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# Effects of Different Wastewater Irrigation on Soil Properties and Vegetable Productivity in the North China Plain

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**Abstract:** The interest in reusing wastewater for irrigation is being popularized in most countries. The objective of this study was to evaluate the effects of different wastewater and nitrogen fertilizer on soil fertility and plant quality, as well as to identify the optimal irrigation mode in the North China Plain. A total of nine treatments, including control (groundwater, no fertilizer), piggery wastewater, reclaimed water, and saline water, combined with nitrogen fertilizer (300 kg/ha and 200 kg/ha), were conducted in a greenhouse in 2019 (Xinxiang, Henan Province). Soil pH, electrical conductivity, organic matter, heavy metals contents, and cucumber yield and quality were analyzed. The results showed that: (1) compared with the underground water (control), soil pH value with a decrement of 0.21 units in piggery wastewater (PW), and 0.24 units in saline water treatments (SW). Soil electrical conductivity (EC) value significantly increased by 5.8~20.9% in PW and SW treatments, while there was no significant difference in EC in reclaimed water. The highest EC (770 µS/cm) was recorded in SW treatment. (2) No dramatic difference on the concentrations of soil lead (Pb) and cadmium (Cd) in the PW, RW, and SW treatments, compared with the control, but soil organic matter, copper (Cu), and zinc (Zn) concentrations in wastewater treatments were increased by 2.1~43.4%, 24.4~27.0%, and 14.9~21.9%, respectively. (3) There were no significant differences in cucumber yield and quality in RW treatment, while there was a slight decrease by 1.4% in yield in the SW treatment. The highest cucumber yield was observed in PWH treatment, with an increment of 17.5%. In addition, the contents of Vitamin C, soluble sugar, and protein were also improved by PW treatment. In this study, PW treatment showed the strongest ability to promote cucumber yield and quality, thus indicating that piggery wastewater irrigation with 300 kg/ha nitrogen would be the optimal practice in this region. Long-term study is necessary to monitor potential risk of heavy metals on the quality of soil and plant.

**Keywords:** unconventional water resources; nitrogen level; soil heavy metals; vegetable productivity; North China Plain

## 1. Introduction

The shortage of freshwater is a common problem in most regions of the world; it is estimated that the water shortage will reach 1.3 × 10 $m^3$ by 2030 in China [1,2]. Extensive use of irrigation, environmental pollution, and decreasing water resources have threatened the sustainable development of agriculture; alternative sources of water should be considered to maintain the further development [3]. Reusing wastewater is considered to an environmentally disposal practice that helps to prevent wasting the limited resources and minimize the environmental pollution (i.e., direct disposal of wastewater into surface or groundwater) [4]. In addition, studies have shown that wastewater irrigation can enhance soil fertility and crop productivity [5]. However, this practice may cause environmental problems if not appropriately treated and managed [6–8].

To a certain extent, wastewater includes aquaculture wastewater, urban sewage, and saline water, etc. [1]. As an alternative resource, the safe utilization of wastewater has received significant attention, and much literature has been reported frequently [9–14]. It has been reported that reclaimed water significantly increased tomato yields, soluble sugar, and titratable acidity content of the fruit, due to its high levels of nitrogen, organic matter, and other available nutrients [15]. Xu et al. [16] showed that reclaimed water irrigation significantly improved the growth and yield of pakchoi, but had no significant effect on its quality. Within a certain range, saline water irrigation can improve water use efficiency and plant growth, without a dramatic decline in yield [17].

Cucumber (*Cucumis sativus* L.), due to its high controllability and economic benefits, is widely cultivated in several countries, especially China [18]. How to make this cultivation has a greater economic return and higher yield than open-field cultivation does, which becomes the most critical issue for local farmers and drive farmers to overuse water and fertilizers to achieve higher vegetable yields [18]. Clearly, scientific irrigation combined with fertilizer application for plant–soil is necessary to investigate. The interest in reusing wastewater of irrigation is an attractive option of disposal; because of its characteristics, it provides a direct or indirect influence, regarding the relationship between soil and plants. Although the wastewater irrigation is extensively popularized by many countries as an important measure to alleviate scarcity of water resource and reduce fertilizer application, it might aggravate soil salinity, nutritional disorder, poor soil structure, and toxic stress to crop growth [19–23]. Therefore, the management of wastewater irrigation should consider the characteristics of the crop and soil, nature of water source, climate, and other factors. Most of the studies mainly focuses on the effects of single irrigation water quality, irrigation norms, and irrigation patterns [24–27], and there is a lack of systematic research on the effects of different wastewater irrigation on the water–soil–plant in North China Plain. Therefore, considering the regional importance and the uncertain influenced by wastewater irrigation in cultivated land fertility and crop productivity, the objectives of our experiment were to: (1) clarify the effects of different wastewater and N application on soil physicochemical properties, cucumber yield, and quality in North China Plain; (2) obtain the optimal irrigation mode of cultivated land; and (3) provide scientific support for optimizing the reuse of wastewater irrigation in this region.

## 2. Materials and Methods

### *2.1. Experimental Site*

The experiment was carried out in a greenhouse in April–July of 2019 at the Agricultural Water and Soil Environmental Field Science Research Station, Chinese Academy of Agricultural Sciences (Xinxiang City, Henan Province, 35°19′ N, 113°53′ E). The meteorological data of 60-year was obtained from Xinxiang Weather Station. The experimental site has a warm temperate continental monsoon climate, with annual average temperature was 14.1 °C, annual average precipitation was 588.8 mm, frost-free period was 210 d, and sunshine duration was 2398.8 h. The soil type is tidal soil, and the physical and chemical properties of 0–20 cm soil layer are as follows: soil bulk density: 1.35 g/cm$^3$, pH value: 8.57, organic matter content: 7.3 g/kg, field capacity: 20.5%, available nitrogen: 0.78 mg/kg, available phosphorus: 18.5 mg/kg, and available potassium: 102.6 mg/kg.

*2.2. Description of Experiment*

Cucumber cultivar "CASS-106" (*Cucumis sativus L.*) seedlings was provided by the experimental station. A randomized block design (4 × 2) with three replications, and nine treatments in this experiment (total of twenty-nine plots), including control (groundwater, no fertilizer), unconventional wastewater (piggery, reclaim water and saline water), and two nitrogen applications (high: 300 kg/ha and low: 200 kg/ha); the details of experimental design are shown in Table 1.

**Table 1.** Experimental design in this study.

| Treatments | Water Quality | Nitrogen Fertilization (kg/ha) |
|---|---|---|
| Control (CK) | Groundwater | 0 |
| CKWH | Groundwater | 300 |
| CKWL | Groundwater | 200 |
| PWH | Piggery wastewater | 300 |
| PWL | Piggery wastewater | 200 |
| RWH | Reclaimed water | 300 |
| RWL | Reclaimed water | 200 |
| SWH | Saline water | 300 |
| SWL | Saline water | 200 |

Note: control (CK): groundwater; PW: piggery wastewater; RW: reclaimed water; SW: saline water; H: 300 kg/ha nitrogen application; L: 200 kg/ha nitrogen application.

Each plot area was about 6 $m^2$ (1 m × 6 m), protective rows were set in each treatment block. Following the local conventional fertilizer application, chicken manure 30 t/ha (organic matter ≥ 45%) was applied before cucumber seedlings were transplanted (2 April). The amount of fertilizer was $P_2O_5$ 78 kg/ha, $K_2O$ 51 kg/ha. Throughout the cucumber growth period, irrigation occurred once every 3–5 days, and the total irrigation amount for the experiment was 2100 $m^3$/ha. Groundwater was pumped from the nearby wells; piggery wastewater was taken from the biogas project in Xinxiang city, Henan Province. Reclaimed water was obtained from the Luotuowan domestic sewage treatment plant in Xinxiang City. Saline water was prepared with sea salt at a concentration of 4 g/L in the laboratory. The water quality of wastewater was judged by using the water quality standard for farmland irrigation (GB5084 2005), as shown in Table 2.

**Table 2.** The quality of four water source in experiment.

| Water Quality | pH | EC μS/cm | TN mg/L | TP mg/L | $K^+$ mg/L | COD mg/L | $NH_4^+$ μg/L | $NO_3^-$ μg/L |
|---|---|---|---|---|---|---|---|---|
| GW(Control) | 8.51 | 178 | 0.98 | 0.51 | 8.3 | 0.4 | 1.56 | 2.88 |
| PW | 7.45 | 1020 | 167.8 | 17.53 | 58.1 | 1036 | 869.32 | 35.64 |
| RW | 8.38 | 593 | 11.9 | 1.12 | 10.1 | 4.0 | 25.36 | 8.78 |
| SW | 7.30 | 4320 | 3.21 | 0.47 | 22.5 | 0.5 | 1.69 | 3.08 |

Note: EC: electrical conductivity; TN: total nitrogen; TP: total phosphorus; COD: chemical oxygen demand; GW: groundwater; PW: piggery wastewater; RW: reclaimed water; SW: saline water.

*2.3. Sampling and Measurements*

2.3.1. Soil Sample

After vegetable harvesting, soil samples were collected as the five-point mixing method. After air-dried naturally, the samples were ground and passed through a 2 mm sieve.

Soil pH was measured by using potentiometric method with soil and water extract at a ratio of 1:2.5 (*w*/*v*) (PHS-3E pH meter, Shanghai Electronic Scientific Instrument Co., Ltd., Shanghai, China). Soil electrical conductivity (EC) was measured in a 1:5 soil and water extract (*w*/*v*) by using portable conductivity meter measurement (DDB-303A, Shanghai Electronic Scientific Instrument Co., Ltd., Shanghai, China.) Soil bulk density was measured by cutting ring method described by Lu [28]. Soil organic matter was determined by using potassium dichromate external heating method [28]. Soil heavy metals were measured by using microwave digestion-atomic absorption spectrophotometry (AA7000F, Shimadzu, Kyoto, Japan).

#### 2.3.2. Cucumber Sample

Mature cucumbers were harvested from plants in each plot and weighed; cucumber count was converted to number per hectare, and cucumber weight was converted to kilogram per hectare to standardize yield measurements.

To estimate the quality of cucumber, four fruits per plot were sampled and washed in deionized water to determine vegetable quality.

Fruit soluble sugar content was measured by anthrone sulfuric acid colorimetry, according to the method of Lu [28]. Vitamin C content was analyzed by using 2,6-dichlorophenol titration, following the method of Wu et al. [29]. Titratable acidity was determined using sodium hydroxide titration [30]. The protein content was determined by the Kjeldahl nitrogen determination method [30]. The content of nitrate was determined by the phenol sulfonic acid method, according to the procedures described by Li et al. [30].

### *2.4. Data Analysis*

Data was calculated by Microsoft excel 2016. Statistical analyses were conducted via the two-way analyses of variance (ANOVA), and the least significant difference (LSD) test for significance using the SPSS 26.0 software (IBM Crop.). Origin 2018 software was used for graphical presentation of results.

## 3. Results

### *3.1. Effects of Irrigation with Different Water Quality on Soil Physical and Chemical Properties*

#### 3.1.1. Soil pH after Irrigating

Effect of irrigation with different wastewater on soil pH value at 0–40 cm layer, as shown in Table 3. Within 0–20 cm soil layer, soil pH decreased by 0.08 units in PWH and 0.21 units in PWL treatment, compared with the control, but with no significant difference between them. A similar decreasing trend was observed in SW, with 0.24 units in SWH and 0.22 units in SWL treatment. The soil pH values in RW treatment were higher than that in the control, with increment of 0.09 in RWH and 0.11 units in RWL treatment. Except for RW treatment, other treatments decreased by 0.08–0.13 units, compared with the control, in the 20–40 cm layer. The highest pH value of 8.58 was recorded in RWL treatment, followed by 8.56 in RWH treatment (Table 3). The ANOVA showed that the interaction between nitrogen application and water quality had no significant effect on soil pH (Table 3).

**Table 3.** Changes in soil pH under different irrigation treatments.

| Treatments | 0–20 cm | 20–40 cm |
|---|---|---|
| Control (CK) | 8.47 ± 0.06a | 8.40 ± 0.09ab |
| CKWH | 8.42 ± 0.18a | 8.32 ± 0.15b |
| CKWL | 8.46 ± 0.14a | 8.40 ± 0.07ab |
| PWH | 8.39 ± 0.32a | 8.27 ± 0.30b |
| PWL | 8.26 ± 0.21a | 8.32 ± 0.01b |
| RWH | 8.56 ± 0.19a | 8.55 ± 0.03a |
| RWL | 8.58 ± 0.23a | 8.43 ± 0.09ab |
| SWH | 8.23 ± 0.05a | 8.35 ± 0.03ab |
| SWL | 8.25 ± 0.03a | 8.35 ± 0.04ab |
| Water quality (WQ) | NS | NS |
| Nitrogen application (N) | NS | NS |
| WQ × N | NS | NS |

Note: control (CK): groundwater; PW: piggery wastewater; RW: reclaimed water; SW: saline water; H: 300 kg/ha nitrogen application; L: 200 kg/ha nitrogen application. Different letters indicate a significant level of 5% between the different treatments. NS: no significant difference.

### 3.1.2. Soil Electrical Conductivity after Irrigating

Results on the effects of different water quality irrigation on soil electrical conductivity (EC) were presented in Figure 1. Compared with the control, the EC values significantly increased by 5.8~20.9% in PW and SW treatments ($p < 0.05$), and there was a dramatic difference in EC variability between the two nitrogen levels of the PW treatments ($p < 0.05$). However, the EC of RW treatment had no significant change, compared with the control (Figure 1). The highest increment was observed in the SWL treatment (770 µS/cm), followed by the SWH treatment (760 µS/cm), which increased by 20.9% and 19.3%, respectively. Moreover, a marked difference was observed in water quality among the unconventional irrigation, as shown in Table 4.

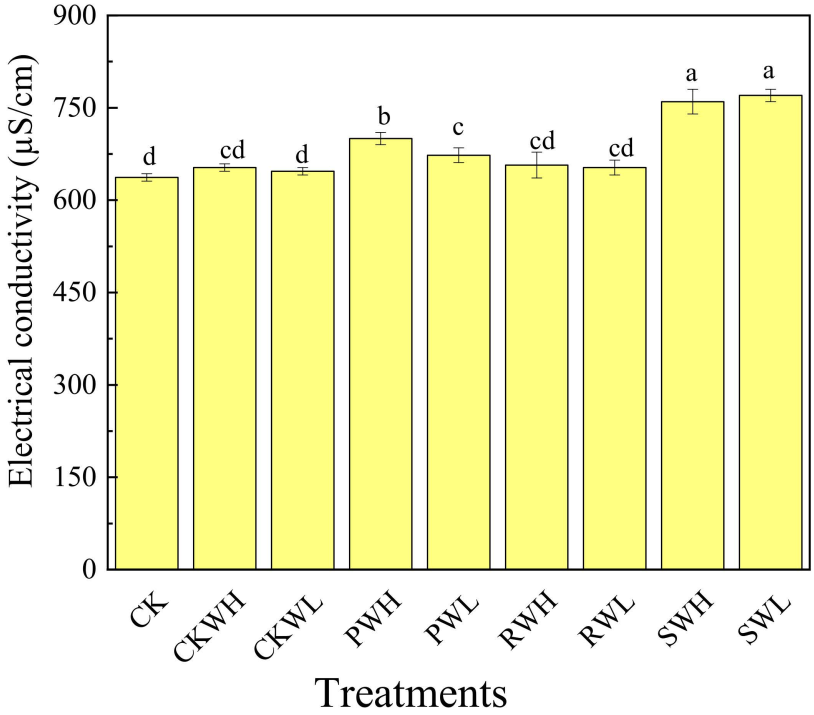


**Figure 1.** Effects of different irrigation treatments on soil electrical conductivity. Note: control (CK): groundwater; PW: piggery wastewater; RW: reclaimed water; SW: saline water; H: 300 kg/ha nitrogen application; L: 200 kg/ha nitrogen application. Different letters indicate a significant level of 5% between the different treatments.

**Table 4.** ANOVA analysis for effects of different irrigation treatments on soil EC.

| Soil EC | |
|---|---|
| Water quality (WQ) | ** |
| Nitrogen application (N) | NS |
| WQ × N | NS |

Note: ** means $p < 0.01$; NS: no significant difference.

### 3.1.3. Soil Organic Matter after Irrigating

Compared to that in the control, a highly significant difference in soil organic matter change was observed in different wastewater irrigation, as shown in Figure 2. Except for the RWH treatment, the soil organic matter content of other treatments was significantly higher than that of the control, but there was no significant difference between nitrogen levels. In the 0–20 cm soil layer, organic matter content of PW treatment was significantly higher than that of the control, with increment of 2.1~43.4% ($p < 0.05$). The highest organic matter content was recorded in PWH treatment, with the value of 19.36 g/kg (Figure 2). In this study, there was significant difference in soil organic matter between water quality and nitrogen application, and the same behavior was found in their interaction (Table 5).

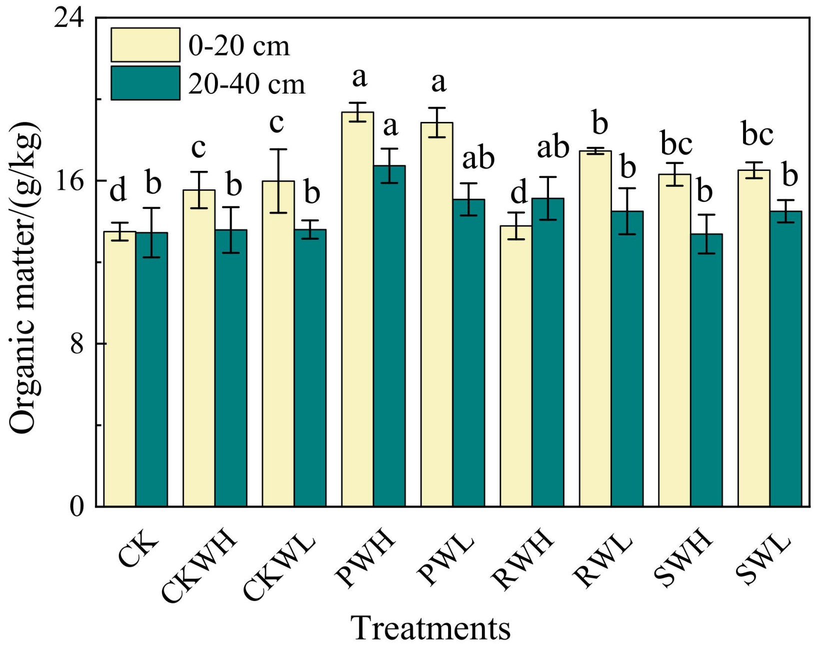


**Figure 2.** Effects of different irrigation treatments on soil organic matter. Note: control (CK): groundwater; PW: piggery wastewater; RW: reclaimed water; SW: saline water; H: 300 kg/ha nitrogen application; L: 200 kg/ha nitrogen application. Different letters indicate a significant level of 5% between the different treatments.

**Table 5.** ANOVA analysis for effects of different irrigation treatments on soil organic matter.

| SOM | 0–20 cm | 20–40 cm |
| --- | --- | --- |
| Water quality (WQ) | ** | ** |
| Nitrogen application (N) | * | NS |
| WQ × N | ** | NS |

Note: * means $p < 0.05$; ** means $p < 0.01$; NS: no significant difference.

The treatment effect for soil organic matter was not pronounced or significant, except for the PWH treatment in the 20–40 cm soil layer. Meanwhile, our results demonstrated that the interaction between nitrogen application and water quality had no dramatic difference in organic matter variability, but a highly significant difference in organic matter change was observed with different water quality for irrigation ($p < 0.01$, Table 5).

### 3.1.4. Soil Heavy Metal after Irrigating

As shown in Table 6, the concentrations of soil heavy metals under different wastewater irrigation were significant different. Soil total copper (Cu) concentration of eight treatments was significantly higher than that of the control, with the highest increment of 27% in PWH treatment, followed by PWL treatment (26.8%). A similar increasing trend was also detected, and the treatment effect was dramatic in total zinc (Zn) concentration modification. The concentration of Zn increased by 21.9%, 21.3%, 17.7%, and 17.2% for PWH, PWL, SWL, and SWH treatments, respectively, compared with the control ($p < 0.05$, Table 6). The highest Zn content was obtained in PWH treatment, with the value of 25.07 mg/kg. The ANOVA indicated that only the quality of wastewater had significant effects on soil Cu and Zn concentrations.

**Table 6.** Effects of different irrigation treatments on the concentration of soil heavy metals.

| Treatments | Cu (mg/kg) | Zn (mg/kg) | Pb (mg/kg) | Cd (mg/kg) |
|---|---|---|---|---|
| Control (CK) | 18.00 ± 0.25c | 20.57 ± 0.61d | 9.12 ± 0.27a | 0.19 ± 0.01abc |
| CKWH | 21.80 ± 0.5b | 23.98 ± 0.31c | 9.07 ± 0.12a | 0.18 ± 0.01c |
| CKWL | 21.77 ± 0.12b | 23.99 ± 0.41c | 9.09 ± 0.26a | 0.19 ± 0.02abc |
| PWH | 22.86 ± 0.44a | 25.07 ± 1.05a | 9.25 ± 0.25a | 0.20 ± 0.01a |
| PWL | 22.83 ± 0.53a | 24.95 ± 0.33ab | 9.21 ± 0.11a | 0.19 ± 0.01ab |
| RWH | 22.4 ± 0.36ab | 23.83 ± 0.17c | 8.94 ± 0.13a | 0.18 ± 0.01bc |
| RWL | 22.38 ± 0.77ab | 23.64 ± 0.42c | 9.18 ± 0.08a | 0.20 ± 0.01ab |
| SWH | 22.55 ± 0.51ab | 24.10 ± 0.23c | 9.13 ± 0.17a | 0.20 ± 0.01ab |
| SWL | 22.51 ± 0.29ab | 24.21 ± 0.33abc | 9.25 ± 0.08a | 0.19 ± 0.01abc |
| Water quality (WQ) | * | ** | NS | NS |
| Nitrogen application (N) | NS | NS | NS | NS |
| c | NS | NS | NS | NS |

Note: control (CK): groundwater; PW: piggery wastewater; RW: reclaimed water; SW: saline water; H: 300 kg/ha nitrogen application; L: 200 kg/ha nitrogen application. Different letters indicate a significant level of 5% between the different treatments. * means $p < 0.05$; ** means $p < 0.01$; NS: no significant difference.

The results regarding the concentrations of lead (Pb) and cadmium (Cd) indicated that there was no significant difference in the three unconventional water treatments, compared with the control. Similarly, the results showed that the interaction between nitrogen application and water irrigation had no significant difference on soil Pb and Cd concentration (Table 6).

### *3.2. Cucumber Yield and Quality under Different Water Quality Irrigation*

#### 3.2.1. Cucumber Yield

Results on the effect of irrigation treatments on single fruit weight and yield are presented in Table 7. Data on single fruit weight indicated that no significant differences in SW treatments compared with the control. However, irrigating plant with wastewater, resulted in a percentage increase in single fruit weight in PWH, PWL, RWH, and RWL treatments (23.5%, 17.9%, 8.7%, and 9.2%, respectively), compared with the control. The highest increment occurred under PWH treatment, followed by PWL treatment (Table 7). Based on our results, it was concluded that the interaction between water quality and nitrogen application had no significant difference on single fruit weight.

**Table 7.** Effects of different irrigation treatments on weight per fruit and cucumber yield.

| Treatments | Single Fruit Weight (g) | Yield (kg/ha) |
|---|---|---|
| Control (CK) | 148.42 ± 2.84d | 88,613.87 ± 681.07e |
| CKWH | 163.93 ± 5.8b | 91,469.93 ± 303.26c |
| CKWL | 164.29 ± 5.04b | 90,234.93 ± 685.96d |
| PWH | 183.28 ± 4.64a | 104,157.83 ± 1154.73a |
| PWL | 174.97 ± 4.64a | 101,371.67 ± 394.61b |
| RWH | 161.40 ± 4.97bc | 88,960.07 ± 112.34e |
| RWL | 162.11 ± 5bc | 88,077.00 ± 535.61ef |
| SWH | 152.75 ± 3.52cd | 87,425.03 ± 728.32f |
| SWL | 150.66 ± 3.37d | 87,401.73 ± 361.16f |
| Water quality (WQ) | ** | ** |
| Nitrogen application (N) | NS | ** |
| WQ × N | NS | ** |

Note: control (CK): groundwater; PW: piggery wastewater; RW: reclaimed water; SW: saline water; H: 300 kg/ha nitrogen application; L: 200 kg/ha nitrogen application. Different letters indicate a significant level of 5% between the different treatments. ** means $p < 0.01$; NS: no significant difference.

Moreover, a marked difference in cucumber yield was recorded in PW treatment, which increased by 17.5% and 14.4%, respectively, compared to that of the control. Interestingly, the yield was significantly different between the two-level nitrogen application, indicating that the cucumber yield increased with increasing nitrogen application. However, data on the yield of cucumber indicated a slight decrease of 1.4% and 1.3%, respectively, in the SWL and SWH treatments, compared with the control. Additionally, there was no significant difference in cucumber yield under RW treatment. Treatments with wastewater irrigation significantly enhanced cucumber yield, compared with the control, and PWH treatment showed the most pronounced promoting effect. The ANOVA suggested that the interaction between water irrigation and nitrogen application had significant difference in the yield of cucumber ($p < 0.05$, Table 7).

#### 3.2.2. Cucumber Quality

The effects of different wastewater treatments on the quality indexes of cucumber are demonstrated in Table 8. Data regarding the content of vitamin C, soluble sugar, and nitrate in cucumber showed no significant changes in the RW and SW treatments, compared with the control. The highest content of titratable acidity (1.49 g/kg) was observed in the SW treatment, with a percentage increase of 18.2% ($p < 0.05$).

**Table 8.** Effects of different irrigation treatments on the quality of cucumber.

| Treatments | Vitamin C mg/kg | Soluble Sugar % | Titratable Acidity g/kg | Nitrate mg/kg | Protein mg/kg |
|---|---|---|---|---|---|
| Control (CK) | 106.96 ± 5.23bc | 3.48 ± 0.17bc | 1.26 ± 0.06c | 33.67 ± 0.29ab | 90.14 ± 3.67c |
| CKWH | 100.05 ± 10.75c | 3.79 ± 0.16ab | 1.36 ± 0.05bc | 33.33 ± 0.58ab | 96.61 ± 8.59c |
| CKWL | 108.55 ± 17.22c | 3.76 ± 0.26ab | 1.26 ± 0.1c | 33.33 ± 0.29ab | 102.9 ± 5.16bc |
| PWH | 153.18 ± 16.45a | 3.95 ± 0.01a | 1.39 ± 0.05ab | 33.67 ± 0.29ab | 128.49 ± 15.36a |
| PWL | 151.01 ± 0.32a | 3.83 ± 0.07ab | 1.41 ± 0.04ab | 34.00 ± 0.5ab | 109.1 ± 4.06bc |
| RWH | 120.99 ± 4.85b | 3.54 ± 0.21bc | 1.42 ± 0.05ab | 33.83 ± 1.26ab | 119.98 ± 12.43ab |
| RWL | 120.31 ± 7.69b | 3.42 ± 0.36bc | 1.35 ± 0.09bc | 34.00 ± 1.32ab | 91.7 ± 17.68c |
| SWH | 116.67 ± 0.58bc | 3.55 ± 0.1bc | 1.49 ± 0.03a | 34.5 ± 1ab | 95.5 ± 10.04c |
| SWL | 116.33 ± 4.16bc | 3.54 ± 0.23bc | 1.49 ± 0.07a | 32.67 ± 0.76b | 100.5 ± 6.06bc |
| Water quality (WQ) | ** | * | ** | NS | * |
| Nitrogen application (N) | NS | NS | NS | NS | NS |
| WQ × N | NS | NS | NS | NS | * |

Note: control (CK): groundwater; PW: piggery wastewater; RW: reclaimed water; SW: saline water; H: 300 kg/ha nitrogen application; L: 200 kg/ha nitrogen application. Different letters indicate a significant level of 5% between the different treatments. * means $p < 0.05$; ** means $p < 0.01$; NS: no significant difference.

The contents of vitamin C, soluble sugar, and protein in PWH treatment were significantly higher than that of the control, which increased by 43.2%, 13.4%, and 42.5%, respectively ($p < 0.05$). Results showed that quality of cucumber was significantly influenced by different wastewater irrigation, except for nitrate content. However, the interaction between water quality and nitrogen application only had a significant difference in protein content ($p < 0.05$, Table 8).

### *3.3. Correlation Analysis between Soil Properties and Yield and Quality of Cucumber*

Cucumber yields were positively correlated with OM, Vc, SS, protein, and soil total Zn concentration, but negatively correlated with soil pH value. Soil EC had a significant positive correlation with TA and soil total Cu concentration. There were dramatically positive correlations between the OM and Vc, SS, Cu, Zn, Pn, and Cd concentrations. The Vc content of cucumber had significantly positive correlations with protein, Cu, Zn, and Cd concentrations, while the nitrate content of vegetable had no significant correlation with the tested indexes in our experiment (Table 9).

**Table 9.** Correlation analysis between soil properties, cucumber yield, and quality.

| Index | EC | pH | OM | Vc | SS | TA | Nitrate | Protein | Cu | Zn | Pb | Cd | Yield |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EC | 1 | | | | | | | | | | | | |
| pH | 0.316 | 1 | | | | | | | | | | | |
| OM | 0.293 | −0.257 | 1 | | | | | | | | | | |
| Vc | 0.161 | −0.259 | 0.704 ** | 1 | | | | | | | | | |
| SS | −0.109 | −0.364 | 0.415 * | 0.313 | 1 | | | | | | | | |
| TA | 0.669 ** | 0.269 | 0.154 | 0.172 | 0.031 | 1 | | | | | | | |
| nitrate | −0.083 | 0.212 | −0.016 | 0.207 | −0.101 | 0.203 | 1 | | | | | | |
| protein | 0.026 | −0.091 | 0.335 | 0.594 ** | 0.302 | 0.287 | 0.043 | 1 | | | | | |
| Cu | 0.427 * | 0.054 | 0.607 ** | 0.428 * | 0.198 | 0.513 ** | 0.123 | 0.436 * | 1 | | | | |
| Zn | 0.355 | −0.057 | 0.686 ** | 0.518 ** | 0.433 * | 0.416 * | −0.022 | 0.476 * | 0.862 ** | 1 | | | |
| Pb | 0.301 | −0.234 | 0.491 ** | 0.281 | 0.027 | 0.115 | −0.075 | 0.084 | 0.121 | 0.026 | 1 | | |
| Cd | 0.227 | −0.056 | 0.560 ** | 0.627 ** | 0.099 | 0.144 | 0.189 | 0.247 | 0.161 | 0.245 | 0.27 | 1 | |
| yield | −0.084 | −0.525 ** | 0.697 ** | 0.794 ** | 0.624 ** | −0.007 | 0.065 | 0.585 ** | 0.307 | 0.495 ** | 0.257 | 0.319 | 1 |

Note: EC: electrical conductivity; OM: organic matter; Vc: vitamin C; SS: soluble sugar; TA: titratable acidity; * means $p < 0.05$; ** means $p < 0.01$.

## 4. Discussions

### *4.1. Irrigation with Different Wastewater on Soil Properties*

It is necessary to investigate the reuse of inferior water–soil–plant relationship because the maintenance of soil health and plant fertility is conducive to the rational construction of sustainable development [31]. Soil pH is an important attribute of saline-alkali, and directly reflect soil nutrient availability and crop growth [17,32]. Liu et al. [33] showed that livestock wastewater irrigation slightly decreased the soil pH, compared with the freshwater. Yang et al. [34] reported that the soil pH in saline water was slightly lower than that of the control. These results were consistent with the findings of this study, i.e., that piggery wastewater and saline water irrigation reduced the soil pH value, as compared with the control. The decrease may be related to the high organic or inorganic nitrogen in piggery wastewater, which promotes an intense nitrification reaction and releases a certain number of protons in the process [17,33]. This slight changes in soil pH could be attributed to the release of exchangeable cations during soil organic matter mineralization process [32,35].

Soil EC is an important indicator for judging soil acidification and secondary salinization [36,37]. The results of this study showed that soil EC was not significantly influenced by reclaimed water irrigation, which was consistent with Wang et al. [5]. However, Liu et al. [38] reported that EC value was greater than 16% in reclaimed water irrigation. A general increase in EC was noted in piggery wastewater irrigation in this study, this result was supported by the findings of Kiziloglu et al. [32], who found that cauliflower and red cabbage having high EC of the wastewater with the slaughterhouse effluent. The discrepancy in EC may be related to the nature of water sources, irrigation frequency, and irrigation amount. The previous study [5,17] showed that EC increased dramatically under saline water irrigation, which was also supported by our result, showed that the highest EC value was obtained in saline water treatment, increased by 20.9% than that of the control. The results in this experiment showed that organic matter significantly increased by 2.1~43.4% in unconventional water irrigation in the 0–20 cm soil layer, and the highest value was observed in piggery water treatment. The same results were obtained in a study by Lu et al. [39], who indicated that biogas slurry irrigation significantly increased the organic matter of rhizosphere soils. The results of this study suggest that piggery wastewater irrigation could be favorable to improve soil structure and aeration [40].

Although many studies have been conducted to examine the impacts of wastewater irrigation on soil heavy metals (such as Cd, Cu, Ni, Zn, Cr, Pb, etc.), there is no consensus on them [32,40,41]. In this study, there were no significant differences regarding the concentrations of the soil's total Pb and Cd under wastewater irrigation, while there were dramatically increased Cu and Zn concentrations. Similar results were supported by the findings of Liu et al. [33], who reported that reclaimed water and piggery wastewater significantly increased Cu and Zn content, with no marked changes in Pb and Cd concentrations in the North China Plain. Huang et al. [41,42] also found that piggery wastewater irrigation caused a notable increase in Cu and Zn contents. The possible reason for this phenomenon may be related to the high Cu and Zn concentrations in the treatments. Though higher concentrations of Cu and Zn were observed in wastewater irrigation, the concentrations of them still within the permissible limits of the Soil Pollution Risk Control Standard for Soil Environmental Quality and Agricultural Land [43].

### *4.2. Irrigation with Different Water Quality on Cucumber Yield and Quality*

Health soil physicochemical properties and nutritional status can produce crop yield and quality [32,44–46]. In the present study, the single fruit weight of cucumber under piggery wastewater and reclaimed water irrigation was significantly increased by 8.7~23.5%. Wu et al. [47] found that cucumber yield in reclaimed water treatment was 24% higher than that of freshwater, while there was no significant change in our study. The study also showed that a higher cucumber yield was observed in piggery wastewater treatment than in the control, which increased by 17.5% and 14.4%, respectively, indicating that yield increased with the increasing nitrogen application in the tested area. In addition, piggery wastewater treatment had the highest value of cucumber yield in this experiment, as a result of the complex factors in the soil. Our results were consistent with the findings of Kiziloglu et al. [32], who found that wastewater irrigation positively affected cauliflower and cabbage yield. Piggery wastewater has an abundance of mineral elements and organic matter, and these characteristics of biogas slurry may enhance crop yield [40,48]. Furthermore, the correlation analysis showed that cucumber yield was significantly correlated with soil organic matter (Table 9), thus indicating that organic matter plays a positive role in increasing vegetable yield. This study found piggery wastewater led to a slight increase in the contents of Vc, soluble sugar, and protein, compared with the control, but there was only significant difference in the protein content in reclaimed water treatment.

Saline water irrigation has been reported to play a negative role in plant growth and crop yield with high salinity [49,50]. In this study, no significant change was recorded in single fruit weight in saline water treatment, but cucumber yield was 1.4% lower than that of the control. The result was consistent with Huang et al. [23], who found that saline water irrigation reduced melon yield in northwest China. Mugwanya et al. [21] also reported that cucumber growth and yield was significantly decreased by saline water irrigation. The reason for a slight decrease in yield may be due to the highest value of soil EC (770 μS/cm), which was observed in saline water treatment, and high salt concentration may cause the disturbance of several physicochemical and physiological attributes, including soil bulk density, water uptake, nutritional disorder, and photosynthetic capacity, etc. [51–54]. This study only found that the content of titratable acidity was significantly influenced by saline water treatment. Unconventional water irrigation was still limited by various objective or subjective factors, such as the nature of water, irrigation amount and frequency, soil texture, crop, and other uncertainties [55–57]. Therefore, it is necessary to conduct in-depth research on promoting the advantages of unconventional water. The above-mentioned results indicated that piggery wastewater had the most positive effect on vegetable yield and quality in this study.

## 5. Conclusions

Three unconventional water irrigation types affect the soil properties, cucumber yield, and quality, apparently differently, in this study. Therefore, the characteristics of wastewater, soil, and crops should be considered in managing wastewater irrigation. Compared with groundwater irrigation, piggery wastewater and saline water irrigation decreased the soil pH but significantly increased the soil EC; the highest soil EC was observed in saline water. The results of wastewater irrigation indicated no significant changes in soil Pb and Cd concentrations, but remarkably increased in soil organic matter, Cu, and Zn concentrations, but the concentrations of Cu and Zn were far lower than the standard limit, indicating that short-term irrigation would not cause the accumulation of heavy metals pollution in soil.

Saline water irrigation resulted in a percentage decrease in cucumber yield. Piggery wastewater irrigation not only significantly improved the yield of cucumber, but also increased the content of Vc, soluble sugar, and protein. In this study, piggery wastewater was superior to all the other irrigation and had the highest cucumber yield. Considering the economic and environmental benefits, piggery wastewater irrigation combined with 300 kg/ha nitrogen was the optimal mode for this region. Further experimental research is needed.

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## References

1. Hashem, M.S.; Qi, X. Treated Wastewater Irrigation—A Review. *Water* **2021**, *13*, 1527. [CrossRef]
2. Xiao, Y.; Shao, J.; Cui, Y.; Zhang, G.; Zhang, Q. Groundwater circulation and hydrogeochemical evolution in Nomhon of Qaidam Basin, northwest China. *J. Earth Syst. Sci.* **2017**, *126*, 26. [CrossRef]
3. Hussain, M.I.; Muscolo, A.; Farooq, M.; Ahmad, W. Sustainable use and management of non-conventional water resources for rehabilitation of marginal lands in arid and semiarid environments. *Agric. Water Manag.* **2019**, *221*, 462–476. [CrossRef]
4. Zhang, X.; Qin, W.; Chen, S.; Shao, L.; Sun, H. Responses of yield and WUE of winter wheat to water stress during the past three decades—A case study in the North China Plain. *Agric. Water Manag.* **2017**, *179*, 47–54. [CrossRef]
5. Wang, G.; Du, Z.; Ning, H.; Liu, H.; Abubakar, S.A.; Gao, Y. Changes in GHG Emissions Based on Irrigation Water Quality in Short-Term Incubated Agricultural Soil of the North China Plain. *Agriculture* **2021**, *11*, 1268. [CrossRef]
6. Xu, M.; Bai, X.; Pei, L.; Pan, H. A research on application of water treatment technology for reclaimed water irrigation. *Int. J. Hydrogen Energy* **2016**, *41*, 15930–15937. [CrossRef]
7. Lu, S.; Wang, J.; Pei, L. Study on the Effects of Irrigation with Reclaimed Water on the Content and Distribution of Heavy Metals in Soil. *Int. J. Environ. Res. Public Health* **2016**, *13*, 298. [CrossRef]
8. Lu, S.; Xie, F.; Zhang, X.; Pei, L.; Tang, Y. Health evaluation on migration and distribution of heavy metal Cd after reclaimed water drip irrigation. *Environ. Geochem. Health* **2020**, *42*, 841–848. [CrossRef]
9. Liu, M.; Yang, J.; Li, X.; Yu, M.; Wang, J. Effects of irrigation water quality and drip tape arrangement on soil salinity, soil moisture distribution, and cotton yield (*Gossypium hirsutum* L.) under mulched drip irrigation in Xinjiang, China. *J. Integr. Agric.* **2012**, *11*, 502–511. [CrossRef]
10. Wu, W.; Hu, Y.; Guan, X.; Xu, L. Advances in research of reclaimed water irrigation in China. *Irrig. Drain.* **2020**, *11*, 119–126. [CrossRef]
11. Wang, Z.; Li, J.; Li, Y. Using reclaimed water for agricultural and landscape irrigation in China: A review. *Irrig. Drain.* **2017**, *66*, 672–686. [CrossRef]
12. Gwenzi, W.; Munondo, R. Long-Term impacts of pasture irrigation with treated sewage effluent on nutrient status of a sandy soil in Zimbabwe. *Nutr. Cycl. Agroecosyst.* **2008**, *82*, 197–207. [CrossRef]
13. Mohammad Rusan, M.J.; Hinnawi, S.; Rousan, L. Long term effect of waste water irrigation of forage crops on soil and plant quality parameters. *Nutr. Cycl. Agroecosyst.* **2007**, *215*, 143–152. [CrossRef]

14. Maestre-Valero, J.F.; Gonzalez-Ortega, M.J.; Martinez-Alvarez, V.; Gallego-Elvira, B.; Conesa-Jodar, F.J.; Martin-Gorriz, B.J.A.W.M. Revaluing the nutrition potential of reclaimed water for irrigation in southeastern Spain. *Agric. Water Manag.* **2019**, *218*, 174–181. [CrossRef]
15. Lu, S.; Zhang, X.; Liang, P. Influence of drip irrigation by reclaimed water on the dynamic change of the nitrogen element in soil and tomato yield and quality. *J. Clean. Prod.* **2016**, *139*, 561–566. [CrossRef]
16. Xu, Y.; Wei, Y.; Sun, Y.; Qin, X.; Zhou, Q.; Dai, X.; Lin, D. Effect of irrigation on growth and development and quality of Chinese cabbage. *J. Irrig. Drain.* **2008**, *27*, 1–4.
17. Liu, C.; Cui, B.; Zeleke, K.T.; Hu, C.; Wu, H.; Cui, E.; Huang, P.; Gao, F. Risk of secondary soil salinization under mixed irrigation using brackish water and reclaimed Water. *Agronomy* **2021**, *11*, 2039. [CrossRef]
18. Ding, H.; Ahmad, A.; Cheng, Z. Effect of green garlic/cucumber crop rotation for 3 years on the dynamics of soil properties and cucumber yield in Chinese anthrosol. *J. Sci. Food Agric.* **2020**, *100*, 362–370. [CrossRef]
19. Basile, A.; Buttafuoco, G.; Mele, G.; Tedeschi, A. Complementary techniques to assess physical properties of a fine soil irrigated with saline water. *Environ. Earth Sci.* **2012**, *66*, 1797–1807. [CrossRef]
20. Murtaza, G.; Ghafoor, A.; Qadir, M. Irrigation and soil management strategies for using saline-sodic water in a cotton-wheat rotation. *Agric. Water Manag.* **2006**, *81*, 98–114. [CrossRef]
21. Mugwanya, M.; Kimera, F.; Dawood, M.; Sewilam, H. Elucidating the effects of combined treatments of salicylic acid and L-proline on greenhouse-grown cucumber under saline drip irrigation. *J. Plant Growth Regul.* **2022**, 1–17. [CrossRef]
22. Wang, Q.; Huo, Z.; Zhang, L.; Wang, J.; Zhao, Y. Impact of saline water irrigation on water use efficiency and soil salt accumulation for spring maize in arid regions of China. *Agric. Water Manag.* **2016**, *163*, 125–138. [CrossRef]
23. Huang, C.; Zong, L.; Buonanno, M.; Xue, X.; Wang, T.; Tedeschi, A. Impact of saline water irrigation on yield and quality of melon (Cucumis melo cv. Huanghemi) in northwest China. *Eur. J. Agron.* **2012**, *43*, 68–76. [CrossRef]
24. Lopez-Galvez, F.; Gil, M.I.; Pedrero-Salcedo, F.; Alarcón, J.; Allende, A. Monitoring generic Escherichia coli in reclaimed and surface water used in hydroponically cultivated greenhouse peppers and the influence of fertilizer solutions. *Food Control.* **2016**, *67*, 90–95. [CrossRef]
25. Paranychianakis, N.V.; Nikolantonakis, M.; Spanakis, Y.; Angelakis, A.N. The effect of recycled water on the nutrient status of Soultanina grapevines grafted on different rootstocontrols. *Agric. Water Manag.* **2006**, *81*, 185–198. [CrossRef]
26. Angelakis, A.N.; Bontoux, L. Wastewater reclamation and reuse in Eureau countries. *Water Policy* **2001**, *3*, 47–59. [CrossRef]
27. Lubello, C.; Gori, R.; Nicese, F.P.; Ferrini, F. Municipal-treated wastewater reuse for plant nurseries irrigation. *Water Res.* **2004**, *38*, 2939–2947. [CrossRef] [PubMed]
28. Lu, R. *Analysis Methods of Soil and Agricultural Chemistry*; China Agricultural Science and Technology Press: Beijing, China, 2000.
29. Wu, S.; Zhang, Y.; Tan, Q.; Sun, X.; Wei, W.; Hu, C. Biochar is superior to lime in improving acidic soil properties and fruit quality of Satsuma mandarin. *Sci. Total Environ.* **2020**, *714*, 136722. [CrossRef]
30. Li, X.; Zhang, L. *Experimental Guidance on Plant Physiology*, 5th ed.; Higher Education Press: Beijing, China, 2016.
31. Mohammad, M.J.; Mazahreh, N. Changes in soil fertility parameters in response to irrigation of forage crops with secondary treated wastewater. *Commun. Soil Sci. Plant Anal.* **2003**, *34*, 1281–1294. [CrossRef]
32. Kiziloglu, F.M.; Turan, M.; Sahin, U.; Kuslu, Y.; Dursun, A. Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (*Brassica olerecea* L. var. botrytis) and red cabbage (*Brassica olerecea* L. var. rubra) grown on calcareous soil in Turkey. *Agric. Water Manag.* **2008**, *95*, 716–724. [CrossRef]
33. Liu, Y.; Cui, E.; Li, Z.; Du, Z.; Gao, F.; Fan, X. Differences of nutrient and heavy metals migration on soil-plant system irrigated by reclaimed water and livestock wastewater. *J. Irrig. Drain.* **2018**, *37*, 45–51. (In Chinese with English abstract) [CrossRef]
34. Yang, J.; Shao, Y.; Gao, W.; Ren, S. Effects of saline water irrigation on soil salinity and crop yield. *Bull. Soil Water Conserv.* **2013**, *33*, 17–20. (In Chinese with English abstract) [CrossRef]
35. Tedeschi, A.; Dell'Aquila, R. Effects of irrigation with saline waters, at different concentrations, on soil physical and chemical characteristics. *Agric. Water Manag.* **2005**, *77*, 308–322. [CrossRef]
36. Oubane, M.; Khadra, A.; Ezzariai, A.; Kouisni, L.; Hafidi, M. Heavy metal accumulation and genotoxic effect of long-term wastewater irrigated peri-urban agricultural soils in semiarid climate. *Agric. Water Manag.* **2021**, *794*, 148611. [CrossRef]
37. Katerji, N.; van Hoorn, J.W.; Hamdy, A.; Mastrorilli, M. Salinity effect on crop development and yield, analysis of salt tolerance according to several classification methods. *Agric. Water Manag.* **2003**, *62*, 37–66. [CrossRef]
38. Liu, Y.; Cui, E.; Li, Z.; Du, Z.; Gao, F.; Fan, X. Effects of irrigating biochar-and pectin-amended soil with treated municipal wastewater and swine wastewater on soil salinity and sodicity. *J. Irrig. Drain.* **2018**, *37*, 16–23. (In Chinese with English abstract) [CrossRef]
39. You, L.; Yu, S.; Liu, H.; Wang, C.; Zhou, Z.; Zhang, L.; Hu, D. Effects of biogas slurry fertilization on fruit economic traits and soil nutrients of Camellia oleifera Abel. *PLoS ONE* **2019**, *14*, e0208289. [CrossRef]
40. Qiang, X.; Sun, J.; Ning, H. Impact of subsoiling on cultivated horizon construction and grain yield of winter wheat in the North China Plain. *Agriculture* **2022**, *12*, 236. [CrossRef]
41. Rattan, R.K.; Datta, S.P.; Chhonkar, P.K.; Suribabu, K.; Singh, A.K. Environment. Long-Term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater—A case study. *Agric. Ecosyst. Environ.* **2005**, *109*, 310–322. [CrossRef]

42. Huang, Z.; Xu, B.; Tu, D.; Zhang, K. Spatial variability and affecting factors of Pb, Cd and As in farmland soils irrigated by swine wastewater. *Trans. CSAE* **2008**, *24*, 77–83. (In Chinese with English abstract)
43. Huang, Z.; Zhang, K.; Xu, B.; Li, X. Heavy metal pollution and risk assessment of swine wastewater irrigation. *Environ. Sci. Technol.* **2008**, *31*, 132–137. (In Chinese with English abstract) [CrossRef]
44. Wei, Y.; Xu, Y.; Zhou, Q.; Qin, X.; Sun, Y.; Dai, X.; Lin, D. Effects of irrigation with reclaimed water on soil salinize-alkalization and heavy metal distribution. *J. Irrig. Drain.* **2008**, *27*, 5–8. (In Chinese with English abstract) [CrossRef]
45. Ayoub, S.; Al-Shdiefat, S.; Rawashdeh, H.; Bashabsheh, I. Utilization of reclaimed wastewater for olive irrigation: Effect on soil properties, tree growth, yield and oil content. *Agric. Water Manag.* **2016**, *176*, 163–169. [CrossRef]
46. Jung, K.; Jang, T.; Jeong, H.; Park, S. Assessment of growth and yield components of rice irrigated with reclaimed wastewater. *Agric. Water Manag.* **2014**, *138*, 17–25. [CrossRef]
47. Cabello, M.J.; Castellanos, M.T.; Romojaro, F. Yield and quality of melon grown under different irrigation and nitrogen rates. *Agric. Water Manag.* **2009**, *96*, 866–874. [CrossRef]
48. Wu, W.; Xu, C.; Liu, H.; Hao, Z.; Ma, F.; Ma, Z. Effect of reclaimed water irrigation on yield and quality of fruity vegetables. *Trans. CSAE* **2010**, *26*, 36–40. (In Chinese with English abstract)
49. Guan, T.; Ma, G.; Ma, Z.; Liu, Z.; Zhang, F.; Zhang, Y.; Deng, J.; Ma, X.; Han, Y. Effects of continuous application of chicontrolen manure on field-grown cucumber yield, quality, and soil properties. *J. Plant Nutr. Fertil.* **2021**, *27*, 1260–1351. (In Chinese with English abstract)
50. Yildirim, E.; Turan, M.; Guvenc, I. Effect of foliar salicylic acid applications on growth, chlorophyll, and mineral content of cucumber grown under salt stress. *J. Plant Nutr.* **2008**, *31*, 593–612. [CrossRef]
51. Shrivastava, P.; Kumar, R. Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. *Saudi J. Biol. Sci.* **2015**, *22*, 123–131. [CrossRef]
52. Chen, W.; Wang, Z.; Jin, M.; Ferré, T.; Wang, J.; Huang, J.; Wang, X. Effect of sodium chloride and manganese in irrigation water on cotton growth. *Agron. J.* **2018**, *110*, 900–909. [CrossRef]
53. Huang, J.; Jin, M.; Kuo, Y.M.; Di, Z.; Xian, Y.; Yuan, J. Compartment model for estimating element content in a water–soil–cotton system. *Agron. J.* **2015**, *108*, 129–140. [CrossRef]
54. Kurunc, A. Effects of water and salinity stresses on growth, yield, and water use of iceberg lettuce. *J. Sci. Food Agric.* **2021**, *101*, 5688–5696. [CrossRef] [PubMed]
55. Adewumi, J.R.; Ilemobade, A.A.; van Zyl, J.E. Treated wastewater reuse in South Africa: Overview, potential and challenges. *Resour. Conserv. Recycl.* **2011**, *55*, 221–231. [CrossRef]
56. Libutti, A.; Gatta, G.; Gagliardi, A.; Vergine, P.; Pollice, A.; Beneduce, L.; Disciglio, G.; Tarantino, E. Agro-Industrial wastewater reuse for irrigation of a vegetable crop succession under Mediterranean conditions. *Agric. Water Manag.* **2018**, *196*, 1–14. [CrossRef]
57. Hajjami, K.; Ennaji, M.M.; Fouad, S.; Oubrim, N.; Cohen, N. Assessment of helminths health risk associated with reuse of raw and treated wastewater of the Settat city (Morocco). *Resour. Environ.* **2012**, *2*, 193–201. [CrossRef]