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A study on the effects of water quality, cultivars, organic and chemical fertilizers on potato (*Solanum tuberosum* L.) growth and yield to calculate the economic feasibility

Duraid K. A. AL-Taey[1*], Imad J. C. Al-Naely[2], Bassim H. Kshash[3]

[1,3]*Al-Qasim Green University, Faculty of Agriculture, Department of Horticulture Science, Babylon city, Al-Qasim District, 964 Iraq*
[2]*Agriculture Ministry, AL- Qadisiya Directories, Iraq*
[*]*E-mail:* duraidaltaey@gmail.com

Abstract

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A field experiment was conducted to study the effects of quality of irrigation water at two levels (1.2 and 8 $dS.m^{-1}$) as the main plot and two testing cultivars of potatoes (Burren and Arizona) as sub-plots. The fertilizer combinations from interacting the organic fertilizers and chemical fertilizers were used as sub-sub plots to study the traits of growth and yield. The tolerance level of potato to the salt stress was also assessed in the absence of salt stress experiments on potato plant in middle and southern Iraq. The study results inferred that the salinity of irrigation water caused a decrease in all the traits of vegetative growth and yield. The quality of fresh irrigation water has excelled on all studied traits. The results showed significant differences between the two cultivars (Burren and Arizona) in some of the mentioned traits. The Burren cultivar achieved the highest averages in all the traits of vegetative growth and total yield for the tubers. The combinations of fertilizers achieved significant differences where the interaction between NPK fertilizer (50%) and rice wastes got significantly excelled in most traits of the vegetative growth, especially under saline stress.

Keywords: salinity; organic matter; chemical fertilizers; oxidative stress; economic feasibility

Introduction

Potato (*Solanum tuberosum* L.) belongs to *Solanaceae* family and is considered one of the most important vegetable crops that are rich in nutrients and energy. It is also the mostly used crop that tops the list of tubers (Hassan, 1999). It ranks in fourth-order as a strategic and economic crop after wheat, corn, and rice (Bowen, 2003).The salinity-affected areas are increasing across the globe where it forms 20-50% percentage of either irrigated or rainfed agricultural land (Ruimanuel & Ricardo, 2017; AL-Taey & Saadoon, 2012). The landmass in Iraq, especially in the middle and southern areas, suffers from several problems including salinity. Close to 75% of these areas under potato cultivation are affected by salts (AL-Taey & Majid, 2018). (Al Khateeb et al., 2019) showed that presence of NaCl in reduced significantly most of the studied germination and growth characteristics (plant fresh weight, shoot length, number of leaves and roots for both *S. nigrum* and *S. lycopersicum* while Ghosh et al. (2012) mention to that total dry matter production significantly decreased with increasing salt level. The decrease of dry matter production was relatively higher in tubers than in the other parts of the plant of potato, in order to reduce the effects of salinity, organic fertilizers and chemical fertilizers of various kinds and sources are being used (Burhan & AL-Taey, 2018) and is considered one of the production inputs that contribute effectively in agricultural development and food security. This also reduces the gap between the produced quantities and imported food (Mazid et al., 2002). Rady (2012) reached to the organo-mineral fertilizer-treated plants showed increased growth, proline, chlorophyll and nutrient contents. They also revealed increased fruit yield and quality, and increased activity of antioxidant enzymes when compared to the control plants in tomato (*Solanum lycopersicum* L.).

Therefore, the study aims to reduce the effect of salinity on growth and yield of potato plants using organic and chemical fertilizers and leverage the best from using drainage water with good irrigation management system.

Materials and Methods

This experiment was conducted during the autumn season 2018 in the field of one farmer in Al-Sannia district, Diwaniyah province, 20 km north of Diwaniyah city, Iraq. Soil samples were taken from the surface layer at a depth of (0-30 cm) to study some physical and chemical traits before starting the cultivating as shown in Table 1.

Table 1. The physical and chemical properties for the field soil

Type of analysis	Results
T.D.S ppm	700
EC (1:1) dc/m	1.2
PH	7.4
$CaSO_4.H_2O$. Meg/L	1
$CaCO_3$ %	27.5
N %	0.24
P ppm	0.7
K ppm	2.6
O.M. %	4.8
Texture	Silt loam

The land was prepared for cultivation by conducting the plowing with moldboard plows, two perpendicular plowings to a depth of about 30 cm. The soil was smoothed and leveled. Moreover, the land was divided into sections and plots with an area of 3 m^2 (2 × 1.5 m).

Seeds for the two common cultivars (Burren and Arizona) class A were obtained from refrigerated storages for Nahar Al-Awrad Company from the yield of the previous spring season 2018, which was cultivated with E class and stored at 4°C. These two cultivars are from Dutch cultivars produced by the Dutch company (Agrico). Seeds were received before 15 days from cultivating and stored in a shading place at room temperature until growing for the purpose of stimulating tubers on Sprouting before cultivating (Wanted et al., 1989). The tubers adopted with the size of (35-55 mm), the experimental unit included one furrow with a length of 2 m consists of two lines of cultivation, the distance between them 0.75 m. The area of the experimental unit was 3 m^2 with leaving a distance of 0.50 m between the experimental units for fertilizer treatments and 1 m between the quality irrigation water as well as a distance of 1 m between the plots.

The potato tubers have been treated before cultivating with fungicide (Super Bravo 75% SC) for 5 min and then cultivated on both sides of the furrow by making an incision with a depth of (10 to 15 cm) in the top of the furrow on 16/9/2018. The tubers were placed inside the incision and the distance between tuber and another was 0.25 m. The tubers were then covered with soil. The orientation of the furrow was (east-west). The number of cultivated tubers in each line from the furrow was 8 tubers, so the experimental unit contained 16 tubers per experimental unit.

The research was conducted using Split-Split- Plot Design according to The Randomized Complete Block Design (RCBD). The experiment included three factors. The quality of irrigation water was the Main Plots, while, the cultivar was the Sub-Plots. The chemical and organic fertilizers are the Sub-Sub-Plots, it included the following treatments: T1: The control treatment without using organic and chemical fertilizers, T2: Treatment of chemical fertilizer (N, P, K 100%) according to the recommended dose, T3: Compost treatment (rice wastes) only, T4: Compost treatment (rice wastes + chemical fertilizer (N, P, K) 50% of the recommended dose. T5, Compost treatment (rice wastes + chemical fertilizer (N, P, K) 25% of the recommended dose

Thus, the number of treatments (20) treatment (2 × 2 × 5), with three replicates, so the total of experimental units is becoming (60 units). The averages were compared with the least significant difference (LSD) at 0.5% (Al-Rawi & Khalaf Allah, 2000). Plant height (cm), the number of aerial stems, the percentage of chlorophyll in leaves: it was measured by spectrophotometer with (663 nm and 645 nm wavelengths) (Gianquinto et al., 2004) and measured in SPAD units (Jemison & Williams, 2006), the leaf area for the plant ($cm^2.plant^{-1}$), Percentage of dry matter in the leaves and total yield ($tons.ha^{-1}$) were recorded.

Results and Discussion

Plant height (cm)

Table 2 shows significant differences in the average plant height between two qualities of irrigation water. The treatment irrigated with freshwater (1.2 $dS.m^{-1}$) achieved the highest average amounted to (57.07 cm) compared to the treatment irrigated with drainage water (8 $dS.m^{-1}$) which achieved the lowest average i.e., 45.97 cm. There were also significant differences between the two cultivars i.e., the Burren cultivar (C1) yielded the highest average for plant height amounted to (55.34 cm) compared to Arizona cultivar (C2) which yielded the lowest average for plant height i.e., 47.70 cm). With regards to the fertilizer combinations, a significant increase in plant height was achieved i.e., the T4 treatment (rice wastes+ 50% NPK) significantly excelled on all treatments through yielding the highest average plant height amounted to (57.92 cm) compared to the control treatment that yielded the lowest average plant height amounted to (44.00 cm). The triple interaction in Table 3 shows significant differences between the treatments, where the W.Q1 C1 T4 treatment achieved an average of 69.00 cm when irrigated with fresh water. When irrigated with drainage water, the W.Q1 C2 T1 treatment achieved the lowest average amounted to (44.33 cm) compared to the control treatment.

Number of aerial stems

Table 2 shows the significant differences between the two qualities of irrigation water in the number of aerial stems, where the treatments irrigated with freshwater (1.2 $dS.m^{-1}$) excelled compared to the treatments irrigated with drainage water (8 $dS.m^{-1}$) which achieved the average of (4.132, 3.056 $stems.plant^{-1}$), respectively. It was also observed that there were significant differences between the two cultivars, where the Arizona cultivar (C2) excelled through an average 4.321 $stems.plant^{-1}$compared to the Burren cultivar (C1) which yielded the lowest average amounted to (2.866 $stems.plant^{-1}$).With regards to the fertilizer combinations, there were significant differences observed between the treatments, where the T4 treatment (rice wastes + 50% NPK) significantly excelled providing the highest average number of aerial stems amounted to (4.554 $stems.plant^{-1}$) on all treatments while the control treatment achieved the lowest average amounted to (2.666 $stems.plant^{-1}$). The triple interaction in Table 3 shows the significant differences between the treatments i.e., W.Q1C2T4 treatment achieved the highest average amounted to (7.441 $stems.plant^{-1}$) while the W.Q1C1T1 treatment achieved the lowest average amounted to (2.222 $stems.plant^{-1}$) in case of irrigating with freshwater. With irrigation using drainage water, it was observed that the W.Q2C2T2 treatment excelled through its highest average that amounted to (4.667 $stems.plant^{-1}$), which did not differ from the W.Q2C2T3 treatment i.e., the average value was (4.444 $stems.plant^{-1}$), while the control treatment (W.Q2C1T1) achieved the lowest average amounted to (1.889 $stems.plant^{-1}$).

Percentage of chlorophyll in leaves

Table 2 showed significant differences in the percentage of chlorophyll in leaves between the two qualities of irrigation water. The treatment irrigated with fresh water (1.2 $dS.m^{-1}$) produced the highest average (36.33 SPAD units) compared to the treatment irrigated with drainage water (8 $dS.m^{-1}$) (33.51 SPAD units). It was also observed that there were significant differences between the two cultivars, where the Burren Arizona cultivar (C1) excelled through an average production of (40.09 SPAD units) compared

Table 2. Effect of the quality of irrigation water, cultivar, organic fertilizers on some vegetative and yield parameters.

Treatments	Plant height cm	Number of stems	Percentage of chlorophyll in leaves (spad)	Leaf Area cm^2	Percentage of dry matter in leaves %	The average weight of the marketable tuber (gm)	The total yield $ton.ha^{-1}$
WQ1	57.07	4.132	36.33	4423	10.663	161.8	28.98
WQ2	45.97	3.056	33.51	3795	9.274	125.0	21.18
LSD (0.05)	1.668	0.2533	2.577	373.8	0.7055	4.55	4.370
CV1	55.34	2.866	40.09	4694	10.457	166.4	27.66
CV2	47.70	4.321	29.75	3523	9.479	120.4	22.51
LSD (0.05)	2.470	0.4582	1.416	454.4	0.8251	13.86	2.332
T1	44.00	2.666	32.25	2355	8.704	115.8	19.93
T2	53.24	3.722	35.97	4303	10.513	150.3	25.31
T3	51.20	3.833	34.77	4258	9.733	140.6	24.20
T4	57.92	4.554	37.09	5346	10.980	170.0	30.78
T5	51.25	3.194	34.53	4282	9.910	140.0	25.19
LSD (0.05)	1.949	0.4249	1.205	316.1	0.5531	13.17	2.489

Table 3. Triple interaction among the quality of irrigation water, cultivar, organic fertilizers on some vegetative and yield parameters.

Treatments	Plant height cm	Number of stems	Percentage of chlorophyll in leaves (spad)	Leaf Area cm^2	Percentage of dry matter in leaves %	The average weight of the marketable tuber (gm)	The total yield $ton.ha^{-1}$
W1C1T1	53.44	2.222	39.73	3220	9.453	143.2	25.62
W1C1T2	61.07	3.556	43.76	5874	11.307	223.7	38.37
W1C1T3	59.60	3.111	42.05	5339	10.840	172.1	28.06
W1C1T4	69.00	4.442	44.63	7477	13.040	224.2	44.54
W1C1T5	62.22	3.222	40.25	4300	10.960	170.2	27.78
W1C2T1	44.33	3.888	28.91	2223	9.653	109.1	20.22
W1C2T2	56.33	4.220	29.45	3633	11.693	136.4	25.44
W1C2T3	52.33	5.443	30.14	4281	9.053	128.2	23.55
W1C2T4	61.66	7.441	35.40	4376	10.533	163.0	29.62
W1C2T5	50.77	3.778	28.99	3505	10.093	147.6	26.64
W2C1T1	43.55	1.889	35.36	2339	8.053	115.6	17.84
W2C1T2	53.33	2.444	40.42	3420	10.307	138.6	21.15
W2C1T3	49.44	2.333	37.37	3920	9.747	154.2	23.24
W2C1T4	55.15	3.111	37.53	5529	10.893	185.5	26.59
W2C1T5	46.66	2.333	39.82	5526	9.973	136.5	23.43
W2C2T1	34.66	2.667	24.99	1639	7.657	95.3	16.05
W2C2T2	42.22	4.667	30.26	4285	8.747	102.8	16.28
W2C2T3	43.44	4.444	29.54	3491	9.293	108.1	21.94
W2C2T4	45.89	3.222	30.82	4001	9.453	107.3	22.38
W2C2T5	45.33	3.444	29.04	3796	8.613	105.9	22.93
LSD(0.05)	3.997	0.8358	2.715	680.3	1.2095	25.65	5.206

to the Arizona cultivar (C2) in which the lowest average production (29.75 SPAD units) was achieved. With regards to the fertilizer combinations, significant differences were observed between the treatments i.e., T4 treatment (rice wastes + 50% NPK) significantly excelled through highest percentage of chlorophyll in leaves amounted to (37.09 SPAD units) which did not significantly differ from the T2 treatment (100% NPK) that resulted in the average value (35.97 SPAD units). However, the control treatment produced the lowest average amounted to (32.25 SPAD units). The triple interaction between the studied factors, shown in Table 3, explained that the W.Q1C1T4 treatment excelled through the highest average amounted to (44.63 SPAD units), which did not significantly differ from the treatments (W.Q1C1T2, W.Q1C1T3), which gave an average amounted to (43.76, 42.05 SPAD units), respectively. The W.Q1C2T1 treatment achieved the lowest average amounted to (28.91 SPAD units) when irrigating with freshwater. In case of irrigation using drainage water, it was observed that the W.Q2C1T2 treatment excelled through producing the highest average amounted to (40.42 SPAD units), compared to W.Q2C2T1 treatment, which gave the lowest average amounted to (24.99 SPAD units).

Leaf Area ($cm^2.plant^{-1}$)

Table 2 shows significant differences between the two qualities of irrigation water in the average leaf area, where the treatment irrigated with freshwater (1.2 $dS.m^{-1}$) excelled compared to the treatment irrigated with drainage water (8 $dS.m^{-1}$) and their average values was 4413 and 3795 $cm^2.plant^{-1}$ respectively. It was also observed that there were significant differences between the two cultivars, where the Burren cultivar (C1) excelled through an average value of 4694 $cm^2.plant^{-1}$compared to the Arizona cultivar (C2), which achieved the lowest average amounted to (5323 $cm^2.plant^{-1}$). With regards to fertilizer combinations, significant differences were observed between the treatments, where the T4 treatment (rice wastes + 50% NPK) significantly excelled through highest average leaf area amounted to (5346 $cm^2.plant^{-1}$) while the control treatment produced the lowest average amounted to (2355 $cm^2.plant^{-1}$). The triple interaction between the studied factors in Table 3 showed significant excellence in W.Q1C1T4 treatment through producing the highest average amounted to (7477 $cm^2.plant^{-1}$). The W.Q1C2T1 treatment gave the lowest average amounted to (2223 $cm^2.plant^{-1}$ when irrigating with freshwater. In case of irrigation with drainage water, it was observed that the

W.Q2C1T4 treatment excelled through producing the highest average amounted to (5529 $cm^2.plant^{-1}$) and this did not differ from the W.Q2C1T5 treatment which gave an average amounted to (5526 $cm^2.plant^{-1}$). The W.Q2C1T1 treatment achieved the lowest average amounted to (1639 $cm^2.plant^{-1}$).

Percentage of dry matter in leaves

Table 2 showed significant differences between the two qualities of irrigation water in the percentage of dry matter in leaves. The treatment irrigated with fresh water (1.2 $dS.m^{-1}$) achieved the highest average amounted to (10.663 %) compared to the treatment irrigated with drainage water (8 $dS.m^{-1}$) which produced the lowest average amounted to (9.274 %). It was also observed that there were significant differences between the two cultivars where the Burren cultivar (C1) excelled through an average value of (10.457 %) compared to the Arizona cultivar (C2), which produced the lowest average amounted to (9.479 %). With regards to fertilizer combinations, significant differences were observed between the treatments, where the T4 treatment (rice wastes + 50% NPK) significantly excelled through the highest percentage of dry matter amounted to (10.980 %) which did not significantly differ from the T2 treatment (100% NPK) which produced an average value of (10.513 %) while the control treatment yielded the lowest average amounted to (8.554 %). The triple interaction between the studied factors in Table 3 showed significant excellence in case of W.Q1C1T4 treatment since it produced the highest average amounted to (13.040 %). The W.Q1C2T1 treatment produced the lowest average amounted to (9.053 %) and this is in case when irrigating with freshwater. In case of irrigation with drainage water, it was observed that the W.Q2C1T4 treatment excelled through the highest average amounted to (10.893 %) compared to the control treatment (W.Q2C1T1) which achieved the lowest average amounted to (7.657 %).

Average weight of the marketable yield

Table 2 showed significant differences between the two qualities of irrigation water in the average weight of the marketable tuber. The treatment irrigated with freshwater (1.2 $dS.m^{-1}$) excelled through the highest average weight of the marketable tuber amounted to (161.8 g) compared to the treatment irrigated with drainage water (8 $dS.m^{-1}$) which achieved the lowest average amounted to (125.0 g). It was also observed that there were significant differences between the two cultivars, where the Burren cultivar (C1) excelled through an average amount up to (166.4 g) compared to the Arizona cultivar (C2), which gave the lowest average amounted to (120.4 g).With regards to fertilizer combinations, significant differences were observed between the treatments, where the T4 treatment (rice wastes + 50% NPK) significantly excelled on all the treatments, achieving the highest average weight of the marketable tuber per plant amounting to (170.0 g). The T1 treatment achieved the lowest average weight of the marketable tuber amounting to (115.8 g). The triple interaction between the studied factors in Table 3 showed significant excellence in case of W.Q1C1T4 treatment through highest average amounted to (224.2 g). However, it did not differ significantly from the W.Q1C1T2 treatment, which produced an average value, amounted to (223.7 g). The lowest average recorded by the W.Q1C2T1 treatment amounted to (109.1 g) in case of irrigating with freshwater. In case of irrigation with drainage water, it was observed that the W.Q2C1T4 treatment excelled on all treatments through its highest average amounted to (185.5 g) compared to the control treatment (W.Q2C1T1) which gave the lowest average amounted to (95.3 g).

Total yield ($tons.ha^{-1}$)

Table 2 showed significant differences between the two qualities of irrigation water in the total yield , where the treatments irrigated with freshwater (1.2 $dS.m^{-1}$) excelled by producing the highest average of total yield amounted to (28.98 $tons.ha^{-1}$) compared to the treatments irrigated with drainage water (8 $dS.m^{-1}$) which achieved the lowest average amounted to (21.18 $tons.ha^{-1}$). It was also observed that there were significant differences between the two cultivars, where the Burren cultivar (C1) excelled through an average value amounted to (27.66 $tons.ha^{-1}$) compared to the Arizona cultivar (C2), which achieved the lowest average amounted to (22.51 $tons.ha^{-1}$).With regards to fertilizer combinations, significant differences were observed between the treatments, where the T4 treatment (rice wastes + 50% NPK) significantly excelled on all the treatments, achieving the highest average of total yield amounted to (30.78 $tons.ha^{-1}$). The T1 treatment achieved the lowest average of total yield for tubers amounted to (19.93 $tons.ha^{-1}$). The triple interaction between the studied factors in Table 3 showed significant excellence in case of W.Q1C1T4 treatment on all treatments since it produced the highest average amounted to (44.54 $tons.ha^{-1}$). However, the lowest average recorded by the W.Q2C1T4 treatment amounted to (20.22 $tons.ha^{-1}$) when irrigating with freshwater. In case of irrigation with drainage water, it was observed that the W.Q2C1T4 treatment excelled on all treatments through highest average amounted to (26.59 $tons.ha^{-1}$) compared to the control treatment (W.Q2C2T1) which gave the lowest average amounted to (16.05 $tons.ha^{-1}$).

The results indicate that there is a significant reducing in vegetative growth indicators when using saline water in comparison with fresh water. This may be due to osmotic effect resulting from the increased salt in the soil. This eventually leads to lack of water absorption by the plant, which in turn lack of nutrient that reflects negatively on cellular metabolic processes, bioactivities within the cell and accordingly the photosynthesis and respiration processes (Golezani et al., 2011; AL-Taey & Saadoon, 2014). This was also confirmed by studies conducted earlier (Eraslan et al., 2008) The osmotic pressure increases with increasing salinity and it is known that the increase in the osmotic pressure of the solution results in decreased water potential, which hinders the transmission of water through root system. This negatively affects the traits of vegetative growth. On the other hand, this decrease may be due to the accumulation of sodium and chloride ions to the level of toxicity, causing inactivation of the meristem tissue and inhibition of cell division and elongation (Sakr et al., 2007). This affects the traits of vegetative growth reducing the plant height, number of aerial stems, leaf area, and percentage of dry matter and ultimately the amount of yield. These results are in alignment with Golezani et al. (2011).

Further, the average weight of the marketable yield and the total yield reduced with elevation of saline water which is possibly due to the direct salinity effect or indirect effect like osmotic effect. In addition to the low percentage of total chlorophyll due to the inhibition of the growth hormones, there may be an increase in growth inhibitors which would've reduced the rate of photosynthesis and production of carbohydrates stored in tubers. This might be a reason for the reduced size and weight of tubers affecting the total yield since this factor depends on the weight and volume of formed tubers (Al-Hamdani & Mohammed, 2014). It was also noted that there were significant differences between the cultivars in vegetative and quantitative traits. This may be due to genetic differences between the cultivars caused by the variation in genetic factors responsible for vegetative growth traits (Sagt, 2013). Fertilizer combinations significantly affected the outcomes i.e., T4 treatment (rice wastes+ 50%NPK) excelled through producing the highest averages in the traits of vegetative growth and it did not differ significantly from the T2 treatment which included 100% NPK fertilizer in terms of percentage of chlorophyll and dry matter in leaves. Further, the fertilizer treatment T4 (rice wastes+ 50% NPK) excelled in the traits of quantitative yield including average weight of the marketable tuber and total yield . This may be due to the fact that the addition of organic and chemical fertilizers led to increased nutrients availability for plant (NPK) as well as amino acids. These factors play an important role in the growth of the plant and improve the chemical properties of the soil that got positively reflected in the increased vegetative growth and yield (Alabi, 2006; Khalaf, 2010). These results are in alignment with (Ouda & Mahadeen, 2008) that the usage of fertilizers (organic fertilizer + mineral fertilizer) significantly increases the vegetative growth by increasing the number of leaves and the chlorophyll content of leaves.

Conclusion

The saline water led to reduce the yield with reduction ratio 27% , Burren cultivar achieved the best values compared with Arizona cultivar while the best treatment combination was T4 (Rice wastes + 50% chemical fertilizer) specially in the total yield which achieved 30 tons.ha^{-1} .

The treatments which irrigated with 1.2 dS.m^{-1} achieved highest results in total and marketable yield with T2 and T4 combinations which planting with the Burren cultivar while the T4 and T5 combinations achieved the best results which planting with Arizona cultivar.

In the case of saline water (8 dS.m^{-1}) the best results achieved at the T4 combinations in the Burren cultivar while the T3, T4 and T5 combinations recorded the best the results in the case of Arizona cultivar, Finally the Burren cultivar was more tolerant to the Saline water compare with Arizona cultivar, and response to the compost of rice wastes more than Arizona cultivar.

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