J. of Plant Production, Mansoura Univ., Vol. 15 (11):761 - 768, 2024

Journal of Plant Production

Journal homepage & Available online at: www.jpp.journals.ekb.eg

Reusing Agricultural Wastewater for Tomato Production using Different Sources of Organic Fertilizer under the Conditions of the Delta Region

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ABSTRACT

The availability of fresh water (both in quantity and quality) is decreasing and becoming a major concern worldwide. The agricultural sector is the largest consumer of fresh water, so there is an urgent need to improve the agricultural practices to fill the gap between both water supply and demand, which is a fundamental aspect of the main baisics of sustainable agriculture. Hence, one of the possible strategies to achieve this is the reuse of agricultural drainage water, especially with the current climate change. This research focuses on reusing agricultural wastewater in tomato production by applying organic fertilizers. The impacts of applied bioshar, compost, cattle manure and vermicompost on vegetative growth, leaf chemical composition, and productivity of tomato plants irrigated with agricultural drainage water were evaluated. As a result of the experiments, all organic soil amendments significantly enhanced vegetative growth parameters including plant height, fresh, dry weights, and leaf area compared to the control plants. These treatments also significantly increased photosynthetic pigments, yield and fruit quality of tomato plants. Conversely, the activity of antioxidant enzymes and heavy metal content were significantly reduced in response to organic fertilizers. Biochar exhibited the highest values for the studied vegetative growth parameters, leaf pigments, nutrient content as well as productivity, but the lowest levels of enzymatic activity and heavy metal content. Overall, the research suggests that agricultural wastewater can be reused for tomato production, especially in area with limited fresh water availability by using organic fertilizers such as biochar, vermicompost, compost and cattle manure.

Keywords: Tomato – Agricultural drainage water – Biochar – Vermicompost

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is popular vegetable crop rich in vitamins and has appropriate sugar content, so it is considered the most consumed fruit on the planet, whether fresh, dried, or manufactured. It is produced worldwide, grown under different soils and climate conditions and covers nearly over 6.5 million hectares (FAOSTAT, 2022). Tomato is a high water-demand crop, so it considered as a sensitive crop to water stress (Hou *et al.* 2020). Global water demand is increasing due to the rapid industrialization, climate change, and economic activities worldwide. This has eventually led to a scarcity of fresh water supply and increase wastewater generation, which was 359 billion m^3 in 2020. It is predicted to reach nearly 470 billion m^3 by 2030 and may increase to about 574 billion m3 by 2050 (Qadir *et al.* 2020). Water scarcity, exacerbated by the current climate changes seriously affects the sustainable development of agriculture, productivity, and economic growth leading to potential risks for food security (Paudel *et al.* 2018).

There is an urgent need to improve the agriculture practices and methods to achieve the balance between both water supply and demand, also at the same time improve the resilience to climate changes (Fischer *et al.* 2019) specially with agriculture expansion and water scarcity. A promising instrument to address this need is reusing agriculture wastewater. Reusing wastewater has already been used in many regions, Egypt reuses about six Billion m^3 of wastewater in the Delta Nile for crops production (Hawary and Shaban, 2018). Besides reducing stress on freshwater and pollution, it is rich in nutrients which enhances soil fertility and reduces chemical fertilizer requirement, so provides farmers with economic benefits (Seyoum *et al.*, 2022). On tomato production, Kolekar *et al.* 2023 indicated that irrigation with treated wastewater increased not only soil fertility, but also improved crop yield.

Additionally, organic manure can be applied to improve wastewater quality. Organic manure, derived from animals and plants waste and can improve soil fertility by increasing organic matter content, available nutrients, and improving soil moisture availability, which in turn improves tomato quality (Gao *et al.* 2023a). Appropriate management of agricultural waste as organic fertilizer is necessity for sustainable agricultural development, which is why biochar, compost, cattle manure as well as vermicompost have been studied. Biochar, an organic fertilizer derived from the thermal decomposition of organic matter, contributes to sustainable development and mitigates pollution caused by waste incineration. Consequently, it has many environmental, economic and agricultural benefits (Obadi *et al.* 2024) and enhancing crop production, soil properties, and water use efficiency by reducing the adverse impacts of drought and salinity stresses (Faloye *et al.* 2019). Biochar addition enhanced vegetative growth traits, increase yield, and enhanced tomato fruit quality (Obadi *et al.*, 2024).

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DOI: 10.21608/jpp.2024.336010.1415

Compost, a suitable way of waste management that converts large volumes of waste into materials, contributes to improving soil minerals and organic matter. It also has positive impacts on both the microbial and physicochemical properties of the soil (Toledo *et al.,* 2018). The combination of compost and wastewater enhanced tomato growth and productivity (Tzortzakis *et al.,* 2020). Cattle manure is produced in large quantities due to the rapid development of animal breeding on livestock farms. Un-processed cattle manure is directly applied to the soil as organic manure to improve crop yield, as it contains large amounts of nutrients (Lee *et al.* 2021). Gao *et al.*, 2023b indicated that animal manure significantly enhanced tomato growth, yield and quality.

Vermicompost, an organic fertilizer derived from earthworms, increase soil fertility, supplies essential nutrients, and improves soil structure, and enhancing beneficial soil microorganisms (Mohammed and Alkobaisy, 2024). The application of vermicompost significantly improved not only vegetative growth, but also tomato yield and quality tomato (Turan *et al.*, 2023).

The research aims to reuse agricultural drainage water and reduce its harmful effects by using organic fertilizers (biochar, compost, cattle manure, and vermicompost) on tomato production under the conditions of Delta.

MATERIALS AND METHODS

Experimental Layout and Treatments:

To investigate the effects of biochar, compost, cattle manure, and vermicompost manure on tomato plants performance and productivity, the study was conducted at a private vegetable farm in Sahragt Elsoghra village, Aga district, Dakahlia governorate, Egypt, during the early summer seasons of 2022 and 2023. The tomato cultivar Ellisa was transplanted on February 10th in both seasons using drip irrigation system. The experiment plot area was 72 m^2 (2 drip lines × 30 m long × 1.2 m wide). Tomato seedlings were transplanted on one side of the drip line, spaced 60 cm apart. Some physical and chemical properties of the experimental site are shown in Table 1. Soil preparation, pest control, fertigation were conducted according to the guideline of the Ministry of Agriculture and land reclamation throughout the growing season,. The experiment design was a randomized complete blocks design with four replicates.

Table 1. Some physical and chemical properties of soil profile from the experimental cultivated area.

Soil texture	Organic matter	pH	EC dsm^{-1}	Na^+	K^+	Ca^{++}	Mg^{++}	$CO3^-$	Cl^-	SO_4^{2-}
Clay loam	1.22 %	7.78	0.899	3.97	0.15	12.49	11.53	1.68	4.86	0.99

Soil Organic Amendments

The four organic soil amendment treatments were: the individual application of biochar (5 m^3/fed), compost (8 ton/fed), cattle manure (8 ton/fed), vermicompost (2 ton/fed), and the control. The different applied organic manure were added to the soil and incorporated before cultivation, in conjunction with plowing, as recommended by the Egyptian Ministry of Agriculture and land reclamation. Table 2 presents some properties of the applied organic manure. All plants were irrigated with agricultural drainage water under drip irrigation system. The characteristics of agricultural drainage water used in this study presented in Table 3.

Table 2. Some properties of biochar, compost, cattle manure, and vermicompost applied to the soil.

Properties	Units	Biochar	Compost	Cattle manure	Vermicompost
pH	---	8.82	7.5	-	6.0
EC	(dSm^{-1})	1.71	3.5	-	6.0
O.M		30.33	75	20.3	34.5
C	(%)	60	33.11	12.2	18
N		0.24	1.82	1.22	1.5
C:N ratio	---	250:1	18:1	10:1	12:1
P		0.22	1.29	0.3	0.75
K	(%)	0.88	1.25	2.9	5.05
Moisture		3.53	25	17.6	-
Mn	ppm	-	1110	446	18
Zn	ppm	-	280	180	20

Table 3. The characteristics of agricultural drainage water used in this study

Parameter	Unit	Drainage water
pH	---	7.85
EC	dS/m	2.43
Na^+		154.1
K^+		9.89
Ca^{++}		22.5
Mg^{++}	mg L^{-1}	48.9
$CO3^-$		0.04
HCO_3^-		6.79
Cl^-		2.9
Fe^{++}		0.451
Zn^{++}		0.388
Mn^{++}		0.389
Cd^{++}	µg L^{-1}	0.049
Cu^{++}		0.71
Ni^{++}		0.589
Pb^{++}		0.434

Parameters:

Morphological, chemical and productivity parameters were tested to assess the impacts of drainage water on plant performance in response to the different applied organic sources. Morphological and chemical data were recorded two months after transplanting. Five plants from each plot were randomly chosen to determine the following:

Vegetative growth Characteristics included: plant height, total fresh and dry weight and leaf area as described by Koller (1972).

photosynthetic pigments content of leaves: Chlorophyll a, b, Total chlorophylls (a+b) as well as carotenoids according to the methods described by Wettstein (1957).

Mineral content of Leaves: Samples of 100 grams were taken from the leaves two months after transplanting, dried in an oven at 70 °C for three days, and weighed to determine the concentrations N, P, K and Ca as described by Kalra (1998).

Enzymes activity in leaves: Peroxidase, Superoxide dismutase, Catalase activity according to Cao *et al.* (2005)

Yield parameters: (early yield, total yield, and marketable yield): Fruits were harvested starting three months after transplanting. Early yield calculated from fruit fresh weight of the first two pickings and calculated as ton/fed. Concerning marketable yield, the weight of usually healthy fruits (which are not infected by any disease and free from physiological defects).

Fruit Quality: Samples of 10 uniform, fully red-ripe fruits were sampled at the 3rd picking from each plot to estimate the total soluble solids, vitamin C, and acidity as described as indicated in AOAC (2012) and lycopene according to the method of Nagata and Yamashita (1992).

Heavy Metals Content in Fruits: Samples of the 3rd picking throughout the season were collected to determine Fe, Zn, Mn, Cu and Pb. were analyzed in tomato fruits according to Rangana (1977).

Statistical analysis

The collected data underwent statistical analysis through Analysis of Variance (ANOVA), and the least significant differences (LSD) method, following the procedure detailed by Duncan (1955), were used to distinguish means at a significance level of 0.05. This analytical approach aligned with the methodology prescribed by Gomez and Gomez (1984**).**

RESULTS AND DISCUSSION

Results

Vegetative growth and leaf pigments:

Tables 4 and 5 show that there is a positive impact of the different applied organic manure (biochar, compost, cattle manure and vermicompost) on vegetative growth parameters including plant height, fresh and dry weights, leaf area and leaf pigments such as chlorophylls a, b, total chlorophyll as well as carotenoids of plants irrigated with agricultural drainage water in both seasons. The superior performance of plants (vegetative growth and leaf pigments) was noticed when plants were supplied with biochar. Plants supplied with compost came second followed by plants supplied with vermicompost in most cases in both growing season. In contrast, the lowest values of all mentioned studied parameters were recorded by tomato plants irrigated with agriculture wastewater in the absence of organic manure, this may depend on irrigation water quality.

Table 4. Vegetative growth characteristics of tomato plants as affected by irrigation with agriculture drainage water and some organic fertilizer treatments during the summer seasons of 2022 and 2023.

Treatments	Plant height (cm)		Total fresh weight (gm/plant)		Total dry weight (gm/plant)		Leaf area (cm^2/plant)	
	2022	2023	2022	2023	2022	2023	2022	2023
Biochar	91.1 a	80.0 a	1048.6 a	981.3 a	117.9 a	124.7 a	85.24 a	94.79 a
Compost	83.7 b	76.2 b	932.3 b	885.8 b	102.0 b	107.2 b	68.08 b	79.57 b
Cattel manure	79.3 c	71.3 c	871.4 c	821.1 c	101.4 b	106.5 b	63.08 c	74.08 c
Vermicompost	77.2 c	69.3 c	855.2 c	815.9 c	92.7 c	89.9 c	59.94 c	73.27 c
Control	62.1 d	55.5 d	712.8 d	672.6 d	72.5 d	77.5 d	36.27 d	44.89 d

Means followed by the same letter in the same column are significantly different at the 5% level according to Duncan's multiple range test.

Table 5. Photo-synthetic pigments content of tomato leaves as affected by irrigation with agriculture drainage water and some organic fertilizer treatments during the summer seasons of 2022 and 2023.

Treatments	Chl. (a)(mg/gm F. Wt.)		Chl. (b) (mg/gm F. Wt.)		Total chl. (a + b) (mg/gm F.Wt.)		Carotenoids (mg/gm F. Wt.)	
	2022	2023	2022	2023	2022	2023	2022	2023
Biochar	1.433 a	1.577 a	0.955 a	0.889 a	2.388 a	2.466 a	0.848 a	0.837 a
Compost	1.166 b	1.251 b	0.940 a	0.880 a	2.106 b	2.131 b	0.773 b	0.786 b
Cattel manure	1.163 b	1.248 b	0.827 b	0.750 b	1.990 b	1.998 c	0.687 c	0.709 c
Vermicompost	1.060 c	1.144 c	0.755 b	0.707 bc	1.815 c	1.851 d	0.620 d	0.630 d
Control	1.048 c	1.132 c	0.671 c	0.654 c	1.720 c	1.786 d	0.571 e	0.559 e

Means followed by the same letter in the same column are significantly different at the 5% level according to Duncan's multiple range test.

Leaves mineral content:

Concerning the mineral content in the leaves, it can be noted that N, P, K and Ca elements under agriculture wastewater irrigation significantly increased in tomato leaves in response to all applied organic fertilizers in both growing seasons (Table 6). Comparing the effects of biochar, compost, cattle manure and vermicompost, plants supplied with biochar are superior in all parameters compared to the control. In contrast, the lowest contents in tomato leaves were observed in plants irrigated with agricultural drainage water in both seasons.

Table 6. Macro-minerals content of tomato leaves as affected by irrigation with agriculture drainage water and some organic fertilizer treatments during the summer seasons of 2022 and 2023.

Treatments	N (%)		P (%)		K (%)		Ca (%)	
	2022	2023	2022	2023	2022	2023	2022	2023
Biochar	2.67 a	3.07 a	0.96 a	1.00 a	3.85 a	3.34 a	0.28 a	0.27 a
Compost	0.94 b	1.32 b	0.69 b	0.74 b	3.14 b	2.91 b	0.22 b	0.21 b
Cattel manure	0.76 bc	1.22 b	0.53 c	0.58 c	3.37 b	2.86 b	0.22 b	0.21 b
Vermicompost	0.45 cd	0.65 c	0.48 c	0.52 c	3.29 b	2.78 b	0.21 b	0.20 b
Control	0.22 d	0.40 c	0.30 d	0.34 d	2.07 c	1.56 c	0.17 c	0.16 c

Means followed by the same letter in the same column are significantly different at the 5% level according to Duncan's multiple range test.

Enzymes activity:

Data in Table 7 show significant differences in peroxidase, superoxide dismutase as well as catalase activity in tomato leaves. In general, the maximum activity of the mentioned antioxidative enzymes was recorded in the untreated tomato leaves. No significant differences were recorded between the control treatment, compost and cattle manure in catalase and superoxide dismutase activity respectively in the two seasons. Conversely, the lowest values were observed in the leaves of plants supplied with biochar.

Table 7. Enzymes activity of tomato leaves as affected by irrigation with agriculture drainage water and some organic fertilizer treatments during the summer seasons of 2022 and 2023.

Treatments	Peroxidase activity (/g F. Wt./h)		Superoxide dismutase activity (/g F. Wt./h)		Catalase activity (/g F. Wt./h)	
	2022	2023	2022	2023	2022	2023
Biochar	194.02 d	193.12 d	102.6 b	102.5 b	179.01 b	187.93 b
Compost	198.9 c	197.8 c	102.6 b	102.5 b	233.72 a	2.44 a
Cattel manure	224.38 b	223.4 b	109.6 a	109.5 a	202.35 b	212.73 b
Vermicompost	201.7 c	200.8 c	104.6 b	104.5 b	204.95 ab	215.23 ab
Control	286.5 a	285.6 a	111.6 a	111.5 a	233.72 a	244.16 a

Means followed by the same letter in the same column are significantly different at the 5% level according to Duncan's multiple range test.

Yield and fruit quality:

Soil application with biochar, compost, cattle manure and vermicompost (Table 8) displayed a significant enhancement in early, total and marketable yield of tomato compared to the untreated plants. Comparing all added organic manure, plants grown in biochar-treated soil showed maximum values of early, total as well as marketable yield in both seasons. Concerning fruit quality, similar significance was noticed in response to soil application with organic fertilizers in most cases (Table 9). The highest values of total soluble solids, vitamin C, lycopene as well as acidity were observed in response to biochar application. No significant differences were recorded among all organic fertilizers in vitamin C content. Also, no significant differences were found between biochar and compost in total soluble solids in the first season and acidity in both seasons. The lowest values of the mentioned traits were registered in the absence of organic fertilizers.

Table 8. Yield parameters of tomato plants as affected by irrigation with agriculture drainage water and some organic fertilizer treatments during the summer seasons of 2022 and 2023.

Treatments	Early yield (ton/fed.)		Total yield (ton/fed.)		Marketable yield (ton/fed.)	
	2022	2023	2022	2023	2022	2023
Biochar	10.428 a	9.469 a	41.278 a	41.711 a	37.629 a	38.582 a
Compost	9.302 b	8.462 b	35.773 b	36.206 b	32.870 b	34.052 b
Cattel manure	9.051 b	8.354 bc	36.775 b	37.208 b	33.652 b	34.370 b
Vermicompost	8.511 c	8.012 bc	33.611 c	34.044 c	30.532 c	31.615 c
Control	7.718 d	7.654 c	30.441 d	30.874 d	27.352 d	28.464 d

Means followed by the same letter in the same column are significantly different at the 5% level according to Duncan's multiple range test.

Table 9. Fruits quality parameters of tomato plants as affected by irrigation with agriculture drainage water and some organic fertilizer treatments during the summer seasons of 2022 and 2023.

Treatments	Total soluble solids (%)		Vitamin C (mg/100g)		Lycopene (mg/100g)		Acidity (%)	
	2022	2023	2022	2023	2022	2023	2022	2023
Biochar	4.53 a	4.56 a	12.119 a	12.714 a	12.62 a	12.47 a	0.39 a	0.51 a
Compost	4.33 a	4.36 b	12.090 a	12.651 a	11.27 c	11.14 b	0.37 a	0.49 a
Cattel manure	4.44 a	4.47 ab	12.091 a	12.685 a	12.14 b	12.00 a	0.33 b	0.45 b
Vermicompost	3.53 b	3.55 c	11.629 a	12.323 a	11.52 c	11.37 b	0.32 b	0.44 b
Control	3.43 b	3.42 c	8.795 b	9.590 b	10.46 d	10.30 c	0.28 c	0.39 c

Means followed by the same letter in the same column are significantly different at the 5% level according to Duncan's multiple range test.

Heavy metals:

Table 10 indicates that there is a a reduction in the content of heavy metals (Fe, Zn, Mn, Cu and Pb) in tomato fruits as a result of applying different organic manures (biochar, compost, cattle manure, and vermicompost) in both seasons. In contrast, plants in the absence of organic manure recorded the best values of the previous mentioned parameters followed by plants supplied with compost in the two seasons. Plants grown in soil supplied with biochar recorded the lowest values of Fe, Zn, Mn, Cu and Pb in tomato fruits.

Table 10. Heavy metals content of tomato fruits as affected by irrigation with agriculture drainage water and some organic fertilizer treatments during the summer seasons of 2022 and 2023.

Treatments	Fe (mg/kg dry weight)		Zn (mg/kg dry weight)		Mn (mg/kg dry weight)		Cu (mg/kg dry weight)		Pb (mg/kg dry weight)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
Biochar	78.4 c	68.4 c	9.86 d	11.20 d	146.2 e	136.1 e	74.2 b	16.1b	21.8 b	28.3 b
Compost	167.7 b	192.4 b	14.27 b	15.27 b	231.6 b	221.5 b	88.7 b	22.0b	25.7 b	37.4 b
Cattel manure	208.7 ab	190.8 b	11.49 c	12.83 c	214.6 c	204.5 c	100.3 b	33.6b	23.9 b	29.6 b
Vermicompost	210.8 ab	203.1 b	10.72 cd	12.06 cd	194.2 d	184.1 d	82.7 b	40.9b	33.3 b	37.4 b
Control	225.7 a	241.3 a	17.19 a	18.52 a	244.2 a	234.1 a	298.6 a	232.3 a	159.7 a	157.5 a

Means followed by the same letter in the same column are significantly different at the 5% level according to Duncan's multiple range test.

Discussion

Agriculture is considered the main consumer of fresh water (70 % of fresh water resources) (Kolekar *et al.* 2021), hence water is one of the main limiting factors in agriculture production. Reusing agriculture drainage water is considered the need of the hour because water quantity consumed for agriculture purposes is increasing due to water scarcity and the expansion of agriculture (Dhawan, 2017). Agricultural wastewater provides crops with nutrients due to its nutrient content (Table 3). On the other hand, reusing wastewater have negative impacts such as contamination of heavy metals, microbial pathogenic agents, other hazardous compounds and salinization (Perulli *et al.,* 2021). So, one of the sustainable approaches for managing agricultural drainage water is converting it into useful forms. Also, it is necessary to choose crops that suits irrigation with treated wastewater.

In the current study, the effects of biochar, vermicompost, compost as well as cattle manure as contaminants removal on tomato performance were examined under irrigation with agricultural drainage water. The recorded results confirmed that all the aforementioned treatments significantly improved vegetative growth traits as plant height, fresh and dry weights, leaf area, leaf pigments (chl a, b, total as well as carotenoids), chemical contents including N, P, K and Ca, yield parameters as early, total and marketable yield of tomato as well as fruits quality including total soluble solids, vitamin C, lycopene as well as acidity and fruits heavy metal contents of tomato plants irrigated with agricultural drainage water.

The observed positive effects of all applied organic manure in most cases may be due to the fact that they are considered an enriched source of the most essential nutrients which are necessary for growth and development as well as microorganisms that greatly affects soil chemical and physical properties and fertility, resulting higher yield (Table 2 and Ganeshnauth *et al.*, 2018). Additionally, wastewater combined with organic treatments stimulates soil metabolism through increasing organic and mineral nutrients, nitrification indices (NO_3^- and NH_4^+) as well as metabolic (dehydrogenase activity/water-soluble carbon) (Masciandaro *et al.* 2014). Concerning the observed differences between the applied organic manure, Awogbemi and Oyewumi 2022 illustrated that the efficiency of contaminants removal depends on the type, source, the adsorbent's chemical and physical properties, anion or cation exchange capacity, and the adsorbent's dose.

Regarding the applied biochar, Awogbemi and Kallon, 2023 concluded that, biochar is easy to use, effective, and efficient wastewater contaminant adsorbent. The application of biochar as a modification technique to enhance wastewater efficiency may be due to its polarity, porosity, high surface area, a high removal of heavy metals, nutrients, organic matter nitrate and other pollutants form wastewater, so it can offer both economic and environmental advantages (Gao *et al.* 2024 and as shown in fig 1). Besides being high contaminant removal from wastewater, it is noted in the above-mentioned results that biochar is the superior as it is considered as a long-term effective soil carbon chelator, improves soil structure and nutrient supply and improves soil microbial diversity (Ren *et al.*, 2020) as well as enhancing root activity (Xiang *et al.* (2017). Similar positive effects of biochar on vegetative growth were studied by Carter *et al.*, (2013) on cabbage and lettuce and Hannachi *et al.*, (2023) on eggplant.

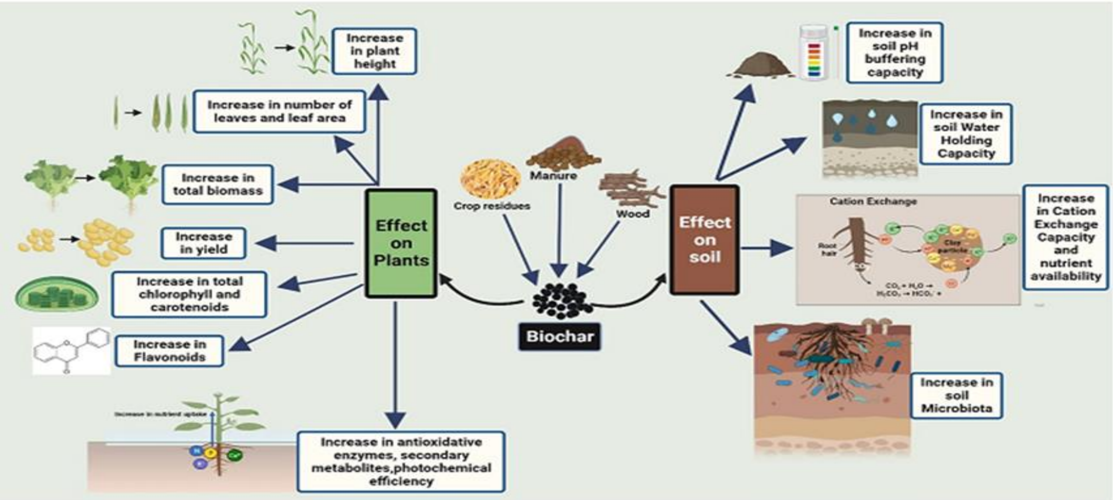

Fig. 1. The effect of biochar on soil and plant. Feedstock in the form of manure, wood and farm residues can be used for biochar manufacture. Biochar positively influences plant properties like height, number of leaves, leaf area, total biomass, yield, pigments, flavonoids, nutrient uptake and soil properties like pH buffering capacity, WHC, CEC and soil microbiota (Upadhyay et al., 2024).

The increase in chlorophylls a, b and total as well as carotenoids (Table 5) is the outcome of increasing nutrients availability such as Mg (the component of chlorophyll), N and S nutrients that positively correlate with photosynthesis rate (Gao *et al.* 2021). Similar findings were obtained by Zeeshan *et al.* (2020) on tomato. Biochar can also improve nutrients uptake by enhancing the availability of N, P, K and micronutrients in soil that are vital for biochemical processes of plants (Wong *et al.* 2021) soil microbes (Bolan *et al.* 2023) including bacteria and mycorrhizae. Pavlíková *et al.* (2017) and Durukan *et al.* (2020) observed that N, P, K, and Ca concentrations in lettuce, spinach and sugar beet plants increased with biochar amendment in agreement with the obtained results in Table 6.

The negative response of peroxidase activity, superoxide dismutase as well as catalase activity in response to biochar supplement (Table 7) may be because biochar soil application modulates reactive oxygen species (ROS) levels by affecting the antioxidants defense system (Ghassemi-Golezani and Abdoli 2023). Additionally, improving water and nutrient availability contributes to a balanced soil environment, leading to better plant health, reducing ROS production and enhancing resistance to abiotic and biotic stresses (Mansoor *et al.*, 2021). In the same manner, biochar application resulted in the highest early, total and marketable tomato yield when irrigated with agricultural wastewater (Table 8). The increased tomato yield in response to biochar application may be attributed the enhanced vegetative growth, chlorophyll content, carotenoids, and leaf mineral content (Tables 4, 5 and 6 respectively) which positively reflected on crop yield. Additionally, the increase in yield may be due to biochar's ability to enhance microbial activity, nutrients availability and improve soil structure (Agbede and Oyewumi, 2022). Gao *et al.* 2021 indicated that increased N and P uptake by tomato plants supplied with biochar resulted in higher tomato yield. Similar findings were obtained by Almaroai and Eissa, 2020 and Obadi *et al*. 2024 on tomato.

The positive effects of biochar application on total soluble solids, vitamin C, lycopene as well as acidity (Table 9) can be attributed to the improved growth (Table 4), increased photosynthetic rate (Table 5), increased nutrient content in leaves (Table 6), improved soil fertility as well as the protection against plant pathogens (Sharma *et al.* 2022). Similar results were observed by several investigators who stated that biochar increased the vitamin C content lycopene and titratable acidity of tomatoes (Almaroai and Eissa, 2020, and Obadi *et al.* 2024 on tomato. Concerning the negative effect of biochar on heavy metal content in fruits (Table 10), this may be because biochar application of can remove nearly 80–98 % of the contaminants (heavy metals, acids, ions, pesticides, N, P, K, Ca, Zn, Mg, Cu, Ni, Na and others) in wastewater, making water suitable for irrigation and other agricultural or industrial purposes (Awogbemi and Kallon, 2023, Srikhaow *et al.*, 2023 and Xu *et al.*, 2023). Additionally, the structure of biochar enhances beneficial microorganisms, adsorbing pollutants and preventing the uptake of organic contaminants and heavy metals by plants, hence contributing to the availability of clean water (Qiu *et al.*, 2021).

The positive impacts of compost on tomato performance may be due to the continuous and slow release of nitrogen from compost into the soil, which increases soil fertility and reduces nitrogen leaching, positively affecting both growth and yield (Weber *et al.*, 2014). Concerning the animal-derived organic manure, it improves soil physical properties as well as soil microbial community, which has a positive effect on plant performance (Thomas *et al.*, 2019). These findings are inagreement with with Gao *et al.*, (2023b) on tomato plants.

Regarding the effects of vermicompost on tomato plants performance, the combination of vermicompost and wastewater is effective in enhancing soil fertility by increasing nutrient availability, microbial activity, and productivity as well as improving quality (Masciandaro *et al.* 2014 and fig 2). Vermicompost also enriches plant growth and improves microbial activity in the soil, which supports plant growth and enhances photosynthesis (Raza *et al.* 2024). Similar results were obtained by Alam *et al.*, 2024 indicating that the use of vermicompost and irrigation with wastewater significantly affected tomato plants performance, particularly in terms of growth and yield.

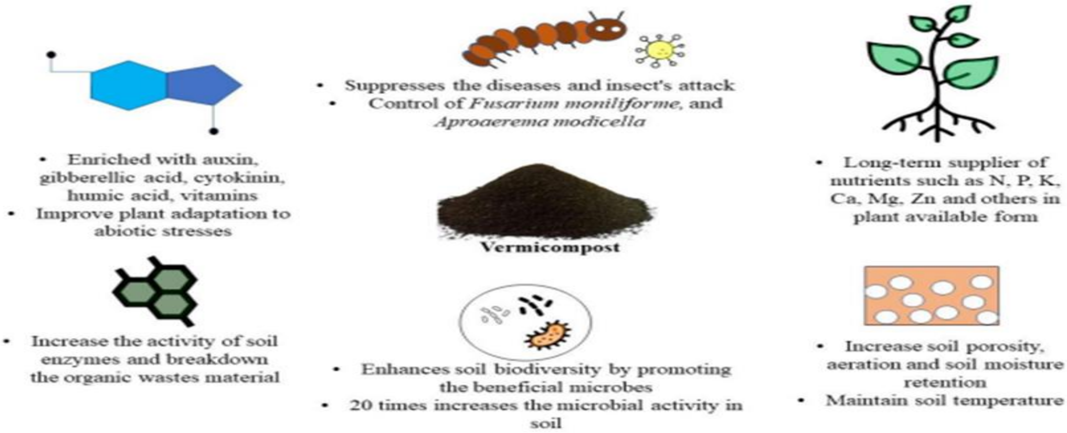

Fig. 2. Vermicompost serves as a plant growth regulator and biocontrol agent, enhancing the physical, biochemical, and fertility properties of soil while suppressing pest attack (Rehman et al., 2023).

CONCLUSION

The findings of this study highlight the significant potential impacts of biochar, vermicompost, compost and cattle manure on enhancing the growth, yield, and quality of tomato plants irrigated with agriculture wastewater. Furthermore, all treatments increased vegetative growth, photosynthetic pigments, leaf N, P, K and Ca content which consequently led to improving yield as well as fruits quality of tomato plants. Thus, the applied organic manure could be used for contaminant removal from agricultural wastewater, not only to overcome water scarcity and protect fresh water resources, but also to increase productivity and improve quality. Moreover, these results underscore the importance of reusing agricultural watewater in tomato production. Moving forward, further exploration and adoption of organic manure in other crops irrigated with agricultural wastewater should also be recommended, as part of a holistic strategy towards sustainable agriculture. By harnessing the benefits of these organic materials, we can not only improve the agricultural productivity but also contribute to environmental conservation and food security goals.

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إعادة إستخدام مياه الصرف الزراعي لإنتاج الطماطم بإستخدام مصادر مختلفه من الأسمدة العضوية تحت ظروف منطقة الدلتا

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الملخص

ينخفض توافر المياه العذبة (كما ونوعا) في جميع أنحاء العالم و يعد القطاع الزراعي هو الأكثر استهلاكا للمياه العذبة لذلك هناك حاجة ملحة لتطوير الممارسات الزراعية لسد الفجوة بين الإحتياجات والمتوافر (العرض والطلب) على المياه باعتبارها واحدة من الركائز الأساسية للزراعة المستدامة. ومن هنا فان احدى الاستراتيجيات الممكنة لتحقيق ذلك هي اعادة استخدام مياه الصرف الزراعي خاصة فى ظل تحديات التغيرات المناخية. لذلك يهدف البحث الى إعادة استخدام مياه الصرف الزراعي في انتاج الطماطم من خلال اضافة بعض الأسمدة العضوية. ومن أجل تحقيق ذلك تم دراسة تأثير كل من البيوشار والكمبوست والسماد الدودي والسماد البلدي على النمو الخضري والمحتوى الكيميائي للأوراق وكذلك انتاجية نباتات الطماطم ومحتوى الثمار من العناصر الثقيلة. أظهرت النتائج أن جميع الأسمدة العضوية المضافة الى التربة أدت الى تحسين مؤشرات النمو الخضرى المتمثلة في ارتفاع النبات و الوزن الطازج والجاف و المساحة الورقية وذلك مقارنة بالنباتات التى تم الري بماء الصرف الزراعي فقط. كذلك أدت هذه المعاملات الى زيادة معنوية في محتوى الأوراق من صبغات البناء الضوئي والعناصر الغذائية وكذلك محصول وجودة ثمار الطماطم. وعلى العكس سجل نشاط الانزيمات المضادة للأكسدة وكذلك محتوى الثمار من العناصر الثقيلة أقل القيم. سجلت النباتات التى تم تسميدها بالبيوشار أفضل القيم للقياسات الخضرية وصبغات البناء الضوئي ومحتوى الأوراق من العناصر الغذائية والمحصول وجودة الثمار ولكن أقلها للنشاط الانزيمي والمعادن الثقيلة. وبصفة عامة يشير البحث الى امكانية إعادة استخدام ميا ه الصرف الزراعي لإنتاج محصول الطماطم وتقليل الأثار المترتبة على ذلك عن طريق اضافة الاسمدة العضوية مثل البيوشار أوالسماد الدودي أوالكمبوست أوالسماد البلدي تحت ظروف المنطقة محل الدراسة.

الكلمات الدالة : الطماطم – مياه الصرف الزراعى – البيوشار – السماد الدودى