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EFFECTS OF ABATTOIR WASTEWATER ON THE GROWTH OF *Solanum lycopersicum* L. (TOMATO)

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ABSTRACT

With the growing necessity to use wastewater for irrigation due to water scarcity, farmers face the challenge of using wastewater containing non-profiled nutrients that may be detrimental to crop productivity. The study investigated the effects of water from abattoirs on tomato plant growth and development. Abattoir wastewater (AWW) was obtained from Surulere and Agege abattoirs in Lagos State. The experimental design implemented a randomized complete design (RCD) with three replications. Tomato plants were grown in experimental pots and treated with different amounts of AWW: Tap water (control), 20, 40, 60, 80, and 100%. Data on plant height, branch and leaf numbers, fruit yield, stem girth, and root length, were collected at two-week intervals for five months. Data was subjected to analysis of variance (ANOVA), and the means were separated using the Tukey HSD test at a threshold of 5% (P<0.05). The study revealed that AWW significantly increased tomato growth characteristics and fruit yield at 100% AWW concentration. Thus, AWW may be an alternative source of organic nutrients for vegetable crop irrigation and could assist farmers with the escalating issues of freshwater scarcity and drought challenges worldwide.

Keywords: Abattoir, Irrigation, Organic manure, *Solanum lycopersicum,* Wastewater.

INTRODUCTION

An abattoir is a place where animals are slaughtered for meat production or other protein products for human consumption (Weobong and Adinyira, 2011). Alonge (2005) also defined it as a facility designed to receive, hold, inspect, and slaughter animals to obtain meat products before releasing them to the public. Akange *et al.* (2016) attest that the main abattoir activities are meat processing, which involves cleaning, slaughtering, hide removal, intestinal management, and trimming. Historical records on animal slaughter, slaughter location, and meat inspection are linked to ancient Egypt, including Jewish, Greek, and Roman civilizations (David-West, 2002). Meat inspection practices were also observed in France as early as 1162 and in Germany around 1276 (Nwanta *et al.,* 2008). Abattoirs became public meat processing facilities around the 15th and 16th centuries (Bello and Oyedemi, 2009).

There are few records of meat hygiene regulations during the pre-colonial period in Nigeria. However, there were laws in Northern Nigeria as early as 1942 requiring authorized inspection of animal hides and skins for export trade (Fasanmi, 2002). In 1967, the government of Northern Nigeria drafted a code of practice for meat inspection that initiated active meat inspection and best practices for slaughterhouse management (David-West, 2002). These guidelines remain critical to protecting human lives and preventing disease spread from the consumption of meat slaughtered under unhygienic conditions (Nwanta *et al.,* 2008).

Abattoir wastewater (AWW) contains urine, blood, water, dissolved solids, meat pieces, fat pieces, grease, hair, feathers, undigested feeds, and some pathogens, such as *Salmonella* spp. and *Shigella* spp. (Olarewaju and Olofayo, 2004; Aniebo *et al.,* 2009; Franke-Whittle and Insam, 2013). AWW can serve as organic manure, and using it for irrigation may result in low-cost wastewater management. It could be a source of nutrients for plants grown on infertile soils and potentially lead to enhanced plant growth and development (Kekere *et al.,* 2020). AWW for agricultural purposes has many benefits concerning nutrient recycling and minimizing both surface runoff and groundwater pollution (Sparling *et al.*, 2006; Al-Hamaiedeh and Bino, 2010; Nwachukwu, 2015).

Despite these benefits, AWW is a source of concern considering its varied, ill-profiled, and dynamic composition (Gauri, 2006). The amount of suspended solids, contaminated solvents, and odorous gases could pose environmental challenges where AWW is not properly channeled (Adriana *et al.,* 2011; Ezeoha and Ugwuishiwu, 2011). In addition, this class of mixed wastes comprises substances that contribute to greenhouse gas emissions that induce climate change (Alonge, 2005; Adeyemi and Adeyemo, 2007; Chukwu, 2008). For low-income countries already grappling with freshwater scarcity due to climate change, for instance, AWW discharge into waterbodies can be an added environmental problem in areas with proximity to freshwater sources or man-made water storage reservoirs and further constitute a menace to public health (Madramootoo and Morrison, 2013).

Staple food and cash crops, such as *Solanum lycopersicum L.* (tomato), are also implicated in the increasing challenges of freshwater (Zhou *et al.*, 2019). Tomato plant cultivation is water-intensive, with substantial demands for essential nutrients such as nitrogen and phosphorus (Patanè *et al.*, 2011; Beckles, 2012; Fageria *et al.*, 2013). In locations with scarce freshwater, AWW could serve as an alternative option for the cultivation of this plant (Kekere *et al.*, 2020). Tomato is a plant domesticated globally for culinary and medicinal purposes (Olayemi *et al.*, 2010; Blanca *et al.*, 2012; Marti *et al.*, 2016). This plant is a rich source of lycopene, carotene, water-soluble vitamins, essential amino acids, sugars, dietary fibre, proteins, and low amounts of lipids (Ayandiji and Adeniyi, 2011; Achoja and Okoh, 2014). Tomato has antioxidant properties for cataract prevention and asthma management (Friedman, 2013; Pem and Jeewon, 2015).

It is anticipated that by 2050, global freshwater demand will be 20–30% higher than the current estimates due to human population growth and socioeconomic development (Boretti and Rosa, 2019; FAO, 2020). This demand would only heighten freshwater scarcity, resulting in limited availability for agriculture (Beck *et al.*, 2021). Sole reliance on freshwater irrigation may not be the ultimate solution. Moreover, irrigation farming globally is facing significant issues with climate-induced droughts and anthropogenic factors (Zaveri and Lobell, 2019; Awazi, 2022). Water shortage from competing sources will affect tomato cultivation, creating an urgent need for an alternative source of reusable water to meet this demand (Cominelli *et al.,* 2005; Rockstrom *et al.,* 2007).

Global tomato production could immensely benefit from AWW irrigation because, currently, it is insufficient to meet the demands of the rapidly expanding human population (Toungus *et al.,* 2018; Kekere *et al.,* 2020). For instance, the Horticultural Institute of Nigeria reported in 2017 that the country produced 2.3 million metric tons of tomatoes, less than the 3 million metric tons required to meet the national demand. Freshwater scarcity was identified as the cause of the crop yield reduction (Shiri *et al.,* 2011; Kekere *et al.,* 2020), although this condition could have been ameliorated by AWW irrigation (Bandaw and Herago, 2017; Shilpi *et al.,* 2018).

There is a growing demand for water on farmlands across the world. Farmers are confronted with deciphering the type and amount of wastewater most suitable for crop cultivation (Shilpi *et al.,* 2018). This study investigated the unexplored benefits of AWW in tomato cultivation, emphasizing its potential as an organic nutrient source for crops on infertile soils. The findings offer valuable insights for growers seeking alternative irrigation methods (Bustamante *et al.*, 2007; Matheyarasu *et al.*, 2016; Kekere *et al.*, 2020).

MATERIALS AND METHODS

Study Area

The screen house experiment was conducted from January to May 2022 at the Botanical and Zoological Garden of the University of Lagos (UNILAG), Nigeria. The institution is located between Longitude 3^0 23´56˝E and Latitude 6^0 30´55˝N. The climate is tropical, and the annual precipitation varies between 1381.7 mm and 2733.4 mm, with an average of 2500 mm (Ogundele, 2012; Osuala *et al.,* 2020). There are wet (April to July and October to November) and dry (December to March) seasons. The relative humidity of the study area is typically high while August and September are both dry and wet periods (Adekanmbi and Ogundipe, 2010; Ogundele, 2012; Ajikah *et al.,* 2015). The land mass area of UNILAG is approximately 802 acres (3.25 km^2) (Nodza *et al.,* 2014).

The two abattoir sites sampled were Surulere and Oko-Oba Agege Abattoirs in Lagos State (Figure 1). The Surulere abattoir is on the Lagos mainland (Longitude 3^0 21'35´E and Latitude 6^0 05'30´N). Surulere is one of the largest local government areas (LGAs) in Lagos State. It shares borders with Mushin and Shomolu LGAs in the North, Ajeromi-Ifelodun and Apapa LGAs in the South, Oshodi-Isolo and Amuwo-Odofin LGAs in the West, and Lagos Mainland LGA in the East. Oko-Oba Agege abattoir is located in Agege LGA of Lagos State (Longitude 3^0 17´01´E and Latitude 6^0 39´32´N). It shares borders with Ifako/Ijaiye LGA in the North, Alimosho LGA in the West, and Ikeja LGA in the South and West.

Figure 1: Map of Lagos State depicting the Surulere and Agege Abattoir sites.

Study Materials

The study species was *Solanum lycopersicum* L. (tomato), and five concentrations of abattoir wastewater (20, 40, 60, 80, and 100%) were utilized, with ordinary tap water. AWW was collected from the Surulere and Agege abattoirs using 50 L sterilized plastic containers. After the collection, the physicochemical characteristics of the AWW samples were assessed for nutrient content using the laboratory procedures by the Association of Official Analytical Chemists (AOAC, 2005), as outlined in Kekere *et al.* (2020).

The physicochemical characteristics investigated included pH, total dissolved solids (TDS), temperature, turbidity, conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved carbon (TOC), potassium (K), nitrate (N), phosphate (PO_4), sulfate (SO_4), chromium (Cr), copper (Cu), lead (Pb) and zinc (Zn).

Data Collection

The effects of AWW on the tomato plant based on plant height, branch numbers, leaf numbers, root length, fruit yield, and stem girth were determined. The AWW concentration required for tomato growth was assessed as previously described (Matheyarasu *et al.,* 2016; Kekere *et al.* 2020). The plant height and root length were measured using the meter rule, while the stem circumference was quantified with a Vernier caliper. Tomato branch numbers, leaf numbers, and fruit numbers were manually counted (Usman 2015; Kekere *et al.*, 2020).

Data Analysis

Data generated from the study were analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Morphological data obtained from the tomato plants were subjected to a one-way analysis of variance (ANOVA) with means separated by the Tukey HSD Posthoc test at a threshold of 5% ($P<0.05$) according to the methods of Shilpi *et al.* (2018) and Kekere *et al.* (2020). The AWW concentration effects were visually assessed by the morphological characteristics of the tomato plants. The means of the morphological characteristics were compared for both abattoirs. The values of the AWW physicochemical properties were compared for both sites.

RESULTS

Effects of Abattoir Waste Water (AWW) on tomato morphological characteristics.

From the two sites in Lagos State (Surelere and Agege Abattoirs), the effects of AWW on tomato morphological characteristics were significantly higher than those irrigated with ordinary tap water ($P<0.05$). During the cultivation period, AWW significantly increased tomato growth parameters, with the highest performance observed at 100% AWW concentration from both the Surulere and Agege sites (Tables 1-3; Figures 2–4).

Table 1: The effects of AWW on tomato plant height (cm).

	Surulere Abattoir					
Abattoir wastewater Concentration	**Plant height (cm)/ Weeks After Treatment**					
	2	**4**	**6**	**8**	**10**	**Mean**
0%	26.80^{c}	30.50^{b}	32.83^{b}	40.93^{c}	44.93^{c}	35.20^{b}
20%	29.33^{bc}	35.76^{ab}	43.60^{b}	43.36^{bc}	57.10^{bc}	41.83^{b}
40%	30.67^{abc}	37.60^{a}	41.60^{ab}	49.07^{bc}	60.93^{c}	43.97^{b}
60%	34.37^{ab}	38.00^{a}	40.03^{ab}	47.37^{b}	64.83^{b}	44.92^{b}
80%	33.87^{ab}	41.50^{a}	51.67^{a}	56.57^{a}	68.10^{a}	50.34^{a}
100%	37.20^{a}	43.27^{a}	52.67^{a}	62.07^{a}	69.97^{a}	53.04^{a}
	Agege Abattoir					
	2	**4**	**6**	**8**	**10**	**Mean**
0%	25.50^{d}	29.60^{d}	32.56^{b}	37.13^{c}	43.77^{b}	33.71^{b}
20%	30.37^{c}	34.07^{cd}	44.90^{a}	51.57^{b}	65.50^{a}	45.28^{b}
40%	32.37^{bc}	35.63^{bc}	47.07^{a}	58.93^{ab}	65.17^{a}	47.83^{b}
60%	33.07^{b}	39.50^{bc}	45.50^{a}	58.43^{a}	66.23^{a}	48.55^{a}
80%	34.37^{b}	43.40^{ab}	48.10^{a}	56.47^{a}	67.43^{a}	49.95^{a}
100%	36.93^{a}	51.07^{a}	51.13^{a}	59.63^{a}	74.37^{a}	54.63^{a}

Means with the different superscript on the same column are significantly different at $P<0.05$ (Tukey HSD test). The means in each column with the same superscript are not statistically different.

Table 2: The effects of AWW on tomato branch numbers.

	Surulere Abattoir					
Abattoir wastewater	**Weeks After Treatment**					
Concentration	**2**	**4**	**6**	**8**	**10**	**Mean**
0%	5.67^{b}	8.00^{b}	8.33^{b}	9.67^{c}	12.00^{d}	8.73^{b}
20%	7.67^{ab}	9.67^{ab}	11.67^{a}	13.30^{b}	17.00^{c}	11.86^{b}
40%	8.00^{ab}	10.67^{ab}	12.00^{a}	13.33^{b}	19.67^{b}	12.73^{b}
60%	8.67^{ab}	11.33^{a}	14.00^{a}	16.00^{ab}	22.00^{ab}	14.40^{a}
80%	8.67^{ab}	12.00^{a}	14.00^{a}	18.33^{a}	23.00^{a}	15.20^{a}
100%	9.30^{a}	11.67^{a}	14.67^{a}	18.67^{a}	25.00^{a}	15.86^{a}
	Agege Abattoir					
	2	**4**	**6**	**8**	**10**	**Mean**
0%	3.00^{b}	4.01^{b}	5.22^{b}	6.54^{b}	8.01^{c}	5.36^{b}
20%	8.67^{ab}	10.00^{ab}	11.00^{ab}	12.00^{b}	16.00^{c}	11.53^{b}
40%	8.00^{ab}	10.00^{ab}	11.33^{ab}	12.33^{b}	17.00^{bc}	11.73^{b}
60%	8.00^{ab}	12.00^{ab}	14.67^{a}	17.67^{a}	21.67^{bc}	14.80^{a}
80%	10.33^{a}	14.00^{a}	14.67^{a}	19.00^{a}	22.96^{ab}	16.19^{a}
100%	11.67^{a}	14.00^{a}	17.00^{a}	21.00^{a}	25.67^{a}	17.87^{a}

Means with the different superscript on the same column are significantly different at $P<0.05$ (Tukey HSD test). The means in each column with the same superscript are not statistically different.

Table 3: The effects of AWW on tomato leaf numbers.

Surulere Abattoir						
Abattoir wastewater	**Weeks After Treatment**					
Concentration	**2**	**4**	**6**	**8**	**10**	**Mean**
0%	18.33^{b}	31.33^{c}	44.33^{b}	51.67^{b}	62.67^{d}	41.67^{b}
20%	22.00^{b}	39.33^{bc}	52.33^{ab}	63.33^{ab}	76.33^{cd}	50.66^{b}
40%	31.33^{a}	46.33^{ab}	56.00^{ab}	68.00^{ab}	84.67^{bc}	57.27^{b}
60%	32.00^{a}	44.00^{ab}	59.00^{ab}	72.00ab	89.33^{bc}	59.27^{b}
80%	32.67^{a}	49.00^{ab}	65.33^{a}	78.00^{a}	95.00^{a}	64.00^{a}
100%	33.00^{a}	53.00^{a}	67.67^{a}	82.33^{a}	107.67^{a}	68.73^{a}

Agege Abattoir						
	2	**4**	**6**	**8**	**10**	**Mean**
0%	19.67^{c}	31.33^{b}	39.33^{c}	49.67^{d}	64.67^{d}	40.93^{b}
20%	37.33^{b}	46.33^{a}	58.33^{b}	66.00^{b}	83.67^{c}	58.33^{b}
40%	34.67^{ab}	48.33^{a}	61.33^{b}	70.33^{b}	94.33^{b}	61.80^{b}
60%	38.67^{ab}	50.33^{a}	61.67^{b}	80.00^{bc}	97.33^{b}	65.60^{b}
80%	40.67^{ab}	52.67^{a}	65.00^{ab}	81.67^{b}	100.67^{b}	68.14^{a}
100%	45.33^{a}	56.67^{a}	74.00^{a}	101.00^{a}	120.33^{a}	79.47^{a}

Means with the different superscript on the same column are significantly different at P<0.05 (Tukey HSD test). The means in each column with the same superscript are not statistically different.

The AWW concentration required for tomato cultivation.

Tomato plant morphological characteristics significantly increased across all AWW concentrations (P<0.05). AWW increased tomato plant height and leaf numbers, and significantly higher at 80% and 100% compared to other concentrations and control (Tables 1 and 3). The effects of AWW increased tomato branch numbers across all concentrations but significantly increased from 60% to 100% (Table 2). Also, AWW increased tomato root length, fruit numbers, and stem girth across all concentrations but showed a significant increase at only 80% and 100% (P<0.05; Figures 2-4).

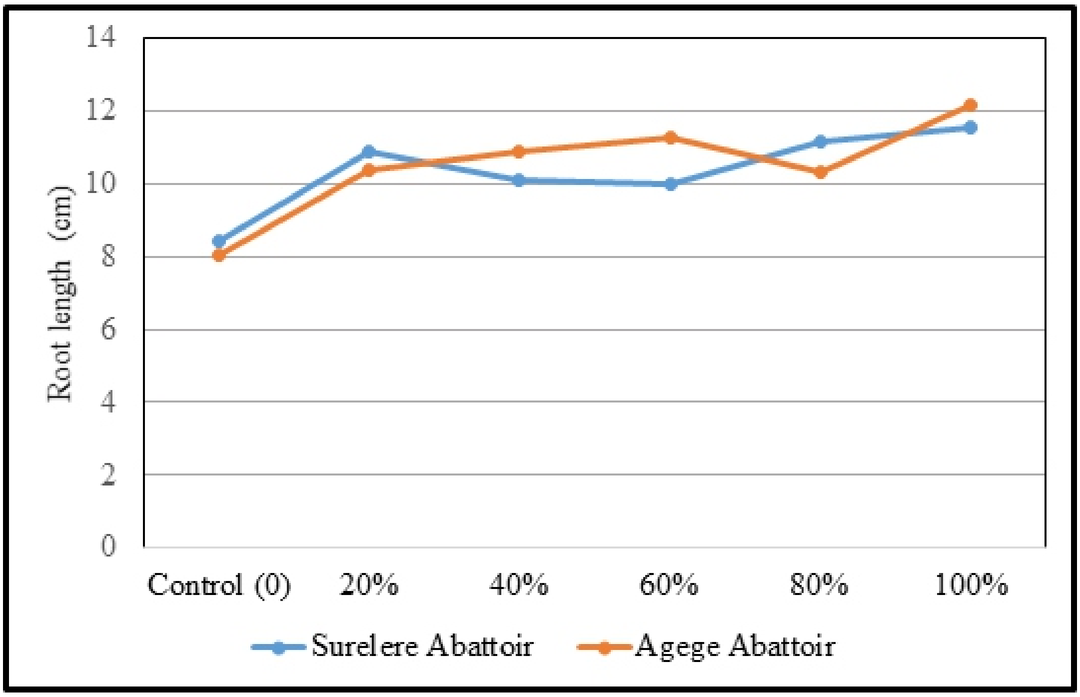

Figure 2: The effect of AWW on tomato root length (cm).

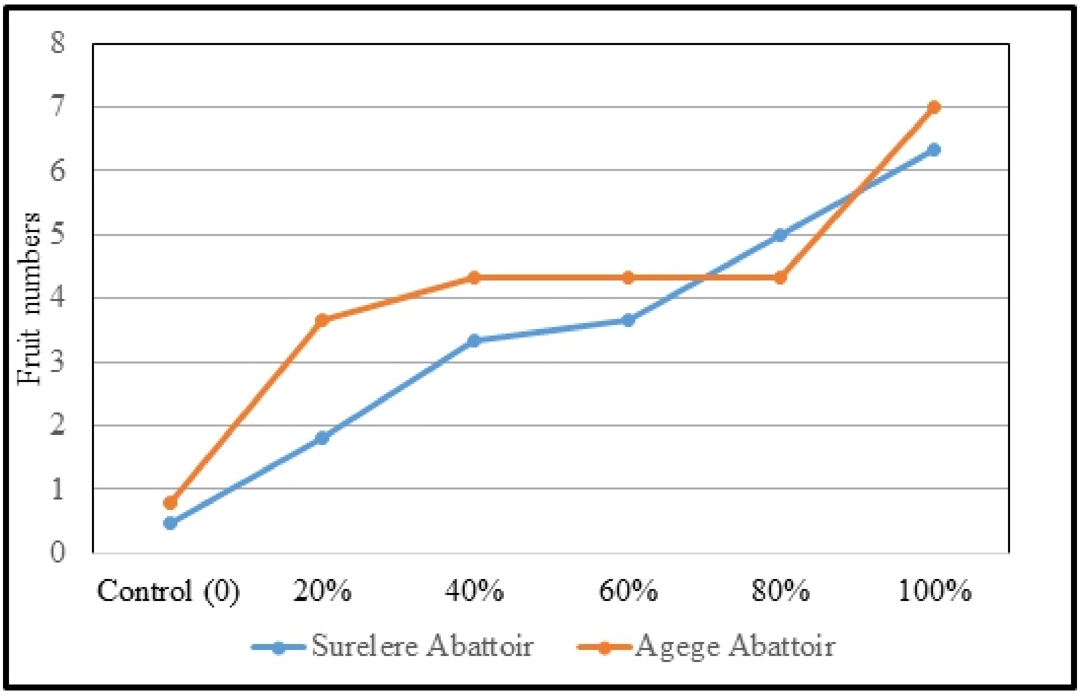

Figure 3: The effect of AWW on tomato fruit yield.

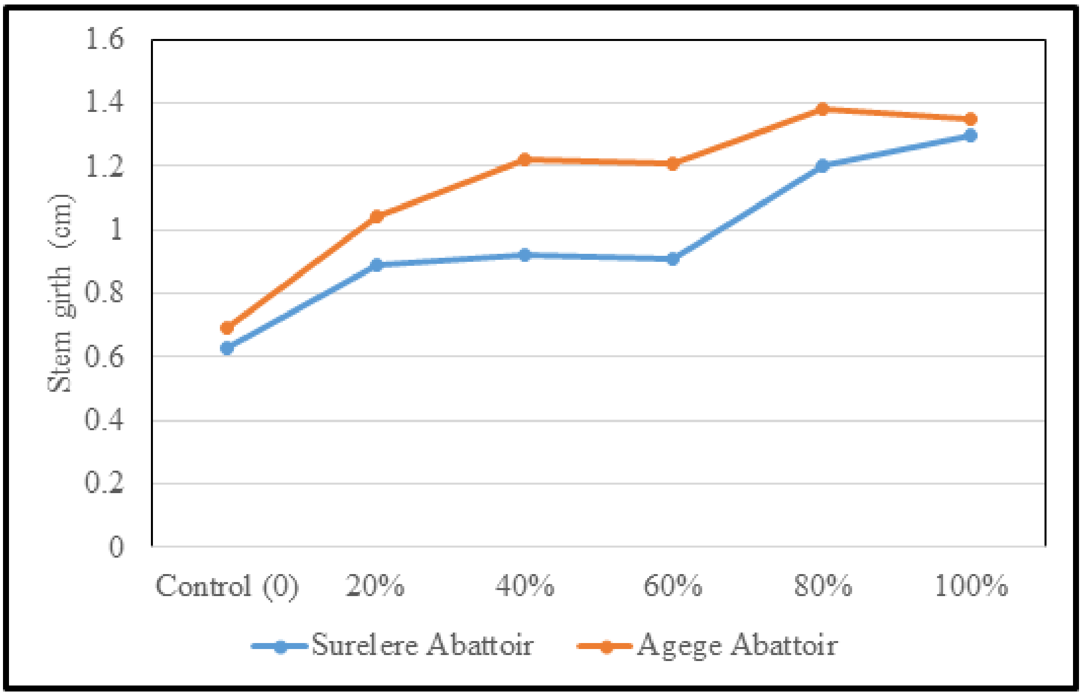

Figure 4: The effect of AWW on tomato stem girth (cm).

Comparative assessment of the Surulere and Agege Abattoirs.

The AWW from the sites in Surulere and Agege were compared for their effects on tomato growth characteristics using the means obtained from the data. The undiluted AWW (100% concentration) from both sites had the most significant effects on the tomato plants (Tables 1-3; Figures 2-4). The physicochemical and morphological characteristics of AWW from Agege were significantly higher than the Surulere AWW (Table 4). Plant height, number of tomato branches, leaf numbers, root length, fruit numbers and stem girth of tomatoes irrigated with Agege AWW were higher than those with Surulere AWW (Tables 1-3; Figure 4).

Table 4: Physicochemical parameters of Surulere and Agege Abattoir wastewater (AWW).

S/N	Parameters	Unit	Surulere Abattoir (Study site 1)	Agege Abattoir (Study site 2)
1.	pH	-	6.20	6.10
2.	Total Dissolved Solids (TDS)	Ppm	1570.00	2765.00
3.	Temperature	0^0	25.90	25.90
4.	Total Suspended Solids (TSS)	Ppm	10.00	12.00
5.	Turbidity	FTU	6.00	8.00
6.	Conductivity	μScm^{-1}	3140.0	5530.0
7.	Dissolved Oxygen (DO)	Ppm	1.00	1.50
8.	Biological Oxygen Demand (BOD)	ppm	52.00	55.00
9.	Chemical Oxygen Demand (COD)	Ppm	106.00	112.00
10.	Total Organic Carbon (TOC)	Ppm	7.90	8.80
11.	Potassium (K)	Ppm	9.61	11.73
12.	Nitrate (No_3)	Ppm	6.54	8.64
13.	Phosphate (PO_4)	Ppm	7.89	10.50
14.	Sulfate (SO_4)	Ppm	45.60	51.60
15.	Chromium (Cr)	Ppm	0.96	1.13
16.	Copper (Cu)	Ppm	0.01	0.01
17.	Lead (Pb)	Ppm	0.03	0.002
18.	Zinc (Zn)	Ppm	9.73	10.11

DISCUSSION

Abattoir wastewater (AWW) is a potential alternative to freshwater for crop irrigation as described by some studies (Usman, 2015; Matheyarasu *et al.,* 2016; Kekere *et al.,* 2020). This study assessed the effects of different AWW concentrations (0-100%) on *Solanum lycopersicum* (tomato) growth and morphological characteristics (plant height, branch numbers, leaf numbers, root length, fruit yield, and stem girth). The undiluted AWW at 100% enhanced tomato growth characteristics compared with other concentrations. This result is consistent with Kekere *et al.* (2020), who reported similar significant growth and morphological enhancements on tomato and *Capsicum annuum* (sweet pepper) at 100% AWW concentration. They observed that AWW could lead to increased crop yield compared to ordinary tap water. Ojobor and Egbuchua (2020) also observed that *Oryza sativa* (rice) irrigated with AWW showed higher growth rates than rice irrigated with nitrogen, phosphorus, and potassium (NPK)-based inorganic fertilizers.

In this study, tomato plant height was significantly higher than ordinary tap water at the different AWW concentrations. This result further corroborates the findings of Ojeniyi *et al.* (2007), who reported that tomato plant morphological attributes were significantly improved above ordinary tap water with AWW collected from two different sites in Akure, Ondo State. Tomato growth enhancement could be attributed to the high organic matter content present in AWW, and its subsequent improvement of soil fertility (Glick, 2012). Similarly, Roy *et al.* (2013) showed that AWW irrigation significantly improved the height of tomato (42.50 cm), sweet pepper (42.00 cm), and *S. melongena* (32.05 cm) compared to the control (tap water) (37.05 cm, 32.00cm, and 22.5 cm, respectively).

On tomato branch numbers, AWW irrigation significantly increased this parameter. Interestingly, the effects of AWW were not visible between weeks 2 and 6 after treatment. However, between 8 and 10 weeks after treatment, tomato branching was visibly enhanced. This AWW effect on tomato branching was significant at higher AWW (60–100%) concentrations. One of the contributing components to the tomato plant's optimum growth and development is the presence of organic nutrients (Shilpi *et al.,* 2018; Kakar *et al.,* 2020). Plant nutrients such as nitrite and phosphate are provided by AWW for the enhancement of tomato growth and development. These nutrients had a significant effect on tomato branches (Matheyarasu *et al.,* 2016; Naz *et al.,* 2019). The increase in branch numbers is similar to the results of Matheyarasu *et al.* (2016), who indicated improvements in tomato branching on poor nutrient soils some weeks after AWW application. This phenomenon could be due to the time and resource allocation required to develop a well-formed branching system in the plant.

Tomato leaf numbers also increased across all AWW concentrations, but this effect was highest at 80–100% AWW concentrations. This trend could be attributed to the role of plant macronutrients such as nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg), among other intrinsic organic substances present in AWW, on plant leaf economics, as exemplified by Kekere *et al.* (2020). This observation further corroborates the work of Kaur and Sharma (2017), who reported that AWW irrigation on *Triticum aestivum* (wheat) yielded higher leaf numbers than those grown with ordinary water. Tomato growth and development benefit from an array of plant nutrients in AWW because leaf economics could improve the vegetative biomass and sugar content of tomato fruits (Rowland *et al.,* 2020). Nutrient-deficient plants develop stunted growth. Poor growth results in few leaves, which lowers the plant's dry weight and fruit yield. A sufficient amount of organic nutrients in the plant can promote meristem tissue division, root growth, and leaf development, which affect water absorption to an optimum level (Abou-Amer *et al.,* 2014; Mooy *et al.,* 2019). In general, crop branching and leaf numbers cultivated in an organic production system appear to have higher biomass than those from conventional farming systems (Riahi *et al.,* 2009; Marmiroli *et al.,* 2012; Youssef and Eissa, 2017).

Tomato root length significantly increased at 80–100% AWW concentrations. However, the highest effects of AWW on tomato root length were recorded ten weeks after treatment. Tomato root length enhancements occurred and could be due to the particular presence of potassium in the AWW. Potassium is implicated in plant root development (Mehdizadeh *et al.,* 2013; Sustr *et al.,* 2019). AWW from the Surulere and Agege study sites had relatively high potassium values of 9.61 ppm and 11.73 ppm, respectively (Table 4). However, Kekere *et al.* (2020), who used AWW mixtures from abattoir sites in Akungba-Akoko, Ondo State, found low potassium levels in the wastewater, with little to no difference between the AWW and the tap water control on tomato root length. In this regard, they found that AWW did not differ significantly from the control. This disparity could likely emerge from the types and constituents of organic compounds in the AWW studied, and different abattoirs would produce dynamic wastewater with various chemical constituents. This study has not been investigated across the abattoirs in Nigeria.

In general, results from this study revealed that AWW can enhance tomato fruit yield, particularly in its undiluted form. This enhancement may be due to organic and inorganic nutrients contained in AWW. For instance, Rusan *et al.* (2007) observed improvements in *Triticum aestivum* (wheat) and *Lolium perenne* (AberMagic grass) grain production, which was credited to the presence of some inorganic elements (such as Cu and Zn) implicated in fruit formation in the test AWW (Wang *et al.,* 2021). This is also consistent with Roy *et al.* (2013), who reported higher tomato fruit yields after irrigation with AWW than those grown solely with inorganic fertilizers with diammonium phosphate and potash.

Finally, tomato stem girth was significantly enhanced at 80-100% AWW concentrations compared to ordinary tap water. This observation is similar to the report of Kekere *et al.* (2020). AWW can boost plant growth and biomass production, which increases stem girth (Marmiroli *et al.,* 2012). The nitrogen, phosphorus, and potassium rates in AWW significantly increased tomato stem girth. The findings suggest that these organic nutrients jointly improve soil fertility and increase stem girth (Tsige *et al.,* 2022). This result is also similar to the findings of Ojobor and Egbuchua (2020), who reported improvements in rice stem girth after irrigation with AWW, above what they obtained with ordinary tap water and conventional NPK fertilizers.

CONCLUSION

Abattoir wastewater (AWW) could potentially revolutionize organic farming as a potent source of essential nutrients to enhance crop productivity and development above scarce freshwater and problem-prone inorganic fertilizers. This study demonstrated enhanced growth and development of tomato plants through AWW application at five different test concentrations. Therefore, AWW can be useful in tomato and other vegetable crop cultivation on a global scale. The significant increase in tomato growth was highest with undiluted AWW (100% concentration). This strongly implies that the raw state of AWW is more effective for vegetable crop irrigation than its diluted forms. Furthermore, nutrients present in the AWW could be applicable as recommended to crops grown on infertile soils. The prospects of broad-scale AWW irrigation could help meet food security challenges and repurpose this wastewater with minimal treatment for use globally.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest in this work.

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