Utilization of fishery wastewater as a fertilizer and its impact on the growth performance of Spinacia oleracea (Spinach)

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Abstract. Aquaculture produces fishery wastewater (FWW), has polluted the environment and negatively impact the aquatic life. Utilizing FWW as a nutrient will promote sustainable agriculture and offer alternatives to conventional fertilizers. Some of the techniques used in water treatment, mainly the elimination of contaminants includes the use of screening, equalization tanks, aeration tanks, and sludge settling tanks before the treated water is released back to the environment or to be reused as a fertilizer. To evaluate the effects of the different FWW concentrations on the growth of spinach, the present study was carried out for 3.5 months using a complete randomized design with six groups of pot treatments that gave rise to 18 experimental units. Parameters such as height of plant, length of the root, number of leaves, fresh weight and the dry weight measurements were recorded. According to the experiments the pots which were treated with 20 ml FWW showed the best growth performance measures where shoot length was increased by 30% and root length by 60% compared to the control implying the prospect of the wastewater as a source of nutrients for agriculture. This research has implications toward the development of sustainable practices for both aquaculture and agriculture, in terms of reduction of global warming and climate change.

1 Introduction

In 2020, the global aquaculture and fisheries sector produced a record high of 214 million tons of food [1,2]; thus, this industry has significantly contributed to global food security. Nevertheless, it has generated a huge volume of wastewater rich in organic matter and other pollutants that are of key environmental concern [3]. Efforts have been channeled into finding alternative uses for this waste stream in order to address environmental problems caused by it and promote principles of sustainable resource management. Previous studies have proved fishery wastewater (FWW) suitability for use in agriculture for its nutrient-rich content [4].

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Effects on crop growth and yield using FWW as fertilizer revealed the same positive response for crops such as sweet pepper [5] and cherry tomato [6].

While these studies are very promising, specific studies using FWW on *Spinacia oleracea* (spinach) cultivation remain limited. Unlike in crops like sweet pepper and cherry tomato [5,6], which have received studies, there is scant information on spinach's response to FWW. There is limited information concerning the effects of FWW on the aspects of soil related to plant growth, specifically spinach, in the long-run. Thus, this study seeks to address this research question: Is it possible to use FWW as nutrients for spinach production? In essence, this study increases the base of knowledge and evidence to create better practices that are more sustainable and eco-friendlier in applying agricultural practices.

But, the most challengeable aspect is that, pollutant containing FWW if not treated beforehand, poses a threat to the environment. Decomposition results in water pollution, emergence of bad smell, eutrophication as well as emission of hazardous gases such as hydrogen sulphide, methane and ammonia which are culprits of global warming and climate change. The following pollutants are dangerous to both water life and the human population [4,7]. Thus, even though FWW can be considered a valuable input, the proper handling of this input should be given considerable attention in order to reduce any pollution consequences and optimize the use of related solutions.

The purpose of this research is to study the potentiality of FWW as a source of fertilizer for *Spinacia oleracea* (spinach) and impacts on the plant growth and yield which would fulfill sustainable development goals shown in Figure 1.

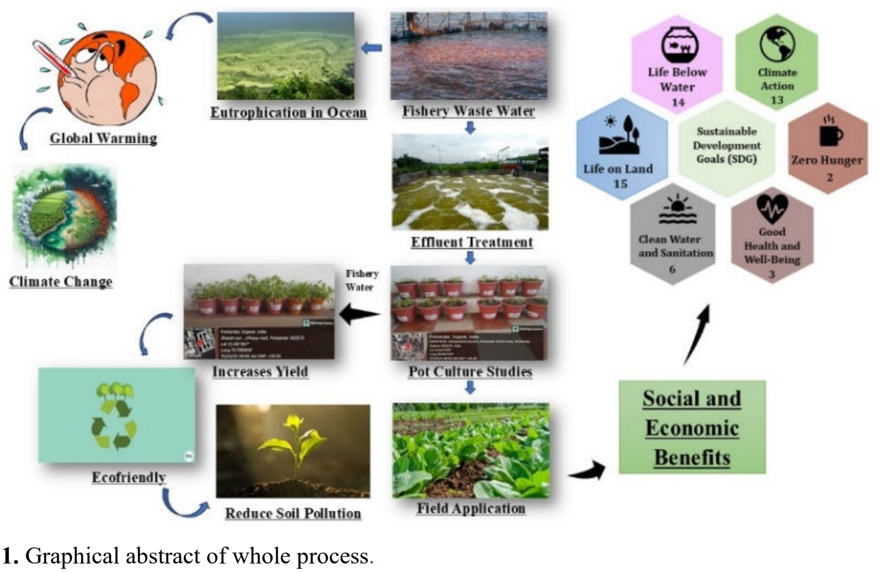

Fig. 1. Graphical abstract of whole process.

2 Materials and methodology

2.1 Experimental design

An experiment that enrolled pot culture was done to determine the ability of FWW as a fertilizer to promote spinach growth. FWW samples were obtained from Siddiq Sea Food Unit ETP Plant, as presented in Figure 2 the physical, and chemical characterization of the FWW and the nutrient property of the wastewater were also analyzed and presented in table

1 and 2 respectively. The waste water was diluted to prepare different solutions of 10, 15, 20, 25, 30 ml/pot of spinach seeds.

18 identical pots were taken and filled with 3.2 kgs of soil, and six treatment groups were set: three pots were established with one unfertilized control and five others in triplicates (Figure 4) were taken with weekly applications of the diluted FWW. Spinach seeds were planted in each of the pots, and all plants were grown under natural sun light, temperature (30 °C), and humidity (74%) conditions.

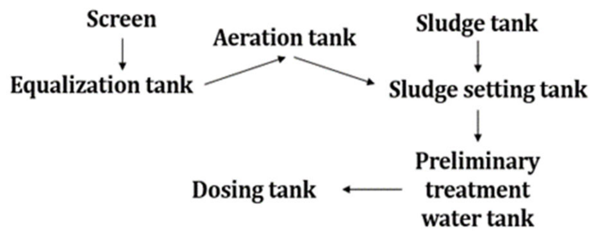

Fig. 2. Siddiq sea food unit ETP plant.

2.2 Growth parameters

During the experiment, shoot and root length, fresh and dry weight (biomass) were monitored at regular intervals (per week), for determining plant growth and development [8].

2.3 Data analysis

Information gathered on growth related parameters of the plants was analyzed statistically with the aim of comparing the impacts of various concentrations of FWW on spinach production. In this experiment, a completely randomized design (CRD) was used, whereby spinach growth and development were measured to determine the impact of FWW. The results of the descriptive statistics were determined for all the treatment groups. We used one-way analysis of variance (ANOVA) at 0.1 to look into differences in the overall group mean in more detail. For root and shoot length measurements, the largest standard deviation was ±1.15 and ±1.38, respectively.

Table 1. Fishery Wastewater Analysis.

Sr.no	Parameters	Unit	Test method	Range of test	Results
1	pH	pH unit	4500H+B APHA 23rd edition 2017	1 – 14 pH value	7.53
2	Colour	pt.co.sc.	2120 B APHA 23rd edition 2017	2 - 99 Hazen	20
3	TDS	mg/l	2540 C APHA	10-2000000mg/l	2214
4	Suspended solids	mg/l	2540 D APHA	2-10000mg	28
5	Ammonical nitrogen	mg/l	4500 NH_3 & C APHA	1-2000mg/l	14
6	Percent sodium	% Na	IS11624-1986 (Reaffirmed 2009)	0.101-100%	61
7	Chloride	mg/l	4500CI B APHA	1-50000mg/l	1040

8	Sulphate	mg/l	4500SO₄ E (23rd edition) APHA	2-40 mg/l	326
9	COD	mg/l	5220B (23rd edition) APHA	5-50000mg/l	310
10	Oil & grease	mg/l	5520B Liquid partition	1-1000mg/l	0.4
11	BOD	mg/l	IS3025 (Reaffirmed 1993)	5-50000mg/l	98

Table 2. Test report of FWW nutrient analysis and soil nutrient analysis.

Sr. No.	Parameters	Fishery waste water	Soil
1	Nitrogen	2.5 mg/l	8.5 mg/Kg
2	Phosphorus	1.0 mg/l	6.0 mg/Kg
3	Potassium	5.7 mg/l	16.8 mg/Kg
4	Organic carbon	7%	5.7%

3 Results and discussion

Different concentrations of FWW (0, 10, 15, 20, 25, and 30 ml/pot), were used to assess the effect of FWW on the growth of spinach through pot culture experiments. The measurement variables were assessed for plant growth with respect to shoot and root length, fresh and dry biomass over the period of 3.5 months. The results (Figure 3 (a) and 3 (b)) indicate a positive correlation, at a significance level, relating the application of FWW to the growth of spinach up to the 20 ml/pot treatment. In comparison to control plant, the shoot length increased with all the application of FWW. The enhancement in the overall growth of plants under FWW treatment can be attributed to the supply of nutrients like nitrogen, phosphorus, and potassium as indicated in the analysis of the wastewater in Table 2. These nutrients are essential in metabolism and plant growth [9]. Under the mentioned conditions, plants receiving 20 ml/pot FWW had a considerably longer shoot length, root length, and biomass compared with the control and other treatments. However, increasing the concentration of FWW up to 30ml/pot led to reduced growth of plants, this could be attributed to possible phytotoxicity, considering that the FWW contains a considerably large quantity of sodium (61% Na). Further research will be needed to ascertain whether this will lead to long-term soil salinization or be otherwise detrimental to the plants [10–12]. Characterization of the FWW showed it to be of a complex composition, with varying nutrient and other constituent levels (Table 1). While the presence of essential nutrients contributed to the growth enhancement observed, careful consideration should still be taken into account for sustainable FWW utilization in agriculture, considering that the sodium content was relatively high and the presence of organic matter content as reflected by COD which may have an impact on soil microbial activity and nutrient availability [13-14]. Long-term studies are still required to explore the effects of FWW on soil properties, plant health, and the environment. The root shoot length of spinach plant at the vegetative stage of growth is presented in Figure 4 (a).

Over all, it was observed that all FWW-treated groups had higher growth rates, thus pointing to the benefit of the fertilizer under study. Nonetheless, there was marked improvement in growth results among the group that was treated with 20 ml of FWW as having higher than other groups with shoot length increase of 60% and root length increase of 30%. As it can be seen in Figure 4 (b) , spinach plant fresh and dry weight (shoot and root) were also affected. Here, the results showed that all FWW treated groups increased in their growth. There is very little information on the effects of FWW to individual crops such as spinach though they may not react similarly to other crops due to the differences in requirements. FWW nutrient content can fluctuate; however, crop specifics have not been previously addressed these fluctuations impact on crop yields and quality. Research on the mode and frequency of application of FWW is also limited, and this is essential in order to optimize benefits compared to the detriment. Further research on FWW as a fertilizer should aim at developing efficient treatment technologies that remove or reduce unwanted components. Research in the area of nutrient recovery and wastewater treatment technologies [14,15] can also help in developing sustainable and economically viable FWW.

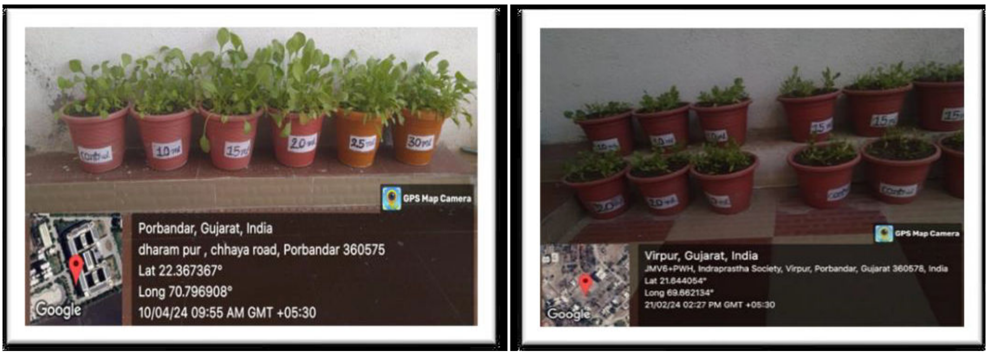

Fig. 3. (a) Growth performance of Spinach plant with various concentrations of FWW, **(b)** Growth performance of Spinach plant in pot trials in triplicate.

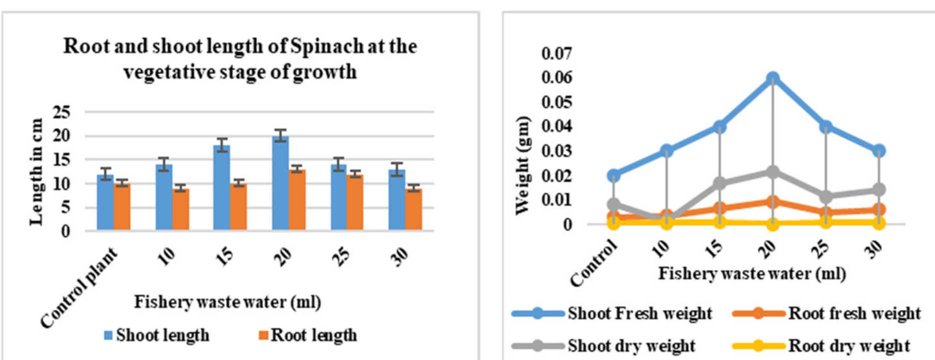

Fig. 4. (a) The results of root and shoot length of Spinach at the vegetative stage of growth, **(b)** Effect of fishery waste water on shoot root fresh and dry weight of Spinach.

4 Conclusion

The present work elucidated the possible role of FWW as a resource in sustainable agriculture. The optimization of the application rate of FWW in farm areas can provide tremendous improvements in spinach growth and yield. Nevertheless, further research is essential on this complex FWW, primarily on its long-term effects on soil health and crop productivity. In addition, research and development should also be aimed at application to more crop types and different classes of soil. In this way, we can help drive the quest for agricultural practices that are both sustainable and environmentally friendly. The results indicate that an optimal application rate of 20 ml per week significantly enhances the growth parameters of *Spinacia oleracea*, including shoot and root length, fresh and dry weight, and overall plant. These findings suggest that FWW can serve as a sustainable alternative to conventional fertilizers, contributing to the reduction of environmental pollutants and promoting eco-friendly agricultural practices. However, the study also highlights the importance of dosage regulation, as higher concentrations (above 20 ml) may lead to sodium toxicity, nutrient imbalances and hinder plant growth. These results underscore the need for further research to explore the long-term impacts of FWW application on soil health and its efficacy across different crop types.

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