50% increase in agricultural production and 15% of water consumption. However, the quantities of fresh water to achieve this projected expansion are not available [6]. FAO [7] recognizes that the amounts of water used by agriculture can only increase by 10% over the next decades.

In this context of water scarcity, particular interest is increasingly reserved for the valorization of treated wastewater as additional resources. Urban water reuse is recognized as a promising and necessary measure to alleviate increasing water stress, especially in arid and semi-arid agricultural areas [8], such as some Mediterranean countries, in response to water scarcity, reclaimed wastewater is needed for agricultural purposes [9]. With a current volume of wastewater of 700 Mm^3 and an estimate of 1 MMm^3 in 2050, the treated wastewater constitutes for Morocco an appreciable part of the water potential with which certain uses could be

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satisfied subject to an appropriate adequacy of their quality. Morocco aims to reuse 340 Mm^3 of TW in 2050. This work is part of this research perspective of the potential offered by treated wastewater in agricultural irrigation. Tests are carried out on lettuce (*Lactuca sativa L.*) which is an important commercial vegetable crop in many countries. It is an excellent source of carbohydrates, fiber, essential amino acids, vitamins and other nutrients [10]. As a globally popular leaf vegetable and representative plant of the Asteraceae family, lettuce has great economic importance [11]. Recently, lettuce has attracted more attention and has become one of the main ingredients in the ready-to-eat fresh cut vegetable salad because of its convenience of use, freshness, its healthiness and high nutritional value [12].
The main objective of the present work is to study, through an experimental trial, the productivity of the types of purified wastewater in the agricultural field. The work aims to evaluate on the one hand, the fertilizing effect of wastewater previously treated by activated sludge process on lettuce cultivation in comparison with conventional water with and without addition of mineral fertilizers. Monitoring crop behavior in relation to irrigation, according to the four aforementioned treatments, is undertaken by determining the cultural growth parameters.

2 Materials and methods

2.1 Experimental site

Within the WWTP of Imzouren-Bni Bouayach tests on experimental units made up of plastic pots. The WWTP site is located at the following coordinates: latitude is 35° 11' North and longitude is 03° 50' West with an altitude of 12.05m. It is located about 3 km northeast of the town of Imzouren, in the irrigated perimeter of Oued Nekor: 500 m from the left bank and about 2.5 km from the Mediterranean Sea.
The Imzouren-Bni Bouayach WWTP returned to operation in November 2006 with a natural lagoon purification process, a rehabilitation and restructuring project for the station began in January 2018 to go from a nominal flow of 4616 m^3/ d at a nominal flow of 10,800 m^3/d with a capacity of 150,000 Eq/inhabitant and extends over an area of 18 ha [13]. The treatment process applied is low-load activated sludge biological treatment including downstream microfiltration and UV disinfection.
The study area is characterized by a semi-arid climate with an average annual rainfall of 267 mm and with average summer temperatures between 20 and 28°C and average winter temperatures between 9 and 17°C (data from the CT 3001 weather station in Imzouren).

2.2 Factor study

Factor structure: Irrigation water samples were taken from the Imzouren Bni Bouayach wastewater treatment plant. This station is located in the urban environment of the city of Imzouren where intensive agriculture is practiced, vegetable crops (lettuce in particular) irrigated with wastewater purified in an unauthorized way. The structure of the 'type of irrigation water' factor consists of four modalities, one of which is a control (Table 1).

Table 1. Irrigation water type structure

Type of irrigation water	Abbreviation
Conventional water (Control)	CW
Conventional water + Fertilizers	CWF
Treated waste water	TW
Treated waste water + Fertilizers	TWF

Fertilization: The contribution of fertilizers concerned only the major elements: phosphate (P_2O_5), potash (K_2O) and nitrogen. The amounts of nutrients were determined following the reasoning [14]:

$$qf = Qf \times (ms.p/ve \times ds) \times np$$

qf: Quantity of fertilizer to apply,
Qf: Quantity of recommended fertilizer per hectare,
ms: Amount of soil potted,
ve: Volume of soil explored by the system root per hectare,
ds: Apparent density of the soil placed in pots,
np: Number of pots in the experimental device.

The quantities of phosphate, potash and nitrogen calculated for growing lettuce are 3.4 g, 17.2 g and 6.8 g respectively
These were obtained by considering the following values:

- Recommended amounts of mineral fertilization for lettuce: 50 kg/ha for phosphate, 250 kg/ha for potash and 100 kg/ha for nitrogen [15].
- The depth of soil required for the development of the root system of lettuce plants is 0.30 m [16].
- The apparent density of the soil to be put in pots is 1.4 kg/l,
- The number of pots in the experimental device is 16.
- The weight of the potted soil is 18 Kg.

Experimental units: The experimental units consist of pots with a capacity of 20 liters. In order to avoid the risk of asphyxiation of the plants and facilitate the drainage of irrigation water, the bottoms of the pots were drilled with holes and covered with a layer of gravel. The pot after adding gravel weighs 3 kg. The soil used is a loamy-clayey soil which was collected from the topsoil between 15 and 30 cm from the agricultural land of the Nekor perimeter, air-dried at a temperature ranging from 20 to 25°C for several days, cleaned of plant debris, homogenized and carefully mixed by hand before being placed in 20 L plastic pots.

2.3 Experimental apparatus

The experimental site is arranged in a device in complete random blocks with four repetitions and four treatments and which are: conventional water (CW), conventional water added to a fertilizer (CWF), waste water purified by activated sludge process (TW), wastewater purified by activated sludge added to a fertilizer (TWF). So we will have a total of 16 experimental units in the device. Table 3 represents the randomization of the experimental units at the block level. It was done using the random permutation table.

Table 2. Randomization of treatments

Block 1	CW	WCF	TW	TWF
Block 2	TWF	CW	CWF	TW
Block 3	TW	TWF	CW	CWF
Block 4	CWF	TW	TWF	CW

2.4 Physicochemical analysis of treated wastewater

Physicochemical analysis consists of determining pollution parameters such as:

- The parameters on site, namely the temperature, the oxygen below, the conductivity and the pH.
- Physicochemical parameters: Suspended matter, COD, BOD5, Nitrate, Nitrite and Phosphorus.

After having taken and preserved the samples according to the conditions required for treated wastewater, the measurements of the pH, the conductivity and the oxygen below are carried out respectively by a pH-meter of the type HACH model Sension 2, a conductivity meter of the HACH type model Sension 5, and a HACH model HQ10 Oximeter. On the other hand, the analyzes of COD, BOD_5, Nitrate, Nitrite and phosphorus and suspended matter were carried out according to the recommended protocols [17] within the laboratories of the National Office for Electricity and Drinking Water (ONEE – Water Branch).

2.5 Physicochemical soil analysis

The soil was also analyzed to assess its degree of fertility and its composition in mineral elements. The determined parameters are: pH, electrical conductivity, organic matter, carbon, potassium, nitrogen and phosphorus. It should also be noted that all the chemical analyzes were carried out in the pedology laboratory of the National Institute for Agronomic Research.
After air drying, the soil samples were sieved at 2 mm. pH and electrical conductivity (EC) were measured directly in the filtered extract. The pH is determined by the potentiometric method using a pH meter and the electrical conductivity by the saturated paste method, after centrifugation the supernatant solution is read with a conductivity meter. Organic matter and carbon content were determined using the Walkley and black dichromate oxidation method [18,19]. Olsen's method [20] was used to estimate available phosphorus. Total nitrogen was studied by the kjeldahl procedure [21] and for potassium the extraction is carried out using a neutral and normal solution of acetate.

2.6 Analysis of plant material

The choice of lettuce is based on the survey already carried out on the main crops in the Nekor perimeter and which are irrigated with treated wastewater in an unauthorized way, lettuce was among these crops.
The seeds of lettuce (Lactuca sativa capitata) were sown in plastic pots on April 08, 2022. The harvest was carried out after two months from sowing. The pots were watered with the different types of water to moisture at field capacity initially and then as needed.The measurement and data collection were carried out on six essential parameters, namely: the number of leaves, the leaf area, the weight of the fresh material of the aerial part of the plants, the dry weight, the diameter and the height of the plants.

The number of leaves, height and diameter of lettuce seedlings were measured once a week to assess the growth of plant individuals. The height was measured from the ground surface to the head of the lettuce shoot and the number of leaves was counted by eye. The lettuces were harvested after six to seven weeks of growth, which is close to the natural growth period of lettuce (60 to 90 days). After harvest, fresh weight was measured immediately

[22] and leaf area was measured using Mesurim2 software.

2.7 Statistical study

The statistical method adopted to process the results obtained is based on the analysis of variance with a single factor, followed by the Student Newman-Keuls post hoc test, which was used to compare the differences in means ($p < 0.05$). Different letters indicate significant differences. The calculations are carried out using the SPSS statistics 25 software for windows 10.
The essential purpose of analysis and interpreting the observed data is to verify that there is a sufficiently significant difference of the effect of the "type of irrigation water" on the production vegetal.

3 Results and discussion

3.1 Physicochemical characteristics of purified wastewater

The treated wastewater collected at the outlet of the Imzouren-Bni Bouayach wastewater treatment plant represents non-conventional renewable water, which could be an attractive and cheap source to use in agriculture. The physicochemical data recorded for lettuce irrigation wastewater from the study site lead us to the following conclusions (Table 3).

Table 3. Physicochemical characteristics of purified wastewater

Parameters measured	Unity	Values obtained
Temperature	(C°)	28
pH	-	7.89
Electrical conductivity	(µS/cm)	2350
Oxygen below	(mg/l)	7.5
Suspended matter	(mg/l)	18
BOD5	(mg O_2/l)	9
COD	(mg O_2/l)	< 15
Nitrate	(mg/l)	2.33
Nitrite	(mg/l)	< 0.5
Phosphorus	(mg/l)	1.31

The chemical composition of the treated wastewater used in this study is shown in Table 3. The treated wastewater was generally alkaline in nature with the pH value being 7.18. Normally, pH is a routine measurement in irrigation water quality assessment that serves as an indicator of water acidity or basicity, but is rarely a problem in itself. However, the normal pH range for irrigation water is 6.5 to 8.4, while pH values outside this range are a good warning that the water is of abnormal quality [23].
It is well known that the main effect of electrical conductivity (EC) on crop productivity is the inability of plants to compete with ions present in the soil for water ([24] Gupta et al., 2015). The EC of the purified wastewater tested reaches 2350 µS/cm, this value is lower than the Moroccan value for water intended for irrigation (12 mS/cm) and that of the limit value for discharge into surface or underground water (2700 µS/cm) [25].
Wastewater tested showed significantly lower amounts of nitrate, nitrite and phosphorus than water intended for irrigation. These results do not agree with Angin et al., Nadav et al., Jahan et al., Akkha et al., Hadji et al., Shan et al. [26,27,28,29,30,31] who concluded that treated wastewater is an important source of nutrients containing a considerable amount of nitrogen, potassium and phosphorus.
However, the purification of wastewater by activated sludge has led us to values of various measured parameters which remain within the limit range of direct discharges [25] and is within the range of Moroccan quality standards. of water for irrigation [32].

3.2 Soil analysis

The results of the physicochemical analyzes of the soil studied (Table 4) showed that the pH is alkaline. However, the contents of organic matter, carbon, phosphorus, nitrogen and potassium are low, which indicates that the soil used during this experiment is a soil poor in organic and mineral elements. It is therefore a poor soil whose agronomic exploitation must be supported by organo-phosphatic inputs.

Table 4. The physicochemical parameters of the soil

Physicochemical parameters	Values obtained	Meaning
pH	8.3	Alkaline [33,34]
Electrical conductivity (ms/cm)	2.43	Unsalted [33,34]
Carbon (%)	0.85	Low [33]
Organic material (%)	1.46	Very poor soil [33,34]
Phosphorus (mg/l)	10.5	Poor [34,35]
Nitrogen (mg/l)	0.06	Poor [35]
Potassium (mg/l)	56.4	Poor [34,35]

3.3 Analysis of plant material

The results obtained during this study showed that there is a significant difference ($p < 0.05$) between the number of leaves, leaf area, fresh weight, dry weight, length and width of lettuce irrigated with conventional waters (CW) which are considered as controls and conventional waters plus fertilizers (CWF) and treated wastewater plus fertilizers (TWF) (Figure 1). The six parameters of lettuce irrigated with TWF showed an increase of 33.89%, 204.85%, 23.91%, 42.62%, 65% and 48.61%, respectively, compared to the control (plants irrigated with conventional water). However, irrigation with CWF increased all parameters and stimulated plant growth (49.15%, 332.62%, 48.76%, 47.54%, 97.5% and 70.83%, respectively). This is explained by the continuous contribution of concentration of nitrogen, phosphorus and potassium in the irrigation waters such as the CWF and TWF and which are immediately accessible to the plants. These results are consistent with those of Urbano et al. and Abouelouafa et al. [36,37], who also worked on lettuce.

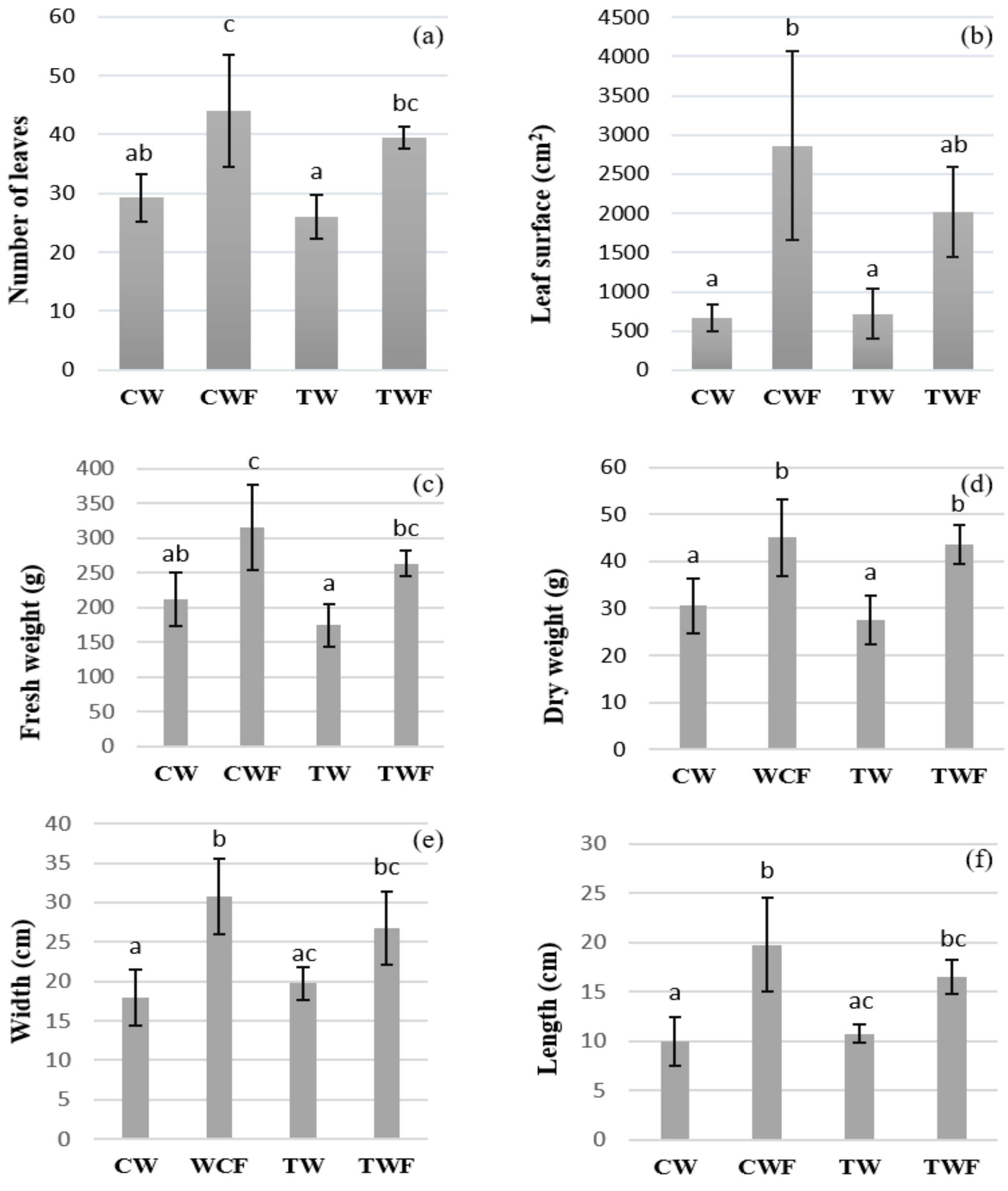

Fig.1. Effect of different irrigation water types on leaf number (a), leaf area (b), fresh weight (c), dry weight (d), width (e), and length (f) lettuce plants.

No significant growth was observed in terms of number of leaves, leaf area, weight of fresh and dry biomass, length and width irrigated with treated wastewater (TW) compared to the control (CW). Statistical analysis by ANOVA (SPSS) indicated that growth on TW medium was insignificant (p-values were >0.05) (Figure 1). These results are consistent with those of Finley et al. [38] who compared the differences between three treatments using conventional water, wastewater and purified wastewater on the culture of lettuce (*Lactuca sativa*), gypsy pigment (*Capsicum annuum*), and small carrots (*Daucus carota sativa*) and observed that there was no significant difference in crop weights between treatments.
In contrast, Ait-Mouheb et al. [39], investigated the impact of two types of irrigation water conventional water (CW) and purified wastewater (TW) on lettuce yield, and noted that irrigation with CW leads to a drop in lettuce yields compared to EUE (between 43 and 85% lower yield depending on the cultivation period). On the other hand, Lee et al. [1] in their studies have shown, from the statistical analyses carried out, that the growth of lettuce is negatively affected in environments irrigated with TW. In addition, Zolti et al. [40] measured the yield of lettuce and tomato irrigated with UES and concluded that irrigation with UES slightly increase soil pH, EC, K, Na and DOC, and decrease fruit and shoot weight of plants, compared to samples irrigated with fresh water. Bigott et al. [41] revealed in their work that irrigation with TW increased the growth of lettuce with significantly higher biomass. Despite studies indicating higher production on crops irrigated with TW [42], it is important to emphasize that it does not replace the use of nitrogen fertilizers, it only provides part of the quantity needed, as pointed out by Fonseca et al. and Damasceno et al. [43,44]. In both studies cited, TW provided some of the necessary fertilizer, and when applied without fertilizer, production did not show desirable levels compared to the crop using fertilizer

4 Conclusion

In this study, we investigated the impacts of irrigation water type on lettuce plant growth. Four different water qualities were evaluated, irrigation with conventional waters (CW) produced almost similar lettuce yields compared to irrigation with TW. Consequently irrigation with treated wastewater plus mineral fertilizers (TWF) showed an increase in number of leaves, leaf area, fresh weight, dry weight, width and length 33.89%, 204, 85%, 23.91%, 42.62%, 65% and 48.61% respectively and by conventional waters plus mineral fertilizers (CWF) also increased the six growth parameters of lettuce 49.15%, 332 .62%, 48.76%, 47.54%, 97.5% and 70.83%, respectively compared to CW and TW.
Physicochemical analyzes of treated wastewater from the Imzouren Bni Bouayach WWTP indicate that this water has a low nutrient content, however, it complies with Moroccan standards for irrigation.
Finally, the use of treated wastewater, at the Imzouren-Beni Bouayach WWTP, for the irrigation of a short crop such as lettuce could be an alternative to increase the availability of irrigation water by period of water shortage.

5 Acknowledgments

The authors would like to thank the National Office for Water and Electricity (ONEE-Branch water) of the province of Al Hoceima, Morocco for hosting the Imzouren-Bni Bouayach wastewater treatment plant. The authors also thank the National Institute of Agronomic Research (INRA) of Al Hoceima.

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