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Organic Fertilizer Application and Saline Water Irrigation in Semi-Arid Region: Effect on Onion (*Allium cepa* L.) Crops Production

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Abstract

In arid and semiarid regions such as Niger, irrigated agriculture leads to soil salinization, particularly through irrigation water salts, and has adverse effects on crop production such as vegetable crops including onion. The main objective of this study, conducted in the experimental site of Djibo Hamani University of Tahoua in Niger, was to evaluate the effects of organic fertilizer on the growth and yield of onion crops irrigated with saline water. The experiment was performed in split-plot design to test tree type of fertilizer (chemical fertilizer, compost and millet glumes) and four (04) levels of irrigation water salinity in electrical conductivity values (ECw) (S0 = 0.28 dS/m as control, S1 = 2 dS/m, S2 = 4 dS/m and S3 = 6 dS/m). The growth parameters and bulb yield were evaluated during 4 months of onion cropping season. The results showed that the use of irrigation saline water significantly decreased the growth and bulb yield of onion crops. The yield in onion bulbs is 1.55 to 3.94 times higher with control (0.28 dS/m) than that with high saline water (ECw = 6 dS/m). Compared to control in irrigation water, the reduction in fresh onion bulb yield was 38.8, 52.6 and 63.5% respectively for ECw of 2, 4 and 6 dS/m. Furthermore, the application of organic fertilizers, particularly compost, improves salt-tolerance of onion crops in order to promote growth and bulb yield. Indeed, when irrigating onion crops with saline water (ECw of 2, 4 and 6 dS/m), the onion bulb yield is significantly higher under compost than under chemical fertilizer and glumes. At high irrigation saline water (ECw = 6 dS/m), the yield in onion bulbs is 1.9 and 2.1 times higher under compost than that under chemical fertilizer and glumes respectively. Thus, the compost is the promising organic amendment in a semiarid region of Tahoua in Niger to reduce the adverse effects of irrigation saline water on onion crop production.

Keywords

Irrigation, Saline Water, Soil Salinization, Organic Amendment, Onion Crops

1. Introduction

Irrigated agriculture, crucial to food production particularly in arid and semiarid regions, provides about 40% of the global crop production [1] [2]. It has a substantial impact on global water resources, and currently about 70% of humanity's demand for fresh water originates from irrigation [3] [4]. In Sub-Saharan Africa, there are varied water endowments where 40 million hectares of land are suitable for irrigation and irrigation development represents the most important interface between water and land resources [4] [5].

Despite its successes, the practice of irrigated agriculture can cause several problems to arise when misused, such as soil salinization. This occurs due to the presence of dissolved salts in the irrigation water that, even at low concentrations, can be absorbed into the soil, making it saline within a few years [6]. The salts are added to the soil with saline water irrigation; therefore, it may lead to soil salinization and crop yields reduction [7] [8]. The use of saline water resources for crop production can pose serious threats to agricultural productivity and food security by increasing salt buildup in the root zone if used inappropriately [8] [9]. Moreover, the use of saline irrigation water has an adverse effect on soil-water-plant relations, occasionally severely restricting the normal physiological activity and productive capacity of the crops [10].

Salinity is one of the major issues leading to irrigated land degradation and it's a serious threat limiting plant growth and crop productivity in many areas especially in arid and semi-arid regions [8] [11]. Globally, saline soils cover approximately 954.8 Mha of land worldwide and are distributed across almost every continent [11] [12]. Each year around 1.5 million hectares of irrigated land, i.e., 800 million hectares worldwide, including 40 million hectares in West Africa [13]-[15], are affected by soil salinization [16] causing a decrease of 10% in global food production [17] [18]. It is expected that by the year 2050, 50% of the cultivated land will be affected by severe salinization [12] [19]. The process of soil salinization, particularly due to anthropic activities, is accelerated especially in arid and semi-arid zones, because of excessive evaporation, restricted drainage and low precipitation to leach soluble salts into soil deep layers [20]-[22].

Vegetable crops are strategic commodities both to improve food security and also to reduce food product imports [23]. The onion (*Allium cepa* L.) is the second most cultivated vegetable crop in the world after the tomato. Green onion is not only an economically significant vegetable crop but also most important in human nutrition and annually produced 38 993 tons from 8739.3 ha of cultivated land [8]. In Niger, onion is the first cultivated vegetable crop with an annual production estimated at 1,212,279.39 tons, generating an income of around 47 billion FCFA [24] [25]. In the Tahoua region of Niger, onion production, which is generally practiced in valleys and/or lowlands by irrigation systems, is a very important activity of small producers, particularly during the dry season. In this region, onion production is estimated at 788,206 tons per year with an average yield of 38 tons/ha, which is 65% of national production [25]. According to local producers, irrigation water, often loaded with salts, is one of the sources of soil salinization and which has adverse effects on vegetable crop production, particularly onion crops [26]. According to the United States Department of Agriculture (USDA), onions are the most sensitive to salinity compared to other vegetable crops. Reference [27] reported that the irrigation water salinity has a significant impact on the number of bulbs per unit area, size, and fresh weight of onion bulbs. It influences the bulbing and quality of harvested bulbs. Also, salinity at various growth stages of onion affects the fresh weight of bulbs at harvest.

Several approaches have been developed to soil salinity reclamation [28] including the physical and hydraulic approach using leaching or ponding techniques [29]-[31], the chemical approach using gypsum amendment [32] [33] and the biological approach i.e., the phytodesalinization using salt-tolerant plants or halophytes [34] [35] or organic amendments such as crop residues, mulch, manure or compost [36] [37]. Reference [37] showed that the application of green waste compost on saline sandy loam soil reduced EC and ESP by 87 and 71%, respectively, and increased organic carbon content by 96% in the 0 - 25 cm soil layer.

In the Tahoua region, the organic amendment techniques were increasingly observed under vegetable crop producers by application of manure, compost or glumes in salt-affected fields [26].

The main objectives of the present study were to i) evaluate the effects of irrigation water salinity on the growth and yield of onion crops and ii) assess the effects of organic fertilizer application on the agronomic performance of onion crops irrigated with saline water.

2. Material and Method

2.1. Study Site

The study was conducted in an experimental site of the Agricultural Sciences Faculty of Djibo Hamani University of Tahoua (14˚51'13,90" N; 05˚16'15,10" E) located in commune 1 of Tahoua city at 2 km of southwest of University (**Figure 1**). The climate in the area is Sahelian type characterized by two main seasons: i) a rainy season during 4 months (June to October) and a dry season in 8 months (October to May). The average annual rainfall is 200 - 300 mm for 4 months (June-October) and the average temperature is 34˚C in April-May and 20˚C in December-January. The soil in the study site is a fluvisol with a sandy loam texture, low content of organic matter (<1%), total phosphorus (34.48 ppm) and assimilable phosphorus (14.9 ppm). Furthermore, the soil is moderately acidic (pH = 5.4) and a very low salinity with an electrical conductivity in saturated paste (ECe) of 0.68 dS/m [38].

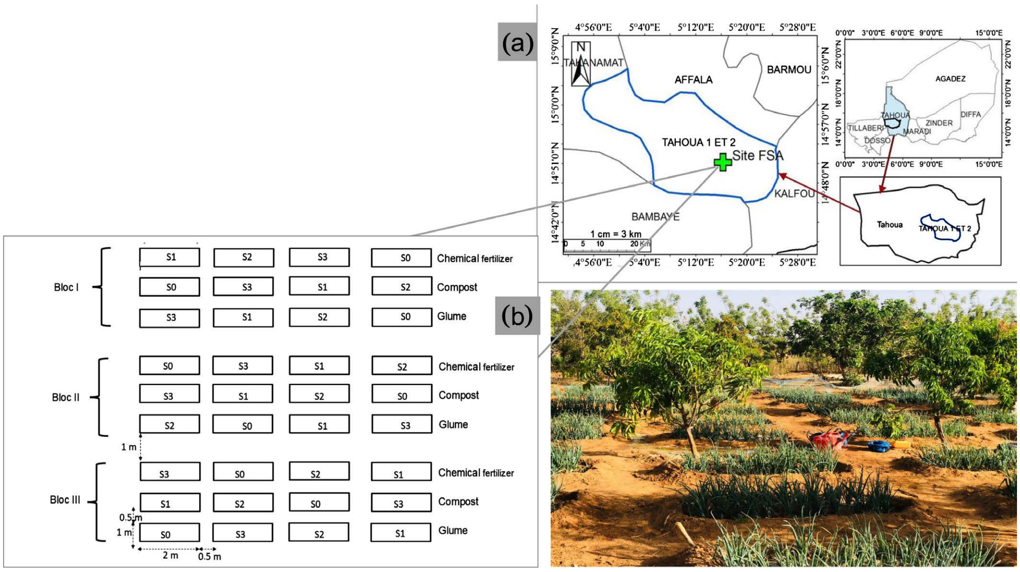

Figure 1. Location of study site (a) and schematic of experimental design (b). S0, S1, S2 and S3 are irrigation water with ECw of 0.28 (control), 2, 4 and 6 dS/m respectively.

2.2. Plant Material

The plant material is onion crops (*Allium cepa* L) of Galmi violet cultivar which is widely used by producers in Tahoua region of Niger. This cultivar has 160 - 170 days of growing cycle and 50 - 55 t/ha of potential yield in fresh bulbs [39]. The onion seeds used in this experiment were collected at the Regional Center of Agronomic Research of Tahoua.

2.3. Experiment Design

The experiment design is split-plot in trees (03) replications composed to fertilizer type with three (03) modalities (Chemical fertilizer, Compost and millet glumes) and salinity levels of irrigation water in four (04) levels of electrical conductivity values (ECw) (S0 = control in drilling water with ECw of 0.28 dS/m, S1 = salinized irrigation water at ECw of 2 dS/m, S2 = salinized irrigation water at ECw of 4 dS/m and S3 = salinized irrigation water at ECw of 6 dS/m). Thus, the experiment design is constituted of 12 treatments installed in elementary plots of 1 m × 2 m (Figure 1).

The compost and glumes were applied in concerned treatments 10 and 45 days after plantation in doses of 3 kg/m^2 respectively after irrigation as practiced by local farmers. However, an additional 5 g/m^2 of NPK (15-15-15) was added at the first application in glume treatment plots. The irrigation saline water of S1, S2 and S3 were obtained by adding NaCl salts in drilling water (S0) at 9, 19 and 30 g/l respectively at each irrigation. The experiment was performed during 4 months (February to May 2024) for one onion cropping season.

2.4. Soil Sampling and Soil Salinity Control

Soil samples were taken with the auger at the beginning and at the end of the experiment in 0 - 30 cm soil layer. One composite soil sample was collected per plot at each date.

Soil electrical conductivity on 1/5 of Soil: water extract ($EC_{1/5}$) was measured in each soil sample according to ISO standard 11265 [40]. At each date, soil electrical conductivity measured on saturated paste (ECe, dS/m) was estimated by:

$$Ece = EC1/5 \times 13.8 \quad (1)$$

With 13.8 the conversion factor of sandy loam soil [41].

2.5. Crops Production and Agronomic Data Collection

The onion plants were previously grown in the nursery for 45 days in plots of 3 m^2 at the study site. After this nursery phase, onion plants were transplanted in the plots according to 15 cm × 15 cm spacing.

The chemical fertilizer NPK (15-15-15) was applied according to a dose of 15 g/m^2 respectively 10 and 45 days after plantation. The irrigation was regular 5 days after plantation by supplying water, uniformly in the plots, 2 to 3 times per week (according to soil moisture) at a dose of 20 mm per plot. The irrigation water was salinized according to S1, S2 and S3 treatment by adding corresponding NaCl salts at each irrigation date. The weeds in the plots were controlled manually.

The growth parameters of onion plants were observed and measured weekly in each plot i.e., the leaves number, the plant height and the stem diameter at the collar. The harvest was performed after bulb maturity by systematic uprooting of plants including aboveground biomass and bulbs in each plot. Thus, the yields in fresh biomass and bulbs were evaluated in each plot.

2.6. Statistic Data Analysis

The analysis of variance ANOVA in two-way was performed on agronomic parameters and soil properties i.e., soil salinity using XLSTAT software, version 2016 to evaluate the influence of type of fertilizer and irrigation water salinity levels on growth and yields of onion crops. When a significant difference exists between the treatments, the ANOVA is completed by comparing means according to Fisher test in the 5% threshold.

3. Results

3.1. Changes in Soil Electrical Conductivity

Soil electrical conductivity (ECe) at the initial state (Initial) and at the end of the experiment (Final) according to irrigation water salinity levels (ECw) (**Figure 2**).

At the initial state, the ECe is almost uniform between the plots and varies from 0.34 to 0.38 dS/m. The difference between the plots is not significant on ECe, thus showing the homogeneity of the experiment site in soil salinity.

However, at the end of the experiment, ECe varies significantly between irrigated plots with different water salinity levels. Indeed, the ECe increases significantly with the irrigation water salinity level (ECw). At the end of the experiment, the ECe is 11.9 times higher under S3 (5.32 dS/m) than that under S0 (0.45 dS/m).

Furthermore, ECe is significantly higher at the end of the experiment than at the initial state in all plots except in plots irrigated with raw drilling water (S0). Indeed, the ECe is 8.4, 9.3 and 14.9 times higher at the end of the experiment than that at the initial state under S1, S2 and S3 respectively.

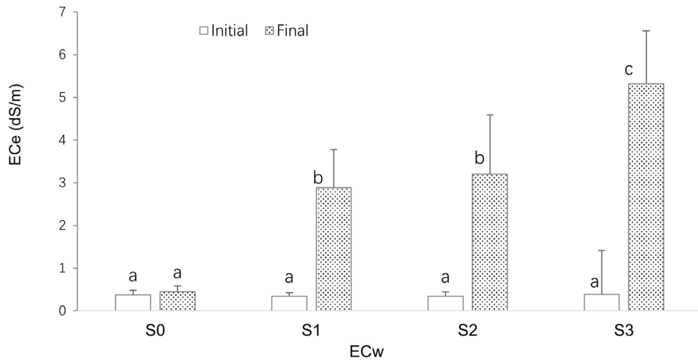

Figure 2. Variations in soil electrical conductivity (ECe) at the initial state (Initial) and at the end of the experiment (Final) according to salinity levels of irrigation water (ECw). *S0, S1, S2 and S3 are irrigation water with ECw of* 0.28 (*control*), 2, 4 *and 6 dS/m respectively. The bars represent the means standard deviations. The histograms assigned by the same letter are not statistically different according to LSD test with* 5% *threshold.*

Considering the type of fertilizer, ECe tends to be lower under compost than under chemical fertilizer and glumes at the end of the experiment, particularly with irrigation saline water (**Table 1**). With high irrigation water salinity levels (S2 and S3), ECe is significantly higher under chemical fertilizers and glumes than under compost. With S3 (ECw = 6 dS/m), ECe is significantly higher under chemical fertilizer (6.45 dS/m) than under the compost and glumes (4.55 and 4.96 dS/m respectively) at the end of the experiment.

Table 1. Changes in electrical conductivity (ECe) at the initial state (Initial) and at the end of the experiment (Final) according to irrigation water salinity levels (ECw) and type of fertilizer. S0, S1, S2 and S3 are irrigation water with ECw of 0.28 (control), 2, 4 and 6 dS/m respectively.

Date	Fertilizer/ECw	S0	S1	S2	S3	ANOVA
Initial	Compost	0.45 a	0.42 a	0.39 a	0.41 a	Pr = 0.625, not significant
	Chemical fertilizer	0.38 a	0.32 a	0.33 a	0.31 a	
	Glume	0.30 a	0.30 a	0.31 a	0.32 a	
Final	Compost	0.43 a	2.99 bcd	2.25 b	4.55 de	Pr < 0.0001, significant
	Chemical fertilizer	0.48 a	2.74 bc	3.97 cde	6.45 f	
	Glume	0.43 a	2.92 bcd	3.37 bcde	4.96 ef	

The means assigned with the same letter at the same date are not statistically different according to LSD test with 5% threshold.

3.2. Temporal Evolution of Onion Crop Growth

Figure 3 shows the temporal evolution of plant height and stem diameter of onion crops under different types of fertilizer and irrigation water salinity levels (ECw).

Globally, onion plants grow over time (Day After Plantation) under all fertilizers and regardless of salinity level of irrigation water. The plants' height is between 15 and 53 cm while the stem diameter of onion plants is 2 to 18 mm. The onion growth in plant height and stem diameter decreases with the salinity level of irrigation water under all fertilizers. Indeed, the onion plants are greater with low ECw (S0 and S1) than with high ECw (S2 and S3), especially with advanced plant age (from 70 Days After Plantation). The plant height and stem diameter are 1.3 to 2 times higher with non-saline irrigation water (S0) than with saline irrigation water (S1, S2 and S3) especially at the end of the experiment.

Furthermore, with control irrigation water (S0), the growth of onion plants is relatively higher under chemical fertilizer than under compost and glumes while the trend is the opposite considering irrigation saline water (S1, S2 and S3). The onion plants appear to be longer and bigger under compost application than under chemical fertilizer and glumes with highly irrigation saline water with advanced plant age (from 70 Days After Plantation). Thus, compost fertilizer appears to improve the salt-tolerance of onion crops irrigated with saline water.

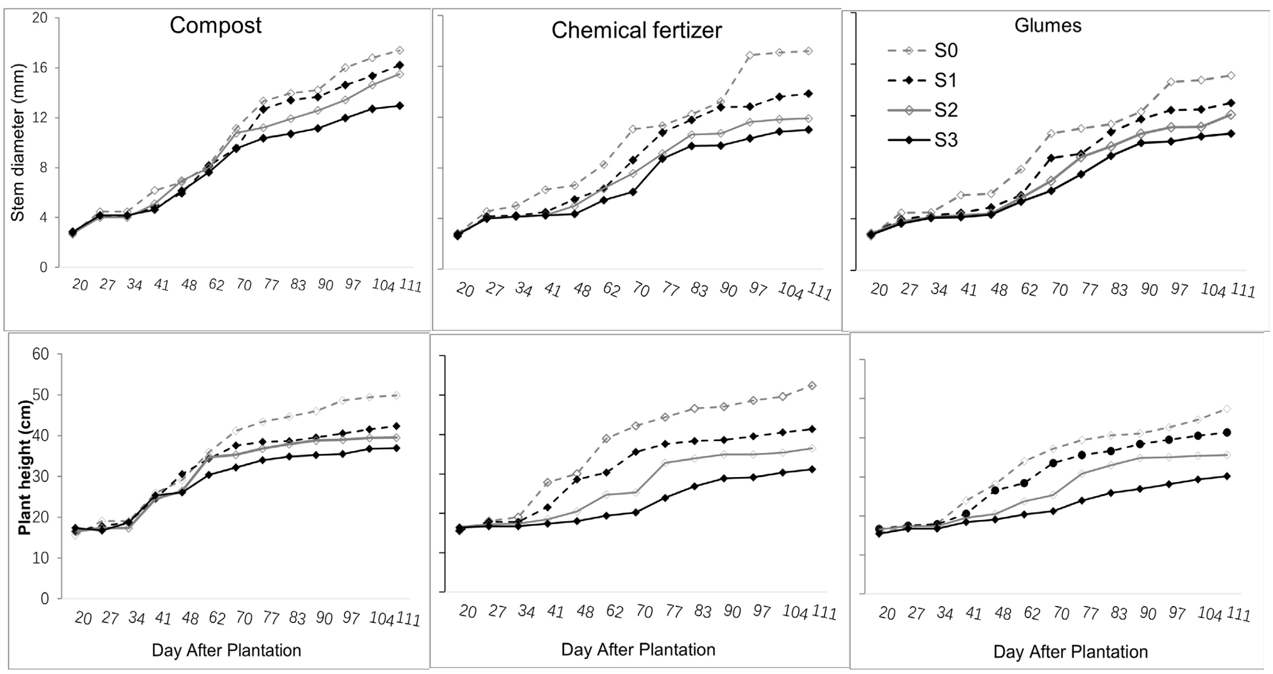

Figure 3. Temporal dynamic of height and stems diameter of onion crops under type of fertilizer according to salinity levels of irrigation water. *S0, S1, S2 and S3 are irrigation water with ECw of* 0.28 (*control*), 2, 4 *and* 6 *dS/m respectively*.

3.3. Changes in Size and Weight of Onion Bulbs

The size (height and diameter) and average weight of onion bulbs vary according to a type of fertilizer and salinity levels of irrigation water (Table 2, Table 3). Globally, the size and average weight of onion bulbs decreased significantly with the salinity level of irrigation water regardless of the type of applied fertilizer (Figure 4). Indeed, the average bulb weight, which is between 28 and 104 g, is 2 to 3 times higher when crops are irrigated with control water (S0) than when with high salinity level (S3). Thus, the increase in ECw of irrigation water from 0.58 to 6 dS/m, resulted in a reduction of average bulb weight by 50.9, 55.2 and 67.4% respectively under compost, glumes and chemical fertilizer. The same trend was also observed with the height and diameter of onion bulbs.

Considering fertilizer type, the height, the diameter and the weight of onion bulbs are significantly higher under compost application than that chemical fertilizer and glumes (Table 3).

Table 2. Variations in bulb size (height and diameter) and bulb weight according to irrigation water salinity levels and type of fertilizers. *S0, S1, S2 and S3 are irrigation water with ECw of* 0.28 (*control*), 2, 4 *and* 6 *dS/m respectively.*

	Height (mm)	Diameter (mm)	Weight (g)
Compost	4.17 b	5.06 b	69.40 b
Glumes	3.83 a	4.27 a	57.76 a
Chemical fertilizer	3.76 a	4.13 a	48.42 a
Pr > F	0.000	0.000	0.000
Significant	Yes	Yes	Yes
S0	4.54 c	5.58 b	92.92 c
S1	3.91 b	4.34 a	57.39 b
S2	3.69 ab	4.01 a	45.06 ab
S3	3.53 a	4.01 a	38.72 a
Pr > F	0.000	0.000	0.000
Significant	Yes	Yes	Yes

The means assigned by the same letter are not statistically different according to LSD test with 5% threshold.

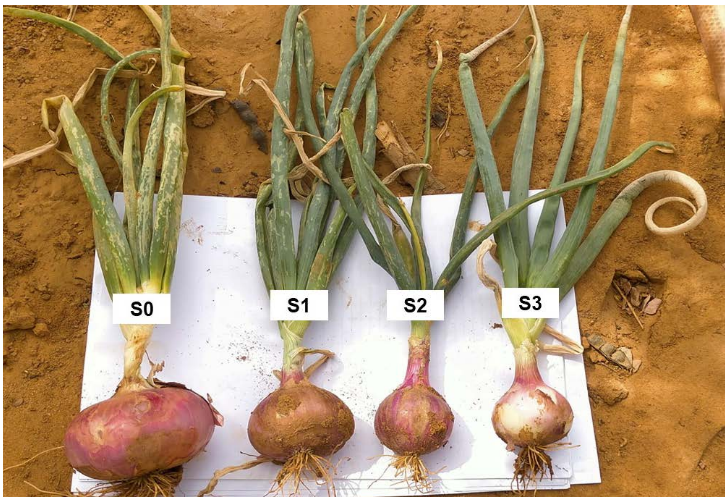

Figure 4. Images of onion bulbs collected in plots irrigated with water at ECw of 0.28 (control), 2, 4 and 6 dS/m respectively for S0, S1, S2 and S3.

Furthermore, considering control irrigation water (S0), the size and the weight of onion bulbs are higher under chemical fertilizer than that under compost and glumes while the trend is opposite when irrigated onion crops with saline water (S1, S2 and S3). Thus, using saline water, size and average weight of onion bulbs appeared to be higher under compost than that under chemical fertilizer and glumes, thus showing the capacity of compost to improve the salt tolerance of onion crops (Table 3).

Table 3. Variations in size (height and diameter) and average weight of onion bulbs according to fertilizers type and irrigation water salinity levels. *S0, S1, S2 and S3 are irrigation water with ECw of* 0.28 (*control*), 2, 4 *and* 6 *dS/m respectively.*

	Bulb height (mm)			Bulb diameter (mm)			Average bulb weight (g)		
	Compost	Chemical fertilizer	Glumes	Compost	Chemical fertilizer	Glume	Compost	Chemical fertilizer	Glume
S0	4.57 ef	4.78 f	4.28 de	5.55 ef	5.89 f	5.32 ef	91.53 e	103.53 e	83.71 de
S1	4.42 ef	3.49 ab	3.83 bcd	5.47 ef	3.45 ab	4.09 bc	82.33 de	28.00 a	61.84 cd
S2	4.15 cde	3.25 a	3.67 abc	4.93 de	3.29 a	3.81 abc	58.80 bc	28.40 a	47.98 abc
S3	3.55 ab	3.52 ab	3.52 ab	4.29 cd	3.89 abc	3.85 abc	44.93 abc	33.73 a	37.51 ab

The means assigned by the same letter are not statistically different according to LSD test with 5% threshold.

3.4. Changes in Onion Bulb Yield

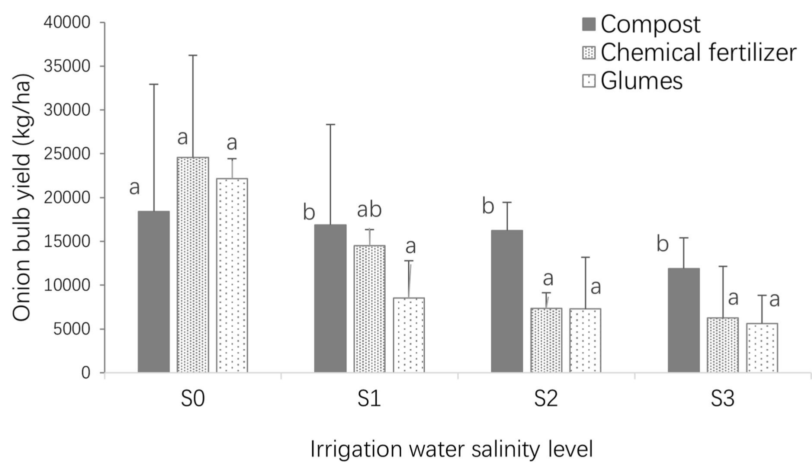

Figure 5. Variation in onion bulb yield according to fertilizer type and salinity level of irrigation water. *S0, S1, S2 and S3 are irrigation water with ECw of* 0.28 (*control*), 2, 4 *and* 6 *dS/m respectively. The bars represent the means standard deviations. The histograms assigned by the same letter are not statistically different according to LSD test with* 5% *threshold.*

Figure 5 shows the variation in onion bulb yield according to fertilizer type and salinity levels of irrigation water. The onion bulb yield, between 5630 and 25000 kg/ha, decreases with the salinity level of irrigation water under all fertilizers. Indeed, the bulb yield is 1.55, 3.92 and 3.94 times higher with control irrigation water S0 (ECw = 0.28 dS/m) than that with high irrigation saline water S3 (ECw = 6 dS/m) respectively under compost, mineral fertilizer and glumes. Furthermore, the bulb yield also varies according to the type of fertilizer. Indeed, when irrigating onion crops with control water (S0), the onion bulb yield was slightly higher under chemical fertilizer (24577 kg/ha) than under compost and millet glumes (18427 and 22155 kg/ha respectively), although the difference was not significant between the types of fertilizers. However, when irrigating onion crops with saline water (S1, S2 and S3), the bulb yield was significantly higher under compost than that under chemical fertilizer and glumes. The onion bulb yield was 1.9 and 2.1 times higher under compost fertilization than that under chemical fertilizer and glumes with the S3 level (6 dS/m) of irrigation water salinity.

Thus, these results show that compost application improves salt-tolerance of onion crops to fresh bulb production.

4. Discussion

4.1. Effects of Saline Water Irrigation on Soil Salinization

This study showed that the use of irrigation saline water for onion crop production increases soil salinity. Indeed, the soil electrical conductivity (ECe), initially very low (0.34 - 0.38 dS/m), increased significantly after 4 months of irrigation with saline water (S1, S2 and S3) whereas it remained almost stable with non-saline (S0). After 4 months of the experiment, the initial ECe increased by 8.4, 9.3 and 14.9 times respectively using irrigation water at ECw of 2, 4 and 6 dS/m for one onion growing season. The increase in soil salinization process by irrigation saline water has been reported by several authors [8] [42] [43]. Reference [43] showed that irrigation with saline water (7.5 dS/m) has led to a significant increase in soil salinity. Soil EC was 4 to 5 times higher in soil irrigated with saline water than in soil irrigated with fresh water (1.2 dS/m). Reference [27] found that initial soil ECe of 1.9 dS/m increased to 2.9, 4.0, 4.7, 5.8 and 7.0 dS/m respectively using saline water irrigation in ECw of 1.2, 1.45, 3.7, 6.2 and 9.5 dS/m after 3 months of onion cultivation on clayey sand soil in Tunisia. Reference [7] reported that the salts are added to the soil with saline water irrigation. Therefore it may lead to soil salinization and crop yield reduction. According to [9] the use of saline water resources for crop production can pose serious threats to agricultural productivity and food security by increasing salt buildup in the root zone. However, Reference [44] showed that in the Senegal River valley where soil salinity is linked to capillary rise of groundwater, the irrigation for one onion cropping season led to a decrease of ECe from 3.62 to 2.06 dS/m, i.e., 43 % in reduction of soil salinity.

Soil salinization process by irrigation saline water, particularly in arid and semi-arid areas, such as in the context of this study, is due to excessive evaporation and limited internal drainage which causes accumulation of inorganic salts in root soil layers disrupting the plant metabolism [45] [46] and explaining the results of this study. Thus, the changes in soil physicochemical properties caused by saline water irrigation will affect the growth and development of crops, finally affecting crop yield [7]. However, the application of organic amendments, especially compost, tends to reduce the salts accumulation from irrigation water in the soil surface layer compared to Chemical fertilizers and glumes. At the irrigation with high saline water (S2 and S3), ECe is significantly higher under chemical fertilizer and glumes than under compost. The reduction in salt accumulation of irrigation saline water and decrease of soil salinity by organic amendment, particularly compost, could be explained by the effect of compost to improve soil structure by aggregation, increases infiltration and salts leaching in order to reduce soil salinity in the root zone as reported by several authors [28] [47].

4.2. Effects of Saline Water Irrigation on Growth and Yields of Onion Crops

The study showed that the use of irrigation saline water reduces the growth and bulb yield of onion crops. Indeed, the plant height and the stem diameter of onion plants significantly decrease with salinity levels of irrigation water. The onion plant growth (height and stem diameter) is relatively greater with low ECw (S0 and S1) than that with high ECw (S2 and S3), especially with advanced plant age (from 70 Days After Plantation). At the end of the experiment, the plant height and stem diameter are 1.3 to 2 times higher with non-saline irrigation water (S0) than with saline irrigation water (S1, S2 and S3). The yield in onion bulbs, between 5630 and 25000 kg/ha, decreases with irrigation water salinity levels (ECw); it was 1.55 to 3.94 times higher with control (0.28 dS/m) than that with high saline water (ECw = 6 dS/m). This yield in onion bulbs is than that observed by [38], between 896 and 8000 kg/ha, who conducted the study on soil pots to test the effect of soil salinity on onion in Niger. However, it is lower than that reported by [48] which is between 24 to 35 t/ha under chemical and organic fertilizers application in Niger.

Compared to control in irrigation water, the reduction in fresh onion bulb yield was 38.8, 52.6 and 63.5% respectively for ECw of 2, 4 and 6 dS/m. The bulb size (height and diameter) also decreases with ECw as reported by [27]. These results are similar to the findings of several authors [49]-[51]. Reference [51] has been reported that the salinity in irrigation water has a significant impact on the number of bulbs per unit area, size, and fresh weight of onion bulbs. It influences the bulbing and quality of harvested bulbs. Reference [50] showed that onion crops growing significantly decreased with ECw and found a reduction in fresh onion bulb yield by 25% for ECw of 2.0 dS/m and 50% for ECw of 2.83 dS/m. According to [52] onion yield potential is 100 % until ECw=0.8 dS/m, 90% for 1.2 dS/m, 75 % for 1.8 dS/m, 50 % for 2.9 dS/m and about 0 % for 5.0 dS/m. Reference [27] found that irrigating onion with water at ECw of 3.7, 6.21 and 9.51 dS/m led to a reduction in bulb weight of 50, 73 and 91% respectively in comparison to plants irrigated with the control water (ECw = 1.21 dS/m). Thus, [27] as well as United States Department of Agriculture (USDA) confirmed that onions are the most sensitive to salinity compared to other vegetable crops. Reference [48] showed that ECw of 2.0 dS/m is the limit to promote the best onion growth in a semiarid region of Brazil. The adverse effect of irrigation saline water salinity in reduce of growth and yields also has been observed on other vegetable crops including peppers [53], green beans [54] on tomatoes [55] or on okra [23]. Reference [56] found that yield and growth parameters of leek were significantly influenced by the salinity of the irrigation water and decreased noticeably after the 2.0 dS/m water salinity levels. The decrease in growth and bulb yield of crops, such as onion crops, due to salinity could be explained by two main processes: osmotic stress and ionic toxicity such as Na^+ [19] [51] [57]. The osmotic pressure under the salinity stress in the soil solution exceeds the osmotic pressure in plant cells due to the presence of more salt and thus limits the ability of plants to absorb water and minerals like K^+ and Ca^{2+} [51]. Thus, this study confirms that saline water irrigation can lead to soil salinization and limit the onion crop production in the Tahoua region of Niger, hence the interest in considering measures to remedy this salinity.

4.3. Effects of Organic Fertilizers Application on Growth and Yield of Onion Irrigated with Saline Water

This study showed that the application of organic fertilizers, particularly compost, improves salt-tolerance of onion crops in order to promote growth and bulb yield of this crop which is very sensitive to salinity. Indeed, the temporal evolution of height, stem diameter and leaf number of onion plants appears to be higher under compost application than under glumes and chemical fertilizer, especially with advanced plant age. At the end of the growth stage (111 Days After Plantation), plant height and stem diameter of onion plants were significantly higher under compost than under glumes and chemical fertilizer. The increase in onion crop growth by organic amendment, including compost, has been reported by previous studies [48] [58] [59] which explained that compost improves soil fertility, available water content and nutrient availability.

Moreover, when irrigating onion crops with non-saline water (S0), the yield in onion bulbs is slightly higher under chemical fertilizer (24577 kg/ha) than that under compost and glumes (18427 and 22155 kg/ha respectively), although the difference was not significant between the types of fertilizers. The chemical fertilizers directly enhance crop yield because plants can assimilate the supplied nutrients directly or indirectly [58]. Still, it can also have negative effects on agricultural ecosystems, such as degradation of soil [60], reduced soil microbiotic diversity, and contamination of groundwater [58] [61].

However, when irrigating onion crops with saline water (ECw of 2, 4 and 6 dS/m), the onion bulb yield is significantly higher under compost than under chemical fertilizer and glumes. At high irrigation saline water (ECw = 6 dS/m), the yield in onion bulbs is 1.9 and 2.1 times higher under compost than that under chemical fertilizer and glumes respectively. Thus, the compost is the promising organic amendment in a semiarid region of Tahoua in Niger to remedy the adverse effect of irrigation saline water on onion crop production. These results are in agreement with the findings of several authors who reported the positive effect of organic amendment in decreasing soil salinity [37] [62] to promoting crop growth [63] [64]. Reference [62] showed that the application of organic amendment including compost significantly reduced the soil EC from 10.6 dS/m to 3.4

dS/m and promoted good germination and growth of the maize crops. Reference [37] founds that the application of green waste compost on salty sandy loam soil reduced the EC by 87%. The use of organic matter including compost improves soil structure, increases soil hydraulic conductivity and promotes salt leaching [65] [66] in order to improve salt-tolerance, growth and yield of crops [67] [68]; thus, explaining the results of this study.

5. Conclusion

This study showed that the use of irrigation saline water increases soil salinity and reduces the growth and bulb yield of onion crops. Indeed, after 4 months of the experiment, the initial ECe significantly increased by 8.4, 9.3 and 14.9 times respectively using irrigation saline water at ECw of 2, 4 and 6 dS/m whereas it remained almost stable with non-saline for one onion growing season. Furthermore, the plant height and the stem diameter of onion plants significantly decrease with salinity levels of irrigation water. The use of irrigation water at ECw of 2.4 and 6 dS/m led to a reduction in onion bulb yield of 38.8, 52.6 and 63.5%, respectively, in comparison to control irrigation water (ECw = 0.28 dS/m). However, the study showed that the application of organic fertilizers, particularly compost, improves salt-tolerance of onion crops in order to promote growth and bulb yield. When irrigating onion crops with saline water at ECw of 6 dS/m, the yield in onion bulbs is 1.9 and 2.1 times higher under compost than that under chemical fertilizer and glumes respectively. Thus, the compost is the promising organic amendment in a semiarid region of Tahoua in Niger to remedy the adverse effect of irrigation saline water on onion crop production.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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