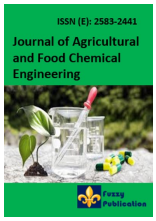
Journal of Agricultural and Food Chemical Engineering, 6(2):46–55, July-December: 2026.
DOI: https://doi.org/10.58612/jafce626

Journal of Agricultural and Food Chemical Engineering
ISSN (Online): 2583-2441

Journal homepage: https://www.fpub.org/journal-details.php?journal-id=45



Research Article

Effects of Organic Waste and Clean Salt Treatment on Reducing Irrigation Water Salinity, Selected Soil Properties, and Wheat Yield

Aws Mahmoud Kreet [1*]

[1]*Al-Mussaib Polytechnic College, Al-Furat Al-Awsat Technical University, Babel, Iraq.*
[*]*Corresponding author: Awsmahmoud.kreet@atu.edu.iq*

Article Info

Keywords: *Irrigation Water Salinity, Salinity Treatment, Organic Waste, Wheat*

Received: *29.09.2026;*
Accepted: *01.11.2026;*
Published: *08.11.2026*

© *2026 by the author's. The terms and conditions of the Creative Commons Attribution (CC BY) license apply to this open access article.*

Abstract

Background: Saline irrigation limits wheat production, so the feasibility of organic amendments and commercial treatments to improve soil conditions and crop performance are being explored. **Objective:** To evaluate the effects of irrigation salinity, organic waste and Clean Salt on soil properties and wheat plant performance, single and combined levels of these factors. **Methodology:** The experiment involved a completely randomized factorial with three irrigation salinities, four poultry–buffalo manure rates, three Clean Salt rates and five replications. Factorial ANOVA and LSD comparison were used to assess the effect of postharvest soil properties and plant traits. **Results:** Higher application of organic waste resulted in statistical reduction in soil electrical conductivity, and also increased the thousand grain weight, shoot dry weight along with the number of tillering. Use of Clean Salt resulted in a reduction in mean conductivity from 5.38 to 4.81 dS m^{-1}. Maximums in grain weight, shoot biomass, and tillering occurred with the highest rates of combined amendments under 3 dS m^{-1} irrigation. Thousand-grain weight, shoot biomass and tillers per plant had corresponding maximums of 46.00 g, 36.37 g $plant^{-1}$ and 8.33 tillers per plant, respectively. The post-harvest pH values were found to be in the range of 7.00–7.40 and increased slightly with the amendment application rates. The soil conductivity elevated in the salinity levels and the plant response was maximum at intermediate soil salinity. **Conclusion:** Although some salinity management is demonstrated by the combined amendments, field verification and measurements of salt balance are needed for any levels of recommendation for application or claim of desalination.

1. Introduction

Salinity of soils and irrigation water are important constraints to sustainable agricultural production especially in arid and semi-arid areas, where high levels of evaporation and low supplies of freshwater means that saline conditions are likely to be present. The global country-level evaluation of salt-impacted soils reflects the magnitude and significance of the salt impact issues for soil fertility, plant growth and food security [1]. Maintenance of salinity management is particularly significant in Iraq, where irrigated farming is highly reliant on water quality management, and drains. It has been revealed by research in central and southern Iraq that over-irrigating and insufficient drainage results in an increase of the groundwater level, salinization of the root zone soil and decreases the productivity of crops [2]. Saline irrigation response is related to the amount of salts added to the soil and how the salts are leached and drained from the soil. While electrical conductivity is a

basic measure of salinity, salinity of irrigation water should not be equated to the salinity of the soil "saturation extract" since the relationship is dependent on management and environment conditions [3]. In addition, sodicity is characterised by high exchangeable sodium contents and can include dispersion of clays and loss of soil hydraulic properties. Soil responses thus must be interpreted taking into account both electrical conductivity and ionic composition and balance [4].

The influences of salinity correspond to osmotic stress by reduction of water uptake by the roots, growth of foliage and ionic stress by sodium and chloride accumulation and senescence acceleration of tissues [5]. The crop tolerance varies and yield responses have been described according to soil salinity threshold and then in terms of a decreasing production, wheat is moderately tolerant [6]. However, there is significant variation in tolerance between cultivars and from one environment to the next. Response of wheat varies due to genetic traits, climate and irrigation management – evaluation under local growing conditions is essential [7]. Organic wastes have potential benefits in salt affected soils as sources of organic matter and nutrients, and as agents to improve soil structural properties and permeability. They affect, however, with variation of material type and application rate. A special review shows that the values of the physical properties of organic materials or the values of the salinity indicators do not always improve when organic material is added [8]. Field study also showed that poultry manure and plant residue compost increased physical, chemical and biological attributes of the saline soil, which ascribe their nature as amendments, however, differences observed between the experimental settings [9]. Organic fertiliser can bring benefits to plant nutrition and not necessarily lowering salt levels. Saline soil study: poultry manure raised the availability of potassium and shoot growth, and did not significantly affect soil electrical conductivity [10]. The finding highlights the need to relate soil data with plant responses and not the efficacy of amendments to single data. A laboratory incubation experiment, additionally, indicated that soil microbial activity and carbon dynamics after organic amendments were influenced by salinity, sodicity and gypsum amendments, demonstrating interactions between the amendments and soil environment [11].

The quality of the waste, the amount of salt, and the degree of decomposition are important in determining agricultural suitability, which is not determined only by whether or not the waste comes from agriculture. The evidence of compost use in salt affected soils shows potential for fertility improvement for appropriate material and levels of contaminants [12]. Animal manure composting literature also highlights, among others, the stability of organic matter, maturity indicators and nitrogen conservation as pathways to assess product quality [13]. To assess benefits and risks in case of saline irrigation, characterisation of the poultry and buffalo manure mixture, and the control of application rates are thus important. Quality assessment also helps to ensure uniform interpretation of all treatments. The longterm data indicates the role of organic amendments as a source of soil carbon and aggregate stability, and that response was dependent to some extent on type, rate and frequency of amendments [14]. These resources should, therefore, be used as part of integrated soil, water and crop management and not as alternatives to leaching or drainage. Saline and sodic situations also highlight the importance of the use of production practices and environmental protection related to tolerant crops [15]. This can facilitate the assessment of the combined effects of salinity and amendments rather than separate ones.

Therefore, the evaluation of the combined organic wastes and Clean Salt treatments in wheat under the different irrigation salinities is merited. Comparable amendment responses can be compared with water conductivity levels of 1.33, 3 and 6 dS m^{-1} this represents increasing salt exposures. A factorial pot experiment will give a framework in which soil electrical conductivity and pH post-harvest will be investigated together with thousand grain weight, shoot dry weight and tiller number. These indicators can together describe the soil and plant responses and treatment interactions without requiring an understanding of the mechanism of the product, or identifying reduced soil salinity as a directly measured reduction in salinity from irrigation water. In view of the uncertainty and lack of information on the combined effects of salinity in irrigation water, different mixes of manure of poultry and buffalo and use of Clean Salt in wheat crop, these were considered in the study. Organic amendments may lead to better nutrition and growth without equivalent salinity reductions and the effects and interactions must be investigated through experiments. The aim is to evaluate the individual and combined (interactions) effects of three salinity levels of irrigation water, four levels of organic amendments and three levels of Clean Salt in a complete randomized design (CRD) factorial pot experiment. To find the appropriate treatments which would enhance soil properties and wheat performance under salinity within the experiment range and measured variables the evaluation parameters include electrical conductivity of the soil, soil pH after harvest, thousand grain weight, shoot dry weight and tiller number.

2. Methodology

2.1. Experimental setup and treatments

This experiment was carried out in the wire house of Technical Institute Al-Musayyab, Babylon/ Iraq. Soil collected from Al-Azawiyah, Al-Mahawil, was ground, sieved at 4 mm and put in plastic pots (28 cm diameter, 25 cm height) and each pot was filled with 10 kg soil. Experimental design was a 3×4×3 completely randomized design consisting of 36 combinations and five pots for each combination (180 pots). Each plant in a pot was a subsample and not replicate treatments [16]. Treatments were irrigation-water EC at W1=1.33, W2=3.00, and W3=6.00 dS m^{-1}; poultry–buffalo manure at O0=0, O1=2.5, O2=5.0, and O3=10.0 t ha^{-1}; and Clean Salt at C0=0, C1=1.5, and C2=3.0 L ha^{-1}. W1 was river water and W2 and W3 was mixture of river and tap water.

2.2. Sample preparation and treatment application

To characterize the soil for the laboratory, air-dry the soil subsample, homogenize it, pass it through a 2 mm sieve, and use hydrometer analysis for texture, air-dry mass/volume for bulk density, Walkley–Black oxidation for organic matter, alkaline-permanganate distillation for available N, Olsen extraction for P, and ammonium-acetate extraction for K. This analysis is carried out according to the FAO laboratory manual [17]. Use documented conversion basis to determine quantities of product for a field. The conversion of an area based rate is from pot amount=field rate× pot area/10,000, pot area and field rate used in the calculation need to be in the same units of area or mass or volume. Always weigh and incorporate on a product rate, not nutrient rate homogenize manure mixture before weighing and incorporating [18]. To characterize manure, take a representative subsample, dry matter, extract total N with oxygen combustion and total P and K with acid digestion followed by ICP-OES. Represent concentrations using explicitly stated masses [19]. Name the treatment as used in Iraqi comparator: Clean Salt. It should be labeled for compatible formulation dilution, timing and route of application with adopted of equal

carrier handling for control. Some differences in the dose level of the comparator based on concentration, and the manuscript based on L ha^{-1} have been observed [20] and cannot be converted.

2.3. Crop management and irrigation

On 1st November 2023, 10 sown wheat seeds were sown indoors per pot and thinned after three weeks to 5 plants, seed variety Barcelona. At the time of sowing 150 kg ha^{-1} superphosphate was incorporated with soil and 160 kg ha^{-1} urea was applied at 2 and 4 weeks after sowing while 100 kg ha^{-1} potassium sulfate was applied. Manual weeding was done. The harvest was on 10 April 2024 and was within the study period of 2023 to 2026, as specified by the author. Use calibrated conductivimeter to confirm blended-water EC. For gravimetric irrigation, field capacity pot mass determined, weighed before irrigation and water loss determined; missing water replaced with water from irrigation assignment and drainage collected separately. Some real world use and bore volumes recorded [21].

2.4. Soil pH and electrical conductivity

To prepare a saturated soil paste simply add deionized water to the standard saturated endpoint in the soil while mixing. The extract should be obtained after equilibration by vacuum filtration and conductivity should be measured with a calibrated conductivity meter, also at 25°C, after which value it should be reported as dS m^{-1}. This is the referred saturation-extract procedure, but keep the original EC designation that the manuscript used, unless the extraction basis can be determined [22]. To measure saturated paste pH, use certified buffers to calibrate the electrode; place the electrode into the saturated paste, let the pH stabilize and rinse the electrode between measurements. Replicate preparation and measurement regimes from baseline and post-harvest samples [23].

2.5. Plant measurements

For measurement of dry mass, harvest the grain and roots from the shoots, oven-dry shoot material at 60°C to a constant mass, weigh, and calculate mean dry mass as the total dry mass for 5 plants / 5 (g $plant^{-1}$). To determine thousand-grain weight, weigh a slip of grain and use the formula [24]:

$$\text{TGW} = 1000 \times \frac{\text{Sample Weight}}{\text{Number of grains}}$$

On each marked plant count the number of basal tillers, other than the main plant. Sum the five counts of plants (n = pot value counted/5), and record the stage of the count. It is important that the same counting definition be applied within and between treatments [25].

2.6. Statistical analysis

Data reported were analyzed by the use of Factorial ANOVA and MS EXCEL. Record plant data at the pot level before subjecting comparisons of plant data to list model main effects, W×O, W×C, O×C and W×O×C. The treatments were tested for differences in their means by LSD at the 0.05 level of significance.

3. Results

The soil was a loam comprising of 340, 440 and 220 g kg^{-1} of sand, silt and clay respectively Table 1. Silt particles were thus the biggest particle-size fraction. The initial pH was 7.70 and EC was 4.30 dS m^{-1} that showed slightly alkaline range. content of organic matter was 5.00 g kg^{-1} and bulk density was 1.40 g cm^{-3}. The available nitrogen, phosphorus and potassium in soil were found to be 32.00, 3.50, and 60.10 mg kg^{-1} respectively. All the measurements listed are for the soil prior to being treated, and represent the baseline for evaluating the changes in soil pH and electrical conductivity that occur after harvesting.

The irrigation waters differed the irrigation waters of Table 2 differ in their properties. EC in the river water (W1) was 1.33 dS m^{-1}, which was increased to 3.00 and 6.00 dS m^{-1} by mixing with water of different ECs. The increase in concentration was also accompanied with increase in the concentration of sodium and chloride from 7.00 and 8.41 mmol L^{-1} in W1 to 18.20 and 20.40 mmol L^{-1} in W3, respectively. The pH in water fell to 7.30 in all the treatments as compared to 8.20 in water without any added treatment. Potassium concentration was still at 0.20 mmol L^{-1} and carbonate was not observed. Therefore, ionic composition and other electrical conductivity of the waters varied.

Table 3 indicates that the poultry–buffalo manure mixture had organic matter and various nutrients. The concentrations of organic matter was 455.01 g kg^{-1}, and total N, P and K were 16.10 g kg^{-1}, 6.86 g kg^{-1} and 5.00 g kg^{-1}, respectively. The highest of these three measured nutrients was nitrogen. The material also had a pH of 7.50 and an EC of 9.51 dS m^{-1}. This conductivity shows that soluble salts were also present in addition to the organic ones. This characterization is for both the organic and nutrient inputs that can be supplied by the amendment and the salinity, which is important to consider when interpreting the soil measurements that follow.

The soil pH for the post-harvest period was near neutral ranging from 7.00 to 7.40 and below the initial level of 7.70 as shown in Table 4. Each level higher up in O and in C increased the mean pH from 7.04 under O0 to 7.19 under O3, and 7.07 under C0 to 7.16 under C2. This was in contrast to the water-treatment means which had a different trend: the highest treatment, W1 (7.19); and the lowest, W3 (7.05). The largest person score was 7.40 under (C2–W1–O3). The pH changed slightly overall increasing in pH with increasing levels of amendments and decreasing in pH under the most saline irrigation treatment.

As determined from Table 5, the post-harvest soil EC remained increased with the different levels of irrigation-water salinity and the average value was 2.77, 6.00, and 6.55 dS m^{-1} for W1, W2 and W3 respectively. However, the organic-amendment level had the opposite trend, decreasing EC from 5.92 dS m^{-1} in O0 to 4.12 in O3. This overall trend was not matched by Clean Salt: Means decreased over the 5.38 of C0 to 4.81 of C2. The lowest EC observed was 2.40 dS m^{-1} at C2, W1 and O3 while the highest was 7.93 dS m^{-1} at C0, W3 and O0. However, these patterns are related to lower residual soil salinity despite different irrigation-water inputs for both higher organic-amendment and lower Clean Salt levels.

Table 1: Initial physical and chemical properties of the studied soil

Property	**Component**	**Value**	**Unit**
Particle-size fraction	Sand	340	g kg^{-1}
	Silt	440	
	Clay	220	
Soil texture	-	Loam	-
Electrical conductivity (EC)	-	4.30	dS m^{-1}
Soil pH	-	7.70	—
Bulk density	-	1.40	g cm^{-3}
Organic matter (O.M)	-	5.00	g kg^{-1}
Dissolved ions in the soil-paste extract			
	Ca^{2+}	14.51	mmol L^{-1}
	Mg^{2+}	9.82	
	Na^{+}	9.00	
	K^{+}	0.60	
	SO_4^{2-}	12.20	
	Cl^{-}	14.21	
	CO_3^{2-}	Nil	
	HCO_3^{-}	5.60	
Available nitrogen (N)	-	32.00	mg kg^{-1}
Available phosphorus (P)	-	3.50	
Available potassium (K)	-	60.10	
Sodium adsorption ratio (SAR)	-	2.58	—

Table 2: Physical and chemical characteristics of the irrigation waters used in the experiment

Water	**River water W1**	**Mixed river and tap water W2**	**Mixed river and tap water W3**	**Unit of measurement**
EC	1.33	3.00	6.00	dS m^{-1}
pH	8.20	7.70	7.30	—
Ca^{2+}	3.30	3.99	4.40	mmol L^{-1}
Mg^{2+}	1.89	3.30	7.10	
Na^{+}	7.00	10.60	18.20	
K^{+}	0.20	0.20	0.20	
CO_3^{2-}	Nil	Nil	Nil	
HCO_3^{-}	2.00	2.30	4.40	
SO_4^{2-}	2.50	5.30	7.10	
Cl^{-}	8.41	8.46	20.40	
SAR	2.60	5.57	7.61	—

Table 3: Chemical characteristics of the poultry–buffalo organic waste

Characteristics	**Unit of measurement**	**Organic waste Poultry and buffalo organic waste**
Electrical conductivity (EC)	dS m^{-1}	9.51
pH	—	7.50
Organic matter (O.M.)	g kg^{-1}	455.01
Total N		16.10
Total P		6.86
Total K		5.00

Table 4: Post-harvest soil pH under irrigation water salinity, Clean Salt, organic waste, and their interactions

Clean Salt (C)	**Water (W)**	**O0**	**O1**	**O2**	**O3**	**Average**
C0	W1	7.03	7.10	7.20	7.20	7.13
	W2	7.00	7.00	7.10	7.10	7.05
	W3	7.00	7.00	7.00	7.10	7.03
C1	W1	7.10	7.17	7.20	7.27	7.18
	W2	7.07	7.07	7.17	7.17	7.12
	W3	7.00	7.00	7.10	7.10	7.05
C2	W1	7.10	7.20	7.27	7.40	7.24
	W2	7.10	7.20	7.17	7.20	7.17
	W3	7.00	7.00	7.10	7.20	7.08
Average	-	7.04	7.08	7.14	7.19	7.12
$LSD_{0.05}$	-	O = 0.016		OCW = 0.047		CW = 0.024
Clean Salt (C)	-	**O0**	**O1**	**O2**	**O3**	**Mean**
C0	-	7.01	7.03	7.10	7.13	7.07
C1	-	7.06	7.08	7.16	7.18	7.12
C2	-	7.07	7.13	7.18	7.27	7.16
Average	-	7.04	7.08	7.14	7.19	7.12
$LSD_{0.05}$	-		OC = 0.027			C = 0.014
Water (W)	-	**O0**	**O1**	**O2**	**O3**	**Mean**
W1	-	7.08	7.16	7.22	7.29	7.19
W2	-	7.06	7.09	7.14	7.16	7.11
W3	-	7.00	7.00	7.07	7.13	7.05
Average	-	7.04	7.08	7.14	7.19	7.12
$LSD_{0.05}$	-		OW = 0.027			W = 0.014

Table 5: Postharvest soil electrical conductivity (dS m^{-1}) under irrigation water salinity (W), organic waste (O), and Clean Salt (C) treatments

Clean Salt (C)	**Water (W)**	**O0**	**O1**	**O2**	**O3**	**Average**
C0	W1	2.95	2.87	2.85	2.69	2.84
	W2	7.04	6.87	6.13	5.11	6.29
	W3	7.93	7.78	7.00	5.37	7.02
C1	W1	2.90	2.88	2.84	2.83	2.86
	W2	6.97	6.44	5.58	5.00	6.00
	W3	7.87	7.03	6.03	5.14	6.52
C2	W1	2.89	2.69	2.45	2.40	2.61
	W2	6.94	6.35	5.16	4.42	5.72
	W3	7.78	7.00	5.54	4.08	6.10
Average		5.92	5.55	4.84	4.12	5.11
$LSD_{0.05}$		O=0.067		OCW=0.201		CW=0.101
Clean Salt (C)		**O0**	**O1**	**O2**	**O3**	**Mean**
C0	-	5.97	5.84	5.33	4.39	5.38
C1	-	5.92	5.45	4.82	4.32	5.13
C2	-	5.87	5.35	4.38	3.64	4.81
Average	-	5.92	5.55	4.84	4.12	5.11
$LSD_{0.05}$	-		OC= 0.116			C= 0.058
Water (W)		**O0**	**O1**	**O2**	**O3**	**Mean**
W1	-	2.91	2.81	2.71	2.64	2.77
W2	-	6.98	6.55	5.62	4.84	6.00
W3	-	7.86	7.27	6.19	4.87	6.55
Average	-	5.92	5.55	4.84	4.12	5.11
$LSD_{0.05}$	-		OW= 0.116			W= 0.058

Table 6 revealed that thousand-grain weight increased with increasing level of organic amendment (from 39.93 g under O0 to 43.15 g under O3). Clean Salt also had a higher mean than C0 (39.95 g) to C2 (42.12 g). W2 gave the highest mean 42.04 g, for the three water treatments, W1 and W3 gave similar values of 40.78 g and 40.62 g. The maximum weight was 46.00 g in C2–W2–O3 while the minimum was 39.07 g in C0–W3–O0. Grain mass, therefore, increased with amendment amounts and salinity did not produce a linear response in comparison to water.

Table 6: Weight of 1000 grains (g) under irrigation water salinity (W), Clean Salt treatment (C), and organic waste (O), including their interactions

Clean Salt (C)	**Water (W)**	**O0**	**O1**	**O2**	**O3**	**Average**
C0	W1	39.34	39.42	39.69	40.42	39.72
	W2	40.52	40.30	40.50	41.49	40.70
	W3	39.07	39.21	39.31	40.11	39.43
C1	W1	39.43	40.07	41.11	43.18	40.95
	W2	40.98	41.18	42.33	44.29	42.19
	W3	39.28	40.27	41.31	43.04	40.97
C2	W1	39.63	40.49	41.51	45.07	41.68
	W2	41.47	42.47	42.97	46.00	43.23
	W3	39.65	40.31	41.07	44.77	41.45
Average	–	39.93	40.41	41.09	43.15	41.15
$LSD_{0.05}$	–	O = 0.191		OCW = 0.573		CW = 0.2877
Clean Salt (C)	–	**O0**	**O1**	**O2**	**O3**	**Mean**
C0	–	39.64	39.64	39.83	40.68	39.95
C1	–	39.90	40.50	41.58	43.50	41.37
C2	–	40.25	41.09	41.85	45.28	42.12
Average	–	39.93	40.41	41.09	43.15	41.15
$LSD_{0.05}$	–	OC = 0.331				C = 0.165
Water (W)	–	**O0**	**O1**	**O2**	**O3**	**Mean**
W1	–	39.47	39.99	40.77	42.89	40.78
W2	–	40.99	41.31	41.93	43.93	42.04
W3	–	39.33	39.93	40.57	42.64	40.62
Average	–	39.93	40.41	41.09	43.15	41.15
$LSD_{0.05}$	–	OW = 0.331				W = 0.165

The shoot dry weights are higher as the organic-amendment and Clean Salt level increases as shown in Table 7. The Organic-amendment mean increased from 30.24 g plant^{-1} under O0 to 33.74 under O3 and the Clean Salt mean increased from 30.89 under C0 to 32.23 under C2. W2 gave the highest water-treatment mean, 31.89 g plant^{-1}, followed by W1 at 31.43 and W3 at 31.21. The C2–W2–O3 treatment combination produced the highest value, 36.37 g plant^{-1} under C2–W2–O3 while the C0–W3–O0 combination produced the lowest value, 30.03 under C0–W3–O0. The results thus indicate increased vegetative dry mass as the amendment was increased with the highest at the W2 irrigation-water treatment.

Table 7: Effects of irrigation-water salinity (W), organic-waste rate (O), and Clean Salt (C), and their interactions, on shoot dry weight (g plant^{-1})

Clean Salt (C)	**Water (W)**	**O0**	**O1**	**O2**	**O3**	**Average**
C0	W1	30.11	30.24	30.85	32.25	30.86
	W2	30.19	30.30	31.06	32.77	31.08
	W3	30.03	30.16	30.72	32.03	30.74
C1	W1	30.23	30.46	31.18	33.22	31.27
	W2	30.35	30.61	31.65	34.68	31.82
	W3	30.10	30.31	31.03	33.11	31.14
C2	W1	30.40	31.06	32.17	35.03	32.17
	W2	30.51	31.28	32.94	36.37	32.78
	W3	30.19	31.03	31.65	34.18	31.76
Average	-	30.24	30.61	31.47	33.74	31.51
$LSD_{0.05}$	-	O=0.143		OCW=0.429		CW=0.214
Clean Salt (C)	**-**	**O0**	**O1**	**O2**	**O3**	**Mean**
C0	-	30.11	30.23	30.88	32.35	30.89
C1	-	30.23	30.46	31.29	33.67	31.41
C2	-	30.37	31.12	32.25	35.19	32.23
Average	-	30.24	30.61	31.47	33.74	31.51
$LSD_{0.05}$	-	OC= 0.248				C= 0.124
Water (W)	**-**	**O0**	**O1**	**O2**	**O3**	**Mean**
W1	-	30.25	30.59	31.40	33.50	31.43
W2	-	30.35	30.73	31.88	34.61	31.89
W3	-	30.11	30.50	31.13	33.11	31.21
Average	-	30.24	30.61	31.47	33.74	31.51
$LSD_{0.05}$	-	OW=0.248				W=0.124

Tiller number rose with increasing levels of organic-amendment and Clean Salt as shown in Table 8. There was a significant increase in mean tillering with increased application rates of O (O0 4.59 tillers plant^{-1} vs O3 6.89 tillers plant^{-1}) and C (C0 4.92 vs C2 6.75 tillers plant^{-1}). W2 mean water-treatment tillers plant^{-1} (6.58) exceeded the water-treatment tillers plant^{-1} of the other water-treatment means (W1 (5.75) and W3 (5.03)) of the three. The largest number recorded was 8.33 (C2-W2-O3) and the least was 3.33 (C0-W3-O0). These results indicate a positive tillering response with increasing levels of amendments, but the maximum response to water-treatment was under W2 and did not increase regularly as irrigation water salinity increased.

Table 8: Effects of irrigation water (W), organic waste (O), and Clean Salt (C) on wheat tillers per plant

Clean Salt (C)	**Water (W)**	**O0**	**O1**	**O2**	**O3**	**Average**
C0	W1	3.67	4.67	5.67	6.33	5.08
	W2	4.00	5.00	6.00	6.67	5.42
	W3	3.33	3.67	4.67	5.33	4.25
C1	W1	4.67	5.00	5.67	7.00	5.58
	W2	5.67	6.33	7.00	7.67	6.67
	W3	3.67	4.33	5.00	6.33	4.83
C2	W1	5.33	6.33	7.33	7.33	6.58
	W2	6.67	7.67	8.00	8.33	7.67
	W3	4.33	6.33	6.33	7.00	6.00
Average	-	4.59	5.48	6.19	6.89	5.79
$LSD_{0.05}$	-		O= 0.415	OCW= 1.245		CW=0.622
Clean Salt (C)	**-**	**O0**	**O1**	**O2**	**O3**	**Mean**
C0	-	3.67	4.44	5.44	6.11	4.92
C1	-	4.67	5.22	5.89	7.00	5.69
C2	-	5.44	6.78	7.22	7.56	6.75
Average	-	4.59	5.48	6.19	6.89	5.79
$LSD_{0.05}$	-		OC= 0.719			C= 0.359
Water (W)	**-**	**O0**	**O1**	**O2**	**O3**	**Mean**
W1	-	4.56	5.33	6.22	6.89	5.75
W2	-	5.44	6.33	7.00	7.56	6.58
W3	-	3.78	4.78	5.33	6.22	5.03
Average	-	4.59	5.48	6.19	6.89	5.79
$LSD_{0.05}$	-		OW= 0.719			W= 0.359

4. Discussion

The results show that wheat performance to irrigation salinity was not linearly affected by organic waste and Clean Salt and they also moderated the residual soil salinity. The soil EC was also seen to increase from 2.77 W1 to 6.55 dS m^{-1} W3 and tillering decreased W1 to W3 (5.75 to 5.03 tillers per plant). This behaviour is typical of that associated with salinity being a limiting factor in water uptake and a subsequent effect on growth through ion accumulation [26]. The relative small salinity effects on shoot biomass and grain weight however indicate that not all developmental processes are equally severely affected by salinity and that effects are not globally inhibitory but different developmental processes are differently affected [27].

The application of manure at the zero level to the O3 level revealed a decrease of 30.4% in the mean soil EC despite the EC of the amendment which was 9.51 dS m^{-1}. This is a response that could be related to improved aggregation and water movement that contributes to salt redistribution or leaching as has been demonstrated with organic amendments in saline soils [28, 29]. These mechanisms are only speculation, since the structure, hydraulic conductivity and drainage salt fluxes of the soils were not measured. It is important to note that amendment conductivity is not only nutrient ions that would be beneficial, but undesirable salts also. It is related to soil EC and its application rate as well as how the manure is extracted and how water is managed, so its reduction does not provide a comprehensive solution to the problems resulting from repeated saline manure application [30].

The post-harvest pH level was higher than the initial pH level, which ranged between 7.00 and 7.40, and rose from 7.04 at O0 to 7.19 at O3. This means that manure does not acidify the soil in comparison to the unamended treatment. This is different from the acidification during the gypsum–manure reclamation mentioned before [31] which highlights the impact of amendment composition and associated treatments. The outcome of integrated gypsum–compost systems can also not be directly applied to this manure mixture [32]. Small increases in pH were observed that might be a result of buffering or contribution of bases (not quantified). In addition, pH and EC cannot provide sodicity remediation without the exchangeable sodium measurement [33].

Organic amendment raised thousand grain weight, shoot dry weight and tiller number by 8.1%, 11.6% and 50.1%, respectively. These gains are most likely the result of soil nutrient addition in areas with low and inadequate soil organic matter and available phosphorus. The results of wheat field studies corroborate a manure contribution to nutrient availability, water holding capacity and productivity [34]. However, all responses have been made to nutrient release, since mineral fertilizers were also provided. Additionally, improved K nutrition may help the osmotic regulation and K^+ /Na^+ balance of cells under saline conditions [35]. For example, an improved ion-homeostasis cannot be excluded as a possible mechanism as tissue nutrient concentrations were not measured.

Although there were no differences in conductivity between W1 and W2, W2 had the greatest mean grain weight, shoot biomass and tillering. This nonmonotonic effect is not proof that saline irrigation is of benefit for wheat or that 3 dS m^{-1} is the generally optimum level of salinity. The waters varied in sodium, chloride, and calcium, magnesium and pH, making conductivity and chemical composition non-distinguishable. In wheat, the retention of potassium [36], the accumulation of sodium in foliage [37] and the partitioning of sodium between the roots and shoot [38] have been shown to affect tolerance, demonstrating the importance of each of these processes. Therefore, it

is possible that variations in ion balance/exposure can play a role in this pattern, but this possibility has not been explored. It will then be an oversimplification to make comparisons that rely on water EC alone.

Clean Salt lowered soil EC by 10.6%, and raised all 3 plant indicators. W3 showed that the C2–O3 treatments reduced the EC from 7.93 in the C0–O0 treatment to 4.08 dS m^{-1}, demonstrating a significant mitigation within the working system. W2, C2–O3 had the highest grain weight (46.00 g) and shoot biomass (36.37 g $plant^{-1}$). In the absence of product composition and ion balance, this response cannot validate sodium displacement or salt removal or irrigation-water desalination. A decrease in soil EC may be due to change in transport, distribution or precipitation and not necessarily represent total salt removal. A coupled water and salt balance, including drainage losses [39] must therefore be considered when interpreting salinity control.

The combination C2–W2–O3 had the largest tillering, but this was less than the difference between this combination and several other combinations found in the same neighborhood than the difference reported by the three factor LSD. It should not be allowed to appear as singularly better suited for this trait; nor should the good combinations be called synergically good unless there have been tests for interaction. In addition, pathogen resistant varieties do not automatically result in higher total grain yield, higher grain weight or higher biomass.

Last, there is limited rooting volume and pot-related water conditions, which are limiting factors in applying to the field [40]. Repeated applications are only recommended after replicated field trials quantify the grain yield, drainage, tissue ions and amendment salt inputs. There is some uncertainty around the soil EC extraction basis and care must be taken when making comparisons to published salinity thresholds. It is also important to establish the same analytical procedures for the baseline and post-harvest samples in order to explain any discrepancies between the samples as solely due to treatment. Furthermore, a solitary documented growing season cannot do that determine the long term persistence, overall economic value or environmental safety of these responses. The results overall justify conditional amendment benefits, but not free saline irrigation or salinity proven desalination.

5. Conclusion

Organic waste and Clean Salt need to be considered as part of integrated salinity management as opposed to replacements for current irrigation and drainage. They are dependent upon the quality of the amendment, water chemistry, soil conditions, and application practices to be agricultural. This study establishes a baseline for future evaluation, but does not lead to desalination from irrigation water nor does it confirm processes of treatment response. Field validation under replication of soils and seasons should be done with measurements of grain yield, nutrient uptake, sodium dynamics and salt balances to provide practical evidence-based recommendations. Future studies should also focus on the effects of cumulative salt loads due to specific applications, environmental safety, and economic viability; this would help to assess the potential of the specific treatments for long-term wheat production under a saline irrigation system.

Article Information

Data Availability: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of Interest: The author declare that they have no conflict of interest.

Funding: No external funding was received for this study.

AI Use Disclosure: No generative artificial intelligence tools were used in the preparation of this manuscript.

References

[1] Food and Agriculture Organization of the United Nations (FAO). Global Status of Salt-Affected Soils: Main Report. Technical report, Food and Agriculture Organization of the United Nations, Rome, 2024. URL https://doi.org/10.4060/cd3044en. ISBN 978-92-5-139307-9.

[2] A. S. Qureshi, W. Ahmad, and A. A. Alfalahi. Salinity Management in Central and Southern Iraq: Prospects under Existing Drainage Conditions. Iraq Salinity Project–Technical Report 13, International Center for Agricultural Research in the Dry Areas (ICARDA), Beirut, 2013. URL https://hdl.handle.net/20.500.11766/9717.

[3] R. S. Ayers and D. W. Westcot. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29, Rev. 1, Food and Agriculture Organization of the United Nations, Rome, 1985. URL https://www.fao.org/4/t0234e/t0234e00.htm. ISBN 92-5-102263-1.

[4] P. Rengasamy. Soil processes affecting crop production in salt-affected soils. *Functional Plant Biology*, 37(7):613–620, 2010. URL https://doi.org/10.1071/FP09249.

[5] R. Munns and M. Tester. Mechanisms of salinity tolerance. *Annual Review of Plant Biology*, 59:651–681, 2008. URL https://doi.org/10.1146/annurev.arplant.59.032607.092911.

[6] E. V. Maas and G. J. Hoffman. Crop Salt Tolerance—Current Assessment. *Journal of the Irrigation and Drainage Division*, 103(2): 115–134, 1977. URL https://doi.org/10.1061/JRCEA4.0001137.

[7] R. Munns, R. A. James, and A. Läuchli. Approaches to increasing the salt tolerance of wheat and other cereals. *Journal of Experimental Botany*, 57(5):1025–1043, 2006. URL https://doi.org/10.1093/jxb/erj100.

[8] M. Diacono and F. Montemurro. Effectiveness of Organic Wastes as Fertilizers and Amendments in Salt-Affected Soils. *Agriculture*, 5 (2):221–230, 2015. URL https://doi.org/10.3390/agriculture5020221.

[9] M. Tejada, C. Garcia, J. L. Gonzalez, and M. T. Hernandez. Use of organic amendment as a strategy for saline soil remediation: Influence on the physical, chemical and biological properties of soil. *Soil Biology and Biochemistry*, 38(6):1413–1421, 2006. URL https://doi.org/10.1016/j.soilbio.2005.10.017.

[10] D. J. Walker and M. P. Bernal. The effects of olive mill waste compost and poultry manure on the availability and plant uptake of nutrients in a highly saline soil. *Bioresource Technology*, 99(2):396–403, 2008. URL https://doi.org/10.1016/j.biortech.2006.12.006.

[11] V. N. L. Wong, R. C. Dalal, and R. S. B. Greene. Carbon dynamics of sodic and saline soils following gypsum and organic material additions: A laboratory incubation. *Applied Soil Ecology*, 41(1):29–40, 2009. URL https://doi.org/10.1016/j.apsoil.2008.08.006.

[12] A. Lakhdar, M. Rabhi, T. Ghnaya, F. Montemurro, N. Jedidi, and C. Abdelly. Effectiveness of compost use in salt-affected soil. *Journal of Hazardous Materials*, 171(1-3):29–37, 2009. URL https://doi.org/10.1016/j.jhazmat.2009.05.132.

[13] M. P. Bernal, J. A. Alburquerque, and R. Moral. Composting of animal manures and chemical criteria for compost maturity assessment: A review. *Bioresource Technology*, 100(22):5444–5453, 2009. URL https://doi.org/10.1016/j.biortech.2008.11.027.

[14] M. Diacono and F. Montemurro. Long-term effects of organic amendments on soil fertility: A review. *Agronomy for Sustainable Development*, 30(2):401–422, 2010. URL https://doi.org/10.1051/agro/2009040.

[15] M. Qadir and J. D. Oster. Crop and irrigation management strategies for saline-sodic soils and waters aimed at environmentally sustainable agriculture. *Science of the Total Environment*, 323(1-3):1–19, 2004. URL https://doi.org/10.1016/j.scitotenv.2003.10.012.

[16] S. H. Hurlbert. Pseudoreplication and the Design of Ecological Field Experiments. *Ecological Monographs*, 54(2):187–211, 1984. URL https://doi.org/10.2307/1942661.

[17] M. R. Motsara and R. N. Roy. *Guide to laboratory establishment for plant nutrient analysis. FAO Fertilizer and Plant Nutrition Bulletin 19*. FAO, Rome, 2008. ISBN 978-92-5-105981-4. URL https://www.fao.org/4/i0131e/i0131e.pdf.

[18] R. Flynn and B. Leinauer. Determining Amounts of Fertilizer for Small Areas. New Mexico State University Extension Guide H-119, 2020. URL https://pubs.nmsu.edu/_h/H119/index.html.

[19] NCDA & CS Waste and Compost Analysis Methods. North Carolina Department of Agriculture & Consumer Services, Agronomic Services Division. URL https://www.ncagr.gov/ncdacs-waste-analysis-methods/open.

[20] S. A. Alkamash, R. B. Al-Nasar-allah, and B. K. Hasan. Role of Salt Ameliorant (Clean Salt) in Reducing the Effects of Salinity and Improving the Productivity of Hordeum vulgare L. *Al-Muthanna Journal for Agricultural Sciences*, 13(1):1–12, 2026. URL https://doi.org/10.52113/mjas04/13.1/40.

[21] B. Mostafazadeh-Fard, M. Heidarpour, A. Aghakhani, and M. Feizi. Effects of leaching on soil desalinization for wheat crop in an arid region. *Plant, Soil and Environment*, 54:20–29, 2008. URL https://doi.org/10.17221/2780-PSE.

[22] FAO GLOSOLAN. Standard operating procedure for saturated soil paste extract. 2021. URL https://openknowledge.fao.org/server/api/core/bitstreams/3750efd4-a162-4288-8b73-6ec8d9d1c02f/content.

[23] USDA NRCS. Kellogg Soil Survey Laboratory Methods Manual, Part One: Current Methods, saturated paste pH method 4C1a1a2. URL https://www.nrcs.usda.gov/sites/default/files/2022-10/SSIR42-v6-pt1.pdf.

[24] E. V. Maas and J. A. Poss. Salt sensitivity of wheat at various growth stages. *Irrigation Science*, 10:29–40, 1989. URL https://doi.org/10.1007/BF00266155.

[25] CIMMYT. Wheat Field Trial Data Collection Manual. International Maize and Wheat Improvement Center. URL https://www.cimmyt.org/content/uploads/2022/09/FDM_Final-2.pdf.

[26] R. Munns. Comparative physiology of salt and water stress. Plant, Cell & Environment. *Plant, Cell & Environment*, 25(2):239–250, 2002. URL https://doi.org/10.1046/j.0016-8025.2001.00808.x.

[27] R. Munns, D. P. Schachtman, and A. G. Condon. The significance of a two-phase growth response to salinity in wheat and barley. *Australian Journal of Plant Physiology*, 22(4):561–569, 1995. URL https://doi.org/10.1071/PP9950561.

[28] A. Wahid, S. Akhtar, I. Ali, and E. Rasul. Amelioration of saline-sodic soils with organic matter and their use for wheat growth. *Communications in Soil Science and Plant Analysis*, 29(15-16):2307–2318, 1998. URL https://doi.org/10.1080/00103629809370112.

[29] T. Zhang, T. Wang, K. S. Liu, L. Wang, K. Wang, and Y. Zhou. Effects of different amendments for the reclamation of coastal saline soil on soil nutrient dynamics and electrical conductivity responses. *Agricultural Water Management*, 159:115–122, 2015. URL https://doi.org/10.1016/j.agwat.2015.06.002.

[30] M. Gondek, D. C. Weindorf, C. Thiel, and G. Kleinheinz. Soluble salts in compost and their effects on soil and plants: A review. *Compost Science & Utilization*, 28(2):59–75, 2020. URL https://doi.org/10.1080/1065657X.2020.1772906.

[31] F. Gonçalo Filho, N. da Silva Dias, S. R. P. Suddarth, J. F. S. Ferreira, R. G. Anderson, C. dos Santos Fernandes, R. B. de Lira, M. F. Neto, and C. R. Cosme. Reclaiming tropical saline-sodic soils with gypsum and cow manure. *Water*, 12(1):57, 2020. URL https://doi.org/10.3390/w12010057.

[32] A. Hanay, F. Büyüksönmez, F. M. Kiziloglu, and M. Y. Canbolat. Reclamation of saline-sodic soils with gypsum and MSW compost. *Compost Science & Utilization*, 12(2):175–179, 2004. URL https://doi.org/10.1080/1065657X.2004.10702177.

[33] M. Qadir and S. Schubert. Degradation processes and nutrient constraints in sodic soils. *Land Degradation & Development*, 13(4): 275–294, 2002. URL https://doi.org/10.1002/ldr.504.

[34] Z. Ding, A. M. S. Kheir, M. G. M. Ali, O. A. M. Ali, A. I. N. Abdelaal, X. Lin, Z. Zhou, B. Wang, B. Liu, and Z. He. The integrated effect of salinity, organic amendments, phosphorus fertilizers, and deficit irrigation on soil properties, phosphorus fractionation and wheat productivity. *Scientific Reports*, 10:2736, 2020. URL https://doi.org/10.1038/s41598-020-59650-8.

[35] S. Shabala and T. A. Cuin. Potassium transport and plant salt tolerance. *Physiologia Plantarum*, 133(4):651–669, 2008. URL https://doi.org/10.1111/j.1399-3054.2007.01008.x.

[36] T. A. Cuin, S. A. Betts, R. Chalmandrier, and S. Shabala. A root's ability to retain K+ correlates with salt tolerance in wheat. *Journal of Experimental Botany*, 59(10):2697–2706, 2008. URL https://doi.org/10.1093/jxb/ern128.

[37] D. P. Schachtman and R. Munns. Sodium accumulation in leaves of Triticum species that differ in salt tolerance. *Australian Journal of Plant Physiology*, 19(3):331–340, 1992. URL https://doi.org/10.1071/PP9920331.

[38] R. Davenport, R. A. James, A. Zakrisson-Plogander, M. Tester, and R. Munns. Control of sodium transport in durum wheat. *Plant Physiology*, 137(3):807–818, 2005. URL https://doi.org/10.1104/pp.104.057307.

[39] D. L. Corwin, J. D. Rhoades, and J. Šimůnek. Leaching requirement for soil salinity control: Steady-state versus transient models. *Agricultural Water Management*, 90(3):165–180, 2007. URL https://doi.org/10.1016/j.agwat.2007.02.007.

[40] J. B. Passioura. The perils of pot experiments. *Functional Plant Biology*, 33(12):1075–1079, 2006. URL https://doi.org/10.1071/FP06223.