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Effect of fertilizer injectors, emitter types, and fertilizer type on solution properties and emitter discharge rate

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Abstract

The concentration of the nutrient solution is very important in the growth of the plant because inappropriately controlling the concentration of the nutrient solution may cause harmful effects due to increased toxins or lack of essential nutrients in the plants. The aim of this study was to analyze the effect of injectors, emitter types, and fertilizer types on pH, electrical conductivity (EC), and temperature of the solution, as well as their effect on the emitter discharge rate for a drip irrigation system. In this study, the GR emitter type provided the highest discharge rate at 2.49 L. h^{-1}, and the Eolos emitter type was the least effective and provided the lowest discharge rate at 2.072 L.h^{-1}. The injectors had a highly significant effect($P<0.05$) on pH and EC. The concentration of the second injector (4 degrees) led to a decrease in pH (6.22) and an increase in electrical conductivity (2.564 dS.m^{-1}). Meanwhile, the type of fertilizer had a significant impact, with phosphoric acid recording the lowest pH (5.74) and the lowest electrical conductivity (2.298 dS.m^{-1}), whereas potassium sulphate recorded the highest values for electrical conductivity (2.599 dS.m^{-1}) and pH (6.82). The solution temperature was higher when phosphoric acid was used which was 34.87°C than when potassium sulphate was used which was 32.18°C. The study shows how important is to choose the right emitters and fertilizers and control injector concentration to make the drip irrigation system work better and lead to a good environment for the plants to grow in.

Keyword: fertilizer injectors, emitter types, EC, pH, emitter discharge rate.

INTRODUCTION

Nutrient solution management represents a fundamental aspect of modern agriculture to ensure crop growth and achieve sustainable productivity. Poor management of fertilizer solutions can disrupt plant growth due to toxicity from excessive nutrients or deficiencies [1]. When the concentration of the nutrient solution becomes excessively high, ionic toxicity may occur, which impedes plant growth [2]. Both pH and electrical conductivity (EC) are critical factors influencing the plant's ability to efficiently absorb nutrients. It is recommended that electrical conductivity remains below 2.0 dSm^{-1} to improve crop quality [3]. Electrical conductivity serves as an indicator of dissolved salt concentration, directly correlated with the number of ions available to plants in the root zone. EC values are primarily influenced by fertilizer addition, as they increase with higher nutrient concentrations [4], [5]. Optimal EC values for solutions range between 2.0 and 2.2 [6]. Additionally, [7] demonstrated that lower nutrient solution concentrations lead to increased pH values and decreased electrical conductivity.

Optimal electrical conductivity varies depending on crop type and environmental conditions. Elevated EC levels can reduce the plant's nutrient uptake ability due to increased osmotic pressure, leading to nutrient loss and higher environmental pollution risks [8]. Although EC does not reflect individual nutrient concentrations, it is widely used as a key indicator because it is cost-effective and easy to measure [9]. Studies indicated that soil EC is directly proportional to nutrient concentration [10] and that injection solution concentration affects EC values and nitrate concentration in the soil [11]. For example, ammonium sulphate increases EC while decreasing pH [12]. The pH level is a crucial factor affecting nutrient solubility and plant absorption. Most crops thrive in environments with a pH range of 5.5 to 6.5 [6]. However, factors such as temperature and ionic strength can significantly alter pH stability [13]. Ammonium sulphate is the most acidic among nitrogen fertilizers and is recommended for soils with pH levels above 5.0. On the other hand, urea, or a mixture of urea with ammonium sulphate is preferred for soils with pH levels below 5.0 [14].

Nutrient solution temperature plays a vital role in plant growth, with optimal temperatures above and below the soil surface ensuring healthy and sustainable growth [15], [16]. Moreover, phosphoric acid is an important source of phosphorus, and its chemical reactions with water influence solution stability and fertilizer system efficiency, especially in continuous flow systems [17]. Regarding irrigation systems, drip irrigation is one of the most efficient and economical methods. However, emitter clogging remains one of the major challenges, significantly affecting the uniform distribution of water and fertilizers. Clogging of emitters by 5-20% can lead to substantial reductions in water distribution uniformity [18]. A study by [19] showed that the GR emitter outperformed the T-TAPE emitter, highlighting the importance of selecting the appropriate type for optimal performance. Despite extensive research in Iraq on nutrient solutions, fertilizers, and testing different emitter types [20], [21], [22], [23], [24], [25], [26], there is a lack of studies integrating the selection of suitable nutrient solutions, fertilizers, and the most efficient emitters. This research gap necessitates a comprehensive study focusing on these interactions to ensure sustainable agricultural productivity. This study aims to calibrate nutrient solution concentrations to identify the most suitable balance of chemical and physical properties, enhance resource efficiency, and determine the best emitters in terms of discharge efficiency.

MATERIALS AND METHODS

The experiment was designed as a factorial experiment in a Completely Randomized Block Design (RCBD) with three factors. The first factor was the injector concentration with two levels: concentration 2 (37 $L.h^{-1}$) and concentration 4 (54 $L.h^{-1}$). The second factor was the type of emitter which had three levels: GR emitter, T-Tape emitter, and Eolos emitter. The last factor was the type of fertilizer with three types: ammonium sulphate (NH4)2SO4, phosphoric acid (H3PO4) and potassium sulphate (K2SO4). The experimental treatments were distributed across three blocks, resulting in 18 treatments with three replications, totaling 54 experimental units. The data was statistically analyzed using the Costat software, and the differences between the means were tested at a significance level of 0.05.

An integrated fertilization system was set up, consisting of a water pump, irrigation water filter, main irrigation pipes, drip irrigation pipes, fertilizer injector, and fertilizer tanks. The water pump draws irrigation water from the reservoir and passes it through the water filter to remove impurities. The water then flows into the main irrigation pipe, followed by the drip irrigation pipes, which are installed vertically along the main irrigation pipe, parallel to each other. A fertilizer injector is installed at the beginning of each drip pipe. The injector contains a suction tube and an adjustable stopper to control the amount of fertilizer (fertilizer concentration) entering the irrigation pipe. The injector also includes a flexible tube that ends with a filter. This tube and filter are placed inside the fertilizer tank, as shown in Figure. 1. The injector draws fertilizer from the pre-prepared fertilizer tank and delivers it into the irrigation pipes, where it mixes with the irrigation water and is directed to the drip emitters. Glass containers are placed under the emitters to collect the solution exiting from the emitters to measure the required properties for the experiment.

Figure 1: Fertilizer Injector

Studied parameters

Fertilizer Solution Properties

The following properties of the fertilizer solution were measured using a solution property measurement device. Figure 2 shows the device used to measure the properties of the fertilizer solution.:

1. pH of the Fertilizer Solution:

The pH was measured using the standard pH scale by immersing the sensor in the collected fertilizer solution from containers placed under the emitters. The readings were recorded through an application installed on the computer.

2. Electrical Conductivity (EC) of the Fertilizer Solution:

EC was measured in Deci siemens per meter ($dS.m^{-1}$) using the same device. The sensor was immersed in the fertilizer solution collected from the containers under the emitters, and the readings were recorded through the computer application.

3. Temperature of the Fertilizer Solution:

The temperature of the fertilizer solution was measured in degrees Celsius (°C) using the solution property measurement device. The sensor was immersed in the collected fertilizer solution, and the readings were recorded through the computer application.

4. Emitter Discharge Rate

The emitter discharge rate was measured by placing glass containers under the emitters during a known time to calculate the volume of water flowing over that period [27]. The emitter discharge rate was measured in liters per hour ($L.h^{-1}$). The formula used to calculate the discharge rate is as follows:

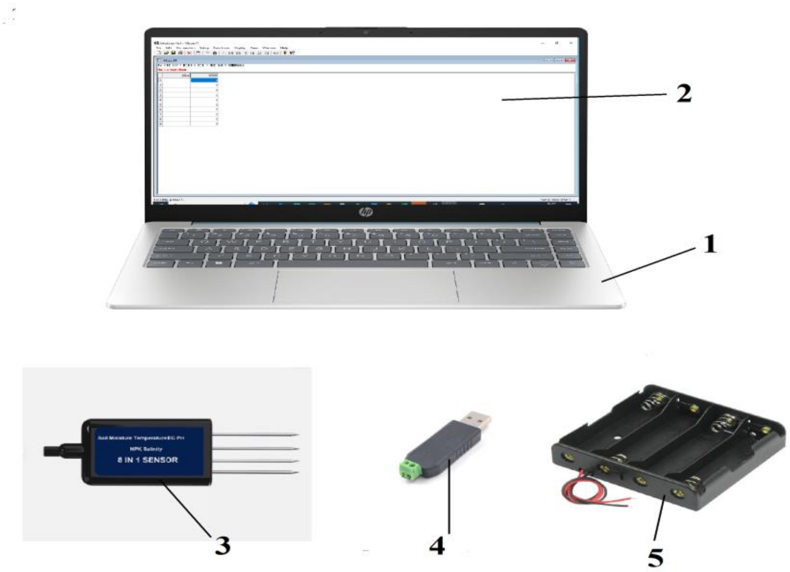
q = v / t

Where:

q: Discharge rate ($L.h^{-1}$).

v: Volume of water flowing (L).

t: Operating time (hours).



1. Laptop 2. Software Modbus Poll 3. Soil sensor 4. Signal converter from RS485 to TTL 5. A battery holder used as a power source

Figure 2: Fertilizer Solution Property Measurement Device

RESULTS AND DISCUSSION

1. Solution pH

Table (1). shows the effect of injector concentration, emitter type, fertilizer type, and their interactions on the pH of the fertilizer solution. Injector concentration showed a significant effect ($P<0.05$) on the pH of the fertilizer solution, where the second concentration (4 degree) recorded the lowest pH of the solution at 6.22, while the first concentration recorded the highest pH at 6.52. This can be attributed to the fact that increasing the fertilizer concentration in the solution leads to more compounds added that release ions that affect the pH. Acids in fertilizers, such as phosphoric acid or ammonium, contribute to increasing the concentration of hydrogen ions (H^+) in the solution, which lowers the pH and increases the acidity. Therefore, an increase in injector concentration had a greater impact on the pH of the fertilizer solution, consistent with the results obtained by [7].

Fertilizer type also showed a significant effect ($P<0.05$) on the pH of the soil. Phosphorus fertilizer recorded the lowest pH at 5.74, while potassium fertilizer recorded the highest pH at 6.82. This can be attributed to the fact that phosphoric acid is inherently acidic, meaning it contributes to lowering the pH (increasing acidity). When phosphoric acid is added to water, it can release hydrogen ions (H^+), which in turn lower the pH. Similarly, ammonium sulphate fertilizer also tends to lower the soil pH, though not as strongly as phosphoric acid. Ammonium sulphate releases ammonium ions (NH_4^+), while potassium sulphate, unlike the previous fertilizers, does not have a strong acidic effect. Potassium ions (K^+) did not lead to a significant increase in hydrogen ion concentration, so the acidity of the solution was less affected.

The two-way interaction between injector concentration and fertilizer type also showed a significant effect ($P<0.05$), where the interaction between the second concentration and phosphorus fertilizer recorded the lowest pH at 5.46. On the other hand, the interaction between the first concentration of the injector and potassium fertilizer recorded the highest pH at 7.01. This can be attributed to the high concentration of phosphoric acid in the solution, which results in the lowest ph. However, none of the two-way interactions between injector concentration and emitter type, or emitter type and fertilizer type, showed any significant effect ($P<0.05$) on the pH of the fertilizer solution. Additionally, the three-way interaction between injector concentration, emitter type, and fertilizer type had no significant effect on the pH of the fertilizer solution.

Table (1): shows the effect of injector concentration, emitter type, fertilizer type on Solution pH

Parameters		Solution pH			
		Concentration× Emitter× Fertilizer			Concentration × Emitter
Concentration	Emitter	Fertilizer			
		Ammonium sulphate	Phosphoric acid	Potassium sulphate	
Concentration1	T-Tape	6.55	5.97	7.05	6.52
	Eolos	6.58	6.14	7.06	6.59
	GR	6.47	5.92	6.91	6.43
Concentration2	T-Tape	6.55	5.43	6.63	6.20
	Eolos	6.57	5.51	6.74	6.27
	GR	6.53	5.46	6.57	6.18
L.S.D $_{0.05}$		N. S			N. S
Fertilizer		6.54	5.74	6.82	
L.S.D $_{0.05}$		0.23			
Emitter		Emitter × Fertilizer			Emitter
T-Tape		6.55	5.70	6.84	6.36
Eolos		6.58	5.82	6.9	6.43
GR		6.50	5.69	6.74	6.31
L.S.D $_{0.05}$		N. S			N. S
Concentration		Concentration× Fertilizer			Concentration
Concentration1		6.53	6.01	7.01	6.52

Concentration2	6.55	5.46	6.64	6.22
L.S.D $_{0.05}$	0.333			0.192

2.Electrical Conductivity (EC)

Table (2). shows the effect of injector concentration, emitter type, fertilizer type, and their interactions on the electrical conductivity. Injector concentration showed a significant effect ($P<0.05$) on electrical conductivity, where the second concentration (4 degree) recorded the highest electrical conductivity at 2.564 $dS.m^{-1}$, while the first concentration recorded the lowest electrical conductivity at 2.311 $dS.m^{-1}$. This can be attributed to the fact that increasing the injector concentration leads to an increase in the number of fertilizers added to the water, which in turn increases the dissolved ions in the fertilizer solution (such as cations and anions). Ions are responsible for conducting electricity, so an increase in ions leads to an increase in electrical conductivity. This is consistent with the results obtained by [4], [5], [7], [10].

Fertilizer type also showed a significant effect on the electrical conductivity of the solution, where phosphorus fertilizer recorded the lowest electrical conductivity at 2.298 $dS.m^{-1}$, while potassium fertilizer recorded the highest electrical conductivity at 2.599 $dS.m^{-1}$. This is consistent with the results obtained by [14]. On the other hand, emitter type did not conductivity.

None of the two-way interactions between injector concentration and emitter type, injector concentration and fertilizer type, or emitter type and fertilizer type showed any significant effect on electrical conductivity. Similarly, the three-way interaction among injector concentration, emitter type, and fertilizer type had no significant effect on electrical conductivity.

Table (2): shows the effect of injector concentration, emitter type, fertilizer type on the electrical conductivity

Parameters		Electrical Conductivity (EC) $dS.m^{-1}$			
		Concentration× Emitter× Fertilizer			Concentration × Emitter
Concentration	Emitter	Fertilizer			
		Ammonium sulphate	Phosphoric acid	Potassium sulphate	
Concentration1	T-Tape	2.459	2.173	2.243	2.292
	Eolos	2.439	2.169	2.222	2.277
	GR	2.495	2.259	2.344	2.366
Concentration2	T-Tape	2.796	2.395	2.480	2.557
	Eolos	2.570	2.222	2.459	2.417
	GR	2.835	2.571	2.749	2.718
L.S.D $_{0.05}$		N. S			N. S

Fertilizer	2.599	2.298	2.416	
L.S.D $_{0.05}$	0.200			
Emitter	Emitter × Fertilizer			Emitter
T-Tape	2.627	2.284	2.362	2.424
Eolos	2.504	2.196	2.441	2.347
GR	2.665	2.415	2.546	2.542
L.S.D $_{0.05}$	N. S			N. S
Concentration	Concentration× Fertilizer			Concentration
Concentration1	2.464	2.2	2.270	2.311
Concentration2	2.734	2.396	2.563	2.564
L.S.D $_{0.05}$	N. S			0.163

3.Fertilizer Solution Temperature

Table (3). shows the effect of injector concentration, emitter type, fertilizer type, and their interactions on the fertilizer solution temperature. Fertilizer type showed a significant effect ($P<0.05$) on the fertilizer solution temperature, where phosphorus fertilizer recorded the highest temperature.

at 34.87°C, while potassium fertilizer recorded the lowest temperature at 32.18°C. This can be attributed to the fact that phosphoric acid fertilizer significantly raises the temperature of the fertilizer solution due to the exothermic reactions resulting from its rapid dissolution and release of acidic ions. On the other hand, ammonium sulphate fertilizer causes a lesser increase in temperature because it produces moderate reactions upon dissolution. Potassium sulphate, however, produces the lowest temperature since its dissolution is endothermic and does not release significant thermal energy.

While injector concentration and emitter type did not show any significant effect on the fertilizer solution temperature, none of the two-way interactions, whether between injector concentration and emitter type, injector concentration and fertilizer type, or emitter type and fertilizer type, showed any significant effect on the fertilizer solution temperature. Similarly, the three-way interaction among injector concentration, emitter type, and fertilizer type did not have any significant effect on the fertilizer solution temperature.

Table (3): shows the effect of injector concentration, emitter type, fertilizer type on the fertilizer solution temperature

Parameters		Fertilizer Solution Temperature			
		Concentration× Emitter× Fertilizer			Concentration × Emitter
Concentration	Emitter	Fertilizer			
		Ammonium sulphate	Phosphoric acid	Potassium sulphate	
Concentration1	T-Tape	32.53	34.20	32.43	33.05
	Eolos	32.96	33.46	32.7	33.04
	GR	32.24	71 .34	32.23	33.06
Concentration2	T-Tape	32.08	35.61	31.91	33.20

	Eolos	32.05	35.61	31.96	33.20
	GR	32.09	35.76	31.99	33.28
L.S.D $_{0.05}$		N. S			N. S
Fertilizer		32.32	34.89	32.20	
L.S.D $_{0.05}$		1.255			
Emitter		Emitter × Fertilizer			Emitter
T-Tape		32.30	34.91	32.17	33.13
Eolos		32.51	34.54	32.33	33.12
GR		32.17	35.23	32.11	33.17
L.S.D $_{0.05}$		N. S			N. S
Concentration		Concentration× Fertilizer			Concentration
Concentration1		32.58	34.12	32.45	33.05
Concentration2		32.078	35.66	31.95	33.23
L.S.D $_{0.05}$		N. S			N. S

4.Emitter Discharge Rate

The emitter type showed a significant effect ($P<0.05$) on the emitter discharge rate, with the GR emitter recording the highest discharge rate of 2.49 $L.h^{-1}$, while the Eolos emitter recorded the lowest discharge rate at 2.072 $L.h^{-1}$. This difference was primarily due to variations in the internal design of the emitters, flow control mechanisms, and the materials used in their construction. The GR emitter may have a less precise pressure control mechanism, allowing for higher water flow when pressure increases, whereas the Eolos emitter may have a more precise flow control mechanism, resulting in faster flow compared to the GR emitter, which may be made from more rigid or resistant materials. The GR emitter is likely designed to allow a larger water flow, while the Eolos emitter is designed to adjust flow more precisely, resulting in lower discharge. This is consistent with the results obtained by [19].

Regarding injector concentration and fertilizer type, no significant effect($P<0.05$) was observed on the emitter discharge rate. None of the two-way interactions, whether between injector concentration and emitter type, injector concentration and fertilizer type, or emitter type and fertilizer type, showed any significant impact on emitter discharge. Similarly, the three-way interaction among injector concentration, emitter type, and fertilizer type had no significant effect on the emitter discharge rate.

Table (4). shows the effect of injector concentration, emitter type, fertilizer type on emitter discharge rate

Parameters		Emitter Discharge Rate ($L.h^{-1}$)	
		Concentration× Emitter× Fertilizer	Concentration ×
Concentration	Emitter	Fertilizer	

		Ammonium sulphate	Phosphoric acid	Potassium sulphate	Emitter
Concentration1	T-Tape	2.2	2.28	2.22	2.23
	Eolos	2.05	1.95	1.947	1.98
	GR	2.46	2.49	2.527	2.49
Concentration2	T-Tape	2.21	2.31	2.367	2.29
	Eolos	2.19	2.07	2.227	2.16
	GR	2.5	2.493	2.567	2.52
$L.S.D_{0.05}$		N. S			N. S
Fertilizer		2.268	2.265	2.30	
$L.S.D_{0.05}$		N. S			
Emitter		Emitter × Fertilizer			Emitter
T-Tape		2.20	2.29	2.29	2.26
Eolos		2.12	2.01	2.087	2.072
GR		2.48	2.49	2.54	2.50
$L.S.D_{0.05}$		N. S			0.126
Concentration		Concentration× Fertilizer			Concentration
Concentration1		2.23	2.24	2.23	2.23
Concentration2		2.3	2.29	2.38	2.32
$L.S.D_{0.05}$		N. S			N. S

CONCLUSION

The study showed that emitter type had a significant effect on water discharge, with the GR emitter recording the highest discharge at 2.49 $L.h^{-1}$, while the Eolos emitter recorded the lowest discharge at 2.072 $L.h^{-1}$. As for the electrical conductivity of the fertilizer solution, the effect of injector concentration was evident, with the second injector concentration (4 degrees) recording the highest electrical conductivity at 2.564 $dS.m^{-1}$, while the first injector concentration (2 degrees) recorded the lowest conductivity at 2.311 $dS.m^{-1}$. The type of fertilizer also influenced electrical conductivity, with ammonium sulphate fertilizer recording the highest conductivity at 2.599 $dS.m^{-1}$, while phosphoric acid fertilizer recorded the lowest at 2.298 $dS.m^{-1}$.

Regarding the pH of the fertilizer solution, it was clearly influenced by injector concentration and fertilizer type. The second injector concentration (4 degrees) recorded a pH of 6.22, while the first concentration (2 degrees) recorded a pH of 6.52. Phosphoric acid fertilizer had the most significant effect on reducing pH, with a value of 5.74, while potassium sulphate fertilizer had a lesser effect, with a pH of 6.82. The interaction between the second injector concentration and phosphoric acid fertilizer resulted in the lowest pH of 5.46, while the interaction between the first injector concentration and potassium sulphate fertilizer resulted in the highest pH of 7.01.

The results also demonstrated that fertilizer type had a significant effect on the fertilizer solution temperature. Phosphoric acid fertilizer recorded the highest temperature at 34.87°C, while potassium sulphate recorded the lowest temperature at 32.18°C. This difference is attributed to the exothermic reactions of phosphoric acid, which increase the temperature, whereas potassium sulphate results in a decrease in temperature due to its endothermic dissolution reactions.

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