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Fishpond Wastewater Versus Chemical Fertilizer On Tomato Productivity In Jimma, Oromia Region, Ethiopia

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ABSTRACT

The study was conducted to assess the potential of fish pond culture wastewater fertilizing effect as an organic fertilizer versus artificial fertilizer (DAP) as an inorganic fertilizer on the productivity of tomato farm. The experiment included a wastewater plot (T1) and an inorganic fertilizer plot (T2) and a control plot obtaining water from the source. The experiment required nine equal areas of 2m² plots for two treatments, and one control with their triplications. Total phosphorous and nitrogen of pond wastewater were analyzed to calculate the balance with chemical composition of inorganic fertilizer (DAP) in percentage and amount of wastewater required. The tomato seeds were germinated, and the equal number of seedlings were transplanted into nine different, but equal areas of 2 m² plots of two treatments and one control for the comparison of fish wastewater (T1) versus the artificial fertilizer (T2). 40gm of DAP were used per/m² as the rate recommended by DAEMACE, and about 1.5 inches of water were used per week in the mornings and afternoons. The experiments were conducted in triplicates, and lasted for 90 days. Tomato productivity parameter data were subjected to a one-way analysis of variance using the SPSS Version 16. The result showed that in Olericulture, there was no significant difference between T1 and T2 in all parameters of tomato productivity ($P > 0.05$). But, both T1 and T2 had a significant difference with the control group ($p < 0.05$). Therefore, it can be concluded that, the use of wastewater originated from fish culture as a fertilizer for vegetable (tomato) production was preferable, considering its minimum effects on the environment and minimum cost, as compared to the artificial fertilizers.

Keywords: *Artificial fertilizer, Organic fertilizer, Olericulture, Waste water.*

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1. INTRODUCTION

Historically, integrated plant-fish farm systems have been family farms. Families have produced food, fiber, fuel and other essentials on the same plot of land. Wastewater from one activity was an input for another, e.g., animal manure has been used as a fertilization for plant crops. Integrated systems have allowed farmers to make higher use of diversified resources, and decreased the depletion of certain system components such as fertilizers. Hence, considering integrated systems with the aquaculture industry might provide valuable resources to reduce production costs, enhance productivity, and help eliminate some of the negative consequences such as water pollution via the discharge of effluents. Linking aquaculture and other human activities not only revolves around agriculture, e.g., stocking fish in irrigation dams or canals, it also includes the roles of sewage treatment and nutrient recovery such as in hydroponic-fish systems. Waste heat energy from power plants and other sources can be used in fish culture systems to increase the sub-optimal water temperature (Castro *el al.,* 2006).

Wastewater application as a fertilizer to agricultural lands is more environmentally friendly and economically beneficial than the application of chemical fertilizers. By alleviating costs, increasing the income of farmers, and increasing the production, it could drastically benefit not only the farmers but also the consumers. Within agriculture, input costs such as transport, animal feeds and fertilizers play a large role in determining the success or failure of a farming enterprise, and more so with the global increase in energy prices (FSSA, 2008).The fish pond waste water can be a viable source to supplement irrigation water to crops and, as well, it can bridge the gap of chemical fertilizer requirements, especially nitrogen to a marginal amount. Farmers owning irrigation source, fish pond and crop land can supply the water to the pond, and the pond water to the crop land for irrigation to increase the stocking density of fish, to supplement the nitrogen fertilizers to the crops, and thereby increase the income (Lala *et al.,* 2010).Thus, in this study, it was needed to compare the beneficial uses of wastewater as organic and chemical fertilizers to agricultural land, which can be environmentally and economically friendly.

One of the most attractive forms of integrated aquaculture systems is the integrated plant-fish systems, which tend to be the most convenient for the application due to the plants' requirement of nutrient rich water in the form of fustigation to allow for proper growth. Perfect synergy is shaped between the two systems when they are in balance with plant fertilization needs by using the major waste of the aquaculture which is nutrient rich effluents (Neori *et al.,* 2004). Fish farming which is included in the peasant economies can be integrated to crop and animal production. This was practiced in ancient China, and the immigrant Chinese have introduced it to several Southeast Asian countries. In Chinese vegetable experiment, wastewater from stationary ponds is used in Agriculture, and the wastewater could replace chemical fertilizers as much as 80-100% of the application rate (Chunnasit *et al.,* 2000). Therefore**,** the current study was designed based on the Chinese vegetable experiment.

In Integrated multi-trophic aquaculture (IMTA), the byproducts (wastes) from one species are recycled to become inputs (fertilizers, food) for another. Fed aquaculture (for example, fish, shrimp) is mixed with inorganic extractive and organic extractive (for example, shellfish) aquaculture to make balanced systems for environmental sustainability (biomitigation), economic stability (product diversification and risk reduction) and social acceptability (better management practices) (Chopin, *et al,* 2001). "Multi-trophic" refers to using species from various trophic or nutritional levels in the same system (Chopin T. 2006).

Tomato (Lycopersicon esculentum Mill) belongs to the family Solanaceae. Tomato is the major vegetable crop grown worldwide, with a production estimate of 95 million Mt (FAOSTAT, 2002). Tomato is one of the most widely consumed vegetable crops in the world, with an estimated 99.4 million tons of tomatoes being produced worldwide each year (FAOSTAT, 2002). Since tomato plays an important role in human health, the quality of the nutritional components of this major crop fruit is of particular concern to producers throughout the world. Tomato is a key food and cash crop for many low income farmers in the tropics. Tomato production is a major horticultural crop with an estimated global production of over 120 million metric tons. Tomato is a rapidly growing crop with a growing period of 90 to 150 days, it is the second most consumed vegetable after potato, and unquestionably the most popular garden crop (FAOSTAT, 2001). Tomato fruit contains lots of minerals and vitamins which are parts of essential human food nutrients required for proper growth and development (Ibitoye *et al.,* 2009). Tomato is one of the major global vegetable crops with a total production of around 141 million tons on a cultivated area of about 5 million hectares (FAOSTAT, 2009). Tomatoes can grow on different types of soil; generally, they grow very well on well-drained, uniform clay or silty loams. Lycopene is an important antioxidant present in ripe red tomato fruit which has some anticancer properties (Ibitoye *et al.,* 2009). Thus, in this study, tomato plants were selected for Olericulture farm.

Aquaculture in Ethiopia remains more potential rather than actual practice, despite the fact that the country's physical and socio-economic conditions support its development (Abdilahi Dill, 2010). Integrated fish-poultry farming seems to be economically viable and environmentally friendly (Kebede Alemu, 2003). Aweitu stream which is a part of the Omo-Ghibe basin is the primary source of water for a range of activities. The pH and temperature of most natural waters are in the range of 6.0-8.5 and 0-30^{0}C; respectively (Chapman, 1996; Kebede Alemu, 2003; Israel Deneke, 2007). Therefore**,** Aweitu stream is found to be within the natural range of pH and temperature for fisheries and aquatic life. Thus, integrated fish-Olericulture farming seems to be economically feasible and environmentally friendly.

Agriculture has important share in gross domestic product in Ethiopia (Demese Chanyalew *et al.,* 2010), and aquaculture is an essential agricultural activity, but not started yet in the country. Ethiopia is a land-locked country and depends on its inland water bodies for fish supply for its population. The country's water bodies have a surface area estimated at 7334 km^2 of major lakes and reservoirs, and 275 km^2 of small water bodies, with 7185 km length of rivers within the country (FAO, 2001). Agricultural by-products can be a source of feed and fertilizer for small-scale farming and increase the natural production of the ponds. For the commercial fish farming, such by-products can reduce feed costs by replacing some formulated feeds needed (Nyina-wamwiza, *et al*., 2007).

Olericulture is the area of horticulture, and it is the science and technology of cultivating which deals with the production, storage, processing and marketing of non-woody (herbaceous) vegetables for food (Rhodes, 2010). Therefore**,** this research can be used to generate baseline data on integrated pond aquaculture wastewater from Nile tilapia as an organic fertilizer compared with chemical fertilizers on Olericulture farm, and also to compare its environmental friendly, economically beneficial and productivity of tomato plants.

2. MATERIALS AND METHODS

2.1. Description of experimental sites:

This experiment was carried out at Jimma University, located 350 km southwest of Addis Ababa, capital city of Ethiopia at an altitude of 1700 m above sea level. The mean daily temperature and annual rainfall of the study area were 20.71°C and 123.01 mm, respectively (Jimma Meteorological Station, April, 2012). The study required earthen fish pond aquaculture as a source of wastewater obtained from fish which shows better growth performance, feed utilization, fish condition and survival rate at 35 % CP level as reported by Admasu *et al.* (2017) for T_1, and water from the main source of Aweitu River for control plots and inorganic fertilizer (DAP) for T_2. In Olericulture farm, one plot was prepared in separate area to germinate tomato seeds, and other nine experimental plots with 2m^2 area were prepared to do the experiment. The study area was fenced with wire mesh and barbed wires to keep out vegetables and fish from predators and other animals.

2.2. Design of tomato plots:

The Olericulture was designed based on Chinese vegetable experiment involving the use of wastewater from stationary ponds in agriculture (Chunnasit *et al*., 2000). According to Chunnasit *et al.,* (2000), wastewater from fish culture could replace chemical fertilizers as much as 80-100 % according to the application rate. There were two treatments (fish pond wastewater and DAP) for testing and comparing the productivity of tomatoes. The treatments were fish pond wastewater (T1), artificial fertilizer (Diammonium Phosphate, DAP) as (T2) and Control (without chemical fertilizer and wastewater, the required water source was used from the main source). The amount of DAP used was according to the rate recommended by the Department of Agricultural Extension, the Ministry of Agriculture and Cooperatives, Ethiopia.

Tomato vegetables were also chosen for the field experiments, because tomatoes can grow in a variety of soil types, and they do best in well-drained, uniform clay or silty loams. They are the most widely consumed vegetable crops, and they play an important role in human health (containing lots of minerals and vitamins, and nutritional components). Tomatoes are a key food and cash crop for many low income farmers. They rapidly grow with a growing period of 90 to 150 days, and they are the second most consumed vegetable after potato, and the most popular garden crop (Takase *et al.,*2010).

Tomato seeds were nursed on raised beds, after which a shade was raised to protect the seeds from excessive sunshine, and the plots were prepared as indicated in figure 1. Equal number of tomato seedlings was transplanted to each of the equal area plots of the experimental field in the 4th week. Weeding was done with hoes and cutlasses on four occasions: 1st weeding at 2nd week after transplanting, 2nd weeding before flowering of the tomato, 3rd weeding after flowering of the tomato, and 4th weeding during fruiting, according to Takase *et al*., (2010) as indicated in figure 2. All the experiments were conducted with their replications.

Figure 1. Tomato seeds were nursed on raised beds and prepared for the experimental plots

Figure 2. Tomato seedlings were transplanted to plots, watered and weeded

2.3. Wastewater analysis and application:

The proximate analysis of chemical composition of wastewater was determined using validated analytical methods following the procedures of the Association of Analytical Communities International (AOAC, 1990). Accordingly, the proximate analysis of composition of wastewater such as total nitrogen and phosphorous from fish pond wastewater was done in duplicate at the laboratory of animal nutrition, College of Agriculture and Veterinary Medicine, Jimma University as indicated in figure 3. The total nitrogen content of fish pond wastewater was estimated using the Kjeldahl method, and the total phosphorous of pond wastewater was determined by spectrophotometer at 430nm absorbance.

The inorganic fertilizer Diammonium Phosphate (DAP) containing N, P and K concentrated ratio up to 18-24-0 which was reported by the manufacturers to have total nitrogen of 18% and phosphorus of 24%. Based on the recommended amount, $40g/m^2$ of DAP, totally 240gm of DAP was used for tomato plants of T2. Similarly, wastewater from fish ponds was used for the first treatment (T1) of tomato plots. According to Ohio State University, tomato plants need about 1-1.5 inches of water per week, which can be calculated by $Liter=inch^3/64.024$. Based on this, the required amount of wastewater applied in vegetable plot of T1 was calculated based on the percentage of N and P content in wastewater until the equivalence reached to the range of inorganic fertilizers. The results of wastewater analysis were total Nitrogen of (0.035 %) and Phosphorous of (0.027 %). Based on these results, totally about 88.90 liter of wastewater per plot was used. Accordingly, $Inch^3=88.90L \times 64.024=17.86$, were divided into twelve weeks of experimental period. Therefore, the above formulas for about 1.5 inches of wastewater were used per week throughout the study period.

Figure 3. Wastewater analysis of phosphorus and total nitrogen

2.4. Data collection

2.4.1. Measuring Tomato productivity:

The productivity of tomato was measured considering its growth and development parameters from germination to harvesting (Takase *et al.,* 2010). All data of each parameter were observed in all (nine) plants per each plot and each treatment separately. The plants' heights were measured with a tape from the base of the plant to the tip of the plant. The number of branches per plant, and the number of flowers per plant were counted when the tomato started bearing flowers. The number of fruits per plant was counted when the plants started fruiting as indicated in figure 4. The fruits' weights were determined after harvesting the tomatoes using a weighing balance (Ahmed *et al*., 2004; Takase *et al.,* 2010; Khan, *et al.,* 2011; Ertek, *et al.,* 2012).

Figure 4. Watering, weeding and measuring productivity parameters of tomato plant

2.5. Data Analysis

2.5.1. Measurements Tomato Plant Productivity:

Plant productivity was measured and analyzed by the following characteristics of Vegetative and Growth Property parameters: Plant Height (PH) (in cm), Plant size (girth or the stem diameter) (cm), Number of branches per plant (lateral branch number (LBN), Number of flowers per plant, the fruits' number (FN) and the fruits' weight (FW), (Ahmed *et al*., 2004, Takase *et al.,* 2010; Ertek, *et al.,* 2012). All the data of each parameter were collected from eight plants per each treatment separately. Data analysis was done by one-way ANOVA, and the mean comparison was done using POSTHOC=TUKEY test.

2.5.2. Economic Analysis:

The production cost-effectiveness of the experiment was calculated following the method used by Edwards *et al*. (2010) based on the current market price of the ingredients/fertilizers in Ethiopia used for vegetable farms. Economic evaluation in terms of Investment Cost Analysis (ICA), Production Value (PV), and Net Profit Value (NPV), and also the cost of DAP used for Olericulture were determined.

- Investment Cost Analysis (ICA) = Cost of DAP + Cost of transport + plots Construction (Labor) cost + Materials cost
- Production Value (PV) = Mean weight gain of tomato (kg) x Total number of survival (n) x cost per kg.
- Net profit Value (NPV) = Production Value – Investment cost

3. RESULTS

3.1. Comparison of wastewater and DAP:

The productivity of tomato plants with regard to the mean results of each parameter in each treatment has been presented in Table 1. There were no statistically significant differences between T1 (wastewater treatment) and T2 (inorganic fertilizer treatment) for all the parameters measured (P > 0.05). However, the control group significantly differed from both T1 and T2 for all the parameters (P < 0.005).

Table 1. The effect of wastewater and artificial fertilizers on productivity of tomato plants.

Treatments	Productivity Parameters and their mean result of tomato plant					
	PH (cm)	**P S(cm)**	**LBN**	**NF**	**FN**	**FW(gm)**
T1	60.63±4.241[a]	5.13±0.835[a]	5.25±1.753[a]	30.75±9.254[a]	26.25±9.192[a]	45.25±3.240[a]
T2	58.50±5.237[a]	5.00±0.926[a]	5.13±1.458[a]	29.88±8.935[a]	26.88±9.203[a]	46.00±2.450[a]
Control	41.25±5.339[b]	3.88±0.641[b]	3.13±1.356[b]	14.63±8.228[b]	10.00±6.676[b]	33.13±5.249[b]

T1=Wastewater, T2=Artificial fertilizer, Plant Height (PH), Plant Size(girth) (cm)(HS), Lateral branch number/plant (LBN), Number of flower/plant (NF), Fruit number/plant (FN) and Fruit weight (gm) (FW).NB. The superscripts a, b stand for mean values in the same row that were significantly different from each other at p < 0.05.

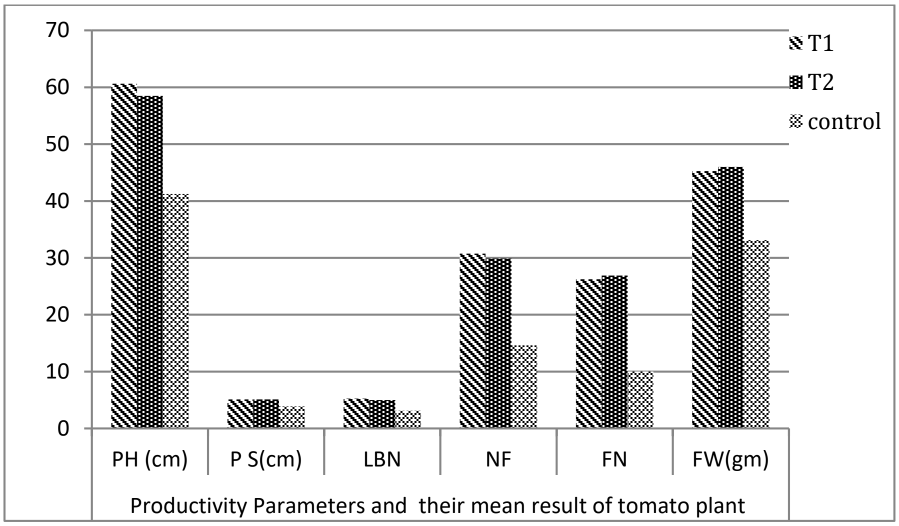

Figure 5. Variation of wastewater, artificial fertilizer and control group on productivity of tomato plants. T1=Wastewater, T2=Artificial fertilizer, Control, Plant Height (PH), Plant Size(girth) (cm)(HS), Lateral branch number/plant (LBN), Number of flower/plant (NF), Fruit number/plant (FN) and Fruit weight (gm) (FW).

3.2. Economic Analysis:

ICA equals the cost of DAP plus the cost of transport plus the plots construction cost plus the materials' cost and labor. Since the juveniles were collected from wild and the assumed labor cost might be covered by the farmer him/herself, and the pond was already constructed by the university, the current cost of DAP per kilo gram was 9 birr. Thus, the cost for 240gm of DAP used for tomato plant was 2.15 birr, the cost of transporting was DAP 4 birr and the cost of materials was 5 birr, the current cost of tomato was 8.00birr/kg. But, there was no cost for fish pond wastewater.

Table 2. The cost analysis of Olericulture farm

Treatments	Mean Productivity Parameters value and their economic analysis					
	FN	**FW(gm)**	**Total FW (gm/treatment)**	**ICA**	PV	NPV
T1	26.25	45.25	1187.8x3=3563.4gm	5.00birr	28.5birr	23.5
T2	26.88	46.00	1236.48x3=3709.44gm	11.15birr	29.68birr	18.53
Control	10.00	33.13	331.3x3=993.9gm	5.00birr	7.95birr	2.95

T1=Wastewater, T2=Artificial fertilizer, Fruit number/plant (FN) and Fruit weight (gm) (FW), Investment Cost Analysis (ICA), Production Value (PV) and Net profit Value (NPV).

4. DISCUSSION

4.1. Comparison of wastewater and artificial fertilizer on Tomato Plant:

In this study, wastewater and artificial fertilizers (DAP) were compared considering their effects on the productivity of Tomato Plants *(Lycopersicon esculentum)* at Jimma University, College of agriculture around fish pond aquaculture. All parameters were observed from eight plants in each treatment separately. The higher biomass yield and the maximum mean result of plant height were obtained in T1, and followed by T2, wastewater and artificial fertilizer treatments, respectively. The lowest mean result of plant height was recorded for the control group. These results indicated that there was no significant difference between T1 and T2 (p>0.05) considering the plant height growth, but both T1 and T2 showed significant differences with the control group (p < 0.05). The maximum mean result of plant size (stem girth) and the minimum mean result of plant size (girth) were observed in T1 and T2, respectively. There was no significant difference in T1 and T2 ($p > 0.05$). The lowest mean result of plant size was recorded for the control group. But, both T1 and T2 had significant differences from the control group ($p < 0.05$). In this study, the maximum mean result of the number of branches per plant (lateral branch number (LBN), and the minimum mean result were observed in T1 and T2, respectively. There was no significant difference between T1 and T2 ($p > 0.05$). The least mean result was recorded for the control group but both T1 and T2 had significant differences from the control group ($p < 0.05$). The highest and the lowest mean result mean results of the number of flowers per plant were observed in T1 and T2; respectively. There was no significant difference between T1 and T2 ($p > 0.05$). The least mean result was recorded for the control group. But both T1 and T2 had significant differences from the control group ($p < 0.05$). The maximum and the minimum mean result of the fruit number per plant were observed in T2 and T1 among the treatments, respectively. There was no significant difference between T1 and T2 ($p > 0.05$). The least mean result was recorded for the control group, but both T1 and T2 had significant differences from the control group ($p < 0.05$). The maximum and minimum mean result of the fruit weight per plant were observed in T2 and T1, respectively. There was no significant difference between T2 and T1 ($p > 0.05$). The least mean result was recorded for the control group, but both T2 and T1 were significantly different from the control group ($p < 0.05$).

Field experiment was conducted by Khan, *et al.,* (2011) to study the effect of tube well (TW) and waste water (WW) with or without basal dose of NP and K on the yield of tomato. The maximum tomato plant height and plant biomass were observed in Wastewater + half dose of combined NP and K fertilizers, and wastewater without fertilizers. The minimum plant height was observed in Tub well + NP and K fertilizers. The least plant height was observed in the control group. A similar trend of higher fresh and dry biomass was noted as was noted for the plant height being the lowest in plots irrigated with tube well water, and it was significantly ($p<0.05$) higher in the waste water plots and tube well water supplemented with basal NPK dose. The higher biomass yield and the plant height in the waste water plots might be associated with their enrichment with the essential plant nutrients (both macro and micronutrients). Segura *et al*., (2004) advocated the re-use of waste water in arid and semiarid regions of the world. They reported that significantly higher yield of tomato was obtained, when the crops were irrigated with effluents in the greenhouse crops. The positive effect of the effluent waste water was due to its significantly higher amount of N, P and K. In another study by Akitaka*et al*. (2002), tomato growth, yield and quality were not affected by the addition of wastewater compared to tap water. Khan *et al.* (2008) also reported the economic benefits of irrigating maize with effluents of waste stabilization ponds. This can also be explained from the results obtained in tube well water along with the basal dose of fertilizer where the yield was apparently increased by the addition of basal application of NP and K.

A study was conducted by Ertek*et al.,* (2012) to determine the effects of different water and nitrogen application levels on irrigated tomato plants. The amount of water usage irrigation for three treatments and three nitrogen (N) levels were carried out. The average yield amounts tended to increase depending on the applied irrigation water levels without N fertilization; it was not increased as much as in fertilizer (N) treatments. The tomato yield of fruit number (FN), fruit weight (FW), plant height (PH), lateral branch number (LBN) and stem diameter (SD) were greater with the higher N application rates; an increase in *N* fertilizer in treatments with the same amount of water applied led to a nearly 2-4 times increase in yields. Thus, the increased frequency and the increased amount of irrigation water positively correlated with the increases in fruit numbers and fruit yields. On the other hand, N fertilization significantly increased PH, LBN, and SD.

4.2. Economic Analysis:

Integrated fish-vegetable farming and fish pond wastewater had no cost at all. Rather, it can be used to minimize waste effect when applied as an organic fertilizer in vegetable farming as more environmentally friendly and economically beneficial than the application of chemical fertilizers. But, based on the current cost, the estimated amount of 40kg of DAP used per one hectare was 360 birr without transporting and its environmental impacts. Therefore, fish pond wastewater was integrated with the agricultural land to obtain better results. Perhaps, the results were expected to have a wide range of application in different parts of the country.

5. CONCLUSIONS

The results of the study indicated that in all parameters of tomato productivity, there was no significant difference in both wastewater and DAP. In addition, wastewater that is used in organic farming, promotes and enhances the productivity by releasing nutrients, improves the structure of the soil, and increases its ability to hold water and nutrients. Therefore, from this study it can be concluded that the fishpond wastewater is the best option for growing tomatoes, since wastewater application as a fertilizer to agricultural land is more environmentally friendly and economically beneficial than the application of artificial fertilizers. It has also been a viable source to supplement irrigation water to vegetable growth, and as well, it has bridged the gap existing in chemical fertilizer requirements.

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