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# Water Footprint and Productivity of Lettuce with Non-conventional Water Resources

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**ABSTRACT: Climate change is a major global challenge in the 21st Century. The effects of climate change on water availability are well documented with projections indicating an increase in water stress due to decreasing fresh water availability, ultimately resulting in increasing non-conventional water reuse for agriculture. But, it is a great challenge to use non-conventional water resources as alternative to improve productivity with reduced water footprint by protecting human health, agriculture and environment. Hence, a field trial was carried out with lettuce plant under polycarbonate polyhouse from 1st October 2021 to 15th December 2021, with three different types of water i.e., a) Fresh Water (FW) b) Waste Water (WW) and c) Fish Pond Water (FPW) with the aim of reutilization of non-conventional water resources in an effective way. There were six pots for each water treatment having a surface radius of 11 cm and a height of 18 cm. The average temperature and relative humidity maintained during the experiment was around 26°C and 46%; respectively under polyhouse. After harvesting it was found that the weight of lettuce leaves of FW pot, FPW pot and WW pot was 161 gm, 214 gm and 310 gm; respectively and root length was of 12.5 cm, 14.5 cm and 17.1 cm; respectively. Water Productivity for FW, FPW and WW was found as 13, 26 and 39 mg/cc, respectively. Water footprints was 77, 38 and 26 cc/gm under FW, FPW and WW; respectively. Hence, the WW pot showed the highest water productivity ($p<0.05$) with least water footprint ($p<0.05$) followed by FPW and FW pot. Therefore, the WW irrigation showed the superiority in lettuce farming over other irrigation practices in this study.**

**Keywords:** Fish Pond Water, Lettuce, Water footprint, Water productivity, Waste water.

## INTRODUCTION

Agriculture sector is the prevalent water user worldwide (Choudhary *et al.,* 2021). Climate change (Arundhati *et al.,* 2021), rapid urbanization and indiscriminate use of freshwater in different sectors lead to a hasty reduction in freshwater resources for agricultural irrigation (Abdelraouf, 2019; Alayu and Leta 2021). Hence, non-conventional irrigation in agricultural field can be an alternative practice throughout the world, especially in developing nations (Biswas, 2021). Several researches related to non-conventional water use in different agricultural crops like rice (Qi *et al*., 2020), radish (de Almeida Dantas *et al.,* 2014), lettuce (Jesse *et al*., 2019), lemon (Pedrero *et al.,* 2012), and eggplant and tomato (Cirelli *et al.,* 2012) concluded the advantages of using non-conventional water resources (Karim *et al.,* 2021) for irrigation such as increase of nutrients on soil and crop yield, and reduction on fertilizers dosage (Biswas *et al.,* 2020).

Agricultural vegetable production to meet our daily needs is highly interlinked with water quality uses for irrigation. Lettuce (*Lactuca sativa* L.) is a very popular leafy vegetable, which has a healthy source of antioxidants, vitamins, minerals, and fibre (Camejo *et al*., 2020). Kim *et al.* (2016) reported that the consumption of leafy vegetables such as lettuce reduces public chronic diseases such as diabetes, cancer, and cardiovascular diseases. Lettuce is grown efficiently under controlled climatic conditions by providing greenhouse facility where quality and quantity of water, chemicals, and micro-environment used to be supplied (Manisha *et al*., 2017; Thomas *et al*., 2021).

In recognition of the importance of study about using non-conventional water resources safely in vegetable production, the current study focused on growing lettuces crop under controlled micro-climatic conditions (polycarbonate polyhouse) and growth monitored for 3 different types of water applications such as Freshwater (FW), Wastewater (WW), and Fish pond water (FPW). Water productivities and footprints of lettuce were also estimated under different irrigation practices to find out the most efficient irrigation practice in the present study.

## MATERIALS AND METHODS

*A. Study Area*

The polyhouse experiment was carried out in Centurion University of Technology and Management (CUTM), Paralakhemundi, Gajapati district, Odisha. The experimental site is located at 18.78°N latitude and 84.09°E longitude. The normal annual rainfall in the study area is around 1926 mm, 80% of which occurs during monsoon period (June-September). The whole year is divided into four seasons. The summer season starts from March to May followed by the South-West monsoon (June - September). The South-West monsoon is the principal source of rainfall. The post monsoon season is from October to November and the cold season is from December to February.

*B. Experimental Setup*

The polyhouse experiments were carried out with lettuce plants during winter season (December-February) of 2021-22 in 18 (3 m × 3 m) earthen pots under conventional (CON) and non-conventional water managements. Three water treatments (FW, WW and FPW) with six replications of each treatment were carried out under polyhouse. The WW and FPW treatment was carried out with no fertilizer application during experiment; whereas the FW treatment allows fertilizer application. The 15 days seedlings were transplanted for each treatment.

*C. Water Management*

The treated WW and the FPW were applied as non-conventional water resources. All experimental pots for each treatment were applied water twice (i.e. one in morning and another one in afternoon) in a day from the third stage (beginning of head formation) up to final growth stage (harvest). One time water application was followed during first two growth stages. The rate of water application was 100 ml per pot for WW and FPW; whereas for FW, the application rate was 150 ml/pot. Each pot size was 14 cm (bottom width) × 22 cm (top width) × 18 cm (height) for each treatment.

*D. Data Collection*

The data were grouped into water and crop data. Numbers of leaf, leaf length and width were collected for each pot of all treatments. Along with these, root length and root weight were also measured for each water treatment. After harvesting, the weight of lettuce plants was measured for each treatment. Amount of applied water for each treatment was also estimated in this study.

**(i) Water Productivity.** Water productivity (WP) is a measure of crop yield (Y) per unit of applied water (AP) (Biswas *et al.,* 2021). Mathematically, it can be expressed as follows:

$$\mathrm{WP} = \frac{\mathrm{Y}}{\mathrm{AP}} \quad (1)$$

**(ii) Water Footprint.** Water footprint (WF) is a measure of total volume of water (TVW) required producing crop (Biswas *et al.,* 2021). Mathematically, it can be expressed as follows:

$$\mathrm{WF} = \frac{\mathrm{TVM}}{\mathrm{Y}} \quad (2)$$

*E. Data Analysis*

The data of yield, WP and WF were statistically analyzed by the analysis of variance (ANOVA). One way ANOVA was employed to assess the differences between the treatment means at the 5% significance level. All statistical analyses were performed using SPSS software.

## RESULTS

*A. Water Applied*

Total amount of water applied for each treatment is shown in Table 1. The total amount of water applied for WW and FPW treatment was significantly ($p<0.05$) reduced by about 33% as compared to FW treatment.

*B. Crop Parameters*

Different crop parameters of lettuce growth under FW, WW and FPW treatments are represented in Table 1. Number of lettuce leaves under WW treatment was found to be higher ($p<0.05$) by 47% as compared to FW and 25% as compared to FPW treatment. Similarly, length and width of leaves were also more under WW treatment as compared to FW and FPW (Table 1). Root length and weight was substantially ($p<0.05$) more by 37% and 79% in WW treatment as compared to FW practice (Table 1).

*C. Crop Yield*

The yield responses of lettuce under three water treatments were characterized by wet weight of lettuce leaves (Table 1). The lettuce yield was found to be the highest under WW treatment and it was significantly ($p<0.05$) more by 93% and 33% in comparison with FW and FPW, respectively.

**Table 1: Water applied, Crop parameters and yield, Water footprint and productivity of lettuce.**

| Sr. No. | Parameters | | Water treatments | | |
|---|---|---|---|---|---|
| | | | FW | FPW | WW |
| 1. | Water applied (cc) | | 12003 | 8000 | 8069 |
| 2. | Crop parameters | No. of leaf | 17 | 20 | 25 |
| | | Length of leaf (cm) | 16 | 18 | 20 |
| | | Width of leaf (cm) | 11 | 14 | 15 |
| | | Root length (cm) | 12.5 | 14.5 | 17.1 |
| | | Root weight (gm) | 2.8 | 3.8 | 5 |
| 3. | Crop yield (gm) | | 161 | 214 | 310 |
| 4. | Water productivity (mg/cc) | | 13 | 26 | 39 |
| 5. | Water footprint (cc/gm) | | 77 | 38 | 26 |

*D. Water Productivity*

Table 1 represents the variation of water productivity (WP) of lettuce under FW, WW and FPW treatments. The highest WP was obtained under WW treatment. The WW treatment improved ($p<0.05$) WP of lettuce about 192% and 108% as compared to FW and FPW, respectively.

*E. Water Footprint*

Water footprint (WF) was found to be the least under WW treatment (Table 1). The WF under WW reduced ($p<0.05$) by about 196% and 46% as compared to FW and FPW, respectively.

## DISCUSSIONS

The WW application exhibited the best potential to improve ($p<0.05$) WP with least ($p<0.05$) WF for lettuce farming. Number of leaves, leaf width and length were found to be the highest under WW application. The improvement was found to be statistically ($p<0.05$) significant as compared to FW and FPW. Similar results were also found for root length and weight of lettuce under WW application. Urbano *et al.* (2017) recommended treated wastewater over conventional as it increased soil nutrients and productivity of lettuce without damaging soil physical properties. Carvalho *et al.* (2018) used wastewater for lettuce under hydroponic system and suggested higher nutrient absorption rate with wastewater application. The study of Chen *et al.* (2019) documented 89.39% more economic water use efficiency of lettuce under non-traditional technique as compared to conventional. Similar kind of conclusion in WW application for lettuce was also drawn by Santos *et al.* (2021) in their study. The study recommended WW application for reduction of fertilizer cost during lettuce farming. Thomas *et al.* (2021) also concluded that non-conventional advanced treatment system improved productivity of lettuce as compared to traditional practice.

## CONCLUSIONS

The present study compared the performance of non-conventional water resource application with fresh water for lettuce farming. The FPW and WW were taken as non-conventional water resources here. The following conclusions were drawn from this study:

- The weight of lettuce leaves was found to be the highest for WW application (310 gm).
- The no. of leaves was more under WW application (25 per pot) as compared to FW and FPW.
- The root length was also the highest under WW application (17.10 cm).
- The WP was estimated to be the highest under WW application (39 mg/cc).
- The WF was the least under WW application (26 cc/gm)

Therefore, this comparative study recommended WW over FW and FPW for lettuce farming. However, more researches on non-conventional water resources are required in future to validate this kind of finding for other agricultural crops in diverse environments.

## FUTURE SCOPE

The future scope of this study is documented below:

- Climate change impact on water footprint and productivity of lettuce with non-conventional water resources in future.
- Impact of non-conventional water resources on quality of lettuce in future.

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**Conflict of Interest.** None.

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