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Improving Potato Plant Growth and Marketable Yield by Magnetized Irrigation Water and Spraying with Jasmonic Acid

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Abstract

A field experiment was conducted for two consecutive spring seasons 2023-2024 in a private field in Al-Mahawil District (45 km) north of Babil Governorate to study the response of the potato plant, Synergy variety, to irrigation water type (River or drainage) treated magnetically and sprayed with jasmonic acid and the extent of the effect of the treatments on potato growth and productivity. The experiment was a Split-Split Plot Design, R.C.B.D, 24 treatments with three replicates and 72 experimental units. Irrigation water quality (river or drainage) took the main plot, magnetization levels (1500 Gauss with contact path 38.5 cm^2 * 1, 2, or 3 K) in sub plot and spraying with jasmonic acid (0, 15, 30) $mg.L^{-1}$ was in sub-sub plot. The results of the experiment showed that river water at a level of 1.47 ds m^{-1} was significantly higher than drainage water in all studied characteristics. The positive effect also increased in magnetized water with contact path 38.5 cm^2 * 3. A similar effect was recorded with spraying with jasmonic acid especially at a concentration of 30 mgL^{-1} compared to treatments sprayed at a lower concentration or control. The results showed that the interaction of river water 1.47 ds m^{-1} magnetized with a contact path of 38.5*3 cm^2 and spraying with jasmonic acid 30 mg L^{-1} recorded the highest values in the number of aerial stems, number of leaves, total leaf area, and shoot dry weight compared to other treatments. The same treatment led to the highest marketable yield (33.24 and 37.48) tons ha^{-1} for both seasons respectively, with a significant difference from the control which recorded (11.84 and 13.24) tons ha^{-1}.

Keywords:

Irrigation, fertilization, field crops, growth regulator, solanum.

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Introduction

Potato *Solanum tuberosum* L. is a vegetable crop belonging to the Solanum family. Potato is widely cultivated in the world because it is a strategic vegetable crop with high economic value. The plant is relatively sensitive to stress, especially water stress, which may cause a 79% reduction in productivity in the absence of its water requirements (Luitel et al., 2015). China is the world's largest producer of potatoes with about 99.12 million tons per year, followed by India with 43.77 million tons per year (FAO, 2019). Iraq's potato production is about 270,591 thousand tons per year (Annual Statistical Abstract, 2023).

Soil salinity is one of the main causes facing agriculture in arid and semi-arid lands (Plaut et al., 2013). Therefore, the optimal use of water resources is done through qualitative analysis of water and its evaluation to meet agricultural needs (Alipoura et al., 2016). In light of the severe shortage of water resources worldwide, and to reduce dependence on traditional water sources, attention has turned to non-traditional saline water sources such as sewage, groundwater and drainage water for use in various agricultural and industrial fields (Hamoudi, 2013). Therefore, water is often treated before being used for agricultural purposes, and one of these processes is water treatment by magnetization (Monica Nandini, 2024). The magnetization process is accompanied by a set of changes in the chemical and physical properties of water, including reducing surface tension and viscosity, increasing water polarity and the number of molecules making up a water droplet by breaking down the hydrogen bonds that connect the molecules.

On the other hand, Jasmonic acid $C_{12}H_{18}O_3$ is one of the growth regulators that was first isolated from the fungus Lasiodipiodia obromae and increased interest in it as one of the derivatives of jasmonic MeJA MethyI Jasmonic due to its aromatic smell. It was extracted from the essential oils of white jasmine and rosemary plants, and Linolenic acid is considered the raw material for the production of jasmonic naturally in plastids and peroxisoma inside the plant (Taiz & Zeiger, 2006). Jasmonic acid is classified as a growth hormone that has a beneficial effect on plant growth and development (Sirhindi et al., 2016). Therefore, the study aimed to determine the effect of magnetically treated water with a flux of 1500 Kwh according to different water contact paths in the presence of vegetative spraying with jasmonic acid on the growth and characteristics of the potato crop, Synergy variety, and its role in reducing salt stress in the potato crop sensitive to salinity (Nandy & Dubey, 2024; Nahir, 2016).

Materials and Methods

The study was conducted as a field experiment for two consecutive spring seasons 2023-2024, starting in January in one of the fields of Al-Azzawiyah area/Al-Mahawil district, 45 km north of Babylon Governorate. The response of the potato plant, Synergy variety, to the quality of magnetically treated irrigation water and spraying with jasmonic acid was studied in some growth and productivity indicators (Bekri et al., 2023). The experiment included 24 treatments distributed according to the Split Split Plot Design system according to (R.C.B.D) with three replicates, 72 experimental units (Ramakrishnan et al., 2022). Irrigation water quality (River W1 and Drainage W2) in Main plot, magnetization treatments of sub plot (M) included irrigation with normal water M0 or magnetically treated water with a flux intensity of 1500Gauss with a contact path of 38.5 cm^2 once (M1) or twice (*2) M2 or tripled (*3) M3, while spraying with jasmonic acid was applied in sub plot using Jasmonic acid (S) at three concentrations 0, 15, or 30 mg L^{-1}, S0, S1, and S2, respectively.

Table 1. Some chemical and physical properties of the experimental soil before planting

Character/measurement		2023 Season	2024 Season	unit
Ph		7.33	7.12	-----
EC		1.9	2.7	$ds.m^{-1}$
OM		0.63	0.69	%
N		35.0	31.7	$mg\ Kg^{-1}$
P		3.46	3.15	
K		30.0	33.9	
Bulk density		1.33	1.35	$g\ cm^3$
Soil texture	Sand	520	525	$g\ Kg^{-1}$
	Silt	388	380	
	Clay	92	95	

Table 2. The quality characteristics of irrigation water used in the study

Water Type	EC $ds.m^{-1}$	pH	Dissolved ions							
			Na^+ mg/L	K^+ mg/L	SO_4^- mg/L	Cl^- mg/L	CO_3^- mg/L	HCO_3^- mg/L	Mg^{++} mg/L	Ca^{++} mg/L
River	1.2ds/m	7.97	7.66	0.21	3.13	3.80	Nill	1.50	0.14	0.42
Drainage	4.5ds/m	7.78	25.79	0.31	6.27	19.00	Nill	2.30	0.41	1.25

Indicators Under Study

The data of vegetative growth indicators were taken for five random plants from each experimental unit. The measurements included the number of main aerial stems (plant $stem^{-1}$), the number of total leaves (plant $leaf^{-1}$), the total leaf area of the plant (dm^2 $plant^{-1}$) based on the method of and described (Sadik et al., 2011) using a scanner and the Digimizer program loaded on the computer. The dry weight of the vegetative group (g $plant^{-1}$) was also calculated (Hocking et al., 1997). The marketable yield (ton ha^{-1}) was also estimated where the number of marketable tubers (tuber $plant^{-1}$) was calculated after excluding infected, deformed and small tubers. The marketable yield of the experimental unit from tubers was calculated and then attributed to the hectare.

$$\textit{Markitable yield} = \frac{\text{experiment unit yield (Ton)} \times 10000\text{m}^2}{\textit{Experiental unit area}(\text{m}^2)}$$

Results and Discussion

It was noted from the results that the quality of irrigation water significantly affected all vegetative growth traits and total yield. River water with EC level of 1.47 ds m^{-1} significantly outperformed the trait (number of aerial stems Table 1, number of leaves Table 2, total leaf area Table 3, dry weight of vegetative mass Table 4 and total yield Table 5 which recorded values of 2.98 and 3.28 stem $plant^{-1}$), 60.54) and 67.72 $plant^{-1}$ leaf), 2893.3) and 3291.4 cm^2. $plant^{-1}$), (60.27 and 61.41 gm $plant^{-1}$), (25.33 and 28.68 $tons.ha^{-1}$) for both seasons respectively compared to drainage water with EC level of 5.70 ds m^{-1} which recorded significantly lower values (1.58 and 1.73 plant $stem^{-1}$), (38.66 and 43.65 $plant^{-1}$ leaf), (1284.6 and 1569.1 $cm^2.plant^{-1}$), (41.52 and 42.18 gm $plant^{-1}$), (18.54 and 21.01 $tons.ha^{-1}$) for both quarterly seasons respectively (Attia, 2006).

Table 3. Response of number of main aerial stems (plant stem^{-1}) in potato plants to water quality, water magnetizing, and foliar spray with Jasmonic acid for two growing seasons

Irrigation water quality	Magnetizing Water treatments	Growing season 2023					Growing season 2024				
		Jasmonic acid			W*M	W	Jasmonic acid			W*M	W
		S0	S1	S2			S0	S1	S2		
River	M0	2.53	2.59	2.66	2.59	2.98	2.78	2.84	2.93	2.85	3.28
	M1	2.70	2.74	2.78	2.74		2.96	3.01	3.06	3.01	
	M2	2.89	2.98	3.11	3.00		3.18	3.28	3.42	3.30	
	M3	3.42	3.53	3.80	3.58		3.76	3.88	4.17	3.94	
Drainage	M0	1.12	1.17	1.21	1.17	1.58	1.23	1.28	1.33	1.28	1.73
	M1	1.27	1.34	1.47	1.36		1.39	1.48	1.62	1.50	
	M2	1.61	1.74	1.84	1.73		1.77	1.91	2.02	1.90	
	M3	1.91	2.06	2.19	2.05		2.11	2.26	2.41	2.26	
	Average	2.18	2.27	2.38			2.40	2.49	2.62		
L.S.D. (P≤0.05)		W= 0.35, S= 0.01, M= 0.05, M*S= 0.05, W*S= 0.35, W*M= 0.30, W*M*S= 0.30					W= 0.38, S= 0.01, M= 0.05, M*S= 0.06, W*S= 0.38, W*M= 0.33, W*M*S= 0.33				

The magnetically treated water with a contact path doubled M3 times was also the highest significantly in increasing all study indicators for both seasons respectively (1.88 and 2.07 plant stem^{-1}) and (33.97 and 38.46 plant^{-1} leaf) and (1231.9 and 1413.4 cm^{2}.plant^{-1}) and (34.91 and 35.62 gm plant^{-1}) and (16.87 and 19.09 tons ha^{-1}) for both spring seasons respectively with significant differences from the control treatment treated with normal water. On the other hand, it was found that spraying with jasmonic acid, especially at the highest concentration, spraying treatment 30 mg L^{-1}, had a higher effect than the rest of the treatments, recording (2.38 and 2.62 plant stem^{-1}), (53.06 and 59.51 plant^{-1} leaf), (2300.0 and 2669.4 cm2.plant^{-1}), (54.98 and 55.95 gm plant^{-1}), and (23.22 and 26.27 tons ha^{-1}) for both seasons, respectively, compared to the spraying treatment with distilled water with the lowest values (2.18 and 2.40 plant stem^{-1}), (46.34 and 52.11 plant^{-1} leaf), (1890.7 and 2205.7 cm^{2}.plant^{-1}), and (47.23 and 48.16 gm plant^{-1}). (20.67 and 23.33 tons ha^{-1}) for both seasons respectively.

Table 4. Response of number of leaf (leaf plant^{-1}) in potato plants to water quality, water magnetizing, and foliar spray with Jasmonic acid for two growing seasons

Irrigation water quality	Magnetizing Water treatments	Growing season 2023					Growing season 2024				
		Jasmonic acid			W*M	W	Jasmonic acid			W*M	W
		S0	S1	S2			S0	S1	S2		
River	M0	40.35	44.20	47.32	43.96	60.54	35.32	49.85	53.38	49.52	67.72
	M1	51.53	45.73	85.21	54.82		58.00	60.89	65.01	61.30	
	M2	62.58	66.12	70.34	66.35		70.16	73.94	78.57	74.22	
	M3	73.55	76.41	81.10	77.02		82.08	85.26	90.21	85.85	
Drainage	M0	20.52	23.61	27.79	23.97	38.66	23.56	26.96	31.70	27.41	43.65
	M1	31.52	34.17	38.19	34.63		35.90	38.59	43/26	39.25	
	M2	41.32	43.66	46.11	43.70		46.48	49.26	51.91	49.21	
	M3	49.31	52.34	55.41	52.35		55.36	58.80	62.00	58.72	
	Average	46.34	49.41	53.06			52.11	55.44	59.51		
L.S.D. (P≤0.05)		W= 5.43, S= 0.20, M= 1.67, M*S= 1.69, W*S= 5.37, W*M= 4.16, W*M*S= 4.14					W= 5.98, S= 0.22, M= 1.84, M*S= 1.68, W*S= 5.91, W*M= 4.57, W*M*S= 4.56				

In general, it was noted that the interaction of the three factors under study had the highest significant effect in increasing growth indicators and yield, as treatment W1M3S2 recorded the highest values of number of aerial stems Table 1, number of leaves Table 2, total leaf area dry Table 3.

Table 5. Response of leaf area (cm^2 $plant^{-1}$) in potato plants to water quality, water magnetizing, and foliar spray with Jasmonic acid for two growing seasons

Irrigation water quality	Magnetizing Water treatments	Growing season 2023					Growing season 2024				
		Jasmonic acid			W*M	W	Jasmonic acid			W*M	W
		S0	S1	S2			S0	S1	S2		
River	M0	1626.5	1811.3	1994.5	1810.8	2893.3	1840.4	2064.8	2271.9	2059.0	3291.4
	M1	2248.2	2449.2	2667.8	2455.1		2546.8	2729.7	2998.3	2785.2	
	M2	2957.1	3184.3	3462.8	3201.4		3355.1	3646.7	3978.8	3660.2	
	M3	3717.2	4065.8	4535.1	4106.1		4298.5	4666.3	5099.6	4688.1	
Drainage	M0	538.3	644.8	775.9	653.0	1284.6	622.7	750.8	929.8	767.8	1569.1
	M1	937.7	1059.9	1189.6	1062.4		1107.5	1251.9	1499.4	1286.3	
	M2	1341.2	1470.0	1584.3	1465.2		1690.5	1826.6	1991.3	1836.1	
	M3	1758.9	1925.1	2189.8	1957.9		2184.0	2388.5	2586.6	2386.4	
	Average	**1890.7**	**2076.3**	**2300.0**			**2205.7**	**2415.7**	**2669.4**		
L.S.D. (P≤0.05)		W= 399.6, S= 13.19, M= 100.95, M*S= 102.45, W*S= 396.02, W*M= 312.61, W*M*S= 310.56					W= 427.8, S= 14.44, M= 118.80, M*S= 120.33, W*S= 423.81, W*M= 330.22, W*M*S= 328.67				

Table 6. Response of shoot dry weight (g $plant^{-1}$) in potato plants to water quality, water magnetizing, and foliar spray with Jasmonic acid for two growing seasons

Irrigation water quality	Magnetizing Water treatments	Growing season 2023					Growing season 2024				
		Jasmonic acid			W*M	W	Jasmonic acid			W*M	W
		S0	S1	S2			S0	S1	S2		
River	M0	40.15	42.22	48.61	43.66	60.27	40.56	43.26	49.36	44.39	61.41
	M1	50.34	53.64	59.85	54.61		51.42	54.54	60.73	55.56	
	M2	62.67	65.16	71.19	66.34		63.87	66.38	72.05	67.43	
	M3	73.87	67.34	79.17	76.46		75.12	78.34	81.26	78.24	
Drainage	M0	23.21	25.78	29.46	26.15	41.52	23.76	26.68	30.09	26.84	42.18
	M1	33.12	36.87	39.76	36.58		34.27	37.49	40.51	37.42	
	M2	42.91	45.17	48.35	45.48		43.81	46.18	49.35	46.45	
	M3	51.53	85.61	63.42	57.85		52.44	57.34	64.25	85.01	
	Average	**47.23**	**50.47**	**54.98**			**48.16**	**51.28**	**55.95**		
L.S.D. (P≤0.05)		W= 4.66, S= 0.24, M= 1.74, M*S= 1.77, W*S= 4.56, W*M= 3.58, W*M*S= 3.58					W= 4.78, S= 0.24, M= 1.76, M*S= 1.79, W*S= 4.24, W*M= 3.66, W*M*S= 3.67				

Weight of the vegetative group Table 4 and total yield with values of (3.80 and 4.17 plant $stem^{-1}$) and (81.10 and 90.21 $plant^{-1}$ leaf) and (4535.1 and 5099.6 cm2. $plant^{-1}$) and (79.17 and 81.26 gm $plant^{-1}$) and (33.24 and 37.48 tons ha^{-1}) for both seasons, respectively, compared to treatment W2M0S0, which recorded the lowest values (1.12 and 1.23 stem $plant^{-1}$) and (20.52 and 23.56 leaf $plant^{-1}$) and (538.3 and 622.7 cm^2 $plant^{-1}$), (23.21 and 23.76 g $plant^{-1}$), and (11.84 and 13.24 tons ha^{-1}) for the study indicators for both seasons, respectively. Response of shoot dry weight (g $plant^{-1}$) in potato plants to water quality, water magnetizing, and foliar spray with Jasmonic acid for two growing seasons shown in Table 6 and Response of potato marketable yield (ton ha^{-1}) in potato plants to water quality, water magnetizing, and foliar spray with Jasmonic acid for two growing seasons shown in Table 7.

Table 7. Response of potato marketable yield (ton ha^{-1}) in potato plants to water quality, water magnetizing, and foliar spray with Jasmonic acid for two growing seasons

Irrigation water quality	Magnetizing Water treatments	Growing season 2023					Growing season 2024				
		Jasmonic acid			W*M	W	Jasmonic acid			W*M	W
		S0	S1	S2			S0	S1	S2		
River	M0	19	2.59	2.66	2.59	2.98	2.78	2.84	2.93	2.85	3.28
	M1	2.70	2.74	2.78	2.74		2.96	3.01	3.06	3.01	
	M2	2.89	2.98	3.11	3.00		3.18	3.28	3.42	3.30	
	M3	3.42	3.53	3.80	3.58		3.76	3.88	4.17	3.94	
Drainage	M0	1.12	1.17	1.21	1.17	1.58	1.23	1.28	1.33	1.28	1.73
	M1	1.27	1.34	1.47	1.36		1.39	1.48	1.62	1.50	
	M2	1.61	1.74	1.84	1.73		1.77	1.91	2.02	1.90	
	M3	1.91	2.06	2.19	2.05		2.11	2.26	2.41	2.26	
	Average	2.18	2.27	2.38			2.40	2.49	2.62		
L.S.D. ($P \leq 0.05$)		W= 1.69, S= 0.08, M= 0.56, M*S= 0.57, W*S= 1.66, W*M= 1.29, W*M*S= 1.29					W= 1.91, S= 0.09, M= 0.64, M*S= 0.65, W*S= 1.87, W*M= 1.45, W*M*S= 1.45				

The results of the study indicate that there are significant differences in the vegetative growth indicators and the marketable yield of potatoes when using different types of irrigation water, with a decrease in the vegetative growth indicators and yield when using drainage water. This is due to the presence of salts and heavy elements in drainage water compared to river water, which is attributed to the osmotic effect resulting from the increase in salts in the soil. This leads to a decrease in water absorption by the plant, which in turn leads to a decrease in the entry of nutrients, which negatively affects cellular metabolic processes and important vital activities inside the cell, thus affecting the effectiveness of photosynthesis and respiration (Ghassemi-Golezani et al., 2011). The results of the study are consistent with (Al-Taey & Al-Musawi, 2019). Other negative effects include increased production of active oxygen radicals (ROS), which leads to disruption of cellular metabolism and oxidation of some internal structures of cell components such as the cell wall. Salinity increases osmotic pressure, and it is noted that increasing the osmotic pressure of the solution causes a decrease in the water potential, which hinders the transfer of water through the root system. As a result, it negatively affects the characteristics of the vegetative system and the yield. The reason for this decrease is due to the accumulation of sodium and chloride ions to the toxic level, causing a decrease in the activity of the meristematic tissues and inhibiting cell division and elongation (Azevedo & Ashraf, 2009). This results in a decrease in vegetative growth indicators (number of aerial stems, number of leaves, total leaf area, dry weight of the vegetative system, and marketable yield), and thus reducing the amount of the yield. It was indicated that there is an inverse correlation between the increase in water salinity and the decrease in the number of aerial stems and leaf area in potato plants (Susan et al., 2013).

As for the water treated with magnets in the contact path, it had a clear moral effect in improving the studied vegetative growth indicators compared to plants that were watered with normal water. The reason for this is mostly due to the effect of magnetism in increasing the fluidity of water and reducing the viscosity of the liquid, which allows it to penetrate faster into the cell membranes (Issa et al., 2016). Magnetically treated water increases the transfer of nutrients to the plant in addition to increasing the flexibility of the cell walls and elongating the cells. It was also found that the intensity of the magnetic field changes many of the physical and chemical properties of water, such as reducing the surface tension, viscosity and density of water, which makes the water lighter and easier to absorb and penetrate through the cell membranes of the root system (Abdul et al., 2005).

The results of the study also showed that spraying with jasmonic acid showed a clear effect in improving the vegetative growth indicators (number of aerial stems, number of leaves, total leaf area, dry weight of the vegetative system) of potato plants compared to control plants. Studies indicate the role of this acid in protecting the plant and improving growth by stimulating the process of carbon metabolism and increasing characteristics. Therefore, the presence of acid in the plant body leads to improving the permeability of membranes to important nutrients, which leads to improving vegetative growth indicators with a positive effect on increasing production (Ahmad et al., 2019).

Conclusion

Finally, the research showed that, across all growth and production metrics, the Synergy potato variety performed better when irrigated with river water (1.47 ds m^{-1}) rather than drainage water. The beneficial benefits were amplified when magnetized water with a 38.5 cm^2 contact path at 3 K was used along with jasmonic acid spraying at a dosage of 30 mg L^{-1}. The most optimal conditions for maximum aerial stem count, leaf count, total leaf area, shoot dry weight, and marketable yield were achieved in the 2023 and 2024 seasons, respectively, by combining river water with magnetization at 38.5 cm^2 * 3 and jasmonic acid spraying at 30 mg L^{-1}. When it comes to increasing potato growth and production, this strategy worked better than any other technique. It's clear that magnetization, water quality optimization, and the administration of plant growth regulators are significant.

Author Contributions

All Authors contributed equally.

Conflict of Interest

The authors declared that no conflict of interest.

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